Rebasing the Networking TS on C++20

This paper updates the Networking TS working draft (N4771) to use C++20 as its base document, rather than C++14.

The main changes proposed are:

— Conform to current LWG conventions such as using the Mandates: and Constraints: elements.
— Replace type requirements like MoveConstructible with Cpp17MoveConstructible and use preferred terminology (“meets”).
— Use consistent formatting for type requirements, to distinguish them from template parameters and other identifiers.
— Remove redundant operator== and operator!= overloads which can be synthesized by the compiler. Replace operator< etc. with operator<=.
— Use _v variable templates for traits.
— Remove reference to Library Fundamentals TS, as string_view is in the IS now.

The changes are presented as additions and removals with the entire paper as context, even the parts with no changes. Updated cross-references of the form C++ 2014[structure.specifications] are shown as C++ 2020 [structure.specifications] without repeating 2014 every time.

Open questions:

— Should most uses of decay_t be changed to remove_cvref_t?
— Should most non-member operators be specified as hidden friends?
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1 Scope

This document describes extensions to the C++ Standard Library. This document specifies requirements for implementations of an interface that computer programs written in the C++ programming language may use to perform operations related to networking, such as operations involving sockets, timers, buffer management, host name resolution and internet protocols. This document is applicable to information technology systems that can perform network operations, such as those with operating systems that conform to the POSIX interface. This document is applicable only to vendors who wish to provide the interface it describes.
2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

[Editor’s note: The document number for the Library Fundamentals TS was wrong, Clause 5 referred to fundamentals_v2, so it should have been ISO/IEC TS 19568:2017. but rebasing on C++ 2020 means we don’t need it now anyway.]

[Editor’s note: The correct ISO document number for POSIX includes ’/IEEE” according to the ISO webstore: https://www.iso.org/standard/50516.html. There is a newer version of POSIX, IEEE Std 1003.1-2017, but it doesn’t appear to have been adopted as an ISO standard.]

1 — ISO/IEC 14882:2014, Programming languages — C++
2 — ISO/IEC TS 19568:2015, C++ Extensions for Library Fundamentals
4 — ISO/IEC 2382-1:1993, Information technology — Vocabulary

The programming language and library described in ISO/IEC 14882 is herein called the C++ Standard. References to clauses within the C++ Standard are written as “C++ 2020 [library]”. The operating system interface described in ISO/IEC/IEEE 9945 is herein called POSIX.

This document mentions commercially available operating systems for purposes of exposition. POSIX® is a registered trademark of The IEEE. Windows® is a registered trademark of Microsoft Corporation. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO or IEC of these products.

Unless otherwise specified, the whole of the C++ Standard’s Library introduction (C++ 2020 [library]) is included into this document by reference.
3 Terms and definitions [defs]

1 For the purposes of this document, the terms and definitions given in ISO/IEC 14882:2014, ISO/IEC 2382-1:1993, and the following apply.

2 ISO and IEC maintain terminological databases for use in standardization at the following addresses:

   2. ISO Online browsing platform: available at https://www.iso.org/obp

3 Terms that are used only in a small portion of this document are defined where they are used and italicized where they are defined.

3.1 [defs.host.byte.order] host byte order
the arrangement of bytes in any integer type when using a specific machine architecture

3.2 [defs.net.byte.order] network byte order
the way of representing any integer type such that, when transmitted over a network via a network endpoint, the int type is transmitted as an appropriate number of octets with the most significant octet first, followed by any other octets in descending order of significance

3.3 [defs.sync.op] synchronous operation
operation where control is not returned until the operation completes

3.4 [defs.async.op] asynchronous operation
operation where control is returned immediately without waiting for the operation to complete

[Note 1 to entry: Multiple asynchronous operations may be executed concurrently. — end note]
4 General Principles

4.1 Conformance

Conformance is specified in terms of behavior. Ideal behavior is not always implementable, so the conformance subclauses take that into account.

4.1.1 POSIX conformance

Some behavior is specified by reference to POSIX. How such behavior is actually implemented is unspecified.

[Note: This constitutes an “as if” rule allowing implementations to call native operating system or other APIs. — end note]

Implementations are encouraged to provide such behavior as it is defined by POSIX. Implementations shall document any behavior that differs from the behavior defined by POSIX. Implementations that do not support exact POSIX behavior are encouraged to provide behavior as close to POSIX behavior as is reasonable given the limitations of actual operating systems and file systems. If an implementation cannot provide any reasonable behavior, the implementation shall report an error as specified in Error Reporting (Clause 9).

[Note: This allows users to rely on an exception being thrown or an error code being set when an implementation cannot provide any reasonable behavior. — end note]

Implementations are not required to provide behavior that is not supported by a particular operating system.

4.1.2 Conditionally-supported features

This document defines conditionally-supported features, in the form of additional member functions on types that satisfy meet the Protocol (18.2.6), Endpoint (18.2.4), SettableSocketOption (18.2.9), GettableSocketOption (18.2.8) or IoControlCommand (18.2.12) requirements.

[Note: This is so that, when the additional member functions are available, C++ programs can extend the library to add support for other protocols and socket options. — end note]

For the purposes of this document, implementations that provide all of the additional member functions are known as extensible implementations.

[Note: Implementations are encouraged to provide the additional member functions, where possible. It is intended that POSIX and Windows implementations will provide them. — end note]

4.2 Acknowledgments

The design of this specification is based, in part, on the Asio library written by Christopher Kohlhoff.
5 Namespaces and headers

[Editor’s note: Although there is unlikely to be a second edition of the TS, it seems useful to update the v1 namespace in the working draft to avoid confusion.]

The components described in this document are experimental and not part of the C++ standard library. All components described in this document are declared in namespace `std::experimental::net::v1` or a sub-namespace thereof unless otherwise specified. The headers described in this document shall import the contents of `std::experimental::net::v1` into `std::experimental::net` as if by:

```cpp
namespace std::experimental::net {
    namespace experimental {
        namespace net {
            inline namespace v1 v2 {}
        }
    }
}
```

Unless otherwise specified, references to other entities described in this document are assumed to be qualified with `std::experimental::net::v1 v2::`, references to entities described in the C++ standard are assumed to be qualified with `std::`, and references to entities described in C++ Extensions for Library Fundamentals are assumed to be qualified with `std::experimental::fundamentals_v2::`. 
6 Future plans (Informative) [plans]

1 This clause describes tentative plans for future versions of this document and plans for moving content into future versions of the C++ Standard.

2 The C++ committee may release new versions of this document, containing networking library extensions we hope to add to a near-future version of the C++ Standard. Future versions will define their contents in std::experimental::net::v2, std::experimental::net::v3, std::experimental::net::v4, etc., with the most recent implemented version inlined into std::experimental::net.

3 When an extension defined in this or a future version of this document represents enough existing practice, it will be moved into the next version of the C++ Standard by replacing the experimental::net::vN segment of its namespace with net, and by removing the experimental/ prefix from its header’s path.


7 Feature test macros (Informative) [feature.test]

1 These macros allow users to determine which version of this document is supported by the headers defined by the specification. All headers in this document shall define the __cpp_lib_experimental_net feature test macro in Table 1.

2 If an implementation supplies all of the conditionally-supported features specified in 4.1.2, all headers in this document shall additionally define the __cpp_lib.experimental_net_extensible feature test macro.

[Editor's note: The 202000L value will be set by the editor.]

<table>
<thead>
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<th>Macro name</th>
<th>Value</th>
</tr>
</thead>
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<td>201803202000L</td>
</tr>
<tr>
<td>__cpp_lib.experimental_net_extensible</td>
<td>201803202000L</td>
</tr>
</tbody>
</table>
8 Method of description (Informative) [description]

1 This subclause describes the conventions used to specify this document, in addition to those conventions specified in C++ 2020 [description].

8.1 Structure of each clause [structure]

8.1.1 Detailed specifications [structure.specifications]

1 In addition to the elements defined in C++ 2020 [structure.specifications], descriptions of function semantics contain the following elements (as appropriate):

(1.1) — Completion signature: if the function initiates an asynchronous operation, specifies the signature of a completion handler used to receive the result of the operation.

8.2 Other conventions [conventions]

8.2.1 Nested classes [nested.class]

1 Several classes defined in this document are nested classes. For a specified nested class A::B, an implementation is permitted to define A::B as a synonym for a class with equivalent functionality to class A::B. [Note: When A::B is a synonym for another type A provides a nested type B, to emulate the injected class name. — end note]
9 Error reporting

9.1 Synchronous operations

Most synchronous network library functions provide two overloads, one that throws an exception to report system errors, and another that sets an `error_code` (C++ 2020 [syserr]).

[Note: This supports two common use cases:

(1.1) — Uses where system errors are truly exceptional and indicate a serious failure. Throwing an exception is the most appropriate response.

(1.2) — Uses where system errors are routine and do not necessarily represent failure. Returning an error code is the most appropriate response. This allows application specific error handling, including simply ignoring the error.

— end note]

Functions not having an argument of type `error_code&` report errors as follows, unless otherwise specified:

(2.1) — When a call by the implementation to an operating system or other underlying API results in an error that prevents the function from meeting its specifications, the function exits via an exception of a type that would match a handler of type `system_error`.

(2.2) — Destructors throw nothing.

Functions having an argument of type `error_code&` report errors as follows, unless otherwise specified:

(3.1) — If a call by the implementation to an operating system or other underlying API results in an error that prevents the function from meeting its specifications, the `error_code&` argument `ec` is set as appropriate for the specific error. Otherwise, the `ec` argument is set such that !`ec` is `true`.

Where a function is specified as two overloads, with and without an argument of type `error_code&`:

```cpp
R f(A1 a1, A2 a2, ..., AN aN);
R f(A1 a1, A2 a2, ..., AN aN, error_code& ec);
```

then, when `R` is non-void, the effects of the first overload are as if:

```cpp
error_code ec;
R r(f(a1, a2, ..., aN, ec));
if (ec) throw system_error(ec, S);
return r;
```

otherwise, when `R` is void, the effects of the first overload are as if:

```cpp
error_code ec;
if (ec) throw system_error(ec, S);
```

except that the type thrown may differ as specified above. `S` is an NTBS indicating where the exception was thrown. [Note: A possible value for `S` is `__func__`. — end note]

For both overloads, failure to allocate storage is reported by throwing an exception as described in the C++ standard (C++ 2020 [res.on.exception.handling]).

In this document, when a type requirement is specified using two function call expressions `f`, with and without an argument `ec` of type `error_code`:

§ 9.1
then the effects of the first call expression of \( f \) shall be as described for the first overload above.

9.2 Asynchronous operations

Asynchronous network library functions in this document are identified by having the prefix `async_` and take a completion handler (13.2.7.2). These asynchronous operations report errors as follows:

1. If a call by the implementation to an operating system or other underlying API results in an error that prevents the asynchronous operation from meeting its specifications, the completion handler is invoked with an error_code value `ec` that is set as appropriate for the specific error. Otherwise, the error_code value `ec` is set such that `!ec` is true.

2. Asynchronous operations shall not fail with an error condition that indicates interruption of an operating system or underlying API by a signal. [Note: Such as POSIX error number EINTR — end note] Asynchronous operations shall not fail with any error condition associated with non-blocking operations. [Note: Such as POSIX error numbers EWOULDBLOCK, EAGAIN, or EINPROGRESS; Windows error numbers WSAEWOULDBLOCK or WSAEINPROGRESS — end note]

In this document, when a type requirement is specified as a call to a function or member function having the prefix `async_`, then the function shall satisfy the error reporting requirements described above.

9.3 Error conditions

Unless otherwise specified, when the behavior of a synchronous or asynchronous operation is defined “as if” implemented by a POSIX function, the error_code produced by the function shall meet the following requirements:

1. If the failure condition is one that is listed by POSIX for that function, the error_code shall compare equal to the error’s corresponding enum class `errc` (C++ 2020 [syserr]) or enum class resolver_-errc (21.3) constant.

2. Otherwise, the error_code shall be set to an implementation-defined value that reflects the underlying operating system error.

[Example: The POSIX specification for shutdown lists EBADF as one of its possible errors. If a function that is specified “as if” implemented by shutdown fails with EBADF then the following condition holds for the error_code value `ec`: `ec == errc::bad_file_descriptor — end example]

When the description of a function contains the element Error conditions, this lists conditions where the operation may fail. The conditions are listed, together with a suitable explanation, as enum class constants. Unless otherwise specified, this list is a subset of the failure conditions associated with the function.

9.4 Suppression of signals

Some POSIX functions referred to in this document may report errors by raising a SIGPIPE signal. Where a synchronous or asynchronous operation is specified in terms of these POSIX functions, the generation of SIGPIPE is suppressed and an error condition corresponding to POSIX EPIPE is produced instead.
10 Library summary

Table 2 — Networking library summary

<table>
<thead>
<tr>
<th>Clause</th>
<th>Header(s)</th>
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</thead>
<tbody>
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<td>Convenience header (Clause 11)</td>
<td>&lt;experimental/net&gt;</td>
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<tr>
<td>Forward declarations (Clause 12)</td>
<td>&lt;experimental/netfwd&gt;</td>
</tr>
<tr>
<td>Asynchronous model (Clause 13)</td>
<td>&lt;experimental/executor&gt;</td>
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<td>Basic I/O services (Clause 14)</td>
<td>&lt;experimental/io_context&gt;</td>
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<td>Timers (Clause 15)</td>
<td>&lt;experimental/timer&gt;</td>
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<tr>
<td>Buffers (Clause 16)</td>
<td>&lt;experimental/buffer&gt;</td>
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<tr>
<td>Buffer-oriented streams (Clause 17)</td>
<td></td>
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<tr>
<td>Sockets (Clause 18)</td>
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<tr>
<td>Socket iostreams (Clause 19)</td>
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<tr>
<td>Socket algorithms (Clause 20)</td>
<td></td>
</tr>
<tr>
<td>Internet protocol (Clause 21)</td>
<td>&lt;experimental/internet&gt;</td>
</tr>
</tbody>
</table>

Throughout this document, where template parameters are not constrained, the names of the template parameters are used to express type requirements, as listed in Table 3. If a template parameter’s name is a name in the first column, the template argument shall meet the corresponding type requirements in the second column.

[Editor’s note: Many of these type requirements should be replaced by concepts, but that will be proposed separately.]

Table 3 — Template parameters and type requirements

<table>
<thead>
<tr>
<th>template parameter name</th>
<th>type requirements</th>
</tr>
</thead>
<tbody>
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<td>AcceptableProtocol</td>
<td>acceptable protocol (18.2.7)</td>
</tr>
<tr>
<td>Allocator</td>
<td>Cpp17Allocator (C++ 2020 [allocator.requirements])</td>
</tr>
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<td>AsyncReadStream</td>
<td>buffer-oriented asynchronous read stream (17.1.2)</td>
</tr>
<tr>
<td>AsyncWriteStream</td>
<td>buffer-oriented asynchronous write stream (17.1.4)</td>
</tr>
<tr>
<td>Clock</td>
<td>Cpp17Clock (C++ 2020 [time.clock.req])</td>
</tr>
<tr>
<td>CompletionCondition</td>
<td>completion condition (17.1.5)</td>
</tr>
<tr>
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</tr>
<tr>
<td>ConnectCondition</td>
<td>connect condition (18.2.13)</td>
</tr>
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<td>ConstBufferSequence</td>
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</tr>
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<tbody>
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</tr>
<tr>
<td>Protocol</td>
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</tr>
<tr>
<td>WaitTraits</td>
<td>wait traits (15.2.1)</td>
</tr>
</tbody>
</table>
11 Convenience header [convenience.hdr]

11.1 Header <experimental/net> synopsis [convenience.hdr.synop]

```
#include <experimental/executor>
#include <experimental/io_context>
#include <experimental/timer>
#include <experimental/buffer>
#include <experimental/socket>
#include <experimental/internet>
```

1 [Note: This header is provided as a convenience for programs so that they may access all networking facilities via a single, self-contained #include. — end note]
12 Forward declarations [fwd.decl]

12.1 Header <experimental/netfwd> synopsis [fwd.decl.synop]

```cpp
namespace std {
namespace experimental {
namespace net {
inline namespace std::experimental::net::inline_v1v2 {

class execution_context;
template<class T, class Executor>
class executor_binder;
template<class Executor>
class executor_work_guard;
class system_executor;
class executor;
template<class Executor>
class executor;
class strand;

class io_context;

template<class Clock> struct wait_traits;
template<class Clock, class WaitTraits = wait_traits<Clock>>
class basic_waitable_timer;
using system_timer = basic_waitable_timer<chrono::system_clock>;
using steady_timer = basic_waitable_timer<chrono::steady_clock>;
using high_resolution_timer = basic_waitable_timer<chrono::high_resolution_clock>;

template<class Protocol>
class basic_socket;
template<class Protocol>
class basic_datagram_socket;
template<class Protocol>
class basic_stream_socket;
template<class Protocol>
class basic_socket_acceptor;
template<class Protocol, class Clock = chrono::steady_clock, class WaitTraits = wait_traits<Clock>>
class basic_socket_streambuf;
template<class Protocol, class Clock = chrono::steady_clock, class WaitTraits = wait_traits<Clock>>
class basic_socket_iostream;

namespace ip {

class address;
class address_v4;
class address_v6;
template<class Address>
class basic_address_iterator;
using address_v4_iterator = basic_address_iterator<address_v4>;
using address_v6_iterator = basic_address_iterator<address_v6>;
```
template<class Address>
    class basic_address_range;
using address_v4_range = basic_address_range<address_v4>;
using address_v6_range = basic_address_range<address_v6>;
class network_v4;
class network_v6;
template<class InternetProtocol>
    class basic_endpoint;
    template<class InternetProtocol>
        class basic_resolver_entry;
    template<class InternetProtocol>
        class basic_resolver_results;
    template<class InternetProtocol>
        class basic_resolver;
    class tcp;
class udp;

} // namespace ip
} // inline namespace std::experimental::net::v2
} // namespace std

1 Default template arguments are described as appearing both in `<netfwd>` and in the synopsis of other headers but it is well-formed to include both `<netfwd>` and one or more of the other headers. [Note: It is the implementation’s responsibility to implement headers so that including `<netfwd>` and other headers does not violate the rules about multiple occurrences of default arguments. —end note]
13 Asynchronous model [async]

13.1 Header <experimental/executor> synopsis [async.synop]

```cpp
namespace std {
    namespace experimental {
        namespace net {
            #inline-namepaces std::experimental::net::inline v1 {

                template<class CompletionToken, class Signature>
                class async_result;

                template<class CompletionToken, class Signature>
                struct async_completion;

                template<class T, class ProtoAllocator = allocator<void>>
                struct associated_allocator;

                template<class T, class ProtoAllocator = allocator<void>>
                using associated_allocator_t = typename associated_allocator<T, ProtoAllocator>::type;

                // 13.6, get_associated_allocator:

                template<class T>
                associated_allocator_t<T> get_associated_allocator(const T& t) noexcept;

                template<class T, class ProtoAllocator>
                associated_allocator_t<T, ProtoAllocator>
                get_associated_allocator(const T& t, const ProtoAllocator& a) noexcept;

                enum class fork_event {
                    prepare,
                    parent,
                    child
                };

                class execution_context;

                class service_already_exists;

                template<class Service> Service& use_service(execution_context& ctx);

                template<class Service, class... Args> Service&
                make_service(execution_context& ctx, Args&&... args);

                template<class Service> bool has_service(execution_context& ctx) noexcept;

                template<class T> struct is_executor;

                template<class T>
                #inline constexpr bool is_executor_v = is_executor<T>::value;

                struct executor_arg_t { };  
                #inline constexpr executor_arg_t executor_arg = executor_arg_t();
```

§ 13.1

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template<class T, class Executor> struct uses_executor;

template<class T, class Executor>
    inline constexpr bool uses_executor_v = uses_executor<T, Executor>::value;

template<class T, class Executor = system_executor>
    struct associated_executor;

template<class T, class Executor = system_executor>
    using associated_executor_t = typename associated_executor<T, Executor>::type;

// 13.13, get_associated_executor:

template<class T>
    associated_executor_t<T> get_associated_executor(const T& t) noexcept;

template<class T, class Executor>
    associated_executor_t<T, Executor>
    get_associated_executor(const T& t, const Executor& ex) noexcept;

template<class T, class ExecutionContext>
    associated_executor_t<T, typename ExecutionContext::executor_type>
    get_associated_executor(const T& t, ExecutionContext& ctx) noexcept;

template<class T, class Executor>
    class executor_binder;

template<class T, class Executor, class Signature>
    class async_result<executor_binder<T, Executor>, Signature>;

template<class T, class Executor, class ProtoAllocator>
    struct associated_allocator<executor_binder<T, Executor>, ProtoAllocator>;

template<class T, class Executor, class Executor1>
    struct associated_executor<executor_binder<T, Executor>, Executor1>;

// 13.15, bind_executor:

template<class Executor, class T>
    executor_binder<decay_t<T>, Executor>
    bind_executor(const Executor& ex, T&& t);

template<class ExecutionContext, class T>
    executor_binder<decay_t<T>, typename ExecutionContext::executor_type>
    bind_executor(ExecutionContext& ctx, T&& t);

template<class Executor>
    class executor_work_guard;

// 13.17, make_work_guard:

template<class Executor>
    executor_work_guard<Executor>
    make_work_guard(const Executor& ex);

template<class ExecutionContext>
    executor_work_guard<typename ExecutionContext::executor_type>
    make_work_guard(ExecutionContext& ctx);

template<class T>
executor_work_guard<associated_executor_t<T>>
make_work_guard(const T& t);

template<class T, class U>
auto make_work_guard(const T& t, U&& u)
    -> decltype(make_work_guard(get_associated_executor(t, forward<U>(u))));

class system_executor;
class system_context;

bool operator==(const system_executor&, const system_executor&);

bool operator!=(const system_executor& a, const system_executor& b);

class bad_executor;
class executor;

bool operator==(const executor& a, const executor& b) noexcept;
bool operator==(const executor& e, nullptr_t) noexcept;
bool operator==(nullptr_t, const executor& e) noexcept;
bool operator!=(const executor& a, const executor& b) noexcept;
bool operator!=(const executor& e, nullptr_t) noexcept;
bool operator!=(nullptr_t, const executor& e) noexcept;

// 13.22, dispatch:

template<class CompletionToken>
    DEDUCED dispatch(CompletionToken& token);

template<class Executor, class CompletionToken>
    DEDUCED dispatch(const Executor& ex, CompletionToken& token);

template<class ExecutionContext, class CompletionToken>
    DEDUCED dispatch(ExecutionContext& ctx, CompletionToken& token);

// 13.23, post:

template<class CompletionToken>
    DEDUCED post(CompletionToken& token);

template<class Executor, class CompletionToken>
    DEDUCED post(const Executor& ex, CompletionToken& token);

template<class ExecutionContext, class CompletionToken>
    DEDUCED post(ExecutionContext& ctx, CompletionToken& token);

// 13.24, defer:

template<class CompletionToken>
    DEDUCED defer(CompletionToken& token);

template<class Executor, class CompletionToken>
    DEDUCED defer(const Executor& ex, CompletionToken& token);

template<class ExecutionContext, class CompletionToken>
    DEDUCED defer(ExecutionContext& ctx, CompletionToken& token);

template<class Executor>
    class strand;

class strand;

template<class Executor>
    bool operator==(const strand<Executor>& a, const strand<Executor>& b);


13.2 Requirements

13.2.1 Proto-allocator requirements

A type `A` meets the `ProtoAllocator` requirements if `A` meets the requirements of `CopyConstructible` (C++20 [copyconstructible]), `Destructible` (C++20 [destructible]), and `allocator_traits<A>::rebind_alloc<U>` meets the `Allocator` requirements (C++20 [allocator.requirements]), where `U` is a `cv-unqualified` object type. [Note: For example, `allocator<void>` meets the proto-allocator requirements but not the allocator requirements. —end note]

No comparison operator, copy operation, move operation, or swap operation on these types shall exit via an exception.

13.2.2 Executor requirements

The library describes a standard set of requirements for executors. A type meeting the `Executor` requirements embodies a set of rules for determining how submitted function objects are to be executed.

A type `X` meets the `Executor` requirements if it satisfies the requirements of `CopyConstructible` (C++20 [copyconstructible]) and `Destructible` (C++20 [destructible]), as well as the additional requirements listed below.

No comparison operator, copy operation, move operation, swap operation, or other member functions defined in these requirements shall introduce data races as a result of concurrent calls to those functions from different threads. The member function `dispatch` may be recursively reentered.

Let `ctx` be the execution context returned by the executor’s `context()` member function. An executor becomes invalid when the first call to `ctx.shutdown()` returns. The effect of calling `on_work_started`, `on_work_finished`, `dispatch`, `post`, or `defer` on an invalid executor is undefined. [Note: The copy constructor, comparison operators, and `context()` member function continue to remain valid until `ctx` is destroyed. —end note]
In Table 4, \( x_1 \) and \( x_2 \) denote \((\text{possibly const})\) values of type \((\text{possibly const})\) \( X \), \( m_{x1} \) denotes an \( x \) value of type \( X \), \( f \) denotes a function object of \( \text{MoveConstructible Cpp17MoveConstructible} \) \((\text{C++ 2020 [moveconstructible]})\) type \( \text{Func} \) such that \( f() \) is a valid expression, \( a \) denotes a \((\text{possibly const})\) value of type \((\text{possibly const})\) \( A \) where \( A \) is a type meeting the \( \text{ProtoAllocator} \) \( \text{ProtoAllocator} \) requirements \((13.2.1)\), and \( u \) denotes an identifier.

Table 4 — \textbf{Executor Executor} \textbf{requirements}

<table>
<thead>
<tr>
<th>expression</th>
<th>type</th>
<th>assertion/note pre/post-conditions</th>
</tr>
</thead>
</table>
| \( X \ \( u(x_1); \)\) | | Shall not exit via an exception.  
\textit{post:} Postconditions: \( u == x_1 \) and \( \text{std::addressof}(u.\text{context}()) == \text{std::addressof}(x_1.\text{context}()) \). |
| \( X \ \( u(m_{x1}); \)\) | | Shall not exit via an exception.  
\textit{post:} Postconditions: \( u \) equals the prior value of \( m_{x1} \) and \( \text{std::addressof}(u.\text{context}()) \) equals the prior value of \( \text{std::addressof}(m_{x1}.\text{context}()) \). |
| \( x_1 == x_2 \) | \text{bool} | Returns \text{true} only if \( x_1 \) and \( x_2 \) can be interchanged with identical effects in any of the expressions defined in these type requirements. \textit{[Note: Returning \text{false} does not necessarily imply that the effects are not identical. — end note]()} \( \text{operator}== \) shall be reflexive, symmetric, and transitive, and shall not exit via an exception. |
| \( x_1 != x_2 \) | \text{bool} | Same as \( ! (x_1 == x_2) \). |
| \( x_1.\text{context}() \) | \text{execution_
}-context&, or \( E_k \) where \( E \) is a type that meets \( \text{ExecutionContext} \) \( \text{ExecutionContext} \) \((13.2.3)\) requirements. | Shall not exit via an exception. The comparison operators and member functions defined in these requirements shall not alter the reference returned by this function. |
| \( x_1.\text{on\_work\_started}() \) | | Shall not exit via an exception. |
| \( x_1.\text{on\_work\_finished}() \) | | Shall not exit via an exception.  
\textit{Precondition:} A preceding call \( x_2.\text{on\_work\_started}() \) where \( x_1 == x_2 \). |
Table 4 — Executor requirements (continued)

<table>
<thead>
<tr>
<th>expression</th>
<th>type</th>
<th>assertion/note pre/post-conditions</th>
</tr>
</thead>
</table>
| x1.dispatch(  
  std::move(f), a) |  
  Effects: Creates an object f1 initialized with DECAY_COPY(std::forward<Func>(f)) (C++ 2020 [thread.decaycopy]) in the current thread of execution. Calls f1() at most once. The executor may block forward progress of the caller until f1() finishes execution. Executor implementations should use the supplied allocator to allocate any memory required to store the function object. Prior to invoking the function object, the executor shall deallocate any memory allocated. [Note: Executors defined in this document always use the supplied allocator unless otherwise specified. — end note]  
  Synchronization: The invocation of dispatch synchronizes with (C++ 2020 [intro.multithread]) the invocation of f1. |  |
| x1.post(std::move(f), a) |  
  Effects: Creates an object f1 initialized with DECAY_COPY(std::forward<Func>(f)) in the current thread of execution. Calls f1() at most once. The executor shall not block forward progress of the caller pending completion of f1(). The executor may begin f1’s progress before the call to post completes. Executor implementations should use the supplied allocator to allocate any memory required to store the function object. Prior to invoking the function object, the executor shall deallocate any memory allocated. [Note: Executors defined in this document always use the supplied allocator unless otherwise specified. — end note]  
  Synchronization: The invocation of post synchronizes with (C++ 2020 [intro.multithread]) the invocation of f1. |  |
13.2.3 Execution context requirements

A type \( X \) meets the \texttt{ExecutionContext} requirements if it is publicly and unambiguously derived from \texttt{execution_context}, and satisfies the additional requirements listed below.

In Table 5, \( x \) denotes a value of type \( X \).

<table>
<thead>
<tr>
<th>expression</th>
<th>type</th>
<th>assertion/note pre/post-condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>( x.\neg X() )</td>
<td>( X::executor_type )</td>
<td>Returns an executor object that is associated with the execution context.</td>
</tr>
<tr>
<td>( x.\text{get}_executor() )</td>
<td>( X::executor_type )</td>
<td>Returns an executor object that is associated with the execution context.</td>
</tr>
</tbody>
</table>

13.2.4 Service requirements

A class is a service if it is publicly and unambiguously derived from \texttt{execution\_context::service}, or if it is

<table>
<thead>
<tr>
<th>expression</th>
<th>return type</th>
<th>assertion/note pre/post-condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>( X::executor_type )</td>
<td>type meeting \texttt{Executor} \textbf{(13.2.2)}</td>
<td></td>
</tr>
<tr>
<td>( x.\neg X() )</td>
<td>Destroyed all unexecuted function objects that were submitted via an executor object that is associated with the execution context.</td>
<td></td>
</tr>
</tbody>
</table>

---

Table 5 — \texttt{ExecutionContext} requirements

<table>
<thead>
<tr>
<th>expression</th>
<th>return type</th>
<th>assertion/note pre/post-condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>( X::executor_type )</td>
<td>type meeting \texttt{Executor} \textbf{(13.2.2)}</td>
<td></td>
</tr>
<tr>
<td>( x.\neg X() )</td>
<td>Destroyed all unexecuted function objects that were submitted via an executor object that is associated with the execution context.</td>
<td></td>
</tr>
<tr>
<td>( x.\text{get}_executor() )</td>
<td>( X::executor_type )</td>
<td>Returns an executor object that is associated with the execution context.</td>
</tr>
</tbody>
</table>
publicly and unambiguously derived from another service. For a service $S$, $S::\text{key\_type}$ shall be valid and denote a type \((\text{C++ 2020 [temp.deduct]})\), \text{is\_base\_of\_v<typename S::key\_type, S> shall be true, and S shall satisfy meet the Destructible Cpp17Destructible requirements (C++ 2020 [destructible])}.

2 The first parameter of all service constructors shall be an lvalue reference to execution_context. This parameter denotes the execution_context object that represents a set of services, of which the service object will be a member. [Note: These constructors can be called by the \text{make\_service} function. — end note]

3 A service shall provide an explicit constructor with a single parameter of lvalue reference to execution_context. [Note: This constructor can be called by the \text{use\_service} function. — end note]

4 [Example:

```cpp
class my_service : public execution_context::service
{
    public:
        using key_type = my_service;
        explicit my_service(execution_context& ctx);
        my_service(execution_context& ctx, int some_value);
    private:
        virtual void shutdown() noexcept override;
        ...
};
```

— end example]

5 A service’s shutdown member function shall destroy all copies of function objects that are held by the service.

13.2.5 Signature requirements [async.reqmts.signature]

1 A type satisfies meets the signature Signature requirements if it is a call signature \((\text{C++ 2020 [func.def]})\).

13.2.6 Associator requirements [async.reqmts.associator]

1 An associator \text{associator} defines a relationship between different types and objects where, given:

\begin{enumerate}
\item[(1.1)] — a source object $s$ of type $S$,
\item[(1.2)] — type requirements $R$, and
\item[(1.3)] — a candidate object $c$ of type $C$ meeting the type requirements $R$,
\end{enumerate}

an associated type $A$ meeting the type requirements $R$ may be computed, and an associated object $a$ of type $A$ may be obtained.

2 An associator shall be a class template that takes two template type arguments. The first template argument is the source type $S$. The second template argument is the candidate type $C$. The second template argument shall be defaulted to some default candidate type $D$ that satisfies meet the type requirements $R$.

3 An associator shall additionally satisfy meet the requirements in Table 6. In this table, $X$ is a class template that meets the associator requirements, $S$ is the source type, $s$ is a value of type $S$ or $\text{const} S$, $C$ is the candidate type, $c$ is a (possibly $\text{const}$) value of type (possibly $\text{const}$) $C$, $D$ is the default candidate type, and $d$ is a (possibly $\text{const}$) value of type (possibly $\text{const}$) $D$ that is the default candidate object.

<table>
<thead>
<tr>
<th>expression</th>
<th>return type</th>
<th>assertion/note</th>
<th>pre/post-conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>$X&lt;S&gt;::\text{type}$</td>
<td>$X&lt;S, D&gt;::\text{type}$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

§ 13.2.6
The associator’s primary template shall be defined. A program may partially specialize the associator class template for some program-defined type S.

Finally, the associator shall provide the following type alias and function template in the enclosing namespace:

```cpp
template<class S, class C = D> using X_t = typename X<S, C>::type;

template<class S, class C = D>
typename X<S, C>::type get_X(const S& s, const C& c = d)
{
    return X<S, C>::get(s, c);
}
```

where X is replaced with the name of the associator class template. [Note: This function template is provided as a convenience, to automatically deduce the source and candidate types. —end note]

### 13.2.7 Requirements on asynchronous operations

This subclause uses the names Alloc1, Alloc2, alloc1, alloc2, Args, CompletionHandler, completion_handler, Executor1, Executor2, ex1, ex2, f, i, N, Signature, token, T1, t, work1, and work2 as placeholders for specifying the requirements below.

#### 13.2.7.1 General asynchronous operation concepts

An initiating function is a function which may be called to start an asynchronous operation. A completion handler is a function object that will be invoked, at most once, with the result of the asynchronous operation.

The life cycle of an asynchronous operation is comprised of the following events and phases:

- **Event 1:** The asynchronous operation is started by a call to the initiating function.
- **Phase 1:** The asynchronous operation is now outstanding.
- **Event 2:** The externally observable side effects of the asynchronous operation, if any, are fully established. The completion handler is submitted to an executor.
- **Phase 2:** The asynchronous operation is now completed.
- **Event 3:** The completion handler is called with the result of the asynchronous operation.

In this document, all functions with the prefix async_ are initiating functions.

### 13.2.7.2 Completion tokens and handlers

Initiating functions:

- are function templates with template parameter CompletionToken;
- accept, as the final parameter, a completion token object token of type CompletionToken;
- specify a completion signature, which is a call signature (C++ 2020 [func.def]) Signature that determines the arguments to the completion handler.
An initiating function determines the type `CompletionHandler` of its completion handler function object by performing `typename async_result<decay_t<CompletionToken>, Signature>::completion_handler_type`. The completion handler object `completion_handler` is initialized with `std::forward<CompletionToken>(token)`. [Note: No other requirements are placed on the type `CompletionToken`. — end note]

The type `CompletionHandler` shall satisfy the requirements of `DestructibleCpp17Destructible` (C++ 2020 [destructible]) and `MoveConstructibleCpp17MoveConstructible` (C++ 2020 [moveconstructible]), and be callable with the specified call signature.

In this document, all initiating functions specify a `Completion signature: element` that defines the call signature `Signature`. The `Completion signature: elements` in this document have named parameters, and the results of an asynchronous operation are specified in terms of these names.

### 13.2.7.3 Deduction of initiating function return type [async.reqmts.async.return.type]

The return type of an initiating function is `typename async_result<decay_t<CompletionToken>, Signature>::return_type`.

For the sake of exposition, this document sometimes annotates functions with a return type `DEDUCED`. For every function declaration that returns `DEDUCED`, the meaning is equivalent to specifying the return type as `typename async_result<decay_t<CompletionToken>, Signature>::return_type`.

### 13.2.7.4 Production of initiating function return value [async.reqmts.async.return.value]

An initiating function produces its return type as follows:

1. **(1.1)** — constructing an object `result` of type `async_result<decay_t<CompletionToken>, Signature>`, initialized as `result(completion_handler)`; and

2. **(1.2)** — using `result.get()` as the operand of the return statement.

[Example: Given an asynchronous operation with Completion signature `void(R1 r1, R2 r2)`, an initiating function meeting these requirements may be implemented as follows:

```cpp
template<class CompletionToken>
auto async_xyz(T1 t1, T2 t2, CompletionToken&& token)
{
    typename async_result<decay_t<CompletionToken>, void(R1, R2)>::completion_handler_type
        completion_handler(forward<CompletionToken>(token));

    async_result<decay_t<CompletionToken>, void(R1, R2)> result(completion_handler);

    // initiate the operation and cause completion_handler to be invoked with
    // the result

    return result.get();
}
```

For convenience, initiating functions may be implemented using the `async_completion` template:

```cpp
template<class CompletionToken>
auto async_xyz(T1 t1, T2 t2, CompletionToken&& token)
{
    async_completion<CompletionToken, void(R1, R2)> init(token);

    // initiate the operation and cause init.completion_handler to be invoked
    // with the result

    return init.result.get();
}
```

§ 13.2.7.4
13.2.7.5 Lifetime of initiating function arguments

Unless otherwise specified, the lifetime of arguments to initiating functions shall be treated as follows:

(1.1) — If the parameter has a pointer type or has a type of lvalue reference to non-const, the implementation may assume the validity of the pointee or referent, respectively, until the completion handler is invoked. [Note: In other words, the program is responsible for guaranteeing the validity of the argument until the completion handler is invoked. — end note]

(1.2) — Otherwise, the implementation does not assume the validity of the argument after the initiating function completes. [Note: In other words, the program is not required to guarantee the validity of the argument after the initiating function completes. — end note] The implementation may make copies of the argument, and all copies shall be destroyed no later than immediately after invocation of the completion handler.

13.2.7.6 Non-blocking requirements on initiating functions

An initiating function shall not block (C++ 2020 [defns.block]) the calling thread pending completion of the outstanding operation.

[Note: Initiating functions can still block the calling thread for other reasons. For example, if an initiating function locks a mutex in order to synchronize access to shared data. — end note]

13.2.7.7 Associated executor

Certain objects that participate in asynchronous operations have an associated executor. These are obtained as specified below.

13.2.7.8 I/O executor

An asynchronous operation has an associated executor satisfying meeting the Executor Executor (13.2.2) requirements. If not otherwise specified by the asynchronous operation, this associated executor is an object of type system_executor.

All asynchronous operations in this document have an associated executor object that is determined as follows:

(2.1) — If the initiating function is a member function, the associated executor is that returned by the get_executor member function on the same object.

(2.2) — If the initiating function is not a member function, the associated executor is that returned by the get_executor member function of the first argument to the initiating function.

Let Executor1 be the type of the associated executor. Let ex1 be a value of type Executor1, representing the associated executor object obtained as described above.

13.2.7.9 Completion handler executor

A completion handler object of type CompletionHandler has an associated executor satisfying meeting the Executor Executor requirements (13.2.2). The type of this associated executor is associated_executor_t<CompletionHandler, Executor1>. Let Executor2 be the type associated_executor_t<CompletionHandler, Executor1>. Let ex2 be a value of type Executor2 obtained by performing get_associated_executor(completion_handler, ex1).
13.2.7.10 Outstanding work

Until the asynchronous operation has completed, the asynchronous operation shall maintain:

(1.1) an object work1 of type executor_work_guard<Executor1>, initialized as work1(ex1), and where work1.owns_work() == true; and

(1.2) an object work2 of type executor_work_guard<Executor2>, initialized as work2(ex2), and where work2.owns_work() == true.

13.2.7.11 Allocation of intermediate storage

Asynchronous operations may allocate memory. [Note: Such as a data structure to store copies of the completion_handler object and the initiating function’s arguments. — end note]

Let Alloc1 be a type, satisfying the ProtoAllocator requirements, that represents the asynchronous operation’s default allocation strategy. [Note: Typically allocator<void>. — end note] Let alloc1 be a value of type Alloc1.

A completion handler object of type CompletionHandler has an associated allocator object alloc2 of type Alloc2 satisfying the ProtoAllocator requirements. The type Alloc2 is associated_allocator_t<CompletionHandler, Alloc1>. Let alloc2 be a value of type Alloc2 obtained by performing get_associated_allocator(completion_handler, alloc1).

The asynchronous operations defined in this document:

(4.1) If required, allocate memory using only the completion handler’s associated allocator.

(4.2) Prior to completion handler execution, deallocate any memory allocated using the completion handler’s associated allocator.

[Note: The implementation can perform operating system or underlying API calls that perform memory allocations not using the associated allocator. Invocations of the allocator functions do not introduce data races (see C++2020 [res.on.data.races]). — end note]

13.2.7.12 Execution of completion handler on completion of asynchronous operation

Let Args... be the argument types of the completion signature Signature and let N be sizeof...(Args). Let i be in the range [0, N). Let Ti be the ith type in Args... and let ti be the ith completion handler argument associated with Ti.

Let f be a function object, callable as f(), that invokes completion_handler as if by completion_handler(forward<T0>(t0), ..., forward<TN-1>(tN-1)).

If an asynchronous operation completes immediately (that is, within the thread of execution calling the initiating function, and before the initiating function returns), the completion handler shall be submitted for execution as if by performing ex2.post(std::move(f), alloc2). Otherwise, the completion handler shall be submitted for execution as if by performing ex2.dispatch(std::move(f), alloc2).

13.2.7.13 Completion handlers and exceptions

Completion handlers are permitted to throw exceptions. The effect of any exception propagated from the execution of a completion handler is determined by the executor which is executing the completion handler.

13.2.7.14 Composed asynchronous operations

In this document, a composed asynchronous operation is an asynchronous operation that is implemented in terms of zero or more intermediate calls to other asynchronous operations. The intermediate asynchronous operations are performed sequentially. [Note: That is, the completion handler of an intermediate operation initiates the next operation in the sequence. — end note]
An intermediate operation’s completion handler shall have an associated executor that is either:

(1.1) — the type Executor2 and object ex2 obtained from the completion handler type CompletionHandler and object completion_handler; or

(1.2) — an object of an unspecified type satisfying meeting the changedExecutor Executor requirements (13.2.2), that delegates executor operations to the type Executor2 and object ex2.

An intermediate operation’s completion handler shall have an associated allocator that is either:

(1.3) — the type Alloc2 and object alloc2 obtained from the completion handler type CompletionHandler and object completion_handler; or

(1.4) — an object of an unspecified type satisfying meeting the ProtoAllocator ProtoAllocator requirements (13.2.1), that delegates allocator operations to the type Alloc2 and object alloc2.

### 13.3 Class template async_result

[async.async.result]

The async_result class template is a customization point for asynchronous operations. Template parameter CompletionToken specifies the model used to obtain the result of the asynchronous operation. Template parameter Signature is the call signature (C++ 2020 [func.def]) for the completion handler type invoked on completion of the asynchronous operation. The async_result template:

(1.1) — transforms a CompletionToken into a completion handler type that is based on a Signature; and

(1.2) — determines the return type and return value of an asynchronous operation’s initiating function.

```cpp
namespace std {
namespace experimental {
namespace net {
namespace std::experimental::net::inline v1v2 {

template<class CompletionToken, class Signature>
class async_result
{
public:
    using completion_handler_type = CompletionToken;
    using return_type = void;

    explicit async_result(completion_handler_type&) {}
    async_result(const async_result&) = delete;
    async_result& operator=(const async_result&) = delete;

    return_type get() {}
};

} // inline namespace std::experimental::net::v1v2
} // namespace net
} // namespace experimental
} // namespace std
```

The template parameter CompletionToken shall be an object type. The template parameter Signature shall be a call signature (C++ 2020 [func.def]).

Specializations of async_result shall satisfy meet the Destructible Cpp17Destructible requirements (C++ 2020 [destructible]) in addition to the requirements in Table 7. In this table, R is a specialization of async_result; r is a modifiable lvalue of type R; and h is a modifiable lvalue of type R::completion_handler_type.

---

1 The async_result class template is a customization point for asynchronous operations. Template parameter CompletionToken specifies the model used to obtain the result of the asynchronous operation. Template parameter Signature is the call signature (C++ 2020 [func.def]) for the completion handler type invoked on completion of the asynchronous operation. The async_result template:

(1.1) — transforms a CompletionToken into a completion handler type that is based on a Signature; and

(1.2) — determines the return type and return value of an asynchronous operation’s initiating function.

2 The template parameter CompletionToken shall be an object type. The template parameter Signature shall be a call signature (C++ 2020 [func.def]).

3 Specializations of async_result shall satisfy meet the Destructible Cpp17Destructible requirements (C++ 2020 [destructible]) in addition to the requirements in Table 7. In this table, R is a specialization of async_result; r is a modifiable lvalue of type R; and h is a modifiable lvalue of type R::completion_handler_type.
Table 7 — async_result specialization requirements

<table>
<thead>
<tr>
<th>Expression</th>
<th>Return type</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>R::completion_handler_type</td>
<td>A type satisfying meeting MoveConstructible</td>
<td>Cpp17MoveConstructible requirements (C++ 2020 [moveconstructible]). An object of type completion_handler_type shall be a function object with call signature Signature, and completion_handler_type shall be constructible with an rvalue of type CompletionToken.</td>
</tr>
<tr>
<td>R::return_type</td>
<td>void; or a type satisfying meeting MoveConstructible requirements (C++ 2020 [moveconstructible])</td>
<td></td>
</tr>
<tr>
<td>R r(h); r.get()</td>
<td>R::return_type</td>
<td>[Note: An asynchronous operation’s initiating function uses the get() member function as the sole operand of a return statement. — end note]</td>
</tr>
</tbody>
</table>

13.4 Class template async_completion
[async.async.completion]

Class template async_completion is provided as a convenience, to simplify the implementation of asynchronous operations that use async_result.

```cpp
namespace std {
namespace experimental {
namespace net {
  inline namespace std::experimental::net::inline v1 {

    template<class CompletionToken, class Signature>
    struct async_completion {
      using completion_handler_type = async_result<decay_t<CompletionToken>, Signature>::completion_handler_type;
      explicit async_completion(CompletionToken& t);
      async_completion(const async_completion&) = delete;
      async_completion& operator=(const async_completion&) = delete;

      see below completion_handler;
      async_result<decay_t<CompletionToken>, Signature> result;
    };
  } // inline namespace std::experimental::net::inline
} // namespace net
} // namespace experimental
} // namespace std
```

2 The template parameter Signature shall be a call signature (C++ 2020 [func.def]).

```cpp
explicit async_completion(CompletionToken& t);
```

3 Effects: If CompletionToken and completion_handler_type are the same type, binds completion_handler to t; otherwise, initializes completion_handler with std::forward<CompletionToken>(t).
Initializes result with completion_handler.

see below completion_handler;

4 Type: completion_handler_type& if CompletionToken and completion_handler_type are the same type; otherwise, completion_handler_type.

13.5 Class template associated_allocator

1 Class template associated_allocator is an associator (13.2.6) for the ProtoAllocator (13.2.1) type requirements, with default candidate type allocator<void> and default candidate object allocator<void>().

```cpp
namespace std {
    namespace experimental {
        namespace net {
            namespace std::experimental::net::inline_v1v2 {
                template<class T, class ProtoAllocator = allocator<void>>
                struct associated_allocator {
                    using type = see below;
                    static type get(const T& t, const ProtoAllocator& a = ProtoAllocator()) noexcept;
                };
            } // inline namespace std::experimental::net::v1v2
        } // namespace net
    } // namespace experimental
} // namespace std
```

2 Specializations of associated_allocator shall satisfy the requirements in Table 8. In this table, X is a specialization of associated_allocator for the template parameters T and ProtoAllocator; t is a (possibly const) value of type (possibly const) T; and a is an object of type ProtoAllocator.

<table>
<thead>
<tr>
<th>Expression</th>
<th>Return type</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>typename X::type</td>
<td>A type meeting the proto-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>allocator (13.2.1) requirements.</td>
<td></td>
</tr>
<tr>
<td>X::get(t)</td>
<td>X::type</td>
<td>Shall not exit via an exception. Equivalent to X::get(t, ProtoAllocator()).</td>
</tr>
<tr>
<td>X::get(t, a)</td>
<td>X::type</td>
<td>Shall not exit via an exception.</td>
</tr>
</tbody>
</table>

13.5.1 associated_allocator members

1 Using type = see below;

Type: T::allocator_type if the qualified-id T::allocator_type is valid and denotes a type (C++ 2020 [temp.deduct]). Otherwise ProtoAllocator.

```cpp
type get(const T& t, const ProtoAllocator& a = ProtoAllocator()) noexcept;
```

2 Returns: t.get_allocator() if the qualified-id T::allocator_type is valid and denotes a type (C++ 2020 [temp.deduct]). Otherwise a.
13.6 Function get_associated_allocator  

\[
\text{template<class T>} \\
\quad \text{associated_allocator_t\textless T\textgreater \ get\_associated\_allocator(const T\& t) noexcept;} \\
\]

\text{Returns: associated Allocator\textless T\textgreater \::get(t).}

\[
\text{template<class T, class ProtoAllocator>} \\
\quad \text{associated_allocator_t\textless T, ProtoAllocator>\ } \\
\quad \text{get\_associated\_allocator(const T\& t, const ProtoAllocator& a) noexcept;} \\
\]

\text{Returns: associated Allocator\textless T, ProtoAllocator\textgreater \::get(t, a).}

13.7 Class execution_context  

Class execution_context implements an extensible, type-safe, polymorphic set of services, indexed by service type.

\[
\text{name space std\{} \\
\quad \text{name space experimental\{} \\
\quad \text{name space net\{} \\
\quad \text{inline name space std::experimental::net::inline v1v2 }\{ \\
\quad \text{class execution context } \\
\quad \{} \\
\quad \text{public:} \\
\quad \text{class service;} \\
\quad \\
\quad \text{// 13.7.1, construct / copy / destroy:} \\
\quad \text{execution context();} \\
\quad \text{execution context(const execution context&) = delete;} \\
\quad \text{execution context& operator=(const execution context&) = delete;} \\
\quad \text{virtual ~execution context();} \\
\quad \\
\quad \text{// 13.7.3, execution context operations:} \\
\quad \text{void notify_fork(fork_event e);} \\
\quad \text{protected:} \\
\quad \\
\quad \text{// 13.7.4, execution context protected operations:} \\
\quad \text{void shutdown() noexcept; } \\
\quad \text{void destroy() noexcept; } \\
\quad \}; \\
\quad \} // name space net \\
\quad \} // name space experimental \\
\}
\]
Access to the services of an `execution_context` is via three function templates, `use_service`, `make_service` and `has_service`.

In a call to `use_service<Service>`, the type argument chooses a service, identified by `Service::key_type`, from a set of services in an `execution_context`. If the service is not present in the `execution_context`, an object of type `Service` is created and added to the `execution_context`. A program can check if an `execution_context` implements a particular service with the function template `has_service<Service>`.

Service objects may be explicitly added to an `execution_context` using the function template `make_service<Service>`. If the service is already present, `make_service` exits via an exception of type `service_already_exists`.

Once a service reference is obtained from an `execution_context` object by calling `use_service`, that reference remains usable until a call to `destroy()`.

If a call to a specialization of `use_service` or `make_service` recursively calls another specialization of `use_service` or `make_service` which would choose the same service (identified by `key_type`) from the same `execution_context`, then the behavior is undefined. 

---

### 13.7.1 `execution_context` constructor

```cpp
execution_context();
```

**Effects:** Creates an object of class `execution_context` which contains no services. 

---

### 13.7.2 `execution_context` destructor

```cpp
~execution_context();
```

**Effects:** Destroys an object of class `execution_context`. Performs `shutdown()` followed by `destroy()`.

### 13.7.3 `execution_context` operations

```cpp
void notify_fork(fork_event e);
```

**Effects:** For each service object `svc` in the set:

1. If `e == fork_event::prepare`, performs `svc->notify_fork(e)` in reverse order of addition to the set.
2. Otherwise, performs `svc->notify_fork(e)` in order of addition to the set.

### 13.7.4 `execution_context` protected operations

```cpp
void shutdown() noexcept;
```

**Effects:** For each service object `svc` in the `execution_context` set, in reverse order of addition to the set, performs `svc->shutdown()`. For each service in the set, `svc->shutdown()` is called only once irrespective of the number of calls to `shutdown` on the `execution_context`.

```cpp
void destroy() noexcept;
```

**Effects:** Destroys each service object in the `execution_context` set, and removes it from the set, in reverse order of addition to the set.
13.7.5 execution_context globals

The functions use_service, make_service, and has_service do not introduce data races as a result of concurrent calls to those functions from different threads.

```cpp
template<class Service> typename Service::key_type&
use_service(execution_context& ctx);
```

*Effects:* If an object of type Service::key_type does not already exist in the execution_context set identified by ctx, creates an object of type Service, initialized as Service(ctx), and adds it to the set.

*Returns:* A reference to the corresponding service of ctx.

*Remarks:* The reference returned remains valid until a call to destroy.

```cpp
template<class Service, class... Args> Service&
make_service(execution_context& ctx, Args&&... args);
```

[Editor’s note: This is not a precondition, because the Throws: paragraph defines it.]

*Requires:* A service object of type Service::key_type does not already exist in the execution_context set identified by ctx.

*Effects:* Creates an object of type Service, initialized as Service(ctx, forward<Args>(args)...), and adds it to the execution_context set identified by ctx.

*Throws:* service_already_exists if a corresponding service object of type Service::key_type is already present in the set.

*Remarks:* The reference returned remains valid until a call to destroy.

```cpp
template<class Service> bool has_service(const execution_context& ctx) noexcept;
```

*Returns:* true if an object of type Service::key_type is present in ctx, otherwise false.

13.8 Class execution_context::service

```cpp
namespace std {
namespace experimental {
namespace net {
inline namespace std::experimental::net::inline v1v2 {

class execution_context::service {

protected:
   // construct / copy / destroy:

   explicit service(execution_context& owner);
   service(const service&) = delete;
   service& operator=(const service&) = delete;
   virtual ~service();

   // service observers:

   execution_context& context() noexcept;

private:
   // service operations:

   virtual void shutdown() noexcept = 0;

   } // class execution_context::service

} // namespace net
} // namespace experimental
} // namespace std
```
virtual void notify_fork(fork_event e) {}

execution_context& context_; // exposition only
};

} // inline namespace std::experimental::net::v1
} // namespace net
} // namespace experimental
} // namespace std

explicit service(execution_context& owner);

Postconditions: std::addressof(context_) == std::addressof(owner).

execution_context& context() noexcept;

Returns: context_.

13.9 Class template is_executor

The class template is_executor can be used to detect executor types satisfying meeting the Executor (13.2.2) type requirements.

namespace std {
namespace experimental {
namespace net {
inline namespace std::experimental::net::inline_v1_v2 {

template<class T> struct is_executor;

} // inline namespace std::experimental::net::v1_v2
} // namespace net
} // namespace experimental
} // namespace std

The template argument T shall be a complete type.

Class template is_executor is a UnaryTypeTrait Cpp17UnaryTypeTrait (C++ 2020 [meta.rqmts]) with a BaseCharacteristic base characteristic of true_type if the type T meets the syntactic requirements for Executor (13.2.2), otherwise false_type.

13.10 Executor argument tag

namespace std {
namespace experimental {
namespace net {
inline namespace std::experimental::net::inline_v1_v2 {

struct executor_arg_t { }; 
constexpr executor_arg_t executor_arg = executor_arg_t();

} // inline namespace std::experimental::net::v1_v2
} // namespace net
} // namespace experimental
} // namespace std

§ 13.10
1 The `executor_arg_t` struct is an empty structure type used as a unique type to disambiguate constructor and function overloading. Specifically, types may have constructors with `executor_arg_t` as the first argument, immediately followed by an argument of a type that satisfies the `Executor` requirements (13.2.2).

13.11 `uses_executor` [async.uses.executor]

13.11.1 `uses_executor` trait [async.uses.executor.trait]

```cpp
namespace std {
namespace experimental {
namespace net {
inline namespace std::experimental::net::inline v1 v2 {

    template<class T, class Executor>
    struct uses_executor;
}
}
}
}
```

1 Remarks: Detects whether T has a nested `executor_type` that is convertible from `Executor`. Meets the `BinaryTypeTrait Cpp17BinaryTypeTrait` requirements (C++ 2020 [meta.rqmts]). The implementation provides a definition that is derived from has a base characteristic of `true_type` if the qualified-id `T::executor_type` is valid and denotes a type and `is_convertible_v<Executor, T::executor_type>::value` != false, otherwise it is derived from has a base characteristic of `false_type`. A program may specialize this template to derive from `true_type` for a `uses` program-defined type T that does not have a nested `executor_type` but nonetheless can be constructed with an executor if the first argument of a constructor has type `executor_arg_t` and the second argument has type `Executor`.

13.11.2 `uses-executor` construction [async.uses.executor.cons]

Uses-executor construction with executor `Executor` refers to the construction of an object `obj` of type `T`, using constructor arguments `v1`, `v2`, ..., `vN` of types `V1`, `V2`, ..., `VN`, respectively, and an executor `ex` of type `Executor`, according to the following rules:

1. (1.1) if `uses_executor_v<T, Executor>` is true and `is_constructible_v<T, executor_arg_t, Executor, V1, V2, ..., VN>::value` is true, then `obj` is initialized as `obj(executor_arg, ex, v1, v2, ..., vN);
2. (1.2) otherwise, `obj` is initialized as `obj(v1, v2, ..., vN).

13.12 Class template `associated_executor` [async.assoc.exec]

Class template `associated_executor` is an associator (13.2.6) for the `Executor` requirements, with default candidate type `system_executor` and default candidate object `system_executor()`.

```cpp
namespace std {
namespace experimental {
namespace net {
inline namespace std::experimental::net::inline v1 v2 {

    template<class T, class Executor = system_executor>
    struct associated_executor {
        using type = see below;
        static type get(const T& t, const Executor& e = Executor()) noexcept;
    };
}
}
}
```
Specializations of `associated_executor` shall meet the requirements in Table 9. In this table, `X` is a specialization of `associated_executor` for the template parameters `T` and `Executor`; `t` is a (possibly const) value of `type (possibly const) T`; and `e` is an object of type `Executor`.

<table>
<thead>
<tr>
<th>Expression</th>
<th>Return type</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>typename X::type</code></td>
<td>A type meeting <code>Executor</code> requirements (13.2.2).</td>
<td></td>
</tr>
<tr>
<td><code>X::get(t)</code></td>
<td><code>X::type</code></td>
<td>Shall not exit via an exception. Equivalent to <code>X::get(t, Executor())</code>.</td>
</tr>
<tr>
<td><code>X::get(t, e)</code></td>
<td><code>X::type</code></td>
<td>Shall not exit via an exception.</td>
</tr>
</tbody>
</table>

### 13.12.1 `associated_executor` members

**using type = see below;**

1. *Type:* `T::executor_type` if the qualified-id `T::executor_type` is valid and denotes a type (`C++ 2020 [temp.deduct]`). Otherwise `Executor`.

```cpp
type get(const T& t, const Executor& e = Executor()) noexcept;
```

2. *Returns:* `t.get_executor()` if the qualified-id `T::executor_type` is valid and denotes a type (`C++ 2020 [temp.deduct]`). Otherwise `e`.

### 13.13 Function `get_associated_executor`

**template<class T>**

```cpp
associated_executor_t<T> get_associated_executor(const T& t) noexcept;
```

1. *Returns:* `associated_executor<T>::get(t)`. 

**template<class T, class Executor>**

```cpp
associated_executor_t<T, Executor> get_associated_executor(const T& t, const Executor& ex) noexcept;
```

2. *Returns:* `associated_executor<T, Executor>::get(t, ex)`. 
3. *Remarks:* This function shall not participate in overload resolution unless `Constraints: is_executor_v<Executor>` is true.

**template<class T, class ExecutionContext>**

```cpp
associated_executor_t<T, typename ExecutionContext::executor_type> get_associated_executor(const T& t, ExecutionContext& ctx) noexcept;
```

4. *Returns:* `get_associated_executor(t, ctx.get_executor())`. 
5. *Remarks:* This function shall not participate in overload resolution unless `Constraints: is_convertible_v<ExecutionContext&, execution_context&>::value` is true.
The class template `executor_binder` binds executors to objects. A specialization `executor_binder<T, Executor>` binds an executor of type `Executor` to an object or function of type `T`.

```cpp
namespace std {
namespace experimental {
namespace net {
inline namespace std::experimental::net::inline v1 v2 {

template<class T, class Executor>
class executor_binder
{
    public:
        // types:
        using target_type = T;
        using executor_type = Executor;

        // 13.14.1, construct / copy / destroy:
        executor_binder(T t, const Executor& ex);
        executor_binder(const executor_binder& other) = default;
        executor_binder(executor_binder&& other) = default;
        template<class U, class OtherExecutor>
        executor_binder(const executor_binder<U, OtherExecutor>& other);
        template<class U, class OtherExecutor>
        executor_binder(executor_binder<U, OtherExecutor>&& other);
        template<class U, class OtherExecutor>
        executor_binder(executor_arg_t, const Executor& ex,
                        const executor_binder<U, OtherExecutor>& other);
        template<class U, class OtherExecutor>
        executor_binder(executor_arg_t, const Executor& ex,
                        executor_binder<U, OtherExecutor>&& other);
        executor_binder();

        // 13.14.2, executor binder access:
        T& get() noexcept;
        const T& get() const noexcept;
        executor_type get_executor() const noexcept;

        // 13.14.3, executor binder invocation:
        template<class... Args>
        result_of_t<T&(Args&&...)> invoke_result_t<T&, Args&&...> operator()(Args&&... args);
        template<class... Args>
        result_of_t<const T&(Args&&...)> invoke_result_t<const T&, Args&&...> operator()(Args&&... args) const;

    private:
        Executor ex_; // exposition only
        T target_; // exposition only
};
```
template<class T, class Executor, class Signature>
class async_result<executor_binder<T, Executor>, Signature>;

template<class T, class Executor, class ProtoAllocator>
struct associated_allocator<executor_binder<T, Executor>, ProtoAllocator>;

template<class T, class Executor, class Executor1>
struct associated_executor<executor_binder<T, Executor>, Executor1>;

} // inline namespace std::experimental::net::v2
} // namespace net
} // namespace experimental
} // namespace std

13.14.1 executor_binder constructors

executor_binder(T t, const Executor& ex);

Effects: Initializes \texttt{ex} with \texttt{ex}. Initializes \texttt{target} by performing uses-executor construction, using the constructor argument \texttt{std::move(t)} and the executor \texttt{ex}.

template<class U, class OtherExecutor>
exectuor_binder(const executor_binder<U, OtherExecutor>& other);

Requires: If \texttt{U} is not convertible to \texttt{T}, or if \texttt{OtherExecutor} is not convertible to \texttt{Executor}, the program is ill-formed. Mandates: \texttt{is\_convertible\_v<U, T> is true} and \texttt{is\_convertible\_v<OtherExecutor, Executor> is true}.

Effects: Initializes \texttt{ex} with \texttt{other.get\_executor()}. Initializes \texttt{target} by performing uses-executor construction, using the constructor argument \texttt{other.get()} and the executor \texttt{ex}.

template<class U, class OtherExecutor>
exectuor_binder(executor_arg_t, const Executor& ex,
const executor_binder<U, OtherExecutor>& other);

Requires: If \texttt{U} is not convertible to \texttt{T} the program is ill-formed. Mandates: \texttt{is\_convertible\_v<U, T> is true}.

Effects: Initializes \texttt{ex} with \texttt{ex}. Initializes \texttt{target} by performing uses-executor construction, using the constructor argument \texttt{other.get()} and the executor \texttt{ex}.

[Editor's note: Failing to meet this Requires: was undefined, not ill-formed, but I'm changing it to Mandates: because that seems right.]
Requires: \( U \) is convertible to \( T \). Mandates: \( \text{is\_same\_v}<U, T> \) is true or \( \text{is\_convertible\_v}<U, T> \) is true.

Effects: Initializes \( \text{ex\_} \) with \( \text{ex} \). Initializes \( \text{target\_} \) by performing \( \text{uses\-executor} \) construction, using the constructor argument \( \text{std\::move(other.get())} \) and the executor \( \text{ex\_} \).

### 13.14.2 executor\_binder access [async.exec.binder.access]

\[ T& \text{ get()} \text{ noexcept}; \]
\[ \text{const T& get()} \text{ const noexcept}; \]

```
Returns: \( \text{target\_} \).
```

```
executor\_type \text{ get\_executor()} \text{ const noexcept};
```

```
Returns: \( \text{executor\_} \).
```

### 13.14.3 executor\_binder invocation [async.exec.binder.invocation]

```
template<class... Args>
result\_of_t<T\&(Args&&...)> \_invoke\_result\_t<T, Args...> \text{ operator()}(Args&&... args);
template<class... Args>
result\_of_t<const T\&(Args&&...)> \_invoke\_result\_t<const T, Args...> \text{ operator()}(Args&&... args) const;
```

```
Returns: \( \text{\_invoke(get(), forward<Args>(args)...)} \) (C++ 2020 [func.require]).
```

### 13.14.4 Class template partial specialization async\_result [async.exec.binder.async.result]

```
namespace std {
namespace experimental {
namespace net {
inline namespace std::experimental::net::inline v1\_v2 {

```
explicit async_result(completion_handler_type& h);

Effects: Initializes target_ as target_(h.get()).

return_type get();

Returns: target_.get().

13.14.5 Class template partial specialization associated_allocator
[async.exec.binder.assoc.alloc]

namespace std {
namespace experimental {
namespace net {
inline namespace std::experimental::net::inline v1v2 {

template<class T, class Executor, class ProtoAllocator>
struct associated_allocator<executor_binder<T, Executor>, ProtoAllocator>
{
    using type = associated_allocator_t<T, ProtoAllocator>;

    static type get(const executor_binder<T, Executor>& b,
        const ProtoAllocator& a = ProtoAllocator()) noexcept;
};
}
} // namespace net
} // namespace experimental
} // namespace std

static type get(const executor_binder<T, Executor>& b,
    const ProtoAllocator& a = ProtoAllocator()) noexcept;

Returns: associated_allocator<T, ProtoAllocator>::get(b.get(), a).

13.14.6 Class template partial specialization associated_executor
[async.exec.binder.assoc.exec]

namespace std {
namespace experimental {
namespace net {
inline namespace std::experimental::net::inline v1v2 {

template<class T, class Executor, class Executor1>
struct associated_executor<executor_binder<T, Executor>, Executor1>
{
    using type = Executor;

    static type get(const executor_binder<T, Executor>& b,
        const Executor1& e = Executor1()) noexcept;
};
}
} // namespace net
} // namespace experimental
} // namespace std

§ 13.14.6

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13.15 Function bind_executor

[async.bindexecutor]

[Editor’s note: Should these functions use remove_cvref_t instead of decay_t?]

template<class Executor, class T>
executor_binder<decay_t<T>, Executor>
bind_executor(const Executor& ex, T& t);

1
Returns: executor_binder<decay_t<T>, Executor>(forward<T>(t), ex).

2
Remarks: This function shall not participate in overload resolution unless Constraints: is_executor_v<Executor> is true.

template<class ExecutionContext, class CompletionToken>
executor_binder<decay_t<T>, typename ExecutionContext::executor_type>
bind_executor(ExecutionContext& ctx, T& t);

3
Returns: bind_executor(ctx.get_executor(), forward<T>(t)).

4
Remarks: This function shall not participate in overload resolution unless Constraints: is_convertible_v<ExecutionContext&, execution_context&>::value is true.

13.16 Class template executor_work_guard

[async.exec.work.guard]

namespace std {
namespace experimental {
namespace net {
inline namespace std::experimental::net::inline v1 v2 {

template<class Executor>
class executor_work_guard
{
public:
  // types:
  using executor_type = Executor;

  // construct / copy / destroy:
  explicit executor_work_guard(const executor_type& ex) noexcept;
  executor_work_guard(const executor_work_guard& other) noexcept;
  executor_work_guard(executor_work_guard& other) noexcept;
  executor_work_guard& operator=(const executor_work_guard&) = delete;
  ~executor_work_guard();

  // executor work guard observers:
  executor_type get_executor() const noexcept;
  bool owns_work() const noexcept;

  // executor work guard modifiers:

static type get(const executor_binder<T, Executor>& b, const Executor1& e = Executor1()) noexcept;

1
Returns: b.get_executor().
void reset() noexcept;

private:
    Executor ex_; // exposition only
    bool owns_; // exposition only
};

// inline namespace std::experimental::net::v2
} // namespace net
} // namespace experimental
} // namespace std

13.16.1 executor_work_guard members [async.exec.work.guard.members]

explicit executor_work_guard(const executor_type& ex) noexcept;
1  Effects: Initializes ex_ with ex, and then performs ex_.on_work_started().
2  Postconditions: ex_ == ex and owns_ == true.

evaluator_work_guard(const executor_work_guard& other) noexcept;
3  Effects: Initializes ex_ with other.ex_. If other.owns_ == true, performs ex_.on_work_started().
4  Postconditions: ex_ == other.ex_ and owns_ == other.owns_.

executor_work_guard(executor_work_guard& other) noexcept;
5  Effects: Initializes ex_ with std::move(other.ex_) and initializes owns_ with other.owns_, and sets other.owns_ to false.

~executor_work_guard();
6  Effects: If owns_ is true, performs ex_.on_work_finished().

executor_type get_executor() const noexcept;
7  Returns: ex_.

bool owns_work() const noexcept;
8  Returns: owns_.

void reset() noexcept;
9  Effects: If owns_ is true, performs ex_.on_work_finished().
10  Postconditions: owns_ == false.

13.17 Function make_work_guard [async.make.work.guard]

template<class Executor>
evaluator_work_guard<Executor>
make_work_guard(const Executor& ex);
1  Returns: evaluator_work_guard<Executor>(ex).
2  Remarks: This function shall not participate in overload resolution unless Constraints: is_executor_<
<Executor> is true.

template<class ExecutionContext>
evaluator_work_guard<typename ExecutionContext::executor_type>
make_work_guard(ExecutionContext& ctx);
Returns: make_work_guard(ctx.get_executor()).

Remarks: This function shall not participate in overload resolution unless Constraints: is_convertible_v<ExecutionContext&, execution_context&>::value is true.

template<class T>
executor_work_guard<associated_executor_t<T>>
make_work_guard(const T& t);

Returns: make_work_guard(get_associated_executor(t)).

Remarks: This function shall not participate in overload resolution unless Constraints: is_executor_v<T> is false and is_convertible_v<T&, execution_context&>::value is false.

template<class T, class U>
auto make_work_guard(const T& t, U&& u)
-> decltype(make_work_guard(get_associated_executor(t, forward<U>(u))));

Returns: make_work_guard(get_associated_executor(t, forward<U>(u))).

13.18 Class system_executor [async.system.exec]

Class system_executor represents a set of rules where function objects are permitted to execute on any thread.

namespace std {
namespace experimental { -
namespace net { -
inline namespace std::experimental::net::inline v1 v2 {

class system_executor
{
  public:
    // constructors:
    system_executor() {} 

    // 13.18.1, executor operations:
    system_context& context() const noexcept;

    void on_work_started() const noexcept {}
    void on_work_finished() const noexcept {}

    template<class Func, class ProtoAllocator>
    void dispatch(Func&& f, const ProtoAllocator& a) const;
    template<class Func, class ProtoAllocator>
    void post(Func&& f, const ProtoAllocator& a) const;
    template<class Func, class ProtoAllocator>
    void defer(Func&& f, const ProtoAllocator& a) const;
  
  bool operator==(const system_executor&, const system_executor&) noexcept;
  bool operator!=(const system_executor&, const system_executor&) noexcept;
}

} // inline namespace std::experimental::net::v1
} // namespace net
} // namespace experimental
} // namespace std

§ 13.18
Class `system_executor` satisfies the `DestructibleCpp17Destructible` (C++ 2020 [destructible]), `DefaultConstructibleCpp17DefaultConstructible` (C++ 2020 [defaultconstructible]), and `ExecutorExecutor` (13.2.2) type requirements.

To satisfy meet the `ExecutorExecutor` requirements for the `post` and `defer` member functions, the system executor may create `thread` objects to run the submitted function objects. These `thread` objects are collectively referred to as system threads.

### 13.18.1 `system_executor` operations

```cpp
system_context& context() const noexcept;
```

Returns: A reference to an object with static storage duration. All calls to this function return references to the same object.

```cpp
template<class Func, class ProtoAllocator>
void dispatch(Func&& f, const ProtoAllocator& a) const;
```

Effects: Equivalent to `DECAY_COPY(forward<Func>(f))()` (C++ 2020 [thread.decaycopy]).

```cpp
template<class Func, class ProtoAllocator>
void post(Func&& f, const ProtoAllocator& a) const;
```

```cpp
template<class Func, class ProtoAllocator>
void defer(Func&& f, const ProtoAllocator& a) const;
```

Effects: If `context().stopped()` is `false`, creates an object `f1` initialized with `DECAY_COPY(forward<Func>(f))`, and calls `f1()` as if in a thread of execution represented by a `thread` object. Any exception propagated from the execution of `DECAY_COPY(forward<Func>(f))()` initialization of `f1` or the call `f1()` results in a call to `std::terminate`.

### 13.18.2 `system_executor` comparisons

```cpp
bool operator==(const system_executor&, const system_executor&) noexcept;
```

Returns: `true`.

```cpp
bool operator!=(const system_executor&, const system_executor&) noexcept;
```

Returns: `false`.

### 13.19 `system_context`

Class `system_context` implements the execution context associated with `system_executor` objects.

```cpp
namespace std {
    namespace experimental {
        namespace net {
            inline namespace std::experimental::net::inline_v1v2 {

                class system_context : public execution_context {
                    public:
                        // types:
                        using executor_type = system_executor;
                        // construct / copy / destroy:
                        system_context() = delete;

            § 13.19       P2171R0
The class `system_context` satisfies the `ExecutionContext` type requirements.

The `system_context` member functions `get_executor`, `stop`, and `stopped`, and the `system_executor` copy constructors, member functions and comparison operators, do not introduce data races as a result of concurrent calls to those functions from different threads of execution.

Effects: Performs `stop` followed by `join`.

Returns: `system_executor`.

Effects: Signals all system threads to exit as soon as possible. If a system thread is currently executing a function object, the thread will exit only after completion of that function object. Returns without waiting for the system threads to complete.

Postconditions: `stopped() == true`.

Returns: `true` if the `system_context` has been stopped by a prior call to `stop`.

Effects: Blocks the calling thread (C++ 2020 [defns.block]) until all system threads have completed.

Synchronization: The completion of each system thread synchronizes with (C++ 2020 [intro.multithread]) the corresponding successful `join()` return.


```cpp
inline namespace std::experimental::net::inline v1v2 {

class bad_executor : public exception
{
public:
    // constructor:
    bad_executor() noexcept;
};
} // inline namespace std::experimental::net::v1v2
} // namespace net
} // namespace experimental
} // namespace std

bad_executor() noexcept;
```

Effects: constructs a `bad_executor` object.

Postconditions: `what()` returns an implementation-defined NTBS.

### 13.21 Class executor

The `executor` class provides a polymorphic wrapper for types that satisfy the `Executor` requirements (13.2.2).

```cpp
namespace std {
namespace experimental {
namespace net {
    inline namespace std::experimental::net::inline v1v2 {
    
    class executor
    {
    public:
    // 13.21.1, construct / copy / destroy:

        executor() noexcept;
        executor(nullptr_t) noexcept;
        executor(const executor& e) noexcept;
        executor(executor&& e) noexcept;
        template<class Executor> executor(Executor e);
        template<class Executor, class ProtoAllocator>
        executor(allocator_arg_t, const ProtoAllocator& a, Executor e);

        executor& operator=(const executor& e) noexcept;
        executor& operator=(executor&& e) noexcept;
        executor& operator=(nullptr_t) noexcept;
        template<class Executor> executor& operator=(Executor e);

        ~executor();
    
    // 13.21.4, executor modifiers:

        void swap(executor& other) noexcept;
        template<class Executor, class ProtoAllocator>
        void assign(Executor e, const ProtoAllocator& a);
    
    // 13.21.5, executor operations:

```
 execution_context& context() const noexcept;

void on_work_started() const noexcept;
void on_work_finished() const noexcept;

template<class Func, class ProtoAllocator>
    void dispatch(Func&& f, const ProtoAllocator& a) const;
template<class Func, class ProtoAllocator>
    void post(Func&& f, const ProtoAllocator& a) const;
template<class Func, class ProtoAllocator>
    void defer(Func&& f, const ProtoAllocator& a) const;

// 13.21.6, executor capacity:
explicit operator bool() const noexcept;

// 13.21.7, executor target access:
const type_info& target_type() const noexcept;
template<class Executor> Executor* target() noexcept;
template<class Executor> const Executor* target() const noexcept;

// 13.21.8, executor comparisons:
bool operator==(const executor& a, const executor& b) noexcept;
bool operator==(const executor& e, nullptr_t) noexcept;
bool operator!=(nullptr_t, const executor& e) noexcept;

// 13.21.9, executor specialized algorithms:
void swap(executor& a, executor& b) noexcept;

} // inline namespace experimental::net::v2
} // namespace net
} // namespace experimental

// namespace std

Class executor meets the requirements of Executor Executor (13.2.2), DefaultConstructible Cpp17DefaultConstructible (C++ 2020 [defaultconstructible]), and CopyAssignable Cpp17CopyAssignable (C++ 2020 [copyassignable]).

[Note: To meet the noexcept requirements for executor copy constructors and move constructors, implementations can share a target between two or more executor objects. — end note]

The target is the executor object that is held by the wrapper.

13.21.1 executor constructors
executor() noexcept;
   \textit{Postconditions:} \!*\! this.

executor(nullptr_t) noexcept;
   \textit{Postconditions:} \!*\! this.

executor(const executor& e) noexcept;
   \textit{Postconditions:} \!*\! this if \!e; otherwise, \!*\! this targets e.target() or a copy of e.target().

executor(executor&& e) noexcept;
   \textit{Effects:} If \!e, \!*\! this has no target; otherwise, moves e.target() or move-constructs the target of \!e into the target of \!*\! this, leaving \!e in a valid state with an unspecified value.

\template<class Executor> executor(Executor e);
   \textit{Effects:} \!*\! this targets a copy of \!e initialized with std::move(\!e).

\template<class Executor, class ProtoAllocator>
executor(allocator_arg_t, const ProtoAllocator& a, Executor e);
   \textit{Effects:} \!*\! this targets a copy of \!e initialized with std::move(\!e).
   A copy of the allocator argument is used to allocate memory, if necessary, for the internal data structures of the constructed \texttt{executor} object.

\subsection{executor assignment} \quad [\texttt{async.executor.assign}]

executor& operator=(const executor& e) noexcept;
   \textit{Effects:} executor(e).swap(*this).
   \textit{Returns:} \!*\! this.

executor& operator=(executor&& e) noexcept;
   \textit{Effects:} Replaces the target of \!*\! this with the target of \!e, leaving \!e in a valid state with an unspecified value.
   \textit{Returns:} \!*\! this.

executor& operator=(nullptr_t) noexcept;
   \textit{Effects:} executor(nullptr).swap(*this).
   \textit{Returns:} \!*\! this.

\template<class Executor> executor& operator=(Executor e);
   \textit{Effects:} executor(std::move(\!e)).swap(*this).
   \textit{Returns:} \!*\! this.

\subsection{executor destructor} \quad [\texttt{async.executor.dtor}]

-executor();
   \textit{Effects:} If \!*\! this \!= nullptr, releases shared ownership of, or destroys, the target of \!*\! this.
13.21.4 executor modifiers

```cpp
void swap(executor& other) noexcept;
```

*Effects:* Interchanges the targets of *this and other.

```cpp
template<class Executor, class ProtoAllocator>
void assign(Executor e, const ProtoAllocator& a);
```

*Effects:* executor(alloactor_arg, a, std::move(e)).swap(*this).

13.21.5 executor operations

```cpp
execution_context& context() const noexcept;
```

*Requires:* *this != nullptr.

*Preconditions:* *this != nullptr.

*Returns:* `e.context()`, where `e` is the target object of *this.

```cpp
void on_work_started() const noexcept;
```

*Requires:* *this != nullptr.

*Preconditions:* *this != nullptr.

*Effects:* `e.on_work_started()`, where `e` is the target object of *this.

```cpp
void on_work_finished() const noexcept;
```

*Requires:* *this != nullptr.

*Preconditions:* *this != nullptr.

*Effects:* `e.on_work_finished()`, where `e` is the target object of *this.

```cpp
template<class Func, class ProtoAllocator>
void dispatch(Func&& f, const ProtoAllocator& a) const;
```

Let `e` be the target object of *this. Let `a1` be the allocator that was specified when the target was set. Let `fd` be the result of `DECAY_COPY(f)` (C++ 2020 [thread.decaycopy]).

*Effects:* `e.dispatch(g, a1)`, where `g` is a function object of unspecified type that, when called as `g()`, performs `fd()`. The allocator `a` is used to allocate any memory required to implement `g`.

```cpp
template<class Func, class ProtoAllocator>
void post(Func&& f, const ProtoAllocator& a) const;
```

Let `e` be the target object of *this. Let `a1` be the allocator that was specified when the target was set. Let `fd` be the result of `DECAY_COPY(f)`.

*Effects:* `e.post(g, a1)`, where `g` is a function object of unspecified type that, when called as `g()`, performs `fd()`. The allocator `a` is used to allocate any memory required to implement `g`.

```cpp
template<class Func, class ProtoAllocator>
void defer(Func&& f, const ProtoAllocator& a) const;
```

Let `e` be the target object of *this. Let `a1` be the allocator that was specified when the target was set. Let `fd` be the result of `DECAY_COPY(f)`.

*Effects:* `e.defer(g, a1)`, where `g` is a function object of unspecified type that, when called as `g()`, performs `fd()`. The allocator `a` is used to allocate any memory required to implement `g`.

13.21.6 executor capacity

```cpp
explicit operator bool() const noexcept;
```

*Returns:* `true` if *this has a target, otherwise false.
13.21.7 executor target access

```
const type_info& target_type() const noexcept;
```

**Returns:** If `*this` has a target of type `T`, `typeid(T)`; otherwise, `typeid(void)`.

```
template<class Executor> Executor* target() noexcept;
template<class Executor> const Executor* target() const noexcept;
```

**Returns:** If `target_type() == typeid(Executor)` a pointer to the stored executor target; otherwise a null pointer value.

13.21.8 executor comparisons

```
bool operator==(const executor& a, const executor& b) noexcept;
```

**Returns:**

1. true if `!a` and `!b`;
2. true if `a` and `b` share a target;
3. true if `e` and `f` are the same type and `e == f`, where `e` is the target of `a` and `f` is the target of `b`;
4. otherwise false.

```
bool operator==(const executor& e, nullptr_t) noexcept;
bool operator==(nullptr_t, const executor& e) noexcept;
```

**Returns:** `!e`.

```
bool operator!=(const executor& a, const executor& b) noexcept;
```

**Returns:** `!(a == b)`.

```
bool operator!=(const executor& e, nullptr_t) noexcept;
bool operator!=(nullptr_t, const executor& e) noexcept;
```

**Returns:** `(bool) e`.

13.21.9 executor specialized algorithms

```
void swap(executor& a, executor& b) noexcept;
```

**Effects:** `a.swap(b)`.

13.22 Function dispatch

```
template<class CompletionToken>
DEDUCED dispatch(CompletionToken&& token);
```

**Completion signature:** void().

**Effects:**

1. Constructs an object `completion` of type `async_completion<CompletionToken, void()>`, initialized with `token`.
2. Performs `ex.dispatch(std::move(completion.completion_handler), alloc)`, where `ex` is the result of `get_associated_executor(completion.completion_handler)`, and `alloc` is the result of `get_associated_allocator(completion.completion_handler)`.

template<class Executor, class CompletionToken>
    DEDUCED dispatch(const Executor& ex, CompletionToken& token);

    Completion signature: void().

    Effects:
    (6.1) — Constructs an object completion of type async_completion<CompletionToken, void()>, initialized with token.
    (6.2) — Constructs a function object f containing as members:
        (6.2.1) — a copy of the completion handler h, initialized with std::move(completion.completion_handler),
        (6.2.2) — an executor_work_guard object w for the completion handler's associated executor, initialized with make_work_guard(h),
            and where the effect of f() is:
            (6.3.1) — w.get_executor().dispatch(std::move(h), alloc), where alloc is the result of get_associated_allocator(h), followed by
            (6.3.2) — w.reset().
    (6.3) — Performs ex.dispatch(std::move(f), alloc), where alloc is the result of get Associated allocator(completion.completion_handler) prior to the construction of f.

    Returns: completion.result.get().

Remarks: This function shall not participate in overload resolution unless Constraints: is_executor_v<Executor> is true.

template<class ExecutionContext, class CompletionToken>
    DEDUCED dispatch(ExecutionContext& ctx, CompletionToken& token);

    Completion signature: void().

    Returns: net::dispatch(ctx.get_executor(), forward<CompletionToken>(token)).

Remarks: This function shall not participate in overload resolution unless Constraints: is_convertible_v<ExecutionContext&, execution_context&>::value is true.

13.23 Function post

    [ Note: The function post satisfies meets the requirements for an asynchronous operation (13.2.7). — end note ]

    template<class CompletionToken>
        DEDUCED post(CompletionToken& token);

    Completion signature: void().

    Effects:
    (3.1) — Constructs an object completion of type async_completion<CompletionToken, void()>, initialized with token.
    (3.2) — Performs ex.post(std::move(completion.completion_handler), alloc), where ex is the result of get Associated executor(completion.completion_handler), and alloc is the result of get Associated allocator(completion.completion_handler).

    Returns: completion.result.get().

§ 13.23
template<class Executor, class CompletionToken>
    DEDUCED post(const Executor& ex, CompletionToken& token);

Completion signature: void().

Effects:
(6.1) — Constructs an object completion of type async_completion<CompletionToken, void()>.
    initialized with token.
(6.2) — Constructs a function object f containing as members:
    (6.2.1) — a copy of the completion handler h, initialized with std::move(completion.completion_handler),
    (6.2.2) — an executor_work_guard object w for the completion handler’s associated executor, initialized
        with make_work_guard(h),
        and where the effect of f() is:
        (6.2.3) w.get_executor().dispatch(std::move(h), alloc), where alloc is the result of get_associated_allocator(h), followed by
    (6.2.4) — w.reset().
(6.3) — Performs ex.post(std::move(f), alloc), where alloc is the result of get_associated_allocator(completion.completion_handler) prior
        to the construction of f.

Returns: completion.result.get().

Remarks: This function shall not participate in overload resolution unless Constraints: is_executor_v<Executor> is true.

template<class ExecutionContext, class CompletionToken>
    DEDUCED post(ExecutionContext& ctx, CompletionToken& token);

Completion signature: void().

Returns: net::post(ctx.get_executor(), forward<CompletionToken>(token)).

Remarks: This function shall not participate in overload resolution unless Constraints: is_convertible_v<ExecutionContext&, execution_context&>::value is true.

13.24 Function defer [async.defer]
[Note: The function defer satisfies the requirements for an asynchronous operation (13.2.7), except for
the requirement that the operation uses post if it completes immediately. — end note]

template<class CompletionToken>
    DEDUCED defer(CompletionToken& token);

Completion signature: void().

Effects:
(3.1) — Constructs an object completion of type async_completion<CompletionToken, void()>.
    initialized with token.
(3.2) — Performs ex.defer(std::move(completion.completion_handler), alloc), where ex is the
        result of get_associated_executor(completion.completion_handler), and alloc is the result
        of get_associated_allocator(completion.completion_handler).

Returns: completion.result.get().
template<class Executor, class CompletionToken>
 DEDUCED defer(const Executor& ex, CompletionToken&& token);

5 Completion signature: void().

Effects:
(6.1) — Constructs an object completion of type async_completion<CompletionToken, void>(), initialized with token.
(6.2) — Constructs a function object f containing as members:
(6.2.1) — a copy of the completion handler h, initialized with std::move(completion.completion_handler),
(6.2.2) — an executor_work_guard object w for the completion handler’s associated executor, initialized with make_work_guard(h),
and where the effect of f() is:
(6.2.3) — w.get_executor().dispatch(std::move(h), alloc), where alloc is the result of get_associated_allocator(h), followed by
(6.2.4) — w.reset().
(6.3) — Performs ex.defer(std::move(f), alloc), where alloc is the result of get_associated_allocator(completion.completion_handler) prior to the construction of f.

Returns: completion.result.get().

Remarks: This function shall not participate in overload resolution unless Constraints: is_executor_v<Executor> is true.

template<class ExecutionContext, class CompletionToken>
 DEDUCED defer(ExecutionContext& ctx, CompletionToken&& token);

9 Completion signature: void().

Returns: net::defer(ctx.get_executor(), forward<CompletionToken>(token)).

Remarks: This function shall not participate in overload resolution unless Constraints: is_convertible_v<ExecutionContext&, execution_context&>::value is true.

13.25 Class template strand

The class template strand is a wrapper around an object of type Executor satisfying meeting the Executor requirements (13.2.2).

namespace std {
 namespace experimental {
 namespace net {
    inline namespace std::experimental::net::inline_v1v2 {

 template<class Executor>
 class strand
 {
  public:
   // types:

   using inner_executor_type = Executor;

   // 13.25.1, construct / copy / destroy:
strand();
explicit strand(Executor ex);
template<class ProtoAllocator>
  strand(allocator_arg_t, const ProtoAllocator& alloc, Executor ex);
strand(const strand& other) noexcept;
strand(strand&& other) noexcept;
template<class OtherExecutor> strand(const strand<OtherExecutor>& other) noexcept;
template<class OtherExecutor> strand(strand<OtherExecutor>&& other) noexcept;

strand& operator=(const strand& other) noexcept;
strand& operator=(strand&& other) noexcept;
template<class OtherExecutor> strand& operator=(const strand<OtherExecutor>& other) noexcept;
template<class OtherExecutor> strand& operator=(strand<OtherExecutor>&& other) noexcept;

~strand();

// 13.25.4, strand operations:

inner_executor_type get_inner_executor() const noexcept;

bool running_in_this_thread() const noexcept;

execution_context& context() const noexcept;

void on_work_started() const noexcept;
void on_work_finished() const noexcept;

template<class Func, class ProtoAllocator>
  void dispatch(Func&& f, const ProtoAllocator& a) const;
template<class Func, class ProtoAllocator>
  void post(Func&& f, const ProtoAllocator& a) const;
template<class Func, class ProtoAllocator>
  void defer(Func&& f, const ProtoAllocator& a) const;

private:
  Executor inner_ex_; // exposition only
};

bool operator==(const strand<Executor>& a, const strand<Executor>& b);
bool operator!=(const strand<Executor>& a, const strand<Executor>& b);

} // inline namespace std::experimental::net::v2
  } // namespace net
  } // namespace experimental
  } // namespace std

strad<Executor> satisfies the Executor (13.2.2) requirements.

A strand provides guarantees of ordering and non-concurrency. Given:

(3.1) — strand objects s1 and s2 such that s1 == s2
(3.2) — a function object f1 added to the strand s1 using post or defer, or using dispatch when s1.running_in_this_thread() is false
(3.3) — a function object f2 added to the strand s2 using post or defer, or using dispatch when s2.running_in_this_thread() is false

§ 13.25
then the implementation invokes $f_1$ and $f_2$ such that:

(4.1) — the invocation of $f_1$ is not concurrent with the invocation of $f_2$

(4.2) — the invocation of $f_1$ synchronizes with the invocation of $f_2$.

Furthermore, if the addition of $f_1$ happens before the addition of $f_2$, then the invocation of $f_1$ happens before the invocation of $f_2$.

All member functions, except for the assignment operators and the destructor, do not introduce data races on *this, including its ordered, non-concurrent state. Additionally, constructors and assignment operators do not introduce data races on lvalue arguments.

If any function $f$ executed by the strand throws an exception, the subsequent strand state is as if $f$ had exited without throwing an exception.

### 13.25.1 strand constructors

**strand();**

*Effects:* Constructs an object of class `strand<Executor>` that represents a unique ordered, non-concurrent state. Initializes `inner_ex_` as `inner_ex_()`.

*Remarks:* This overload shall not participate in overload resolution unless `Executor` satisfies the `DefaultConstructible` requirements (C++ 2020 [defaultconstructible]).

*Constraints:* `is_default_constructible_v<Executor>` is true.

**explicit strand(Executor ex);**

*Effects:* Constructs an object of class `strand<Executor>` that represents a unique ordered, non-concurrent state. Initializes `inner_ex_` as `inner_ex_(ex)`.

**template<class ProtoAllocator> strand(allocator_arg_t, const ProtoAllocator& a, Executor ex);**

*Effects:* Constructs an object of class `strand<Executor>` that represents a unique ordered, non-concurrent state. Initializes `inner_ex_` as `inner_ex_(ex)`. A copy of the allocator argument $a$ is used to allocate memory, if necessary, for the internal data structures of the constructed strand object.

**strand(const strand& other) noexcept;**

*Effects:* Initializes `inner_ex_` as `inner_ex_`(other.`inner_ex_`).

*Postconditions:*

(6.1) — *this == other

(6.2) — `get_inner_executor()` == other.`get_inner_executor()`

**strand(strand&& other) noexcept;**

*Effects:* Initializes `inner_ex_` as `inner_ex_`(std::move(other.`inner_ex_`)).

*Postconditions:*

(8.1) — *this is equal to the prior value of other

(8.2) — `get_inner_executor()` == other.`get_inner_executor()`

**template<class OtherExecutor> strand(const strand<OtherExecutor>& other) noexcept;**

[Editor’s note: The next two constructors are changed to be constrained, so that `is_constructible` gives the right answer.]
Requires: OtherExecutor is convertible to Executor. \_Constraints: is\_convertible\_v<OtherExecutor, Executor> is true.

Effects: Initializes inner\_ex\_ as inner\_ex\_ (other.inner\_ex\_).

Postconditions: *this == other.

template<class OtherExecutor> strand(strand<OtherExecutor>&& other) noexcept;

Requires: OtherExecutor is convertible to Executor. \_Constraints: is\_convertible\_v<OtherExecutor, Executor> is true.

Effects: Initializes inner\_ex\_ as inner\_ex\_ (std::move(other.inner\_ex\_)).

Postconditions: *this is equal to the prior value of other.

### 13.25.2 strand assignment

[async.strand.assign]

strando operator=(const strando other) noexcept;

Requires: Executor is CopyAssignable (C++ 2020 [copyassignable]). \_Mandates: is\_copy\_assignable\_v<Executor> is true.

Postconditions:

1. *this == other
2. get\_inner\_executor() == other.get\_inner\_executor()

Returns: *this.

strando operator=(strando other) noexcept;

Requires: Executor is MoveAssignable (C++ 2020 [moveassignable]). \_Mandates: is\_move\_assignable\_v<Executor> is true.

Postconditions:

1. *this is equal to the prior value of other
2. get\_inner\_executor() == other.get\_inner\_executor()

Returns: *this.

template<class OtherExecutor> strando operator=(const strando<OtherExecutor>& other) noexcept;

Requires: OtherExecutor is convertible to Executor. Executor is CopyAssignable (C++ 2020 [copyassignable]). \_Mandates: is\_convertible\_v<OtherExecutor, Executor> is true and is\_copy\_assignable\_v<Executor> is true.

Effects: Assigns other.inner\_ex\_ to inner\_ex\_.

Postconditions: *this == other.

Returns: *this.

template<class OtherExecutor> strando operator=(strando<OtherExecutor>&& other) noexcept;

Requires: OtherExecutor is convertible to Executor. Executor is MoveAssignable (C++ 2020 [moveassignable]). \_Mandates: is\_convertible\_v<OtherExecutor, Executor> is true and is\_move\_assignable\_v<Executor> is true.

Effects: Assigns std::move(other.inner\_ex\_) to inner\_ex\_.

Postconditions: *this is equal to the prior value of other.

Returns: *this.
13.25.3 strand destructor

- strand();

 Effects: Destroys an object of class strand<Executor>. After this destructor completes, objects that were added to the strand but have not yet been executed will be executed in a way that meets the guarantees of ordering and non-concurrency.

13.25.4 strand operations

inner_executor_type get_inner_executor() const noexcept;

 Returns: inner_ex_.

bool running_in_this_thread() const noexcept;

 Returns: true if the current thread of execution is running a function that was submitted to the strand, or to any other strand object s such that s == *this, using dispatch, post or defer; otherwise false. [Note: That is, the current thread of execution’s call chain includes a function that was submitted to the strand. —end note]

execution_context& context() const noexcept;

 Returns: inner_ex_.context().

void on_work_started() const noexcept;

 Effects: Calls inner_ex_.on_work_started().

void on_work_finished() const noexcept;

 Effects: Calls inner_ex_.on_work_finished().

template<class Func, class ProtoAllocator>
void dispatch(Func&& f, const ProtoAllocator& a) const;

 Effects: If running_in_this_thread() is true, calls DECAY_COPY(forward<Func>(f))() (C++ 2020 [thread.decaycopy]). [Note: If f exits via an exception, the exception propagates to the caller of dispatch(). —end note] Otherwise, requests invocation of f, as if by forwarding the function object f and allocator a to the executor inner_ex_, such that the guarantees of ordering and non-concurrency are met.

template<class Func, class ProtoAllocator>
void post(Func&& f, const ProtoAllocator& a) const;

 Effects: Requests invocation of f, as if by forwarding the function object f and allocator a to the executor inner_ex_, such that the guarantees of ordering and non-concurrency are met.

template<class Func, class ProtoAllocator>
void defer(Func&& f, const ProtoAllocator& a) const;

 Effects: Requests invocation of f, as if by forwarding the function object f and allocator a to the executor inner_ex_, such that the guarantees of ordering and non-concurrency are met.

13.25.5 strand comparisons

bool operator==(const strand<Executor>& a, const strand<Executor>& b);

 Returns: true, if the strand objects share the same ordered, non-concurrent state; otherwise false.

bool operator!=(const strand<Executor>& a, const strand<Executor>& b);

 Returns: !(a == b).
13.26 Class template use_future_t

The class template use_future_t defines a set of types that, when passed as a completion token (13.2.7.2) to an asynchronous operation's initiating function, cause the result of the asynchronous operation to be delivered via a future (C++ 2020 [futures.uniquefuture]).

```cpp
namespace std {
    namespace experimental {
        namespace net {
            inline namespace std::experimental::net::inline v1v2 {

            template<class ProtoAllocator = allocator<void>>
                class use_future_t {
                    public:
                        // use_future_t types:
                        using allocator_type = ProtoAllocator;
                        // use_future_t members:
                        constexpr use_future_t() noexcept(noexcept(allocator_type()) is_nothrow_default_constructible_v<allocator_type>);
                        explicit use_future_t(const allocator_type& a) noexcept;
                        template<class OtherProtoAllocator> use_future_t<OtherProtoAllocator> rebind(const OtherProtoAllocator& a) const noexcept;
                        allocator_type get_allocator() const noexcept;
                        template<class F> unspecified operator()(F&& f) const;
                };
            }
        }
    }
}

13.26.1 use_future_t constructors

constexpr use_future_t() noexcept(noexcept(allocator_type()) is_nothrow_default_constructible_v<allocator_type>);  
[Editor's note: Allocators don't have to be default constructible.]

1

Mandates: is_default_constructible_v<allocator_type> is true.

2

Effects: Constructs a use_future_t with a default-constructed allocator.

explicit use_future_t(const allocator_type& a) noexcept;

3

Postconditions: get_allocator() == a.

13.26.2 use_future_t members

template<class OtherProtoAllocator> use_future_t<OtherProtoAllocator> rebind(const OtherProtoAllocator& a) const noexcept;

1

Returns: A use_future_t object where get_allocator() == a.

allocator_type get_allocator() const noexcept;

2

Returns: The associated allocator object.

template<class F> unspecified operator()(F&& f) const;
```
Let $T$ be a completion token type. Let $H$ be a completion handler type and let $h$ be an object of type $H$. Let $FD$ be the type $\text{decay\_t}<F>$ and let $fd$ be an lvalue of type $FD$ constructed with $\text{std\::forward}<F>(f)$. Let $R(\text{Args}...)$ be the completion signature of an asynchronous operation using $H$ and let $N$ be $\text{sizeof}\...(\text{Args})$. Let $i$ be in the range $[0, N)$ and let $A_i$ be the $i^{th}$ type in $\text{Args}$. Let $a_i$ be the argument associated with $A_i$.

Returns: A completion token $t$ of type $T$.

Remarks: The return type $T$ satisfies the $\text{Destructible Cpp17Destructible}$ ($C++\ 2020$ [destructible]) and $\text{MoveConstructible Cpp17MoveConstructible}$ ($C++\ 2020$ [moveconstructible]) requirements.

The object $h$ of type $H$ is an asynchronous provider with an associated shared state ($C++\ 2020$ [futures.state]). The effect of $h(a_0, \ldots, a_{N-1})$ is to atomically store the result of $\text{INVOKE}(fd, \text{forward}<A_0>(a_0), \ldots, \text{forward}<A_{N-1}>(a_{N-1}))$ ($C++\ 2020$ [func.require]) in the shared state and make the shared state ready. If $fd$ exits via an exception then that exception is atomically stored in the shared state and the shared state is made ready.

The implementation provides a partial specialization $\text{template<class Result, class... Args>
async_result<T, Result(Args...)>>}$ such that:

1. the nested type $\text{completion\_handler\_type}$ is a type $H$;
2. the nested type $\text{return\_type}$ is a type $\text{future<result\_of_t<FD,(\text{decaying_t<Arg}\ldots)>>>>}$ and
3. when an object $r_1$ of type $\text{async\_result<T, Result(Args...)>>}$ is constructed from $h$, the expression $r_1.\text{get()}$ returns a future with the same shared state as $h$.

For any executor type $E$, the associated object for the associator $\text{associated\_executor<H, E>>}$ is an executor where, for function objects executed using the executor’s $\text{dispatch()}$, $\text{post()}$ or $\text{defer()}$ functions, any exception thrown is caught by a function object and stored in the associated shared state.

### 13.26.3 Partial class template specialization async_result for use_future_t

```
[async.use.future.result]

template<class ProtoAllocator, class Result, class... Args>
class async_result<use_future_t<ProtoAllocator>, Result(Args...)>
{
    using completion_handler_type = see below;
    using return_type = see below;

    explicit async_result(completion_handler_type& h);
    async_result(const async_result&) = delete;
    async_result& operator=(const async_result&) = delete;

    return_type get();
};
```

1. Let $R$ be the type $\text{async\_result<use\_future\_t<ProtoAllocator>, Result(Args...)>>}$. Let $F$ be the nested function object type $R::\text{completion\_handler\_type}$.
2. An object $t_1$ of type $F$ is an asynchronous provider with an associated shared state ($C++\ 2020$ [futures.state]). The type $F$ provides $\text{F::\operator()}$ such that the expression $t_1(\text{declval<Arg}\ldots)$ is well formed.
3. The implementation specializes $\text{associated\_executor}$ for $F$. For function objects executed using the associated executor’s $\text{dispatch()}$, $\text{post()}$ or $\text{defer()}$ functions, any exception thrown is caught by the executor and stored in the associated shared state.
For any executor type E, the associated object for the associator `associated_executor<F, E>` is an executor where, for function objects executed using the executor’s `dispatch()`, `post()` or `defer()` functions, any exception thrown by a function object is caught by the executor and stored in the associated shared state.

When an object `r1` of type `R` is constructed from `t1`, the expression `r1.get()` returns a future with the same shared state.

The type of `R::return_type` and the effects of `F::operator()` are defined in Table 10. After establishing these effects, `F::operator()` makes the shared state ready. In this table, \( N \) is the value of `sizeof...(Args)`; let \( i \) be in the range \([0, N)\) and let \( T_i \) be the \( i^{th} \) type in \( Args \); let \( U_i \) be \( \text{decay}_t<T_i> \) for each type \( T_i \) in \( Args \); let \( A_i \) be the deduced type of the \( i^{th} \) argument to `F::operator()`; and let \( a_i \) be the \( i^{th} \) argument to `F::operator()`.

<table>
<thead>
<tr>
<th>( N )</th>
<th>( U_0 )</th>
<th><code>R::return_type</code></th>
<th><code>F::operator()</code> effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td><code>future&lt;void&gt;</code></td>
<td>None.</td>
</tr>
<tr>
<td>1</td>
<td><code>error_code</code></td>
<td><code>future&lt;void&gt;</code></td>
<td>If ( a_0 ) evaluates to <code>true</code>, atomically stores the exception pointer produced by <code>make_exception_ptr(system_error(a_0))</code> in the shared state.</td>
</tr>
<tr>
<td>1</td>
<td><code>exception_ptr</code></td>
<td><code>future&lt;void&gt;</code></td>
<td>If ( a_0 ) is non-null, atomically stores the exception pointer ( a_0 ) in the shared state.</td>
</tr>
<tr>
<td>1</td>
<td>all other types</td>
<td><code>future&lt;U_0&gt;</code></td>
<td>Atomically stores <code>forward&lt;A_0&gt;(a_0)</code> in the shared state.</td>
</tr>
<tr>
<td>2</td>
<td><code>error_code</code></td>
<td><code>future&lt;U_1&gt;</code></td>
<td>If ( a_0 ) evaluates to <code>true</code>, atomically stores the exception pointer produced by <code>make_exception_ptr(system_error(a_0))</code> in the shared state; otherwise, atomically stores <code>forward&lt;A_1&gt;(a_1)</code> in the shared state.</td>
</tr>
<tr>
<td>2</td>
<td><code>exception_ptr</code></td>
<td><code>future&lt;U_1&gt;</code></td>
<td>If ( a_0 ) is non-null, atomically stores the exception pointer in the shared state; otherwise, atomically stores <code>forward&lt;A_1&gt;(a_1)</code> in the shared state.</td>
</tr>
<tr>
<td>2</td>
<td>all other types</td>
<td><code>future&lt;tuple&lt;U_0, U_1&gt;&gt;</code></td>
<td>Atomically stores <code>forward_as_tuple(forward&lt;A_0&gt;(a_0), forward&lt;A_1&gt;(a_1))</code> in the shared state.</td>
</tr>
<tr>
<td>&gt;2</td>
<td><code>error_code</code></td>
<td><code>future&lt;tuple&lt;U_1, ..., U_{N-1}&gt;&gt;</code></td>
<td>If ( a_0 ) evaluates to <code>true</code>, atomically stores the exception pointer produced by <code>make_exception_ptr(system_error(a_0))</code> in the shared state; otherwise, atomically stores <code>forward_as_tuple(forward&lt;A_1&gt;(a_1), ..., forward&lt;A_{N-1}&gt;(a_{N-1}))</code> in the shared state.</td>
</tr>
<tr>
<td>&gt;2</td>
<td><code>exception_ptr</code></td>
<td><code>future&lt;tuple&lt;U_1, ..., U_{N-1}&gt;&gt;</code></td>
<td>If ( a_0 ) is non-null, atomically stores the exception pointer in the shared state; otherwise, atomically stores <code>forward_as_tuple(forward&lt;A_1&gt;(a_1), ..., forward&lt;A_{N-1}&gt;(a_{N-1}))</code> in the shared state.</td>
</tr>
<tr>
<td>&gt;2</td>
<td>all other types</td>
<td><code>future&lt;tuple&lt;U_0, ..., U_{N-1}&gt;&gt;</code></td>
<td>Atomically stores <code>forward_as_tuple(forward&lt;A_0&gt;(a_0), ..., forward&lt;A_{N-1}&gt;(a_{N-1}))</code> in the shared state.</td>
</tr>
</tbody>
</table>
13.27 Partial specialization of async_result for packaged_task
[async.packaged.task.spec]

```cpp
namespace std {
namespace experimental {

namespace net {

inline namespace std::experimental::net::inline v1v2 {

  template<class Result, class... Args, class Signature>
  class async_result<packaged_task<Result(Args...)>, Signature> {
  public:
    using completion_handler_type = packaged_task<Result(Args...)>
    using return_type = future<Result>;
    explicit async_result(completion_handler_type& h);
    async_result(const async_result&) = delete;
    async_result& operator=(const async_result&) = delete;
    return_type get();

  private:
    return_type future_; // exposition only
  }

} // inline namespace std::experimental::net::inline v1v2
} // namespace net
} // namespace experimental
} // namespace std
```

1 Effects: Initializes `future_` with `h.get_future()`.

```cpp
return_type get();
```

2 Returns: std::move(future_).
14 Basic I/O services

14.1 Header <experimental/io_context> synopsis

namespace std {
namespace experimental {
namespace net {
inline namespace std::experimental::net::inline_v1v2 {

class io_context;
}
} // inline namespace std::experimental::net::v1v2
} // namespace net
} // namespace experimental
} // namespace std

14.2 Class io_context

namespace std {
namespace experimental {
namespace net {
inline namespace std::experimental::net::inline_v1v2 {

class io_context : public execution_context {
public:

// types:
class executor_type;
using count_type = implementation-defined;

// construct / copy / destroy:
io_context();
explicit io_context(int concurrency_hint);
io_context(const io_context&) = delete;
io_context& operator=(const io_context&) = delete;

// io_context operations:
executor_type get_executor() noexcept;
count_type run();
template<class Rep, class Period>
count_type run_for(const chrono::duration<Rep, Period>& rel_time);
template<class Clock, class Duration>
count_type run_until(const chrono::time_point<Clock, Duration>& abs_time);
count_type run_one();
template<class Rep, class Period>
count_type run_one_for(const chrono::duration<Rep, Period>& rel_time);
template<class Clock, class Duration>

The class `io_context` satisfies the `ExecutionContext` type requirements (13.2.3). `count_type` is an implementation-defined unsigned integral type of at least 32 bits.

The `io_context` member functions `run`, `run_for`, `run_until`, `run_one`, `run_one_for`, `run_one_until`, `poll`, and `poll_one` are collectively referred to as the `run functions`. The run functions must be called for the `io_context` to perform asynchronous operations (3.4) on behalf of a C++ program. Notification that an asynchronous operation has completed is delivered by execution of the associated completion handler function object, as determined by the requirements for asynchronous operations (13.2.7).

For an object of type `io_context`, `outstanding work` is defined as the sum of:

1. the total number of calls to the `on_work_started` function, less the total number of calls to the `on_work_finished` function, to any executor of the `io_context`.
2. the number of function objects that have been added to the `io_context` via any executor of the `io_context`, but not yet executed; and
3. the number of function objects that are currently being executed by the `io_context`.

If at any time the outstanding work falls to 0, the `io_context` is stopped as if by `stop()`.

The `io_context` member functions `get_executor`, `stop`, and `stopped`, the run functions, and the `io_context::executor_type` copy constructors, member functions and comparison operators, do not introduce data races as a result of concurrent calls to those functions from different threads of execution. [Note: The `restart` member function is excluded from these thread safety requirements. —end note] The run functions may be recursively reentered.

### 14.2.1 `io_context` members

`io_context();`  
`explicit io_context(int concurrency_hint);`

1. **Effects:** Creates an object of class `io_context`.
2. **Remarks:** The `concurrency_hint` parameter is a suggestion to the implementation on the number of threads that should process asynchronous operations and execute function objects.

`executor_type get_executor() noexcept;`

3. **Returns:** An executor that may be used for submitting function objects to the `io_context`.

§ 14.2.1
count_type run();

Effects: Equivalent to:

    count_type n = 0;
    while (run_one())
        if (n != numeric_limits<count_type>::max())
            ++n;

Returns: n.

[ Note: Calling run from a thread that is currently calling a run function can introduce the potential for deadlock. It is the caller’s responsibility to avoid such deadlocks. — end note ]

template<class Rep, class Period>
    count_type run_for(const chrono::duration<Rep, Period>& rel_time);

Effects: Equivalent to:

    return run_until(chrono::steady_clock::now() + rel_time);

template<class Clock, class Duration>
    count_type run_until(const chrono::time_point<Clock, Duration>& abs_time);

Effects: Equivalent to:

    count_type n = 0;
    while (run_one_until(abs_time))
        if (n != numeric_limits<count_type>::max())
            ++n;

Returns: n.

count_type run_one();

Effects: If the io_context object has no outstanding work, performs stop(). Otherwise, blocks while the io_context has outstanding work, or until the io_context is stopped, or until one function object has been executed.

If an executed function object throws an exception, the exception propagates to the caller of run_one(). The io_context state is as if the function object had returned normally.

Returns: 1 if a function object was executed, otherwise 0.

Remarks: This function may invoke additional function objects through nested calls to the io_context executor’s dispatch member function. These do not count towards the return value.

[ Note: Calling run_one from a thread that is currently calling a run function can introduce the potential for deadlock. It is the caller’s responsibility to avoid such deadlocks. — end note ]

template<class Rep, class Period>
    count_type run_one_for(const chrono::duration<Rep, Period>& rel_time);

Effects: Equivalent to:

    return run_one_until(chrono::steady_clock::now() + rel_time);

template<class Clock, class Duration>
    count_type run_one_until(const chrono::time_point<Clock, Duration>& abs_time);
Effects: If the `io_context` object has no outstanding work, performs `stop()`.
Otherwise, blocks while the `io_context` has outstanding work, or until the expiration of the absolute timeout (C++ 2020 [thread.req.timing]) specified by `abs_time`, or until the `io_context` is stopped, or until one function object has been executed.

If an executed function object throws an exception, the exception propagates to the caller of `run_one()`. The `io_context` state is as if the function object had returned normally.

Returns: 1 if a function object was executed, otherwise 0.

Remarks: This function may invoke additional function objects through nested calls to the `io_context` executor’s `dispatch` member function. These do not count towards the return value.

count_type poll();

Effects: Equivalent to:

```cpp
count_type n = 0;
while (poll_one())
  if (n != numeric_limits<count_type>::max())
    ++n;
```

Returns: `n`.

count_type poll_one();

Effects: If the `io_context` object has no outstanding work, performs `stop()`. Otherwise, if there is a function object ready for immediate execution, executes it.

If an executed function object throws an exception, the exception propagates to the caller of `poll_one()`. The `io_context` state is as if the function object had returned normally.

Returns: 1 if a function object was invoked, otherwise 0.

Remarks: This function may invoke additional function objects through nested calls to the `io_context` executor’s `dispatch` member function. These do not count towards the return value.

void stop();

Effects: Stops the `io_context`. Concurrent calls to any run function will end as soon as possible. If a call to a run function is currently executing a function object, the call will end only after completion of that function object. The call to `stop()` returns without waiting for concurrent calls to run functions to complete.

Postconditions: `stopped()` == true.

[Note: When `stopped()` == true, subsequent calls to a run function will exit immediately with a return value of 0, without executing any function objects. An `io_context` remains in the stopped state until a call to `restart()`. — end note]

bool stopped() const noexcept;

Returns: true if the `io_context` is stopped.

void restart();

Postconditions: `stopped()` == false.
14.3 Class io_context::executor_type

namespace std {
namespace experimental {
namespace net {

inline namespace std::experimental::net::inline v1v2 {

class io_context::executor_type
{
public:
  // 14.3.1, construct / copy / destroy:

  executor_type(const executor_type& other) noexcept;
  executor_type(executor_type&& other) noexcept;
  executor_type& operator=(const executor_type& other) noexcept;
  executor_type& operator=(executor_type&& other) noexcept;

  // 14.3.3, executor operations:

  bool running_in_this_thread() const noexcept;
  io_context& context() const noexcept;
  void on_work_started() const noexcept;
  void on_work_finished() const noexcept;

  template<class Func, class ProtoAllocator>
  void dispatch(Func&& f, const ProtoAllocator& a) const;
  template<class Func, class ProtoAllocator>
  void post(Func&& f, const ProtoAllocator& a) const;
  template<class Func, class ProtoAllocator>
  void defer(Func&& f, const ProtoAllocator& a) const;

  bool operator==(const io_context::executor_type& a,
                  const io_context::executor_type& b) noexcept;

};

} // inline namespace std::experimental::net::inline v1v2
} // namespace net
} // namespace experimental
} // namespace std

io_context::executor_type is a type satisfying meeting the Executor Executor requirements (13.2.2). Objects of type io_context::executor_type are associated with an io_context, and function objects submitted using the dispatch, post, or defer member functions will be executed by the io_context from within a run function.

14.3.1 io_context::executor_type constructors

executor_type(const executor_type& other) noexcept;

Postconditions: *this == other.

executor_type(executor_type& other) noexcept;

Postconditions: *this is equal to the prior value of other.
14.3.2 **io_context::executor_type assignment**

```cpp
evaluator_type& operator=(const evaluator_type& other) noexcept;
```

*Postconditions:* `*this == other`.

*Returns:* `*this`.

```cpp
evaluator_type& operator=(valuator_type&& other) noexcept;
```

*Postconditions:* `*this` is equal to the prior value of `other`.

*Returns:* `*this`.

14.3.3 **io_context::executor_type operations**

```cpp
bool running_in_this_thread() const noexcept;
```

*Returns:* true if the current thread of execution is calling a run function of the associated io_context object. *[Note: That is, the current thread of execution's call chain includes a run function. —end note]*

```cpp
evaluator_type& context() const noexcept;
```

*Returns:* A reference to the associated io_context object.

```cpp
void on_work_started() const noexcept;
```

*Effects:* Increments the count of outstanding work associated with the io_context.

```cpp
void on_work_finished() const noexcept;
```

*Effects:* Decrements the count of outstanding work associated with the io_context.

```cpp
template<class Func, class ProtoAllocator>
void dispatch(Func&& f, const ProtoAllocator& a) const;
```

*Effects:* If `running_in_this_thread()` is true, calls `DECAY_COPY(forward<Func>(f))()` (C++ 2020 [thread.decaycopy]). *[Note: If f exits via an exception, the exception propagates to the caller of dispatch(). —end note]* Otherwise, calls `post(forward<Func>(f), a)`.

```cpp
template<class Func, class ProtoAllocator>
void post(Func&& f, const ProtoAllocator& a) const;
```

*Effects:* Adds f to the io_context.

```cpp
template<class Func, class ProtoAllocator>
void defer(Func&& f, const ProtoAllocator& a) const;
```

*Effects:* Adds f to the io_context.

14.3.4 **io_context::executor_type comparisons**

```cpp
bool operator==(const io_context::executor_type& a,
    const io_context::executor_type& b) noexcept;
```

*Returns:* `addressof(a.context()) == addressof(b.context())`.

```cpp
bool operator!=(const io_context::executor_type& a,
    const io_context::executor_type& b) noexcept;
```

*Returns:* `(a != b)`. 
15 Timers

This clause defines components for performing timer operations.

Example: Performing a synchronous wait operation on a timer:

```cpp
io_context c;
steadty_timer t(c);
t.expires_after(seconds(5));
t.wait();
```
—end example—

Example: Performing an asynchronous wait operation on a timer:

```cpp
void handler(error_code ec) { ... }
...
io_context c;
steadty_timer t(c);
t.expires_after(seconds(5));
t.async_wait(handler);
c.run();
```
—end example—

15.1 Header <experimental/Timer> synopsis

```
#include <chrono>

namespace std {
namespace experimental {
namespace net {
inline namespace std::experimental::net::inline v1v2 {

template<class Clock> struct wait_traits;

template<class Clock, class WaitTraits = wait_traits<Clock>>
class basic_waitable_timer;

using system_timer = basic_waitable_timer<chrono::system_clock>;
using steady_timer = basic_waitable_timer<chrono::steady_clock>;
using high_resolution_timer = basic_waitable_timer<chrono::high_resolution_clock>;

} // inline namespace std::experimental::net::inline v1v2
} // namespace net
} // namespace experimental
} // namespace std
```

15.2 Requirements

15.2.1 Wait traits requirements

The basic_waitable_timer template uses wait traits to allow programs to customize wait and async_wait behavior. [Note: Possible uses of wait traits include:
(1.1) — To enable timers based on non-realtime clocks.
(1.2) — Determining how quickly wallclock-based timers respond to system time changes.
(1.3) — Correcting for errors or rounding timeouts to boundaries.
(1.4) — Preventing duration overflow. That is, a program can set a timer’s expiry e to be `Clock::max()` (meaning never reached) or `Clock::min()` (meaning always in the past). As a result, computing the duration until timer expiry as e − `Clock::now()` can cause overflow.

— end note

2 For a type `Clock` meeting the `ClockCpp17Clock` requirements (C++ 2020 [time.clock.req]), a type X meets the `WaitTraits` requirements if it satisfies the requirements listed below.

3 In Table 11, t denotes a (possibly const) value of type (possibly const) `Clock::time_point`; and d denotes a (possibly const) value of type (possibly const) `Clock::duration`.

<table>
<thead>
<tr>
<th>expression</th>
<th>return type</th>
<th>assertion/note pre/post-condition</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>X::to_wait_duration(d)</code></td>
<td><code>Clock::duration</code></td>
<td>Returns a <code>Clock::duration</code> value to be used in a <code>wait</code> or <code>async_wait</code> operation. [Note: The return value is typically representative of the duration d. — end note]</td>
</tr>
<tr>
<td><code>X::to_wait_duration(t)</code></td>
<td><code>Clock::duration</code></td>
<td>Returns a <code>Clock::duration</code> value to be used in a <code>wait</code> or <code>async_wait</code> operation. [Note: The return value is typically representative of the duration from <code>Clock::now()</code> until the time point t. — end note]</td>
</tr>
</tbody>
</table>

15.3 Class template `wait_traits` [timer.waittraits]

```cpp
namespace std {
namespace experimental {
namespace net {
  // inline namespace std::experimental::net::inline v1v2 {

  template<class Clock>
  struct wait_traits {
    static typename Clock::duration to_wait_duration(
      const typename Clock::duration& d);

    static typename Clock::duration to_wait_duration(
      const typename Clock::time_point& t);
  };

  // inline namespace std::experimental::net::v1v2
  } // // namespace net
} // // namespace experimental
} // // namespace std
```

1 Class template `wait_traits` satisfies the `WaitTraits` type requirements. Template argument `Clock` is a type meeting the `ClockCpp17Clock` requirements (C++ 2020 [time.clock.req]).
static typename Clock::duration to_wait_duration(
    const typename Clock::duration& d);

Returns: d.

static typename Clock::duration to_wait_duration(
    const typename Clock::time_point& t);

Returns: Let now be Clock::now(). If now + Clock::duration::max() is before t, Clock::duration::max(); if now + Clock::duration::min() is after t, Clock::duration::min(); otherwise, t - now.

15.4 Class template basic_waitable_timer

namespace std {
    namespace experimental {
        namespace net {
            template<class Clock, class WaitTraits = wait_traits<Clock>>
            class basic_waitable_timer
            {
                public:
                    // types:
                    using executor_type = io_context::executor_type;
                    using clock_type = Clock;
                    using duration = typename clock_type::duration;
                    using time_point = typename clock_type::time_point;
                    using traits_type = WaitTraits;

                    // 15.4.1, construct / copy / destroy:
                    explicit basic_waitable_timer(io_context& ctx);
                    basic_waitable_timer(io_context& ctx, const time_point& t);
                    basic_waitable_timer(io_context& ctx, const duration& d);
                    basic_waitable_timer(const basic_waitable_timer&) = delete;
                    basic_waitable_timer(basic_waitable_timer&& rhs);
                    ~basic_waitable_timer();

                    basic_waitable_timer& operator=(const basic_waitable_timer&); // delete
                    basic_waitable_timer& operator=(basic_waitable_timer&& rhs);

                    // 15.4.4, basic_waitable_timer operations:
                    executor_type get_executor() noexcept;
                    size_t cancel();
                    size_t cancel_one();

                    time_point expiry() const;
                    size_t expires_at(const time_point& t);
                    size_t expires_after(const duration& d);

                    void wait();
                    void wait(error_code& ec);
            }
        }
    }
}

Instances of class template `basic_waitable_timer` meet the requirements of `Destructible` (C++20 [destructible]), `MoveConstructible` (C++20 [move-constructible]), and `MoveAssignable` (C++20 [moveassignable]).

### 15.4.1 basic_waitable_timer constructors

#### 1
**explicit basic_waitable_timer(io_context& ctx);**

**Effects:** Equivalent to `basic_waitable_timer(ctx, time_point())`.

```cpp
basic_waitable_timer(io_context& ctx, const time_point& t);
```

**Postconditions:**

1. `get_executor() == ctx.get_executor()`.
2. `expiry() == t`.

```cpp
basic_waitable_timer(io_context& ctx, const duration& d);
```

**Effects:** Sets the expiry time as if by calling `expires_after(d)`.

**Postconditions:**

1. `get_executor() == ctx.get_executor()`.

```cpp
basic_waitable_timer(basic_waitable_timer&& rhs);
```

**Effects:** Move constructs an object of class `basic_waitable_timer<Clock, WaitTraits>` that refers to the state originally represented by `rhs`.

**Postconditions:**

1. `get_executor() == rhs.get_executor()`.
2. `expiry() == time_point()`.

### 15.4.2 basic_waitable_timer destructor

`~basic_waitable_timer();`

**Effects:** Destroys the timer, canceling any asynchronous wait operations associated with the timer as if by calling `cancel()`.

### 15.4.3 basic_waitable_timer assignment

**basic_waitable_timer& operator=(basic_waitable_timer&& rhs);**

**Effects:** Cancels any outstanding asynchronous operations associated with `*this` as if by calling `cancel()`, then moves into `*this` the state originally represented by `rhs`.

**Postconditions:**

§ 15.4.3
15.4.4 basic_waitable_timer operations

```cpp
timer::waitable_ops

executor_type get_executor() noexcept;

Returns: The associated executor.

size_t cancel();

Effects: Causes any outstanding asynchronous wait operations to complete. Completion handlers for canceled operations are passed an error code `ec` such that `ec == errc::operation_canceled` yields `true`.

Returns: The number of operations that were canceled.

Remarks: Does not block (C++ 2020 [defns.block]) the calling thread pending completion of the canceled operations.

size_t cancel_one();

Effects: Causes the outstanding asynchronous wait operation that was initiated first, if any, to complete as soon as possible. The completion handler for the canceled operation is passed an error code `ec` such that `ec == errc::operation_canceled` yields `true`.

Returns: 1 if an operation was canceled, otherwise 0.

Remarks: Does not block (C++ 2020 [defns.block]) the calling thread pending completion of the canceled operation.

time_point expiry() const;

Returns: The expiry time associated with the timer, as previously set using `expires_at()` or `expires_after()`.

size_t expires_at(const time_point& t);

Effects: Cancels outstanding asynchronous wait operations, as if by calling `cancel()`. Sets the expiry time associated with the timer.

Returns: The number of operations that were canceled.

Postconditions: `expiry() == t`.

size_t expires_after(const duration& d);

Returns: `expires_at(clock_type::now() + d)`.

void wait();
void wait(error_code& ec);

Effects: Establishes the postcondition as if by repeatedly blocking the calling thread (C++ 2020 [defns.block]) for the relative time produced by `WaitTraits::to_wait_duration(expiry())`.

Postconditions: `ec || expiry() <= clock_type::now()`.
```

template<class CompletionToken>
DEDUCED async_wait(CompletionToken& token);
```
Completion signature: `void(error_code ec)`.

*Effects:* Initiates an asynchronous wait operation to repeatedly wait for the relative time produced by `WaitTraits::to_wait_duration(e)`, where `e` is a value of type `time_point` such that `e <= expiry()`. The completion handler is submitted for execution only when the condition `ec || expiry() <= clock_type::now()` yields `true`.

[Note: To implement `async_wait`, an `io_context` object `ctx` could maintain a priority queue for each specialization of `basic_waitable_timer<Clock, WaitTraits>` for which a timer object was initialized with `ctx`. Only the time point `e` of the earliest outstanding expiry need be passed to `WaitTraits::to_wait_duration(e)`. — end note]
16 Buffers

16.1 Header `<experimental/buffer>` synopsis

```cpp
namespace std {
    namespace experimental {
        namespace net {
            inline namespace std::experimental::net::inline_v1v2 {

                enum class stream_errc {
                    eof = an implementation-defined non-zero value,
                    not_found = an implementation-defined non-zero value
                };

                const error_category& stream_category() noexcept;
                error_code make_error_code(stream_errc e) noexcept;
                error_condition make_error_condition(stream_errc e) noexcept;

                class mutable_buffer;
                class const_buffer;

                // 16.6, buffer type traits:
                template<class T> struct is_mutable_buffer_sequence;
                template<class T> struct is_const_buffer_sequence;
                template<class T> struct is_dynamic_buffer;

                template<class T>
                \added{\inline} constexpr bool is_mutable_buffer_sequence_v = is_mutable_buffer_sequence<T>::value;
                template<class T>
                \added{\inline} constexpr bool is_const_buffer_sequence_v = is_const_buffer_sequence<T>::value;
                template<class T>
                \added{\inline} constexpr bool is_dynamic_buffer_v = is_dynamic_buffer<T>::value;

                // 16.7, buffer sequence access:
                const mutable_buffer* buffer_sequence_begin(const mutable_buffer& b) noexcept;
                const const_buffer* buffer_sequence_begin(const const_buffer& b) noexcept;
                const mutable_buffer* buffer_sequence_end(const mutable_buffer& b) noexcept;
                const const_buffer* buffer_sequence_end(const const_buffer& b) noexcept;
                template<class C> auto buffer_sequence_begin(C& c) noexcept -> decltype(c.begin());
                template<class C> auto buffer_sequence_begin(const C& c) noexcept -> decltype(c.begin());
                template<class C> auto buffer_sequence_end(C& c) noexcept -> decltype(c.end());
                template<class C> auto buffer_sequence_end(const C& c) noexcept -> decltype(c.end());

                // 16.8, buffer size:
                template<class ConstBufferSequence>
                size_t buffer_size(const ConstBufferSequence& buffers) noexcept;

                // 16.9, buffer copy:
```
template<class MutableBufferSequence, class ConstBufferSequence>
size_t buffer_copy(const MutableBufferSequence& dest,
const ConstBufferSequence& source) noexcept;

template<class MutableBufferSequence, class ConstBufferSequence>
size_t buffer_copy(const MutableBufferSequence& dest,
const ConstBufferSequence& source,
size_t max_size) noexcept;

// 16.10, buffer arithmetic:

mutable_buffer operator+(const mutable_buffer& b, size_t n) noexcept;
mutable_buffer operator+(size_t n, const mutable_buffer& b) noexcept;
const_buffer operator+(const const_buffer&, size_t n) noexcept;
const_buffer operator+(size_t, const const_buffer&) noexcept;

// 16.11, buffer creation:

mutable_buffer buffer(void* p, size_t n) noexcept;
const_buffer buffer(const void* p, size_t n) noexcept;
mutable_buffer buffer(const mutable_buffer& b) noexcept;
mutable_buffer buffer(const mutable_buffer& b, size_t n) noexcept;
const_buffer buffer(const const_buffer& b) noexcept;
const_buffer buffer(const const_buffer& b, size_t n) noexcept;

template<class T, size_t N>
mutable_buffer buffer(T (&data)[N]) noexcept;

template<class T, size_t N>
const_buffer buffer(const T (&data)[N]) noexcept;

template<class T, size_t N>
mutable_buffer buffer(array<T, N>& data) noexcept;

template<class T, size_t N>
const_buffer buffer(const array<T, N>& data) noexcept;

template<class T, class Allocator>
mutable_buffer buffer(vector<T, Allocator>& data) noexcept;

template<class T, class Allocator>
const_buffer buffer(const vector<T, Allocator>& data) noexcept;

template<class CharT, class Traits, class Allocator>
mutable_buffer buffer(basic_string<CharT, Traits, Allocator>& data) noexcept;

template<class CharT, class Traits, class Allocator>
const_buffer buffer(const basic_string<CharT, Traits, Allocator>& data) noexcept;

template<class CharT, class Traits>
const_buffer buffer(basic_string_view<CharT, Traits> data) noexcept;

template<class T, size_t N>
mutable_buffer buffer(T (&data)[N], size_t n) noexcept;

template<class T, size_t N>
const_buffer buffer(const T (&data)[N], size_t n) noexcept;

template<class T, size_t N>
mutable_buffer buffer(array<T, N>& data, size_t n) noexcept;

template<class T, size_t N>
const_buffer buffer(array<const T, N>& data, size_t n) noexcept;
template<class T, size_t N>
    const_buffer buffer(const array<T, N>& data, size_t n) noexcept;
template<class T, class Allocator>
    mutable_buffer buffer(vector<T, Allocator>& data, size_t n) noexcept;
template<class T, class Allocator>
    const_buffer buffer(const vector<T, Allocator>& data, size_t n) noexcept;
template<class CharT, class Traits, class Allocator>
    mutable_buffer buffer(basic_string<CharT, Traits, Allocator>& data, size_t n) noexcept;
template<class CharT, class Traits, class Allocator>
    const_buffer buffer(const basic_string<CharT, Traits, Allocator>& data, size_t n) noexcept;
template<class CharT, class Traits>
    const_buffer buffer(basic_string_view<CharT, Traits> data, size_t n) noexcept;

template<class T, class Allocator>
    class dynamic_vector_buffer;

template<class CharT, class Traits, class Allocator>
    class dynamic_string_buffer;

// 16.14, dynamic buffer creation:

template<class T, class Allocator>
    dynamic_vector_buffer<T, Allocator>
    dynamic_buffer(vector<T, Allocator>& vec) noexcept;
template<class T, class Allocator>
    dynamic_vector_buffer<T, Allocator>
    dynamic_buffer(vector<T, Allocator>& vec, size_t n) noexcept;

template<class CharT, class Traits, class Allocator>
    dynamic_string_buffer<CharT, Traits, Allocator>
    dynamic_buffer(basic_string<CharT, Traits, Allocator>& str) noexcept;
template<class CharT, class Traits, class Allocator>
    dynamic_string_buffer<CharT, Traits, Allocator>
    dynamic_buffer(basic_string<CharT, Traits, Allocator>& str, size_t n) noexcept;

class transfer_all;
class transfer_at_least;
class transfer_exactly;

// 17.5, synchronous read operations:

template<class SyncReadStream, class MutableBufferSequence>
    size_t read(SyncReadStream& stream, const MutableBufferSequence& buffers);
template<class SyncReadStream, class MutableBufferSequence>
    size_t read(SyncReadStream& stream, const MutableBufferSequence& buffers, error_code& ec);
template<class SyncReadStream, class MutableBufferSequence, class CompletionCondition>
    size_t read(SyncReadStream& stream, const MutableBufferSequence& buffers, CompletionCondition completion_condition);
template<class SyncReadStream, class MutableBufferSequence,  
class CompletionCondition>
    size_t read(SyncReadStream& stream,  
               const MutableBufferSequence& buffers,  
               CompletionCondition completion_condition,  
               error_code& ec);

template<class SyncReadStream, class DynamicBuffer>  
    size_t read(SyncReadStream& stream, DynamicBuffer&& b);

template<class SyncReadStream, class DynamicBuffer>  
    size_t read(SyncReadStream& stream, DynamicBuffer&& b,  
               error_code& ec);

template<class SyncReadStream, class DynamicBuffer,  
class CompletionCondition>  
    size_t read(SyncReadStream& stream, DynamicBuffer&& b,  
               CompletionCondition completion_condition);

template<class SyncReadStream, class DynamicBuffer,  
class CompletionCondition>  
    size_t read(SyncReadStream& stream, DynamicBuffer&& b,  
               CompletionCondition completion_condition,  
               error_code& ec);

// 17.6, asynchronous read operations:

template<class AsyncReadStream, class MutableBufferSequence,  
class CompletionToken>  
    DEDUCED async_read(AsyncReadStream& stream,  
                       const MutableBufferSequence& buffers,  
                       CompletionToken&& token);

template<class AsyncReadStream, class MutableBufferSequence,  
class CompletionCondition, class CompletionToken>  
    DEDUCED async_read(AsyncReadStream& stream,  
                       const MutableBufferSequence& buffers,  
                       CompletionCondition completion_condition,  
                       CompletionToken&& token);

// 17.7, synchronous write operations:

template<class SyncWriteStream, class ConstBufferSequence>  
    size_t write(SyncWriteStream& stream,  
                 const ConstBufferSequence& buffers);

template<class SyncWriteStream, class ConstBufferSequence>  
    size_t write(SyncWriteStream& stream,  
                 const ConstBufferSequence& buffers,  
                 error_code& ec);

template<class SyncWriteStream, class ConstBufferSequence,  
class CompletionCondition>  
    size_t write(SyncWriteStream& stream,  
                 const ConstBufferSequence& buffers,  
                 CompletionCondition completion_condition);
template<class SyncWriteStream, class ConstBufferSequence,  
    class CompletionCondition>  
size_t write(SyncWriteStream& stream,  
    const ConstBufferSequence& buffers,  
    CompletionCondition completion_condition,  
    error_code& ec);

template<class SyncWriteStream, class DynamicBuffer>  
size_t write(SyncWriteStream& stream, DynamicBuffer& b);

template<class AsyncWriteStream, class ConstBufferSequence,  
    class CompletionToken>  
DEDUCED async_write(AsyncWriteStream& stream,  
    const ConstBufferSequence& buffers,  
    CompletionToken& token);

template<class AsyncWriteStream, class DynamicBuffer,  
    class CompletionToken>  
DEDUCED async_write(AsyncWriteStream& stream, 
    DynamicBuffer& b, CompletionToken& token);

// 17.9, synchronous delimited read operations:

template<class SyncReadStream, class DynamicBuffer>  
size_t read_until(SyncReadStream& s, DynamicBuffer& b, char delim);

template<class SyncReadStream, class DynamicBuffer,  
    char delim, error_code& ec)  
size_t read_until(SyncReadStream& s, DynamicBuffer& b, char delim, error_code& ec);

template<class SyncReadStream, class DynamicBuffer,  
    string_view delim)  
size_t read_until(SyncReadStream& s, DynamicBuffer& b, string_view delim, error_code& ec);
// 17.10, asynchronous delimited read operations:

```cpp
template<class AsyncReadStream, class DynamicBuffer, class CompletionToken>
DEDUCED async_read_until(AsyncReadStream& s,
    DynamicBuffer&& b, char delim,
    CompletionToken&& token);

template<class AsyncReadStream, class DynamicBuffer, class CompletionToken>
DEDUCED async_read_until(AsyncReadStream& s,
    DynamicBuffer&& b, string_view delim,
    CompletionToken&& token);
```

} // inline namespace experimental::net::v1
} // namespace net
} // namespace experimental

```cpp
template<> struct is_error_code_enum<experimental::net::v1::stream_errc>
: public true_type {};
```

} // namespace std

16.2 Requirements [buffer.reqmts]

16.2.1 Mutable buffer sequence requirements [buffer.reqmts.mutablebuffersequence]

1 A *mutable buffer sequence* represents a set of memory regions that may be used to receive the output of an operation, such as the `receive` operation of a socket.

2 A type `X` meets the *MutableBufferSequence* requirements if it satisfies the requirements of `Destructible Cpp17Destructible` (C++ 2020 [destructible]) and `CopyConstructible Cpp17CopyConstructible` (C++ 2020 [copyconstructible]), as well as the additional requirements listed in Table 12.

3 In Table 12, `x` denotes a (possibly `const`) value of type (possibly `const`) `X`, and `u` denotes an identifier.
Table 12 — `MutableBufferSequence` requirements

<table>
<thead>
<tr>
<th>expression</th>
<th>return type</th>
<th>assertion/note</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>net::buffer_sequence_.begin(x)</code></td>
<td>An iterator type whose reference type is convertible to <code>mutable_buffer</code>, and which satisfies all the requirements for bidirectional iterators (C++ 2020 [bidirectional.iterators]) except that:</td>
<td>For a dereferenceable iterator, no increment, decrement, or dereference operation, or conversion of the reference type to <code>mutable_buffer</code>, shall exit via an exception.</td>
</tr>
<tr>
<td><code>net::buffer_sequence_.end(x)</code></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For a dereferenceable iterator, no increment, decrement, or dereference operation, or conversion of the reference type to `mutable_buffer`, shall exit via an exception.

\[
X \ u(x) ;
\]

**Postconditions:**

\[
\text{equal}(
\text{net::buffer_sequence_.begin(x)}, \\
\text{net::buffer_sequence_.end(x)}, \\
\text{net::buffer_sequence_.begin(u)}, \\
\text{net::buffer_sequence_.end(u)}, \\
[]\text{(const mutable_buffer & b1,} \\
\text{const mutable_buffer & b2)} \\
\{ \\
\text{return b1.data() == b2.data()}; \\
\text{bk b1.size() == b2.size();} \\
\})
\]

16.2.2 Constant buffer sequence requirements  [buffer.reqmts.constbuffersequence]

1 A constant buffer sequence represents a set of memory regions that may be used as input to an operation, such as the `send` operation of a socket.

2 A type `X` meets the `ConstBufferSequence` requirements if it satisfies the requirements of `Destructible` (C++ 2020 [destructible]) and `CopyConstructible` (C++ 2020 [copyconstructible]), as well as the additional requirements listed in Table 13.

3 In Table 13, `x` denotes a `(possibly const)` value of type `(possibly const) X`, and `u` denotes an identifier.
Table 13 — `ConstBufferSequence` requirements

<table>
<thead>
<tr>
<th>expression</th>
<th>return type</th>
<th>assertion/note</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>net::buffer_sequence_\begin(x)</code></td>
<td>An iterator type whose <code>reference</code> type is convertible to <code>const_buffer</code>, and</td>
<td>For a dereferenceable iterator, no increment, decrement, or dereference</td>
</tr>
<tr>
<td><code>net::buffer_sequence_\end(x)</code></td>
<td>which satisfies all the requirements for bidirectional iterators (C++ 2020</td>
<td>operation, or conversion of the reference type to <code>const_buffer</code>, shall exit</td>
</tr>
<tr>
<td></td>
<td>[bidirectional.iterators]) except that:</td>
<td>via an exception.</td>
</tr>
<tr>
<td></td>
<td>— there is no requirement that <code>operator-&gt;</code> is provided, and</td>
<td></td>
</tr>
<tr>
<td></td>
<td>— there is no requirement that <code>reference</code> be a reference type.</td>
<td></td>
</tr>
</tbody>
</table>

```
X u(x);
post: Postconditions:
equal(
    net::buffer_sequence_\begin(x),
    net::buffer_sequence_\end(x),
    net::buffer_sequence_\begin(u),
    net::buffer_sequence_\end(u),
    [](const const_buffer& b1,
         const const_buffer& b2)
    {
        return b1.data() == b2.data()
        && b1.size() == b2.size();
    })
```

16.2.3 Buffer size

Several places in this document make unqualified calls to `buffer_size`. The context in which these calls are evaluated shall ensure that a unary non-member function named `buffer_size` is selected via overload resolution (C++ 2020 [over.match]) on a candidate set that includes:

(1.1) — the `buffer_size` function template defined in `<experimental/buffer>` (16.1) and
(1.2) — the lookup set produced by argument-dependent lookup (C++ 2020 [basic.lookup.argdep]).

16.2.4 Dynamic buffer requirements

A dynamic buffer encapsulates memory storage that may be automatically resized as required, where the memory is divided into two regions: readable bytes followed by writable bytes. These memory regions are
internal to the dynamic buffer, but direct access to the elements is provided to permit them to be efficiently used with I/O operations. [Note: Such as the send or receive operations of a socket. The readable bytes would be used as the constant buffer sequence for send, and the writable bytes used as the mutable buffer sequence for receive. —end note] Data written to the writable bytes of a dynamic buffer object is appended to the readable bytes of the same object.

2 A type X meets the DynamicBuffer requirements if it satisfies the requirements of Destructible (C++ 2020 [destructible]) and MoveConstructible (C++ 2020 [moveconstructible]), as well as the additional requirements listed in Table 14.

3 In Table 14, x denotes a value of type X, x1 denotes a (possibly const) value of type X, and n denotes a (possibly const) value of type size_t.

Table 14 — DynamicBuffer requirements

<table>
<thead>
<tr>
<th>expression</th>
<th>type</th>
<th>assertion/note</th>
<th>pre/post-conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>X::constBuffersType</td>
<td>type meeting ConstBufferSequence</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>requirements.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X::mutableBuffersType</td>
<td>type meeting MutableBufferSequence</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>requirements.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>x1.size()</td>
<td>size_t</td>
<td></td>
<td>Returns the number of readable bytes.</td>
</tr>
<tr>
<td>x1.max_size()</td>
<td>size_t</td>
<td></td>
<td>Returns the maximum number of bytes, both readable and writable, that can be held by x1.</td>
</tr>
<tr>
<td>x1.capacity()</td>
<td>size_t</td>
<td></td>
<td>Returns the maximum number of bytes, both readable and writable, that can be held by x1 without requiring reallocation.</td>
</tr>
<tr>
<td>x1.data()</td>
<td>X::constBuffersType</td>
<td></td>
<td>Returns a constant buffer sequence u that represents the readable bytes, and where buffer_size(u) == size().</td>
</tr>
<tr>
<td>x.prepare(n)</td>
<td>X::mutableBuffersType</td>
<td></td>
<td>Returns a mutable buffer sequence u representing the writable bytes, and where buffer_size(u) == n. The dynamic buffer reallocates memory as required. All constant or mutable buffer sequences previously obtained using data() or prepare() are invalidated. Throws: length_error if size() + n exceeds max_size().</td>
</tr>
<tr>
<td>x.commit(n)</td>
<td></td>
<td></td>
<td>Appends n bytes from the start of the writable bytes to the end of the readable bytes. The remainder of the writable bytes are discarded. If n is greater than the number of writable bytes, all writable bytes are appended to the readable bytes. All constant or mutable buffer sequences previously obtained using data() or prepare() are invalidated.</td>
</tr>
</tbody>
</table>

§ 16.2.4
Table 14 — DynamicBuffer requirements (continued)

<table>
<thead>
<tr>
<th>expression</th>
<th>type</th>
<th>assertion/note pre/post-conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>x.consume(n)</td>
<td></td>
<td>Removes n bytes from beginning of the readable bytes. If n is greater than the number of readable</td>
</tr>
<tr>
<td></td>
<td></td>
<td>bytes, all readable bytes are removed. All constant or mutable buffer sequences previously obtained</td>
</tr>
<tr>
<td></td>
<td></td>
<td>using data() or prepare() are invalidated.</td>
</tr>
</tbody>
</table>

16.2.5 Requirements on read and write operations [buffer.reqmts.read.write]

1 A read operation is an operation that reads data into a mutable buffer sequence argument of a type meeting the MutableBufferSequence (16.2.1) requirements. The mutable buffer sequence specifies memory where the data should be placed. A read operation shall always fill a buffer in the sequence completely before proceeding to the next.

2 A write operation is an operation that writes data from a constant buffer sequence argument of a type meeting the ConstBufferSequence (16.2.2) requirements. The constant buffer sequence specifies memory where the data to be written is located. A write operation shall always write a buffer in the sequence completely before proceeding to the next.

3 If a read or write operation is also an asynchronous operation (13.2.7), the operation shall maintain one or more copies of the buffer sequence until such time as the operation no longer requires access to the memory specified by the buffers in the sequence. The program shall ensure the memory remains valid until:

   (3.1) — the last copy of the buffer sequence is destroyed, or
   (3.2) — the completion handler for the asynchronous operation is invoked, whichever comes first.

16.3 Error codes [buffer.err]

const error_category& stream_category() noexcept;

Returns: A reference to an object of a type derived from class error_category. All calls to this function return references to the same object.

The object’s default_error_condition and equivalent virtual functions behave as specified for the class error_category. The object’s name virtual function returns a pointer to the string "stream".

error_code make_error_code(stream_errc e) noexcept;

Returns: error_code(static_cast<int>(e), stream_category()).

erreur_condition make_error_condition(stream_errc e) noexcept;

Returns: error_condition(static_cast<int>(e), stream_category()).

16.4 Class mutable_buffer [buffer.mutable]

namespace std {
namespace experimental {
namespace net {
inline namespace std::experimental::net::inline_v1v2 {

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class mutable_buffer
{
  public:
    // constructors:
    mutable_buffer() noexcept;
    mutable_buffer(void* p, size_t n) noexcept;
    // members:
    void* data() const noexcept;
    size_t size() const noexcept;
    mutable_buffer& operator+=(size_t n) noexcept;

  private:
    void* data_; // exposition only
    size_t size_; // exposition only
};

namespace
{
  // inline namespace std::experimental::net::v1
  namespace net
  {
    namespace experimental
    {
      namespace std
      {
        inline namespace std::experimental::net::inline v1
        { // inline namespace std::experimental::net::v1

          class const_buffer
          {
            public:
              mutable_buffer() noexcept;
              // Postconditions: data_ == nullptr and size_ == 0.
              mutable_buffer(void* p, size_t n) noexcept;
              // Postconditions: data_ == p and size_ == n.
              void* data() const noexcept;
              // Returns: data_.
              size_t size() const noexcept;
              // Returns: size_.
              mutable_buffer& operator+=(size_t n) noexcept;
              // Effects: Sets data_ to static_cast<char*>(data_) + min(n, size_), and then size_ to size_ - min(n, size_).
              // Returns: *this.
          }
        }
      }
    }
  }
}

1 The mutable_buffer class satisfies the requirements of MutableBufferSequence (16.2.1), DefaultConstructible (C++ 2020 [defaultconstructible]), and CopyAssignable (C++ 2020 [copyassignable]).

mutable_buffer() noexcept;
  Postconditions: data_ == nullptr and size_ == 0.

mutable_buffer(void* p, size_t n) noexcept;
  Postconditions: data_ == p and size_ == n.

void* data() const noexcept;
  Returns: data_.

size_t size() const noexcept;
  Returns: size_.

mutable_buffer& operator+=(size_t n) noexcept;
  Effects: Sets data_ to static_cast<char*>(data_) + min(n, size_), and then size_ to size_ - min(n, size_).
  Returns: *this.

16.5 Class const_buffer

The `const_buffer` class satisfies requirements of `ConstBufferSequence` (16.2.2), `DefaultConstructible` (C++ 2020 [defaultconstructible]), and `CopyAssignable` (C++ 2020 [copyassignable]).

```cpp
const_buffer() noexcept;
```

1. **Postconditions:** `data_` == nullptr and `size_` == 0.

```cpp
const_buffer(const void* p, size_t n) noexcept;
```

2. **Postconditions:** `data_` == `p` and `size_` == `n`.

```cpp
const_buffer(const mutable_buffer& b);
```

3. **Postconditions:** `data_` == `b.data()` and `size_` == `b.size()`.

```cpp
const void* data() const noexcept;
```

4. **Returns:** `data_`.

```cpp
size_t size() const noexcept;
```

5. **Returns:** `size_`.

```cpp
const_buffer& operator+=(size_t n) noexcept;
```

6. **Effects:** Sets `data_` to `static_cast<const char*>(data_) + min(n, size_)`, and then `size_` to `size_ - min(n, size_)`.

7. **Returns:** `*this`.

### 16.6 Buffer type traits

```cpp
namespace std {
namespace experimental {
namespace net {
inline namespace std::experimental::net::inline ++v2 {

template<class T> struct is_mutable_buffer_sequence;

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```
This subclause contains templates that may be used to query the properties of a type at compile time. Each of these templates is a UnaryTypeTrait Cpp17UnaryTypeTrait (C++ 2020 [meta.rqmts]) with a BaseCharacteristic base characteristic of true_type if the corresponding condition is true, otherwise false_type.

Table 15 — Buffer type traits

<table>
<thead>
<tr>
<th>Template</th>
<th>Condition</th>
<th>Preconditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>template&lt;class T&gt; struct is_mutable_buffer_sequence</td>
<td>T meets the syntactic requirements for mutable buffer sequence (16.2.1).</td>
<td>T is a complete type.</td>
</tr>
<tr>
<td>template&lt;class T&gt; struct is_const_buffer_sequence</td>
<td>T meets the syntactic requirements for constant buffer sequence (16.2.2).</td>
<td>T is a complete type.</td>
</tr>
<tr>
<td>template&lt;class T&gt; struct is_dynamic_buffer</td>
<td>T meets the syntactic requirements for dynamic buffer (16.2.4).</td>
<td>T is a complete type.</td>
</tr>
</tbody>
</table>

16.7 Buffer sequence access [buffer.seq.access]

const mutable_buffer* buffer_sequence_begin(const mutable_buffer& b) noexcept;
const const_buffer* buffer_sequence_begin(const const_buffer& b) noexcept;

Returns: std::addressof(b).

const mutable_buffer* buffer_sequence_end(const mutable_buffer& b) noexcept;
const const_buffer* buffer_sequence_end(const const_buffer& b) noexcept;

Returns: std::addressof(b) + 1.

template<class C> auto buffer_sequence_begin(C& c) noexcept -> decltype(c.begin());
template<class C> auto buffer_sequence_begin(const C& c) noexcept -> decltype(c.begin());

Returns: c.begin().

template<class C> auto buffer_sequence_end(C& c) noexcept -> decltype(c.end());
template<class C> auto buffer_sequence_end(const C& c) noexcept -> decltype(c.end());

Returns: c.end().
16.8 Function buffer_size

\[
\begin{aligned}
&\text{template<class ConstBufferSequence> } \\
&\text{size_t buffer_size(const ConstBufferSequence& buffers) noexcept;} \\
&\quad \text{Returns: The total size of all buffers in the sequence, as if computed as follows:} \\
&\quad \quad \text{size_t total_size = 0;} \\
&\quad \quad \text{auto i = std::experimental::net::buffer_sequence_begin(buffers);} \\
&\quad \quad \text{auto end = std::experimental::net::buffer_sequence_end(buffers);} \\
&\quad \quad \text{for (; i != end; ++i)} \\
&\quad \quad \quad \{ \\
&\quad \quad \quad \quad \text{const_buffer b(*i);} \\
&\quad \quad \quad \quad \text{total_size += b.size();} \\
&\quad \quad \quad \} \\
&\quad \text{return total_size;} \\
\end{aligned}
\]

16.9 Function buffer_copy

\[
\begin{aligned}
&\text{template<class MutableBufferSequence, class ConstBufferSequence> } \\
&\text{size_t buffer_copy(const MutableBufferSequence& dest,} \\
&\quad \text{const ConstBufferSequence& source) noexcept;} \\
&\text{template<class MutableBufferSequence, class ConstBufferSequence> } \\
&\text{size_t buffer_copy(const MutableBufferSequence& dest,} \\
&\quad \text{const ConstBufferSequence& source,} \\
&\quad \text{size_t max_size) noexcept;} \\
&\quad \text{Effects: Copies bytes from the buffer sequence source to the buffer sequence dest, as if by calls to memcpy.} \\
&\quad \text{The number of bytes copied is the lesser of:} \\
&\quad \quad \text{(2.1) buffer_size(dest);} \\
&\quad \quad \text{(2.2) buffer_size(source); and} \\
&\quad \quad \text{(2.3) max_size, if specified.} \\
&\quad \text{The mutable buffer sequence dest specifies memory where the data should be placed. The operation} \\
&\quad \text{always fills a buffer in the sequence completely before proceeding to the next.} \\
&\quad \text{The constant buffer sequence source specifies memory where the data to be written is located. The} \\
&\quad \text{operation always copies a buffer in the sequence completely before proceeding to the next.} \\
&\quad \text{Returns: The number of bytes copied from source to dest.} \\
\end{aligned}
\]

16.10 Buffer arithmetic

\[
\begin{aligned}
&\text{mutable_buffer operator+(const mutable_buffer& b, size_t n) noexcept;} \\
&\text{mutable_buffer operator+(size_t n, const mutable_buffer& b) noexcept;} \\
&\quad \text{Returns: A mutable_buffer equivalent to} \\
&\quad \quad \text{mutable_buffer(} \\
&\quad \quad \quad \text{static_cast<char*>(b.data()) + min(n, b.size()),} \\
&\quad \quad \quad b\text{.size() - min(n, b\text{.size()});} \\
&\quad \text{const_buffer operator+(const const_buffer& b, size_t n) noexcept;} \\
&\quad \text{const_buffer operator+(size_t n, const const_buffer& b) noexcept;} \\
&\quad \text{Returns: A const_buffer equivalent to} \\
\end{aligned}
\]

§ 16.10
const_buffer(
  static_cast<const char*>(b.data()) + min(n, b.size()),
  b.size() - min(n, b.size()));

16.11 Buffer creation functions [buffer.creation]

1 In the functions below, T shall be a trivially copyable or standard-layout type (C++ 2020 [basic.types]).
[Editor’s note: vector<> and basic_strings<> are not valid types.]

2 For the function overloads below that accept an argument of type vector<> , the buffer objects returned are
invalidated by any vector operation that also invalidates all references, pointers and iterators referring to the
elements in the sequence (C++ 2020 [vector]).

3 For the function overloads below that accept an argument of type basic_string<> , the buffer objects
returned are invalidated according to the rules defined for invalidation of references, pointers and iterators
referring to elements of the sequence (C++ 2020 [string.require]).

mutable_buffer buffer(void* p, size_t n) noexcept;
4 Returns: mutable_buffer(p, n).

const_buffer buffer(const void* p, size_t n) noexcept;
5 Returns: const_buffer(p, n).

mutable_buffer buffer(const mutable_buffer& b) noexcept;
6 Returns: b.

mutable_buffer buffer(const mutable_buffer& b, size_t n) noexcept;
7 Returns: mutable_buffer(b.data(), min(b.size(), n)).

const_buffer buffer(const const_buffer& b) noexcept;
8 Returns: b.

const_buffer buffer(const const_buffer& b, size_t n) noexcept;
9 Returns: const_buffer(b.data(), min(b.size(), n)).

template<class T, size_t N>
  mutable_buffer buffer(T (&data)[N]) noexcept;
template<class T, size_t N>
  const_buffer buffer(const T (&data)[N]) noexcept;
template<class T, size_t N>
  mutable_buffer buffer(array<T, N>& data) noexcept;
template<class T, size_t N>
  const_buffer buffer(const array<T, N>& data) noexcept;
template<class T, class Allocator>
  mutable_buffer buffer(vector<T, Allocator>& data) noexcept;
template<class T, class Allocator>
  const_buffer buffer(const vector<T, Allocator>& data) noexcept;
template<class T, class Allocator>
  mutable_buffer buffer(const array<T, N>& data) noexcept;
template<class T, class Allocator>
  const_buffer buffer(const array<T, N>& data) noexcept;

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Returns:

```cpp
buffer(
    begin(data) != end(data) ? std::addressof(*begin(data)) : nullptr,
    (end(data) - begin(data)) * sizeof(*begin(data)))
```

```cpp
template<class T, size_t N>
mutable_buffer buffer(T (&data)[N], size_t n) noexcept;
template<class T, size_t N>
const_buffer buffer(const T (&data)[N], size_t n) noexcept;
template<class T, size_t N>
mutable_buffer buffer(array<T, N>& data, size_t n) noexcept;
template<class T, size_t N>
const_buffer buffer(const array<T, N>& data, size_t n) noexcept;
template<class T, size_t N>
const_buffer buffer(array<const T, N>& data, size_t n) noexcept;
template<class T, size_t N>
mutable_buffer buffer(vector<T, Allocator>& data, size_t n) noexcept;
template<class T, size_t N>
const_buffer buffer(const vector<T, Allocator>& data, size_t n) noexcept;
template<class CharT, class Traits, class Allocator>
mutable_buffer buffer(basic_string<CharT, Traits, Allocator>& data,
                      size_t n) noexcept;
template<class CharT, class Traits, class Allocator>
const_buffer buffer(const basic_string<CharT, Traits, Allocator>& data,
                    size_t n) noexcept;
template<class CharT, class Traits>
const_buffer buffer(basic_string_view<CharT, Traits> data,
                    size_t n) noexcept;
```

Returns: `buffer(buffer(data), n)`.

### 16.12 Class template `dynamic_vector_buffer`

Class template `dynamic_vector_buffer` is an adaptor used to automatically grow or shrink a `vector` object, to reflect the data successfully transferred in an I/O operation.

```cpp
namespace std {
namespace experimental {
namespace net {
inline namespace std::experimental::net::inline v1 {

template<class T, class Allocator>
class dynamic_vector_buffer {
{
public:
    // types:
    using const_buffers_type = const_buffer;
    using mutable_buffers_type = mutable_buffer;

    // constructors:
    explicit dynamic_vector_buffer(vector<T, Allocator>&& vec) noexcept;
    dynamic_vector_buffer(vector<T, Allocator>&& vec,
                           size_t maximum_size) noexcept;
    dynamic_vector_buffer(dynamic_vector_buffer&&) = default;

    // members:

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```
size_t size() const noexcept;
size_t max_size() const noexcept;
size_t capacity() const noexcept;
const_buffers_type data() const noexcept;
mutable_buffers_type prepare(size_t n);
void commit(size_t n);
void consume(size_t n);

private:
  vector<T, Allocator>& vec_; // exposition only
  size_t size_; // exposition only
  const size_t max_size_; // exposition only
};

2 The dynamic_vector_buffer class template meets the requirements of DynamicBuffer (16.2.4).

3 The dynamic_vector_buffer class template requires that T is a trivially copyable or standard-layout type
   (C++ 2020 [basic.types]) and that sizeof(T) == 1, otherwise the program is ill-formed.

explicit dynamic_vector_buffer(vector<T, Allocator>& vec) noexcept;

4 Effects: Initializes vec_ with vec, size_ with vec.size(), and max_size_ with vec.max_size().

dynamic_vector_buffer(vector<T, Allocator>& vec,
                      size_t maximum_size) noexcept;

5 Requires: Preconditions: vec.size() <= maximum_size.
6 Effects: Initializes vec_ with vec, size_ with vec.size(), and max_size_ with maximum_size.

size_t size() const noexcept;

7 Returns: size_.

size_t max_size() const noexcept;

8 Returns: max_size_.

size_t capacity() const noexcept;

9 Returns: vec_.capacity().

cost_buffers_type data() const noexcept;

10 Returns: buffer(vec_, size_).

mutableBuffers_type prepare(size_t n);

11 Effects: Performs vec_.resize(size_ + n).
12 Returns: buffer(buffer(vec_) + size_, n).
13 Remarks: Throws: length_error if size() + n exceeds max_size().
14  \textit{Effects:} Performs:
\begin{verbatim}
size_ += \min(n, \text{vec}_.size() - size_);
vec_.resize(size_);
\end{verbatim}

void consume(size_t n);

15  \textit{Effects:} Performs:
\begin{verbatim}
size_t m = \min(n, size_);
vec_.erase(vec_.begin(), vec_.begin() + m);
size_ -= m;
\end{verbatim}

16.13  Class template \texttt{dynamic\_string\_buffer}  \texttt{[buffer.dynamic.string]}

Class template \texttt{dynamic\_string\_buffer} is an adaptor used to automatically grow or shrink a \texttt{basic\_string} object, to reflect the data successfully transferred in an I/O operation.

namespace std {
namespace experimental {
namespace net {
    \texttt{\inline namespace std::experimental::net::\inline v1\_v2 \{}

    template<class CharT, class Traits, class Allocator>
    class dynamic\_string\_buffer {
    public:
        \texttt{// types:}
        using const\_buffers\_type = const\_buffer;
        using mutable\_buffers\_type = mutable\_buffer;

        \texttt{// constructors:}
        explicit dynamic\_string\_buffer(basic\_string\langle CharT, Traits, Allocator\rangle\& str) noexcept;
        dynamic\_string\_buffer(basic\_string\langle CharT, Traits, Allocator\rangle\& str,
                                 size_t maximum\_size) noexcept;
        dynamic\_string\_buffer(dynamic\_string\_buffer\&\&) = default;

        \texttt{// members:}
        size_t size() const noexcept;
        size_t max\_size() const noexcept;
        size_t capacity() const noexcept;
        const\_buffers\_type data() const noexcept;
        mutable\_buffers\_type prepare(size_t n);
        void commit(size_t n) noexcept;
        void consume(size_t n);

    private:
        basic\_string\langle CharT, Traits, Allocator\rangle\& str_;  \texttt{// exposition only}
        size_t size_;  \texttt{// exposition only}
        const size_t max\_size_;  \texttt{// exposition only}
    };

    \}} // inline namespace std::experimental::net::\inline v1\_v2
    \}} // namespace net
    \}} // namespace experimental
} // namespace std

\} // \texttt{buffer.dynamic.string}
The `dynamic_string_buffer` class template meets the requirements of `dynamic_buffer` (16.2.4).

The `dynamic_string_buffer` class template requires that `sizeof(CharT) == 1`, otherwise the program is ill-formed.

```cpp
explicit dynamic_string_buffer(basic_string<CharT, Traits, Allocator>& str) noexcept;
```

*Effects:* Initializes `str_` with `str`, `size_` with `str.size()`, and `max_size_` with `str.max_size()`.

```cpp
dynamic_string_buffer(basic_string<CharT, Traits, Allocator>& str, size_t maximum_size) noexcept;
```

*Requires:* `str.size() <= maximum_size`.

*Preconditions:* `str.size() <= maximum_size`.

*Effects:* Initializes `str_` with `str`, `size_` with `str.size()`, and `max_size_` with `maximum_size`.

```cpp
size_t size() const noexcept;
```

*Returns:* `size_`.

```cpp
size_t max_size() const noexcept;
```

*Returns:* `max_size_`.

```cpp
size_t capacity() const noexcept;
```

*Returns:* `str_.capacity()`.

```cpp
const_buffers_type data() const noexcept;
```

*Returns:* `buffer(str_, size_)`.

```cpp
mutable_buffers_type prepare(size_t n);
```

*Effects:* Performs `str_.resize(size_ + n)`.

*Returns:* `buffer(buffer(str_) + size_, n)`.

*Remarks:* Throws: `length_error` if `size() + n` exceeds `max_size()`.

```cpp
void commit(size_t n) noexcept;
```

*Effects:* Performs:

```cpp
size_ += min(n, str_.size() - size_);
str_.resize(size_);
```

```cpp
void consume(size_t n);
```

*Effects:* Performs:

```cpp
size_t m = min(n, size_);
str_.erase(0, m);
s size_ -= m;
```
16.14 Dynamic buffer creation functions

[buffer.dynamic.creation]

template<class T, class Allocator>
    dynamic_vector_buffer<T, Allocator>
    dynamic_buffer(vector<T, Allocator>& vec) noexcept;

1 Returns: dynamic_vector_buffer<T, Allocator>(vec).

template<class T, class Allocator>
    dynamic_vector_buffer<T, Allocator>
    dynamic_buffer(vector<T, Allocator>& vec, size_t n) noexcept;

2 Returns: dynamic_vector_buffer<T, Allocator>(vec, n).

template<class CharT, class Traits, class Allocator>
    dynamic_string_buffer<CharT, Traits, Allocator>
    dynamic_buffer(basic_string<CharT, Traits, Allocator>& str) noexcept;

3 Returns: dynamic_string_buffer<CharT, Traits, Allocator>(str).

template<class CharT, class Traits, class Allocator>
    dynamic_string_buffer<CharT, Traits, Allocator>
    dynamic_buffer(basic_string<CharT, Traits, Allocator>& str, size_t n) noexcept;

4 Returns: dynamic_string_buffer<CharT, Traits, Allocator>(str, n).
17 Buffer-oriented streams  [buffer.stream]

17.1 Requirements  [buffer.stream.reqmts]

17.1.1 Buffer-oriented synchronous read stream requirements  [buffer.stream.reqmts.syncreadstream]

A type \(X\) meets the SyncReadStream requirements if it satisfies the requirements listed in Table 16.

An orderly shutdown is the procedure for shutting down a stream after all work in progress has been completed, without loss of data.

In Table 16, \(a\) denotes a value of type \(X\), \(mb\) denotes a (possibly const) value of a (possibly const) type satisfying the MutableBufferSequence (16.2.1) requirements, and \(ec\) denotes an object of type error_code.

<table>
<thead>
<tr>
<th>operation</th>
<th>type</th>
<th>semantics, pre/post-conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a).read_some(mb)</td>
<td>size_t</td>
<td>Meets the requirements for a read operation (16.2.5). If (buffer_size(mb) &gt; 0), reads one or more bytes of data from the stream (a) into the buffer sequence (mb). If successful, sets (ec) such that (!ec) is true, and returns the number of bytes read. If an error occurred, sets (ec) such that (!ec) is true, and returns 0. If all data has been read from the stream, and the stream performed an orderly shutdown, sets (ec) to stream_errc::eof and returns 0. If (buffer_size(mb) == 0), the operation shall not block. Sets (ec) such that (!ec) is true, and returns 0.</td>
</tr>
<tr>
<td>(a).read_some(mb,ec)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

17.1.2 Buffer-oriented asynchronous read stream requirements  [buffer.stream.reqmts.asyncreadstream]

A type \(X\) meets the AsyncReadStream requirements if it satisfies the requirements listed below.

In the table below, \(a\) denotes a value of type \(X\), \(mb\) denotes a (possibly const) value of a (possibly const) type satisfying the MutableBufferSequence (16.2.1) requirements, and \(t\) is a completion token.
Table 17 — **AsyncReadStream** requirements

<table>
<thead>
<tr>
<th>operation</th>
<th>type</th>
<th>semantics, pre/post-conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.get_executor()</td>
<td>A type satisfying the</td>
<td>Returns the associated I/O executor.</td>
</tr>
<tr>
<td></td>
<td>Executor requirements</td>
<td></td>
</tr>
<tr>
<td>a.async_read_some(mb,t)</td>
<td>The return type is determined according to the requirements for an asynchronous operation (13.2.7).</td>
<td>Meets the requirements for a read operation (16.2.5) and an asynchronous operation (13.2.7) with completion signature void(error_code ec, size_t n). If buffer_size(mb) &gt; 0, initiates an asynchronous operation to read one or more bytes of data from the stream a into the buffer sequence mb. If successful, ec is set such that !ec is true, and n is the number of bytes read. If an error occurred, ec is set such that !!ec is true, and n is 0. If all data has been read from the stream, and the stream performed an orderly shutdown, ec is stream_errc::eof and n is 0. If buffer_size(mb) == 0, the operation completes immediately. ec is set such that !ec is true, and n is 0.</td>
</tr>
</tbody>
</table>

17.1.3 Buffer-oriented synchronous write stream requirements

Table 18 — **SyncWriteStream** requirements

<table>
<thead>
<tr>
<th>operation</th>
<th>type</th>
<th>semantics, pre/post-conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.write_some(cb)</td>
<td>size_t</td>
<td>Meets the requirements for a write operation (16.2.5). If buffer_size(cb) &gt; 0, writes one or more bytes of data to the stream a from the buffer sequence cb. If successful, sets ec such that !ec is true, and returns the number of bytes written. If an error occurred, sets ec such that !!ec is true, and returns 0.</td>
</tr>
<tr>
<td>a.write_some(cb,ec)</td>
<td></td>
<td>If buffer_size(cb) == 0, the operation shall not block. Sets ec such that !ec is true, and returns 0.</td>
</tr>
</tbody>
</table>
17.1.4 Buffer-oriented asynchronous write stream requirements
[buffer.stream.reqmts.asyncwritestream]

1 A type X meets the AsyncWriteStream requirements if it satisfies the requirements listed below.

2 In the table below, a denotes a value of type X, cb denotes a (possibly const) value of a (possibly const) type satisfying the ConstBufferSequence requirements, and t is a completion token.

Table 19 — AsyncWriteStream requirements

<table>
<thead>
<tr>
<th>operation</th>
<th>type</th>
<th>semantics, pre/post-conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.get_executor()</td>
<td>A type satisfying the Executor requirements (13.2.2).</td>
<td>Returns the associated I/O executor.</td>
</tr>
<tr>
<td>a.async_write_some(cb,t)</td>
<td>The return type is determined according to the requirements for an asynchronous operation (13.2.7).</td>
<td>Meets the requirements for a write operation (16.2.5) and an asynchronous operation (13.2.7) with completion signature void(error_code ec, size_t n). If buffer_size(cb) &gt; 0, initiates an asynchronous operation to write one or more bytes of data to the stream a from the buffer sequence cb. If successful, ec is set such that !ec is true, and n is the number of bytes written. If an error occurred, ec is set such that !!ec is true, and n is 0. If buffer_size(cb) == 0, the operation completes immediately. ec is set such that !ec is true, and n is 0.</td>
</tr>
</tbody>
</table>

17.1.5 Completion condition requirements
[buffer.stream.reqmts.completioncondition]

1 A completion condition is a function object that is used with the algorithms read (17.5), async_read (17.6), write (17.7), and async_write (17.8) to determine when the algorithm has completed transferring data.

2 A type X meets the CompletionCondition requirements if it satisfies the requirements of Destructible Cpp17Destructible (C++ 2020 [destructible]) and CopyConstructible Cpp17CopyConstructible (C++ 2020 [copyconstructible]), as well as the additional requirements listed below.

3 In the table below, x denotes a value of type X, ec denotes a (possibly const) value of type (possibly const) error_code, and n denotes a (possibly const) value of type (possibly const) size_t.
Table 20 — CompletionCondition requirements

<table>
<thead>
<tr>
<th>expression</th>
<th>return type</th>
<th>assertion/note pre/post-condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>x(ec, n)</td>
<td>size_t</td>
<td>Let n be the total number of bytes transferred by the read or write algorithm so far. Returns the maximum number of bytes to be transferred on the next read_some, async_read_some, write_some, or async_write_some operation performed by the algorithm. Returns 0 to indicate that the algorithm is complete.</td>
</tr>
</tbody>
</table>

17.2 Class transfer_all

The class transfer_all is a completion condition that is used to specify that a read or write operation should continue until all of the data has been transferred, or until an error occurs.

```cpp
namespace std {
    namespace experimental {
        namespace net {
            namespace std::experimental::net::inline v1v2 {

                class transfer_all {
                    public:
                        size_t operator()(const error_code& ec, size_t) const;
                    
                } // class transfer_all
            } // namespace std::experimental::net::inline v1v2
        } // namespace net
    } // namespace experimental
} // namespace std
```

The class transfer_all satisfies the CompletionCondition requirements.

```cpp
size_t operator()(const error_code& ec, size_t) const;
```

Returns: If !ec, an unspecified non-zero value. Otherwise 0.

17.3 Class transfer_at_least

The class transfer_at_least is a completion condition that is used to specify that a read or write operation should continue until a minimum number of bytes has been transferred, or until an error occurs.

```cpp
namespace std {
    namespace experimental {
        namespace net {
            namespace std::experimental::net::inline v1v2 {

                class transfer_at_least {
                    public:
                        explicit transfer_at_least(size_t m);
                        size_t operator()(const error_code& ec, size_t n) const;
                    
                } // class transfer_at_least
            } // namespace std::experimental::net::inline v1v2
        } // namespace net
    } // namespace experimental
} // namespace std
```

§ 17.3
The class `transfer_at_least` **satisfies** the `CompletionCondition` requirements.

```cpp
class transfer_at_least
{
    public:
        explicit transfer_at_least(size_t m);
    postconditions: minimum_ == m.

    size_t operator()(const error_code& ec, size_t n) const;
    returns: If !ec && n < minimum_, an unspecified non-zero value. Otherwise 0.
}
```

### 17.4 Class `transfer_exactly`

The class `transfer_exactly` is a completion condition that is used to specify that a read or write operation should continue until an exact number of bytes has been transferred, or until an error occurs.

```cpp
namespace std {
    namespace experimental {
        namespace net {
            inline namespace std::experimental::net::inline_v1 {

                class transfer_exactly
                {
                    public:
                        explicit transfer_exactly(size_t e);
                    size_t operator()(const error_code& ec, size_t n) const;
                    private:
                        size_t exact_; // exposition only
                }
            }
        }
    }
}
```

The class `transfer_exactly` **satisfies** the `CompletionCondition` requirements.

```cpp
class transfer_exactly
{
    public:
        explicit transfer_exactly(size_t e);
    postconditions: exact_ == e.

    size_t operator()(const error_code& ec, size_t n) const;
    returns: If !ec && n < exact_, the result of \( \min(\text{exact}_- n, N) \), where \( N \) is an unspecified non-zero value. Otherwise 0.
}
17.5 Synchronous read operations

Template:

```cpp
template<class SyncReadStream, class MutableBufferSequence>
size_t read(SyncReadStream& stream,
            const MutableBufferSequence& buffers);
template<class SyncReadStream, class MutableBufferSequence>
size_t read(SyncReadStream& stream,
            const MutableBufferSequence& buffers, error_code& ec);
template<class SyncReadStream, classMutableBufferSequence,
class CompletionCondition>
size_t read(SyncReadStream& stream,
            const MutableBufferSequence& buffers,
            CompletionCondition completion_condition);
template<class SyncReadStream, class MutableBufferSequence,
class CompletionCondition>
size_t read(SyncReadStream& stream,
            const MutableBufferSequence& buffers,
            CompletionCondition completion_condition,
            error_code& ec);
```

Effect: A read operation (16.2.5).

1. Clears `ec`, then reads data from the buffer-oriented synchronous read stream (17.1.1) object `stream` by performing zero or more calls to the stream’s `read_some` member function.

2. The `completion_condition` parameter specifies a completion condition to be called prior to each call to the stream’s `read_some` member function. The completion condition is passed the `error_code` value from the most recent `read_some` call, and the total number of bytes transferred in the synchronous read operation so far. The completion condition return value specifies the maximum number of bytes to be read on the subsequent `read_some` call. Overloads where a completion condition is not specified behave as if called with an object of class `transfer_all`.

3. The synchronous read operation continues until:
   - (4.1) the total number of bytes transferred is equal to `buffer_size(buffers)`; or
   - (4.2) the completion condition returns 0.

4. On return, `ec` contains the `error_code` value from the most recent `read_some` call.

Returns: The total number of bytes transferred in the synchronous read operation.

Remarks: This function shall not participate in overload resolution unless `is_mutable_buffer_sequence_v<MutableBufferSequence> is true`.

Template:

```cpp
template<class SyncReadStream, class DynamicBuffer>
size_t read(SyncReadStream& stream, DynamicBuffer&& b);
template<class SyncReadStream, class DynamicBuffer>
size_t read(SyncReadStream& stream, DynamicBuffer&& b, error_code& ec);
template<class SyncReadStream, class DynamicBuffer,
class CompletionCondition>
size_t read(SyncReadStream& stream, DynamicBuffer&& b,
            CompletionCondition completion_condition);
template<class SyncReadStream, class DynamicBuffer,
class CompletionCondition>
size_t read(SyncReadStream& stream, DynamicBuffer&& b,
            CompletionCondition completion_condition,
            error_code& ec);
```

Effect: Clears `ec`, then reads data from the synchronous read stream (17.1.1) object `stream` by performing zero or more calls to the stream’s `read_some` member function.
Data is placed into the dynamic buffer (16.2.4) object \( b \). A mutable buffer sequence (16.2.1) is obtained prior to each \texttt{read_some} call using \( b.\text{prepare}(N) \), where \( N \) is an unspecified value less than or equal to \( b.\text{max_size}() - b.\text{size}() \). \footnote{Note: Implementations can use \( b.\text{capacity}() \) when determining \( N \), to minimize the number of \texttt{read_some} calls performed on the stream. \textit{End note}} After each \texttt{read_some} call, the implementation performs \( b.\text{commit}(n) \), where \( n \) is the return value from \texttt{read_some}.

The \texttt{completion_condition} parameter specifies a completion condition to be called prior to each call to the stream’s \texttt{read_some} member function. The completion condition is passed the \texttt{error_code} value from the most recent \texttt{read_some} call, and the total number of bytes transferred in the synchronous read operation so far. The completion condition return value specifies the maximum number of bytes to be read on the subsequent \texttt{read_some} call. Overloads where a completion condition is not specified behave as if called with an object of class \texttt{transfer_all}.

The synchronous read operation continues until:

\begin{enumerate}
\item \( b.\text{size}() == b.\text{max_size}() \); or
\item the completion condition returns \( 0 \).
\end{enumerate}

On return, \( \texttt{ec} \) contains the \texttt{error_code} value from the most recent \texttt{read_some} call.

Returns: The total number of bytes transferred in the synchronous read operation.

Remarks: This function shall not participate in overload resolution unless \texttt{Constraints: is_dynamic_buffer_v<DynamicBuffer> is true}.

\section*{17.6 Asynchronous read operations} [buffer.async.read]

\begin{verbatim}
template<class AsyncReadStream, class MutableBufferSequence, class CompletionToken>
 DEDUCED async_read(AsyncReadStream& stream,
 const MutableBufferSequence& buffers,
 CompletionToken&& token);

template<class AsyncReadStream, class MutableBufferSequence, class CompletionCondition,
         class CompletionToken>
 DEDUCED async_read(AsyncReadStream& stream,
 const MutableBufferSequence& buffers,
 CompletionCondition completion_condition,
 CompletionToken&& token);
\end{verbatim}

A composed asynchronous read operation (13.2.7.14, 16.2.5).

Completion signature: void(error_code ec, size_t n).

Effects: Reads data from the buffer-oriented asynchronous read stream (17.1.2) object \( \texttt{stream} \) by invoking the stream’s \texttt{async_read_some} member function (henceforth referred to as asynchronous read_some operations) zero or more times.

The \texttt{completion_condition} parameter specifies a completion condition to be called prior to each asynchronous read_some operation. The completion condition is passed the \texttt{error_code} value from the most recent asynchronous read_some operation, and the total number of bytes transferred in the asynchronous read operation so far. The completion condition return value specifies the maximum number of bytes to be read on the subsequent asynchronous read_some operation. Overloads where a completion condition is not specified behave as if called with an object of class \texttt{transfer_all}.

This asynchronous read operation is outstanding until:

\begin{enumerate}
\item the total number of bytes transferred is equal to \texttt{buffer_size(buffers)}; or
\item the completion condition returns \( 0 \).
\end{enumerate}

The program shall ensure the \texttt{AsyncReadStream} object \( \texttt{stream} \) is valid until the completion handler for the asynchronous operation is invoked.
Completion signature: void(error_code ec, size_t n).

Effects: Initiates an asynchronous operation to read data from the buffer-oriented asynchronous read stream (17.1.2) object stream by performing one or more asynchronous read_some operations on the stream.

Data is placed into the dynamic buffer (16.2.4) object b. A mutable buffer sequence (16.2.1) is obtained prior to each async_read_some call using b.prepare(N), where N is an unspecified value such that N is less than or equal to b.max_size() - b.size(). [Note: Implementations can use b.capacity() when determining N, to minimize the number of asynchronous read_some operations performed on the stream. —end note] After the completion of each asynchronous read_some operation, the implementation performs b.commit(n), where n is the value passed to the asynchronous read_some operation's completion handler.

The completion_condition parameter specifies a completion condition to be called prior to each asynchronous read_some operation. The completion condition is passed the error_code value from the most recent asynchronous read_some operation, and the total number of bytes transferred in the asynchronous read operation so far. The completion condition return value specifies the maximum number of bytes to be read on the subsequent asynchronous read_some operation. Overloads where a completion condition is not specified behave as if called with an object of class transfer_all.

The asynchronous read operation is outstanding until:

— b.size() == b.max_size(); or

— the completion condition returns 0.

The program shall ensure the AsyncReadStream object stream is valid until the completion handler for the asynchronous operation is invoked.

On completion of the asynchronous operation, ec is the error_code value from the most recent asynchronous read_some operation, and n is the total number of bytes transferred.

Remarks: This function shall not participate in overload resolution unless Constraints: is_dynamic_buffer_v<DynamicBuffer> is true.

17.7 Synchronous write operations

template<class SyncWriteStream, class ConstBufferSequence>
size_t write(SyncWriteStream& stream,
const ConstBufferSequence& buffers);

§ 17.7
template<class SyncWriteStream, class ConstBufferSequence,  
    class CompletionCondition>
size_t write(SyncWriteStream& stream,  
    const ConstBufferSequence& buffers,  
    CompletionCondition completion_condition);
template<class SyncWriteStream, class ConstBufferSequence,  
    class CompletionCondition>
size_t write(SyncWriteStream& stream,  
    const ConstBufferSequence& buffers,  
    CompletionCondition completion_condition,  
    error_code& ec);

1 A write operation (16.2.5).
2 Effects: Writes data to the buffer-oriented synchronous write stream (17.1.3) object stream by performing zero or more calls to the stream’s write_some member function.
3 The completion_condition parameter specifies a completion condition to be called prior to each call to the stream’s write_some member function. The completion condition is passed the error_code value from the most recent write_some call, and the total number of bytes transferred in the synchronous write operation so far. The completion condition return value specifies the maximum number of bytes to be written on the subsequent write_some call. Overloads where a completion condition is not specified behave as if called with an object of class transfer_all.
4 The synchronous write operation continues until:
(4.1) — the total number of bytes transferred is equal to buffer_size(buffers); or
(4.2) — the completion condition returns 0.
5 On return, ec contains the error_code value from the most recent write_some call.
6 Returns: The total number of bytes transferred in the synchronous write operation.
7 Remarks: This function shall not participate in overload resolution unless Constraints: is_const_buffer_sequence_v<ConstBufferSequence>::value is true.

template<class SyncWriteStream, class DynamicBuffer>
size_t write(SyncWriteStream& stream, DynamicBuffer&& b);
template<class SyncWriteStream, class DynamicBuffer>
size_t write(SyncWriteStream& stream, DynamicBuffer&& b, error_code& ec);
template<class SyncWriteStream, class DynamicBuffer, class CompletionCondition>
size_t write(SyncWriteStream& stream, DynamicBuffer&& b,  
    CompletionCondition completion_condition);
template<class SyncWriteStream, class DynamicBuffer, class CompletionCondition>
size_t write(SyncWriteStream& stream, DynamicBuffer&& b,  
    CompletionCondition completion_condition,  
    error_code& ec);

8 Effects: Writes data to the synchronous write stream (17.1.3) object stream by performing zero or more calls to the stream’s write_some member function.
9 Data is written from the dynamic buffer (16.2.4) object b. A constant buffer sequence (16.2.2) is obtained using b.data(). After the data has been written to the stream, the implementation performs b.consume(n), where n is the number of bytes successfully written.
10 The completion_condition parameter specifies a completion condition to be called after each call to the stream’s write_some member function. The completion condition is passed the error_code value from the most recent write_some call, and the total number of bytes transferred in the synchronous write operation so far. The completion condition return value specifies the maximum number of bytes to
be written on the subsequent `write_some` call. Overloads where a completion condition is not specified behave as if called with an object of class `transfer_all`.

The synchronous write operation continues until:

1. \( \text{b.size() == 0; or} \)
2. \( \text{the completion condition returns 0.} \)

On return, \( \text{ec} \) contains the `error_code` value from the most recent `write_some` call.

**Returns:** The total number of bytes transferred in the synchronous write operation.

**Remarks:** This function shall not participate in overload resolution unless `Constraints; is_dynamic_buffer_v<DynamicBuffer>` is true.

### 17.8 Asynchronous write operations

[buffer.async.write]

```cpp
template<class AsyncWriteStream, class ConstBufferSequence, class CompletionToken>
DEDUCED async_write(AsyncWriteStream& stream,
                     const ConstBufferSequence& buffers,
                     CompletionToken& token);
```

A composed asynchronous write operation (13.2.7.14, 16.2.5).

**Completion signature:** `void(error_code ec, size_t n)`.

**Effects:** Initiates an asynchronous operation to write data to the buffer-oriented asynchronous write stream (17.1.4) object `stream` by performing zero or more asynchronous operations on the stream using the stream’s `async_write_some` member function (henceforth referred to as asynchronous `write_some` operations).

The `completion_condition` parameter specifies a completion condition to be called prior to each asynchronous `write_some` operation. The completion condition is passed the `error_code` value from the most recent asynchronous `write_some` operation, and the total number of bytes transferred in the asynchronous write operation so far. The completion condition return value specifies the maximum number of bytes to be written on the subsequent asynchronous `write_some` operation. Overloads where a completion condition is not specified behave as if called with an object of class `transfer_all`.

The asynchronous write operation continues until:

1. \( \text{the completion condition returns 0.} \)
2. \( \text{the total number of bytes transferred is equal to buffer_size(buffers); or} \)

The program shall ensure the `AsyncWriteStream` object `stream` is valid until the completion handler for the asynchronous operation is invoked.

On completion of the asynchronous operation, \( \text{ec} \) is the `error_code` value from the most recent asynchronous `write_some` operation, and \( n \) is the total number of bytes transferred.

**Remarks:** This function shall not participate in overload resolution unless `Constraints; is_const_buffer_sequence_v<ConstBufferSequence>::value` is true.
class CompletionToken>

async_write(AsyncWriteStream& stream,
        DynamicBuffer&& b,
        CompletionCondition completion_condition,
        CompletionToken&& token);

Completion signature: void(error_code ec, size_t n).

Effects: Initiates an asynchronous operation to write data to the buffer-oriented asynchronous write stream (17.1.4) object stream by performing zero or more asynchronous write_some operations on the stream.

Data is written from the dynamic buffer (16.2.4) object b. A constant buffer sequence (16.2.2) is obtained using b.data(). After the data has been written to the stream, the implementation performs b.consume(n), where n is the number of bytes successfully written.

The completion_condition parameter specifies a completion condition to be called prior to each asynchronous write_some operation. The completion condition is passed the error_code value from the most recent asynchronous write_some operation, and the total number of bytes transferred in the asynchronous write operation so far. The completion condition return value specifies the maximum number of bytes to be written on the subsequent asynchronous write_some operation. Overloads where a completion condition is not specified behave as if called with an object of class transfer_all.

The asynchronous write operation continues until:
- b.size() == 0; or
- the completion condition returns 0.

The program shall ensure both the AsyncWriteStream object stream and the memory associated with the dynamic buffer b are valid until the completion handler for the asynchronous operation is invoked.

On completion of the asynchronous operation, ec is the error_code value from the most recent asynchronous write_some operation, and n is the total number of bytes transferred.

Remarks: This function shall not participate in overload resolution unless Constraints: is_dynamic_buffer_v<DynamicBuffer> is true.

17.9 Synchronous delimited read operations

template<class SyncReadStream, class DynamicBuffer>
size_t read_until(SyncReadStream& s, DynamicBuffer&& b, char delim);

template<class SyncReadStream, class DynamicBuffer>
size_t read_until(SyncReadStream& s, DynamicBuffer&& b, char delim, error_code& ec);

template<class SyncReadStream, class DynamicBuffer>
size_t read_until(SyncReadStream& s, DynamicBuffer&& b, string_view delim);

template<class SyncReadStream, class DynamicBuffer>
size_t read_until(SyncReadStream& s, DynamicBuffer&& b,
        string_view delim, error_code& ec);

Effects: Reads data from the buffer-oriented synchronous read stream (17.1.1) object stream by performing zero or more calls to the stream’s read_some member function, until the readable bytes of the dynamic buffer (16.2.4) object b contains the specified delimiter delim.

Data is placed into the dynamic buffer object b. A mutable buffer sequence (16.2.1) is obtained prior to each read_some call using b.prepare(N), where N is an unspecified value such that N <= max_size() - size(). [Note: Implementations can use b.capacity() when determining N, to minimize the number of read_some calls performed on the stream. — end note] After each read_some call, the implementation performs b.commit(n), where n is the return value from read_some.

The synchronous read_until operation continues until:
(3.1)  — the readable bytes of \( b \) contains the delimiter \( \text{delim} \); or
(3.2)  — \( b.\text{size}() == b.\text{max\_size}() \); or
(3.3)  — an asynchronous \text{read\_some} operation fails.

On exit, if the readable bytes of \( b \) contains the delimiter, \( \text{ec} \) is set such that \(!\text{ec}\) is \text{true}. Otherwise, if \( b.\text{size}() == b.\text{max\_size}() \), \( \text{ec} \) is set such that \( \text{ec} == \text{stream\_errc::not\_found} \). If \( b.\text{size}() < b.\text{max\_size}() \), \( \text{ec} \) contains the \text{error\_code} from the most recent \text{read\_some} call.

5 Returns: The number of bytes in the readable bytes of \( b \) up to and including the delimiter, if present. [\text{Note:} On completion, the buffer can contain additional bytes following the delimiter. —end note] Otherwise returns 0.

17.10 Asynchronous delimited read operations \[\text{buffer.async.read.until}\]

\[
\text{template<class AsyncReadStream, class DynamicBuffer, class CompletionToken>}
\]

\[
\text{DEDUCED async\_read\_until(AsyncReadStream& s, DynamicBuffer& b, char delim, CompletionToken& token)};
\]

\[
\text{template<class AsyncReadStream, class DynamicBuffer, class CompletionToken>}
\]

\[
\text{DEDUCED async\_read\_until(AsyncReadStream& s, DynamicBuffer& b, string\_view delim, CompletionToken& token)};
\]

1 A composed asynchronous operation \((13.2.7.14)\).

2 \text{Completion signature: void(error\_code ec, size\_t n)}. \\
3 Effects: Initiates an asynchronous operation to read data from the buffer-oriented asynchronous read stream \((17.1.2)\) object \( \text{stream} \) by performing zero or more asynchronous \text{read\_some} operations on the stream, until the readable bytes of the dynamic buffer \((16.2.4)\) object \( b \) contain the specified delimiter \( \text{delim} \).

4 Data is placed into the dynamic buffer object \( b \). A mutable buffer sequence \((16.2.1)\) is obtained prior to each \text{async\_read\_some} call using \( b.\text{prepare}(N) \), where \( N \) is an unspecified value such that \( N <= \text{max\_size}() - \text{size}() \). [\text{Note:} Implementations can use \( b.\text{capacity}() \) when determining \( N \), to minimize the number of asynchronous \text{read\_some} operations performed on the stream. —end note] After the completion of each asynchronous \text{read\_some} operation, the implementation performs \( b.\text{commit}(n) \), where \( n \) is the value passed to the asynchronous \text{read\_some} operation’s completion handler.

5 The asynchronous \text{read\_until} operation continues until:
(5.1)  — the readable bytes of \( b \) contain the delimiter \( \text{delim} \); or
(5.2)  — \( b.\text{size}() == b.\text{max\_size}() \); or
(5.3)  — an asynchronous \text{read\_some} operation fails.

6 The program shall ensure the \text{AsyncReadStream} object \( \text{stream} \) is valid until the completion handler for the asynchronous operation is invoked.

7 If \( \text{delim} \) is of type \text{string\_view}, the implementation copies the underlying sequence of characters prior to initiating an asynchronous \text{read\_some} operation on the stream. [\text{Note:} This means that the caller is not required to guarantee the validity of the delimiter string after the call to \text{async\_read\_until} returns. —end note]

8 On completion of the asynchronous operation, if the readable bytes of \( b \) contain the delimiter, \( \text{ec} \) is set such that \(!\text{ec}\) is \text{true}. Otherwise, if \( b.\text{size}() == b.\text{max\_size}() \), \( \text{ec} \) is set such that \( \text{ec} == \text{stream\_errc::not\_found} \). If \( b.\text{size}() < b.\text{max\_size}() \), \( \text{ec} \) is the \text{error\_code} from the most recent asynchronous \text{read\_some} operation. \( n \) is the number of readable bytes in \( b \) up to and including the delimiter, if present, otherwise 0.
18 Sockets

18.1 Header <experimental/socket> synopsis

namespace std {
namespace experimental {
namespace net {
inline namespace std::experimental::net::inline_v1v2 {

enum class socket_errc {
  already_open = an implementation-defined non-zero value,
  not_found = an implementation-defined non-zero value
};

const error_category& socket_category() noexcept;
error_code make_error_code(socket_errc e) noexcept;
error_condition make_error_condition(socket_errc e) noexcept;

// Sockets:
class socket_base;

template<class Protocol>
class basic_socket;

template<class Protocol>
class basic_datagram_socket;

template<class Protocol>
class basic_stream_socket;

template<class Protocol>
class basic_socket_acceptor;

// Clause 19, Socket streams:

template<class Protocol, class Clock = chrono::steady_clock,
class WaitTraits = wait_traits<Clock>>
class basic_socket_streambuf;

template<class Protocol, class Clock = chrono::steady_clock,
class WaitTraits = wait_traits<Clock>>
class basic_socket_iostream;

// 20.1, synchronous connect operations:

template<class Protocol, class EndpointSequence>
typename Protocol::endpoint connect(basic_socket<Protocol>& s,
const EndpointSequence& endpoints);

template<class Protocol, class EndpointSequence>
typename Protocol::endpoint connect(basic_socket<Protocol>& s,
const EndpointSequence& endpoints,
    error_code& ec);

template<class Protocol, class EndpointSequence, class ConnectCondition>
    typename Protocol::endpoint connect(basic_socket<Protocol>& s,
    const EndpointSequence& endpoints,
    ConnectCondition c);

template<class Protocol, class EndpointSequence, class ConnectCondition>
    typename Protocol::endpoint connect(basic_socket<Protocol>& s,
    const EndpointSequence& endpoints,
    ConnectCondition c,
    error_code& ec);

template<class Protocol, class InputIterator>
    InputIterator connect(basic_socket<Protocol>& s,
    InputIterator first, InputIterator last);

template<class Protocol, class InputIterator>
    InputIterator connect(basic_socket<Protocol>& s,
    InputIterator first, InputIterator last,
    error_code& ec);

template<class Protocol, class InputIterator, class ConnectCondition>
    InputIterator connect(basic_socket<Protocol>& s,
    InputIterator first, InputIterator last,
    ConnectCondition c);

template<class Protocol, class InputIterator, class ConnectCondition>
    InputIterator connect(basic_socket<Protocol>& s,
    InputIterator first, InputIterator last,
    ConnectCondition c,
    error_code& ec);

// 20.2, asynchronous connect operations:

template<class Protocol, class EndpointSequence, class CompletionToken>
    DEDUCED async_connect(basic_socket<Protocol>& s,
    const EndpointSequence& endpoints,
    CompletionToken&& token);

template<class Protocol, class EndpointSequence, class ConnectCondition,
    class CompletionToken>
    DEDUCED async_connect(basic_socket<Protocol>& s,
    const EndpointSequence& endpoints,
    ConnectCondition c,
    CompletionToken&& token);

template<class Protocol, class InputIterator, class CompletionToken>
    DEDUCED async_connect(basic_socket<Protocol>& s,
    InputIterator first, InputIterator last,
    CompletionToken&& token);

template<class Protocol, class InputIterator, class ConnectCondition,
    class CompletionToken>
    DEDUCED async_connect(basic_socket<Protocol>& s,
    InputIterator first, InputIterator last,
    ConnectCondition c,
    CompletionToken&& token);

} // inline namespace std::experimental::net::v2

} // namespace net

§ 18.1
The figure below illustrates relationships between various types described in this document. A solid line from A to B that is terminated by an open arrow indicates that A is derived from B. A solid line from A to B that starts with a diamond and is terminated by a solid arrow indicates that A contains an object of type B. A dotted line from A to B indicates that A is a synonym for the class template B with the specified template argument.

Figure 1 — Socket and socket stream types [non-normative]

18.2 Requirements [socket.reqmts]

18.2.1 Requirements on synchronous socket operations [socket.reqmts.sync]

1 In this subclause, synchronous socket operations are those member functions specified as two overloads, with and without an argument of type `error_code&`:

\[
R f(A1 a1, A2 a2, \ldots, AN aN);
R f(A1 a1, A2 a2, \ldots, AN aN, error_code& ec);
\]

2 For an object s, the conditions under which its synchronous socket operations may block the calling thread (C++ 2020 [defns.block]) are determined as follows.

3 If:
— \( s.\text{non\_blocking}() == \text{true} \),
— the synchronous socket operation is specified in terms of a POSIX function other than \text{poll},
— that POSIX function lists \text{EWOULDBLOCK} or \text{EAGAIN} in its failure conditions, and
— the effects of the operation cannot be established immediately
then the synchronous socket operation shall not block the calling thread.  \[ \text{Note: And the effects of the operation are not established. \text{— end note}} \]

Otherwise, the synchronous socket operation shall block the calling thread until the effects are established.

### 18.2.2 Requirements on asynchronous socket operations

In this subclause, \textit{asynchronous socket operations} are those member functions having prefix \texttt{async\_}.

For an object \( s \), a program may initiate asynchronous socket operations such that there are multiple simultaneously outstanding asynchronous operations.

When there are multiple outstanding asynchronous read operations (16.2.5) on \( s \):

(3.1) — having no argument \texttt{flags} of type \texttt{socket\_base::message\_flags}, or
(3.2) — having an argument \texttt{flags} of type \texttt{socket\_base::message\_flags} but where \((\texttt{flags} \& \texttt{socket\_base::message\_out\_of\_band}) == 0\)

then the \texttt{buffers} are filled in the order in which these operations were issued.  The order of invocation of the completion handlers for these operations is unspecified.

When there are multiple outstanding asynchronous read operations (16.2.5) on \( s \) having an argument \texttt{flags} of type \texttt{socket\_base::message\_flags} where \((\texttt{flags} \& \texttt{socket\_base::message\_out\_of\_band}) \neq 0\) then the \texttt{buffers} are filled in the order in which these operations were issued.

When there are multiple outstanding asynchronous write operations (16.2.5) on \( s \), the \texttt{buffers} are transmitted in the order in which these operations were issued.  The order of invocation of the completion handlers for these operations is unspecified.

### 18.2.3 Native handles

Several classes described in this document have a member type \texttt{native\_handle\_type}, a member function \texttt{native\_handle}, and member functions that return or accept arguments of type \texttt{native\_handle\_type}.  The presence of these members and their semantics is implementation-defined.

When an operation has its effects specified as if by passing the result of \texttt{native\_handle()} to a POSIX function the effect is as if \texttt{native\_handle\_type} is the type \texttt{int}.

[\textit{Note: These members allow implementations to provide access to their implementation details. Their names are specified to facilitate portable compile-time detection. Actual use of these members is inherently non-portable. For operating systems that are based on POSIX, implementations can define the native\_handle\_type for sockets as int, representing the native file descriptor associated with the socket. \textit{— end note}}]

### 18.2.4 Endpoint requirements

A type \( X \) meets the Endpoint \textit{Endpoint} requirements if it satisfies the requirements of \texttt{Destructible \texttt{Cpp17Destructible} (C++ 2020 [destructible])}, \texttt{DefaultConstructible \texttt{Cpp17DefaultConstructible} (C++ 2020 [defaultconstructible])}, \texttt{CopyConstructible \texttt{Cpp17CopyConstructible} (C++ 2020 [copyconstructible])}, and \texttt{CopyAssignable \texttt{Cpp17CopyAssignable} (C++ 2020 [copyassignable])}, as well as the additional requirements listed below.

In the table below, \( a \) denotes a (possibly const) value of type (possibly const) \( X \), and \( u \) denotes an identifier.
Table 21 — *Endpoint* requirements

<table>
<thead>
<tr>
<th>expression</th>
<th>type</th>
<th>assertion/note pre/post-conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>X::protocol_type</code></td>
<td>type meeting Protocol</td>
<td>Protocol (18.2.6) requirements</td>
</tr>
<tr>
<td><code>a.protocol()</code></td>
<td>protocol_type</td>
<td></td>
</tr>
</tbody>
</table>

3 In the table below, a denotes a (possibly const) value of type (possibly const) `X`, b denotes a value of type `X`, and s denotes a (possibly const) value of a type that is convertible to `size_t` and denotes a size in bytes.

Table 22 — *Endpoint* requirements for extensible implementations

<table>
<thead>
<tr>
<th>expression</th>
<th>type</th>
<th>assertion/note pre/post-conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>a.data()</code></td>
<td>const void*</td>
<td>Returns a pointer suitable for passing as the address argument to functions such as POSIX <code>connect</code>, or as the dest_addr argument to functions such as POSIX <code>sendto</code>. The implementation shall perform a static_cast on the pointer to convert it to const sockaddr*.</td>
</tr>
<tr>
<td><code>b.data()</code></td>
<td>void*</td>
<td>Returns a pointer suitable for passing as the address argument to functions such as POSIX <code>accept</code>, <code>getpeername</code>, <code>getsockname</code> and <code>recvfrom</code>. The implementation shall perform a static_cast on the pointer to convert it to sockaddr*.</td>
</tr>
<tr>
<td><code>a.size()</code></td>
<td>size_t</td>
<td>Returns a value suitable for passing as the address_len argument to functions such as POSIX <code>connect</code>, or as the dest_len argument to functions such as POSIX <code>sendto</code>, after appropriate integer conversion has been performed.</td>
</tr>
</tbody>
</table>
| `b.resize(s)` |             | pre: Preconditions: s >= 0
post: Postconditions: a.size() == s
Passed the value contained in the address_len argument to functions such as POSIX `accept`, `getpeername`, `getsockname`, and `recvfrom`, after successful completion of the function. Permitted to throw an exception if the protocol associated with the endpoint object a does not support the specified size. |
| `a.capacity()` | size_t       | Returns a value suitable for passing as the address_len argument to functions such as POSIX `accept`, `getpeername`, `getsockname`, and `recvfrom`, after appropriate integer conversion has been performed. |
18.2.5 Endpoint sequence requirements

A type \( X \) meets the requirements if it satisfies the requirements of \( \text{DestructibleCpp17Destructible} \) (C++ 2020 [destructible]) and \( \text{CopyConstructibleCpp17CopyConstructible} \) (C++ 2020 [copyconstructible]), as well as the additional requirements listed below.

In the table below, \( x \) denotes a (possibly const) value of type (possibly const) \( X \).

<table>
<thead>
<tr>
<th>Expression</th>
<th>Return Type</th>
<th>Assertion/Note Pre/Post-condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>( x.\text{begin()} )</td>
<td>A type meeting the requirements for forward iterators (C++ 2020 [forward.iterators]) whose value type is convertible to a type satisfying the ( \text{Endpoint} ) (18.2.4) requirements.</td>
<td>( [x.\text{begin()}, x.\text{end()}] ) is a valid range.</td>
</tr>
</tbody>
</table>

18.2.6 Protocol requirements

A type \( X \) meets the requirements if it satisfies the requirements of \( \text{DestructibleCpp17Destructible} \) (C++ 2020 [destructible]), \( \text{CopyConstructibleCpp17CopyConstructible} \) (C++ 2020 [copyconstructible]), and \( \text{CopyAssignableCpp17CopyAssignable} \) (C++ 2020 [copyassignable]), as well as the additional requirements listed below.

In the table below, \( a \) denotes a (possibly const) value of type (possibly const) \( X \).

<table>
<thead>
<tr>
<th>Expression</th>
<th>Return Type</th>
<th>Assertion/Note Pre/Post-condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>( X.\text{:endpoint} )</td>
<td>type meeting ( \text{Endpoint} ) (18.2.4) requirements</td>
<td></td>
</tr>
</tbody>
</table>

Table 24 — Protocol requirements for extensible implementations

<table>
<thead>
<tr>
<th>Expression</th>
<th>Return Type</th>
<th>Assertion/Note Pre/Post-condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>( a.\text{family()} )</td>
<td>int</td>
<td>Returns a value suitable for passing as the domain argument to POSIX socket (or equivalent).</td>
</tr>
<tr>
<td>( a.\text{type()} )</td>
<td>int</td>
<td>Returns a value suitable for passing as the type argument to POSIX socket (or equivalent).</td>
</tr>
</tbody>
</table>
Table 25 — Protocol requirements for extensible implementations (continued)

<table>
<thead>
<tr>
<th>expression</th>
<th>return type</th>
<th>assertion/note pre/post-conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.protocol()</td>
<td>int</td>
<td>Returns a value suitable for passing as the protocol argument to POSIX socket (or equivalent).</td>
</tr>
</tbody>
</table>

18.2.7 Acceptable protocol requirements

A type X meets the AcceptableProtocol requirements if it satisfies the requirements of Protocol (18.2.6) as well as the additional requirements listed below.

Table 26 — AcceptableProtocol requirements

<table>
<thead>
<tr>
<th>expression</th>
<th>return type</th>
<th>assertion/note pre/post-conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>X::socket</td>
<td>A type that satisfies the requirements of Destructible Cpp17Destructible (C++ 2020 [destructible]) and MoveConstructible Cpp17MoveConstructible (C++ 2020 [move-constructible]), and that is publicly and unambiguously derived from basic_socket&lt;X&gt;.</td>
<td></td>
</tr>
</tbody>
</table>

18.2.8 Gettable socket option requirements

A type X meets the GettableSocketOption requirements if it satisfies the requirements listed below.

2 In the table below, a denotes a (possibly const) value of type (possibly const) X, b denotes a value of type X, p denotes a value of a (possibly const) type that meets the Protocol requirements, and s denotes a value of a (possibly const) type that is convertible to size_t and denotes a size in bytes.

Table 27 — GettableSocketOption requirements for extensible implementations

<table>
<thead>
<tr>
<th>expression</th>
<th>type</th>
<th>assertion/note pre/post-conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.level(p)</td>
<td>int</td>
<td>Returns a value suitable for passing as the level argument to POSIX getsockopt (or equivalent).</td>
</tr>
<tr>
<td>a.name(p)</td>
<td>int</td>
<td>Returns a value suitable for passing as the option_name argument to POSIX getsockopt (or equivalent).</td>
</tr>
</tbody>
</table>
### 18.2.9 Settable socket option requirements

A type \( X \) meets the **SettableSocketOption** requirements if it satisfies the requirements listed below.

In the table below, \( a \) denotes a (possibly const) value of type (possibly const) \( X \), \( p \) denotes a (possibly const) value of a (possibly const) type that meets the Protocol (18.2.6) requirements, and \( u \) denotes an identifier.

<table>
<thead>
<tr>
<th>expression</th>
<th>type</th>
<th>assertion/note pre/post-conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>( b).data(p)</td>
<td>void*</td>
<td>Returns a pointer suitable for passing as the ( \text{option_value} ) argument to POSIX \text{getsockopt} (or equivalent).</td>
</tr>
<tr>
<td>( a).size(p)</td>
<td>size_t</td>
<td>Returns a value suitable for passing as the ( \text{option_len} ) argument to POSIX \text{getsockopt} (or equivalent), after appropriate integer conversion has been performed.</td>
</tr>
<tr>
<td>( b).resize(p,s)</td>
<td>post</td>
<td>Passed the value contained in the ( \text{option_len} ) argument to POSIX \text{getsockopt} (or equivalent) after successful completion of the function. Permitted to throw an exception if the socket option object ( b ) does not support the specified size.</td>
</tr>
</tbody>
</table>

### 18.2.10 Boolean socket options

A type \( X \) meets the **BooleanSocketOption** requirements if it satisfies the requirements of

- **Destructible Cpp17Destructible** (C++ 2020 [destructible]),
- **DefaultConstructible Cpp17DefaultConstructible** (C++ 2020 [defaultconstructible]),
- **CopyConstructible Cpp17CopyConstructible** (C++ 2020 [copyconstructible]),
- **CopyAssignable Cpp17CopyAssignable** (C++ 2020 [copyassignable]),
- **GettableSocketOption** (18.2.8), and
- **SettableSocketOption** (18.2.9),

\( X \) is contextually convertible to bool, and \( X \)
satisfies the additional requirements listed below.

In the table below, \( a \) denotes a \((\text{possibly const})\) value of type \((\text{possibly const})\) \( X \), \( v \) denotes a \((\text{possibly const})\) value of type \((\text{possibly const})\) \( \text{bool} \), and \( u \) denotes an identifier.

<table>
<thead>
<tr>
<th>expression</th>
<th>type</th>
<th>assertion/note</th>
<th>pre/post-conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>( X u; )</td>
<td>( \text{post} )</td>
<td>!u.value()</td>
<td></td>
</tr>
<tr>
<td>( X u(v); )</td>
<td>( \text{post} )</td>
<td>u.value() == v</td>
<td></td>
</tr>
<tr>
<td>( a.value() )</td>
<td>( \text{bool} )</td>
<td></td>
<td>Returns the current boolean value of the socket option object.</td>
</tr>
</tbody>
</table>
| \( \text{static
cast<bool>(a)} \) | \( \text{bool} \) |                | Returns \( a.value() \). |
| \( \!a \) | \( \text{bool} \) |                | Returns \( \!a.value() \). |

3 In this document, types that satisfy meet the \( \text{BooleanSocketOption} \) \( \text{BooleanSocketOption} \) requirements are defined as follows.

```cpp
class C
{
public:
    // constructors:
    C(bool v) noexcept;
    C() noexcept;

    // members:
    C& operator=(bool v) noexcept;
    bool value() const noexcept;
    explicit operator bool() const noexcept;
    bool operator!() const noexcept;
};
```

4 Extensible implementations provide the following member functions:

```cpp
class C
{
public:
    template<class Protocol> int level(const Protocol& p) const noexcept;
    template<class Protocol> int name(const Protocol& p) const noexcept;
    template<class Protocol> void* data(const Protocol& p) noexcept;
    template<class Protocol> const void* data(const Protocol& p) const noexcept;
    template<class Protocol> size_t size(const Protocol& p) const noexcept;
    template<class Protocol> void resize(const Protocol& p, size_t s);
    // remainder unchanged
private:
    int value_; // exposition only
};
```

5 Let \( L \) and \( N \) identify the POSIX macros to be passed as the \text{level} and \text{option_name} arguments, respectively, to POSIX \text{setsockopt} and \text{getsockopt}.

\( C() \) noexcept;

§ 18.2.10
Postconditions: !value().

explicit C(bool v) noexcept;

    Postconditions: value() == v.

C& operator=(bool v) noexcept;

    Returns: *this.

Postconditions: value() == v.

bool value() const noexcept;

    Returns: The stored socket option value. For extensible implementations, returns value_ != 0.

explicit operator bool() const noexcept;

    Returns: value().

bool operator!() const noexcept;

    Returns: !value().

template<class Protocol> int level(const Protocol& p) const noexcept;

    Returns: L.

template<class Protocol> int name(const Protocol& p) const noexcept;

    Returns: N.

template<class Protocol> void* data(const Protocol& p) noexcept;

    Returns: std::addressof(value_).

template<class Protocol> const void* data(const Protocol& p) const noexcept;

    Returns: std::addressof(value_).

template<class Protocol> size_t size(const Protocol& p) const noexcept;

    Returns: sizeof(value_).

template<class Protocol> void resize(const Protocol& p, size_t s);

Remarks: Thrown: length_error if s is not a valid data size for the protocol specified by p.

18.2.11 Integer socket options

A type X meets the IntegerSocketOption requirements if it satisfies the requirements of Destructible Cpp17Destructible (C++ 2020 [destructible]), DefaultConstructible Cpp17DefaultConstructible (C++ 2020 [defaultconstructible]), CopyConstructible Cpp17CopyConstructible (C++ 2020 [copyconstructible]), CopyAssignable Cpp17CopyAssignable (C++ 2020 [copyassignable]), GettableSocketOption GettableSocketOption (18.2.8), and SettableSocketOption SettableSocketOption (18.2.9), as well as the additional requirements listed below.

In the table below, a denotes a (possibly const) value of type (possibly const) X, v denotes a (possibly const) value of type (possibly const) int, and u denotes an identifier.
Table 30 — \texttt{IntegerSocketOption} requirements

<table>
<thead>
<tr>
<th>expression</th>
<th>type</th>
<th>assertion/note</th>
<th>pre/post-conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>X u;</td>
<td></td>
<td>post:</td>
<td>Postconditions: u.value() == 0.</td>
</tr>
<tr>
<td>X u(v);</td>
<td></td>
<td>post:</td>
<td>Postconditions: u.value() == v.</td>
</tr>
<tr>
<td>a.value()</td>
<td>int</td>
<td></td>
<td>Returns the current integer value of the socket option object.</td>
</tr>
</tbody>
</table>

3 In this document, types that satisfy meet the \texttt{IntegerSocketOption} requirements are defined as follows.

```cpp
class C {
  public:
    // constructors:
    C() noexcept;
    explicit C(int v) noexcept;

    // members:
    int value() const noexcept;
};
```

4 Extensible implementations provide the following member functions:

```cpp
class C {
  public:
    template<class Protocol> int level(const Protocol& p) const noexcept;
    template<class Protocol> int name(const Protocol& p) const noexcept;
    template<class Protocol> void* data(const Protocol& p) noexcept;
    template<class Protocol> const void* data(const Protocol& p) const noexcept;
    template<class Protocol> size_t size(const Protocol& p) const noexcept;
    template<class Protocol> void resize(const Protocol& p, size_t s);

    // remainder unchanged
    private:
    int value_; // exposition only
};
```

5 Let \( L \) and \( N \) identify the POSIX macros to be passed as the \texttt{level} and \texttt{option_name} arguments, respectively, to POSIX \texttt{setsockopt} and \texttt{getsockopt}.

```cpp
C() noexcept;
```

6 \textit{Postconditions:} \(!\text{value}()\).

```cpp
explicit C(int v) noexcept;
```

7 \textit{Postconditions:} \(\text{value}() == v\).

```cpp
C& operator=(int v) noexcept;
```

8 \textit{Returns:} \(\ast\text{this}\).

9 \textit{Postconditions:} \(\text{value}() == v\).
int value() const noexcept;

>Returns: The stored socket option value. For extensible implementations, returns value_.

template<class Protocol> int level(const Protocol& p) const noexcept;

>Returns: L.

template<class Protocol> int name(const Protocol& p) const noexcept;

>Returns: N.

template<class Protocol> void* data(const Protocol& p) noexcept;

>Returns: std::addressof(value_).

template<class Protocol> const void* data(const Protocol& p) const noexcept;

>Returns: std::addressof(value_).

template<class Protocol> size_t size(const Protocol& p) const noexcept;

>Returns: sizeof(value_).

template<class Protocol> void resize(const Protocol& p, size_t s);

Remarks: Throws: length_error if s is not a valid data size for the protocol specified by p.

18.2.12 I/O control command requirements [socket.reqmts.iocontrolcommand]

A type X meets the IoControlCommand requirements if it satisfies the requirements listed below.

In the table below, a denotes a (possibly const) value of type (possibly const) X, and b denotes a value of type X.

<table>
<thead>
<tr>
<th>expression</th>
<th>type</th>
<th>assertion/note pre/post-conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.name()</td>
<td>int</td>
<td>Returns a value suitable for passing as the request argument to POSIX ioctl (or equivalent).</td>
</tr>
<tr>
<td>b.data()</td>
<td>void*</td>
<td></td>
</tr>
</tbody>
</table>

18.2.13 Connect condition requirements [socket.reqmts.connectcondition]

A type X meets the ConnectCondition requirements if it satisfies the requirements of Destructible (C++ 2020 [destructible]) and CopyConstructible (C++ 2020 [copyconstructible]), as well as the additional requirements listed below.

In the table below, x denotes a value of type X, ec denotes a (possibly const) value of type (possibly const) error_code, and ep denotes a (possibly const) value of a (possibly const) type satisfying the endpoint (18.2.4) requirements.
Table 32 — ConnectCondition requirements

<table>
<thead>
<tr>
<th>expression</th>
<th>return type</th>
<th>assertion/note pre/post-condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>x(ec, ep)</td>
<td>bool</td>
<td>Returns true to indicate that the connect or async_connect algorithm should attempt a connection to the endpoint ep. Otherwise, returns false to indicate that the algorithm should not attempt connection to the endpoint ep, and should instead skip to the next endpoint in the sequence.</td>
</tr>
</tbody>
</table>

18.3 Error codes

const error_category& socket_category() noexcept;

1 Returns: A reference to an object of a type derived from class error_category. All calls to this function return references to the same object.

2 The object’s default_error_condition and equivalent virtual functions behave as specified for the class error_category. The object’s name virtual function returns a pointer to the string "socket".

error_code make_error_code(socket_errc e) noexcept;

3 Returns: error_code(static_cast<int>(e), socket_category()).

error_condition make_error_condition(socket_errc e) noexcept;

4 Returns: error_condition(static_cast<int>(e), socket_category()).

18.4 Class socket_base

namespace std {

namespace experimental {

namespace net {

inline namespace std::experimental::net::inline v1v2 {

    class socket_base {
    {
        public:
            class broadcast;
            class debug;
            class do_not_route;
            class keep_alive;
            class linger;
            class out_of_band_inline;
            class receive_buffer_size;
            class receive_low_watermark;
            class reuse_address;
            class send_buffer_size;
            class send_low_watermark;

            using shutdown_type = T1;
            static constexpr shutdown_type shutdown_receive;
            static constexpr shutdown_type shutdown_send;
            static constexpr shutdown_type shutdown_both;


§ 18.4
using wait_type = T2;
static constexpr wait_type wait_read;
static constexpr wait_type wait_write;
static constexpr wait_type wait_error;

using message_flags = T3;
static constexpr message_flags message_peek;
static constexpr message_flags message_out_of_band;
static constexpr message_flags message_do_not_route;

static const int max_listen_connections;

protected:
    socket_base();
    -socket_base();
};

} // inline namespace std::experimental::net::v2
} // namespace net
} // namespace experimental
} // namespace std

1 socket_base defines several member types:

(1.1) — socket option classes broadcast, debug, do_not_route, keep_alive, linger, out_of_band_inline, receive_buffer_size, receive_low_watermark, reuse_address, send_buffer_size, and send_low_watermark;

(1.2) — an enumerated type, shutdown_type, for use with the basic_socket<Protocol> class’s shutdown member function.

(1.3) — an enumerated type, wait_type, for use with the basic_socket<Protocol> and basic_socket_acceptor<Protocol> classes’ wait and async_wait member functions,

(1.4) — a bitmask type, message_flags, for use with the basic_stream_socket<Protocol> class’s send, async_send, receive, and async_receive member functions, and the basic_datagram_socket<Protocol> class’s send, async_send, send_to, async_send_to, receive, async_receive, receive_from, and async_receive_from member functions.

(1.5) — a constant, max_listen_connections, for use with the basic_socket_acceptor<Protocol> class’s listen member function.

<table>
<thead>
<tr>
<th>Constant Name</th>
<th>POSIX macro</th>
<th>Definition or notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>shutdown_receive</td>
<td>SHUT_RD</td>
<td>Disables further receive operations.</td>
</tr>
<tr>
<td>shutdown_send</td>
<td>SHUT_WR</td>
<td>Disables further send operations.</td>
</tr>
<tr>
<td>shutdown_both</td>
<td>SHUT_RDWR</td>
<td>Disables further send and receive operations.</td>
</tr>
</tbody>
</table>
Table 33 — *socket_base* constants (continued)

<table>
<thead>
<tr>
<th>Constant Name</th>
<th>POSIX macro</th>
<th>Definition or notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>wait_read</code></td>
<td></td>
<td>Wait until the socket is ready-to-read. For a given socket, when a <em>wait</em> or <em>async_wait</em> operation using <code>wait_read</code> completes successfully, a subsequent call to the socket’s <code>receive</code> or <code>receive_from</code> functions may complete without blocking. Similarly, for a given acceptor, when a <em>wait</em> or <em>async_wait</em> operation using <code>wait_read</code> completes successfully, a subsequent call to the acceptor’s <code>accept</code> function may complete without blocking.</td>
</tr>
<tr>
<td><code>wait_write</code></td>
<td></td>
<td>Wait until the socket is ready-to-write. For a given socket, when a <em>wait</em> or <em>async_wait</em> operation using <code>wait_write</code> completes successfully, a subsequent call to the socket’s <code>send</code> or <code>send_to</code> functions may complete without blocking.</td>
</tr>
<tr>
<td><code>wait_error</code></td>
<td></td>
<td>Wait until the socket has a pending error condition. For a given socket, when a <em>wait</em> or <em>async_wait</em> operation using <code>wait_error</code> completes successfully, a subsequent call to one of the socket’s synchronous operations may complete without blocking. The nature of the pending error condition determines which.</td>
</tr>
<tr>
<td><code>message.peek</code></td>
<td>MSG_PEEK</td>
<td>Leave received data in queue.</td>
</tr>
<tr>
<td><code>message.out_of_band</code></td>
<td>MSG_OOB</td>
<td>Out-of-band data.</td>
</tr>
<tr>
<td><code>message.do_not_route</code></td>
<td>MSG_DONTROUTE</td>
<td>Send without using routing tables.</td>
</tr>
<tr>
<td><code>max_listen_connections</code></td>
<td>SOMAXCONN</td>
<td>The implementation-defined limit on the length of the queue of pending incoming connections.</td>
</tr>
</tbody>
</table>

18.5 Socket options

In the table below, let *C* denote a socket option class; let *L* identify the POSIX macro to be passed as the *level* argument to POSIX `setsockopt` and `getsockopt`; let *N* identify the POSIX macro to be passed as the *option_name* argument to POSIX `setsockopt` and `getsockopt`; and let *T* identify the type of the value whose address will be passed as the *option_value* argument to POSIX `setsockopt` and `getsockopt`.

<table>
<thead>
<tr>
<th><em>C</em></th>
<th><em>L</em></th>
<th><em>N</em></th>
<th><em>T</em></th>
<th>Requirements, definition or notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>socket_base::</td>
<td>SOL_SOCKET</td>
<td>SO_BROADCAST</td>
<td>int</td>
<td><strong>Satisfies</strong></td>
</tr>
<tr>
<td>broadcast</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

§ 18.5
Table 34 — Socket options (continued)

<table>
<thead>
<tr>
<th>Function</th>
<th>Type</th>
<th>Requirements, definition or notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>socket_base::debug</code></td>
<td><code>SO_DEBUG</code> int</td>
<td>Satisfies the BooleanSocketOption BooleanSocketOption (18.2.10) type requirements. Determines whether debugging information is recorded by the underlying protocol.</td>
</tr>
<tr>
<td><code>socket_base::do_not_route</code></td>
<td><code>SO_DONTROUTE</code> int</td>
<td>Satisfies the BooleanSocketOption BooleanSocketOption (18.2.10) type requirements. Determines whether outgoing messages bypass standard routing facilities.</td>
</tr>
<tr>
<td><code>socket_base::keep_alive</code></td>
<td><code>SO_KEEPALIVE</code> int</td>
<td>Satisfies the BooleanSocketOption BooleanSocketOption (18.2.10) type requirements. Determines whether a socket permits sending of keep alive messages, if supported by the protocol.</td>
</tr>
<tr>
<td><code>socket_base::linger (18.5.1)</code></td>
<td><code>SO_LINGER</code> linger</td>
<td>Controls the behavior when a socket is closed and unsent data is present.</td>
</tr>
<tr>
<td><code>socket_base::out_of_band_inline</code></td>
<td><code>SO_OOBINLINE</code> int</td>
<td>Satisfies the BooleanSocketOption BooleanSocketOption (18.2.10) type requirements. Determines whether out-of-band data (also known as urgent data) is received inline.</td>
</tr>
<tr>
<td><code>socket_base::receive_buffer_size</code></td>
<td><code>SO_RCVBUF</code> int</td>
<td>Satisfies the IntegerSocketOption IntegerSocketOption (18.2.11) type requirements. Specifies the size of the receive buffer associated with a socket.</td>
</tr>
<tr>
<td><code>socket_base::receive_low_watermark</code></td>
<td><code>SO_RCVLOWAT</code> int</td>
<td>Satisfies the IntegerSocketOption IntegerSocketOption (18.2.11) type requirements. Specifies the minimum number of bytes to process for socket input operations.</td>
</tr>
<tr>
<td><code>socket_base::reuse_address</code></td>
<td><code>SO_REUSEADDR</code> int</td>
<td>Satisfies the BooleanSocketOption BooleanSocketOption (18.2.10) type requirements. Determines whether the validation of endpoints used for binding a socket should allow the reuse of local endpoints, if supported by the protocol.</td>
</tr>
<tr>
<td><code>socket_base::send_buffer_size</code></td>
<td><code>SO_SNDBUF</code> int</td>
<td>Satisfies the IntegerSocketOption IntegerSocketOption (18.2.11) type requirements. Specifies the size of the send buffer associated with a socket.</td>
</tr>
<tr>
<td><code>socket_base::send_low_watermark</code></td>
<td><code>SO_SNDLOWAT</code> int</td>
<td>Satisfies the IntegerSocketOption IntegerSocketOption (18.2.11) type requirements. Specifies the minimum number of bytes to process for socket output operations.</td>
</tr>
</tbody>
</table>
18.5.1 Class `socket_base::linger` [socket.opt linger]

The `linger` class represents a socket option for controlling the behavior when a socket is closed and unsent data is present.

```cpp
namespace std {
namespace experimental {
namespace net {
inline namespace std::experimental::net::inline v1v2 {

class socket_base::linger {
public:
  // constructors:
  linger() noexcept;
  linger(bool e, chrono::seconds t) noexcept;

  // members:
  bool enabled() const noexcept;
  void enabled(bool e) noexcept;

  chrono::seconds timeout() const noexcept;
  void timeout(chrono::seconds t) noexcept;
};

} // inline namespace std::experimental::net::v1v2
} // namespace net
} // namespace experimental
} // namespace std
```

2 `linger` satisfies the requirements of `Destructible` (C++ 2020 [destructible]), `DefaultConstructible` (C++ 2020 [defaultconstructible]), `CopyConstructible` (C++ 2020 [copyconstructible]), `CopyAssignable` (C++ 2020 [copyassignable]), `GettableSocketOption` (18.2.8), and `SettableSocketOption` (18.2.9).

3 Extensible implementations provide the following member functions:

```cpp
namespace std {
namespace experimental {
namespace net {
inline namespace std::experimental::net::inline v1v2 {

class socket_base::linger {
public:
  template<class Protocol> int level(const Protocol& p) const noexcept;
  template<class Protocol> int name(const Protocol& p) const noexcept;
  template<class Protocol> void data(const Protocol& p) noexcept;
  template<class Protocol> const void* data(const Protocol& p) const noexcept;
  template<class Protocol> size_t size(const Protocol& p) const noexcept;
  template<class Protocol> void resize(const Protocol& p, size_t s);

  // remainder unchanged
private:
   ::linger value_; // exposition only
};

} // inline namespace std::experimental::net::v1v2
} // namespace net
} // namespace experimental
} // namespace std
```
 linger() noexcept;
   \textit{Postconditions:} !\texttt{enabled()} && \texttt{timeout()} == \texttt{chrono::seconds(0)}.
 linger(bool e, \texttt{chrono::seconds t}) noexcept;
   \textit{Postconditions:} \texttt{enabled()} == e && \texttt{timeout()} == t.

 bool \texttt{enabled()} const noexcept;
   \textit{Returns:} value_.l_onoff != 0.

 void \texttt{enabled(bool e)} noexcept;
   \textit{Postconditions:} \texttt{enabled()} == e.

 \texttt{chrono::seconds timeout()} const noexcept;
   \textit{Returns:} \texttt{chrono::seconds(value_.l_linger)}.

 void \texttt{timeout(chrono::seconds t)} noexcept;
   \textit{Postconditions:} \texttt{timeout()} == t.

 template<class Protocol> \texttt{int level(const Protocol& p)} const noexcept;
   \textit{Returns:} \texttt{SOL_SOCKET}.

 template<class Protocol> \texttt{int name(const Protocol& p)} const noexcept;
   \textit{Returns:} \texttt{SO_LINGER}.

 template<class Protocol> \texttt{void* data(const Protocol& p)} const noexcept;
   \textit{Returns:} \texttt{std::addressof(value_)}.

 template<class Protocol> \texttt{const void* data(const Protocol& p)} const noexcept;
   \textit{Returns:} \texttt{std::addressof(value_)}.

 template<class Protocol> \texttt{size_t size(const Protocol& p)} const noexcept;
   \textit{Returns:} \texttt{sizeof(value_)}.

 template<class Protocol> \texttt{void resize(const Protocol& p, size_t s)};
   \textit{Remarks:} \texttt{length_error} if s != \texttt{sizeof(value_)}.
18.6  Class template basic_socket

Class template basic_socket<Protocol> is used as the base class for the basic_datagram_socket<Protocol> and basic_stream_socket<Protocol> class templates. It provides functionality that is common to both types of socket.

```cpp
namespace std {
    namespace experimental {
        namespace net {

            // 18.6.4, basic_socket operations:

            template<class Protocol>
            class basic_socket : public socket_base
            {
                public:
                    // types:
                    using executor_type = io_context::executor_type;
                    using native_handle_type = implementation-defined;  // see 18.2.3
                    using protocol_type = Protocol;
                    using endpoint_type = typename protocol_type::endpoint;

                    executor_type get_executor() noexcept;
                    native_handle_type native_handle();  // see 18.2.3
                    void open(const protocol_type& protocol = protocol_type());
                    void open(const protocol_type& protocol, error_code& ec);
                    void assign(const protocol_type& protocol,
                                const native_handle_type& native_socket);
                    void assign(const protocol_type& protocol,
                                const native_handle_type& native_socket,
                                error_code& ec);  // see 18.2.3
                    native_handle_type release();  // see 18.2.3
                    native_handle_type release(error_code& ec);  // see 18.2.3
                    bool is_open() const noexcept;
                    void close();
                    void close(error_code& ec);
                    void cancel();
                    void cancel(error_code& ec);

                    template<class SettableSocketOption>
                    void set_option(const SettableSocketOption& option);
                    template<class SettableSocketOption>
                    void set_option(const SettableSocketOption& option, error_code& ec);

                    template<class GettableSocketOption>
                    void get_option(GettableSocketOption& option) const;
                    template<class GettableSocketOption>
```

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void get_option(GettableSocketOption& option, error_code& ec) const;

template<class IoControlCommand>
void io_control(IoControlCommand& command);

template<class IoControlCommand>
void io_control(IoControlCommand& command, error_code& ec);

void non_block(bool mode);
void non_block(bool mode, error_code& ec);
bool non_block() const;

void native_non_block(bool mode);
void native_non_block(bool mode, error_code& ec);
bool native_non_block() const;

bool at_mark() const;
bool at_mark(error_code& ec) const;

size_t available() const;
size_t available(error_code& ec) const;

void bind(const endpoint_type& endpoint);
void bind(const endpoint_type& endpoint, error_code& ec);

void shutdown(shutdown_type what);
void shutdown(shutdown_type what, error_code& ec);

endpoint_type local_endpoint() const;
endpoint_type local_endpoint(error_code& ec) const;

endpoint_type remote_endpoint() const;
endpoint_type remote_endpoint(error_code& ec) const;

void connect(const endpoint_type& endpoint);
void connect(const endpoint_type& endpoint, error_code& ec);

template<class CompletionToken>
DEDUCED async_connect(const endpoint_type& endpoint,
CompletionToken& token);

void wait(wait_type w);
void wait(wait_type w, error_code& ec);

template<class CompletionToken>
DEDUCED async_wait(wait_type w, CompletionToken& token);

protected:
// 18.6.1, construct / copy / destroy:

explicit basic_socket(io_context& ctx);
basic_socket(io_context& ctx, const protocol_type& protocol);
basic_socket(io_context& ctx, const endpoint_type& endpoint);
basic_socket(io_context& ctx, const protocol_type& protocol,
const native_handle_type& native_socket); // see 18.2.3
basic_socket(const basic_socket&) = delete;
basic_socket(basic_socket&& rhs);
template<class OtherProtocol>
    basic_socket(basic_socket<OtherProtocol>&& rhs);
~basic_socket();
basic_socket& operator=(const basic_socket&) = delete;
basic_socket& operator=(basic_socket&& rhs);
template<class OtherProtocol>
    basic_socket& operator=(basic_socket<OtherProtocol>&& rhs);

private:
    protocol_type protocol_; // exposition only
};

\} // inline namespace std::experimental::net::v2
\} // namespace net
\} // namespace experimental
\} // namespace std

Instances Specializations of class template basic_socket meet the requirements of Destructible Cpp17Destructible (C++ 2020 [destructible]), MoveConstructible Cpp17MoveConstructible (C++ 2020 [moveconstructible]), and MoveAssignable Cpp17MoveAssignable (C++ 2020 [moveassignable]).

When an operation has its effects specified as if by passing the result of native_handle() to a POSIX function, then the operation fails with error condition errc::bad_file_descriptor if is_open() == false at the point in the effects when the POSIX function is called.

18.6.1 basic_socket constructors [socket.basic.cons]

explicit basic_socket(io_context& ctx);

Postconditions:

(1.1) — get_executor() == ctx.get_executor().
(1.2) — is_open() == false.

basic_socket(io_context& ctx, const protocol_type& protocol);

Effects: Opens this socket as if by calling open(protocol).

Postconditions:

(3.1) — get_executor() == ctx.get_executor().
(3.2) — is_open() == true.
(3.3) — non_blocking() == false.
(3.4) — protocol_ == protocol.

basic_socket(io_context& ctx, const endpoint_type& endpoint);

Effects: Opens and binds this socket as if by calling:

    open(endpoint.protocol());
    bind(endpoint);

Postconditions:
basic_socket(io_context& ctx, const protocol_type& protocol, 
    const native_handle_type& native_socket);

Requires: Preconditions: native_socket is a native handle to an open socket.
Effects: Assigns the existing native socket into this socket as if by calling assign(protocol, native_socket).
Postconditions:

(8.1) — get_executor() == ctx.get_executor().
(8.2) — is_open() == true.
(8.3) — non_blocking() == false.
(8.4) — protocol_ == protocol.

basic_socket(basic_socket&& rhs);

Effects: Move constructs an object of class basic_socket<Protocol> that refers to the state originally represented by rhs.
Postconditions:

(10.1) — get_executor() == rhs.get_executor().
(10.2) — is_open() returns the same value as rhs.is_open() prior to the constructor invocation.
(10.3) — non_blocking() returns the same value as rhs.non_blocking() prior to the constructor invocation.
(10.4) — native_handle() returns the prior value of rhs.native_handle().
(10.5) — protocol_ is the prior value of rhs.protocol_.
(10.6) — rhs.is_open() == false.

template<class OtherProtocol>
basic_socket(basic_socket<OtherProtocol>&& rhs);

Requires: OtherProtocol is implicitly convertible to Protocol.
Effects: Move constructs an object of class basic_socket<Protocol> that refers to the state originally represented by rhs.
Postconditions:

(13.1) — get_executor() == rhs.get_executor().
(13.2) — is_open() returns the same value as rhs.is_open() prior to the constructor invocation.
(13.3) — non_blocking() returns the same value as rhs.non_blocking() prior to the constructor invocation.
(13.4) — native_handle() returns the prior value of rhs.native_handle().
(13.5) — protocol_ is the result of converting the prior value of rhs.protocol_.
(13.6) — rhs.is_open() == false.

Remarks: This constructor shall not participate in overload resolution unless OtherProtocol is implicitly convertible to Protocol.
Constraints: is_convertible_v<OtherProtocol, Protocol> is true.
18.6.2  basic_socket destructor  [socket.basic.dtor]

~basic_socket();  

Effects: If \texttt{is\_open()} is \texttt{true}, cancels all outstanding asynchronous operations associated with this socket, disables the linger socket option to prevent the destructor from blocking, and releases socket resources as if by POSIX close(native\_handle()). Completion handlers for canceled operations are passed an error code \texttt{ec} such that \texttt{ec == errc::operation\_canceled} yields \texttt{true}.

18.6.3  basic_socket assignment  [socket.basic.assign]

\begin{verbatim}
basic_socket& operator=(basic_socket&& rhs);  

Effects: If \texttt{is\_open()} is \texttt{true}, cancels all outstanding asynchronous operations associated with this socket. Completion handlers for canceled operations are passed an error code \texttt{ec} such that \texttt{ec == errc::operation\_canceled} yields \texttt{true}. Disables the linger socket option to prevent the assignment from blocking, and releases socket resources as if by POSIX close(native\_handle()). Moves into *\texttt{this} the state originally represented by \texttt{rhs}.

Postconditions:

(2.1) \quad \texttt{get\_executor()} == \texttt{rhs.get\_executor()}.
(2.2) \quad \texttt{is\_open()} returns the same value as \texttt{rhs.is\_open()} prior to the assignment.
(2.3) \quad \texttt{non\_blocking()} returns the same value as \texttt{rhs.non\_blocking()} prior to the assignment.
(2.4) \quad \texttt{protocol\_} is the prior value of \texttt{rhs.protocol\_}.
(2.5) \quad \texttt{rhs.is\_open()} == \texttt{false}.

Returns: *\texttt{this}.
\end{verbatim}

\begin{verbatim}
template<class OtherProtocol>
basic_socket& operator=(basic_socket<OtherProtocol>&& rhs);  

Requires: \texttt{OtherProtocol} is implicitly convertible to \texttt{Protocol}.

Effects: If \texttt{is\_open()} is \texttt{true}, cancels all outstanding asynchronous operations associated with this socket. Completion handlers for canceled operations are passed an error code \texttt{ec} such that \texttt{ec == errc::operation\_canceled} yields \texttt{true}. Disables the linger socket option to prevent the assignment from blocking, and releases socket resources as if by POSIX close(native\_handle()). Moves into *\texttt{this} the state originally represented by \texttt{rhs}.

Postconditions:

(6.1) \quad \texttt{get\_executor()} == \texttt{rhs.get\_executor()}.
(6.2) \quad \texttt{is\_open()} returns the same value as \texttt{rhs.is\_open()} prior to the assignment.
(6.3) \quad \texttt{non\_blocking()} returns the same value as \texttt{rhs.non\_blocking()} prior to the assignment.
(6.4) \quad \texttt{protocol\_} is the result of converting the prior value of \texttt{rhs.protocol\_}.
(6.5) \quad \texttt{rhs.is\_open()} == \texttt{false}.

Returns: *\texttt{this}.

Remarks: This assignment operator shall not participate in overload resolution unless \texttt{OtherProtocol} is implicitly convertible to \texttt{Protocol}.\texttt{Constraints: is\_convertible\_v<OtherProtocol, Protocol> is true}.
18.6.4 basic_socket operations [socket.basic.ops]

executor_type get_executor() noexcept;

Returns: The associated executor.

native_handle_type native_handle();

Returns: The native representation of this socket.

void open(const protocol_type& protocol);
void open(const protocol_type& protocol, error_code& ec);

Effects: Establishes the postcondition, as if by POSIX:

socket(protocol.family(), protocol.type(), protocol.protocol());

Postconditions:

(4.1) — is_open() == true.
(4.2) — non_blocking() == false.
(4.3) — protocol_ == protocol.

Error conditions:

(5.1) — socket_errc::already_open — if is_open() == true.

void assign(const protocol_type& protocol,
            const native_handle_type& native_socket);
void assign(const protocol_type& protocol,
            const native_handle_type& native_socket, error_code& ec);

Preconditions: native_socket is a native handle to an open socket.

Effects: Assigns the native socket handle to this socket object.

Postconditions:

(8.1) — is_open() == true.
(8.2) — non_blocking() == false.
(8.3) — protocol_ == protocol.

Error conditions:

(9.1) — socket_errc::already_open — if is_open() == true.

native_handle_type release();
native_handle_type release(error_code& ec);

Preconditions: is_open() == true.

Effects: Cancels all outstanding asynchronous operations associated with this socket. Completion handlers for canceled asynchronous operations are passed an error code ec such that ec == errc::operation_canceled yields true.

Returns: The native representation of this socket.

Postconditions: is_open() == false.

Remarks: Since the native socket is not closed prior to returning it, the caller is responsible for closing it.
bool is_open() const noexcept;

Returns: A bool indicating whether this socket was opened by a previous call to open or assign.

void close();
void close(error_code& ec);

Effects: If is_open() is true, cancels all outstanding asynchronous operations associated with
this socket, and establishes the postcondition as if by POSIX close(native_handle()). Completion
handlers for canceled asynchronous operations are passed an error code ec such that ec ==
errc::operation_canceled yields true.

Postconditions: is_open() == false.

void cancel();
void cancel(error_code& ec);

Effects: Cancels all outstanding asynchronous operations associated with this socket. Completion
handlers for canceled asynchronous operations are passed an error code ec such that ec ==
errc::operation_canceled yields true.

Error conditions:

— errc::bad_file_descriptor — if is_open() is false.

Remarks: Does not block (C++ 2020 [defs.block]) the calling thread pending completion of the canceled
operations.

template<class SettableSocketOption>
void set_option(const SettableSocketOption& option);
template<class SettableSocketOption>
void set_option(const SettableSocketOption& option, error_code& ec);

Effects: Sets an option on this socket, as if by POSIX:

setsockopt(native_handle(), option.level(protocol_), option.name(protocol_),
option.data(protocol_), option.size(protocol_));

template<class GettableSocketOption>
void get_option(GettableSocketOption& option);
template<class GettableSocketOption>
void get_option(GettableSocketOption& option, error_code& ec);

Effects: Gets an option from this socket, as if by POSIX:

socklen_t option_len = option.size(protocol_);
int result = getsockopt(native_handle(), option.level(protocol_),
option.name(protocol_), option.data(protocol_),
&option_len);
if (result == 0)
    option.resize(option_len);

template<class IoControlCommand>
void io_control(IoControlCommand& command);
template<class IoControlCommand>
void io_control(IoControlCommand& command, error_code& ec);

Effects: Executes an I/O control command on this socket, as if by POSIX:

ioctl(native_handle(), command.name(), command.data());
`void non_blocking(bool mode);`

Effects: Sets the non-blocking mode of this socket. The non-blocking mode determines whether subsequent synchronous socket operations (18.2.1) on `*this` block the calling thread.

Error conditions:
(25.1) — `errc::bad_file_descriptor` — if `is_open()` is false.

Postconditions: `non_blocking() == mode`.

[Note: The non-blocking mode has no effect on the behavior of asynchronous operations. — end note]

`bool non_blocking() const;`

Returns: The non-blocking mode of this socket.

`void native_non_blocking(bool mode);`

Effects: Sets the non-blocking mode of the underlying native socket, as if by POSIX:

```
int flags = fcntl(native_handle(), F_GETFL, 0);
if (flags >= 0)
{
  if (mode)
    flags |= O_NONBLOCK;
  else
    flags &= ~O_NONBLOCK;
  fcntl(native_handle(), F_SETFL, flags);
}
```

The native non-blocking mode has no effect on the behavior of the synchronous or asynchronous operations specified in this clause.

Error conditions:
(31.1) — `errc::bad_file_descriptor` — if `is_open()` is false.
(31.2) — `errc::invalid_argument` — if `mode == false` and `non_blocking() == true`.

[Note: As the combination does not make sense. — end note]

`bool native_non_blocking() const;`

Returns: The non-blocking mode of the underlying native socket.

Remarks: Implementations are permitted and encouraged to cache the native non-blocking mode that was applied through a prior call to `native_non_blocking`. Implementations may return an incorrect value if a program sets the non-blocking mode directly on the socket, by calling an operating system-specific function on the result of `native_handle()`.

`bool at_mark() const;`
`bool at_mark(error_code& ec) const;`

Effects: Determines if this socket is at the out-of-band data mark, as if by POSIX `sockatmark(native_handle())`.

[Note: The `at_mark()` function is used in conjunction with the `socket_base::out_of_band_inline` socket option. — end note]

Returns: A `bool` indicating whether this socket is at the out-of-band data mark. `false` if an error occurs.
size_t available() const;
size_t available(error_code& ec) const;

36 Returns: An indication of the number of bytes that may be read without blocking, or 0 if an error occurs.

37 Error conditions:

(37.1) — errc::bad_file_descriptor — if is_open() is false.

void bind(const endpoint_type& endpoint);
void bind(const endpoint_type& endpoint, error_code& ec);

38 Effects: Binds this socket to the specified local endpoint, as if by POSIX:
   bind(native_handle(), endpoint.data(), endpoint.size());

void shutdown(shutdown_type what);
void shutdown(shutdown_type what, error_code& ec);

39 Effects: Shuts down all or part of a full-duplex connection for the socket, as if by POSIX:
   shutdown(native_handle(), static_cast<int>(what));

endpoint_type local_endpoint() const;
endpoint_type local_endpoint(error_code& ec) const;

40 Effects: Determines the locally-bound endpoint associated with the socket, as if by POSIX:
   endpoint_type endpoint;
   socklen_t endpoint_len = endpoint.capacity();
   int result = getsockname(native_handle(), endpoint.data(), &endpoint_len);
   if (result == 0)
      endpoint.resize(endpoint_len);

41 Returns: On success, endpoint. Otherwise endpoint_type().

endpoint_type remote_endpoint() const;
endpoint_type remote_endpoint(error_code& ec) const;

42 Effects: Determines the remote endpoint associated with this socket, as if by POSIX:
   endpoint_type endpoint;
   socklen_t endpoint_len = endpoint.capacity();
   int result = getpeername(native_handle(), endpoint.data(), &endpoint_len);
   if (result == 0)
      endpoint.resize(endpoint_len);

43 Returns: On success, endpoint. Otherwise endpoint_type().

void connect(const endpoint_type& endpoint);
void connect(const endpoint_type& endpoint, error_code& ec);

44 Effects: If is_open() is false, opens this socket by performing open(endpoint.protocol(), ec).
   If ec, returns with no further action. Connects this socket to the specified remote endpoint, as if by POSIX:
   connect(native_handle(), endpoint.data(), endpoint.size());

template<class CompletionToken>
DEDUCED async_connect(const endpoint_type& endpoint, CompletionToken& token);
Completion signature: void(error_code ec).

Effects: If is_open() is false, opens this socket by performing open(endpoint.protocol(), ec). If ec, the operation completes immediately with no further action. Initiates an asynchronous operation to connect this socket to the specified remote endpoint, as if by POSIX connect(native_handle(), endpoint.data(), endpoint.size()).

When an asynchronous connect operation on this socket is simultaneously outstanding with another asynchronous connect, read, or write operation on this socket, the behavior is undefined.

If a program performs a synchronous operation on this socket, other than close or cancel, while there is an outstanding asynchronous connect operation, the behavior is undefined.

```cpp
void wait(wait_type w);
void wait(wait_type w, error_code& ec);
```

Effects: Waits for this socket to be ready to read, ready to write, or to have error conditions pending, as if by POSIX poll.

Error conditions:

— errc::bad_file_descriptor — if is_open() is false.

```cpp
template<class CompletionToken>
DEDUCED async_wait(wait_type w, CompletionToken&& token);
```

Completion signature: void(error_code ec).

Effects: Initiates an asynchronous operation to wait for this socket to be ready to read, ready to write, or to have error conditions pending, as if by POSIX poll.

When there are multiple outstanding asynchronous wait operations on this socket with the same wait_type value, all of these operations complete when this socket enters the corresponding ready state. The order of invocation of the completion handlers for these operations is unspecified.

Error conditions:

— errc::bad_file_descriptor — if is_open() is false.

### 18.7 Class template basic_datagram_socket

The class template basic_datagram_socket<Protocol> is used to send and receive discrete messages of fixed maximum length.

```cpp
namespace std {
namespace experimental {
namespace net {
inline namespace std::experimental::net::inline v1 v2 {

template<class Protocol>
class basic_datagram_socket : public basic_socket<Protocol> {
    public:
    // types:

    using native_handle_type = implementation-defined; // see 18.2.3
    using protocol_type = Protocol;
    using endpoint_type = typename protocol_type::endpoint;

    // 18.7.1, construct / copy / destroy:

§ 18.7
explicit basic_datagram_socket(io_context& ctx);
basic_datagram_socket(io_context& ctx, const protocol_type& protocol);
basic_datagram_socket(io_context& ctx, const endpoint_type& endpoint);
basic_datagram_socket(io_context& ctx, const protocol_type& protocol,
        const native_handle_type& native_socket);
basic_datagram_socket(const basic_datagram_socket&) = delete;
basic_datagram_socket(basic_datagram_socket&& rhs);
template<class OtherProtocol>
        basic_datagram_socket(basic_datagram_socket<OtherProtocol>&& rhs);
~basic_datagram_socket();

basic_datagram_socket& operator=(const basic_datagram_socket&) = delete;
basic_datagram_socket& operator=(basic_datagram_socket&& rhs);
template<class OtherProtocol>
        basic_datagram_socket& operator=(basic_datagram_socket<OtherProtocol>&& rhs);

// 18.7.3, basic_datagram_socket operations:

template<class MutableBufferSequence>
        size_t receive(const MutableBufferSequence& buffers);

template<class MutableBufferSequence>
        size_t receive(const MutableBufferSequence& buffers,
        error_code& ec);

template<class MutableBufferSequence>
        size_t receive(const MutableBufferSequence& buffers,
        socket_base::message_flags flags);

template<class MutableBufferSequence>
        size_t receive(const MutableBufferSequence& buffers,
        socket_base::message_flags flags, error_code& ec);

template<class MutableBufferSequence, class CompletionToken>
        DEDUCED async_receive(const MutableBufferSequence& buffers,
                CompletionToken&& token);

template<class MutableBufferSequence, class CompletionToken>
        DEDUCED async_receive(const MutableBufferSequence& buffers,
                socket_base::message_flags flags,
                CompletionToken&& token);

template<class MutableBufferSequence>
        size_t receive_from(const MutableBufferSequence& buffers,
                endpoint_type& sender);

template<class MutableBufferSequence>
        size_t receive_from(const MutableBufferSequence& buffers,
                endpoint_type& sender, error_code& ec);

template<class MutableBufferSequence>
        size_t receive_from(const MutableBufferSequence& buffers,
                endpoint_type& sender,
                socket_base::message_flags flags);

template<class MutableBufferSequence>
        size_t receive_from(const MutableBufferSequence& buffers,
template<class MutableBufferSequence, class CompletionToken>
    DEDUCED async_receive_from(const MutableBufferSequence& buffers,
                                endpoint_type& sender,
                                CompletionToken&& token);

template<class ConstBufferSequence>
    size_t send(const ConstBufferSequence& buffers);

template<class ConstBufferSequence>
    size_t send(const ConstBufferSequence& buffers, error_code& ec);

template<class ConstBufferSequence>
    size_t send(const ConstBufferSequence& buffers,
                socket_base::message_flags flags);

template<class ConstBufferSequence>
    size_t send(const ConstBufferSequence& buffers,
                const endpoint_type& recipient);

template<class ConstBufferSequence>
    size_t send(const ConstBufferSequence& buffers,
                const endpoint_type& recipient, error_code& ec);


§ 18.7
CompletionToken& token);

    template<class ConstBufferSequence, class CompletionToken>
    DEDUCED async_send_to(const ConstBufferSequence& buffers,
                          const endpoint_type& recipient,
                          socket_base::message_flags flags,
                          CompletionToken& token);
    
};

} // inline namespace std::experimental::net::v2
} // namespace net
} // namespace experimental
} // namespace std

Instances of class template basic_datagram_socket meet the requirements of Destructible (C++ 2020 [destructible]), MoveConstructible (C++ 2020 [move-constructible]), and MoveAssignable (C++ 2020 [moveassignable]).

If a program performs a synchronous operation on this socket, other than close, cancel, shutdown, send, or send_to, while there is an outstanding asynchronous read operation, the behavior is undefined.

If a program performs a synchronous operation on this socket, other than close, cancel, shutdown, receive, or receive_from, while there is an outstanding asynchronous write operation, the behavior is undefined.

When an operation has its effects specified as if by passing the result of native_handle() to a POSIX function, then the operation fails with error condition errc::bad_file_descriptor if is_open() == false at the point in the effects when the POSIX function is called.

If native_handle_type and basic_socket<Protocol>::native_handle_type are both defined then they name the same type.

### 18.7.1 basic_datagram_socket constructors

```cpp
explicit basic_datagram_socket(io_context& ctx);
```

*Effects:* Initializes the base class with basic_socket<Protocol>(ctx).

```cpp
basic_datagram_socket(io_context& ctx, const protocol_type& protocol);
```

*Effects:* Initializes the base class with basic_socket<Protocol>(ctx, protocol).

```cpp
basic_datagram_socket(io_context& ctx, const endpoint_type& endpoint);
```

*Effects:* Initializes the base class with basic_socket<Protocol>(ctx, endpoint).

```cpp
basic_datagram_socket(io_context& ctx, const protocol_type& protocol,
                      const native_handle_type& native_socket);
```

*Effects:* Initializes the base class with basic_socket<Protocol>(ctx, protocol, native_socket).

```cpp
basic_datagram_socket(basic_datagram_socket&& rhs);
```

*Effects:* Move constructs an object of class basic_datagram_socket<Protocol>, initializing the base class with basic_socket<Protocol>(std::move(rhs)).

```cpp
template<class OtherProtocol>
    basic_datagram_socket(basic_datagram_socket<OtherProtocol>&& rhs);
```
Requires: OtherProtocol is implicitly convertible to Protocol.

Effects: Move constructs an object of class basic_datagram_socket<Protocol>, initializing the base class with basic_socket<Protocol>(std::move(rhs)).

Remarks: This constructor shall not participate in overload resolution unless OtherProtocol is implicitly convertible to Protocol. Constraints: is_convertible_v<OtherProtocol, Protocol> is true.

### 18.7.2 basic_datagram_socket assignment

```cpp
template<class OtherProtocol>
    basic_datagram_socket& operator=(basic_datagram_socket<OtherProtocol>&& rhs);
```

Requires: OtherProtocol is implicitly convertible to Protocol.

Effects: Equivalent to basic_socket<Protocol>::operator=(std::move(rhs)).

Returns: *this.

Remarks: This assignment operator shall not participate in overload resolution unless OtherProtocol is implicitly convertible to Protocol. Constraints: is_convertible_v<OtherProtocol, Protocol> is true.

### 18.7.3 basic_datagram_socket operations

```cpp
template<class MutableBufferSequence>
    size_t receive(const MutableBufferSequence& buffers);
```

A read operation (16.2.5).

Effects: Constructs an array iov of POSIX type struct iovec and length iovlen, corresponding to buffers, and reads data from this socket as if by POSIX:

```cpp
    msghdr message;
    message.msg_name = nullptr;
    message.msg_name_len = 0;
    message.msg_iov = iov;
    message.msg_iovlen = iovlen;
    message.msg_control = nullptr;
    message.msg_controllen = 0;
    message.msg_flags = 0;
    recvmsg(native_handle(), &message, static_cast<int>(flags));
```
Returns: On success, the number of bytes received. Otherwise 0.

[Note: This operation can be used with connection-mode or connectionless-mode sockets, but it is normally used with connection-mode sockets because it does not permit the application to retrieve the source endpoint of received data. — end note]

```cpp
template<class MutableBufferSequence, class CompletionToken>
DEDUCED async_receive(const MutableBufferSequence& buffers,
                        CompletionToken& token);
```

Returns: async_receive(buffers, socket_base::message_flags(), std::forward<CompletionToken>(token)).

```cpp
template<class MutableBufferSequence, class CompletionToken>
DEDUCED async_receive(const MutableBufferSequence& buffers,
                        socket_base::message_flags flags,
                        CompletionToken& token);
```

Completion signature: void(error_code ec, size_t n).

Effects: Initiates an asynchronous operation to read data from this socket. Constructs an array `iov` of POSIX type `struct iovec` and length `iovlen`, corresponding to `buffers`, then reads data as if by POSIX:

```cpp
msghdr message;
message.msg_name = nullptr;
message.msg_namelen = 0;
message.msg_iov = iov;
message.msg_iovlen = iovlen;
message.msg_control = nullptr;
message.msg_controllen = 0;
message.msg_flags = 0;
recvmsg(native_handle(), &message, static_cast<int>(flags));
```

If the operation completes successfully, `n` is the number of bytes received. Otherwise `n` is 0.

[Note: This operation can be used with connection-mode or connectionless-mode sockets, but it is normally used with connection-mode sockets because it does not permit the application to retrieve the source endpoint of received data. — end note]

Error conditions:

(11.1) — errc::invalid_argument — if socket_base::message_peek is set in flags.

```cpp
template<class MutableBufferSequence>
size_t receive_from(const MutableBufferSequence& buffers,
                    endpoint_type& sender);
```

```cpp
template<class MutableBufferSequence>
size_t receive_from(const MutableBufferSequence& buffers,
                    endpoint_type& sender, error_code& ec);
```

Returns: receive_from(buffers, sender, socket_base::message_flags(), ec).

```cpp
template<class MutableBufferSequence>
size_t receive_from(const MutableBufferSequence& buffers,
                    endpoint_type& sender,
                    socket_base::message_flags flags);
```

```cpp
template<class MutableBufferSequence>
size_t receive_from(const MutableBufferSequence& buffers,
```
A read operation (16.2.5).

Effects: Constructs an array `iov` of POSIX type `struct iovec` and length `iovlen`, corresponding to `buffers`, and reads data from this socket as if by POSIX:

```cpp
msghdr message;
message.msg_name = sender.data();
message.msg_name_len = sender.capacity();
message.msg_iov = iov;
message.msg_iovlen = iovlen;
message.msg_control = nullptr;
message.msg_controllen = 0;
message.msg_flags = 0;
ssize_t result = recvmsg(native_handle(), &message, static_cast<int>(flags));
if (result >= 0)
    sender.resize(message.msg_name_len);
```

Returns: On success, the number of bytes received. Otherwise 0.

[Note: This operation can be used with connection-mode or connectionless-mode sockets, but it is normally used with connectionless-mode sockets because it permits the application to retrieve the source endpoint of received data. —end note]

```cpp
template<class MutableBufferSequence, class CompletionToken>
DEDUCED async_receive_from(const MutableBufferSequence& buffers,
    endpoint_type& sender,
    CompletionToken& token);
```

Returns:

```cpp
async_receive_from(buffers, sender, socket_base::message_flags(),
    forward<CompletionToken>(token))
```

```cpp
template<class MutableBufferSequence, class CompletionToken>
DEDUCED async_receive_from(const MutableBufferSequence& buffers,
    endpoint_type& sender,
    socket_base::message_flags flags,
    CompletionToken& token);
```

A read operation (16.2.5).

Completion signature: `void(error_code ec, size_t n)`.

Effects: Initiates an asynchronous operation to read data from this socket. Constructs an array `iov` of POSIX type `struct iovec` and length `iovlen`, corresponding to `buffers`, then reads data as if by POSIX:

```cpp
msghdr message;
message.msg_name = sender.data();
message.msg_name_len = sender.capacity();
message.msg_iov = iov;
message.msg_iovlen = iovlen;
message.msg_control = nullptr;
message.msg_controllen = 0;
message.msg_flags = 0;
```
ssize_t result = recvmsg(native_handle(), &message, static_cast<int>(flags));
if (result >= 0)
    sender.resize(message.msg_namelen);

21 If the operation completes successfully, n is the number of bytes received. Otherwise n is 0.

[Note: This operation can be used with connection-mode or connectionless-mode sockets, but it is
normally used with connectionless-mode sockets because it permits the application to retrieve the
source endpoint of received data. — end note]

22 Error conditions:

(23.1) — errc::invalid_argument — if socket_base::message_peek is set in flags.

template<class ConstBufferSequence>
size_t send(const ConstBufferSequence& buffers);
template<class ConstBufferSequence>
size_t send(const ConstBufferSequence& buffers, error_code& ec);

24 Returns: send(buffers, socket_base::message_flags(), ec).

template<class ConstBufferSequence>
size_t send(const ConstBufferSequence& buffers,
            socket_base::message_flags flags);
template<class ConstBufferSequence>
size_t send(const ConstBufferSequence& buffers,
            socket_base::message_flags flags, error_code& ec);

25 A write operation (16.2.5).

26 Effects: Constructs an array iov of POSIX type struct iovec and length iovlen, corresponding to
buffers, and writes data to this socket as if by POSIX:

    msghdr message;
    message.msg_name = nullptr;
    message.msg_namelen = 0;
    message.msg_iov = iov;
    message.msg_iovlen = iovlen;
    message.msg_controllen = 0;
    message.msg_flags = 0;
    sendmsg(native_handle(), &message, static_cast<int>(flags));

27 Returns: On success, the number of bytes sent. Otherwise 0.

template<class ConstBufferSequence, class CompletionToken>
DEDUCED async_send(const ConstBufferSequence& buffers, CompletionToken&& token);

28 Returns:

    async_send(buffers, socket_base::message_flags(), forward<CompletionToken>(token))

template<class ConstBufferSequence, class CompletionToken>
DEDUCED async_send(const ConstBufferSequence& buffers,
                   socket_base::message_flags flags,
                   CompletionToken&& token);
A write operation (16.2.5).

Completion signature: void(error_code ec, size_t n).

Effects: Initiates an asynchronous operation to write data to this socket. Constructs an array \texttt{iov} of POSIX type \texttt{struct iovec} and length \texttt{iovlen}, corresponding to \texttt{buffers}, then writes data as if by POSIX:

\begin{verbatim}
msghdr message;
message.msg_name = nullptr;
message.msg_namelen = 0;
message.msg_iov = iov;
message.msg_iovlen = iovlen;
message.msg_control = nullptr;
message.msg_controllen = 0;
message.msg_flags = 0;
sendmsg(native_handle(), &message, static_cast<int>(flags));
\end{verbatim}

If the operation completes successfully, \texttt{n} is the number of bytes sent. Otherwise \texttt{n} is 0.

\begin{verbatim}
template<class ConstBufferSequence>
size_t send_to(const ConstBufferSequence& buffers,
               const endpoint_type& recipient);
template<class ConstBufferSequence>
size_t send_to(const ConstBufferSequence& buffers,
               const endpoint_type& recipient, error_code& ec);
\end{verbatim}

Returns: \texttt{send_to(buffers, recipient, socket_base::message_flags(), ec)}.

\begin{verbatim}
template<class ConstBufferSequence>
size_t send_to(const ConstBufferSequence& buffers,
               const endpoint_type& recipient,
               socket_base::message_flags flags);
template<class ConstBufferSequence>
size_t send_to(const ConstBufferSequence& buffers,
               const endpoint_type& recipient,
               socket_base::message_flags flags, error_code& ec);
\end{verbatim}

A write operation (16.2.5).

Effects: Constructs an array \texttt{iov} of POSIX type \texttt{struct iovec} and length \texttt{iovlen}, corresponding to \texttt{buffers}, and writes data to this socket as if by POSIX:

\begin{verbatim}
msghdr message;
message.msg_name = recipient.data();
message.msg_namelen = recipient.size();
message.msg_iov = iov;
message.msg_iovlen = iovlen;
message.msg_control = nullptr;
message.msg_controllen = 0;
message.msg_flags = 0;
sendmsg(native_handle(), &message, static_cast<int>(flags));
\end{verbatim}

Returns: On success, the number of bytes sent. Otherwise 0.

\begin{verbatim}
template<class ConstBufferSequence, class CompletionToken>
DEDUCED async_send_to(const ConstBufferSequence& buffers,
                        const endpoint_type& recipient,
                        CompletionToken&& token);
\end{verbatim}
37    Returns:

    async_send_to(buffers, recipient, socket_base::message_flags(),
                  forward<CompletionToken>(token))

38    template<class ConstBufferSequence, class CompletionToken>
    DEDUCED async_send_to(const ConstBufferSequence& buffers,
                           const endpoint_type& recipient,
                           socket_base::message_flags flags,
                           CompletionToken& token);

39    A write operation (16.2.5).

40    Completion signature: void(error_code ec, size_t n).

41    Effects: Initiates an asynchronous operation to write data to this socket. Constructs an array iov of POSIX type struct iovec and length iovlen, corresponding to buffers, then writes data as if by POSIX:

        msg hdr message;
        message.msg_name = recipient.data();
        message.msg_name len = recipient.size();
        message.msg iov = iov;
        message.msg iovlen = iovlen;
        message.msg control = nullptr;
        message.msg_controllen = 0;
        message.msg_flags = 0;
        sendmsg(native_handle(), &message, static_cast<int>(flags));

42    If the operation completes successfully, n is the number of bytes sent. Otherwise n is 0.

### 18.8 Class template basic_stream_socket

The class template basic_stream_socket<Protocol> is used to exchange data with a peer over a sequenced, reliable, bidirectional, connection-mode byte stream.

```cpp
namespace std {
namespace experimental {
namespace net {

inline namespace std::experimental::net::inline v1 {

    template<class Protocol>
    class basic_stream_socket : public basic_socket<Protocol> {
    public:

      // types:

      using native_handle_type = implementation-defined; // see 18.2.3
      using protocol_type = Protocol;
      using endpoint_type = typename protocol_type::endpoint;

      // 18.8.1, construct / copy / destroy:

      explicit basic_stream_socket(io_context& ctx);
      basic_stream_socket(io_context& ctx, const protocol_type& protocol);
      basic_stream_socket(io_context& ctx, const endpoint_type& endpoint);
      basic_stream_socket(io_context& ctx, const protocol_type& protocol,
                          const native_handle_type& native_socket);

```
basic_stream_socket(const basic_stream_socket&) = delete;
basic_stream_socket(basic_stream_socket& rhs);
template<class OtherProtocol>
    basic_stream_socket(basic_stream_socket<OtherProtocol>&& rhs);

~basic_stream_socket();

basic_stream_socket& operator=(const basic_stream_socket&) = delete;
basic_stream_socket& operator=(basic_stream_socket&& rhs);
template<class OtherProtocol>
    basic_stream_socket& operator=(basic_stream_socket<OtherProtocol>&& rhs);

// 18.8.3, basic_stream_socket operations:

template<class MutableBufferSequence>
    size_t receive(const MutableBufferSequence& buffers);
template<class MutableBufferSequence>
    size_t receive(const MutableBufferSequence& buffers,
                   error_code& ec);

template<class MutableBufferSequence>
    size_t receive(const MutableBufferSequence& buffers,
                   socket_base::message_flags flags);
template<class MutableBufferSequence>
    size_t receive(const MutableBufferSequence& buffers,
                   socket_base::message_flags flags,
                   error_code& ec);

template<class MutableBufferSequence, class CompletionToken>
    DEDUCED async_receive(const MutableBufferSequence& buffers,
                          CompletionToken&& token);

template<class MutableBufferSequence, class CompletionToken>
    DEDUCED async_receive(const MutableBufferSequence& buffers,
                          socket_base::message_flags flags,
                          CompletionToken&& token);

template<class ConstBufferSequence>
    size_t send(const ConstBufferSequence& buffers);
template<ConstBufferSequence>
    size_t send(const ConstBufferSequence& buffers,
                error_code& ec);

template<class ConstBufferSequence>
    size_t send(const ConstBufferSequence& buffers,
                socket_base::message_flags flags);
template<class ConstBufferSequence>
    size_t send(const ConstBufferSequence& buffers,
                socket_base::message_flags flags,
                error_code& ec);

template<class ConstBufferSequence, class CompletionToken>
    DEDUCED async_send(const ConstBufferSequence& buffers,
                      CompletionToken&& token);

template<class ConstBufferSequence, class CompletionToken>
    DEDUCED async_send(const ConstBufferSequence& buffers,
                      socket_base::message_flags flags,
template<class MutableBufferSequence>
size_t read_some(const MutableBufferSequence& buffers);

template<class MutableBufferSequence>
size_t read_some(const MutableBufferSequence& buffers,
error_code& ec);

template<class MutableBufferSequence, class CompletionToken>
DEDUCED async_read_some(const MutableBufferSequence& buffers,
CompletionToken&& token);

template<class ConstBufferSequence>
size_t write_some(const ConstBufferSequence& buffers);

template<class ConstBufferSequence>
size_t write_some(const ConstBufferSequence& buffers,
error_code& ec);

template<class ConstBufferSequence, class CompletionToken>
DEDUCED async_write_some(const ConstBufferSequence& buffers,
CompletionToken&& token);

 Instances Specializations of class template basic_stream_socket meet the requirements of Destructible Cpp17Destructible (C++ 2020 [destructible]), MoveConstructible Cpp17MoveConstructible (C++ 2020 [move-constructible]), MoveAssignable Cpp17MoveAssignable (C++ 2020 [moveassignable]), SyncReadStream SyncReadStream (17.1.1), SyncWriteStream SyncWriteStream (17.1.3), AsyncReadStream AsyncReadStream (17.1.2), and AsyncWriteStream AsyncWriteStream (17.1.4).

3 If a program performs a synchronous operation on this socket, other than close, cancel, shutdown, or send, while there is an outstanding asynchronous read operation, the behavior is undefined.

4 If a program performs a synchronous operation on this socket, other than close, cancel, shutdown, or receive, while there is an outstanding asynchronous write operation, the behavior is undefined.

5 When an operation has its effects specified as if by passing the result of native_handle() to a POSIX function, then the operation fails with error condition errc::bad_file_descriptor if is_open() == false at the point in the effects when the POSIX function is called.

6 If native_handle_type and basic_socket<Protocol>::native_handle_type are both defined then they name the same type.

18.8.1 basic_stream_socket constructors

explicit basic_stream_socket(io_context& ctx);

 Effects: Initializes the base class with basic_socket<Protocol>(ctx).

basic_stream_socket(io_context& ctx, const protocol_type& protocol);

 Effects: Initializes the base class with basic_socket<Protocol>(ctx, protocol).
Effects: Initializes the base class with `basic_socket<Protocol>(ctx, endpoint)`.

```cpp
basic_stream_socket(io_context& ctx, const protocol_type& protocol,
    const native_handle_type& native_socket);
```

Effects: Initializes the base class with `basic_socket<Protocol>(ctx, protocol, native_socket)`.

```cpp
basic_stream_socket(basic_stream_socket&& rhs);
```

Effects: Move constructs an object of class `basic_stream_socket<Protocol>`, initializing the base class with `basic_socket<Protocol>(std::move(rhs))`.

```cpp
template<class OtherProtocol>
    basic_stream_socket(basic_stream_socket<OtherProtocol>&& rhs);

Requires: `OtherProtocol` is implicitly convertible to `Protocol`.

Effects: Move constructs an object of class `basic_stream_socket<Protocol>`, initializing the base class with `basic_socket<Protocol>(std::move(rhs))`.

Remarks: This constructor shall not participate in overload resolution unless `OtherProtocol` is implicitly convertible to `Protocol`. Constraints: `is_convertible_v<OtherProtocol, Protocol>` is true.

### 18.8.2 basic_stream_socket assignment

```cpp
basic_stream_socket& operator=(basic_stream_socket&& rhs);
```

Effects: Equivalent to `basic_socket<Protocol>::operator=(std::move(rhs))`.

```cpp
template<class OtherProtocol>
    basic_stream_socket& operator=(basic_stream_socket<OtherProtocol>&& rhs);

Requires: `OtherProtocol` is implicitly convertible to `Protocol`.

Effects: Equivalent to `basic_socket<Protocol>::operator=(std::move(rhs))`.

Returns: *this.

Remarks: This assignment operator shall not participate in overload resolution unless `OtherProtocol` is implicitly convertible to `Protocol`. Constraints: `is_convertible_v<OtherProtocol, Protocol>` is true.

### 18.8.3 basic_stream_socket operations

```cpp
template<class MutableBufferSequence>
    size_t receive(const MutableBufferSequence& buffers);
```

```cpp
template<class MutableBufferSequence>
    size_t receive(const MutableBufferSequence& buffers,
        socket_base::message_flags flags);
```

```cpp
    size_t receive(const MutableBufferSequence& buffers,
        error_code& ec);
```

Returns: `receive(buffers, socket_base::message_flags(), ec)`.

```cpp
template<class MutableBufferSequence>
    size_t receive(const MutableBufferSequence& buffers,
        socket_base::message_flags flags);
```

```cpp
template<class MutableBufferSequence>
    size_t receive(const MutableBufferSequence& buffers,
        socket_base::message_flags flags, error_code& ec);
```
A read operation (16.2.5).

Effects: If `buffer_size(buffers) == 0`, returns immediately with no error. Otherwise, constructs an array `iov` of POSIX type `struct iovec` and length `iovlen`, corresponding to `buffers`, and reads data from this socket as if by POSIX:

```c
msghdr message;
message.msg_name = nullptr;
message.msg_name_len = 0;
message.msg_iov = iov;
message.msg_iovlen = iovlen;
message.msg_control = nullptr;
message.msg_controllen = 0;
message.msg_flags = 0;
recvmsg(native_handle(), &message, static_cast<int>(flags));
```

Returns: On success, the number of bytes received. Otherwise 0.

Error conditions:

- `stream_errc::eof` — if there is no data to be received and the peer performed an orderly shutdown.

```c
template<class MutableBufferSequence, class CompletionToken>
DEDUCED async_receive(const MutableBufferSequence& buffers,
                      CompletionToken& token);
```

Returns:

```c
async_receive(buffers, socket_base::message_flags(), forward<CompletionToken>(token))
```

```c
template<class MutableBufferSequence, class CompletionToken>
DEDUCED async_receive(const MutableBufferSequence& buffers,
                      socket_base::message_flags flags,
                      CompletionToken& token);
```

A read operation (16.2.5).

Completion signature: `void(error_code ec, size_t n)`.

Effects: Initiates an asynchronous operation to read data from this socket. If `buffer_size(buffers) == 0`, the asynchronous operation completes immediately with no error and `n == 0`. Otherwise, constructs an array `iov` of POSIX type `struct iovec` and length `iovlen`, corresponding to `buffers`, then reads data as if by POSIX:

```c
msghdr message;
message.msg_name = nullptr;
message.msg_name_len = 0;
message.msg_iov = iov;
message.msg_iovlen = iovlen;
message.msg_control = nullptr;
message.msg_controllen = 0;
message.msg_flags = 0;
recvmsg(native_handle(), &message, static_cast<int>(flags));
```

If the operation completes successfully, `n` is the number of bytes received. Otherwise `n` is 0.

Error conditions:

- `errc::invalid_argument` — if `socket_base::message.Peek` is set in `flags`. 

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— stream_errc::eof — if there is no data to be received and the peer performed an orderly shutdown.

```cpp
template<class ConstBufferSequence>
size_t send(const ConstBufferSequence& buffers);
template<class ConstBufferSequence>
size_t send(const ConstBufferSequence& buffers, error_code& ec);
```

Returns: `send(buffers, socket_base::message_flags(), ec)`.

```cpp
template<class ConstBufferSequence>
size_t send(const ConstBufferSequence& buffers,
            socket_base::message_flags flags);
template<class ConstBufferSequence>
size_t send(const ConstBufferSequence& buffers,
            socket_base::message_flags flags, error_code& ec);
```

A write operation (16.2.5).

Effects: If `buffer_size(buffers) == 0`, returns immediately with no error. Otherwise, constructs an array `iov` of POSIX type `struct iovec` and length `iovlen`, corresponding to `buffers`, and writes data to this socket as if by POSIX:

```cpp
msghdr message;
message.msg_name = nullptr;
message.msg_namelen = 0;
message.msg_iov = iov;
message.msg_iovlen = iovlen;
message.msg_control = nullptr;
message.msg_controllen = 0;
message.msg_flags = 0;
sendmsg(native_handle(), &message, static_cast<int>(flags));
```

Returns: On success, the number of bytes sent. Otherwise 0.

```cpp
template<class ConstBufferSequence, class CompletionToken>
DEDUCED async_send(const ConstBufferSequence& buffers, CompletionToken&& token);
```

Returns:

```cpp
async_send(buffers, socket_base::message_flags(), forward<CompletionToken>(token))
```

```cpp
template<class ConstBufferSequence, class CompletionToken>
DEDUCED async_send(const ConstBufferSequence& buffers,
                   socket_base::message_flags flags,
                   CompletionToken&& token);
```

A write operation (16.2.5).

Completion signature: `void(error_code ec, size_t n)`.

Effects: Initiates an asynchronous operation to write data to this socket. If `buffer_size(buffers) == 0`, the asynchronous operation completes immediately with no error and `n == 0`. Otherwise, constructs an array `iov` of POSIX type `struct iovec` and length `iovlen`, corresponding to `buffers`, then writes data as if by POSIX:

```cpp
msghdr message;
message.msg_name = nullptr;
message.msg_name = 0;
```
message.msg_iov = iov;
message.msg_iovlen = iovlen;
message.msg_control = nullptr;
message.msg_controllen = 0;
message.msg_flags = 0;
sendmsg(native_handle(), &message, static_cast<int>(flags));

If the operation completes successfully, n is the number of bytes sent. Otherwise n is 0.

template<class MutableBufferSequence>
size_t read_some(const MutableBufferSequence& buffers);
template<class MutableBufferSequence>
size_t read_some(const MutableBufferSequence& buffers,
                  error_code& ec);

Returns: receive(buffers, ec).

template<class MutableBufferSequence, class CompletionToken>
DEDUCED async_read_some(const MutableBufferSequence& buffers,
                         CompletionToken& token);

Returns: async_receive(buffers, forward<CompletionToken>(token)).

template<class ConstBufferSequence>
size_t write_some(const ConstBufferSequence& buffers);
template<class ConstBufferSequence>
size_t write_some(const ConstBufferSequence& buffers,
                  error_code& ec);

Returns: send(buffers, ec).

template<class ConstBufferSequence, class CompletionToken>
DEDUCED async_write_some(const ConstBufferSequence& buffers,
                         CompletionToken& token);

Returns: async_send(buffers, forward<CompletionToken>(token)).

18.9 Class template basic_socket_acceptor

An object of class template basic_socket_acceptor<AcceptableProtocol> is used to listen for, and queue, incoming socket connections. Socket objects that represent the incoming connections are dequeued by calling accept or async_accept.

namespace std {
namespace experimental {
namespace net {
  inline namespace std::experimental::net::inline_v1v2 {

    template<class AcceptableProtocol>
class basic_socket_acceptor : public socket_base {
    public:
      // types:

      using executor_type = io_context::executor_type;
      using native_handle_type = implementation-defined; // see 18.2.3
      using protocol_type = AcceptableProtocol;
      using endpoint_type = typename protocol_type::endpoint;

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using socket_type = typename protocol_type::socket;

// 18.9.1, construct / copy / destroy:

explicit basic_socket_acceptor(io_context& ctx);
basic_socket_acceptor(io_context& ctx, const protocol_type& protocol);
basic_socket_acceptor(io_context& ctx, const endpoint_type& endpoint,
    bool reuse_addr = true);
basic_socket_acceptor(io_context& ctx, const protocol_type& protocol,
    const native_handle_type& native_acceptor);
basic_socket_acceptor(const basic_socket_acceptor&) = delete;
basic_socket_acceptor(basic_socket_acceptor&& rhs);
template<class OtherProtocol>
    basic_socket_acceptor(basic_socket_acceptor<OtherProtocol>&& rhs);
-
    basic_socket_acceptor();

    basic_socket_acceptor& operator=(const basic_socket_acceptor&) = delete;
basic_socket_acceptor& operator=(basic_socket_acceptor&& rhs);
template<class OtherProtocol>
    basic_socket_acceptor& operator=(basic_socket_acceptor<OtherProtocol>&& rhs);

// 18.9.4, basic_socket_acceptor operations:

    executor_type get_executor() noexcept;

    native_handle_type native_handle(); // see 18.2.3

    void open(const protocol_type& protocol = protocol_type());
    void open(const protocol_type& protocol, error_code& ec);

    void assign(const protocol_type& protocol,
        const native_handle_type& native_acceptor); // see 18.2.3
    void assign(const protocol_type& protocol,
        const native_handle_type& native_acceptor,
        error_code& ec); // see 18.2.3

    native_handle_type release(); // see 18.2.3
    native_handle_type release(error_code& ec); // see 18.2.3

    bool is_open() const noexcept;

    void close();
    void close(error_code& ec);

    void cancel();
    void cancel(error_code& ec);

    template<class SettableSocketOption>
        void set_option(const SettableSocketOption& option);
    template<class SettableSocketOption>
        void set_option(const SettableSocketOption& option, error_code& ec);

    template<class GettableSocketOption>
        void get_option(GettableSocketOption& option) const;
template<class GettableSocketOption>
  void get_option(GettableSocketOption& option, error_code& ec) const;

template<class IoControlCommand>
  void io_control(IoControlCommand& command);
template<class IoControlCommand>
  void io_control(IoControlCommand& command, error_code& ec);

void non_blocking(bool mode);
void non_blocking(bool mode, error_code& ec);
bool non_blocking() const;

void native_non_blocking(bool mode);
void native_non_blocking(bool mode, error_code& ec);
bool native_non_blocking() const;

void bind(const endpoint_type& endpoint);
void bind(const endpoint_type& endpoint, error_code& ec);

void listen(int backlog = max_listen_connections);
void listen(int backlog, error_code& ec);

endpoint_type local_endpoint() const;
endpoint_type local_endpoint(error_code& ec) const;

void enable_connection_aborted(bool mode);
bool enable_connection_aborted() const;

socket_type accept();
socket_type accept(error_code& ec);
socket_type accept(io_context& ctx);
socket_type accept(io_context& ctx, error_code& ec);

template<class CompletionToken>
  DEDUCED async_accept(CompletionToken&& token);
template<class CompletionToken>
  DEDUCED async_accept(io_context& ctx, CompletionToken&& token);

socket_type accept(endpoint_type& endpoint);
socket_type accept(endpoint_type& endpoint, error_code& ec);
socket_type accept(io_context& ctx, endpoint_type& endpoint);
socket_type accept(io_context& ctx, endpoint_type& endpoint,
                  error_code& ec);

template<class CompletionToken>
  DEDUCED async_accept(endpoint_type& endpoint, CompletionToken&& token);
template<class CompletionToken>
  DEDUCED async_accept(io_context& ctx, endpoint_type& endpoint,
                       CompletionToken&& token);

void wait(wait_type w);
void wait(wait_type w, error_code& ec);

template<class CompletionToken>
DEDUCED async_wait(wait_type w, CompletionToken&& token);

private:
  protocol_type protocol_; // exposition only
};

} // inline namespace std::experimental::net::v2
} // namespace std

Instances Specializations of class template basic_socket_acceptor meet the requirements of Destructible Cpp17Destructible (C++ 2020 [destructible]), MoveConstructible Cpp17MoveConstructible (C++ 2020 [move-constructible]), and MoveAssignable Cpp17MoveAssignable (C++ 2020 [moveassignable]).

When there are multiple outstanding asynchronous accept operations the order in which the incoming connections are dequeued, and the order of invocation of the completion handlers for these operations, is unspecified.

When an operation has its effects specified as if by passing the result of native_handle() to a POSIX function, then the operation fails with error condition errc::bad_file_descriptor if is_open() == false at the point in the effects when the POSIX function is called.

18.9.1 basic_socket_acceptor constructors [socket.acceptor.cons]

explicit basic_socket_acceptor(io_context& ctx);

Postconditions:
(1.1) — get_executor() == ctx.get_executor().
(1.2) — is_open() == false.

basic_socket_acceptor(io_context& ctx, const protocol_type& protocol);

Effects: Opens this acceptor as if by calling open(protocol).

Postconditions:
(3.1) — get_executor() == ctx.get_executor().
(3.2) — is_open() == true.
(3.3) — non_blocking() == false.
(3.4) — enable_connection_aborted() == false.
(3.5) — protocol_ == protocol.

basic_socket_acceptor(io_context& ctx, const endpoint_type& endpoint,
    bool reuse_addr = true);

Effects: Opens and binds this acceptor as if by calling:
  open(endpoint.protocol());
  if (reuse_addr)
    set_option(reuse_address(true));
  bind(endpoint);
  listen();

Postconditions:
(5.1) — get_executor() == ctx.get_executor().
(5.2) — is_open() == true.
(5.3) — non_blocking() == false.
(5.4) — enable_connection_aborted() == false.
(5.5) — protocol_ == endpoint.protocol().

basic_socket_acceptor(io_context& ctx, const protocol_type& protocol,
  const native_handle_type& native_acceptor);

- Requires: Preconditions: native_acceptor is a native handle to an open acceptor.

- Effects: Assigns the existing native acceptor into this acceptor as if by calling assign(protocol, native_acceptor).

- Postconditions:

  (8.1) — get_executor() == ctx.get_executor().
  (8.2) — is_open() == true.
  (8.3) — non_blocking() == false.
  (8.4) — enable_connection_aborted() == false.
  (8.5) — protocol_ == protocol.

basic_socket_acceptor(basic_socket_acceptor&& rhs);

- Requires: Postconditions:

  (10.1) — get_executor() == rhs.get_executor().
  (10.2) — is_open() returns the same value as rhs.is_open() prior to the constructor invocation.
  (10.3) — non_blocking() returns the same value as rhs.non_blocking() prior to the constructor invocation.
  (10.4) — enable_connection_aborted() returns the same value as rhs.enable_connection_aborted() prior to the constructor invocation.
  (10.5) — native_handle() returns the same value as rhs.native_handle() prior to the constructor invocation.
  (10.6) — protocol_ is equal to the prior value of rhs.protocol_.
  (10.7) — rhs.is_open() == false.

template<class OtherProtocol>
basic_socket_acceptor(basic_socket_acceptor<OtherProtocol>&& rhs);

- Requires: OtherProtocol is implicitly convertible to Protocol.

- Effects: Move constructs an object of class basic_socket_acceptor<AcceptableProtocol> that refers to the state originally represented by rhs.

- Postconditions:

  (13.1) — get_executor() == rhs.get_executor().
  (13.2) — is_open() returns the same value as rhs.is_open() prior to the constructor invocation.
– non_blocking() returns the same value as rhs.non_blocking() prior to the constructor invocation.

– enable_connection_aborted() returns the same value as rhs.enable_connection_aborted() prior to the constructor invocation.

– native_handle() returns the prior value of rhs.native_handle().

– protocol_ is the result of converting the prior value of rhs.protocol_.

– rhs.is_open() == false.

Remarks: This constructor shall not participate in overload resolution unless OtherProtocol is implicitly convertible to Protocol. Constraints: is_convertible_v<OtherProtocol, Protocol> is true.

18.9.2 basic_socket_acceptor destructor

~basic_socket_acceptor();

Effects: If is_open() is true, cancels all outstanding asynchronous operations associated with this acceptor, and releases acceptor resources as if by POSIX close(native_handle()). Completion handlers for canceled operations are passed an error code ec such that ec == errc::operationCanceled yields true.

18.9.3 basic_socket_acceptor assignment

basic_socket_acceptor& operator=(basic_socket_acceptor&& rhs);

Effects: If is_open() is true, cancels all outstanding asynchronous operations associated with this acceptor, and releases acceptor resources as if by POSIX close(native_handle()). Then moves into *this the state originally represented by rhs. Completion handlers for canceled operations are passed an error code ec such that ec == errc::operationCanceled yields true.

Postconditions:

– get_executor() == rhs.get_executor().

– is_open() returns the same value as rhs.is_open() prior to the assignment.

– non_blocking() returns the same value as rhs.non_blocking() prior to the assignment.

– enable_connection_aborted() returns the same value as rhs.enable_connection_aborted() prior to the assignment.

– native_handle() returns the same value as rhs.native_handle() prior to the assignment.

– protocol_ is the same value as rhs.protocol_ prior to the assignment.

– rhs.is_open() == false.

Returns: *this.

template<class OtherProtocol>
basic_socket_acceptor& operator=(basic_socket_acceptor<OtherProtocol>&& rhs);

Requires: OtherProtocol is implicitly convertible to Protocol.

Effects: If is_open() is true, cancels all outstanding asynchronous operations associated with this acceptor, and releases acceptor resources as if by POSIX close(native_handle()). Then moves into *this the state originally represented by rhs. Completion handlers for canceled operations are passed an error code ec such that ec == errc::operationCanceled yields true.

Postconditions:

– get_executor() == rhs.get_executor().

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— \( \text{is\_open}() \) returns the same value as \( \text{rhs.is\_open}() \) prior to the assignment.
— \( \text{non\_blocking}() \) returns the same value as \( \text{rhs.non\_blocking}() \) prior to the assignment.
— \( \text{enable\_connection\_aborted}() \) returns the same value as \( \text{rhs.enable\_connection\_aborted}() \) prior to the assignment.
— \( \text{native\_handle}() \) returns the same value as \( \text{rhs.native\_handle}() \) prior to the assignment.
— \( \text{protocol\_} \) is the result of converting the value of \( \text{rhs.protocol\_} \) prior to the assignment.
— \( \text{rhs.is\_open}() == \text{false} \).

\( \text{Returns: } *\text{this}. \)

\( \text{Remarks: This assignment operator shall not participate in overload resolution unless } \text{OtherProtocol} \) is implicitly convertible to \( \text{Protocol} \).\( \text{Constraints: } \text{is\_convertible\_v<OtherProtocol, Protocol> is } \text{true}. \)

### 18.9.4 basic_socket_acceptor operations

```
executor_type get_executor() noexcept;
Returns: The associated executor.

native_handle_type native_handle();
Returns: The native representation of this acceptor.

void open(const protocol_type& protocol);
void open(const protocol_type& protocol, error_code& ec);
Effects: Establishes the postcondition, as if by POSIX:
\[
\text{socket(protocol.family()}, \text{protocol.type()}, \text{protocol.protocol}());
\]

Postconditions:

(4.1) \( \text{is\_open}() == \text{true} \).
(4.2) \( \text{non\_blocking}() == \text{false} \).
(4.3) \( \text{enable\_connection\_aborted}() == \text{false} \).
(4.4) \( \text{protocol\_} == \text{protocol} \).

Error conditions:

(5.1) \( \text{socket\_errc::already\_open} \) — if \( \text{is\_open}() \) is true.

void assign(const protocol_type& protocol,
    const native_handle_type& native_acceptor);
void assign(const protocol_type& protocol,
    const native_handle_type& native_acceptor, error_code& ec);
Requires: Preconditions: \( \text{native\_acceptor} \) is a native handle to an open acceptor.
Effects: Assigns the native acceptor handle to this acceptor object.
Postconditions:

(8.1) \( \text{is\_open}() == \text{true} \).
(8.2) \( \text{non\_blocking}() == \text{false} \).
(8.3) \( \text{enable\_connection\_aborted}() == \text{false} \).

§ 18.9.4
— protocol_ == protocol.

Error conditions:
— socket_errc::already_open — if is_open() is true.

native_handle_type release();
native_handle_type release(error_code& ec);

Required: Preconditions: is_open() == true.

Effects: Cancels all outstanding asynchronous operations associated with this acceptor. Completion handlers for canceled asynchronous operations are passed an error code ec such that ec == errc::operation_canceled yields true.

Returns: The native representation of this acceptor.

Postconditions: is_open() == false.

Remarks: Since the native acceptor is not closed prior to returning it, the caller is responsible for closing it.

bool is_open() const noexcept;

Returns: A bool indicating whether this acceptor was opened by a previous call to open or assign.

void close();
void close(error_code& ec);

Effects: If is_open() is true, cancels all outstanding asynchronous operations associated with this acceptor, and establishes the postcondition as if by POSIX close(native_handle()). Completion handlers for canceled asynchronous operations are passed an error code ec such that ec == errc::operation_canceled yields true.

Postconditions: is_open() == false.

void cancel();
void cancel(error_code& ec);

Effects: Cancels all outstanding asynchronous operations associated with this acceptor. Completion handlers for canceled asynchronous operations are passed an error code ec such that ec == errc::operation_canceled yields true.

Error conditions:
— errc::bad_file_descriptor — if is_open() is false.
— errc::operation_not_supported — current conditions do not permit cancelation. The conditions under which cancelation of asynchronous operations is permitted are implementation-defined.

template<class SettableSocketOption>
void set_option(const SettableSocketOption& option);
template<class SettableSocketOption>
void set_option(const SettableSocketOption& option, error_code& ec);

Effects: Sets an option on this acceptor, as if by POSIX:

setsockopt(native_handle(), option.level(protocol_), option.name(protocol_), option.data(protocol_), option.size(protocol_));
template<class GettableSocketOption>
    void get_option(GettableSocketOption& option);

// Using the same type alias.

template<class GettableSocketOption>
    void get_option(GettableSocketOption& option, error_code& ec);

Effects: Gets an option from this acceptor, as if by POSIX:

&template<class GettableSocketOption>
    socklen_t option_len = option.size(protocol_);
    int result = getsockopt(native_handle(), option.level(protocol_),
        option.name(protocol_), option.data(protocol_),
        &option_len);

    if (result == 0)
        option.resize(option_len);

template<class IoControlCommand>
    void io_control(IoControlCommand& command);

// Using the same type alias.

template<class IoControlCommand>
    void io_control(IoControlCommand& command, error_code& ec);

Effects: Executes an I/O control command on this acceptor, as if by POSIX:

&template<class IoControlCommand>
    ioctl(native_handle(), command.name(), command.data());

void non_blocking(bool mode);
void non_blocking(bool mode, error_code& ec);

Effects: Sets the non-blocking mode of this acceptor. The non-blocking mode determines whether
subsequent synchronous socket operations (18.2.1) on *this block the calling thread.

Error conditions:

(24.1) — errc::bad_file_descriptor — if is_open() is false.

Postconditions: non_blocking() == mode.

[ Note: The non-blocking mode has no effect on the behavior of asynchronous operations. — end note ]

bool non_blocking() const;

Returns: The non-blocking mode of this acceptor.

void native_non_blocking(bool mode);
void native_non_blocking(bool mode, error_code& ec);

Effects: Sets the non-blocking mode of the underlying native acceptor, as if by POSIX:

&template<class IoControlCommand>
    int flags = fcntl(native_handle(), F_GETFL, 0);
    if (flags >= 0)
    {
        if (mode)
            flags |= O_NONBLOCK;
        else
            flags &= ~O_NONBLOCK;
        fcntl(native_handle(), F_SETFL, flags);
    }

The native non-blocking mode has no effect on the behavior of the synchronous or asynchronous
operations specified in this clause.

Error conditions:
--- errc::bad_file_descriptor — if is_open() is false.
--- errc::invalid_argument — if mode == false and non_blocking() == true. [Note: As the combination does not make sense. — end note]

bool native_non_blocking() const;

Returns: The non-blocking mode of the underlying native acceptor.
Remarks: Implementations are permitted and encouraged to cache the native non-blocking mode that was applied through a prior call to native_non_blocking. Implementations may return an incorrect value if a program sets the non-blocking mode directly on the acceptor, by calling an operating system-specific function on the result of native_handle().

void bind(const endpoint_type& endpoint);

Effects: Binds this acceptor to the specified local endpoint, as if by POSIX:

bind(native_handle(), endpoint.data(), endpoint.size());

void listen(int backlog = socket_base::max_listen_connections);
void listen(int backlog, error_code& ec);

Effects: Marks this acceptor as ready to accept connections, as if by POSIX:

listen(native_handle(), backlog);

endpoint_type local_endpoint() const;
endpoint_type local_endpoint(error_code& ec) const;

Effects: Determines the locally-bound endpoint associated with this acceptor, as if by POSIX:

endpoint_type endpoint;
socklen_t endpoint_len = endpoint.capacity();
int result = getsockname(native_handle(), endpoint.data(), &endpoint_len);
if (result == 0)
    endpoint.resize(endpoint_len);

Returns: On success, endpoint. Otherwise endpoint_type().

void enable_connection_aborted(bool mode);

Effects: If mode is true, subsequent synchronous or asynchronous accept operations on this acceptor are permitted to fail with error condition errc::connection_aborted. If mode is false, subsequent accept operations will not fail with errc::connection_aborted. [Note: If mode is false, the implementation will restart the call to POSIX accept if it fails with ECONNABORTED. — end note]

Error conditions:

--- errc::bad_file_descriptor — if is_open() is false.

bool enable_connection_aborted() const;

Returns: Whether accept operations on this acceptor are permitted to fail with errc::connection_aborted.

socket_type accept();
socket_type accept(error_code& ec);
Returns: accept(get_executor().context(), ec).

socket_type accept(io_context& ctx);
socket_type accept(io_context& ctx, error_code& ec);

Effect: Extracts a socket from the queue of pending connections of the acceptor, as if by POSIX:

native_handle_type h = accept(native_handle(), nullptr, 0);

Returns: On success, socket_type(ctx, protocol_, h). Otherwise socket_type(ctx).

template<class CompletionToken>
DEDUCED async_accept(CompletionToken& token);

Returns:
async_accept(get_executor().context(), forward<CompletionToken>(token))

template<class CompletionToken>
DEDUCED async_accept(io_context& ctx, CompletionToken& token);

Completion signature: void(error_code ec, socket_type s).

Effect: Initiates an asynchronous operation to extract a socket from the queue of pending connections of the acceptor, as if by POSIX:

native_handle_type h = accept(native_handle(), nullptr, 0);

On success, s is socket_type(ctx, protocol_, h). Otherwise, s is socket_type(ctx).

socket_type accept(endpoint_type& endpoint);
socket_type accept(endpoint_type& endpoint, error_code& ec);

Returns: accept(get_executor().context(), endpoint, ec).

socket_type accept(io_context& ctx, endpoint_type& endpoint);
socket_type accept(io_context& ctx, endpoint_type& endpoint, error_code& ec);

Effect: Extracts a socket from the queue of pending connections of the acceptor, as if by POSIX:

socklen_t endpoint_len = endpoint.capacity();
native_handle_type h = accept(native_handle(),
    endpoint.data(),
    &endpoint_len);

if (h >= 0)
    endpoint.resize(endpoint_len);

Returns: On success, socket_type(ctx, protocol_, h). Otherwise socket_type(ctx).

template<class CompletionToken>
DEDUCED async_accept(endpoint_type& endpoint,
    CompletionToken& token);

Returns:
async_accept(get_executor().context(), endpoint, forward<CompletionToken>(token))

template<class CompletionToken>
DEDUCED async_accept(io_context& ctx, endpoint_type& endpoint,
    CompletionToken& token);
Completion signature: `void(error_code ec, socket_type s)`.  

Effects: Initiates an asynchronous operation to extract a socket from the queue of pending connections of the acceptor, as if by POSIX:

```cpp
socklen_t endpoint_len = endpoint.capacity();
native_handle_type h = accept(native_handle(),
    endpoint.data(),
    &endpoint_len);
if (h >= 0)
    endpoint.resize(endpoint_len);
```

On success, `s` is `socket_type(ctx, protocol_, h)`. Otherwise, `s` is `socket_type(ctx)`.

```cpp
void wait(wait_type w);
void wait(wait_type w, error_code& ec);
```

Effects: Waits for the acceptor to have a queued incoming connection, or to have error conditions pending, as if by POSIX `poll`.

```cpp
template<class CompletionToken>
DEDUCED async_wait(wait_type w, CompletionToken& token);
```

Completion signature: `void(error_code ec)`.

Effects: Initiates an asynchronous operation to wait for the acceptor to have a queued incoming connection, or to have error conditions pending, as if by POSIX `poll`.

When multiple asynchronous wait operations are initiated with the same `wait_type` value, all outstanding operations complete when the acceptor enters the corresponding ready state. The order of invocation of the completions handlers for these operations is unspecified.

Error conditions:

(56.1) — `errc::bad_file_descriptor` — if `is_open()` is false.
19 Socket iostreams

19.1 Class template basic_socket_streambuf

The class basic_socket_streambuf<Protocol, Clock, WaitTraits> associates both the input sequence and the output sequence with a socket. The input and output sequences do not support seeking. [Note: The input and output sequences are independent as a stream socket provides full duplex I/O. —end note]

[Note: This class is intended for sending and receiving bytes, not characters. Any conversion from characters to bytes, and vice versa, occurs elsewhere. —end note]

namespace std {
namespace experimental {
namespace net {

inline namespace std::experimental::net::inline v1v2 {

template<class Protocol, class Clock, class WaitTraits>
class basic_socket_streambuf : public basic_streambuf<char>
{
public:
  // types:
  using protocol_type = Protocol;
  using endpoint_type = typename protocol_type::endpoint;
  using clock_type = Clock;
  using time_point = typename clock_type::time_point;
  using duration = typename clock_type::duration;
  using wait_traits_type = WaitTraits;

  // 19.1.1, construct / copy / destroy:
  basic_socket_streambuf();
  explicit basic_socket_streambuf(basic_stream_socket<protocol_type> s);
  basic_socket_streambuf(const basic_socket_streambuf&) = delete;
  basic_socket_streambuf(basic_socket_streambuf&& rhs);

  virtual ~basic_socket_streambuf();

  basic_socket_streambuf& operator=(const basic_socket_streambuf&) = delete;
  basic_socket_streambuf& operator=(basic_socket_streambuf&& rhs);

  // 19.1.2, members:

  basic_socket_streambuf* connect(const endpoint_type& e);
  template<class... Args> basic_socket_streambuf* connect(Args&&...);

  basic_socket_streambuf* close();

  basic_socket<protocol_type>& socket();
  error_code error() const;
  time_point expiry() const;
  void expires_at(const time_point& t);

  § 19.1
void expires_after(const duration& d);

protected:
    // overridden virtual functions:
    virtual int_type underflow() override;
    virtual int_type pbackfail(int_type c = traits_type::eof()) override;
    virtual int_type overflow(int_type c = traits_type::eof()) override;
    virtual int sync() override;
    virtual streambuf* setbuf(char_type* s, streamsize n) override;

private:
    basic_stream_socket<protocol_type> socket_; // exposition only
    error_code ec_; // exposition only
    time_point expiry_; // exposition only
};

} // inline namespace std::experimental::net::v2
} // namespace net
} // namespace experimental
} // namespace std

Instances Specializations of class template basic_socket_streambuf meet the requirements of Destructible Cpp17Destructible (C++ 2020 [destructible]), MoveConstructible Cpp17MoveConstructible (C++ 2020 [move-constructible]), and MoveAssignable Cpp17MoveAssignable (C++ 2020 [moveassignable]).

19.1.1 basic_socket_streambuf constructors  [socket.streambuf.cons]

basic_socket_streambuf();
1    Effects: Initializes socket_ with ctx, where ctx is an unspecified object of class io_context.
2    Postconditions: expiry() == time_point::max() and !error().

explicit basic_socket_streambuf(basic_stream_socket<protocol_type> s);
3    Effects: Initializes socket_ with std::move(s).
4    Postconditions: expiry() == time_point::max() and !error().

basic_socket_streambuf(basic_socket_streambuf&& rhs);
5    Effects: Move constructs from the rvalue rhs. It is implementation-defined whether the sequence
        pointers in *this (eback(), gptr(), egptr(), pbase(), pptr(), epptr()) obtain the values which
        rhs had. Whether they do or not, *this and rhs reference separate buffers (if any at all) after the
        construction. Additionally *this references the socket which rhs did before the construction, and
        rhs references no open socket after the construction.
6    Postconditions: Let rhs_p refer to the state of rhs just prior to this construction and let rhs_a refer
        to the state of rhs just after this construction.

   — is_open() == rhs_p.is_open()
   (6.1)
   — rhs_a.is_open() == false
   (6.2)
   — error() == rhs_p.error()
   (6.3)
   — !rhs_a.error()
   (6.4)
   — expiry() == rhs_p.expiry()
   (6.5)
   — rhs_a.expiry() == time_point::max()
   (6.6)
virtual ~basic_socket_streambuf();
7  
Effects: If a put area exists, calls overflow(traits_type::eof()) to flush characters. [Note: The socket is closed by the basic_stream_socket<protocol_type> destructor. —end note]

basic_socket_streambuf& operator=(basic_socket_streambuf&& rhs);
8  
Effects: Calls this->close() then move assigns from rhs. After the move assignment *this and rhs have the observable state they would have had if *this had been move constructed from rhs.

Returns: *this.

19.1.2 basic_socket_streambuf members [socket.streambuf.members]

basic_socket_streambuf* connect(const endpoint_type& e);
1  
Effects: Initializes the basic_socket_streambuf as required, closes and re-opens the socket by performing socket_.close(ec_) and socket_.open(e.protocol(), ec_), then attempts to establish a connection as if by POSIX connect(socket_.native_handle(), static_cast<sockaddr*>(e.data()), e.size()), ec_ is set to reflect the error code produced by the operation. If the operation does not complete before the absolute timeout specified by expiry_, the socket is closed and ec_ is set to errc::timed_out.

Returns: if !ec_, this; otherwise, a null pointer.

template<class... Args>
 basic_socket_streambuf* connect(Args&&... args);
3  
Effects: Initializes the basic_socket_streambuf as required and closes the socket as if by calling socket_.close(ec_). Obtains an endpoint sequence endpoints by performing protocol_type::resolver(ctx).resolve(forward<Args>(args)...), where ctx is an unspecified object of class io_context. For each endpoint e in the sequence, closes and re-opens the socket by performing socket_.close(ec_) and socket_.open(e.protocol(), ec_), then attempts to establish a connection as if by POSIX connect(socket_.native_handle(), static_cast<sockaddr*>(e.data()), e.size()), ec_ is set to reflect the error code produced by the operation. If the operation does not complete before the absolute timeout specified by expiry_, the socket is closed and ec_ is set to errc::timed_out.

Returns: if !ec_, this; otherwise, a null pointer.

[Editor's note: Should this also be constrained such that declval<protocol_type::resolver&>().resolve(forward<Args>(args)...) is valid? It's needed for the basic_socket_iostream(Args&&...) constructor to be constrained.]

Remarks: This function shall not participate in overload resolution unless Constraints: Protocol meets the requirements for an internet protocol (21.2.1).
basic_socket_streambuf* close();

Effects: If a put area exists, calls overflow(traits_type::eof()) to flush characters. Regardless of whether the preceding call fails or throws an exception, the function closes the socket as if by basic_socket<protocol_type>::close(ec_). If any of the calls made by the function fail, close fails by returning a null pointer. If one of these calls throws an exception, the exception is caught and rethrown after closing the socket.

Returns: this on success, a null pointer otherwise.

Postconditions: is_open() == false.

basic_socket<protocol_type>& socket();

Returns: socket_.

error_code error() const;

Returns: ec_.

time_point expiry() const;

Returns: expiry_.

void expires_at(const time_point& t);

Postconditions: expiry_ == t.

void expires_after(const duration& d);

Effects: Equivalent to expires_at(clock_type::now() + d).

19.1.3 basic_socket_streambuf overridden virtual functions

virtual int_type underflow() override;

Effects: Behaves according to the description of basic_streambuf<char>::underflow(), with the specialization that a sequence of characters is read from the input sequence as if by POSIX recvmsg, and ec_ is set to reflect the error code produced by the operation. If the operation does not complete before the absolute timeout specified by expiry_, the socket is closed and ec_ is set to errc::timed_out.

Returns: traits_type::to_int_type(*gptr()) to indicate success, and traits_type::eof() to indicate failure.

virtual int_type pbackfail(int_type c = traits_type::eof()) override;

Effects: Puts back the character designated by c to the input sequence, if possible, in one of three ways:

(3.1) If traits_type::eq_int_type(c, traits_type::eof()) returns false, and if the function makes a putback position available, and if traits_type::eq(traits_type::to_char_type(c), gptr()[-1]) returns true, decrements the next pointer for the input sequence, gptr().

Returns: c.

(3.2) If traits_type::eq_int_type(c, traits_type::eof()) returns false, and if the function makes a putback position available, and if the function is permitted to assign to the putback position, decrements the next pointer for the input sequence, and stores c there.

Returns: c.

(3.3) If traits_type::eq_int_type(c, traits_type::eof()) returns true, and if either the input sequence has a putback position available or the function makes a putback position available, decrements the next pointer for the input sequence, gptr().

Returns: traits_type::not_eof(c).
Paragraph 4: Returns: As specified above, or traits_type::eof() to indicate failure.

Paragraph 5: Remarks: The function does not put back a character directly to the input sequence. If the function can succeed in more than one of these ways, it is unspecified which way is chosen. The function can alter the number of putback positions available as a result of any call.

virtual int_type overflow(int_type c = traits_type::eof()) override;

Paragraph 6: Effects: Behaves according to the description of basic_streambuf<char>::overflow(c), except that the behavior of “consuming characters” is performed by output of the characters to the socket as if by one or more calls to POSIX sendmsg, and ec_ is set to reflect the error code produced by the operation. If the operation does not complete before the absolute timeout specified by expiry_, the socket is closed and ec_ is set to errc::timed_out.

Paragraph 7: Returns: traits_type::not_eof(c) to indicate success, and traits_type::eof() to indicate failure.

virtual int sync() override;

Paragraph 8: Effects: If a put area exists, calls overflow(traits_type::eof()) to flush characters.

virtual streambuf* setbuf(char_type* s, streamsize n) override;

Paragraph 9: Effects: If setbuf(nullptr, 0) is called on a stream before any I/O has occurred on that stream, the stream becomes unbuffered. Otherwise the results are unspecified. “Unbuffered” means that pbase() and pptr() always return null and output to the socket should appear as soon as possible.

19.2 Class template basic_socket_iostream

The class template basic_socket_iostream<Protocol, Clock, WaitTraits> supports reading and writing on sockets. It uses a basic_socket_streambuf<Protocol, Clock, WaitTraits> object to control the associated sequences.

[] Note: This class is intended for sending and receiving bytes, not characters. Any conversion from characters to bytes, and vice versa, occurs elsewhere. — end note]
Instances Specializations of class template basic_socket_iostream meet the requirements of Destructible Cpp17Destructible (C++ 2020 [destructible]), MoveConstructible Cpp17MoveConstructible (C++ 2020 [move-constructible]), and MoveAssignable Cpp17MoveAssignable (C++ 2020 [moveassignable]).

### 19.2.1 basic_socket_iostream constructors

[socket.iostream.cons]

```cpp
basic_socket_iostream();
[Editor's note: Using `addressof` here resolves LWG issue 344x.]
```

1. **Effects:** Initializes the base class as `basic_iostream<char>(&sb_);`, value-initializes `sb_`, and performs `setf(std::ios_base::unitbuf).

```cpp
explicit basic_socket_iostream(basic_stream_socket<protocol_type> s);
```

2. **Effects:** Initializes the base class as `basic_iostream<char>(&sb_);`, initializes `sb_` with `std::move(s)`, and performs `setf(std::ios_base::unitbuf).

```cpp
basic_socket_iostream(basic_socket_iostream&& rhs);
```

3. **Effects:** Move constructs from the rvalue `rhs`. This is accomplished by move constructing the base class, and the contained `basic_socket_streambuf`. Next `basic_iostream<char>::set_rdbuf(&sb_)` is called to install the contained `basic_socket_streambuf`.

```cpp
template<class... Args>
explicit basic_socket_iostream(Args&&... args);
```
Effects: Initializes the base class as `basic_iostream<char>(&sb_);`, value-initializes `sb_`, and performs `setf(std::ios_base::unitbuf)`. Then calls `rdbuf()->connect(forward<Args>(args)...). If that function returns a null pointer, calls `setstate(failbit)`.

1. `basic_socket_iostream& operator=(basic_socket_iostream&& rhs);`  
   Effects: Move assigns the base and members of `*this` from the base and corresponding members of `rhs`.  
   Returns: `*this`.

19.2.2 `basic_socket_iostream` members  

```cpp
template<class... Args>
void connect(Args&&... args);
```

Effects: Calls `rdbuf()->connect(forward<Args>(args)...). If that function returns a null pointer, calls `setstate(failbit)` (which may throw `ios_base::failure`).

```cpp
void close();
```

Effects: Calls `rdbuf()->close(). If that function returns a null pointer, calls `setstate(failbit)` (which may throw `ios_base::failure`).

```cpp
basic_socket_streambuf<protocol_type, clock_type, wait_traits_type>* rdbuf() const;
```

Let `SB` be the type `basic_socket_streambuf<protocol_type, clock_type, wait_traits_type>`.  

Returns: `const_cast<SB*>(addressof(sb_))`.  

```cpp
basic_socket<protocol_type>& socket();
```

Returns: `rdbuf()->socket()`.  

```cpp
error_code error() const;
```

Returns: `rdbuf()->error()`.  

```cpp
time_point expiry() const;
```

Returns: `rdbuf()->expiry()`.  

```cpp
void expires_at(const time_point& t);
```

Effects: Equivalent to `rdbuf()->expires_at(t)`.  

```cpp
void expires_after(const duration& d);
```

Effects: Equivalent to `rdbuf()->expires_after(d)`.  

---

§ 19.2.2
20 Socket algorithms

20.1 Synchronous connect operations

```cpp
template<class Protocol, class EndpointSequence>
type Protocol::endpoint connect(basic_socket<Protocol>& s,
    const EndpointSequence& endpoints);
```

1 *Returns:* connect(s, endpoints, [](auto, auto){ return true; }, ec).

```cpp
template<class Protocol, class EndpointSequence>
type Protocol::endpoint connect(basic_socket<Protocol>& s,
    const EndpointSequence& endpoints,
    error_code& ec);
```

2 *Effects:* Performs ec.clear(), then finds the first element ep in the sequence endpoints for which:

(2.1) \(c(ec, ep)\) yields true;
(2.2) \(s.close(ec)\) succeeds;
(2.3) \(s.open(ep.protocol(), ec)\) succeeds; and
(2.4) \(s.connect(ep, ec)\) succeeds.

3 *Returns:* typename Protocol::endpoint() if no such element is found, otherwise ep.

4 *Error conditions:*

(4.1) socket_errc::not_found — if endpoints.empty() or if the function object c returned false for all elements in the sequence.

```cpp
template<class Protocol, class InputIterator>
InputIterator connect(basic_socket<Protocol>& s,
    InputIterator first, InputIterator last);
```

5 *Returns:* connect(s, first, last, [](auto, auto){ return true; }, ec).

```cpp
template<class Protocol, class InputIterator, class ConnectCondition>
InputIterator connect(basic_socket<Protocol>& s,
    InputIterator first, InputIterator last,
    ConnectCondition c);
```

6 *Returns:* connect(s, first, last, first, last, c).
InputIterator first, InputIterator last, ConnectCondition c, error_code& ec);

Effects: Performs ec.clear(), then finds the first iterator i in the range [first, last) for which:

- c(ec, *i) yields true;
- s.close(ec) succeeds;
- s.open(typename Protocol::endpoint(*i).protocol(), ec) succeeds; and
- s.connect(*i, ec) succeeds.

Returns: last if no such iterator is found, otherwise i.

Error conditions:

- socket_errc::not_found — if first == last or if the function object c returned false for all iterators in the range.

20.2 Asynchronous connect operations

```
template<class Protocol, class EndpointSequence, class CompletionToken>
DEDUCED async_connect(basic_socket<Protocol>& s,
    const EndpointSequence& endpoints,
    CompletionToken& token);
```

Returns:

async_connect(s, endpoints, [](auto, auto){ return true; }, forward<CompletionToken>(token))

A composed asynchronous operation (13.2.7.14).

Completion signature: void(error_code ec, typename Protocol::endpoint ep).

Effects: Performs ec.clear(), then finds the first element ep in the sequence endpoints for which:

- c(ec, ep) yields true;
- s.close(ec) succeeds;
- s.open(ep.protocol(), ec) succeeds; and
- the asynchronous operation s.async_connect(ep, unspecified) succeeds.

ec is updated with the result of the s.async_connect(ep, unspecified) operation, if any. If no such element is found, or if the operation fails with one of the error conditions listed below, ep is set to typename Protocol::endpoint(). [Note: The underlying close, open, and async_connect operations are performed sequentially. — end note]

Error conditions:

- socket_errc::not_found — if endpoints.empty() or if the function object c returned false for all elements in the sequence.
- errc::operation_canceled — if s.is_open() == false immediately following an async_connect operation on the underlying socket.
template<class Protocol, class InputIterator, class CompletionToken>
    DEDUCED async_connect(basic_socket<Protocol>& s,
        InputIterator first, InputIterator last,
        CompletionToken& token);

Returns:

    async_connect(s, first, last, [](auto, auto){ return true; },
        forward<CompletionToken>(token))

template<class Protocol, class InputIterator,
        class ConnectCondition, class CompletionToken>
    DEDUCED async_connect(basic_socket<Protocol>& s,
        InputIterator first, InputIterator last,
        ConnectCondition c,
        CompletionToken& token);

A composed asynchronous operation (13.2.7.14).

Completion signature: void(error_code ec, InputIterator i).

Effects: Performs ec.clear(), then finds the first iterator i in the range [first, last) for which:

1. c(ec, *i) yields true;
2. s.close(ec) succeeds;
3. s.open(typename Protocol::endpoint(*i).protocol(), ec) succeeds; and
4. the asynchronous operation s.async_connect(*i, unspecified) succeeds.

Ec is updated with the result of the s.async_connect(*i, unspecified) operation, if any. If no such iterator is found, or if the operation fails with one of the error conditions listed below, i is set to last. [Note: The underlying close, open, and async_connect operations are performed sequentially. —end note]

Error conditions:

1. socket_errc::not_found — if first == last or if the function object c returned false for all iterators in the range.
2. errc::operation_canceled — if s.is_open() == false immediately following an async_connect operation on the underlying socket.
21 Internet protocol

21.1 Header <experimental/internet> synopsis

```cpp
#include <compare>

namespace std {
namespace experimental {
namespace net {
inline namespace std::experimental::net::inline_v1v2 {
namespace ip {

enum class resolver_errc {
  host_not_found = an implementation-defined non-zero value, // EAI_NONAME
  try_again = an implementation-defined non-zero value,       // EAI_AGAIN
  service_not_found = an implementation-defined non-zero value // EAI_SERVICE
};

const error_category& resolver_category() noexcept;
error_code make_error_code(resolver_errc e) noexcept;
error_condition make_error_condition(resolver_errc e) noexcept;

using port_type = uint_least16_t;
using scope_id_type = uint_least32_t;

struct v4_mapped_t {};
constexpr v4_mapped_t v4_mapped;

class address;
class address_v4;
class address_v6;

class bad_address_cast;

// 21.4.4, address comparisons:
constexpr bool operator==(const address&, const address&) noexcept;
constexpr bool operator!=(const address&, const address&) noexcept;
constexpr bool operator<(const address&, const address&) noexcept;
constexpr bool operator<=(const address&, const address&) noexcept;
constexpr bool operator>(const address&, const address&) noexcept;
constexpr bool operator>=(const address&, const address&) noexcept;
constexpr partial Ordering operator<=>(const address&, const address&) noexcept;

// 21.5.5, address_v4 comparisons:
constexpr bool operator==(const address_v4&, const address_v4&) noexcept;
constexpr bool operator!=(const address_v4&, const address_v4&) noexcept;
constexpr bool operator<(const address_v4&, const address_v4&) noexcept;
constexpr bool operator<=(const address_v4&, const address_v4&) noexcept;
constexpr bool operator>(const address_v4&, const address_v4&) noexcept;
constexpr bool operator>=(const address_v4&, const address_v4&) noexcept;
constexpr strong Ordering operator<=>(const address_v4&, const address_v4&) noexcept;
```
// 21.6.5, address_v6 comparisons:
constexpr bool operator==(const address_v6&, const address_v6&) noexcept;
constexpr bool operator!=(const address_v6&, const address_v6&) noexcept;
constexpr bool operator<(const address_v6&, const address_v6&) noexcept;
constexpr bool operator>(const address_v6&, const address_v6&) noexcept;
constexpr bool operator<=(const address_v6&, const address_v6&) noexcept;
constexpr bool operator>=(const address_v6&, const address_v6&) noexcept;
constexpr strong::ordering operator<=>(const address_v6&, const address_v6&) noexcept;

// 21.4.5, address creation:
address make_address(const char*);
address make_address(const char*, error_code&) noexcept;
address make_address(const string&);
address make_address(const string&, error_code&) noexcept;
address make_address(string_view);
address make_address(string_view, error_code&) noexcept;

// 21.5.6, address_v4 creation:
constexpr address_v4 make_address_v4(const address_v4::bytes_type&);
constexpr address_v4 make_address_v4(address_v4::uint_type);
constexpr address_v4 make_address_v4(v4_mapped_t, const address_v6&);
address_v4 make_address_v4(const char*);
address_v4 make_address_v4(const char*, error_code&) noexcept;
address_v4 make_address_v4(const string&);
address_v4 make_address_v4(const string&, error_code&) noexcept;
address_v4 make_address_v4(string_view);
address_v4 make_address_v4(string_view, error_code&) noexcept;

// 21.6.6, address_v6 creation:
constexpr address_v6 make_address_v6(const address_v6::bytes_type&,
    scope_id_type = 0);
constexpr address_v6 make_address_v6(v4_mapped_t, const address_v4&)
    noexcept;
address_v6 make_address_v6(const char*);
address_v6 make_address_v6(const char*, error_code&) noexcept;
address_v6 make_address_v6(const string&);
address_v6 make_address_v6(const string&, error_code&) noexcept;
address_v6 make_address_v6(string_view);
address_v6 make_address_v6(string_view, error_code&) noexcept;

// 21.4.6, address I/O:
template<class CharT, class Traits>
    basic_ostream<CharT, Traits>& operator<<(
        basic_ostream<CharT, Traits>&, const address&);

// 21.5.7, address_v4 I/O:
template<class CharT, class Traits>
    basic_ostream<CharT, Traits>& operator<<(
        basic_ostream<CharT, Traits>&, const address_v4&);

// 21.6.7, address_v6 I/O:
template<class CharT, class Traits>
    basic_ostream<CharT, Traits>& operator<<(
        basic_ostream<CharT, Traits>&, const address_v6&);
template<class> class basic_address_iterator; // not defined

template<> class basic_address_iterator<address_v4>;
using address_v4_iterator = basic_address_iterator<address_v4>;
template<> class basic_address_iterator<address_v6>;
using address_v6_iterator = basic_address_iterator<address_v6>;

template<class> class basic_address_range; // not defined

template<> class basic_address_range<address_v4>;
using address_v4_range = basic_address_range<address_v4>;
template<> class basic_address_range<address_v6>;
using address_v6_range = basic_address_range<address_v6>;

class network_v4;
class network_v6;

// 21.11.3, network_v4 comparisons:
bool operator==(const network_v4& n1, const network_v4& n2) noexcept;
bool operator!=(const network_v4& n1, const network_v4& n2) noexcept;

// 21.12.3, network_v6 comparisons:
bool operator==(const network_v6& n1, const network_v6& n2) noexcept;
bool operator!=(const network_v6& n1, const network_v6& n2) noexcept;

// 21.11.4, network_v4 creation:
network_v4 make_network_v4(const address_v4& addr, int);  
network_v4 make_network_v4(const address_v4& start, const address_v4& end);
network_v4 make_network_v4(const char* string);
network_v4 make_network_v4(const char* string, error_code& ec) noexcept;
network_v4 make_network_v4(const string& s);
network_v4 make_network_v4(const string& s, error_code& ec) noexcept;
network_v4 make_network_v4(string_view sv);
network_v4 make_network_v4(string_view sv, error_code& ec) noexcept;

// 21.12.4, network_v6 creation:
network_v6 make_network_v6(const address_v6& addr, int);  
network_v6 make_network_v6(const char* string);
network_v6 make_network_v6(const char* string, error_code& ec) noexcept;
network_v6 make_network_v6(const string& s);
network_v6 make_network_v6(const string& s, error_code& ec) noexcept;
network_v6 make_network_v6(string_view sv);
network_v6 make_network_v6(string_view sv, error_code& ec) noexcept;

// 21.11.5, network_v4 I/O:
template<class CharT, class Traits>
    basic_ostream<CharT, Traits>& operator<<(basic_ostream<CharT, Traits>& os, const network_v4& network);

// 21.12.5, network_v6 I/O:
template<class CharT, class Traits>
    basic_ostream<CharT, Traits>& operator<<(basic_ostream<CharT, Traits>& os, const network_v6& network);

template<class InternetProtocol>
class basic_endpoint;
/21.13.3, basic_endpoint comparisons:

```cpp
// 21.13.3, basic_endpoint comparisons:
template<class InternetProtocol>
  bool operator==(const basic_endpoint<InternetProtocol>&, const basic_endpoint<InternetProtocol>&);
template<class InternetProtocol>
  bool operator!=(const basic_endpoint<InternetProtocol>&, const basic_endpoint<InternetProtocol>&);
template<class InternetProtocol>
  bool operator<(const basic_endpoint<InternetProtocol>&, const basic_endpoint<InternetProtocol>&);
template<class InternetProtocol>
  bool operator>(const basic_endpoint<InternetProtocol>&, const basic_endpoint<InternetProtocol>&);
template<class InternetProtocol>
  bool operator<=(const basic_endpoint<InternetProtocol>&, const basic_endpoint<InternetProtocol>&);
template<class InternetProtocol>
  bool operator>=(const basic_endpoint<InternetProtocol>&, const basic_endpoint<InternetProtocol>&);
template<class InternetProtocol>
  partial_ordering_operator<=>(const basic_endpoint<InternetProtocol>&, const basic_endpoint<InternetProtocol>&);
```

/21.13.4, basic_endpoint I/O:

```cpp
// 21.13.4, basic_endpoint I/O:
template<class CharT, class Traits, class InternetProtocol>
  basic_ostream<CharT, Traits>& operator<<(basic_ostream<CharT, Traits>&, const basic_endpoint<InternetProtocol>&);

template<class InternetProtocol>
  class basic_resolver_entry;
template<class InternetProtocol>
  class basic_resolver_results;

class resolver_base;
template<class InternetProtocol>
  class basicResolver;

string host_name();
```
string host_name(error_code&);
template<class Allocator>
    basic_string<char, char_traits<char>, Allocator>
    host_name(const Allocator&);
template<class Allocator>
    basic_string<char, char_traits<char>, Allocator>
    host_name(const Allocator&, error_code&);

class tcp;

    // 21.19.1, tcp comparisons:
    bool operator==(const tcp& a, const tcp& b);
    bool operator!=(const tcp& a, const tcp& b);

class udp;

    // 21.20.1, udp comparisons:
    bool operator==(const udp& a, const udp& b);
    bool operator!=(const udp& a, const udp& b);

class v6_only;

namespace unicast {
    class hops;
}

} // namespace unicast

namespace multicast {
    class join_group;
    class leave_group;
    class outbound_interface;
    class hops;
    class enable_loopback;
}

} // namespace multicast

} // inline namespace


} // namespace

// 21.8, hash support

template<> struct is_error_condition_enum<
    std::experimental::net::v1::ip::resolver_errc>
    : public true_type {};

// 21.19, hash support

template<class T> struct hash;
template<> struct hash<
    std::experimental::net::v1::ip::address>;
template<> struct hash<
    std::experimental::net::v1::ip::address_v4>;
template<> struct hash<
    std::experimental::net::v1::ip::address_v6>;

§ 21.1
21.2 Requirements [internet.reqmts]

21.2.1 Internet protocol requirements [internet.reqmts.protocol]

1 A type \( X \) meets the InternetProtocol requirements if it satisfies the requirements of AcceptableProtocol (18.2.7), as well as the additional requirements listed below.

2 In the table below, \( a \) and \( b \) denote (possibly const) values of type (possibly const) \( X \).

<table>
<thead>
<tr>
<th>expression</th>
<th>return type</th>
<th>assertion/note</th>
<th>pre/post-conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>( X::resolver )</td>
<td>( \text{ip::basic_resolver}&lt;X&gt; )</td>
<td>The type of a resolver for the</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>protocol.</td>
<td></td>
</tr>
<tr>
<td>( X::v4() )</td>
<td>( X )</td>
<td>Returns an object representing</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>the IP version 4 protocol.</td>
<td></td>
</tr>
<tr>
<td>( X::v6() )</td>
<td>( X )</td>
<td>Returns an object representing</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>the IP version 6 protocol.</td>
<td></td>
</tr>
<tr>
<td>( a == b )</td>
<td>convertible to bool</td>
<td>Returns true if ( a ) and ( b</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>represent the same IP protocol</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>version, otherwise false.</td>
<td></td>
</tr>
<tr>
<td>( a != b )</td>
<td>convertible to bool</td>
<td>Returns ( ! (a == b) ).</td>
<td></td>
</tr>
</tbody>
</table>

21.2.2 Multicast group socket options [internet.reqmts.opt.mcast]

1 A type \( X \) meets the MulticastGroupSocketOption requirements if it satisfies the requirements of DestructibleCpp17Destructible (C++ 2020 [destructible]), CopyConstructibleCpp17CopyConstructible (C++ 2020 [copyconstructible]), CopyAssignableCpp17CopyAssignable (C++ 2020 [copyassignable]), and SettableSocketOptionSettableSocketOption (18.2.9), as well as the additional requirements listed below.

2 In the table below, \( a \) denotes a (possibly const) value of type (possibly const) address, \( b \) and \( c \) denote (possibly const) values of type address_v4, \( d \) denotes a (possibly const) value of type (possibly const) address_v6, \( e \) denotes a (possibly const) value of type (possibly const) unsigned int, and \( u \) denotes an identifier.

<table>
<thead>
<tr>
<th>expression</th>
<th>type</th>
<th>assertion/note</th>
<th>pre/post-conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>( X u(a) )</td>
<td></td>
<td>Constructs a multicast group</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>socket option to join the group</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>with the specified version-</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>independent address.</td>
<td></td>
</tr>
<tr>
<td>( X u(b, c) )</td>
<td></td>
<td>Constructs a multicast group</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>socket option to join the</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>specified IPv4 address on a</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>specified network interface.</td>
<td></td>
</tr>
<tr>
<td>( X u(d, e) )</td>
<td></td>
<td>Constructs a multicast group</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>socket option to join the</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>specified IPv6 address on a</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>specified network interface.</td>
<td></td>
</tr>
</tbody>
</table>

3 In this document, types that meet the MulticastGroupSocketOption requirements are defined as follows.
class C
{
public:
   // constructors:
   explicit C(const address& multicast_group) noexcept;
   explicit C(const address_v4& multicast_group,
               const address_v4& network_interface = address_v4::any()) noexcept;
   explicit C(const address_v6& multicast_group,
               unsigned int network_interface = 0) noexcept;
};

Extensible implementations provide the following member functions:

class C
{
public:
   template<class Protocol> int level(const Protocol& p) const noexcept;
   template<class Protocol> int name(const Protocol& p) const noexcept;
   template<class Protocol> const void* data(const Protocol& p) const noexcept;
   template<class Protocol> size_t size(const Protocol& p) const noexcept;
   // remainder unchanged
private:
   ip_mreq v4_value_; // exposition only
   ipv6_mreq v6_value_; // exposition only
};

Let \( L \) and \( N \) identify the POSIX macros to be passed as the \texttt{level} and \texttt{option_name} arguments, respectively, to POSIX \texttt{setsockopt} and \texttt{getsockopt}.

explicit C(const address& multicast_group) noexcept;

Effects: If \texttt{multicast_group.is_v6()} is \texttt{true}, calls \( C(\texttt{multicast_group.to_v6}()) \); otherwise, calls \( C(\texttt{multicast_group.to_v4}()) \).

explicit C(const address_v4& multicast_group,
            const address_v4& network_interface = address_v4::any()) noexcept;

Effects: For extensible implementations, \texttt{v4_value_.imr_multiaddr} is initialized to correspond to the address \texttt{multicast_group}, \texttt{v4_value_.imr_interface} is initialized to correspond to address \texttt{network_interface}, and \texttt{v6_value_} is zero-initialized.

explicit C(const address_v6& multicast_group,
            unsigned int network_interface = 0) noexcept;

Effects: For extensible implementations, \texttt{v6_value_.ipv6mr_multiaddr} is initialized to correspond to the address \texttt{multicast_group}, \texttt{v6_value_.ipv6mr_interface} is initialized to \texttt{network_interface}, and \texttt{v4_value_} is zero-initialized.

template<class Protocol> int level(const Protocol& p) const noexcept;

Returns: \( L \).

template<class Protocol> int name(const Protocol& p) const noexcept;

Returns: \( N \).

template<class Protocol> const void* data(const Protocol& p) const noexcept;
template<class Protocol> size_t size(const Protocol& p) const noexcept;

Returns: sizeof(v6_value_) if p.family() == AF_INET6, otherwise sizeof(v4_value_).

21.3 Error codes

const error_category& resolver_category() noexcept;

Returns: A reference to an object of a type derived from class error_category. All calls to this function return references to the same object.

The object’s default_error_condition and equivalent virtual functions behave as specified for the class error_category. The object’s name virtual function returns a pointer to the string "resolver".

error_code make_error_code(resolver_errc e) noexcept;

Returns: error_code(static_cast<int>(e), resolver_category()).

error_condition make_error_condition(resolver_errc e) noexcept;

Returns: error_condition(static_cast<int>(e), resolver_category()).

21.4 Class ip::address

The class address is a version-independent representation for an IP address. An object of class address holds either an IPv4 address, an IPv6 address, or no valid address.

namespace std {
namespace experimental {
namespace net {
inline_namespace std::experimental::net::inline_v1v2 {

namespace ip {

class address {

public:

// 21.4.1, constructors:
constexpr address() noexcept;
constexpr address(const address& a) noexcept;
constexpr address(const address_v4& a) noexcept;
constexpr address(const address_v6& a) noexcept;

// 21.4.2, assignment:
address& operator=(const address& a) noexcept;
address& operator=(const address_v4& a) noexcept;
address& operator=(const address_v6& a) noexcept;

// 21.4.3, members:
constexpr bool is_v4() const noexcept;
constexpr bool is_v6() const noexcept;
constexpr address_v4 to_v4() const;
constexpr address_v6 to_v6() const;
constexpr bool is_unspecified() const noexcept;
constexpr bool is_loopback() const noexcept;
constexpr bool is_multicast() const noexcept;

template<class Allocator = allocator<char>>
  basic_string<char, char_traits<char>, Allocator>
to_string(const Allocator& a = Allocator()) const;

private:
    address_v4 v4_; // exposition only
    address_v6 v6_; // exposition only
};

// 21.4.4, address comparisons:
constexpr bool operator==(const address& a, const address& b) noexcept;
constexpr bool operator!=(const address& a, const address& b) noexcept;
constexpr bool operator<(const address& a, const address& b) noexcept;
constexpr bool operator>(const address& a, const address& b) noexcept;
constexpr bool operator<=(const address& a, const address& b) noexcept;
constexpr bool operator>=(const address& a, const address& b) noexcept;
constexpr partial_ordering operator<=>(const address& a, const address& b) noexcept;

// 21.4.5, address creation:
address make_address(const char* str);
address make_address(const char* str, error_code& ec) noexcept;
address make_address(const string& str);
address make_address(const string& str, error_code& ec) noexcept;
address make_address(string_view str);
address make_address(string_view str, error_code& ec) noexcept;

// 21.4.6, address I/O:
template<class CharT, class Traits>
basic_ostream<CharT, Traits>& operator<<(basic_ostream<CharT, Traits>& os, const address& addr);

} // namespace ip
} // inline namespace std::experimental::net::v1
} // namespace net
} // namespace experimental
} // namespace std

Class `address` satisfies the requirements for `Destructible` [C++ 2020 [destructible]], `CopyConstructible` [C++ 2020 [copyconstructible]], and `CopyAssignable` [C++ 2020 [copyassignable]].

### § 21.4.1 ip::address constructors

`constexpr address() noexcept;`

**Postconditions:** `is_v4()` == true, `is_v6()` == false, and `is_unspecified()` == true.

`constexpr address(const address_v4& a) noexcept;`

**Effects:** Initializes `v4_` with `a`.

**Postconditions:** `is_v4()` == true and `is_v6()` == false.

`constexpr address(const address_v6& a) noexcept;`

**Effects:** Initializes `v6_` with `a`.

**Postconditions:** `is_v4()` == false and `is_v6()` == true.
21.4.2 ip::address assignment

address& operator=(const address_v4& a) noexcept;

1 Postconditions: is_v4() == true and is_v6() == false and to_v4() == a.
2 Returns: *this

address& operator=(const address_v6& a) noexcept;

3 Postconditions: is_v4() == false and is_v6() == true and to_v6() == a.
4 Returns: *this

21.4.3 ip::address members

constexpr bool is_v4() const noexcept;
1 Returns: true if the object contains an IP version 4 address, otherwise false.

constexpr bool is_v6() const noexcept;
2 Returns: true if the object contains an IP version 6 address, otherwise false.

constexpr address_v4 to_v4() const;
3 Returns: v4_.
4 Throws: bad_address_cast if is_v4() == false.

constexpr address_v6 to_v6() const;
5 Returns: v6_.
6 Throws: bad_address_cast if is_v6() == false.

constexpr bool is_unspecified() const noexcept;
7 Returns: If is_v4(), returns v4_.is_unspecified(). Otherwise returns v6_.is_unspecified().

constexpr bool is_loopback() const noexcept;
8 Returns: If is_v4(), returns v4_.is_loopback(). Otherwise returns v6_.is_loopback().

constexpr bool is_multicast() const noexcept;
9 Returns: If is_v4(), returns v4_.is_multicast(). Otherwise returns v6_.is_multicast().

template<class Allocator = allocator<char>>
basic_string<char, char_traits<char>, Allocator>
to_string(const Allocator& a = Allocator()) const;
10 Returns: If is_v4(), returns v4_.to_string(a). Otherwise returns v6_.to_string(a).
21.4.4 ip::address comparisons

```cpp
constexpr bool operator==(const address& a, const address& b) noexcept;
```

Returns:

1. If `a.is_v4()` != `b.is_v4()`, false;
2. If `a.is_v4()`, the result of `a.v4_ == b.v4_`;
3. Otherwise, the result of `a.v6_ == b.v6_`.

```cpp
constexpr bool operator!=(const address& a, const address& b) noexcept;
```

Returns: `!(a == b)`.

```cpp
constexpr bool operator<(const address& a, const address& b) noexcept;
```

Returns:

1. If `a.is_v4()` && `!b.is_v4()`, true;
2. If `!a.is_v4()` && `b.is_v4()`, false;
3. If `a.is_v4()`, the result of `a.v4_ < b.v4_`;
4. Otherwise, the result of `a.v6_ < b.v6_`.

```cpp
constexpr bool operator>(const address& a, const address& b) noexcept;
```

Returns: `b < a`.

```cpp
constexpr bool operator<=(const address& a, const address& b) noexcept;
```

Returns: `!(b < a)`.

```cpp
constexpr bool operator>=(const address& a, const address& b) noexcept;
```

Returns: `!(a < b)`.

```cpp
constexpr partial_ordering operator<=>(const address& a, const address& b) noexcept;
```

Returns:

1. If `a.is_v4()` && `b.is_v4()`, the result of `a.v4_ <=> b.v4_`;
2. If `a.is_v6()` && `b.is_v6()`, the result of `a.v6_ <=> b.v6_`;
3. Otherwise, `partial_ordering::unordered`.

21.4.5 ip::address creation

```cpp
address make_address(const char* str);
```

```cpp
address make_address(const char* str, error_code& ec) noexcept;
```

```cpp
address make_address(const string& str);
```

```cpp
address make_address(const string& str, error_code& ec) noexcept;
```

```cpp
address make_address(string_view str);
```

```cpp
address make_address(string_view str, error_code& ec) noexcept;
```

Effects: Converts a textual representation of an address into an object of class `address`, as if by calling: 

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address a;
address_v6 v6a = make_address_v6(str, ec);
if (!ec)
    a = v6a;
else {
    address_v4 v4a = make_address_v4(str, ec);
    if (!ec)
        a = v4a;
}

Returns: a.

21.4.6 ip::address I/O

template<class CharT, class Traits>
basic_ostream<CharT, Traits>& operator<<(basic_ostream<CharT, Traits>& os, const address& addr);

Returns: os << addr.to_string().c_str().

21.5 Class ip::address_v4

The class address_v4 is a representation of an IPv4 address.

namespace std {
namespace experimental {
namespace net {
    inline_namespace std::experimental::net::inline_v1 {
        namespace ip {

        class address_v4
        {
            public:
                // 21.5.1, types:
                using uint_type = uint_least32_t;
                struct bytes_type;

                // 21.5.2, constructors:
                constexpr address_v4() noexcept;
                constexpr address_v4(const address_v4& a) noexcept;
                constexpr address_v4(const bytes_type& bytes);
                explicit constexpr address_v4(uint_type val);

                // assignment:
                address_v4& operator=(const address_v4& a) noexcept;

                // 21.5.3, members:
                constexpr bool is_unspecified() const noexcept;
                constexpr bool is_loopback() const noexcept;
                constexpr bool is_multicast() const noexcept;
                constexpr bytes_type to_bytes() const noexcept;
                constexpr uint_type to_uint() const noexcept;
                template<class Allocator = allocator<char>>
                basic_string<char, char_traits<char>, Allocator>
                to_string(const Allocator& a = Allocator()) const;

        }
    }
}
}
}
[21.5.4, static members:
static constexpr address_v4 any() noexcept;
static constexpr address_v4 loopback() noexcept;
static constexpr address_v4 broadcast() noexcept;
];

[21.5.5, address_v4 comparisons:
constexpr bool operator==(const address_v4& a, const address_v4& b) noexcept;
constexpr
false
operator!=(const
address
v4&
a,
const
address
v4&
b)
noexcept;
constexpr
false
operator<
(const
address
v4&
a,
const
address
v4&
b)
noexcept;
constexpr
false
operator>
(const
address
v4&
a,
const
address
v4&
b)
noexcept;
constexpr
false
operator<=
(const
address
v4&
a,
const
address
v4&
b)
noexcept;
constexpr
false
operator>=
(const
address
v4&
a,
const
address
v4&
b)
noexcept;
constexpr
strong
ordering
operator<=
(const
address
v4&
a,
const
address
v4&
b)
noexcept;

[21.5.6, address_v4 creation:
constexpr address_v4 make_address_v4(const address_v4::bytes_type& bytes);
constexpr address_v4 make_address_v4(address_v4::uint_type val);
constexpr address_v4 make_address_v4(v4_mapped_t, const address_v6& a);
address_v4 make_address_v4(const char* str);
address_v4 make_address_v4(const char* str, error_code& ec) noexcept;
address_v4 make_address_v4(const string& str);
address_v4 make_address_v4(const string& str, error_code& ec) noexcept;
address_v4 make_address_v4(string_view str);
address_v4 make_address_v4(string_view str, error_code& ec) noexcept;

[21.5.7, address_v4 I/O:
template<class CharT, class Traits>
basic_ostream<CharT, Traits>& operator<<(basic_ostream<CharT, Traits>& os, const address_v4& addr);

§ 21.5.1 Struct ip::address_v4::bytes_type
namespace std {
namespace experimental {
namespace net {
inline namespace std::experimental::net::inline v1 {
namespace ip {
struct address_v4::bytes_type : array<unsigned char, 4>
{
    template<class... T> explicit constexpr bytes_type(T... t)
        : array<unsigned char, 4>{{static_cast<unsigned char>(t)...}} {} 
};
} // namespace ip
} // namespace std::experimental::net::inline v1
} // namespace net
} // namespace experimental
} // namespace std
} // namespace ip

address_v4 satisfies the requirements for Destructible Cpp17Destructible (C++ 2020 [destructible]), CopyConstructible Cpp17CopyConstructible (C++ 2020 [copyconstructible]), and CopyAssignable Cpp17CopyAssignable (C++ 2020 [copyassignable]).
1 The \texttt{ip::address\_v4::bytes\_type} type is a standard-layout struct that provides a byte-level representation of an IPv4 address in network byte order.

\subsection*{21.5.2 \texttt{ip::address\_v4} constructors} \hfill \cite{internet.address.v4.cons}

\begin{itemize}
  \item \texttt{constexpr address\_v4() noexcept;}
    \begin{itemize}
      \item \texttt{Postconditions: to\_bytes()} yields \{0, 0, 0, 0\} and \texttt{to\_uint() == 0}.
    \end{itemize}
  \item \texttt{constexpr address\_v4(const \texttt{bytes\_type}\& \texttt{bytes});}
    \begin{itemize}
      \item \texttt{Remarks: }\underline{\texttt{Throws: out\_of\_range}} if any element of \texttt{bytes} is not in the range \[0, 0xFF\]. \texttt{[Note: For implementations where \texttt{numeric\_limits<unsigned char>::max()} == 0xFF, no out-of-range detection is needed. --end note]}
      \item \texttt{Postconditions: to\_bytes()} == \texttt{bytes} and \texttt{to\_uint()} == \((\texttt{bytes}[0] \ll 24) \mid (\texttt{bytes}[1] \ll 16) \mid (\texttt{bytes}[2] \ll 8) \mid \texttt{bytes}[3].
    \end{itemize}
  \item \texttt{explicit constexpr address\_v4(address\_v4::uint\_type \texttt{val});}
    \begin{itemize}
      \item \texttt{Remarks: }\underline{\texttt{Throws: out\_of\_range}} if \texttt{val} is not in the range \[0, 0xFFFFFFFF\]. \texttt{[Note: For implementations where \texttt{numeric\_limits<Address\_v4::uint\_type>::max()} == 0xFFFFFFFF, no out-of-range detection is needed. --end note]}
      \item \texttt{Postconditions: to\_uint()} == \texttt{val} and \texttt{to\_bytes()} is:
        \{
        (\texttt{val} >> 24) & 0xFF, (\texttt{val} >> 16) & 0xFF, (\texttt{val} >> 8) & 0xFF, \texttt{val} & 0xFF \}
    \end{itemize}
\end{itemize}

\subsection*{21.5.3 \texttt{ip::address\_v4} members} \hfill \cite{internet.address.v4.members}

\begin{itemize}
  \item \texttt{constexpr bool is\_unspecified() const noexcept;}
    \begin{itemize}
      \item \texttt{Returns: \texttt{to\_uint() == 0}.}
    \end{itemize}
  \item \texttt{constexpr bool is\_loopback() const noexcept;}
    \begin{itemize}
      \item \texttt{Returns: (to\_uint() & 0xFF000000) == 0x7F000000.}
    \end{itemize}
  \item \texttt{constexpr bool is\_multicast() const noexcept;}
    \begin{itemize}
      \item \texttt{Returns: (to\_uint() & 0xF0000000) == 0xE0000000.}
    \end{itemize}
  \item \texttt{constexpr \texttt{bytes\_type} to\_bytes() const noexcept;}
    \begin{itemize}
      \item \texttt{Returns: A representation of the address in network byte order (3.2).}
    \end{itemize}
  \item \texttt{constexpr address\_v4::uint\_type to\_uint() const noexcept;}
    \begin{itemize}
      \item \texttt{Returns: A representation of the address in host byte order (3.1).}
    \end{itemize}
  \item \texttt{template<class Allocator = allocator<char>> basic\_string<char, char\_traits<char>, Allocator> to\_string(const Allocator& a = Allocator()) const;}
    \begin{itemize}
      \item \texttt{Returns: If successful, the textual representation of the address, determined as if by POSIX \texttt{inet\_ntop}} when invoked with address family \texttt{AF\_INET}. Otherwise \texttt{basic\_string<char, char\_traits<char>, Allocator>(a).}
    \end{itemize}
\end{itemize}
21.5.4 ip::address_v4 static members

static constexpr address_v4 any() noexcept;
1 Returns: address_v4().

static constexpr address_v4 loopback() noexcept;
2 Returns: address_v4(0x7F000001).

static constexpr address_v4 broadcast() noexcept;
3 Returns: address_v4(0xFFFFFFFF).

21.5.5 ip::address_v4 comparisons

constexpr bool operator==(const address_v4& a, const address_v4& b) noexcept;
1 Returns: a.to_uint() == b.to_uint().

constexpr bool operator!=(const address_v4& a, const address_v4& b) noexcept;
2 Returns: !(a == b).

constexpr bool operator<(const address_v4& a, const address_v4& b) noexcept;
3 Returns: a.to_uint() < b.to_uint().

constexpr bool operator>(const address_v4& a, const address_v4& b) noexcept;
4 Returns: b < a.

constexpr bool operator<=(const address_v4& a, const address_v4& b) noexcept;
5 Returns: !(b < a).

constexpr bool operator>=(const address_v4& a, const address_v4& b) noexcept;
6 Returns: !(a < b).

constexpr strong_ordering operator<=>(const address_v4& a, const address_v4& b) noexcept;
7 Returns: a.to_uint() <=> b.to_uint().

21.5.6 ip::address_v4 creation

constexpr address_v4 make_address_v4(const address_v4::bytes_type& bytes);
1 Returns: address_v4(bytes).

constexpr address_v4 make_address_v4(address_v4::uint_type val);
2 Returns: address_v4(val).

constexpr address_v4 make_address_v4(v4_mapped_t, const address_v6& a);
3 Returns: An address_v4 object corresponding to the IPv4-mapped IPv6 address, as if computed by the following method:

    address_v6::bytes_type v6b = a.to_bytes();
    address_v4::bytes_type v4b(v6b[12], v6b[13], v6b[14], v6b[15]);
    return address_v4(v4b);

Remarks: Throws: bad_address_cast if a.is_v4_mapped() is false.
address_v4 make_address_v4(const char* str);
address_v4 make_address_v4(const char* str, error_code& ec) noexcept;
address_v4 make_address_v4(const string& str);
address_v4 make_address_v4(const string& str, error_code& ec) noexcept;
address_v4 make_address_v4(string_view str);
address_v4 make_address_v4(string_view str, error_code& ec) noexcept;

Effects: Converts a textual representation of an address into a corresponding address_v4 value, as if by POSIX inet_pton when invoked with address family AF_INET.

Returns: If successful, an address_v4 value corresponding to the string str. Otherwise address_v4().

Error conditions:

— errc::invalid_argument — if str is not a valid textual representation of an IPv4 address.

21.5.7 ip::address_v4 I/O

template<class CharT, class Traits>
basic_ostream<CharT, Traits>& operator<<(
basic_ostream<CharT, Traits>& os, const address_v4& addr);

Returns: os << addr.to_string().c_str().

21.6 Class ip::address_v6

The class address_v6 is a representation of an IPv6 address.

namespace std {
    namespace experimental {
        namespace net {
            inline namespace std::experimental::net::inline_v1v2 {
                namespace ip {
                    class address_v6 {
                        public:
                            // 21.6.1, types:
                            struct bytes_type;

                            // 21.6.2, constructors:
                            constexpr address_v6() noexcept;
                            constexpr address_v6(const address_v6& a) noexcept;
                            constexpr address_v6(const bytes_type& bytes,
                                                  scope_id_type scope = 0);

                            // assignment:
                            address_v6& operator=(const address_v6& a) noexcept;

                            // 21.6.3, members:
                            void scope_id(scope_id_type id) const noexcept;
                            constexpr scope_id_type scope_id() const noexcept;
                            constexpr bool is_unspecified() const noexcept;
                            constexpr bool is_loopback() const noexcept;
                            constexpr bool is_multicast() const noexcept;
                            constexpr bool is_link_local() const noexcept;
                            constexpr bool is_site_local() const noexcept;
                            constexpr bool is_v4_mapped() const noexcept;
                            constexpr bool is_multicast_node_local() const noexcept;
                        }
                    }
                }
            }
        }
    }
}

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constexpr bool is_multicast_link_local() const noexcept;
constexpr bool is_multicast_site_local() const noexcept;
constexpr bool is_multicast_org_local() const noexcept;
constexpr bool is_multicast_global() const noexcept;
constexpr bytes_type to_bytes() const noexcept;

template<class Allocator = allocator<char>>
basic_string<char, char_traits<char>, Allocator>
to_string(const Allocator& a = Allocator()) const;

// 21.6.4, static members:
static constexpr address_v6 any() noexcept;
static constexpr address_v6 loopback() noexcept;

// 21.6.5, address_v6 comparisons:
constexpr bool operator==(const address_v6& a, const address_v6& b) noexcept;
constexpr bool operator!=(const address_v6& a, const address_v6& b) noexcept;
constexpr bool operator<(const address_v6& a, const address_v6& b) noexcept;
constexpr bool operator<=(const address_v6& a, const address_v6& b) noexcept;
constexpr bool operator>(const address_v6& a, const address_v6& b) noexcept;
constexpr bool operator>=(const address_v6& a, const address_v6& b) noexcept;
constexpr strong_ordering operator<=>(const address_v6& a, const address_v6& b) noexcept;

// 21.6.6, address_v6 creation:
constexpr address_v6 make_address_v6(const address_v6::bytes_type& bytes, scope_id_type scope_id = 0);
constexpr address_v6 make_address_v6(v4_mapped_t, const address_v4& a) noexcept;
address_v6 make_address_v6(const char* str);
address_v6 make_address_v6(const char* str, error_code& ec) noexcept;
address_v6 make_address_v6(const string& str);
address_v6 make_address_v6(const string& str, error_code& ec) noexcept;
address_v6 make_address_v6(string_view str);
address_v6 make_address_v6(string_view str, error_code& ec) noexcept;

// 21.6.7, address_v6 I/O:
template<class CharT, class Traits>
basic_ostream<CharT, Traits>& operator<<(basic_ostream<CharT, Traits>& os, const address_v6& addr);

} // namespace ip
} // inline namespace std::experimental::net::v1
└> // namespace net
└> // namespace experimental
└> // namespace std

address_v6 satisfies the requirements for Destructible Cpp17Destructible (C++ 2020 [destructible]),
CopyConstructible Cpp17CopyConstructible (C++ 2020 [copyconstructible]), and CopyAssignable Cpp17CopyAssignable
(C++ 2020 [copyassignable]).

[Note: The implementations of the functions is_unspecified, is_loopback, is_multicast, is_link-local, is_site_local, is_v4_mapped, is_multicast_node_local, is_multicast_link_local, is_multicast_site_local, is_multicast_org_local and is_multicast_global are determined by [RFC4291]. —end note]

21.6.1 Struct ip::address_v6::bytes_type
namespace std {
namespace experimental {
namespace net {
inline namespace std::experimental::net::inline v1v2 {
namespace ip {

struct address_v6::bytes_type : array<unsigned char, 16> {
    template<class... T> explicit constexpr bytes_type(T... t)
        : array<unsigned char, 16>{{static_cast<unsigned char>(t)...}} {}{}
};

} // namespace ip
} // inline namespace std::experimental::net::v1v2
} // namespace net
} // namespace experimental
} // namespace std

The ip::address_v6::bytes_type type is a standard-layout struct that provides a byte-level representation of an IPv6 address in network byte order.

21.6.2 ip::address_v6 constructors

```cpp
constexpr address_v6() noexcept;
```

Postconditions: is_unspecified() == true and scope_id() == 0.

```cpp
constexpr address_v6(const bytes_type& bytes,
    scope_id_type scope = 0);
```

Remarks: Throws: out_of_range if any element of bytes is not in the range [0, 0xFF]. [Note: For implementations where numeric_limits<unsigned char>::max() == 0xFF, no out-of-range detection is needed. —end note]

Postconditions: to_bytes() == bytes and scope_id() == scope.

21.6.3 ip::address_v6 members

```cpp
void scope_id(scope_id_type id) noexcept;
```

Postconditions: scope_id() == id.

```cpp
constexpr scope_id_type scope_id() const noexcept;
```

Returns: The scope identifier associated with the address.

```cpp
constexpr bool is_unspecified() const noexcept;
```

Returns: *this == make_address_v6("::").

```cpp
constexpr bool is_loopback() const noexcept;
```

Returns: *this == make_address_v6("::1").

```cpp
constexpr bool is_multicast() const noexcept;
```

Returns: A boolean indicating whether the address_v6 object represents a multicast address, as if computed by the following method:

```cpp
bytes_type b = to_bytes();
return b[0] == 0xFF;
```
constexpr bool is_link_local() const noexcept;

Returns: A boolean indicating whether the address_v6 object represents a unicast link-local address, as if computed by the following method:

```c
bytes_type b = to_bytes();
return b[0] == 0xFE && (b[1] & 0xC0) == 0x80;
```

constexpr bool is_site_local() const noexcept;

Returns: A boolean indicating whether the address_v6 object represents a unicast site-local address, as if computed by the following method:

```c
bytes_type b = to_bytes();
return b[0] == 0xFE && (b[1] & 0xC0) == 0xC0;
```

constexpr bool is_v4_mapped() const noexcept;

Returns: A boolean indicating whether the address_v6 object represents an IPv4-mapped IPv6 address, as if computed by the following method:

```c
bytes_type b = to_bytes();
return b[0] == 0 && b[1] == 0 && b[2] == 0 && b[3] == 0 &&
```

constexpr bool is_multicast_node_local() const noexcept;

Returns: is_multicast() && (to_bytes()[1] & 0x0F) == 0x01.

constexpr bool is_multicast_link_local() const noexcept;

Returns: is_multicast() && (to_bytes()[1] & 0x0F) == 0x02.

constexpr bool is_multicast_site_local() const noexcept;

Returns: is_multicast() && (to_bytes()[1] & 0x0F) == 0x05.

constexpr bool is_multicast_org_local() const noexcept;

Returns: is_multicast() && (to_bytes()[1] & 0x0F) == 0x08.

constexpr bool is_multicast_global() const noexcept;

Returns: is_multicast() && (to_bytes()[1] & 0x0F) == 0x0E.

constexpr bytes_type to_bytes() const noexcept;

Returns: A representation of the address in network byte order (3.2).

```c
template<class Allocator = allocator<char>>
basic_string<char, char_traits<char>, Allocator> to_string(const Allocator& a = Allocator()) const;
```

Effects: Converts an address into a textual representation. If scope_id() == 0, converts as if by POSIX inet_ntop when invoked with address family AF_INET6. If scope_id() != 0, the format is address%scope-id, where address is the textual representation of the equivalent address having scope_id() == 0, and scope-id is an implementation-defined textual representation of the scope identifier.

Returns: If successful, the textual representation of the address. Otherwise basic_string<char, char_traits<char>, Allocator>(a).
21.6.4  ip::address_v6 static members

static constexpr address_v6 any() noexcept;

Returns: An address a such that the a.is_unspecified() == true and a.scope_id() == 0.

static constexpr address_v6 loopback() noexcept;

Returns: An address a such that the a.is_loopback() == true and a.scope_id() == 0.

21.6.5  ip::address_v6 comparisons

constexpr bool operator==(const address_v6& a, const address_v6& b) noexcept;

Returns: a.to_bytes() == b.to_bytes() && a.scope_id() == b.scope_id() .

constexpr bool operator!=(const address_v6& a, const address_v6& b) noexcept;

Returns: !(a == b) .

constexpr bool operator< (const address_v6& a, const address_v6& b) noexcept;

Returns: tie(a.to_bytes(), a.scope_id()) < tie(b.to_bytes(), b.scope_id()) .

constexpr bool operator> (const address_v6& a, const address_v6& b) noexcept;

Returns: b < a .

constexpr bool operator<=(const address_v6& a, const address_v6& b) noexcept;

Returns: !(b < a) .

constexpr bool operator>=(const address_v6& a, const address_v6& b) noexcept;

Returns: !(a < b) .

constexpr strong_ordering operator<=>(const address_v6& a, const address_v6& b) noexcept;

Returns: tie(a.to_bytes(), a.scope_id()) <=> tie(b.to_bytes(), b.scope_id()) .

21.6.6  ip::address_v6 creation

constexpr address_v6 make_address_v6(const address_v6::bytes_type& bytes,
    scope_id_type scope_id);

Returns: address_v6(bytes, scope_id) .

constexpr address_v6 make_address_v6(v4_mapped_t, const address_v4& a) noexcept;

Returns: An address_v6 object containing the IPv4-mapped IPv6 address corresponding to the
    specified IPv4 address, as if computed by the following method:

address_v4::bytes_type v4b = a.to_bytes();
address_v6::bytes_type v6b(0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
    0xFF, 0xFF, v4b[0], v4b[1], v4b[2], v4b[3]);

return address_v6(v6b);

address_v6 make_address_v6(const char* str);
address_v6 make_address_v6(const char* str, error_code& ec) noexcept;
address_v4 make_address_v6(const string& str);
address_v4 make_address_v6(const string& str, error_code& ec) noexcept;
address_v6 make_address_v6(string_view str);
address_v6 make_address_v6(string_view str, error_code& ec) noexcept;
Effects: Converts a textual representation of an address into a corresponding `address_v6` value. The format is either `address` or `address%scope-id`, where `address` is in the format specified by POSIX `inet_pton` when invoked with address family `AF_INET6`, and `scope-id` is an optional string specifying the scope identifier. All implementations accept as `scope-id` a textual representation of an unsigned decimal integer. It is implementation-defined whether alternative scope identifier representations are permitted. If `scope-id` is not supplied, an `address_v6` object is returned such that `scope_id()` == 0.

Returns: If successful, an `address_v6` value corresponding to the string `str`. Otherwise returns `address_v6()`.

Error conditions:

— `errc::invalid_argument` — if `str` is not a valid textual representation of an IPv6 address.

21.6.7 ip::address_v6 I/O

```
template<class CharT, class Traits>
basic_ostream<CharT, Traits>& operator<<(basic_ostream<CharT, Traits>& os, const address_v6& addr);
```

Returns: `os << addr.to_string().c_str()`.

21.7 Class ip::bad_address_cast

An exception of type `bad_address_cast` is thrown by a failed `address_cast`.

```
namespace std {
namespace experimental {
namespace net {
inline namespace std::experimental::net::inline v1v2 {
namespace ip {

class bad_address_cast : public bad_cast {
public:
  // constructor:
  bad_address_cast() noexcept;

}; // namespace ip
} // inline namespace std::experimental::net::inline v1v2
} // namespace net
} // namespace experimental
} // namespace std

bad_address_cast() noexcept;
```

Effects: constructs a `bad_address_cast` object.

Postconditions: `what()` returns an implementation-defined NTBS.

21.8 Hash support

```
template<> struct hash<experimental::net::v1v2::ip::address>;
template<> struct hash<experimental::net::v1v2::ip::address_v4>;
template<> struct hash<experimental::net::v1v2::ip::address_v6>;
```

Requires: the template specializations shall meet the requirements of class template `hash` (C++ 2020 [unord.hash]).

The template specializations are enabled (C++ 2020 [unord.hash]).
21.9 Class template `ip::basic_address_iterator` specializations

The class template `basic_address_iterator` enables iteration over IP addresses in network byte order. This clause defines two specializations of the class template `basic_address_iterator<address_v4>` and `basic_address_iterator<address_v6>`. The members and operational semantics of these specializations are defined below.

```cpp
namespace std {
namespace experimental {
namespace net {

// Specializations

namespace ip {

template<> class basic_address_iterator<Address> {
public:
    // types:
    using value_type = Address;
    using difference_type = ptrdiff_t;
    using pointer = const Address*;
    using reference = const Address&;
    using iterator_category = input_iterator_tag;

    // constructors:
    basic_address_iterator(const Address& a) noexcept;

    // members:
    reference operator*() const noexcept;
    pointer operator->() const noexcept;
    basic_address_iterator& operator++() noexcept;
    basic_address_iterator operator++(int) noexcept;
    basic_address_iterator& operator--() noexcept;
    basic_address_iterator operator--(int) noexcept;

    // other members as required by C++ 2020 [input.iterators]

private:
    Address address_; // exposition only
};

} // namespace ip
} // inline namespace std::experimental::net::v1v2
} // namespace net
} // namespace experimental
} // namespace std
```

Specializations of `basic_address_iterator` satisfy the requirements for input iterators (C++ 2020 [input.iterators]).

1. `basic_address_iterator(const Address& a) noexcept;`
   ```cpp
   Effects: Initializes `address_` with `a`.
   ```

2. `reference operator*() const noexcept;`
   ```cpp
   Returns: `address_`
   ```

3. `pointer operator->() const noexcept;`

4. `basic_address_iterator(const Address& a) noexcept;`
   ```cpp
   Effects: Initializes `address_` with `a`.
   ```

5. `reference operator*() const noexcept;`
   ```cpp
   Returns: `address_`
   ```

6. `pointer operator->() const noexcept;`
Returns: `addressof(address_)`.

```cpp
basic_address_iterator& operator++() noexcept;
```

Effects: Sets `address_` to the next unique address in network byte order.

Returns: `*this`.

```cpp
basic_address_iterator operator++(int) noexcept;
```

Effects: Sets `address_` to the next unique address in network byte order.

Returns: The prior value of `*this`.

```cpp
basic_address_iterator& operator--() noexcept;
```

Effects: Sets `address_` to the prior unique address in network byte order.

Returns: `*this`.

```cpp
basic_address_iterator operator--(int) noexcept;
```

Effects: Sets `address_` to the prior unique address in network byte order.

Returns: The prior value of `*this`.

## 21.10 Class template ip::basic_address_range specializations

[internet.address.range]

The class template `basic_address_range` represents a range of IP addresses in network byte order. This clause defines two specializations of the class template `basic_address_range`: `basic_address_range<address_v4>` and `basic_address_range<address_v6>`. The members and operational semantics of these specializations are defined below.

```cpp
namespace std {
    namespace experimental {
        namespace net {
            namespace std::experimental::net::inline_v1v2 {
                namespace ip {

                    template<> class basic_address_range<Address>
                    {
                        public:
                            // types:
                            using iterator = basic_address_iterator<Address>;

                            // constructors:
                            basic_address_range() noexcept;
                            basic_address_range(const Address& first, const Address& last) noexcept;

                            // members:
                            iterator begin() const noexcept;
                            iterator end() const noexcept;
                            bool empty() const noexcept;
                            size_t size() const noexcept; // not always defined
                            iterator find(const Address& addr) const noexcept;
                        };

                }
            }
        }
    }
}
```

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Specializations of `basic_address_range` satisfy the requirements for `DestructibleCpp17Destructible` (C++ 2020 [destructible]), `CopyConstructibleCpp17CopyConstructible` (C++ 2020 [copyconstructible]), and `CopyAssignableCpp17CopyAssignable` (C++ 2020 [copyassignable]).

```cpp
basic_address_range() noexcept;
```

**Effects:** Constructs an object of type `basic_address_range<Address>` that represents an empty range.

```cpp
basic_address_range(const Address& first, const Address& last) noexcept;
```

**Effects:** Constructs an object of type `basic_address_range<Address>` that represents the half-open range `[first, last)`. 

```cpp
iterator begin() const noexcept;
```

**Returns:** An iterator that points to the beginning of the range.

```cpp
iterator end() const noexcept;
```

**Returns:** An iterator that points to the end of the range.

```cpp
bool empty() const noexcept;
```

**Returns:** `true` if `*this` represents an empty range, otherwise `false`.

```cpp
size_t size() const noexcept;
```

**Returns:** The number of unique addresses in the range. [Editor's note: Should this be done with `Constraints`?]

**Remarks:** This member function is not defined when `Address` is type `address_v6`.

```cpp
iterator find(const Address& addr) const noexcept;
```

**Returns:** If `addr` is in the range, an iterator that points to `addr`; otherwise, `end()`.

**Complexity:** Constant time.

### 21.11 Class template `ip::network_v4` [internet.network.v4]

The class `network_v4` provides the ability to use and manipulate IPv4 network addresses.
constexpr network_v4(const address_v4& addr, const address_v4& mask);

// 21.11.2, members:
constexpr address_v4 address() const noexcept;
constexpr int prefix_length() const noexcept;
constexpr address_v4 netmask() const noexcept;
constexpr address_v4 network() const noexcept;
constexpr address_v4 broadcast() const noexcept;
address_v4_range hosts() const noexcept;
constexpr network_v4 canonical() const noexcept;
constexpr bool is_host() const noexcept;
constexpr bool is_subnet_of(const network_v4& other) const noexcept;

template<class Allocator = allocator<char>>
  basic_string<char, char_traits<char>, Allocator>
to_string(const Allocator& a = Allocator()) const;

// 21.11.3, network_v4 comparisons:
constexpr bool operator==(const network_v4& a, const network_v4& b) noexcept;
constexpr bool operator!=(const network_v4& a, const network_v4& b) noexcept;

// 21.11.4, network_v4 creation:
constexpr network_v4 make_network_v4(const address_v4& addr, int prefix_len);
constexpr network_v4 make_network_v4(const address_v4& addr, const address_v4& mask);
network_v4 make_network_v4(const char* str);
network_v4 make_network_v4(const char* str, error_code& ec) noexcept;
network_v4 make_network_v4(const string& str);
network_v4 make_network_v4(const string& str, error_code& ec) noexcept;
network_v4 make_network_v4(string_view str);
network_v4 make_network_v4(string_view str, error_code& ec) noexcept;

// 21.11.5, network_v4 I/O:
template<class CharT, class Traits>
  basic_ostream<CharT, Traits>& operator<<(basic_ostream<CharT, Traits>& os, const network_v4& net);

} // namespace ip
} // inline namespace std::experimental::net::v2
} // namespace std::experimental
} // namespace std

2 network_v4 satisfies the requirements for Destructible Cpp17Destructible (C++ 2020 [destructible]),
CopyConstructible Cpp17CopyConstructible (C++ 2020 [copyconstructible]), and CopyAssignable Cpp17CopyAssignable
(C++ 2020 [copyassignable]).

21.11.1 ip::network_v4 constructors [internet.network.v4.cons]

constexpr network_v4() noexcept;

Postconditions: this->address().is_unspecified() == true and prefix_length() == 0.

constexpr network_v4(const address_v4& addr, int prefix_len);

Postconditions: this->address() == addr and prefix_length() == prefix_len.

Remarks: Throws: out_of_range if prefix_len < 0 or prefix_len > 32.
constexpr network_v4(const address_v4& addr, const address_v4& mask);

Postconditions: this->address() == addr and prefix_length() is equal to the number of contiguous non-zero bits in mask.

Remarks: Throws: invalid_argument if mask contains non-contiguous non-zero bits, or if the most significant bit is zero and any other bits are non-zero.

21.11.2  ip::network_v4 members

constexpr address_v4 address() const noexcept;

Returns: The address specified when the network_v4 object was constructed.

constexpr int prefix_length() const noexcept;

Returns: The prefix length of the network.

constexpr address_v4 netmask() const noexcept;

Returns: An address_v4 object with prefix_length() contiguous non-zero bits set, starting from the most significant bit in network byte order. All other bits are zero.

constexpr address_v4 network() const noexcept;

Returns: An address_v4 object with the first prefix_length() bits, starting from the most significant bit in network byte order, set to the corresponding bit value of this->address(). All other bits are zero.

constexpr address_v4 broadcast() const noexcept;

Returns: An address_v4 object with the first prefix_length() bits, starting from the most significant bit in network byte order, set to the corresponding bit value of this->address(). All other bits are non-zero.

address_v4_range hosts() const noexcept;

Returns: If is_host() is true, an address_v4_range object representing the single address this->address(). Otherwise, an address_v4_range object representing the range of unique host IP addresses in the network.

[Note: For IPv4, the network address and the broadcast address are not included in the range of host IP addresses. For example, given a network 192.168.1.0/24, the range returned by hosts() is from 192.168.1.1 to 192.168.1.254 inclusive, and neither 192.168.1.0 nor the broadcast address 192.168.1.255 are in the range. — end note]

constexpr network_v4 canonical() const noexcept;

Returns: network_v4(network(), prefix_length()).

constexpr bool is_host() const noexcept;

Returns: prefix_length() == 32.

constexpr bool is_subnet_of(const network_v4& other) const noexcept;

Returns: true if other.prefix_length() < prefix_length() and network_v4(this->address(), other.prefix_length()).canonical() == other.canonical(), otherwise false.

template<class Allocator = allocator<char>>
basic_string<char, char_traits<char>, Allocator>
to_string(const Allocator& a = Allocator()) const;

Returns: this->address().to_string(a) + "/" + std::to_string(prefix_length()).
21.11.3 ip::network_v4 comparisons

constexpr bool operator==(const network_v4& a, const network_v4& b) noexcept;

Returns: true if a.address() == b.address() and a.prefix_length() == b.prefix_length(), otherwise false.

constexpr bool operator!=(const network_v4& a, const network_v4& b) noexcept;

Returns: !(a == b).

21.11.4 ip::network_v4 creation

constexpr network_v4 make_network_v4(const address_v4& addr, int prefix_len);

Returns: network_v4(addr, prefix_len).

constexpr network_v4 make_network_v4(const address_v4& addr, const address_v4& mask);

Returns: network_v4(addr, mask).

network_v4 make_network_v4(const char* str);

network_v4 make_network_v4(const char* str, error_code& ec) noexcept;

network_v4 make_network_v4(const string& str);

network_v4 make_network_v4(const string& str, error_code& ec) noexcept;

network_v4 make_network_v4(string_view str);

network_v4 make_network_v4(string_view str, error_code& ec) noexcept;

Returns: If str contains a value of the form address '/prefix-length', a network_v4 object constructed with the result of applying make_address_v4() to the address portion of the string, and the result of converting prefix-length to an integer of type int. Otherwise returns network_v4() and sets ec to reflect the error.

Error conditions:

— errc::invalid_argument — if str is not a valid textual representation of an IPv4 address and prefix length.

21.11.5 ip::network_v4 I/O

template<class CharT, class Traits>

basic_ostream<CharT, Traits>& operator<<(basic_ostream<CharT, Traits>& os, const network_v4& net);

Returns: os << net.to_string().c_str().

21.12 Class template ip::network_v6

The class network_v6 provides the ability to use and manipulate IPv6 network addresses.

namespace std {
namespace experimental {  
namespace net { 

inline namespace std::experimental::net::inline v1v2 {

namespace ip {

class network_v6
{
public:

// 21.12.1, constructors:
constexpr network_v6() noexcept;
constexpr network_v6(const address_v6& addr, int prefix_len);

// 21.12.2, members:
constexpr address_v6 address() const noexcept;
constexpr int prefix_length() const noexcept;
constexpr address_v6 network() const noexcept;
address_v6_range hosts() const noexcept;
constexpr network_v6 canonical() const noexcept;
constexpr bool is_host() const noexcept;
constexpr bool is_subnet_of(const network_v6& other) const noexcept;
template<class Allocator = allocator<char>>
    basic_string<Char, char_traits<Char>, Allocator>
to_string(const Allocator& a = Allocator()) const;

// 21.12.3, network_v6 comparisons:
constexpr bool operator==(const network_v6& a, const network_v6& b) noexcept;
constexpr bool operator!=(const network_v6& a, const network_v6& b) noexcept;

// 21.12.4, network_v6 creation:
constexpr network_v6 make_network_v6(const address_v6& addr, int prefix_len);
network_v6 make_network_v6(const char* str);
network_v6 make_network_v6(const char* str, error_code& ec) noexcept;
network_v6 make_network_v6(const string& str);
network_v6 make_network_v6(const string& str, error_code& ec) noexcept;
network_v6 make_network_v6(string_view str);
network_v6 make_network_v6(string_view str, error_code& ec) noexcept;

// 21.12.5, network_v6 I/O:
template<class CharT, class Traits>
    basic_ostream<CharT, Traits>& operator<<(
        basic_ostream<CharT, Traits>& os, const network_v6& net);

} // namespace ip
} // inline namespace std::experimental::net::v2
} // namespace net
} // namespace experimental
} // namespace std

network_v6 satisfies the requirements for Destructible Cpp17Destructible (C++ 2020 [destructible]),
CopyConstructible Cpp17CopyConstructible (C++ 2020 [copyconstructible]), and CopyAssignable Cpp17CopyAssignable
(C++ 2020 [copyassignable]).

21.12.1 ip::network_v6 constructors
constexpr network_v6() noexcept;
1 Postconditions: this->address().is_unspecified() == true and prefix_length() == 0.

constexpr network_v6(const address_v6& addr, int prefix_len);
2 Postconditions: this->address() == addr and prefix_length() == prefix_len.
3 Remarks: Throws: out_of_range if prefix_len < 0 or prefix_len > 128.

21.12.2 ip::network_v6 members

§ 21.12.2
constexpr address_v6 address() const noexcept;

Returns: The address specified when the network_v6 object was constructed.

constexpr int prefix_length() const noexcept;

Returns: The prefix length of the network.

constexpr address_v6 network() const noexcept;

Returns: An address_v6 object with the first prefix_length() bits, starting from the most significant bit in network byte order, set to the corresponding bit value of this->address(). All other bits are zero.

address_v6_range hosts() const noexcept;

Returns: If is_host() is true, an address_v6_range object representing the single address this->address(). Otherwise, an address_v6_range object representing the range of unique host IP addresses in the network.

constexpr network_v6 canonical() const noexcept;

Returns: network_v6(network(), prefix_length()).

constexpr bool is_host() const noexcept;

Returns: prefix_length() == 128.

constexpr bool is_subnet_of(const network_v6& other) const noexcept;

Returns: true if other.prefix_length() < prefix_length() and network_v6(this->address(), other.prefix_length()).canonical() == other.canonical(), otherwise false.

template<class Allocator = allocator<char>>
basic_string<char, char_traits<char>, Allocator> to_string(const Allocator& a = Allocator()) const;

Returns: this->address().to_string(a) + "/" + to_string(prefix_length()).c_str().

21.12.3  ip::network_v6 comparisons [internet.network.v6.comparisons]

constexpr bool operator==(const network_v6& a, const network_v6& b) noexcept;

Returns: true if a.address() == b.address() and a.prefix_length() == b.prefix_length(), otherwise false.

constexpr bool operator!=(const network_v6& a, const network_v6& b) noexcept;

Returns: !(a == b).

21.12.4  ip::network_v6 creation [internet.network.v6.creation]

constexpr network_v6 make_network_v6(const address_v6& addr, int prefix_len);

Returns: network_v6(addr, prefix_len).

network_v6 make_network_v6(const char* str);

network_v6 make_network_v6(const char* str, error_code& ec) noexcept;

network_v6 make_network_v6(const string& str);

network_v6 make_network_v6(const string& str, error_code& ec) noexcept;

network_v6 make_network_v6(string_view str);

network_v6 make_network_v6(string_view str, error_code& ec) noexcept;
Returns: If `str` contains a value of the form `address '/' prefix-length`, a `network_v6` object constructed with the result of applying `make_address_v6()` to the address portion of the string, and the result of converting `prefix-length` to an integer of type `int`. Otherwise returns `network_v6()` and sets `ec` to reflect the error.

Error conditions:

- `errc::invalid_argument` — if `str` is not a valid textual representation of an IPv6 address and `prefix length`.

### 21.12.5 `ip::network_v6` I/O

```
21.12.5 ip::network_v6 I/O [internet.network.v6.io]

template<class CharT, class Traits>
    basic_ostream<CharT, Traits>& operator<<(char* os, const network_v6& net);
```

Returns: `os << net.to_string().c_str()`.

### 21.13 Class template `ip::basic_endpoint` [internet.endpoint]

An object of type `basic_endpoint<InternetProtocol>` represents a protocol-specific endpoint, where an endpoint consists of an IP address and port number. Endpoints may be used to identify sources and destinations for socket connections and datagrams.

```cpp
namespace std {
namespace experimental {
namespace net {
inline namespace std::experimental::net::inline_v1 v2 {
namespace ip {

    template<class InternetProtocol>
    class basic_endpoint {
    public:
        // types:
        using protocol_type = InternetProtocol;

        // 21.13.1, constructors:
        constexpr basic_endpoint() noexcept;
        constexpr basic_endpoint(const protocol_type& proto,
                                   port_type port_num) noexcept;
        constexpr basic_endpoint(const ip::address& addr,
                                   port_type port_num) noexcept;

        // 21.13.2, members:
        constexpr protocol_type protocol() const noexcept;
        constexpr ip::address address() const noexcept;
        void address(const ip::address& addr) noexcept;
        constexpr port_type port() const noexcept;
        void port(port_type port_num) noexcept;
    };

    // 21.13.3, basic_endpoint comparisons:
    template<class InternetProtocol>
    constexpr bool operator==(const basic_endpoint<InternetProtocol>& a,
                                const basic_endpoint<InternetProtocol>& b) noexcept;
```
constexpr bool operator!=(const basic_endpoint<InternetProtocol>& a, const basic_endpoint<InternetProtocol>& b) noexcept;

template<class InternetProtocol>
constexpr bool operator<(const basic_endpoint<InternetProtocol>& a, const basic_endpoint<InternetProtocol>& b) noexcept;

template<class InternetProtocol>
constexpr bool operator>(const basic_endpoint<InternetProtocol>& a, const basic_endpoint<InternetProtocol>& b) noexcept;

template<class InternetProtocol>
constexpr bool operator<=(const basic_endpoint<InternetProtocol>& a, const basic_endpoint<InternetProtocol>& b) noexcept;

template<class InternetProtocol>
constexpr bool operator>=(const basic_endpoint<InternetProtocol>& a, const basic_endpoint<InternetProtocol>& b) noexcept;

template<class InternetProtocol>
constexpr partial ordering operator<=>(const basic_endpoint<InternetProtocol>& a, const basic_endpoint<InternetProtocol>& b) noexcept;

// 21.13.4, basic_endpoint I/O:

namespace std
namespace experimental
namespace net
inline namespace std::experimental::net::v1
namespace ip {

template<class CharT, class Traits, class InternetProtocol>
basic_ostream<CharT, Traits>& operator<<(basic_ostream<CharT, Traits>& os, const basic_endpoint<InternetProtocol>& ep);

} // namespace ip
} // inline namespace
} // namespace std::experimental::net::inline
} // namespace std
} // namespace net
} // namespace experimental
} // namespace std

2 Specializations of the basic_endpoint class template meet the requirements for an Endpoint (18.2.4).

3 Extensible implementations provide the following member functions:

namespace std {
namespace experimental {
namespace net {
inline namespace std::experimental::net::inline v1v2 {

namespace ip {

    template<class InternetProtocol>
    class basic_endpoint {
    public:
        void* data() noexcept;
        const void* data() const noexcept;
        constexpr size_t size() const noexcept;
        void resize(size_t s);
        constexpr size_t capacity() const noexcept;
        // remainder unchanged
    private:
        union {
            sockaddr_in v4_;
            sockaddr_in6 v6_;
        }
    }


§ 21.13
21.13.1 ip::basic_endpoint constructors

```cpp
constexpr basic_endpoint() noexcept;

Postconditions: this->address() == ip::address() and port() == 0.
```

```cpp
constexpr basic_endpoint(const protocol_type& proto,
                       port_type port_num) noexcept;
```

```cpp
Requires: Preconditions: proto == protocol_type::v4() || proto == protocol_type::v6().

Postconditions:
1. If proto == protocol_type::v6(), this->address() == ip::address_v6(); otherwise,
   this->address() == ip::address_v4().
2. port() == port_num.
```

```cpp
constexpr basic_endpoint(const ip::address& addr,
                       port_type port_num) noexcept;
```

```cpp
Postconditions: this->address() == addr and port() == port_num.
```

21.13.2 ip::basic_endpoint members

```cpp
constexpr protocol_type protocol() const noexcept;

Returns: protocol_type::v6() if the expression this->address().is_v6() is true, otherwise
protocol_type::v4().
```

```cpp
constexpr ip::address address() const noexcept;

Returns: The address associated with the endpoint.
```

```cpp
void address(const ip::address& addr) noexcept;

Postconditions: this->address() == addr.
```

```cpp
constexpr port_type port() const noexcept;

Returns: The port number associated with the endpoint.
```

```cpp
void port(port_type port_num) noexcept;

Postconditions: port() == port_num.
```
21.13.3  `ip::basic_endpoint` comparisons

```cpp
template<class InternetProtocol>
constexpr bool operator==(const basic_endpoint<InternetProtocol>& a,
const basic_endpoint<InternetProtocol>& b) noexcept;

Returns: a.address() == b.address() && a.port() == b.port()
```

```cpp
template<class InternetProtocol>
constexpr bool operator!=(const basic_endpoint<InternetProtocol>& a,
const basic_endpoint<InternetProtocol>& b) noexcept;

Returns: !(a == b)
```

```cpp
template<class InternetProtocol>
constexpr bool operator<(const basic_endpoint<InternetProtocol>& a,
const basic_endpoint<InternetProtocol>& b) noexcept;

Returns: tie(a.address(), a.port()) < tie(b.address(), b.port())
```

```cpp
template<class InternetProtocol>
constexpr bool operator>(const basic_endpoint<InternetProtocol>& a,
const basic_endpoint<InternetProtocol>& b) noexcept;

Returns: b < a
```

```cpp
template<class InternetProtocol>
constexpr bool operator<=(const basic_endpoint<InternetProtocol>& a,
const basic_endpoint<InternetProtocol>& b) noexcept;

Returns: !(b < a)
```

```cpp
template<class InternetProtocol>
constexpr bool operator>=(const basic_endpoint<InternetProtocol>& a,
const basic_endpoint<InternetProtocol>& b) noexcept;

Returns: !(a < b)
```

```cpp
constexpr partial_ordering operator<=>(const basic_endpoint<InternetProtocol>& a,
const basic_endpoint<InternetProtocol>& b) noexcept;

Returns: tie(a.address(), a.port()) <=> tie(b.address(), b.port())
```

21.13.4  `ip::basic_endpoint` I/O

```cpp
template<class CharT, class Traits, class InternetProtocol>
basic_ostream<CharT, Traits>& operator<<(basic_ostream<CharT, Traits>& os,
basic_endpoint<InternetProtocol>& ep);

Effects: Outputs a representation of the endpoint to the stream, as if it were implemented as follows:
```
basic_ostringstream<CharT, Traits> ss;
if (ep.protocol() == basic_endpoint<InternetProtocol>::protocol_type::v6())
    ss << "[" << ep.address() << "]";
else
    ss << ep.address();
ss << ":" << ep.port();
os << ss.str();
```
Returns: os.

[Note: The representation of the endpoint when it contains an IP version 6 address is based on [RFC2732]. — end note]

### 21.13.5 ip::basic_endpoint members (extensible implementations)

[internet.endpoint.extensible]

```cpp
class basic_endpoint

    void* data() noexcept;
    Returns: addressof(data_).

    const void* data() const noexcept;
    Returns: addressof(data_).

    constexpr size_t size() const noexcept;
    Returns: sizeof(sockaddr_in6) if protocol().family() == AF_INET6, otherwise sizeof(sockaddr_in).

    void resize(size_t s);
```

#### Remarks

**Throws:** length_error if either of the following conditions is true:

1. protocol().family() == AF_INET6 && s != sizeof(sockaddr_in6),
2. protocol().family() == AF_INET4 && s != sizeof(sockaddr_in).

```cpp
    constexpr size_t capacity() const noexcept;
    Returns: sizeof(data_).
```

### 21.14 Class template ip::basic_resolver_entry

[internet.resolver.entry]

An object of type `basic_resolver_entry<InternetProtocol>` represents a single element in the results returned by a name resolution operation.

```cpp
namespace std {
    namespace experimental {
        namespace net {
            inline namespace std::experimental::net::inline v1v2 {
                namespace ip {
                    template<class InternetProtocol>
                    class basic_resolver_entry
                    {
                        public:
                            // types:
                            using protocol_type = InternetProtocol;
                            using endpoint_type = typename InternetProtocol::endpoint;

                            // 21.14.1, constructors:
                            basic_resolver_entry();
                            basic_resolver_entry(const endpoint_type& ep, string_view h, string_view s);

                            // 21.14.2, members:
```
endpoint_type endpoint() const;
operator endpoint_type() const;
template<class Allocator = allocator<char>>
    basic_string<char, char_traits<char>, Allocator>
        host_name(const Allocator& a = Allocator()) const;
template<class Allocator = allocator<char>>
    basic_string<char, char_traits<char>, Allocator>
        service_name(const Allocator& a = Allocator()) const;
};

// 21.14.3, basic_resolver_entry comparisons:
template<class InternetProtocol>
    bool operator==(const basic_resolver_entry<InternetProtocol>& a,
    const basic_resolver_entry<InternetProtocol>& b);
template<class
    bool operator!=(const basic_resolver_entry<InternetProtocol>& a,
    const basic_resolver_entry<InternetProtocol>& b);

} // namespace ip
} // inline namespace std::experimental::net::v2
} // namespace std::experimental
} // namespace net
} // namespace

21.14.1 ip::basic_resolver_entry constructors

basic_resolver_entry();

Effects: Equivalent to basic_resolver_entry<InternetProtocol>(endpoint_type(), "", ").

basic_resolver_entry(const endpoint_type& ep,
    string_view h,
    string_view s);

Postconditions:

(2.1) — endpoint() == ep.
(2.2) — host_name() == h.
(2.3) — service_name() == s.

21.14.2 ip::basic_resolver_entry members

endpoint_type endpoint() const;

Returns: The endpoint associated with the resolver entry.

operator endpoint_type() const;

Returns: endpoint().

template<class Allocator = allocator<char>>
    basic_string<char, char_traits<char>, Allocator>
        host_name(const Allocator& a = Allocator()) const;

Returns: The host name associated with the resolver entry.

Remarks: Ill-formed unless allocator_traits<Allocator>::value_type is char.

Mandates: is_same_v<allocator_traits<Allocator>::value_type, char> is true.
template<class Allocator = allocator<char>>
    basic_string<char, char_traits<char>, Allocator>
    service_name(const Allocator& a = Allocator()) const;

Returns: The service name associated with the resolver entry.

Remarks: Ill-formed unless allocator_traits<Allocator>::value_type is char.

Mandates: is_same_v<allocator_traits<Allocator>::value_type, char> is true.

21.14.3 op::basic_resolver_entry comparisons [internet.resolver.entry.comparisons]

template<class InternetProtocol>
bool operator==(const basic_resolver_entry<InternetProtocol>& a,
    const basic_resolver_entry<InternetProtocol>& b);

Returns: a.endpoint() == b.endpoint() && a.host_name() == b.host_name() && a.service_name() == b.service_name().

template<class InternetProtocol>
bool operator!=(const basic_resolver_entry<InternetProtocol>& a,
    const basic_resolver_entry<InternetProtocol>& b);

Returns: !(a == b).

21.15 Class template ip::basic_resolver_results [internet.resolver.results]

An object of type basic_resolver_results<InternetProtocol> represents a sequence of basic_resolver_entry<InternetProtocol> elements resulting from a single name resolution operation.

namespace std {
    namespace experimental {
        namespace net {
            inline namespace std::experimental::net::inline_v1v2 {
                namespace ip {

                template<class InternetProtocol>
                class basic_resolver_results
                {
                    public:
                        // types:
                        using protocol_type = InternetProtocol;
                        using endpoint_type = typename protocol_type::endpoint;
                        using value_type = basic_resolver_entry<protocol_type>;
                        using const_reference = const value_type&;
                        using reference = value_type&;
                        using const_iterator = implementation-defined;
                        using iterator = const_iterator;
                        using difference_type = ptrdiff_t;
                        using size_type = size_t;

                        // 21.15.1, construct / copy / destroy:
                        basic_resolver_results();
                        basic_resolver_results(const basic_resolver_results& rhs);
                        basic_resolver_results(basic_resolver_results&& rhs) noexcept;
                        basic_resolver_results& operator=(const basic_resolver_results& rhs);
                        basic_resolver_results& operator=(basic_resolver_results&& rhs);
                        ~basic_resolver_results();

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The class template `basic_resolver_results` satisfies the requirements of a sequence container (C++20 [sequence.reqmts]), except that only the operations defined for const-qualified sequence containers are supported. The class template `basic_resolver_results` supports forward iterators.

A default-constructed `basic_resolver_results` object is empty. A non-empty results object is obtained only by calling a `basic_resolver` object’s `wait` or `async_wait` operations, or otherwise by copy construction, move construction, assignment, or swap from another non-empty results object.

### 21.15.1 ip::basic_resolver_results constructors

```
basic_resolver_results();
```

**Postconditions:** `size() == 0`.

```
basic_resolver_results(const basic_resolver_results& rhs);
```

**Postconditions:** `*this == rhs`.

```
basic_resolver_results(basic_resolver_results&& rhs) noexcept;
```

**Postconditions:** `*this` is equal to the prior value of `rhs`.

### 21.15.2 ip::basic_resolver_results assignment

```
basic_resolver_results& operator=(const basic_resolver_results& rhs);
```

**Postconditions:** `*this == rhs`.

**Returns:** `*this`.
basic_resolver_results& operator=(basic_resolver_results& rhs) noexcept;

Postconditions: *this is equal to the prior value of rhs.

Returns: *this.

21.15.3 ip::basic_resolver_results size  
size_type size() const noexcept;

Returns: The number of basic_resolver_entry elements in *this.

size_type max_size() const noexcept;

Returns: The maximum number of basic_resolver_entry elements that can be stored in *this.

bool empty() const noexcept;

Returns: size() == 0.

21.15.4 ip::basic_resolver_results element access  
const_iterator begin() const;
const_iterator cbegin() const;

Returns: A starting iterator that enumerates over all the basic_resolver_entry elements stored in *this.

const_iterator end() const;
const_iterator cend() const;

Returns: A terminating iterator that enumerates over all the basic_resolver_entry elements stored in *this.

21.15.5 ip::basic_resolver_results swap  
void swap(basic_resolver_results& that) noexcept;

Postconditions: *this is equal to the prior value of that, and that is equal to the prior value of *this.

21.15.6 ip::basic_resolver_results comparisons  
template<class InternetProtocol>
bool operator==(const basic_resolver_results<InternetProtocol>& a, const basic_resolver_results<InternetProtocol>& b);

Returns: a.size() == b.size() && equal(a.cbegin(), a.cend(), b.cbegin()).

template<class InternetProtocol>
bool operator!=(const basic_resolver_results<InternetProtocol>& a, const basic_resolver_results<InternetProtocol>& b);

Returns: !(a == b).
21.16 Class ip::resolver_base

```cpp
namespace std {
    namespace experimental {
        namespace net {
            namespace std::experimental::net::inline_v1v2 {
                namespace ip {
                    class resolver_base {
                    public:
                        using flags = T1;
                        static const flags passive;
                        static const flags canonical_name;
                        static const flags numeric_host;
                        static const flags numeric_service;
                        static const flags v4_mapped;
                        static const flags all_matching;
                        static const flags address_configured;

                    protected:
                        resolver_base();
                        ~resolver_base();
                    };
                }
            } // namespace ip
        } // inline namespace std::experimental::net::v1v2
    } // namespace net
} // namespace experimental
} // namespace std
```

1 resolver_base defines a bitmask type, flags, with the bitmask elements shown in Table 37.

<table>
<thead>
<tr>
<th>Constant name</th>
<th>POSIX macro</th>
<th>Definition or notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>passive</td>
<td>AI_PASSIVE</td>
<td>Returned endpoints are intended for use as locally bound socket endpoints.</td>
</tr>
<tr>
<td>canonical_name</td>
<td>AI_CANONNAME</td>
<td>Determine the canonical name of the host specified in the query.</td>
</tr>
<tr>
<td>numeric_host</td>
<td>AI_NUMERICHOST</td>
<td>Host name should be treated as a numeric string defining an IPv4 or IPv6 address and no host name resolution should be attempted.</td>
</tr>
<tr>
<td>numeric_service</td>
<td>AI_NUMERICSERV</td>
<td>Service name should be treated as a numeric string defining a port number and no service name resolution should be attempted.</td>
</tr>
<tr>
<td>v4_mapped</td>
<td>AI_V4MAPPED</td>
<td>If the protocol is specified as an IPv6 protocol, return IPv4-mapped IPv6 addresses on finding no IPv6 addresses.</td>
</tr>
<tr>
<td>all_matching</td>
<td>AI_ALL</td>
<td>If used with v4_mapped, return all matching IPv6 and IPv4 addresses.</td>
</tr>
</tbody>
</table>
Table 37 — Resolver flags (continued)

<table>
<thead>
<tr>
<th>Constant name</th>
<th>POSIX macro</th>
<th>Definition or notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>address_configured</td>
<td>A1_ADDRCONFIG</td>
<td>Only return IPv4 addresses if a non-loopback IPv4 address is configured for the system. Only return IPv6 addresses if a non-loopback IPv6 address is configured for the system.</td>
</tr>
</tbody>
</table>

21.17 Class template `ip::basic_resolver` [internet.resolver]

Objects of type `basic_resolver<InternetProtocol>` are used to perform name resolution. Name resolution is the translation of a host name and service name into a sequence of endpoints, or the translation of an endpoint into its corresponding host name and service name.

```cpp
namespace std {
    namespace experimental {
        namespace net {
            inline namespace std::experimental::net::inline v1v2 {
                namespace ip {

                    template<class InternetProtocol>
                    class basic_resolver : public resolver_base {
                        public:
                            // types:
                            using executor_type = io_context::executor_type;
                            using protocol_type = InternetProtocol;
                            using endpoint_type = typename InternetProtocol::endpoint;
                            using results_type = basic_resolver_results<InternetProtocol>;

                            // 21.17.1, construct / copy / destroy:
                            explicit basic_resolver(io_context& ctx);
                            basic_resolver(const basic_resolver&) = delete;
                            basic_resolver(basic_resolver&& rhs) noexcept;
                            ~basic_resolver();
                            basic_resolver& operator=(const basic_resolver&) = delete;
                            basic_resolver& operator=(basic_resolver&& rhs);

                            // 21.17.4, basic Resolver operations:
                            executor_type get_executor() noexcept;
                            void cancel();

                            results_type resolve(string_view host_name, string_view service_name);
                            results_type resolve(string_view host_name, string_view service_name, error_code& ec);
                            results_type resolve(string_view host_name, string_view service_name, flags f);
                            results_type resolve(string_view host_name, string_view service_name, flags f, error_code& ec);

```
template<class CompletionToken>
    DEDUCED async_resolve(string_view host_name, string_view service_name,
        CompletionToken&& token);

template<class CompletionToken>
    DEDUCED async_resolve(string_view host_name, string_view service_name,
        flags f, CompletionToken&& token);

results_type resolve(const protocol_type& protocol,
    string_view host_name, string_view service_name);

results_type resolve(const protocol_type& protocol,
    string_view host_name, string_view service_name,
    error_code& ec);

results_type resolve(const protocol_type& protocol,
    string_view host_name, string_view service_name,
    flags f);

results_type resolve(const protocol_type& protocol,
    string_view host_name, string_view service_name,
    flags f, error_code& ec);

template<class CompletionToken>
    DEDUCED async_resolve(const protocol_type& protocol,
        string_view host_name, string_view service_name,
        CompletionToken&& token);

template<class CompletionToken>
    DEDUCED async_resolve(const protocol_type& protocol,
        string_view host_name, string_view service_name,
        flags f, CompletionToken&& token);

results_type resolve(const endpoint_type& e);

results_type resolve(const endpoint_type& e, error_code& ec);

template<class CompletionToken>
    DEDUCED async_resolve(const endpoint_type& e,
        CompletionToken&& token);

}; // namespace ip
} // inline namespace std::experimental::net::v2
} // namespace std

21.17.1 ip::basic_resolver constructors [internet.resolver.cons]

explicit basic_resolver(io_context& ctx);

Postconditions: get_executor() == ctx.get_executor().

basic_resolver(basic_resolver&& rhs) noexcept;

Effects: Move constructs an object of class basic_resolver<InternetProtocol> that refers to the
state originally represented by rhs.

Postconditions: get_executor() == rhs.get_executor().

§ 21.17.1
21.17.2  `ip::basic_resolver` destructor  

\[ \text{~basic resolver();} \]

\hspace{0.5cm} Effect: Destroys the resolver, canceling all asynchronous operations associated with this resolver as if by calling `cancel()`.

21.17.3  `ip::basic_resolver` assignment  

\[ \text{basic resolver& operator=(basic resolver& rhs);} \]

\hspace{0.5cm} Effect: Cancels all outstanding asynchronous operations associated with `*this` as if by calling `cancel()`, then moves into `*this` the state originally represented by `rhs`.

\hspace{0.5cm} Postconditions: `get_executor() == rhs.get_executor()`.

\hspace{0.5cm} Return: `*this`.

21.17.4  `ip::basic_resolver` operations  

\[ \text{executor type get executor() noexcept;} \]

\hspace{0.5cm} Return: The associated executor.

\[ \text{void cancel();} \]

\hspace{0.5cm} Effect: Cancels all outstanding asynchronous resolve operations associated with `*this`. Completion handlers for canceled operations are passed an error code `ec` such that `ec == errc::operation_canceled` yields true.

\hspace{0.5cm} Remarks: Does not block (C++ 2020 [defs.block]) the calling thread pending completion of the canceled operations.

\[ \text{results type resolve(string view host name, string view service name);} \]
\[ \text{results type resolve(string view host name, string view service name, error code& ec);} \]

\hspace{0.5cm} Return: `resolve(host name, service name, resolver_base::flags(), ec)`.

\[ \text{results type resolve(string view host name, string view service name, flags f);} \]
\[ \text{results type resolve(string view host name, string view service name, flags f, error code& ec);} \]

\hspace{0.5cm} Effect: If `host name.data() != nullptr`, let `H` be an `ntbs` constructed from `host name`; otherwise, let `H` be `nullptr`. If `service name.data() != nullptr`, let `S` be an `ntbs` constructed from `service name`; otherwise, let `S` be `nullptr`. Resolves a host name and service name, as if by POSIX:

\begin{verbatim}
  addrinfo hints;
  hints.ai_flags = static_cast<int>(f);
  hints.ai_family = AF_UNSPEC;
  hints.ai_socktype = endpoint_type().protocol().type();
  hints.ai_protocol = endpoint_type().protocol().protocol();
  hints.ai_addr = nullptr;
  hints.ai_addrlen = 0;
  hints.ai_canonname = nullptr;
  hints.ai_next = nullptr;
  addrinfo* result = nullptr;
  getaddrinfo(H, S, &hints, &result);
\end{verbatim}
Returns: On success, a non-empty results object containing the results of the resolve operation. Otherwise results_type().

```cpp
template<class CompletionToken>
DEDUCED async_resolve(string_view host_name, string_view service_name,
                       CompletionToken& token);
```

Returns:

```cpp
async_resolve(host_name, service_name, resolver_base::flags(),
               forward<CompletionToken>(token))
```

```cpp
template<class CompletionToken>
DEDUCED async_resolve(string_view host_name, string_view service_name,
                       flags f, CompletionToken& token);
```

Completion signature: void(error_code ec, results_type r).

Effects: If `host_name.data()` != nullptr, let H be an NTBS constructed from `host_name`; otherwise, let H be nullptr. If `service_name.data()` != nullptr, let S be an NTBS constructed from `service_name`; otherwise, let S be nullptr. Initiates an asynchronous operation to resolve a host name and service name, as if by POSIX:

```cpp
addinfo hints;
    hints.ai_flags = static_cast<int>(f);
    hints.ai_family = AF_UNSPEC;
    hints.ai_socktype = endpoint_type().protocol().type();
    hints.ai_protocol = endpoint_type().protocol().protocol();
    hints.ai_addr = nullptr;
    hints.ai_addrlen = 0;
    hints.ai_canonname = nullptr;
    hints.ai_next = nullptr;
    addrinfo* result = nullptr;
    getaddrinfo(H, S, &hints, &result);
```

On success, r is a non-empty results object containing the results of the resolve operation. Otherwise, r is results_type().

```cpp
results_type resolve(const protocol_type& protocol,
                     string_view host_name, string_view service_name);
```

```cpp
results_type resolve(const protocol_type& protocol,
                     string_view host_name, string_view service_name,
                     error_code& ec);
```

Returns: resolve(protocol, host_name, service_name, resolver_base::flags(), ec).

```cpp
results_type resolve(const protocol_type& protocol,
                     string_view host_name, string_view service_name,
                     flags f);
```

```cpp
results_type resolve(const protocol_type& protocol,
                     string_view host_name, string_view service_name,
                     flags f, error_code& ec);
```

Effects: If `host_name.data()` != nullptr, let H be an NTBS constructed from `host_name`; otherwise, let H be nullptr. If `service_name.data()` != nullptr, let S be an NTBS constructed from `service_name`; otherwise, let S be nullptr. Resolves a host name and service name, as if by POSIX:
addrinfo hints;
hints.ai_flags = static_cast<int>(f);
hints.ai_family = protocol.family();
hints.ai_socktype = protocol.type();
hints.ai_protocol = protocol.protocol();
hints.ai_addr = nullptr;
hints.ai_addrlen = 0;
hints.ai_canonname = nullptr;
hints.ai_next = nullptr;
addrinfo* result = nullptr;
getaddrinfo(H, S, &hints, &result);

Returns: On success, a non-empty results object containing the results of the resolve operation. Otherwise results_type().

template<class CompletionToken>
DEDUCED async_resolve(const protocol_type& protocol,
        string_view host_name, string_view service_name,
        CompletionToken&& token);

Returns:
async_resolve(protocol, host_name, service_name, resolver_base::flags(),
        forward<CompletionToken>(token))

template<class CompletionToken>
DEDUCED async_resolve(const protocol& protocol,
        string_view host_name, string_view service_name,
        flags f, CompletionToken&& token);

Completion signature: void(error_code ec, results_type r).

Effects: If host_name.data() != nullptr, let H be an NTBS constructed from host_name; otherwise, let H be nullptr. If service_name.data() != nullptr, let S be an NTBS constructed from service_name; otherwise, let S be nullptr. Initiates an asynchronous operation to resolve a host name and service name, as if by POSIX:

addrinfo hints;
hints.ai_flags = static_cast<int>(f);
hints.ai_family = protocol.family();
hints.ai_socktype = protocol.type();
hints.ai_protocol = protocol.protocol();
hints.ai_addr = nullptr;
hints.ai_addrlen = 0;
hints.ai_canonname = nullptr;
hints.ai_next = nullptr;
addrinfo* result = nullptr;
getaddrinfo(H, S, &hints, &result);

On success, r is a non-empty results object containing the results of the resolve operation. Otherwise, r is results_type().

results_type resolve(const endpoint_type& e);
results_type resolve(const endpoint_type& e, error_code& ec);

Effects: Let S1 and S2 be implementation-defined values that are sufficiently large to hold the host name and service name respectively. Resolves an endpoint as if by POSIX:
char host_name[S1];
char service_name[S2];
int flags = 0;
if (endpoint_type().protocol().type() == SOCK_DGRAM)
    flags |= NI_DGRAM;
int result = getnameinfo((const sockaddr*)e.data(), e.size(),
    host_name, S1,
    service_name, S2,
    flags);
if (result != 0)
{
    flags |= NI_NUMERICSERV;
    result = getnameinfo((const sockaddr*)e.data(), e.size(),
    host_name, S1,
    service_name, S2,
    flags);
}

Returns: On success, a results object with \texttt{size()} == 1 containing the results of the resolve operation. Otherwise \texttt{results_type()}. 

\template<class CompletionToken>
\texttt{DEDUCED async\_resolve(const endpoint\_type\& e,}
\texttt{CompletionToken\& token);} 

Completion signature: void(error\_code ec, results\_type r).

Effects: Let S1 and S2 be implementation-defined values that are sufficiently large to hold the host name and service name respectively. Initiates an asynchronous operation to resolve an endpoint as if by POSIX:

char host_name[S1];
char service_name[S2];
int flags = 0;
if (endpoint_type().protocol().type() == SOCK_DGRAM)
    flags |= NI_DGRAM;
int result = getnameinfo((const sockaddr*)e.data(), e.size(),
    host_name, S1,
    service_name, S2,
    flags);
if (result != 0)
{
    flags |= NI_NUMERICSERV;
    result = getnameinfo((const sockaddr*)e.data(), e.size(),
    host_name, S1,
    service_name, S2,
    flags);
}

On success, r is a results object with \texttt{size()} == 1 containing the results of the resolve operation; otherwise, r is \texttt{results\_type()}. 

\section{Host name functions} 

\texttt{string host\_name();}
\texttt{string host\_name(error\_code\& ec);} 
\template<class Allocator>
basic_string<char, char_traits<char>, Allocator>
host_name(const Allocator& a);

template<class Allocator>
basic_string<char, char_traits<char>, Allocator>
host_name(const Allocator& a, error_code& ec);

1 Returns: The standard host name for the current machine, determined as if by POSIX gethostname.

2 Remarks: In the last two overloads, ill-formed unless allocator_traits<Allocator>::value_type is char.

Mandates: For the last two overloads, is_same_v<allocator_traits<Allocator>::value_type, char> is true.

21.19 Class ip::tcp

The class tcp encapsulates the types and flags necessary for TCP sockets.

```cpp
namespace std {
namespace experimental {
namespace net {
inline namespace std::experimental::net::inline v1v2 {
namespace ip {

class tcp {

public:

// types:
using endpoint = basic_endpoint<tcp>;
using resolver = basic_resolver<tcp>;
using socket = basic_stream_socket<tcp>;
using acceptor = basic_socket_acceptor<tcp>;
using iostream = basic_socket_iostream<tcp>;
class no_delay;

// static members:
static constexpr tcp v4() noexcept;
static constexpr tcp v6() noexcept;

tcp() = delete;

};

// 21.19.1, tcp comparisons:
constexpr bool operator==(const tcp& a, const tcp& b) noexcept;
constexpr bool operator!=(const tcp& a, const tcp& b) noexcept;

}; // namespace ip
}; // inline namespace std::experimental::net::inline v1v2
}; // namespace net
}; // namespace experimental
}; // namespace std
```

2 The tcp class meets the requirements for an InternetProtocol InternetProtocol (21.2.1).

3 Extensible implementations provide the following member functions:

```cpp
namespace std {
namespace experimental {
namespace net {
```
inline namespace std::experimental::net::inline v1v2 {
namespace ip {

class tcp {
public:
    constexpr int family() const noexcept;
    constexpr int type() const noexcept;
    constexpr int protocol() const noexcept;
    // remainder unchanged
};
} // namespace ip
} // inline namespace std::experimental::net::v1v2

} // // namespace net
} // namespace experimental
} // namespace std

The return values for these member functions are listed in Table 38.

Table 38 — Behavior of extensible ip::tcp implementations

<table>
<thead>
<tr>
<th>value</th>
<th>family()</th>
<th>type()</th>
<th>protocol()</th>
</tr>
</thead>
<tbody>
<tr>
<td>tcp::v4()</td>
<td>AF_INET</td>
<td>SOCK_STREAM</td>
<td>IPPROTO_TCP</td>
</tr>
<tr>
<td>tcp::v6()</td>
<td>AF_INET6</td>
<td>SOCK_STREAM</td>
<td>IPPROTO_TCP</td>
</tr>
</tbody>
</table>

[Note: The constants AF_INET, AF_INET6 and SOCK_STREAM are defined in the POSIX <sys/socket.h> header. The constant IPPROTO_TCP is defined in the POSIX <netinet/in.h> header. — end note]

21.19.1 ip::tcp comparisons

constexpr bool operator==(const tcp& a, const tcp& b) noexcept;

Returns: A boolean indicating whether two objects of class tcp are equal, such that the expression tcp::v4() == tcp::v4() is true, the expression tcp::v6() == tcp::v6() is true, and the expression tcp::v4() == tcp::v6() is false.

constexpr bool operator!=(const tcp& a, const tcp& b) noexcept;

Returns: !(a == b).

21.20 Class ip::udp

The class udp encapsulates the types and flags necessary for UDP sockets.

namespace std{
namespace experimental{
namespace net{

inline namespace std::experimental::net::inline v1v2 {
namespace ip {

class udp {
public:
    // types:
    using endpoint = basic_endpoint<udp>;
} // namespace ip
} // namespace net
} // namespace experimental
} // namespace std
using resolver = basic_resolver<udp>;
using socket = basic_datagram_socket<udp>;

// static members:
static constexpr udp v4() noexcept;
static constexpr udp v6() noexcept;

udp() = delete;
}

// 21.20.1, udp comparisons:
constexpr bool operator==(const udp& a, const udp& b) noexcept;

} // namespace ip

} // inline namespace std::experimental::net::v1
} // namespace net
} // std

The udp class meets the requirements for an InternetProtocol (21.2.1).

Extensible implementations provide the following member functions:

namespace std {
namespace experimental {
namespace net {
inline namespace std::experimental::net::inline v1v2 {
namespace ip {

class udp {
public:
    constexpr int family() const noexcept;
    constexpr int type() const noexcept;
    constexpr int protocol() const noexcept;
    // remainder unchanged
};

} // namespace ip

} // inline namespace std::experimental::net::v1v2
} // namespace net
} // namespace experimental
} // namespace std

The return values for these member functions are listed in Table 39.

Table 39 — Behavior of extensible ip::udp implementations

<table>
<thead>
<tr>
<th>value</th>
<th>family()</th>
<th>type()</th>
<th>protocol()</th>
</tr>
</thead>
<tbody>
<tr>
<td>udp::v4()</td>
<td>AF_INET</td>
<td>SOCK_DGRAM</td>
<td>IPPROTO_UDP</td>
</tr>
<tr>
<td>udp::v6()</td>
<td>AF_INET6</td>
<td>SOCK_DGRAM</td>
<td>IPPROTO_UDP</td>
</tr>
</tbody>
</table>

[Note: The constants AF_INET, AF_INET6 and SOCK_DGRAM are defined in the POSIX <sys/socket.h> header. The constant IPPROTO_UDP is defined in the POSIX <netinet/in.h> header. — end note]
21.20.1  ip::udp comparisons

    constexpr bool operator==(const udp& a, const udp& b) noexcept;

1  **Returns:** A boolean indicating whether two objects of class udp are equal, such that the expression udp::v4() == udp::v4() is true, the expression udp::v6() == udp::v6() is true, and the expression udp::v4() == udp::v6() is false.

    constexpr bool operator!=(const udp& a, const udp& b) noexcept;

2  **Returns:** !(a == b).

21.21  Internet socket options

1  In Table 40, let C denote a socket option class; let L identify the POSIX macro to be passed as the *level* argument to POSIX setsockopt and getsockopt; let N identify the POSIX macro to be passed as the *option_name* argument to POSIX setsockopt and getsockopt; let T identify the type of the value whose address will be passed as the *option_value* argument to POSIX setsockopt and getsockopt; let p denote a (possibly const) value of a type meeting the protocol (18.2.6) requirements, as passed to the socket option’s *level* and *name* member functions; and let F be the value of p.family().

<table>
<thead>
<tr>
<th>C</th>
<th>L</th>
<th>N</th>
<th>T</th>
<th>Requirements, definition or notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>ip::tcp::no_delay</td>
<td>IPPROTO_TCP</td>
<td>TCP_NODELAY</td>
<td>int</td>
<td>satisfies Meets the BooleanSocketOption (18.2.10) type requirements. Determines whether a TCP socket will avoid coalescing of small segments. [Note: That is, setting this option disables the Nagle algorithm. — end note]</td>
</tr>
</tbody>
</table>
Table 40 — Internet socket options (continued)

<table>
<thead>
<tr>
<th>C</th>
<th>L</th>
<th>N</th>
<th>T</th>
<th>Requirements, definition or notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>ip::v6_only</td>
<td>IPPROTO_IPV6</td>
<td>IPV6_V6ONLY</td>
<td>int</td>
<td>Satisfies Meets the BooleanSocketOption (18.2.10) type requirements. Determines whether a socket created for an IPv6 protocol is restricted to IPv6 communications only. Implementations are not required to support setting the v6_only option to false, and the initial value of the v6_only option for a socket is implementation-defined. [Note: As not all operating systems support dual stack IP networking. Some operating systems that do provide dual stack support offer a configuration option to disable it or to set the initial value of the v6_only socket option. — end note]</td>
</tr>
</tbody>
</table>
Table 40 — Internet socket options (continued)

<table>
<thead>
<tr>
<th>C</th>
<th>L</th>
<th>N</th>
<th>T</th>
<th>Requirements, definition or notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>ip::unicast::</td>
<td>IPPROTO_IPV6 if F == AF_INET6,</td>
<td>IPV6_UNICAST_-</td>
<td>int</td>
<td>Satisfies the IntegerSocketOption IntegerSocketOption (18.2.11) type requirements. Specifies the default number of hops (also known as time-to-live or TTL) on outbound datagrams. The constructor and assignment operator for the ip::unicast::hops class throw out_of_range if the int argument is not in the range [0, 255].</td>
</tr>
<tr>
<td>hops</td>
<td>otherwise IPPROTO_IP</td>
<td>HOPS if F == AF_INET6,</td>
<td>otherwise IP_TTL</td>
<td></td>
</tr>
<tr>
<td>ip::multicast::</td>
<td>IPPROTO_IPV6 if F == AF_INET6,</td>
<td>IPV6_JOIN_GROUP</td>
<td>ipv6_mreq if F == AF_INET6,</td>
<td>Satisfies the MulticastGroupSocketOption MulticastGroupSocketOption (21.2.2) type requirements. Requests that the socket join the specified multicast group.</td>
</tr>
<tr>
<td>join_group</td>
<td>otherwise IPPROTO_IP</td>
<td>if F == AF_INET6,</td>
<td>otherwise IP_ADD_MEMBERSHIP</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>otherwise IP_ADD_MEMBERSHIP</td>
<td>ip_mreq</td>
<td></td>
</tr>
<tr>
<td>ip::multicast::</td>
<td>IPPROTO_IPV6 if F == AF_INET6,</td>
<td>IPV6_LEAVE_-</td>
<td>ipv6_mreq if F == AF_INET6,</td>
<td>Satisfies the MulticastGroupSocketOption MulticastGroupSocketOption (21.2.2) type requirements. Requests that the socket leave the specified multicast group.</td>
</tr>
<tr>
<td>leave_group</td>
<td>otherwise IPPROTO_IP</td>
<td>GROUP if F == AF_INET6,</td>
<td>otherwise IP_DROP_MEMBERSHIP</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>otherwise IP_DROP_MEMBERSHIP</td>
<td>ip_mreq</td>
<td></td>
</tr>
<tr>
<td>ip::multicast::</td>
<td>IPPROTO_IPV6 if F == AF_INET6,</td>
<td>IPV6_-_</td>
<td>unsigned int if F == AF_INET6,</td>
<td>Specifies the network interface to use for outgoing multicast datagrams.</td>
</tr>
<tr>
<td>outbound_-</td>
<td>otherwise IPPROTO_IP</td>
<td>MULTICAST_IF</td>
<td>otherwise IP_MULTICAST_IF</td>
<td></td>
</tr>
<tr>
<td>interface</td>
<td></td>
<td>if F == AF_INET6,</td>
<td>otherwise in_addr</td>
<td></td>
</tr>
<tr>
<td>(21.21.1)</td>
<td></td>
<td>otherwise</td>
<td>in_addr</td>
<td></td>
</tr>
</tbody>
</table>
Table 40 — Internet socket options (continued)

<table>
<thead>
<tr>
<th>C</th>
<th>L</th>
<th>N available in</th>
<th>T</th>
<th>Requirements, definition or notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>ip::multicast::</td>
<td>IPPROTO_IPV6</td>
<td>IP6_-</td>
<td>int</td>
<td>Satisfies the IntegerSocketOption</td>
</tr>
<tr>
<td>hops</td>
<td>if F == AF_INET6,</td>
<td>MULTICAST_HOPS</td>
<td></td>
<td>(18.2.11) type requirements. Specifies the default number of hops (also known as time-to-live or TTL) on outbound datagrams. The constructor and assignment operator for the ip::multicast::hops class throw out_of_range if the int argument is not in the range [0, 255].</td>
</tr>
<tr>
<td></td>
<td>otherwise</td>
<td>if F == AF_INET6,</td>
<td></td>
<td>IP_- MULTICAST_TTL</td>
</tr>
<tr>
<td></td>
<td>IPPROTO_IP</td>
<td>otherwise</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ip::multicast::</td>
<td>IPPROTO_IPV6</td>
<td>IP6_-</td>
<td>int</td>
<td>Satisfies the BooleanSocketOption</td>
</tr>
<tr>
<td>enable_loopback</td>
<td>if F == AF_INET6,</td>
<td>MULTICAST_LOOP</td>
<td></td>
<td>(18.2.10) type requirements. Determines whether multicast datagrams are delivered back to the local application.</td>
</tr>
<tr>
<td></td>
<td>otherwise</td>
<td>if F == AF_INET6,</td>
<td></td>
<td>IP_- MULTICAST_LOOP</td>
</tr>
<tr>
<td></td>
<td>IPPROTO_IP</td>
<td>otherwise</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

21.21.1 Class ip::multicast::outbound_interface  [internet.multicast.outbound]

The outbound_interface class represents a socket option that specifies the network interface to use for outgoing multicast datagrams.

```cpp
namespace std {
namespace experimental {
namespace net {
inline namespace std::experimental::net::inline_v1 v2 {
namespace ip {
namespace multicast {

class outbound_interface {
{
public:
  // constructors:
  explicit outbound_interface(const address_v4& network_interface) noexcept;
  explicit outbound_interface(unsigned int network_interface) noexcept;
};
```

§ 21.21.1
namespace multicast
    namespace ip
    namespace std::experimental::net::v2
      namespace net
        namespace std::experimental::net::inline_v1
          namespace ip
            namespace multicast
              class outbound_interface
              {
                public:
                    template<class Protocol> int level(const Protocol& p) const noexcept;
                    template<class Protocol> int name(const Protocol& p) const noexcept;
                    template<class Protocol> const void* data(const Protocol& p) const noexcept;
                    template<class Protocol> size_t size(const Protocol& p) const noexcept;
                    // remainder unchanged
                private:
                    in_addr v4_value_; // exposition only
                    unsigned int v6_value_; // exposition only
              };
      } // namespace multicast
    } // namespace ip
  } // inline namespace std::experimental::net::v2
} // namespace net
} // namespace experimental
} // namespace std

2 outbound_interface satisfies the requirements for Destructible<Cpp17Destructible (C++ 2020 [de
structible]), CopyConstructible<Cpp17CopyConstructible (C++ 2020 [copyconstructible]), CopyAssign
able<Cpp17CopyAssignable (C++ 2020 [copyassignable]), and SettableSocketOption (18.2.9).

3 Extensible implementations provide the following member functions:

    namespace std::experimental::net::inline_v1
      namespace ip
        namespace multicast
          class outbound_interface
          {
            public:
              explicit outbound_interface(const address_v4& network_interface) noexcept;
              explicit outbound_interface(unsigned int network_interface) noexcept;
            private:
              in_addr v4_value_; // exposition only
              unsigned int v6_value_; // exposition only
          };
      } // namespace multicast
    } // namespace ip
  } // inline namespace std::experimental::net::v2
} // namespace net
} // namespace experimental
} // namespace std

4 Effects: For extensible implementations, v4_value_ is initialized to correspond to the IPv4 address
            network_interface, and v6_value_ is zero-initialized.

4 explicit outbound_interface(const address_v4& network_interface) noexcept;

5 Effects: For extensible implementations, v6_value_ is initialized to network_interface, and v4_-value_ is zero-initialized.

5 explicit outbound_interface(unsigned int network_interface) noexcept;

5 template<class Protocol> int level(const Protocol& p) const noexcept;

6 Returns: IPPROTO_IPV6 if p.family() == AF_INET6, otherwise IPPROTO_IP.

6 template<class Protocol> int name(const Protocol& p) const noexcept;

7 Returns: IPV6_MULTICAST_IF if p.family() == AF_INET6, otherwise IP_MULTICAST_IF.
template<class Protocol> const void* data(const Protocol& p) const noexcept;

8     \textit{Returns}: \texttt{addressof(v6\_value\_)} if \(p.\text{family}() == \text{AF\_INET6}\), otherwise \texttt{addressof(v4\_value\_)}. 

template<class Protocol> size_t size(const Protocol& p) const noexcept;

9     \textit{Returns}: \texttt{sizeof(v6\_value\_)} if \(p.\text{family}() == \text{AF\_INET6}\), otherwise \texttt{sizeof(v4\_value\_)}. 

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