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Reply to: Herb Sutter (hsutter@microsoft.com)
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async and ~future (Revision 4)

Herb Sutter, Chandler Carruth, Niklas Gustafsson

N3637 documented the consensus of SG1 in Bristol. This paper is a minor update to N3637 to make the "change std::async" part of the proposal explicitly separable by updating the example code and adding three alternate sections to section 3 (3.1, 3.2, 3.3). This is to reflect that the main question at the end of Bristol was about how changing std::async affects binary compatibility, and to reflect the "N3637 except {remove|deprecate|leave-as-is} std::async instead of changing it" straw polls that had the most support in the July Santa Clara SG1 meeting.

In discussion of N3630 and N3637, SG1 expressed support for the following direction:

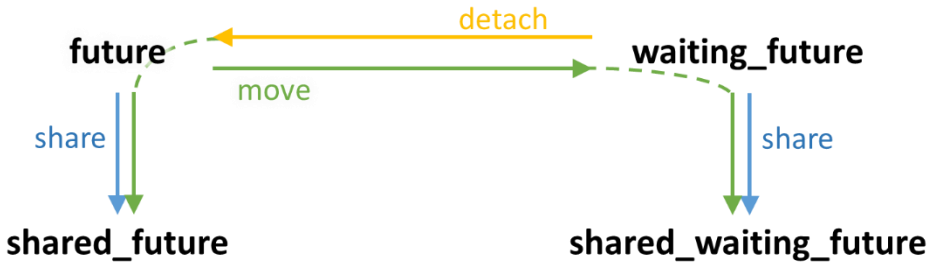
1. Have a distinct 'future' type whose destructor never waits. Have a unique and a shared version of this type.
2. Have a distinct 'future' type whose destructor always waits if the caller did not already call *.get()* or *.wait()*. Have a unique and a shared version of this type.
3. Have compatibility for existing code that uses *async* and relies on its existing semantics, including deferred work. Ideally, code that is valid C++11 but that changes meaning should not compile.

Summary

Accomplish the above as follows:

1. Have ***future<T>*** with unique ownership, and ***shared_future<T>*** with shared ownership, be the type whose destructor never waits. This already true except only when the shared state came from *async* with *launch::async*.
2. Add ***waiting_future<T>*** with unique ownership, and ***shared_waiting_future<T>*** with shared ownership, as the type whose unique or last destructor always waits for non-deferred tasks if the caller did not already call *.get()* or *.wait()*. A *waiting_future<T>* is explicitly move-convertible to a *future<T>* by calling *.detach()*, modeled after *.share()*.
3. (Optionally) Have *async* return a ***waiting_future<T>***.

The type conversions are:



Here are the types in action, with existing valid C++11 code shaded:

```
future<int> f1 = async([]{ return 1; });                    // without #3: ok, C++11 meaning
        // if #3 adopted: error, detach required (this would be the only source breaking
        // change case, incl. shared_future variant below)

auto f2 = async([]{ return 1; });                           // ok, preserves C++11 meaning

future<int> f3 = f2.detach();                               // ok

waiting_future<int> f4 = async([]{ return 1; });            // if #3 adopted: ok
waiting_future<int> f7 = f3;                                // error, move required
waiting_future<int> f8 = move(f3);                          // ok

future<int> f9 = f8;                                        // error, detach required
future<int> f10 = f8.detach();                              // ok

shared_future<int> f11 = async([]{ return 1; });            // without #3: ok, C++11 meaning
        // if #3 adopted: error, detach required
shared_future<int> f12 = f2.detach();                       // ok
shared_future<int> f13 = move(f8);                          // error, detach required
shared_future<int> f14 = f8.detach();                       // ok (move/share implicit)

shared_waiting_future<int> f15 = async([]{ return 1; });    // if #3 adopted: ok
shared_waiting_future<int> f16 = f8;                        // error, move required
shared_waiting_future<int> f17 = move(f8);                  // ok
shared_waiting_future<int> f18 = f9;                        // error, move required
shared_waiting_future<int> f19 = move(f9);                  // ok

shared_future<int> f20 = f3;                                // error, move or share required
shared_future<int> f21 = move(f3);                          // ok
shared_future<int> f22 = f3.share();                        // ok
```

Proposed Wording

1. future and shared_future

Change 30.6.6/9-11 as follows:

```
~future();
```

9 *Effects:*
— releases any shared state (30.6.4) without blocking until the shared state is ready;
— destroys `*this`.

```
future& operator=(future&& rhs) noexcept;
```

10 *Effects:*
— releases any shared state (30.6.4) without blocking until the shared state is ready;~~.~~
— move assigns the contents of `rhs` to `*this`.

11 *Postconditions:*
— `valid()` returns the same value as `rhs.valid()` prior to the assignment.
— `rhs.valid() == false`.

Change 30.6.7/11-15 as follows:

```
~shared_future();
```

11 *Effects:*
— releases any shared state (30.6.4), without blocking for the shared state to be ready;
— destroys `*this`.

```
shared_future& operator=(shared_future&& rhs) noexcept;
```

12 *Effects:*
— releases any shared state (30.6.4) , without blocking for the shared state to be ready;~~.~~
— move assigns the contents of `rhs` to `*this`.

13 *Postconditions:*
— `valid()` returns the same value as `rhs.valid()` prior to the assignment.
— `rhs.valid() == false`.

```
shared_future& operator=(const shared_future& rhs) noexcept;
```

14 *Effects:*
— releases any shared state (30.6.4), without blocking for the shared state to be ready;~~.~~
— assigns the contents of `rhs` to `*this`. [*Note*: As a result, `*this` refers to the same shared state as `rhs` (if any). —*end note*]

15 *Postconditions:* `valid() == rhs.valid()`.

Change 30.6.4 as follows:

5 When an asynchronous return object or an asynchronous provider is said to release its shared state, it means that without blocking for the shared state to be ready:

— if the return object or provider holds the last reference to its shared state, the shared state is destroyed; and
— the return object or provider gives up its reference to its shared state.

2. waiting_future and shared_waiting_future

Add a new sections 30.6.X and .X++ as follows to add *waiting_future* and *shared_waiting_future* (based on *std::future* and *std::shared_future*, with the major differences from the originals highlighted):

30.6.*X* Class template waiting_future [futures.waiting_future]

1 The class template `waiting_future` defines a type for asynchronous return objects which do not share their shared state with other asynchronous return objects and `wait()` for non-deferred shared state automatically when assigned to or destroyed. A default-constructed future object has no shared state. A `waiting_future` object with shared state can be created from a `future`, or from the type returned by `std::async()` (30.6.8), or by moving from another `waiting_future`, and shares its shared state with the original asynchronous provider. The result (value or exception) of a `waiting_future` object can be set by calling a function on an object that shares the same shared state.

2 [*Note:* Member functions of `waiting_future` do not synchronize with themselves or with member functions of `future`, `shared_future`, or `shared_waiting_future`. —*end note*]

3 The effect of calling any member function other than the destructor, the move-assignment operator, or `valid` on a `waiting_future` object for which `valid() == false` is undefined. [*Note:* Implementations are encouraged to detect this case and throw an object of type `future_error` with an error condition of `future_errc::no_state`. —*end note*]

```
namespace std {
  template <class R>
  class waiting_future {
  public:

    waiting_future() noexcept;
    waiting_future(waiting_future &&) noexcept;
    waiting_future(future &&) noexcept;
    waiting_future(const waiting_future& rhs) = delete;
    ~waiting_future();

    waiting_future& operator=(const waiting_future& rhs) = delete;
    waiting_future& operator=(waiting_future&&) noexcept;

    future<R> detach();
    shared_waiting_future<R> share();

    // retrieving the value
    see below get();

    // functions to check state
    bool valid() const noexcept;
```

```
    void wait() const;
    template <class Rep, class Period>
    future_status wait_for(
        const chrono::duration<Rep,Period>& rel_time) const;
    template <class Clock, class Duration>
    future_status wait_until(
        const chrono::time_point<Clock,Duration>& abs_time) const;
  };
}
```

4 The implementation shall provide the template `waiting_future` and two specializations, `waiting_future<R&>` and `waiting_future<void>`. These differ only in the return type and return value of the member function `get`, as set out in its description, below.

```
waiting_future() noexcept;
```

5 *Effects:* constructs an *empty* `waiting_future` object that does not refer to a shared state.

6 *Postcondition:* `valid() == false`.

```
waiting_future(waiting_future&& rhs) noexcept;
waiting_future(future&& rhs) noexcept;
```

7 *Effects:* move constructs a `waiting_future` object that refers to the shared state that was originally referred to by `rhs` (if any).

8 *Postconditions:*
— `valid()` returns the same value as `rhs.valid()` prior to the constructor invocation.
— `rhs.valid() == false`.

```
~waiting_future();
```

9 *Effects:*
— if `valid()` is `true` and the shared state does not contain a deferred function, calls `wait()`;
— releases any shared state (30.6.4);
— destroys `*this`.

```
waiting_future& operator=(waiting_future&& rhs) noexcept;
```

10 *Effects:*
— if `valid()` is `true` and the shared state does not contain a deferred function, calls `wait()`;
— releases any shared state (30.6.4).
— move assigns the contents of `rhs` to `*this`.

11 *Postconditions:*
— `valid()` returns the same value as `rhs.valid()` prior to the assignment.
— `rhs.valid() == false`.

```
future<R> detach();
```

12 *Effects:* transfers ownership of any shared state (30.6.4) of `*this` to a newly constructed `future<R>` object.

13 *Returns*: a `future<R>` object that refers to the shared state that was originally referred to by `*this` (if any).

14 *Postconditions*: `valid() == false`.

```
shared_waiting_future<R> share();
```

15 *Returns*: `shared_waiting_future<R>(std::move(*this))`.

16 *Postcondition*: `valid() == false`.

```
R waiting_future::get();
R& waiting_future<R&>::get();
void waiting_future<void>::get();
```

17 *Note:* As described above, the template and its two required specializations differ only in the return type and return value of the member function `get`.

18 *Effects:* `wait()`s until the shared state is ready, then retrieves the value stored in the shared state.

19 *Returns:*
— `future::get()` returns the value v stored in the object's shared state as `std::move(v)`.
— `future<R&>::get()` returns the reference stored as value in the object's shared state.
— `future<void>::get()` returns nothing.

20 *Throws:* the stored exception, if an exception was stored in the shared state.

21 *Postcondition:* `valid() == false`.

```
bool valid() const noexcept;
```

22 *Returns:* `true` only if `*this` refers to a shared state.

```
void wait() const;
```

23 *Effects:* blocks until the shared state is ready.

```
template <class Rep, class Period>
future_status wait_for(const chrono::duration<Rep, Period>& rel_time) const;
```

24 *Effects:* none if the shared state contains a deferred function (30.6.8), otherwise blocks until the shared state is ready or until the relative timeout (30.2.4) specified by `rel_time` has expired.

25 *Returns:*
— `future_status::deferred` if the shared state contains a deferred function.
— `future_status::ready` if the shared state is ready.
— `future_status::timeout` if the function is returning because the relative timeout (30.2.4) specified by `rel_time` has expired.

```
template <class Clock, class Duration>
future_status wait_until(
    const chrono::time_point<Clock, Duration>& abs_time) const;
```

26 *Effects:* none if the shared state contains a deferred function (30.6.8), otherwise blocks until the shared state is ready or until the absolute timeout (30.2.4) specified by `abs_time` has expired.

27 *Returns:*
— `future_status::deferred` if the shared state contains a deferred function.
— `future_status::ready` if the shared state is ready.
— `future_status::timeout` if the function is returning because the absolute timeout (30.2.4) specified by `abs_time` has expired.

30.6.*X++* Class template shared_waiting_future [futures.shared_waiting_future]

1 The class template `shared_waiting_future` defines a type for asynchronous return objects which may share their shared state with other asynchronous return objects and `wait()` for non-deferred shared state automatically when the `shared_waiting_future` that is the last asynchronous return object that references the shared state is assigned to or destroyed. A default-constructed `shared_waiting_future` object has no shared state. A `shared_waiting_future` object with shared state can be created by conversion from a `future` or `waiting_future` object and shares its shared state with the original asynchronous provider (30.6.4) of the shared state. The result (value or exception) of a `shared_waiting_future` object can be set by calling a respective function on an object that shares the same shared state.

2 [*Note*: Member functions of `shared_waiting_future` do not synchronize with themselves, but they synchronize with the shared shared state. —*end note*]

3 The effect of calling any member function other than the destructor, the move-assignment operator, or `valid()` on a `shared_waiting_future` object for which `valid() == false` is undefined. [*Note*: Implementations are encouraged to detect this case and throw an object of type `future_error` with an error condition of `future_errc::no_state`. —*end note*]

```
namespace std {
  template <class R>
  class shared_waiting_future {
  public:
    shared_waiting_future() noexcept;
    shared_waiting_future(const shared_waiting_future& rhs);
    shared_waiting_future(waiting_future<R>&&) noexcept;
```

```
    shared_waiting_future(shared_waiting_future&& rhs) noexcept;
    ~shared_waiting_future();
    shared_waiting_future& operator=(const shared_waiting_future& rhs);
    shared_waiting_future& operator=(shared_waiting_future&& rhs) noexcept;

    // retrieving the value
    see below get() const;

    // functions to check state
    bool valid() const noexcept;

    void wait() const;
    template <class Rep, class Period>
      future_status wait_for(
          const chrono::duration<Rep, Period>& rel_time) const;
    template <class Clock, class Duration>
      future_status wait_until(
          const chrono::time_point<Clock, Duration>& abs_time) const;

  };

}
```

4 The implementation shall provide the template `shared_waiting_future` and two specializations, `shared_waiting_future<R&>` and `shared_waiting_future<void>`. These differ only in the return type and return value of the member function `get`, as set out in its description, below.

```
shared_waiting_future() noexcept;
```

5 *Effects*: constructs an empty `shared_waiting_future` object that does not refer to an shared state.

6 *Postcondition*: `valid() == false`.

```
shared_waiting_future(const shared_waiting_future& rhs);
```

7 *Effects*: constructs a `shared_waiting_future` object that refers to the same shared state as `rhs` (if any).

8 *Postcondition*: `valid()` returns the same value as `rhs.valid()`.

```
shared_waiting_future(shared_future<R>&& rhs) noexcept;
shared_waiting_future(shared_waiting_future&& rhs) noexcept;
```

9 *Effects*: move constructs a `shared_waiting_future` object that refers to the shared state that was originally referred to by `rhs` (if any).

10 *Postconditions*:
— `valid()` returns the same value as `rhs.valid()` returned prior to the constructor invocation.
— `rhs.valid() == false`.

```
~shared_waiting_future();
```

11 *Effects*:
— if `valid()` is `true`, and `*this` is the last asynchronous return object that references the shared state, and the shared state does not contain a deferred function, then calls `wait()`;
— releases any shared state (30.6.4);
— destroys *this.

```
shared_waiting_future& operator=(shared_waiting_future&& rhs) noexcept;
```

12 *Effects*:
— if `valid()` is `true`, and `*this` is the last asynchronous return object that references the shared state, and the shared state does not contain a deferred function, then calls `wait()`;
— releases any shared state (30.6.4);
— move assigns the contents of `rhs` to `*this`.

13 *Postconditions*:
— `valid()` returns the same value as `rhs.valid()` returned prior to the assignment.
— `rhs.valid() == false`.

```
shared_waiting_future& operator=(const shared_waiting_future& rhs);
```

14 *Effects*:
— if `valid()` is `true`, and `*this` is the last asynchronous return object that references the shared state, and the shared state does not contain a deferred function, then calls `wait()`;
— releases any shared state (30.6.4);
— assigns the contents of `rhs` to `*this`. [*Note*: As a result, `*this` refers to the same shared state as `rhs` (if any). —*end note*]

15 *Postconditions*: `valid() == rhs.valid()`.

```
const R& shared_waiting_future::get() const;
R& shared_waiting_future<R&>::get() const;
void shared_waiting_future<void>::get() const;
```

16 *Note*: as described above, the template and its two required specializations differ only in the return type and return value of the member function `get`.

17 *Note*: access to a value object stored in the shared state is unsynchronized, so programmers should apply only those operations on `R` that do not introduce a data race (1.10).

18 *Effects*: `wait()`s until the shared state is ready, then retrieves the value stored in the shared state.

19 *Returns*:
— `shared_waiting_future::get()` returns a `const` reference to the value stored in the object's shared state. [*Note*: Access through that reference after the shared state has been

destroyed produces undefined behavior; this can be avoided by not storing the reference in any storage with a greater lifetime than the `shared_waiting_future` object that returned the reference. —*end note*]
— `shared_waiting_future<R&>::get()` returns the reference stored as value in the object's shared state.
— `shared_waiting_future<void>::get()` returns nothing.

20 *Throws*: the stored exception, if an exception was stored in the shared state.

```
bool valid() const noexcept;
```

21 *Returns*: `true` only if `*this` refers to a shared state.

```
void wait() const;
```

22 *Effects*: blocks until the shared state is ready.

```
template <class Rep, class Period>
future_status wait_for(const chrono::duration<Rep, Period>& rel_time) const;
```

23 *Effects*: none if the shared state contains a deferred function (30.6.8), otherwise blocks until the shared state is ready or until the relative timeout (30.2.4) specified by `rel_time` has expired.

24 *Returns*:
— `future_status::deferred` if the shared state contains a deferred function.
— `future_status::ready` if the shared state is ready.
— `future_status::timeout` if the function is returning because the relative timeout (30.2.4) specified by `rel_time` has expired.

```
template <class Clock, class Duration>
future_status wait_until(
    const chrono::time_point<Clock, Duration>& abs_time) const;
```

25 *Effects*: none if the shared state contains a deferred function (30.6.8), otherwise blocks until the shared state is ready or until the absolute timeout (30.2.4) specified by `abs_time` has expired.

26 *Returns*
— `future_status::deferred` if the shared state contains a deferred function.
— `future_status::ready` if the shared state is ready.
— `future_status::timeout` if the function is returning because the absolute timeout (30.2.4) specified by `abs_time` has expired.

3. async changes

This is a separable question from the above. All options below are acceptable to the authors as the primary issue is to achieve the goals of making `std::future` composable which is fully satisfied above.

3.1: Option: Do nothing about std::async.

No change required, and `std::async` subtly does not meet the requirements for `future` but we have contained it to `std::async`.

3.2: Option: Remove std::async.

In 30.6.1/1, remove the two declarations of `async`.

In 30.6.1/2 and 30.6.4, remove the Notes about `async`.

Remove subclause 30.6.8 [futures.async].

3.3: Option: Deprecate std::async.

Move the declarations of `async` in 30.6.1/1, and all of subclause 30.6.8 [futures.async], to Annex D.

3.4: Option: Have std::async return a waiting_future.

In 30.6.1, change the declarations of `async` as follows:

1 The function template `async` provides a mechanism to launch a function potentially in a new thread and provides the result of the function in a `waiting_future` object with which it shares ownership of a shared state.

```
template <class F, class... Args>
waiting_future<typename result_of<typename decay<F>::type(typename
decay<Args>::type...)>::type>
async(F&& f, Args&&... args);

template <class F, class... Args>
waiting_future<typename result_of<typename decay<F>::type(typename
decay<Args>::type...)>::type>
async(launch policy, F&& f, Args&&... args);
```

Change 30.6.8/1 as follows:

```
template <class F, class... Args>
waiting_future<typename result_of<typename decay<F>::type(typename
decay<Args>::type...)>::type>
async(F&& f, Args&&... args);

template <class F, class... Args>
waiting_future<typename result_of<typename decay<F>::type(typename
decay<Args>::type...)>::type>
async(launch policy, F&& f, Args&&... args);
```

Change 30.6.8/4 as follows:

4 Returns: An object of type `waiting_future<typename result_of<typename decay<F>::type(typename decay<Args>::type...)>::type>` that refers to the shared state created by this call to `async`.

Change 30.6.8/5 as follows:

5 *Synchronization:* Regardless of the provided `policy` argument,

— the invocation of `async` synchronizes with (1.10) the invocation of `f`. [*Note*: This statement applies even when the corresponding `future` object is moved to another thread. —*end note*]; and

— the completion of the function `f` is sequenced before (1.10) the shared state is made ready. [*Note*: `f` might not be called at all, so its completion might never happen. —*end note*]

If the implementation chooses the `launch::async` policy,

— a call to a waiting function on an asynchronous return object that shares the shared state created by this `async` call shall block until the associated thread has completed, as if joined (30.3.1.5);

— the associated thread completion synchronizes with (1.10) the return from the first function that successfully detects the ready status of the shared state ~~or with the return from the last function that releases the shared state, whichever happens first.~~;

— the associated thread holds a reference to the associated shared state which is released (30.6.4) when the associated thread exits.