Add make_proxy for the Pointer-Semantics-Based Polymorphism Library - Proxy

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Abstract: *Proxy* is a new library feature that is being proposed to delegate general pointer types with the type-erased technique to support non-intrusive polymorphism programming in C++. The focus of paper is on utility functions – *make_proxy*, *allocate_proxy* and *make_proxy_inplace*, which used to be included in the *proxy* proposal as a sub-feature. We believe they are useful tools to help create *proxy* instances properly.

1 Introduction

Paper P3086 proposed a *Pointer-Semantics-Based Polymorphism Library*, which is designed to help people build extendable and efficient polymorphic programs with better abstractions and less intrusive code. This paper is proposing the utility part that is separated from early versions of paper P3086 and P0957.

More specifically, we are eager to add function templates *make_proxy*, *allocate_proxy*, *make_proxy_inplace*, and concept *inplace_proxiable_target* together with the *proxy* library into the standard as library features.

make_proxy's syntax is similar to the constuctors of `std::any`. It is designed to provide simple ways to construct *proxy* instances from values. With *make_proxy*, SBO (small buffer optimization) may implicitly apply to void the potential overhead that may come from unnecessary heap allocations.

allocate_proxy's syntax is similar to `std::allocate_shared`. It is intended for custom allocators.

inplace_proxiable_target is a concept that restricts its associated *facade* type and value type so that calling its correlated *make_proxy_inplace* is well-formd.

make_proxy_inplace, similar to `std::optional`, provides an SBO pointer that stores given values within its storage. More details about *make_proxy_inplace* can be found in Technical specification.

2 Motivation

Class template *proxy* is based on pointer semantics, which means it usually involves heap allocations to instantiate a *proxy* object from value, though sometimes those allocations could be evitable if the value's type is trivial enough.

For example, if the maximum pointer size defined by `F::constraints.max_size` is

$$2 \times \texttt{sizeof(void*)}.$$

When a user wants to have a *proxy* instance for an integer value 2024, they may do

```
struct year_ptr_constraints {
  static constexpr std::size_t max_size = sizeof(void*[2]);
  static constexpr std::size_t max_align = alignof(void*[2]);
  // other constraints for the following year facade
};
struct year {
  static constexpr year_ptr_constraints constraints{};
  // other members to meet the facade name-requirement.
};
std::proxy<year> CreateYear() {
  return std::make_unique<int>(2024);  // implicitly converts to std::proxy<year>
}
```

Apparently, `std::make_unique<int>(2024)` performs an allocation, which may be considered an expensive cost in certain scenarios. To improve the construction from integer values in this case, we shall introduce SBO here. Because the storage size (e.g. 16 bytes on 64-bit machines) of `std::proxy<year>` is mostly sufficient to place a value of integer type (e.g. 4 bytes). With the SBO capability provided by *make_proxy*, which could be an internal implementation of a *fancy pointer* that guarantees space efficiency, users can choose the implementation below for the `CreateYear()` function:

```
std::proxy<year> CreateYear() {
  return std::make_proxy<year>(2024);   // no heap allocation happens
}
```

In simple words, *make_proxy* shall initially try constructing a *proxy* object with given values stored inplace, and then fall back to storing the given values in an arbitrary memory range with heap allocations if the first trial failed. Both conditions, as well as their resolution, shall happen at compile-time.

3 Technical specification

3.1 Additional synopsis for header <memory>

```
namespace std {
  // concept inplace_proxiable_target
  template <class T, class F>
  concept inplace_proxiable_target = proxiable</* inplace−ptr<T> */, F>;

  // the allocate_proxy overloads
  template <facade F, class T, class Alloc, class... Args>
  proxy<F> allocate_proxy(const Alloc& alloc, Args&&... args);

  template <facade F, class T, class Alloc, class U, class... Args>
  proxy<F> allocate_proxy(const Alloc& alloc, std::initializer_list<U> il, Args&&... args);

  template <facade F, class Alloc, class T>
  proxy<F> allocate_proxy(const Alloc& alloc, T&& value);

  // the make_proxy_inplace overloads
  template <facade F, inplace_proxiable_target<F> T, class... Args>
  proxy<F> make_proxy_inplace(Args&&... args)
      noexcept(std::is_nothrow_constructible_v<T, Args...>);

  template <facade F, inplace_proxiable_target<F> T, class U, class... Args>
  proxy<F> make_proxy_inplace(std::initializer_list<U> il, Args&&... args)
      noexcept(std::is_nothrow_constructible_v<
          T, std::initializer_list<U>&, Args...>);

  template <facade F, class T>
  proxy<F> make_proxy_inplace(T&& value)
      noexcept(std::is_nothrow_constructible_v<std::decay_t<T>, T>)
      requires(inplace_proxiable_target<std::decay_t<T>, F>);

  // the make_proxy overloads
  template <facade F, class T, class... Args>
  proxy<F> make_proxy(Args&&... args);

  template <facade F, class T, class U, class... Args>
  proxy<F> make_proxy(std::initializer_list<U> il, Args&&... args);

  template <facade F, class T>
  proxy<F> make_proxy(T&& value);
}
```

The above synopsis is assuming the *memory* header has below synopsis defined in paper 3086:

```
namespace std {
  template <class F>
    concept facade = // see p3086r3;
  template <class P, class F>
    concept proxiable = // see p3086r3;
  template <class F>
    class proxy; // see p3086r3
}
```

3.2 Concept `std::inplace_proxiable_target`

The concept `inplace_proxiable_target<T, F>` specifies that a value type `T`, when wrapped by an implementation-defined non-allocating pointer type, models a contained value type of `proxy<F>`. The size and alignment of this implementation-defined pointer type are guaranteed to be equal to those of type `T`.

3.3 Function template `std::allocate_proxy`

The definition of *allocate_proxy* makes use of an exposition-only class template *allocated-ptr*. An object of type `allocated-ptr<T, Alloc>` allocates the storage for another object of type `T` with an allocator of type `Alloc` and manages the lifetime of this contained object. Similar with `std::optional`, `allocated-ptr<T, Alloc>` provides `operator*` for accessing the contained object with the same qualifiers, but does not necessarily support the state where the contained object is absent.

allocate_proxy returns a constructed *proxy* object. It may throw any exception thrown by allocation or the constructor of `T`.

1. `template <facade F, class T, class Alloc, class... Args>`

   `proxy<F> allocate_proxy(const Alloc& alloc, Args&&... args);`
   Effects: Creates a `proxy<F>` object containing an `allocated-ptr<T, Alloc>` direct-non-list-initialized with `std::forward<Args>(args)...`, where the contained value of type `T` is direct-non-list-initialized with `std::forward<Args>(args)...`.

2. `template <facade F, class T, class Alloc, class U, class... Args>`

   `proxy<F> allocate_proxy(const Alloc& alloc, std::initializer_list<U> il, Args&&... args);`

   Effects: Creates a `proxy<F>` object containing an `allocated-ptr<T, Alloc>` direct-non-list-initialized with `il, std::forward<Args>(args)...`.

3. `template <facade F, class Alloc, class T>`

   `proxy<F> allocate_proxy(const Alloc& alloc, T&& value);`

   Effects: Creates a `proxy<F>` object containing an `allocated-ptr<std::decay_t<T>, Alloc>` direct-non-list-initialized with `std::forward<T>(value)`.

3.4 Function template `std::make_proxy_inplace`

The definition of `make_proxy_inplace` makes use of an exposition-only class template `sbo-ptr`. Similar to `std::optional`, `sbo-ptr<T>` contains the storage for an object of type `T`, manages its lifetime, and provides `operator*` for access with the same qualifiers. However, it does not necessarily support the state where the contained object is absent. `sbo-ptr<T>` has the same size and alignment as `T`.

1. `template <facade F, inplace_proxiable_target<F> T, class... Args>`

   `proxy<F> make_proxy_inplace(Args&&... args)`

       `noexcept(std::is_nothrow_constructible_v<T, Args...>);`
   Effects: Creates a `proxy<F>` object containing a `sbo-ptr<T>` direct-non-list-initialized with

   `std::forward<Args>(args)...`.

2. `template <facade F, inplace_proxiable_target<F> T, class U, class... Args>`

   `proxy<F> make_proxy_inplace(std::initializer_list<U> il, Args&&... args)`

       `noexcept(std::is_nothrow_constructible_v<`

           `T, std::initializer_list<U>&, Args...>);`
   Effects: Creates a `proxy<F>` object containing a `sbo-ptr<T>` direct-non-list-initialized with il,

   `std::forward<Args>(args)...`.

3. `template <facade F, class T>`

   `proxy<F> make_proxy_inplace(T&& value)`

       `noexcept(std::is_nothrow_constructible_v<std::decay_t<T>, T>)`

       `requires(inplace_proxiable_target<std::decay_t<T>, F>);`
   Effects: Creates a `proxy<F>` object containing a `sbo-ptr<std::decay_t<T>>` direct-non-list-initialized with `std::forward<T>(value)`.

3.5 Function template `std::make_proxy`

1. ```
template <facade F, class T, class... Args>
```
   ```
proxy<F> make_proxy(Args&&... args);
```
   *Effects*: Creates an instance of `proxy<F>` with an unspecified pointer type of `T`, where the value of `T` is direct-non-list-initialized with the arguments `std::forward<Args>(args)...` of type.

   Remarks: Implementations are not permitted to use additional storage, such as dynamic memory, to allocate the value of `T` if the following conditions apply:

   – `sizeof(T)` $\leq$ `F::constraints.max_size`, and

   – `alignof(T)` $\leq$ `F::constraints.max_align`, and

   – `T` meets the copyiability requirements defined by `F::constraints.copyability`, and

   – `T` meets the relocatability requirements defined by `F::constraints.relocatability`, and

   – `T` meets the destructibility requirements defined by `F::constraints.destructibility`, and

   – for any reflection type `R` defined by `F::reflection_types`,

     `R` shall be constructible from `std::in_place_type_t<sbo-ptr<T>>`.

2. ```
template <facade F, class T, class U, class... Args>
```
   ```
proxy<F> make_proxy(std::initializer_list<U> il, Args&&... args);
```
   Effects: Equivalent to
   ```
 return make_proxy<F, T>(il, std::forward<Args>(args)...);
```

3. ```
template <facade F, class T>
```
   ```
proxy<F> make_proxy(T&& value);
```
   *Effects*: Equivalent to
   ```
 return make_proxy<F, decay_t<T>>(std::forward<T>(value));
```

## 4 Acknowledgements

## 5 References

## References

[1] [P3086] Proxy: A Pointer-Semantics-Based Polymorphism Library

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[2] [P0957] Proxy: A Polymorphic Programming Library

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[3] Open-source: Microsoft Proxy at GitHub

URL: https://github.com/microsoft/proxy