

Notifications & Events

Notifying someone that something happened.

Overview

- > Notifications and the NotificationCenter
- > Sending notifications to other threads using a NotificationQueue
- > Events

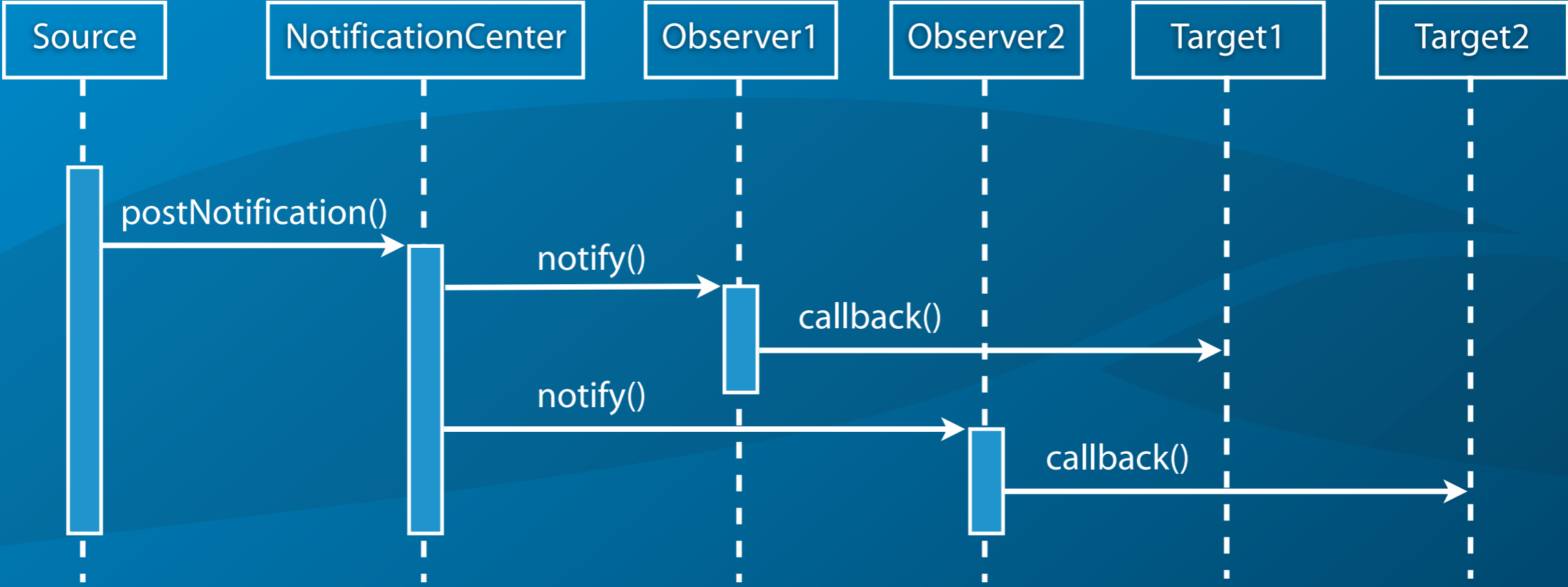
Notifications vs. Events

- > Notifications and events are two mechanisms supported by POOCO to tell a class (the **target**) that something happened in another class (the **source**).
- > Notifications are used if an observer does not know or does not care about the source of an event. A **Poco::NotificationCenter** or **Poco::NotificationQueue** sits between, and decouples sources and targets. Notifications can be sent across thread boundaries.
- > Events are used if an observer does care about the source of an event, or wants to receive events only from a particular source. Events also support asynchronous notification and other features, that notifications do not support.

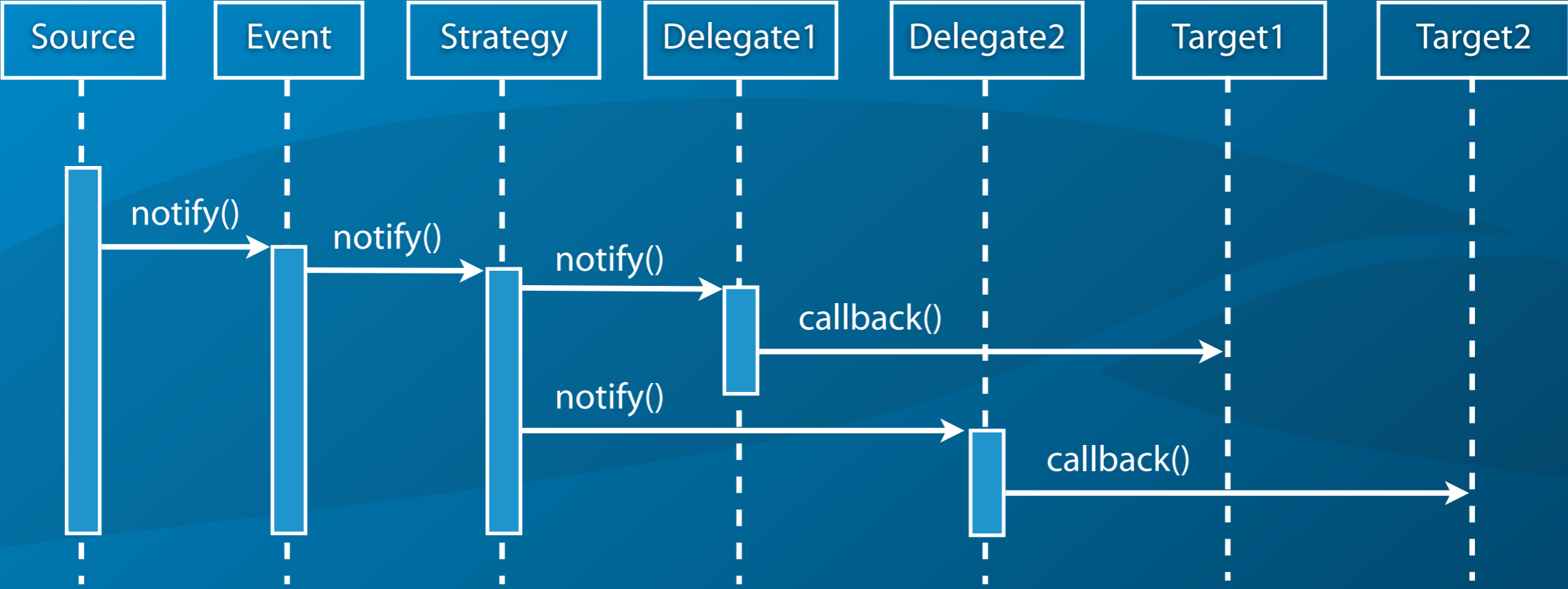
Notifications vs. Events (cont'd)

	Notifications	Events
targets know sources	—	✓
synchronous notification	✓	✓
asynchronous notification	—	✓
works across thread boundaries	✓	—
different notification strategies	—	✓
automatic expirations	—	✓
notification polymorphism	✓	—

Dispatching Notifications



Dispatching Events



Notification Classes

- > Notification classes are derived from `Poco::Notification` and support reference counting (compatible with `Poco::AutoPtr`).
- > A notification object can hold arbitrary data and can provide arbitrary operations.
- > Notification classes do not support value semantics (no copy constructor, no assignment) and are always created on the heap.

The NotificationCenter Class

- > `Poco::NotificationCenter` is a dispatcher for notification objects.
- > `#include "Poco/NotificationCenter.h"`
- > `Poco::NotificationCenter` uses observer objects (subclasses of `Poco::AbstractObserver`) to talk to its targets.
- > An observer object stores a pointer to the target object, and a pointer to the target object's callback member function, and knows which notifications the target is interested in.

Subscribing to Notifications

- > Targets can subscribe to notifications by registering themselves with a `NotificationCenter` using the `addObserver()` member function.
- > `void addObserver(const AbstractObserver& observer)` registers a notification target with the `NotificationCenter`
- > A subscription can be cancelled by calling `removeObserver()`.
- > `void removeObserver(const AbstractObserver& observer)` unregisters a notification target

Observers

- > An Observer stores a pointer to the target object, and a pointer to the target object's callback member function, and knows which notifications the target is interested in.
- > Observers are defined using either the **Observer** or the **NObserver** class template.
- > **Observer** works with plain pointers to **Notification** objects.
- > **NObserver** works with **AutoPtr<Notification>**.
- > **Observer** and **NObserver** are instantiated for a **Notification** class and a target class.

Observers and Callback Functions

- > For **Observer**, the target member function receiving the callback must be defined as:

```
void someCallback(SomeNotification* pNf)
```

where **someCallback** can be any name and **SomeNotification** is the notification to be registered for.

The callback gets shared ownership of the notification object, and must release it when it's no longer needed.

- > For **NObserver**, the target member function is:

```
void someCallback(const AutoPtr<SomeNotification>& pNf)
```

Observers and Callback Functions (cont'd)

- > During a callback, the callback function may unregister itself (or other callbacks) from the **NotificationCenter**, or register new callbacks with the NotificationCenter.
- > Observers that have been added during a notification will be called the first time with the next notification.
- > Observers that have been removed during a notification will not receive the current notification (unless they have already received it).

Posting Notifications

- > Notifications are posted for dispatching by a **NotificationCenter** using the **postNotification()** method.
- > **void postNotification(Notification::Ptr pNotification)** delivers the notification to all targets subscribed for the notification class (or a superclass of it)
- > The notification is delivered to all registered targets. If a target throws an exception while handling the notification, dispatching stops and the exception is propagated to the caller.
- > The **NotificationCenter** assumes ownership of the notification.

Notification Polymorphism

- > Targets subscribed for a particular notification class also receive notifications that are subclasses of that class.
- > If a target subscribes for `Poco::Notification`, it will thus receive all notifications posted to the `NotificationCenter` it has registered with.

```
#include "Poco/NotificationCenter.h"
#include "Poco/Notification.h"
#include "Poco/Observer.h"
#include "Poco/NObserver.h"
#include "Poco/AutoPtr.h"
#include <iostream>

using Poco::NotificationCenter;
using Poco::Notification;
using Poco::Observer;
using Poco::NObserver;
using Poco::AutoPtr;

class BaseNotification: public Notification
{
};

class SubNotification: public BaseNotification
{
};
```

```
class Target
{
public:
    void handleBase(BaseNotification* pNf)
    {
        std::cout << "handleBase: " << pNf->name() << std::endl;
        pNf->release(); // we got ownership, so we must release
    }

    void handleSub(const AutoPtr<SubNotification>& pNf)
    {
        std::cout << "handleSub: " << pNf->name() << std::endl;
    }
};
```

```
int main(int argc, char** argv)
{
    NotificationCenter nc;
    Target target;

    nc.addObserver(
        Observer<Target, BaseNotification>(target, &Target::handleBase)
    );
    nc.addObserver(
        NObserver<Target, SubNotification>(target, &Target::handleSub)
    );

    nc.postNotification(new BaseNotification);
    nc.postNotification(new SubNotification);

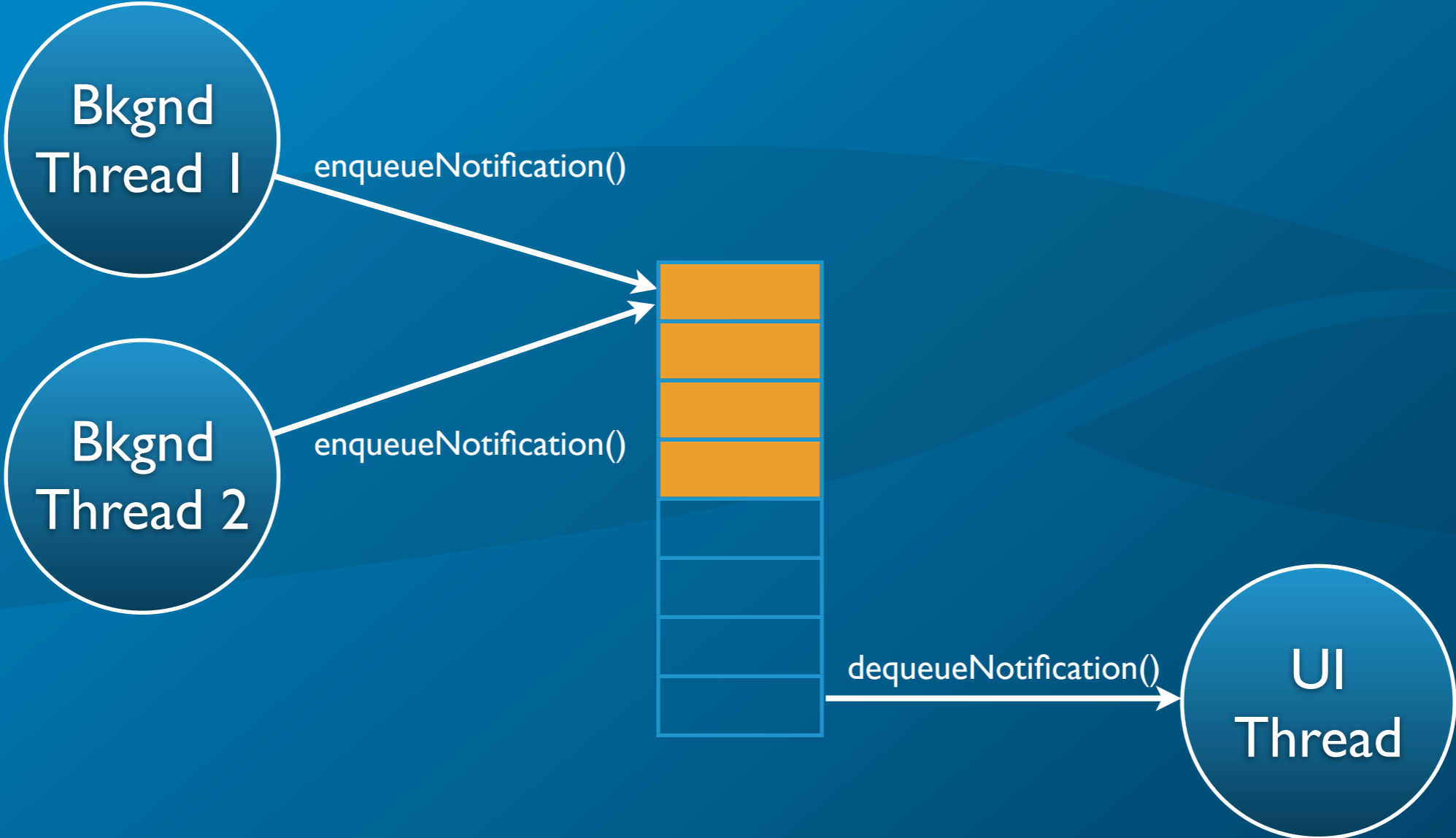
    nc.removeObserver(
        Observer<Target, BaseNotification>(target, &Target::handleBase)
    );
    nc.removeObserver(
        NObserver<Target, SubNotification>(target, &Target::handleSub)
    );

    return 0;
}
```

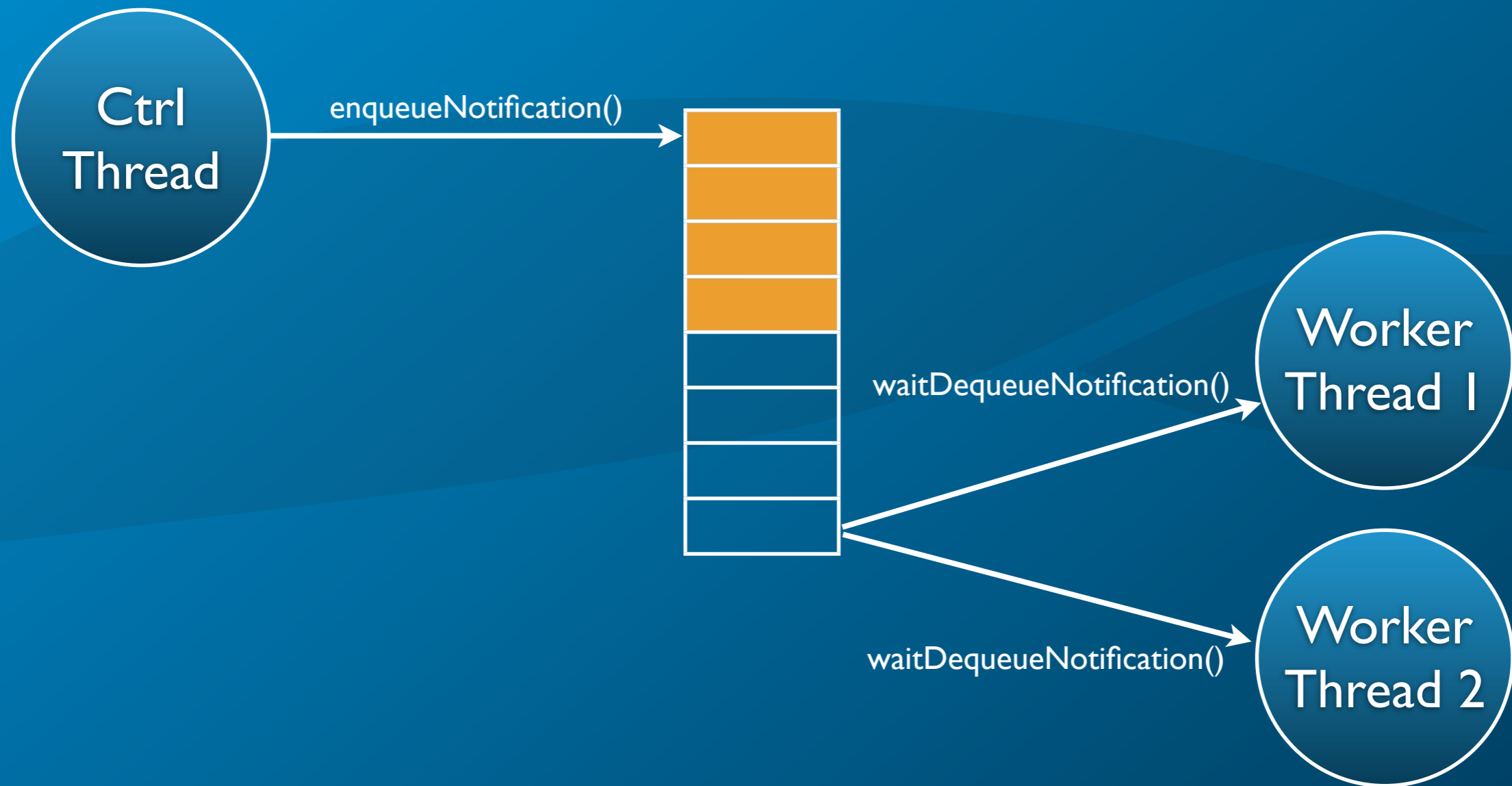
The NotificationQueue Class

- > A `Poco::NotificationQueue` can be used to send notifications asynchronously from one thread to another.
- > `#include "Poco/NotificationQueue.h"`
- > More than one thread can read from a `NotificationQueue`.
- > Use a `NotificationQueue` to
 - > send notifications from background processing threads to the user interface thread, or
 - > send notifications from a controlling thread to one or more worker threads.

Background Thread → UI Thread



Controller Thread → Worker Thread



Enqueueing Notifications

- > `void enqueueNotification(Notification::Ptr pNotification)`
enqueues the given notification by adding it to the end of the queue (FIFO principle). The queue takes ownership of the notification.
- > `void enqueueUrgentNotification(Notification::Ptr pNotification)`
enqueues the given notification by adding it to the beginning of the queue (LIFO principle). The queue takes ownership of the notification.

Dequeuing Notifications

- > `Notification* dequeueNotification()`
dequeues the next pending notification from the beginning of the queue, or null if no notification is available. The caller gains ownership of the notification.
- > `Notification* waitDequeueNotification()`
`Notification* waitDequeueNotification(long timeout)`
dequeues the next pending notification. If no notification is available, waits (at most timeout **milliseconds**) for a notification to be posted. Returns the notification, or null if none is available.

Shutting Down a Queue

- > How to tell worker threads they are done?
- > Three strategies:
 1. Post a special `QuitNotification` for every worker thread;
 2. Set a (global) stop flag and use `waitDequeueNotification()` with a timeout;
 3. Use `wakeUpAll()`: every call to `waitDequeueNotification()` will immediately return null.

Shutting Down a Queue: QuitNotification

- > One `QuitNotification` must be posted for every worker thread.
- > Worker threads must test for and handle `QuitNotification` (using `dynamic_cast` or something similar), and immediately stop dequeuing more notifications.
- > Controller must know the exact number of worker threads.
- > Worker threads can use `waitDequeueNotification()` without a timeout.

Shutting Down a Queue: Stop Flag

- > A (global) stop flag is set to notify workers of pending shutdown.
- > Worker threads must use `waitDequeueNotification()` with a timeout, and periodically check the stop flag.
- > Worker threads can only react to shutdown after timeout expires.

Shutting Down a Queue: `wakeUpAll()`

- > `void wakeUpAll()`
wakes up all threads waiting for a notification using `waitDequeueNotification()`. Every call to `waitDequeueNotification()` will immediately return null.
- > `wakeUpAll()` only works if all worker threads are idle and waiting for notifications.
- > Additionally, a stop flag must be maintained if worker threads use `waitDequeueNotification()` with a timeout.

```
#include "Poco/Notification.h"
#include "Poco/NotificationQueue.h"
#include "Poco/ThreadPool.h"
#include "Poco/Runnable.h"
#include "Poco/SharedPtr.h"

using Poco::Notification;
using Poco::NotificationQueue;
using Poco::ThreadPool;
using Poco::Runnable;
using Poco::SharedPtr;

class WorkNotification: public Notification
{
public:
    WorkNotification(int data): _data(data) {}

    int data() const
    {
        return _data;
    }
private:
    int _data;
};
```

```
class Worker: public Runnable
{
public:
    Worker(NotificationQueue& queue): _queue(queue) {}

    void run()
    {
        AutoPtr<Notification> pNf(_queue.waitDequeueNotification());
        while (pNf)
        {
            WorkNotification* pWorkNf =
                dynamic_cast<WorkNotification*>(pNf.get());
            if (pWorkNf)
            {
                // do some work
            }
            pNf = _queue.waitDequeueNotification();
        }
    }

private:
    NotificationQueue& _queue;
};
```

```
int main(int argc, char** argv)
{
    NotificationQueue queue;

    Worker worker1(queue); // create worker threads
    Worker worker2(queue);

    ThreadPool::defaultPool().start(worker1); // start workers
    ThreadPool::defaultPool().start(worker2);

    // create some work
    for (int i = 0; i < 100; ++i)
    {
        queue.enqueueNotification(new WorkNotification(i));
    }

    while (!queue.empty()) // wait until all work is done
        Poco::Thread::sleep(100);

    queue.wakeUpAll(); // tell workers they're done
    ThreadPool::defaultPool().joinAll();

    return 0;
}
```

Special Queues

- > **PriorityNotificationQueue**
notifications are tagged with a priority and dequeued in order of their priority (lower numerical value means higher priority)
- > **TimedNotificationQueue**
notifications are tagged with a timestamp and dequeued in order of their timestamps

Events

- > Events in POCO are modeled after C# events, but implemented in a true C++ way.
- > In contrast to notifications, events are part of a class interface. Events are defined as public data members.
- > Events support asynchronous notifications, different notification strategies and automatic expirations.
- > Events are defined using the `Poco::BasicEvent` class template.
- > `#include "Poco/BasicEvent.h"`

Events (cont'd)

- > A target subscribes to an event by registering a delegate, using the `Poco::Delegate` class template.
- > `#include "Poco/Delegate.h"`
- > An event has exactly one argument, which can be a subclass of `Poco::EventArgs`.
- > `#include "Poco/EventArgs.h"`

Defining an Event

- > An event is defined using the `Poco::BasicEvent` class template.
- > `Poco::BasicEvent` is instantiated with the type of the event argument.
- > Usually, an event is added as a public data member to a class.

Delegates

- > A target uses `Poco::Delegate` to register a callback member function with the event.
- > `Poco::Delegate` is instantiated with the target class and the event argument type.
- > A delegate is registered with an event using the `+=` operator of the event.
- > Similarly, a delegate is unregistered using the `-=` operator.

Delegates and Callback Functions

- > The callback function used with a delegate must be a function with one of the following signatures:
`void handler(const void* pSender, EventArgs arg)`
- > The first argument points to the object that fired the event.
- > The second is a reference to the argument passed to the event.
- > The callback function may modify the event argument (unless it has been declared `const`) to pass data back to the sender.

Firing Events

- > An event can be fired synchronously by invoking its `notify()` member function (or its function call operator).
- > An event can be fired asynchronously by invoking its `notifyAsync()` member function.
- > If any event handler throws an exception, event dispatching stops immediately and the exception is propagated to the caller.

```
#include "Poco/BasicEvent.h"
#include "Poco/Delegate.h"
#include <iostream>

using Poco::BasicEvent;
using Poco::Delegate;

class Source
{
public:
    BasicEvent<int> theEvent;

    void fireEvent(int n)
    {
        theEvent(this, n);
//         theEvent.notify(this, n); // alternative syntax
    }
};
```

```
class Target
{
public:
    void onEvent(const void* pSender, int& arg)
    {
        std::cout << "onEvent: " << arg << std::endl;
    }
};

int main(int argc, char** argv)
{
    Source source;
    Target target;

    source.theEvent += Poco::delegate(&target, &Target::onEvent);
    source.fireEvent(42);
    source.theEvent -= Poco::delegate(&target, &Target::onEvent);

    return 0;
}
```

Synchronous vs. Asynchronous Events

- > Use `notify` when your handler code is small and the expected number of delegates is low.
- > Use `notify` when you require synchronization.
- > Be careful with `notify()` (and also `notifyAsync()`) when your handler code can trigger other events, i.e. other notifies. In combination with mutexes dead-locks are possible.

Event Considerations

- > Never forget to unregister delegates! Otherwise dangling pointers will cause undefined behavior (crash) in a later notify.
- > Each target can only register one single delegate at one event. If a target registers two callback functions with a single event, the latter will replace the first.
- > Unregistering a delegate that was never registered or has already expired is okay.
- > Events are thread safe, i.e. you can modify the delegate set while a notify is in progress. The new delegate set will not influence the current notify but will take effect with the next notify.

Advanced Events

- > `Poco::FIFOEvent` can be used instead of `Poco::BasicEvent` to ensure delegates are called in the same order in which they have been added.
- > `Poco::PriorityEvent` can be used instead of `Poco::BasicEvent` to add priorities to delegates. Delegates must be added using the `Poco::PriorityDelegate` class template. Delegates are called in order of their priority, with lower priorities coming first.

Advanced Events (cont'd)

- > Automatically expiring delegates can be defined using the `Poco::Expire` class template as a wrapper around `Poco::Delegate`.
- > `Poco::Expire` only works with `Poco::Delegate`. For `Poco::PriorityDelegate`, use `Poco::PriorityExpire`.



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