Asynchronous Method Invocation (AMI) in Java Compat





Asynchronous Method Invocation (AMI) is the term used to describe the client-side support for the asynchronous programming model. AMI supports both oneway and twoway requests, but unlike their synchronous counterparts, AMI requests never block the calling thread. When a client issues an AMI request, the Ice run time hands the message off to the local transport buffer or, if the buffer is currently full, queues the request for later delivery. The application can then continue its activities and poll or wait for completion of the invocation, or receive a callback when the invocation completes.

AMI is transparent to the server: there is no way for the server to tell whether a client sent a request synchronously or asynchronously.

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Basic Asynchronous API in Java

Consider the following simple Slice definition:

```
module Demo
{
   interface Employees
   {
     string getName(int number);
   }
}
```

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Asynchronous Proxy Methods in Java

Besides the synchronous proxy methods, slice2java generates the following asynchronous proxy methods:

```
public interface EmployeesPrx extends Ice.ObjectPrx
{
    // ...
    public Ice.AsyncResult begin_getName(int number);
    public Ice.AsyncResult begin_getName(int number, java.util.Map<String, String> __ctx);
    public String end_getName(Ice.AsyncResult __result);
}
```

(i)

Four additional overloads of begin_getName are generated for use with generic completion callbacks and type-safe completion callbacks.

As you can see, the single getName operation results in begin_getName and end_getName methods. (The begin_method is overloaded so you can pass a per-invocation context.)

- The begin_getName method sends (or queues) an invocation of getName. This method does not block the calling thread.
- The end_getName method collects the result of the asynchronous invocation. If, at the time the calling thread calls end_getName, the result is
 not yet available, the calling thread blocks until the invocation completes. Otherwise, if the invocation completed some time before the call to end_
 getName, the method returns immediately with the result.

A client could call these methods as follows:

```
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EmployeesPrx e = ...;
Ice.AsyncResult r = e.begin_getName(99);

// Continue to do other things here...

String name = e.end_getName(r);
```

Because begin_getName does not block, the calling thread can do other things while the operation is in progress.

Note that begin_getName returns a value of type AsyncResult. This value contains the state that the Ice run time requires to keep track of the asynchronous invocation. You must pass the AsyncResult that is returned by the begin_method to the corresponding end_method.

The begin_method has one parameter for each in-parameter of the corresponding Slice operation. Similarly, the end_method has one out-parameter for each out-parameter of the corresponding Slice operation (plus the AsyncResult parameter). For example, consider the following operation:

```
Slice

double op(int inp1, string inp2, out bool outp1, out long outp2);
```

The begin_op and end_op methods have the following signature:

```
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Ice.AsyncResult begin_op(int inp1, String inp2);
Ice.AsyncResult begin_op(int inp1, String inp2, java.util.Map<String, String> __ctx);
double end_op(Ice.BooleanHolder outp1, Ice.LongHolder outp2, Ice.AsyncResult r);
```

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Asynchronous Exception Semantics in Java

If an invocation raises an exception, the exception is thrown by the end_ method, even if the actual error condition for the exception was encountered during the begin_ method ("on the way out"). The advantage of this behavior is that all exception handling is located with the code that calls the end_ met hod (instead of being present twice, once where the begin_ method is called, and again where the end_ method is called).

There is one exception to the above rule: if you destroy the communicator and then make an asynchronous invocation, the begin_method throws Commun icatorDestroyedException. This is necessary because, once the run time is finalized, it can no longer throw an exception from the end_method.

The only other exception that is thrown by the <code>begin_</code> and <code>end_</code> methods is <code>java.lang.IllegalArgumentException</code>. This exception indicates that you have used the API incorrectly. For example, the <code>begin_</code> method throws this exception if you call an operation that has a return value or outparameters on a oneway proxy. Similarly, the <code>end_</code> method throws this exception if you use a different proxy to call the <code>end_</code> method than the proxy you used to call the <code>begin_</code> method, or if the <code>AsyncResult</code> you pass to the <code>end_</code> method was obtained by calling the <code>begin_</code> method for a different operation.

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AsyncResult Interface in Java

The AsyncResult that is returned by the begin_method encapsulates the state of the asynchronous invocation:

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```
public interface AsyncResult
{
    public void cancel();

    public Communicator getCommunicator();
    public Connection getConnection();
    public ObjectPrx getProxy();
    public String getOperation();

    public boolean isCompleted();
    public void waitForCompleted();

    public boolean isSent();
    public void waitForSent();

    public void throwLocalException();

    public boolean sentSynchronously();
}
```

The methods have the following semantics:

• void cancel(

This method prevents a queued invocation from being sent or, if the invocation has already been sent, ignores a reply if the server sends one. can cel is a local operation and has no effect on the server. A canceled invocation is considered to be completed, meaning isCompleted returns true, and the result of the invocation is an Ice.InvocationCanceledException.

Communicator getCommunicator()

This method returns the communicator that sent the invocation.

Connection getConnection()

This method returns the connection that was used for the invocation. Note that, for typical asynchronous proxy invocations, this method returns a nil value because the possibility of automatic retries means the connection that is currently in use could change unexpectedly. The <code>getConnection</code> on method only returns a non-nil value when the <code>AsyncResult</code> object is obtained by calling <code>begin_flushBatchRequests</code> on a <code>Connection</code> object.

ObjectPrx getProxy()

This method returns the proxy that was used to call the begin_method, or nil if the AsyncResult object was not obtained via an asynchronous proxy invocation.

String getOperation()

This method returns the name of the operation.

• boolean isCompleted()

This method returns true if, at the time it is called, the result of an invocation is available, indicating that a call to the end_method will not block the caller. Otherwise, if the result is not yet available, the method returns false.

void waitForCompleted()

This method blocks the caller until the result of an invocation becomes available.

boolean isSent()

When you call the <code>begin_</code> method, the lce run time attempts to write the corresponding request to the client-side transport. If the transport cannot accept the request, the lce run time queues the request for later transmission. <code>isSent</code> returns true if, at the time it is called, the request has been written to the local transport (whether it was initially queued or not). Otherwise, if the request is still queued or an exception occurred before the request could be sent, <code>isSent</code> returns false.

void waitForSent()

This method blocks the calling thread until a request has been written to the client-side transport, or an exception occurs. After waitForSent returns, isSent returns true if the request was successfully written to the client-side transport, or false if an exception occurred. In the case of a failure, you can call the corresponding end_method or throwLocalException to obtain the exception.

void throwLocalException()

This method throws the local exception that caused the invocation to fail. If no exception has occurred yet, throwLocalException does nothing.

boolean sentSynchronously()

This method returns true if a request was written to the client-side transport without first being queued. If the request was initially queued, sentSynchronously returns false (independent of whether the request is still in the queue or has since been written to the client-side transport).

Polling for Completion in Java

The AsyncResult methods allow you to poll for call completion. Polling is useful in a variety of cases. As an example, consider the following simple interface to transfer files from client to server:

```
Slice
interface FileTransfer
{
    void send(int offset, ByteSeq bytes);
}
```

The client repeatedly calls send to send a chunk of the file, indicating at which offset in the file the chunk belongs. A naïve way to transmit a file would be along the following lines:

```
Java Compat

FileHandle file = open(...);
FileTransferPrx ft = ...;
int chunkSize = ...;
int offset = 0;
while(!file.eof())
{
    byte[] bs;
    bs = file.read(chunkSize); // Read a chunk
    ft.send(offset, bs); // Send the chunk
    offset += bs.length;
}
```

This works, but not very well: because the client makes synchronous calls, it writes each chunk on the wire and then waits for the server to receive the data, process it, and return a reply before writing the next chunk. This means that both client and server spend much of their time doing nothing — the client does nothing while the server processes the data, and the server does nothing while it waits for the client to send the next chunk.

Using asynchronous calls, we can improve on this considerably:

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```
FileHandle file = open(...);
FileTransferPrx ft = ...;
int chunkSize = ...;
int offset = 0;
LinkedList<Ice.AsyncResult> results = new LinkedList<Ice.AsyncResult>();
int numRequests = 5;
while(!file.eof())
   byte[] bs;
   bs = file.read(chunkSize);
   // Send up to numRequests + 1 chunks asynchronously.
   Ice.AsyncResult r = ft.begin_send(offset, bs);
   offset += bs.length;
   // Wait until this request has been passed to the transport.
   r.waitForSent();
   results.add(r);
   // Once there are more than numRequests, wait for the least
   // recent one to complete.
   while(results.size() > numRequests)
       Ice.AsyncResult r = results.getFirst();
       results.removeFirst();
       r.waitForCompleted();
}
// Wait for any remaining requests to complete.
while(results.size() > 0)
   Ice.AsyncResult r = results.getFirst();
   results.removeFirst();
   r.waitForCompleted();
}
```

With this code, the client sends up to numRequests + 1 chunks before it waits for the least recent one of these requests to complete. In other words, the client sends the next request without waiting for the preceding request to complete, up to the limit set by numRequests. In effect, this allows the client to "keep the pipe to the server full of data": the client keeps sending data, so both client and server continuously do work.

Obviously, the correct chunk size and value of numRequests depend on the bandwidth of the network as well as the amount of time taken by the server to process each request. However, with a little testing, you can quickly zoom in on the point where making the requests larger or queuing more requests no longer improves performance. With this technique, you can realize the full bandwidth of the link to within a percent or two of the theoretical bandwidth limit of a native socket connection.

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Generic Completion Callbacks in Java

The begin_method is overloaded to allow you to provide completion callbacks. Here are the corresponding methods for the getName operation:

The second version of <code>begin_getName</code> lets you override the default context. Following the in-parameters, the <code>begin_</code> method accepts a parameter of type <code>Ice.Callback</code>, which is a callback class with a <code>completed</code> method that you must provide. The lce run time invokes the <code>completed</code> method when an asynchronous operation completes. For example:

```
Java Compat

public class MyCallback extends Ice.Callback
{
    public void completed(Ice.AsyncResult r)
    {
        EmployeesPrx e = (EmployeesPrx)r.getProxy();
        try
        {
            String name = e.end_getName(r);
            System.out.println("Name is: " + name);
        }
        catch(Ice.LocalException ex)
        {
            System.err.println("Exception is: " + ex);
        }
    }
}
```

Note that your callback class must derive from Ice.Callback. The implementation of your callback method must call the end_ method. The proxy for the call is available via the getProxy method on the AsyncResult that is passed by the Ice run time. The return type of getProxy is Ice.ObjectPrx, so you must down-cast the proxy to its correct type.

Your callback method should catch and handle any exceptions that may be thrown by the end_ method. If an operation can throw user exceptions, this means that you need an additional catch handler for Ice.UserException (or catch all possible user exceptions explicitly). If you allow an exception to escape from the callback method, the lce run time produces a log entry by default and ignores the exception. (You can disable the log message by setting the property Ice.Warn.AMICallback to zero.)

To inform the Ice run time that you want to receive a callback for the completion of the asynchronous call, you pass the callback instance to the begin_me thad:

```
Java Compat

EmployeesPrx e = ...;

MyCallback cb = new MyCallback();
e.begin_getName(99, cb);
```

This is often written using an anonymous class instead:

An anonymous class is especially useful for callbacks that do only a small amount of work because the code that starts the call and the code that processes the results are physically close together.

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Sharing State Between begin_ and end_ Methods in Java

It is common for the <code>end_</code> method to require access to some state that is established by the code that calls the <code>begin_</code> method. As an example, consider an application that asynchronously starts a number of operations and, as each operation completes, needs to update different user interface elements with the results. In this case, the <code>begin_</code> method knows which user interface element should receive the update, and the <code>end_</code> method needs access to that element.

Assuming that we have a Widget class that designates a particular user interface element, you could pass different widgets by storing the widget to be used as a member of your callback class:

```
Java Compat
```

For this example, we assume that widgets have a writeString method that updates the relevant UI element.

When you call the begin_method, you pass the appropriate callback instance to inform the end_method how to update the display:

```
Java Compat

EmployeesPrx e = ...;
Widget widget1 = ...;
Widget widget2 = ...;

// Invoke the getName operation with different widget callbacks.
e.begin_getName(99, new MyCallback(widget1));
e.begin_getName(24, new MyCallback(widget2));
```

The callback class provides a simple and effective way for you to pass state between the point where an operation is invoked and the point where its results are processed. Moreover, if you have a number of operations that share common state, you can pass the same callback instance to multiple invocations. (If you do this, your callback methods may need to use synchronization.)

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Type-Safe Completion Callbacks in Java

The generic callback API is not entirely type-safe:

- You must down-cast the return value of getProxy to the correct proxy type before you can call the end_ method.
- You must call the correct end_ method to match the operation called by the begin_ method.
- · You must remember to catch exceptions when you call the end_ method; if you forget to do this, you will not know that the operation failed.

slice2java generates an additional type-safe API that takes care of these chores for you. To use type-safe callbacks, you can either implement a callback class or use lambda functions.

Type-Safe Callback Classes in Java

A callback class must define two callback methods:

- a response method that is called if the operation succeeds
- an exception method that is called if the operation raises an exception

The class must derive from the base class that is generated by slice2java. The name of this base class is <module>.Callback_<interface>_<operation>. Here is a callback class for an invocation of the getName operation:

```
Java Compat

public class MyCallback extends Demo.Callback_Employees_getName
{
    public void response(String name)
    {
        System.out.println("Name is: " + name);
    }
    public void exception(Ice.LocalException ex)
    {
        System.err.println("Exception is: " + ex);
    }
}
```

The response callback parameters depend on the operation signature. If the operation has non-void return type, the first parameter of the response call back is the return value. The return value (if any) is followed by a parameter for each out-parameter of the corresponding Slice operation, in the order of declaration.

The exception callback is invoked if the invocation fails because of an Ice run time exception. If the Slice operation can also raise user exceptions, your callback class must supply an additional overloading of exception that accepts an argument of type Ice.UserException.

The proxy methods are overloaded to accept this callback instance:

You pass the callback to an invocation as you would with the generic API:

```
Java Compat

EmployeesPrx e = ...;

MyCallback cb = new MyCallback();
e.begin_getName(99, cb);
```

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Type-Safe Lambda Functions in Java

You can implement your type-safe callbacks using in-line lambda functions. The proxy methods are overloaded to accept these functions:

The names of the internal interfaces used in the API are not important; what matters are their parameterized types, which tell you the arguments that your lambda functions must accept. For example, we can call begin_getName as follows:

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Asynchronous Oneway Invocations in Java

You can invoke operations via oneway proxies asynchronously, provided the operation has void return type, does not have any out-parameters, and does not raise user exceptions. If you call the begin_method on a oneway proxy for an operation that returns values or raises a user exception, the begin_me thod throws an IllegalArgumentException.

The callback methods looks exactly as for a twoway invocation. For the generic API, the Ice run time does not call the completed callback method unless the invocation raised an exception during the begin_method ("on the way out"). For the type-safe API, the response method is never called.

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Flow Control in Java

Asynchronous method invocations never block the thread that calls the <code>begin_</code> method: the loc run time checks to see whether it can write the request to the local transport. If it can, it does so immediately in the caller's thread. (In that case, <code>AsyncResult.sentSynchronously</code> returns true.) Alternatively, if the local transport does not have sufficient buffer space to accept the request, the loc run time queues the request internally for later transmission in the background. (In that case, <code>AsyncResult.sentSynchronously</code> returns false.)

This creates a potential problem: if a client sends many asynchronous requests at the time the server is too busy to keep up with them, the requests pile up in the client-side run time until, eventually, the client runs out of memory.

The API provides a way for you to implement flow control by counting the number of requests that are queued so, if that number exceeds some threshold, the client stops invoking more operations until some of the queued operations have drained out of the local transport.

For the generic API, you can override the sent method:

```
Java Compat

public class MyCallback extends Ice.Callback
{
    public void completed(Ice.AsyncResult r)
    {
        // ...
    }

    public void sent(Ice.AsyncResult r)
    {
        // ...
    }
}
```

You inform the Ice run time that you want to be informed when a call has been passed to the local transport as usual:

```
Java Compat

e.begin_getName(99, new MyCallback());
```

If the Ice run time can immediately pass the request to the local transport, it does so and invokes the sent method from the thread that calls the begin_m ethod. On the other hand, if the run time has to queue the request, it calls the sent method from a different thread once it has written the request to the local transport. In addition, you can find out from the AsyncResult that is returned by the begin_method whether the request was sent synchronously or was queued, by calling sentSynchronously.

For the generic API, the sent method has the following signature:

```
Java Compat

void sent(Ice.AsyncResult r);
```

For the type-safe API, the signature is:

```
Java Compat

void sent(boolean sentSynchronously);
```

For the generic API, you can find out whether the request was sent synchronously by calling sentSynchronously on the AsyncResult. For the type-safe API, the boolean sentSynchronously parameter provides the same information.

The sent methods allow you to limit the number of queued requests by counting the number of requests that are queued and decrementing the count when the lce run time passes a request to the local transport.

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Asynchronous Batch Requests in Java

You can invoke operations via batch oneway proxies asynchronously, provided the operation has void return type, does not have any out-parameters, and does not raise user exceptions. If you call the begin_method on a oneway proxy for an operation that returns values or raises a user exception, the begin_method throws an IllegalArgumentException.

A batch oneway invocation never calls the generic or type-safe callbacks unless an error occurs before the request is queued. The returned Ice.

AsyncResult for a batch oneway invocation is always completed and indicates the successful queuing of the batch invocation. The returned result can also be marked completed if an error occurs before the request is queued.

Applications that send batched requests can either flush a batch explicitly or allow the Ice run time to flush automatically. The proxy method ice_flushBatchRequests performs an immediate flush using the synchronous invocation model and may block the calling thread until the entire message can be sent. Ice also provides asynchronous versions of this method so you can flush batch requests asynchronously.

begin_ice_flushBatchRequests and end_ice_flushBatchRequests are proxy methods that flush any batch requests queued by that proxy.

In addition, similar methods are available on the communicator and the Connection object that is returned by AsyncResult.getConnection. These methods flush batch requests sent via the same communicator and via the same connection, respectively.

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Concurrency Semantics for AMI in Java

The Ice run time always invokes your callback methods from a separate thread, with one exception: it calls the sent callback from the thread calling the be gin_method if the request could be sent synchronously. In the sent callback, you know which thread is calling the callback by looking at the sentSynch ronously member or parameter.

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See Also

- Request Contexts
- Batched Invocations
- Collocated Invocation and Dispatch



