The Internet Communications Engine

Object-oriented Middleware

- Used by the computing industry since the mid-nineties
- The middleware platform takes care of the majority of networking chores
  - Marshaling and unmarshaling
  - Mapping logical object addresses to physical transport endpoints
  - Changing the representation of data according to the native machine architecture
  - Automatically starting servers on demand.

Object-oriented Middleware

- Binary protocols
  - DCOM - a Microsoft-only solution, superceded by .NET
    - Scales badly to large numbers (hundreds of thousands or millions) of objects, largely due to the overhead of its distributed garbage collection mechanism.
  - CORBA - available from a variety of vendors, standardized by OMG
    - Some problems with interoperability
    - Excessive complexity
- XML based, standardized by w3c
  - SOAP
    - Very serious performance penalties on applications, both in terms of network bandwidth and CPU overhead
    - Lack of higher-level abstractions
  - Web Services
    - Still at its infancy

The Internet Communications Engine

- Developed by ZeroC, Inc.
- The main design goals of Ice:
  - Provide an object-oriented middleware platform suitable for use in heterogeneous environments.
  - Provide a full set of features that support development of realistic distributed applications for a wide variety of domains.
  - Avoid unnecessary complexity, making the platform easy to learn and to use.
  - Provide an implementation that is efficient in network bandwidth, memory use, and CPU overhead.
  - Provide an implementation that has built-in security, making it suitable for use over insecure public networks.

The Ice Architecture

- Clients and Servers
  - Clients are active entities. They issue requests for service to servers.
  - Servers are passive entities. They provide services in response to client requests.

Ice Objects

- An Ice object is an entity in the local or a remote address space that can respond to client requests.
- A single Ice object can be instantiated in a single server or, redundantly, in multiple servers.
- Each Ice object has one or more interfaces.
  - An interface is a collection of named operations that are supported by an object.
  - Clients issue requests by invoking operations.
- An operation has zero or more parameters as well as a return value.
  - Parameters and return values have a specific type.
  - Parameters are named and have a direction:
    - in-parameters are initialized by the client and passed to the server;
    - out-parameters are initialized by the server and passed to the client.

Ice Objects

- An Ice object has a distinguished interface, known as its main interface.
    - An Ice object can provide zero or more alternate interfaces, known as facets.
        - Clients can select among the facets of an object to choose the interface they want to work with.
- Each Ice object has a unique object identity.
    - An object's identity is an identifying value that distinguishes the object from all other objects.
    - The Ice object model assumes that object identities are globally unique.

Proxies

- For a client to be able to contact an Ice object, the client must hold a proxy for the Ice object.
  - A proxy is an artifact that is local to the client's address space; it represents the (possibly remote) Ice object for the client.
  - A proxy acts as the local ambassador for an Ice object: when the client invokes an operation on the proxy, the Ice run time:
    - Locates the Ice object
    - Activates the Ice object's server if it is not running
    - Activates the Ice object within the server
    - Transmits any in-parameters to the Ice object
    - Waits for the operation to complete
    - Returns any out-parameters and the return value to the client
      - or throws an exception in case of an error

Servants

- An Ice object is a conceptual entity that has a type, identity, and addressing information.
- Client requests ultimately must end up with a concrete server-side processing entity that can provide the behavior for an operation invocation.
- The server-side artifact that provides behavior for operation invocations is known as a servant.
  - A servant provides substance for (or incarnates) one or more Ice objects.
    - It is simply an instance of a class that is written by the server developer and that is registered with the server-side run time as the servant for one or more Ice objects.
    - Methods on the class correspond to the operations on the Ice object’s interface and provide the behavior for the operations.

At-Most-Once Semantics

- Ice requests have at-most-once semantics
  - The Ice run time does its best to deliver a request to the correct destination and, depending on the exact circumstances, may retry a failed request.
  - Ice guarantees that it will either:
    - Deliver the request
    - Inform the client with an appropriate exception that it cannot deliver the request
    - Under no circumstances is a request delivered twice

Different Ways of Method Invocation

- Synchronous Method Invocation
- Asynchronous Method Invocation
- Oneway Method Invocation
- Batched Oneway Method Invocation
- Datagram Invocations
- Batched Datagram Invocations

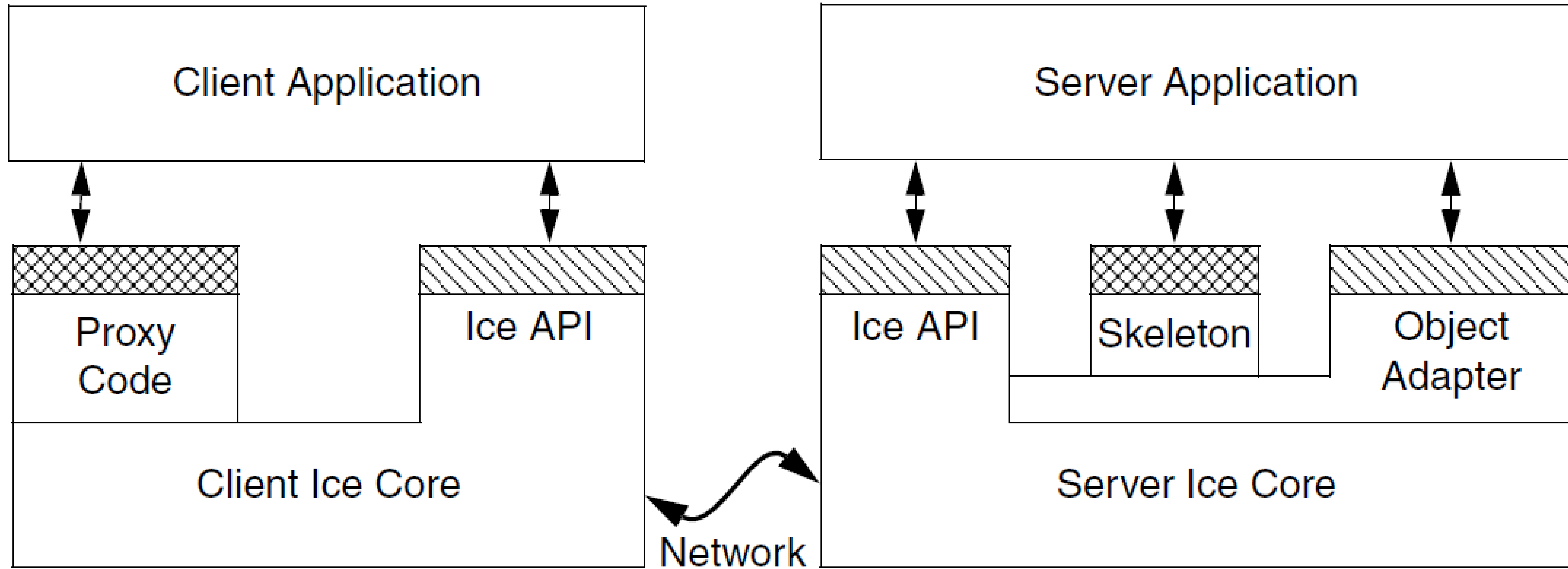
Slice

- Specification Language for Ice
- Each Ice object has an interface with a number of operations. Interfaces, operations, and the types of data that are exchanged between client and server are defined using the Slice language.
- Slice allows you to define the client-server contract in a way that is independent of a specific programming language, such as C++, Java, or C#.
- The Slice definitions are compiled by a compiler into an API for a specific programming language, that is, the part of the API that is specific to the interfaces and types you have defined consists of generated code.

Language Mappings

- The rules that govern how each Slice construct is translated into a specific programming language are known as language mappings.
  - For the C++ mapping a Slice sequence appears as an STL vector
  - For the Java mapping a Slice sequence appears as a Java array.
- In order to determine what the API for a specific Slice construct looks like, you only need the Slice definition and knowledge of the language mapping rules.
- The rules are simple and regular enough to make it unnecessary to read the generated code to work out how to use the generated API.

Client and Server Structure



The Ice Protocol

- Ice provides an RPC protocol that can use either TCP/IP or UDP as an underlying transport.
  - Ice also allows you to use SSL as a transport, so all communication between client and server is encrypted.
- The Ice protocol defines:
  - A number of message types, such as request and reply message types,
  - A protocol state machine that determines in what sequence different message types are exchanged by client and server, together with the associated connection establishment and tear-down semantics for TCP/IP,
  - Encoding rules that determine how each type of data is represented on the wire,
  - A header for each message type that contains details such as the message type, the message size, and the protocol and encoding version in use.

The Ice Protocol

- Ice supports compression on the wire: by setting a configuration parameter, you can arrange for all network traffic to be compressed to conserve bandwidth.
- The Ice protocol is suitable for building highly-efficient event forwarding mechanisms as it permits forwarding of a message without knowledge of the details of the information inside a message.
- The Ice protocol also supports bidirectional operation: if a server wants to send a message to a callback object provided by the client, the callback can be made over the connection that was originally created by the client.

Ice Services

- Freeze
  - Built-in object persistence service.
- IceGrid
  - Ice location service that resolves the symbolic information in an indirect proxy to a protocol – address pair for indirect binding.
- IceBox
  - A simple application server that can orchestrate the starting and stopping of a number of application components
- IceStorm
  - A publish–subscribe service that decouples clients and servers.
- IcePatch2
  - A software patching service.
- Glacier2
  - The Ice firewall traversal service.

Architectural Benefits of Ice

- Object-oriented semantics
- Support for synchronous and asynchronous messaging
- Support for multiple interfaces
- Machine independence
- Language independence
- Implementation independence
- Operating system independence
- Threading support
- Transport independence
- Location and server transparency
- Security
- Built-in persistence
- Source code availability

A Hello World Application

```
// Printer.ice
module Demo {
    interface Printer {
        void printString(string s);
    };
};
```

```
$ slice2cpp Printer.ice
```

- The **`slice2cpp`** compiler produces two C++ source files from this definition, **`Printer.h`** and **`Printer.cpp`**.
  - **`Printer.h`** - C++ type definitions that correspond to the Slice definitions for our Printer interface.
    - This header file must be included in both the client and the server source code.
  - **`Printer.cpp`** - the source code for our Printer interface.
    - The generated source contains type-specific run-time support for both clients and servers.

The Server

```
#include <Ice/Ice.h>
#include <Printer.h>

using namespace std;
using namespace Demo;

class PrinterI : public Printer {
public:
  virtual void printString(const string& s,
                           const Ice::Current&);
};

void
PrinterI::
printString(const string& s,
            const Ice::Current&)
{
  cout << s << endl;
}
```

```
int
main(int argc, char* argv[])
{
  int status = 0;
  Ice::CommunicatorPtr ic;
  try {
      ic = Ice::initialize(argc, argv);
      Ice::ObjectAdapterPtr adapter
        = ic->createObjectAdapterWithEndpoints(
              "SimplePrinterAdapter",
              "default -p 10000");
      Ice::ObjectPtr object = new PrinterI;
      adapter->add(object,
        ic->stringToIdentity("SimplePrinter"));
      adapter->activate();
      ic->waitForShutdown();
  } catch (const Ice::Exception& e) {
      cerr << e << endl;
      status = 1;
  } catch (const char* msg) {
      cerr << msg << endl;
      status = 1;
  }
  if (ic) {
      try {
          ic->destroy();
      } catch (const Ice::Exception& e) {
          cerr << e << endl;
          status = 1;
      }
  }
  return status;
}
```

```
$ g++ -I. Printer.cpp Server.cpp -lIce -lIceUtil
```

The Client

```
#include <Ice/Ice.h>
#include <Printer.h>

using namespace std;
using namespace Demo;

int
main(int argc, char* argv[])
{
    int status = 0;
    Ice::CommunicatorPtr ic;
    try {
        ic = Ice::initialize(argc, argv);
        Ice::ObjectPrx base = ic->stringToProxy(
                                "SimplePrinter:default -p 10000");
        PrinterPrx printer = PrinterPrx::checkedCast(base);
        if (!printer)
            throw "Invalid proxy";

        printer->printString("Hello World!");
    } catch (const Ice::Exception& ex) {
        cerr << ex << endl;
        status = 1;
    } catch (const char* msg) {
        cerr << msg << endl;
        status = 1;
    }
    if (ic)
        ic->destroy();
    return status;
}
```

```
$ g++ -I. Printer.cpp Client.cpp -lIce -lIceUtil
```