

# Developing Distributed Object Computing Applications with CORBA

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## Motivation: the Distributed Software Crisis



### Symptoms

- **Hardware** gets smaller, faster, cheaper
- **Software** gets larger, slower, more expensive

### Culprits

- **Inherent** and **accidental** complexity

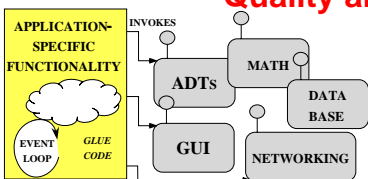
### Solution Approach

- **Components, Frameworks, Patterns, & Architecture**

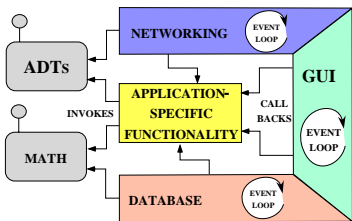


## Techniques for Improving Software Quality and Productivity

Proven solutions →



(A) CLASS LIBRARY ARCHITECTURE

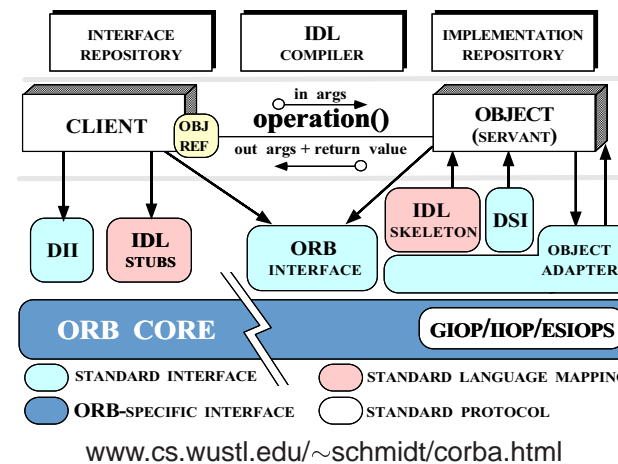


(B) FRAMEWORK ARCHITECTURE

- **Components**
  - Self-contained, “pluggable” ADTs
- **Frameworks**
  - Reusable, “semi-complete” applications
- **Patterns**
  - Problem/solution/context
- **Architecture**
  - Families of related patterns and components



## Overview of CORBA Middleware Architecture

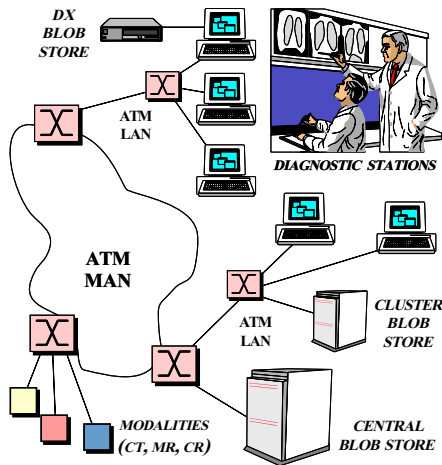


### Goals of CORBA

- Simplify distribution by automating
  - Object location & activation
  - Parameter marshaling
  - Demultiplexing
  - Error handling
- Provide foundation for higher-level services



## Applying CORBA to Medical Imaging



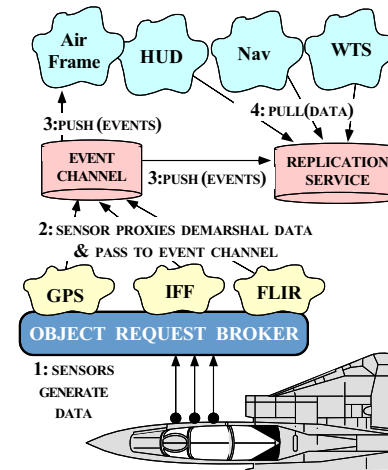
### • Domain Challenges

- Large volume of “Blob” data
  - \* e.g., 10 to 40 Mbps
- “Lossy compression” isn’t viable
- Prioritization of requests

### • URLs

- [~schmidt/PDF/COOTS-96.pdf](#)
- [~schmidt/PDF/av\\_chapter.pdf](#)
- [~schmidt/NMVC.html](#)

## Applying CORBA to Real-time Avionics



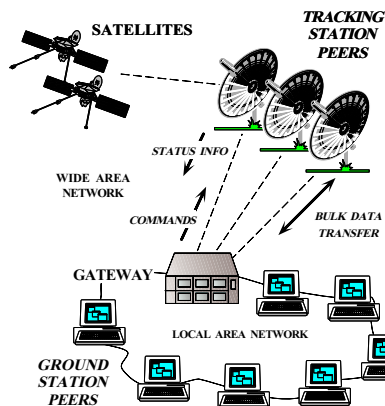
### • Domain Challenges

- Real-time periodic processing
- Complex dependencies
- Very low latency

### • URLs

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- [~schmidt/TAO-boeing.html](#)

## Applying CORBA to Global PCS



### • Domain Challenges

- Long latency satellite links
- High reliability
- Prioritization

### • URL

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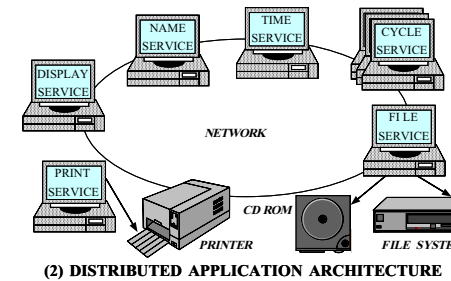
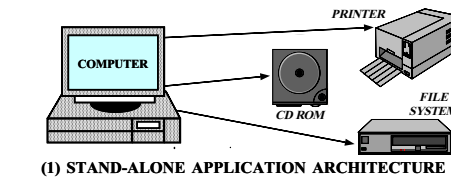
## Tutorial Outline

- Motivation
- Example CORBA Applications
- Coping with Changing Requirements
- Overview of CORBA Architecture
- Evaluations and Recommendations

## Motivation for COTS Middleware

- It is hard to develop distributed applications whose components collaborate *efficiently, reliably, transparently, and scalably*
- To help address this challenge, the Object Management Group (OMG) is specifying the *Common Object Request Broker Architecture (CORBA)*
- OMG is a consortium of ~1,000 computer companies
  - Sun, HP, DEC, IBM, IONA, Borland, Cisco, Motorola, Boeing, etc.
- The latest version of the CORBA spec is now available
  - [www.omg.org/technology/documents/formal/](http://www.omg.org/technology/documents/formal/)

## Sources of Complexity for Distributed Applications



- **Inherent complexity**
  - Latency
  - Reliability
  - Partitioning
  - Ordering
  - Security
- **Accidental Complexity**
  - Low-level APIs
  - Poor debugging tools
  - Algorithmic decomposition
  - Continuous re-invention

## Sources of Inherent Complexity

- *Inherent complexity* results from fundamental challenges in the distributed application domain
- Key challenges include
  - Addressing the impact of latency
  - Detecting and recovering from partial failures of networks and hosts
  - Load balancing and service partitioning
  - Consistent ordering of distributed events

## Sources of Accidental Complexity

- *Accidental complexity* results from limitations with tools and techniques used to develop distributed applications
- Key limitations include
  - Lack of type-safe, portable, re-entrant, and extensible system call interfaces and component libraries
  - Inadequate debugging support
  - Widespread use of *algorithmic* decomposition
  - Continuous rediscovery and reinvention of core concepts and components

## Motivation for CORBA

- Simplifies application interworking
  - CORBA provides higher level integration than traditional *untyped TCP bytestreams*
- Benefits for distributed programming similar to OO languages for non-distributed programming
  - e.g., encapsulation, interface inheritance, polymorphism, and exception handling
- Provides a foundation for higher-level distributed object collaboration
  - e.g., ActiveX and the OMG Common Object Service Specification (COSS)



## CORBA Quoter Example

```
int main (void)
{
    // Use a factory to bind
    // to a Quoter.
    Quoter_var quoter =
        bind_quoter_service ();

    const char *name =
        "ACME ORB Inc.";

    CORBA::Long value =
        quoter->get_quote (name);
    cout << name << " = "
         << value << endl;
}
```

- Ideally, a distributed service should look just like a non-distributed service
- Unfortunately, life is harder when errors occur...



## CORBA Quoter Interface

```
// IDL interface is like a C++
// class or Java interface.
interface Quoter
{
    exception Invalid_Stock {};

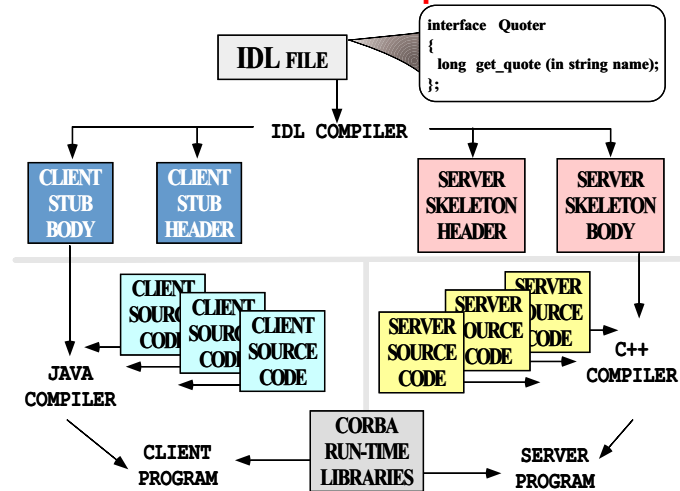
    long get_quote
        (in string stock_name)
        raises (Invalid_Stock);
};
```

- We write an OMG IDL interface for our Quoter
  - Used by both clients and servers

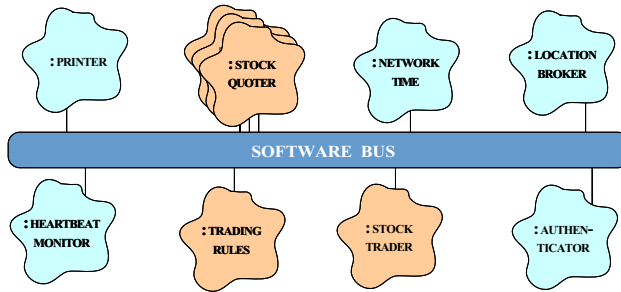
Using OMG IDL promotes *language/platform independence, location transparency, modularity, and robustness*



## OMG IDL Compiler

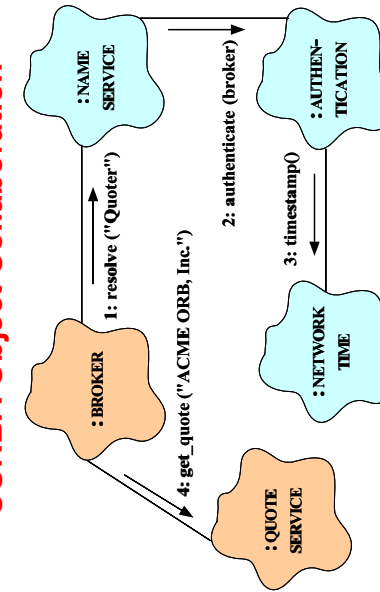


## Software Bus



- CORBA provides a communication infrastructure for a heterogeneous, distributed collection of collaborating objects
- Analogous to “hardware bus”

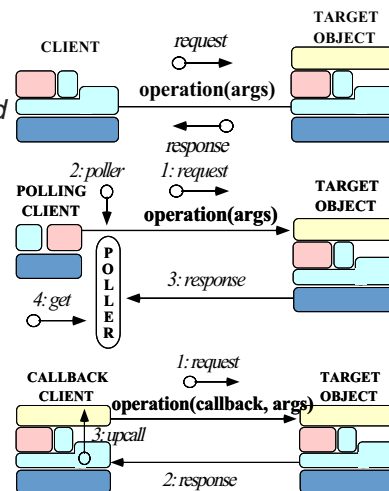
## CORBA Object Collaboration



- Collaborating objects can be either remote or local
  - *i.e.*, distributed or collocated
- For this to work transparently the ORB should support *nested upcalls and collocation optimizations*

## Communication Features of CORBA

- CORBA supports reliable, uni-cast communication
  - *i.e.*, *oneway*, *twoway*, *deferred synchronous*, and *asynchronous*
- CORBA objects can also collaborate in a *client/server*, *peer-to-peer*, or *publish/subscribe* manner
  - *e.g.*, COS Events & Notification Services define a publish & subscribe communication paradigm



## Fundamental CORBA Design Principles

- Separation of interface and implementation
  - Clients depend on interfaces, not implementations
- Location transparency
  - Service use is orthogonal to service location
- Access transparency
  - Invoke operations on objects
- Typed interfaces
  - Object references are typed by interfaces
- Support of multiple inheritance of interfaces
  - Inheritance extends, evolves, and specializes behavior

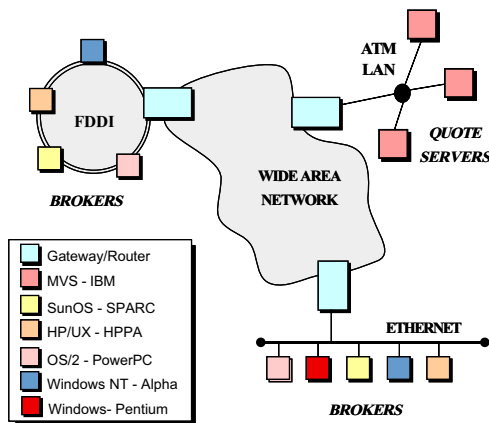
## Related Work

- Traditional RPC (e.g., DCE)
  - Only supports “procedural” integration of application services
  - Doesn’t provide object abstractions, async message passing, or dynamic invocation
  - Doesn’t address inheritance of interfaces
- Windows COM/DCOM/COM+
  - Traditionally limited to desktop applications
  - Does not address heterogeneous distributed computing

## Related Work (cont'd)

- Java RMI
  - Limited to Java only
    - \* Can be extended into other languages, such as C or C++, by using a bridge across the Java Native Interface (JNI)
  - Well-suited for all-Java applications because of its tight integration with the Java virtual machine
    - \* e.g., can pass both object data and code by value
  - However, many challenging issues remain unresolved
    - \* e.g., security, robustness, and versioning

## CORBA Stock Quoter Application Example



- The quote server(s) maintains the current stock prices
- Brokers access the quote server(s) via CORBA
- Note all the heterogeneity!

## Simple OMG IDL Quoter Definition

```

module Stock {
    // Exceptions are similar to structs.
    exception Invalid_Stock {};
    exception Invalid_Factory {};

    // Interface is similar to a C++ class.
    interface Quoter
    {
        long get_quote (in string stock_name)
            raises (Invalid_Stock);
    };

    // A factory that creates Quoter objects.
    interface Quoter_Factory
    {
        // Factory Method that returns a new Quoter
        // selected by name e.g., "Dow Jones,"
        // "Reuters", etc.
        Quoter create_quoter (in string quoter_service)
            raises (Invalid_Factory);
    };
};

```



### Compiling the Interface Definition

- Running the `Stock` module definition through the IDL compiler generates stubs and skeletons
  - The stub is a *proxy* that marshals parameters on the client
  - The skeleton is an *adapter* that demarshals parameters on the server
- CORBA associates a servant to a generated IDL skeleton using either
  1. The Class form of the Adapter pattern (inheritance)
    - POA\_Stock::Quoter
  2. The Object form of the Adapter pattern (object composition, i.e., TIE)
    - template <class Impl> class POA\_Stock::Quoter\_tie

### Automatically-Generated Client-side Stubs

```
namespace Stock
{
    class Quoter
    : public virtual CosLifeCycle::LifecycleObject
    // Quoter also IS-A CORBA::Object.
    {
    public:
        // Proxy interface.
        CORBA::Long get_quote (const char *stock_name);
    };

    class Quoter_Factory
    : public virtual CosLifeCycle::GenericFactory
    // GenericFactory IS-A CORBA::Object.
    {
    public:
        // Proxy Factory method for creation.
        // Inherits:
        // CORBA::Object_ptr create_object
        // (const CosLifeCycle::Key &factory_key,
        // const CosLifeCycle::Criteria &criteria)
    };
    // ...
};
```



### Revised OMG IDL Quoter Definition

#### Apply the CORBA Lifecycle Service

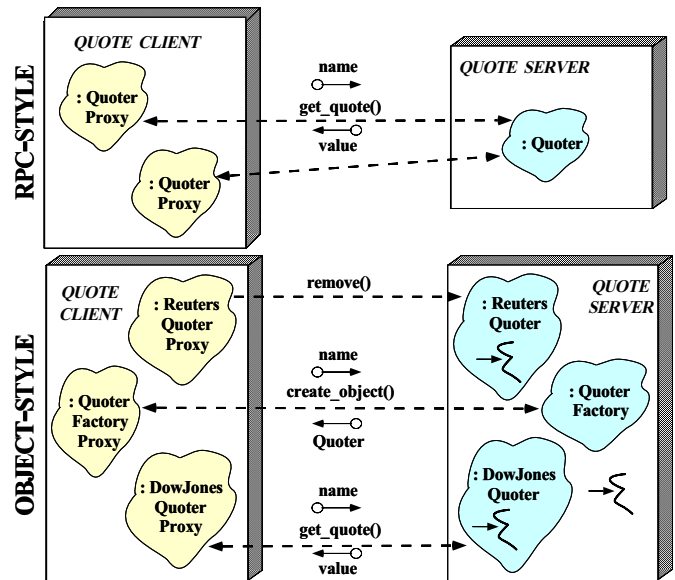
```
module Stock {
    exception Invalid_Stock {}; // Similar to structs.

    // Interface is similar to a C++ class.
    interface Quoter : CosLifeCycle::LifecycleObject
    {
        long get_quote (in string stock_name)
            raises (Invalid_Stock);
        // Inherits:
        // void remove () raises (NotRemovable);
    };

    // Manage the lifecycle of a Quoter object.
    interface Quoter_Factory :
        CosLifeCycle::GenericFactory
    {
        // Returns a new Quoter selected by name
        // e.g., "Dow Jones," "Reuters," etc.
        // Inherits:
        // Object create_object (in Key k,
            in Criteria criteria)
        // raises (NoFactory, InvalidCriteria,
            CannotMeetCriteria);
    };
};
```

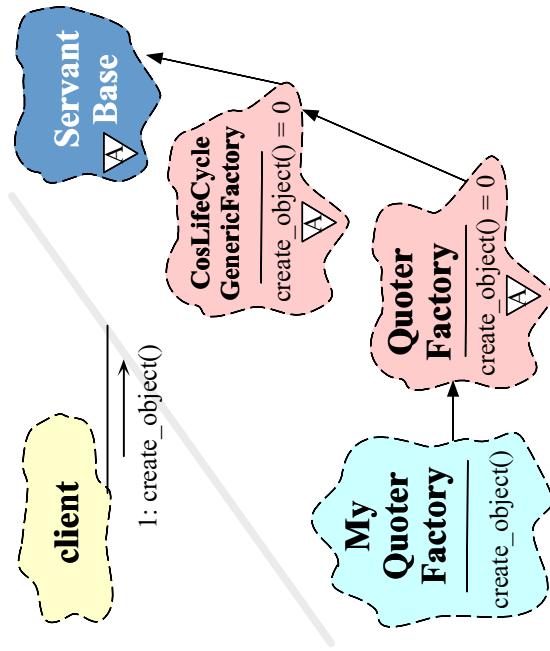


### RPC-style vs. Object-style Communication





## The Class Form of the Adapter Pattern



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## Defining a Servant Using Inheritance

```

class My_Quoter_Factory : public virtual POA_Stock::Quoter_Factory
{
public:
    My_Quoter_Factory (const char *factory_name =
                      "my quoter factory");
    virtual CORBA::Object_ptr // Factory method for creation.
        create_object (const CosLifeCycle::Key &factory_key,
                      const CosLifeCycle::Criteria &the_criteria)
        throw (CORBA::SystemException, QuoterFactory::NoFactory);
};
  
```

The drawback is that implementations inherit from generated skeletons

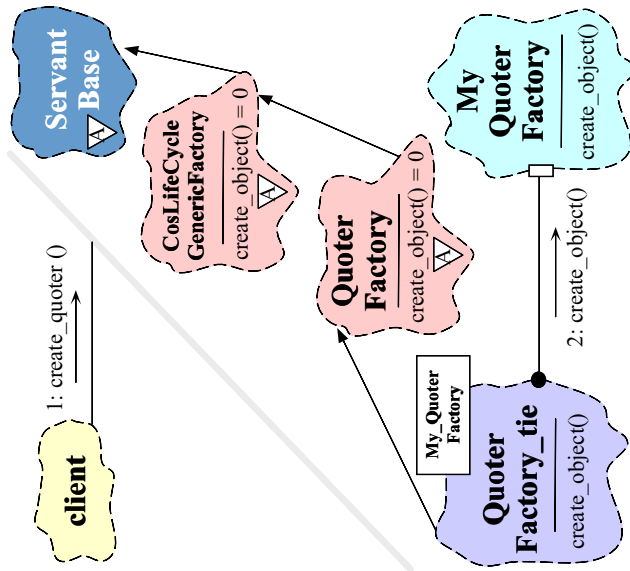
- Can create a “brittle” hierarchy and make it hard to integrate with legacy code, *i.e.*, distributing a stand-alone application
- Virtual inheritance is often poorly implemented



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## The Object Form of the Adapter Pattern



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## A TIE-based Implementation

```

class My_Quoter_Factory {
public:
    My_Quoter_Factory (const char *factory_name =
                      "my quoter factory");
    // Factory method for creation.
    CORBA::Object_ptr create_object
        (const CosLifeCycle::Key &factory_key,
         const CosLifeCycle::Criteria &the_criteria)
        throw (CORBA::SystemException, QuoterFactory::NoFactory);
};
  
```

TIE allows classes to become distributed even if they weren't developed with prior knowledge of CORBA

- There is no use of inheritance and operations need not be virtual!
- However, lifecycle issues can be tricky...



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## Defining a Servant Using TIE

```
namespace POA_Stock
{
    template <class Impl>
    class Quoter_Factory_tie : public Quoter_Factory { /* ... */ };
    // ...
}
```

We generate a typedef and a servant that places an implementation pointer object within the TIE class:

```
typedef POA_Stock::Quoter_Factory_tie<My_Quoter_Factory>
    MY_QUOTER_FACTORY;
MY_QUOTER_FACTORY Factory (new My_Quoter_Factory);
```

All operation calls via the TIE class are then delegated to the implementation object

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## Registering My\_Quoter\_Factory with the Naming Service

```
extern CosNaming::NamingContext_ptr
    name_context;

My_Quoter_Factory::My_Quoter_Factory
    (const char *factory_name)
{
    CosNaming::Name name;
    name.length (1);
    name[0].id = factory_name;
    name[0].kind = "object impl";

    // Obtain object reference and
    // register with the POA.
    Quoter_Factory_var qf = this->_this ();

    // Export our object reference to the
    // naming context.
    name_context->bind (name, qf);
};
```

Real code should handle exceptions...

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## Implementing My\_Quoter\_Factory

```
CORBA::Object_ptr
My_Quoter_Factory::create_object
    (const CosLifecycle::Key &factory_key,
     const CosLifecycle::Criteria &the_criteria)
{
    POA_Stock::Quoter *quoter;

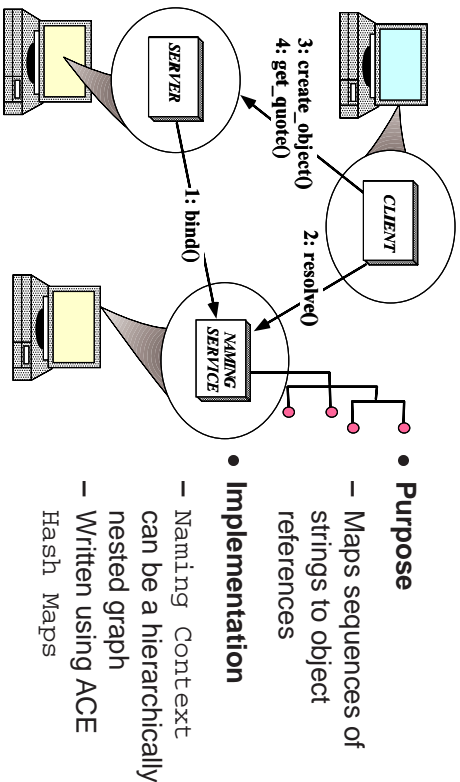
    // Perform Factory Method selection of
    // the subclass of Quoter.
    if (strcmp (factory_key.id,
               "Dow Jones") == 0)
        quoter = new Dow_Jones_Quoter;
    // ...
    else if (strcmp (factory_key.id,
                    "My Quoter") == 0)
        // Dynamically allocate a My_Quoter object.
        quoter = new My_Quoter;
    else
        // Raise exception.
        throw Quoter_Factory::NoFactory ();

    // Create a Stock::Quoter_ptr, register
    // the servant with the default_POA, and
    // return the new Object Reference.
    return quoter->_this ();
};
```

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## Using the CORBA Naming Service



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## The Main Server Program

Uses *persistent activation mode*

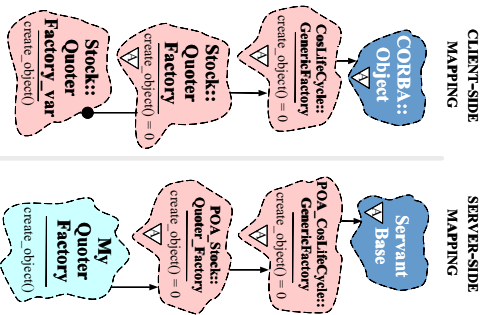
```
int main (int argc, char *argv[])
{
    ORB_Manager orb_manager (argc, argv);

    const char *factory_name = "my quoter factory";

    // Create the servant, which registers with
    // the rootPOA and Naming Service implicitly.
    My_Quoter_Factory factory (factory_name);

    // Could use the TIE approach and explicitly
    // register the servant with the POA, i.e.:
    // MY_QUOTER_FACTORY factory
    // (new My_Quoter_Factory (factory_name));
    // orb_manager.activate (&factory);

    // Block indefinitely waiting for incoming
    // invocations and dispatch upcalls.
    orb_manager.run ();
    // After run() returns, the ORB has shutdown.
}
```



### POA IDL Mappings

- The client-side mapping inherits all interfaces from the Object interface
  - Similar to Java
- The server-side mapping inherits all Servants from ServantBase
  - Note that older versions of CORBA may not support this standard



## Server Initialization Wrapper Facades

```
class ORB_Manager {
public:
    // Initialize the ORB manager.
    ORB_Manager (int argc, char *argv[]) {
        orb_ = CORBA::ORB_init (argc, argv, 0);
        CORBA::Object_var obj =
            orb_->resolve_initial_references ("RootPOA");
        poa_ =
            PortableServer::POA::_narrow (obj);
        poa_manager_ = poa_->the_POAManager ();
    }

    // Register <servant> with the <poa_>.
    int activate (PortableServer::Servant servant) {
        return poa_->activate_object (servant);
    }
    // ORB Accessor.
    CORBA::ORB_ptr orb (void) { return orb_; }

    // Run the main ORB event loop.
    int run (void) {
        poa_manager_->activate ();
        return orb_->run ();
    }
private:
    CORBA::ORB_var orb_;
    PortableServer::POA_var poa_;
    PortableServer::POA_Manager_var poa_manager_;
}
```



### OMG IDL Mapping Rules

- The CORBA specification defines mappings from CORBA IDL to various programming languages
  - e.g., C++, C, Smalltalk, Java, COBOL
- Mapping OMG IDL to C++
  - Each module is mapped to a class or namespace
  - Each interface is mapped to a class
  - Each operation is mapped to a C++ method with appropriate parameters
  - Each read/write attribute is mapped to a pair of get/set methods
    - \* A read-only attribute is only mapped to a single get method
  - An Environment is defined to carry exceptions in languages that lack this feature



## Binding a Client to a CORBA Object

- Several steps:
  1. Client uses `resolve_initial_references` and "Interoperable Naming Service" to obtain a `NamingContext`
    - This is the standard ORB "bootstrapping" mechanism
  2. Client then uses `NamingContext` to obtain desired object reference
  3. The client then invokes operations via object reference
- Object references can be passed as parameters to other remote objects
  - This supports various types of "factory" patterns

## A Client Program

```
int main (int argc, char *argv[])
{
    // Manages refcounts.
    Stock::Quoter_var quoter;

    try { // Use a factory to bind to any quoter.
        Stock::Quoter_Factory_var qf =
            bind_service<Stock::Quoter_Factory>
                ("my quoter factory", argc, argv);
        if (CORBA::is_nil (qf)) return -1;
        const char *stock_name = "ACME ORB Inc.";
        CosLifecycle::Key key; key.length (1);
        key[0].id = "My Quoter";

        // Find a quoter and invoke the call.
        CORBA::Object_var obj = qf->create_object (key);
        quoter = Stock::Quoter::_narrow (obj);
        CORBA::Long value =
            quoter->get_quote (stock_name);
        cout << stock_name << " = " << value << endl;
        // Destructors of *_var release memory.
    } catch (Stock::Invalid_Stock &) {
        cerr << stock_name << " not valid" << endl;
    } catch (...) { /* Handle exception... */ }
    quoter->remove ();
}
```

## Programming with Object References

- Object references are represented by different generated types
  - `_ptr` → C++ pointer to object reference
    - \* Requires programmer management of reference ownership via `_duplicate` and `_release`
  - `_var` → Auto pointer to object reference
    - \* Internally manages reference ownership
  - `_out` → eases passing out parameters between client and server
    - \* Never used directly by user

## Obtaining an Object Reference via the Naming Service

```
static CORBA::ORB_ptr orb;
extern CosNaming::NamingContext_ptr name_context;

template <class T> typename T::_ptr_type /* trait */
bind_service (const char *n, int argc, char *argv[])
{
    CORBA::Object_var obj; // "First time" check.
    if (CORBA::is_nil (name_context)) {
        // Get reference to name service.
        orb = CORBA::ORB_init (argc, argv, 0);
        obj = orb->resolve_initial_references
            ("NameService");
        name_context =
            CosNaming::NamingContext::_narrow (obj);
        if (CORBA::is_nil (name_context)) return T::_nil
    }
    CosNaming::Name svc_name;
    svc_name.length (1); svc_name[0].id = n;
    svc_name[0].kind = "object impl";
    // Find object reference in the name service.
    obj = name_context->resolve (svc_name);

    // Narrow to the T interface and away we go!
    return T::_narrow (obj);
}
```

## Coping with Changing Requirements

- New Quoter features
  - Format changes to extend functionality
  - New interfaces and operations
- Improving existing Quoter features
  - Batch requests
- Leveraging new ORB features
  - Asynchronous Method Invocations (AMI)
  - Server location independence (requires smart ORB)



## New Formats

For example, percentage that stock increased or decreased since start of trading day, volume of trades, etc.

```
module Stock
{
    // ...

    interface Quoter
    {
        long get_quote (in string stock_name,
                       out double percent_change,
                       out long trading_volume)
                       raises (Invalid_Stock);
    };
};
```

Note that even making this simple change would involve a great deal of work for a sockets-based solution...



## Adding Features Unobtrusively

Interface inheritance allows new features to be added without breaking existing interfaces

```
module Stock
{
    // ...
    interface Quoter { /* ... */ };

    interface Stat_Quoter : Quoter // a Stat_Quoter IS-A Quoter
    {
        long get_stats (in string stock_name,
                       out double percent_change,
                       out long trading_volume)
                       raises (Invalid_Stock);
    };
};
```

Note that there are no changes to the existing Quoter interface



## New Interfaces and Operations

For example, adding a trading interface

```
module Stock {
    // Interface Quoter_Factory and Quoter same as before.
    interface Trader {
        void buy (in string name,
                 inout long num_shares,
                 in long max_value) raises (Invalid_Stock);
        void sell (in string name,
                  inout long num_shares,
                  in long min_value) raises (Invalid_Stock);
    };
    interface Trader_Factory { /* ... */ };
};
```

Multiple inheritance is also useful to define a full service broker:

```
interface Full_Service_Broker : Stat_Quoter, Trader {};
```



## Batch Requests

Improve performance for multiple queries or trades

```
interface Batch_Quoter : Stat_Quoter
{ // Batch_Quoter IS-A Stat_Quoter
  typedef sequence<string> Names;
  struct Stock_Info {
    string name;
    long value;
    double change;
    long volume;
  };
  typedef sequence<Stock_Info> Info;
  exception No_Such_Stock { Names stock; };
};

void batch_quote (in Names stock_names,
                 out Info stock_info) raises (No_Such_Stock);
};
```



## Limitations with Workarounds for CORBA's Lack of Asynchrony

- *Synchronous method invocation (SMI)* multi-threading
  - Often non-portable, non-scalable, and inefficient
- *Oneway operations*
  - Best-effort semantics are unreliable
  - Requires *callback* objects
  - Applications must match callbacks with requests
- *Deferred synchronous*
  - Uses DII, thus *very hard* to program
  - Not type-safe



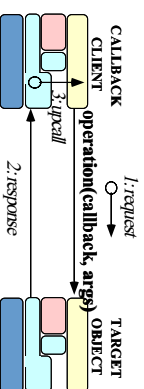
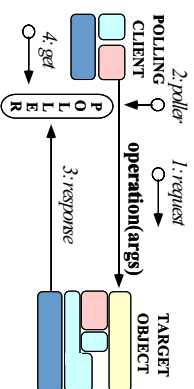
## Motivation for Asynchronous Method Invocations (AMI)

- Early versions of CORBA lacked support for asynchronous two-way invocations
- This omission yielded the following drawbacks
  1. Increase the number of client threads
    - e.g., due to synchronous two-way communication
  2. Increase the end-to-end latency for multiple requests
    - e.g., due to blocking on certain long-delay operations
  3. Decrease OS/network resource utilization
    - e.g., inefficient support for bulk data transfers

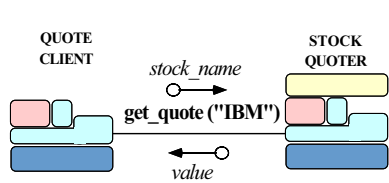


## OMG Solution → CORBA Messaging Specification

- Defines *QoS Policies* for the ORB
  - Timeouts
  - Priority
  - Reliable one-ways
- Specifies two *asynchronous method invocation (AMI)* models
  1. Poller model
  2. Callback model
- Standardizes *time-independent invocation (TII)* model
  - Used for store/forward routers



## AMI Callback Overview



### Quoter IDL Interface:

```
module Stock {
  interface Quoter {
    // Two-way operation to
    // get current stock value.
    long get_quote
      (in string stock_name);
  };
  // ...
}
```

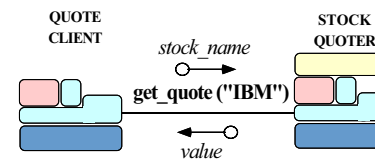
### Implied-IDL for client-side:

```
module Stock {
  // ReplyHandler.
  interface AMI_QuoterHandler
    : Messaging::ReplyHandler {
    // Callback method.
    void get_quote (in long return_value);
  };
}
```

```
interface Quoter {
  // Two-way synchronous operation.
  long get_quote (in string stock_name);

  // Two-way asynchronous operation.
  void sendc_get_quote
    (AMI_QuoterHandler handler,
     in string stock);
};
```

## Example: Synchronous Client



### IDL-generated stub:

```
CORBA::ULong
Stock::Quoter::get_quote
  (const char *name)
{
  // 1. Setup connection
  // 2. Marshal
  // 3. Send request
  // 4. Get reply
  // 5. Demarshal
  // 6. Return
};
```

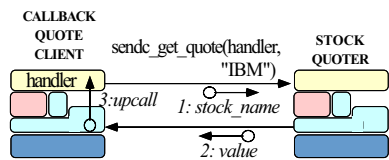
### Application:

```
// NASDAQ abbreviations for ORB vendors.
static const char *stocks[] =
{
  "IONAY" // IONA Orbix
  "INPR" // Borland VisiBroker
  "IBM" // IBM Component Broker
};

// Set the max number of ORB stocks.
static const int MAX_STOCKS = 3;

// Make synchronous two-way calls.
for (int i = 0; i < MAX_STOCKS; i++) {
  CORBA::Long value =
    quoter_ref->get_quote (stocks[i]);
  cout << "Current value of "
        << stocks[i] << " stock: "
        << value << endl;
}
```

## Example: AMI Callback Client



### Asynchronous stub:

```
void
Stock::Quoter::sendc_get_quote
  (AMI_QuoterHandler_ptr,
   const char *name)
{
  // 1. Setup connection
  // 2. Store reply handler
  // in ORB
  // 3. Marshal
  // 4. Send request
  // 5. Return
};
```

### Reply Handler Servant:

```
class My_Async_Stock_Handler
: public POA_Stock::AMI_QuoterHandler {
public:
  My_Async_Stock_Handler (const char *s)
    : stock_(s)
  {}
  ~My_Async_Stock_Handler (void) {}

  // Callback method.
  virtual void get_quote
    (CORBA::Long ami_return_val)
  {
    cout << stock_ << " stock: "
          << ami_return_val << endl;
    // Decrement global reply count.
    reply_count--;
  }
private:
  CORBA::String_var stock_;
};
```

## Example: AMI Callback Client (cont'd)

```
// Global reply count
int reply_count = MAX_STOCKS;

// Initialize ReplyHandler object refs.
for (i = 0; i < MAX_STOCKS; i++)
  handler_refs[i] =
    handlers[i]->_this ();

// Servants.
My_Async_Stock_Handler *
handlers[MAX_STOCKS];

// Make asynchronous two-way calls
// using the callback model.
for (i = 0; i < MAX_STOCKS; i++)
  quoter_ref->sendc_get_quote
    (handler_refs[i],
     stocks[i]);

int i;

// Initialize ReplyHandler
// servants.
for (i = 0; i < MAX_STOCKS; i++)
  handlers[i] = new
    My_Async_Stock_Handler (stocks[i]);

// Event loop to receive all replies.
while (reply_count > 0)
  if (orb->work_pending ())
    orb->perform_work ();
  else
    ...
```



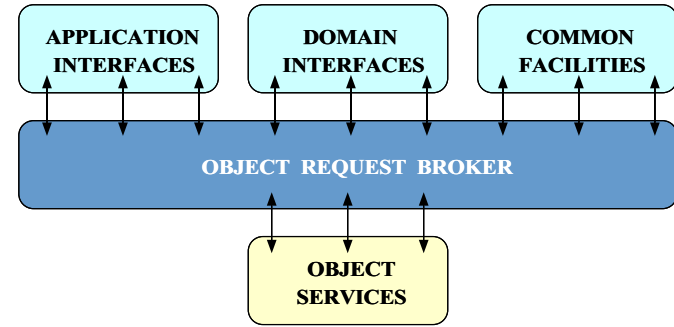
## Overview of CORBA Components

- The CORBA specification contains several components:
  - Object Request Broker (ORB) Core
  - Interoperability Spec (GIOP and IIOP)
  - Interface Definition Language (IDL)
  - Programming language mappings for IDL
  - Static Invocation Interface (SII)
  - Dynamic Invocation Interface (DII)
  - Static Skeleton Interface (SSI) and Dynamic Skeleton Interface (DSI)
  - Portable Object Adapter (POA)
  - Interface and Implementation Repositories

## Additional Information on AMI

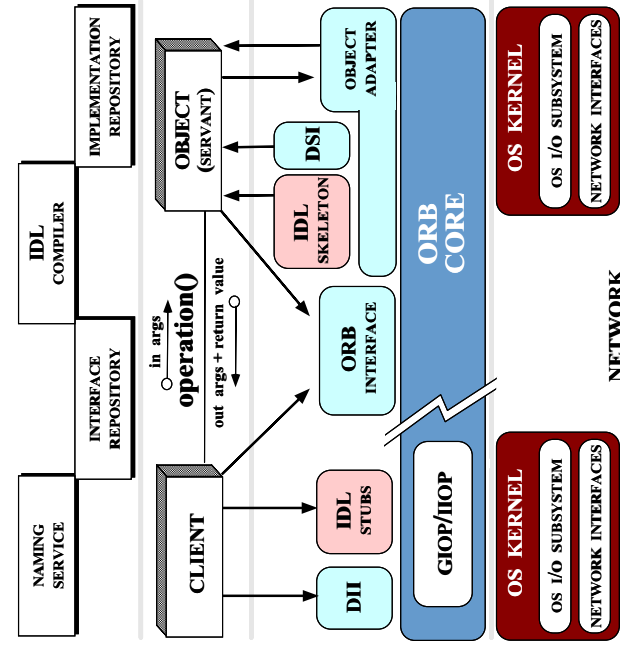
- Messaging specification is integrated into CORBA spec.
  - [www.omg.org](http://www.omg.org)
- See Vinoski's CACM article on CORBA 3.0 for more info.
  - [www.cs.wustl.edu/~schmidt/vinoski-98.pdf.gz](http://www.cs.wustl.edu/~schmidt/vinoski-98.pdf.gz)
- See our papers on AMI
  - [www.cs.wustl.edu/~schmidt/report-doc.html](http://www.cs.wustl.edu/~schmidt/report-doc.html)
  - [www.cs.wustl.edu/~schmidt/PDF/ami1.pdf](http://www.cs.wustl.edu/~schmidt/PDF/ami1.pdf)
  - [www.cs.wustl.edu/~schmidt/PDF/ami2.pdf](http://www.cs.wustl.edu/~schmidt/PDF/ami2.pdf)
- See TAO release to experiment with working AMI examples
  - `$TAO_ROOT/examples/AMI/`

## OMA Reference Model Interface Categories



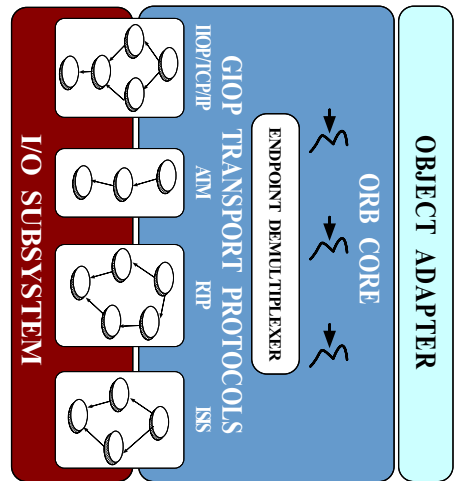
The Object Management Architecture (OMA) Reference Model describes the interactions between various CORBA components and layers

## CORBA ORB Architecture





## Overview of the ORB Core



### Features

- Connection/memory management
- Request transfer
- Endpoint demuxing
- Concurrency control

## GIOP Overview

- Common Data Representation (CDR)
  - Transfer syntax mapping OMG-IDL data types into a bi-canonical low-level representation
    - \* Supports variable byte ordering and aligned primitive types
- Message transfer
  - Request multiplexing, *i.e.*, shared connections
  - Ordering constraints are minimal, *i.e.*, can be asynchronous
- Message formats
  - Client: Request, CancelRequest, LocateRequest
  - Server: Reply, LocateReply, CloseConnection
  - Both: MessageError

## CORBA Interoperability Protocols

	STANDARD CORBA PROGRAMMING API		
ORB MESSAGING COMPONENT	GIOP	GIOP-LITE	ESIOP
ORB TRANSPORT ADAPTER COMPONENT	IIOP	VME-IOP	ATM-IOP RELIABLE SEQUENCED
TRANSPORT LAYER	TCP	VME	AAL5
NETWORK LAYER	IP	DRIVER	ATM

PROTOCOL CONFIGURATIONS

- GIOP
  - Enables ORB-to-ORB interoperability
- IIOP
  - Works directly over TCP/IP, no RPC
- ESIOPs
  - *e.g.*, DCE, DCOM, wireless, etc.

## Example GIOP Format

```

module GIOP {
  enum MsgType {
    Request, Reply, CancelRequest,
    LocateRequest, LocateReply,
    CloseConnection, MessageError
  };

  struct MessageHeader {
    char magic[4];
    Version GIOP_version;
    octet byte_order; // Fragment bit in 1.1.
    octet message_type;
    unsigned long message_size;
  };

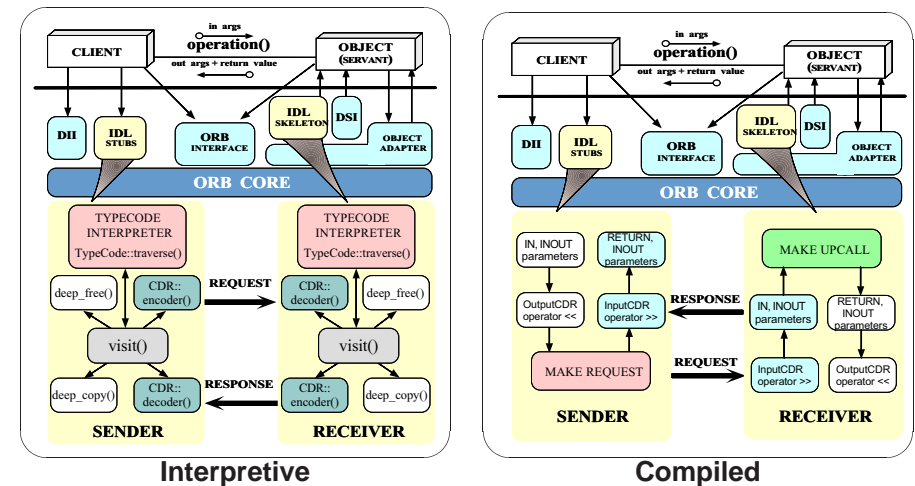
  struct RequestHeader {
    IOP::ServiceContextList service_context;
    unsigned long request_id;
    // Reliable one-way bits in 1.2
    boolean response_requested;
    sequence<octet> object_key;
    string operation;
    Principal requesting_principal;
  };
  // ...
}

```

## IIOB Overview

- IIOB adds to GIOP semantics for TCP/IP connection management
- IIOB bundled with Netscape 4.0
- Inter-ORB Engine available from SunSoft
  - <ftp://ftp.omg.org/pub/interop/iioptar.Z>
- TAO is originally based on SunSoft IIOB
  - However, TAO adds *many* enhancements and optimizations
    - \* [www.cs.wustl.edu/~schmidt/PDF/JSAC-99.pdf](http://www.cs.wustl.edu/~schmidt/PDF/JSAC-99.pdf)
    - \* [www.cs.wustl.edu/~schmidt/TAO.html](http://www.cs.wustl.edu/~schmidt/TAO.html)

## Interpreted vs. Compiled (De)marshaling



## Interface Definition Language (IDL)

- Motivation
  - Developing flexible distributed applications on heterogeneous platforms requires a strict separation of *interface* from *implementation(s)*
- Benefits of using an IDL
  - Ensure platform independence → *e.g.*, Windows NT to UNIX
  - Enforce modularity → *e.g.*, separate concerns
  - Increase robustness → *e.g.*, eliminate common network programming errors
  - Enable language independence → *e.g.*, COBOL, C, C++, Java, etc.

## Related IDLs

- Many IDLs are currently available, *e.g.*,
  - OSI ASN.1
  - OSI GDMO
  - SNMP SMI
  - DCE IDL
  - Microsoft's IDL (MIDL)
  - OMG IDL
  - ONC's XDR
- However, many of these are *procedural* IDLs
  - These are more complicated to extend and reuse since they don't support inheritance

## CORBA Interface Definition Language (IDL)

- **OMG IDL is an object-oriented interface definition language**
  - Used to specify interfaces containing *operations* and *attributes*
  - OMG IDL support interface inheritance (both single and multiple inheritance)
- **OMG IDL is designed to map onto multiple programming languages**
  - *e.g.*, C, C++, Smalltalk, COBOL, Modula 3, DCE, Java, etc.
- **OMG IDL is similar to Java interfaces and C++ abstract classes**



## Application Interfaces

- Interfaces described using OMG IDL may be application-specific, *e.g.*,
  - Databases
  - Spreadsheets
  - Spell checker
  - Network manager
  - Air traffic control
  - Documents
  - Medical imaging systems
- Objects may be defined at any level of granularity
  - *e.g.*, from fine-grained GUI objects to multi-megabyte multimedia “Blobs”



## OMG IDL Features

- **OMG IDL is similar to Java interfaces or C++ abstract classes**
  - It is not a complete programming language, however, since it only defines *interfaces*
- **OMG IDL supports the following features:**
  - modules and interfaces
  - Operations and Attributes
  - Single and multiple inheritance
  - Basic types (*e.g.*, double, long, char, etc).
  - Arrays and sequence
  - struct, enum, union, typedef
  - consts
  - exceptions



## OMG IDL Differences from C++ and Java

- |                                           |                                      |
|-------------------------------------------|--------------------------------------|
| • No control constructs                   | • Unions require a tag               |
| • No data members ( <i>cf</i> valuetypes) | • Different String type              |
| • No pointers ( <i>cf</i> valuetypes)     | • Different Sequence type            |
| • No constructors or destructors          | • Different exception interface      |
| • No overloaded operations                | • No templates                       |
| • No <code>int</code> data type           | • <code>oneway</code> call semantics |
| • Contains parameter passing modes        | • <code>readonly</code> keyword      |



## Static Invocation Interface (SII)

```
// Get object reference.
Quoter_var quoter = // ...
```

```
const char *name =
  "ACME ORB Inc.;"
```

```
CORBA::Long value =
  quoter->get_quote (name);
cout << name << " = "
  << value << endl;
```

- The common way to use OMG IDL is the “Static Invocation Interface” (SII)
- All operations are specified in advance and are known to client via *stubs*
  - Stubs marshal operation calls into request messages

Primary advantages of SII are *simplicity*, *typesafety*, and *efficiency*

## Dynamic Invocation Interface (DII)

- A less common programming API is the “Dynamic Invocation Interface” (DII)
  - Enables clients to invoke operations on objects that aren’t known until run-time
    - \* *e.g.*, MIB browsers
  - Allows clients to “push” arguments onto a request stack and identify operations via an ASCII name
    - \* Type-checking via meta-info in “Interface Repository”
- The DII is more flexible than the SII
  - *e.g.*, it supports *deferred synchronous* invocation
- However, the DII is also more complicated, less typesafe, and inefficient

## An Example DII Client

```
// Get Quoter reference.
Stock::Quoter_var quoter_ref = // ...
CORBA::Long value;

// Create request object.
CORBA::Request_var request =
  quoter_ref->_request ("get_quote");

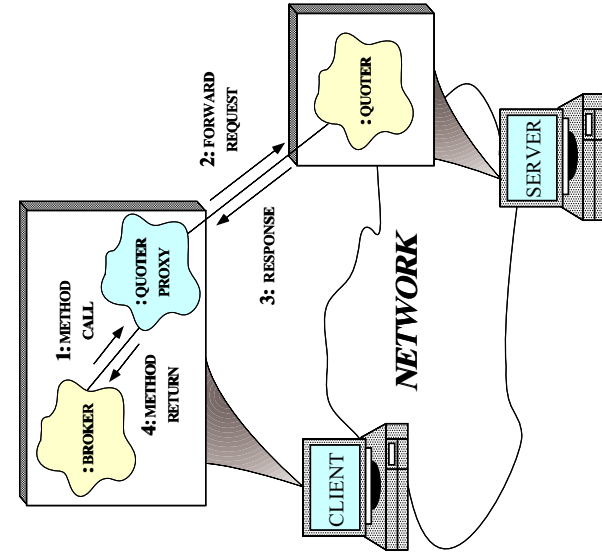
// Add parameter.
request->add_in_arg () <<= "IONAY";
request->set_return_type (CORBA::_tc_long);

// Call method.
request->invoke ();

// Retrieve/print value.
if (request->return_value () >>= value)
  cout << "Current value of IONA stock: "
  << value << endl;
```

This example is *much* more complicated and inefficient than simply using SII...

## Stubs use the Proxy Pattern



Intent: provide a surrogate for another object that controls access to it

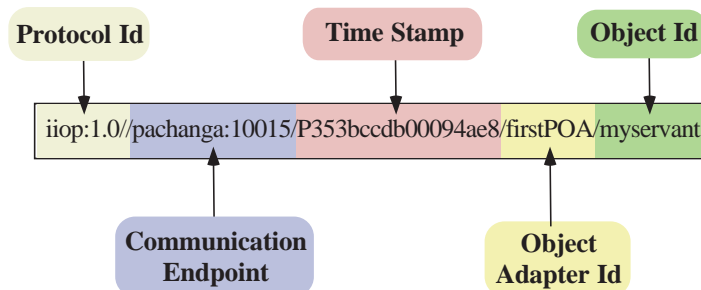
## Static and Dynamic Skeleton Interface

- The Static Skeleton Interface (SSI) is generated automatically by the IDL compiler
  - The SII performs the operation demuxing/dispatching and parameter demarshaling
- The Dynamic Skeleton Interface (DSI) provides analogous functionality for the server-side that the DII provides on the client-side
  - It is defined primarily to build ORB “Bridges”
  - The DSI lets server code handle arbitrary invocations on CORBA objects

## Object References

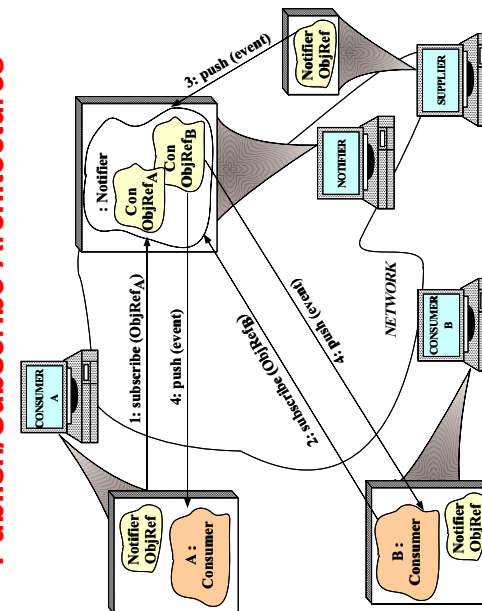
- An “object reference” is an opaque handle to an object
  - It identifies the object's location
- Object references may be passed among processes on separate hosts
  - The underlying CORBA ORB will correctly convert object references into a form that can be transmitted over the network
  - The ORB provides the receiver with a pointer to a proxy in its own address space
    - \* This proxy refers to remote object implementation
- Object references are a powerful feature of CORBA
  - e.g., supports *peer-to-peer* interactions and *distributed callbacks*

## Object Reference in URL Format



- Transient object reference

## Using Object References for Publish/Subscribe Architectures



Note the use of the Observer pattern

## Event Receiver Interface

```
struct Event {
    string topic_; // Used for filtering.
    any value_; // Event contents.
};

interface Consumer
{
    // Inform the Consumer
    // event has occurred.
    void push (in Event event);

    // Disconnect the Consumer
    // from the Notifier.
    void disconnect (in string reason);
};
```

A Consumer is called back by the Notifier



## Notifier Implementation

```
class My_Notifier { // C++ pseudo-code
public:
    CORBA::Long subscribe (Consumer_ptr consumer,
                          const char *fc) {
        insert <consumer> into <consumer_set_> with <fc>.
        return consumer_id;
    }
    void unsubscribe (CORBA::Long consumer_id) {
        remove <consumer_id> from <consumer_set_>.
    }
    void push (const Event &event) {
        foreach <consumer> in <consumer_set_>
            if (event.topic_ matches <consumer>.filter_criteria)
                <consumer>.push (event);
    }
private: // e.g., use an STL map.
    map <string, Consumer_ptr> consumer_set_;
};
```



## Notifier Interface

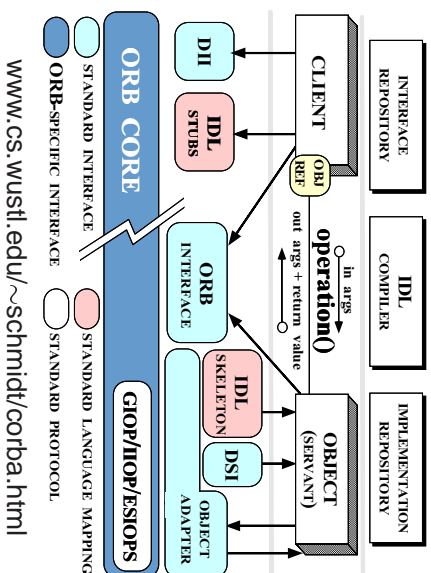
```
interface Notifier {
    // = For Consumers.
    // Subscribe the Consumer to receive
    // events that match filtering_criteria
    // applied by Notifier. Returns ID.
    long subscribe
        (in Consumer consumer,
         in string filtering_criteria);
    // Unsubscribe the Consumer.
    void unsubscribe (in long consumer_id);

    // = For Suppliers.
    // Push the Event to all the consumers
    // who have subscribed and who match
    // the filtering criteria.
    void push (in Event event);
};
```

A Notifier publishes Events to subscribed Consumers



## Advanced CORBA Features



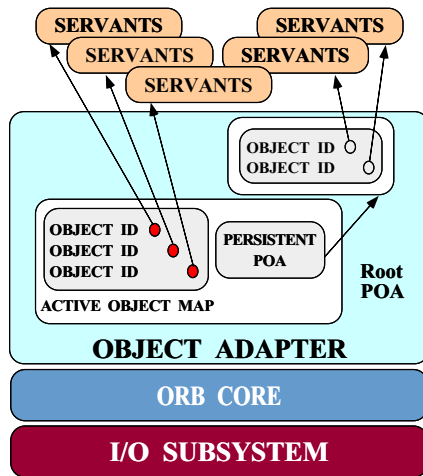
### Features

- Portable Object Adapter
- Multi-threading
- Implementation Repository
- CORBA Component Model

[www.cs.wustl.edu/~schmidt/corba.html](http://www.cs.wustl.edu/~schmidt/corba.html)



## Overview of the Portable Object Adapter (POA)



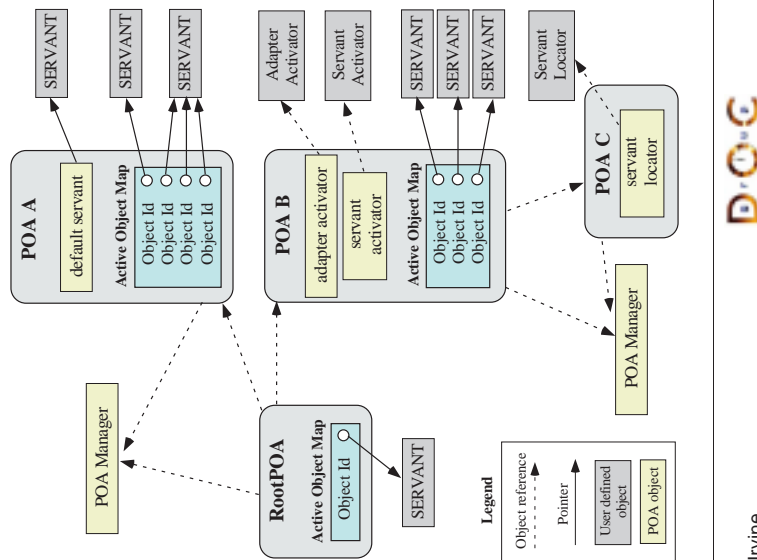
### POA Features

- Creates object refs
  - Activates and deactivates objects
  - Etherealizes and incarnates servants
  - Maps requests to servants
- The POA is very important for certain applications
- *e.g.*, telecom MIBs, enterprise servers

## Design Goals of the Portable Object Adapter

- Servants that are portable between ORBs
- Objects with persistent & transient identities
- Transient objects with minimal programming effort and overhead
- Transparent activation & deactivation of servants
- Implicit and explicit servant activation
- A single servant can support multiple object identities
- Multiple (nested) instances of the POA in a server process
- POA behavior is dictated by creation policies
- Servants can inherit from skeletons or use DSI

## The POA Architecture



## POA Components

- **Client:** Makes requests on an object through one of its references
- **Server:** Computational context for servants
  - Generally, a server corresponds to a process
  - Client and server are “roles” - a program can play both roles
- **Object:** A CORBA programming entity with an identity, an interface, and an implementation
- **Servant:** A programming language entity that implements requests on one or more objects
- **Policy:** Specifies the characteristics of a POA or child POA



## POA Components (cont'd)

- **Object Id:** A value that is used by the POA and by the implementation to identify a particular CORBA object
  - Object Id values may be assigned by the POA, or by the user implementation
  - Object Id values are hidden from clients, encapsulated by references
  - Object Ids have no standard form; they are managed by the POA as uninterpreted octet sequences
- **Object Reference:** Encapsulates an Object Id, a POA identity, and transport profiles
- **POA:** A namespace for Object Ids and a namespace for child POAs
  - Nested POAs form a hierarchical name space for objects in servers

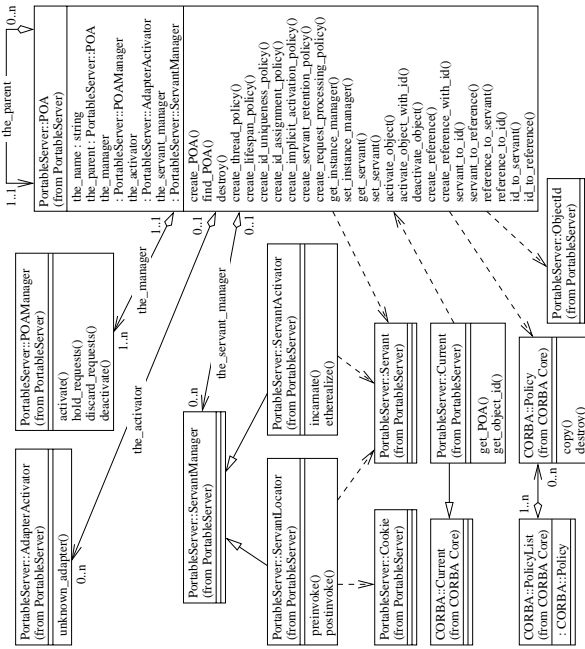


## POA Components (cont'd)

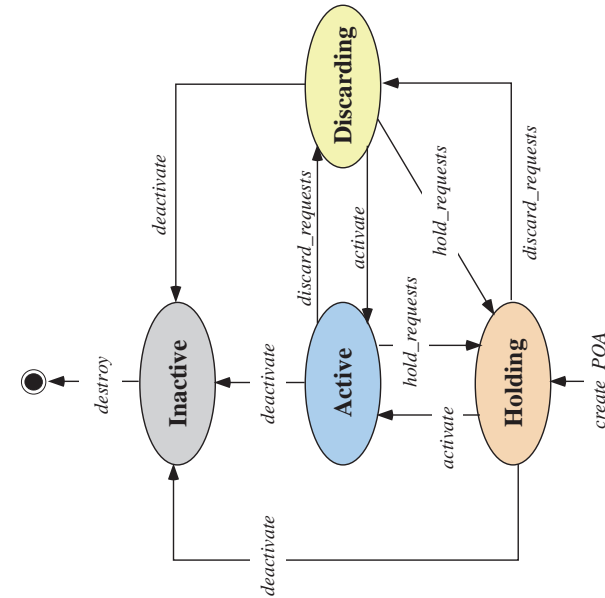
- **POA Manager:** Encapsulates the processing state of associated POAs
  - Can dispatch, hold, or discard requests for the associated POAs and deactivate POA(s)
- **Servant Manager:** Two kinds of callback objects used to incarnate and etherealize servants on demand
  - `ServantActivator` → first time
  - `ServantLocator` → each time
- **Adapter Activator:** Callback object used when a request is received for a child POA that does not exist currently
  - The adapter activator can then create the required POA on demand



## POA Architecture in UML



## POA Manager Processing States



## Getting the Root POA

```
// ORB is ``locality constrained``
CORBA::ORB_var orb = CORBA::ORB_init (argc, argv);

// Root POA is the default POA (locality constrained)
CORBA::Object_var obj =
    orb->resolve_initial_references ("RootPOA");

// Type-safe downcast.
PortableServer::POA_var root_POA
    = PortableServer::POA::_narrow (obj);

// Activate the POA.
PortableServer::POA_Manager_var poa_manager =
    root_POA->the_POAManager ();
poa_manager->activate ();
```



## Creating a Child POA

```
CORBA::PolicyList policies (2);

policies[0] = root_POA->create_id_assignment_policy
    (PortableServer::IdAssignmentPolicy::USER_ID);

policies[1] = root_POA->create_lifespan_policy
    (PortableServer::LifespanPolicy::PERSISTENT);

PortableServer::POA_ptr child_poa =
    root_POA->create_POA
        ("child_poa",
        PortableServer::POAManager::_nil (),
        policies);

for (CORBA::ULong i = 0; i != policies.length (); ++i)
    policies[i]->destroy ();
```



## Explicit Activation with POA-assigned Object Ids

```
// IDL
interface Quoter /* ... */
{
    long get_quote (in string stock_name)
        raises (Invalid_Stock);
};

// Auto-generated for use by servants.
class My_Quoter : public virtual POA_Stock::Quoter
{
public:
    // ...
    CORBA::Long get_quote (const char *stock_name);
};

My_Quoter *quoter = new My_Quoter;
PortableServer::ObjectId_var oid =
    poa->activate_object (quoter);
PortableServer::POA_Manager_var poa_manager =
    poa->the_POAManager ();
poa_manager->activate ();
orb->run ();
```



## Explicit Activation With User-assigned Object Ids

```
// Create a new servant object.
My_Quoter *quoter = new My_Quoter;

// Create a new Object ID for the object.
PortableServer::ObjectId_var oid =
    PortableServer::string_to_ObjectId ("my quoter");

// Activate the object with the new Object ID.
poa->activate_object_with_id (oid,
                             quoter);

PortableServer::POA_Manager_var poa_manager =
    poa->the_POAManager ();
poa_manager->activate ();
// Run the ORB's event loop.
orb->run ();
```



```

PortableServer::ObjectId_var oid =
PortableServer::string_to_ObjectId ("my_quoter");
CORBA::Object_var obj =
    poa->create_reference_with_id (oid,
        "IDL:Quoter:1.0");
// Insert into a name context.
name_context->bind (svc_name, obj);
// ...later...

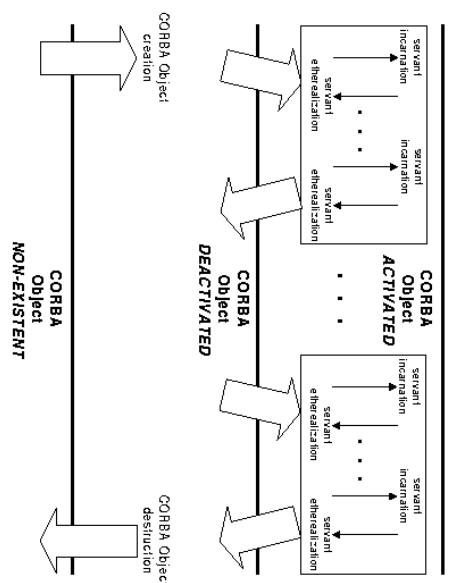
My_Quoter *quoter = new My_Quoter;
poa->activate_object_with_id (oid, quoter);

```

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## Servant Activator Definition

```

typedef ServantBase *Servant;

// Skeleton class
namespace POA_PortableServer
{
    class ServantActivator :
        public virtual ServantManager
    {
        // Destructor.
        virtual ~ServantActivator (void);

        // Create a new servant for <id>.
        virtual Servant incarnate
            (const ObjectId &id,
             POA_ptr poa) = 0;

        // <servant> is no longer active in <poa>.
        virtual void etherealize
            (const ObjectId &,
             POA_ptr poa,
             Servant servant,
             Boolean remaining_activations) = 0;
    };
}

```

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## Custom ServantActivator Definition and Creation

```

// Implementation class.
class My_Quoter_Servant_Activator :
    public POA_PortableServer::ServantActivator
{
    Servant incarnate (const ObjectId &oid,
                      POA_ptr poa) {

        String_var s =
            PortableServer::ObjectId_to_string (oid);

        if (strcmp (s, "my_quoter") == 0)
            return new My_Quoter;
        else
            throw CORBA::OBJECT_NOT_EXIST ();
    }

    void etherealize
        (const ObjectId &oid,
         POA_ptr poa,
         Servant servant,
         Boolean remaining_activations) {
        if (remaining_activations == 0)
            delete servant;
    }
};

```

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## Servant Locator Definition

```
typedef ServantBase *Servant;

// Skeleton class
namespace POA_PortableServer
{
    class ServantLocator :
        public virtual ServantManager
    {
        // Destructor.
        virtual ~ServantLocator (void);

        // Create a new servant for <id>.
        virtual PortableServer::Servant preinvoke
            (const PortableServer::ObjectId &id,
             PortableServer::POA_ptr poa,
             const char *operation,
             PortableServer::Cookie &cookie) = 0;

        // <servant> is no longer active in <poa>.
        virtual void postinvoke
            (const PortableServer::ObjectId &id,
             PortableServer::POA_ptr poa,
             const char *operation,
             PortableServer::Cookie cookie,
             PortableServer::Servant servant) = 0;
    };
}
```

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## Custom ServantLocator Definition and Creation

```
// Implementation class.
class My_Quoter_Servant_Locator :
    public POA_PortableServer::ServantLocator {
    Servant preinvoke
        (const PortableServer::ObjectId &oid,
         PortableServer::POA_ptr poa,
         const char *operation,
         PortableServer::Cookie &cookie) {
        CORBA::String_var str =
            PortableServer::ObjectId_to_string (oid);
        Object_State state;
        if (database_lookup (str, state) == -1)
            throw CORBA::OBJECT_NOT_EXIST ();
        return new My_Quoter (state);
    }

    void postinvoke
        (const PortableServer::ObjectId &id,
         PortableServer::POA_ptr poa,
         const char *operation,
         PortableServer::Cookie cookie,
         PortableServer::Servant servant) {
        database_update (servant);
        delete servant;
    }
};
```

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## Registering Servant Locators

```
PortableServer::ObjectId_var oid =
    PortableServer::string_to_ObjectId ("my_quoter");
CORBA::Object_var obj =
    poa->create_reference_with_id (oid,
                                   "IDL:Quoter:1.0");
// Insert into a name context.
name_context->bind (svc_name, obj);

My_Quoter_Servant_Locator *quoter_locator =
    new My_Quoter_Servant_Locator;

// Locality constrained.
ServantLocator_var locator = quoter_locator->_this ();
poa->set_servant_manager (locator.in ());
PortableServer::POA_Manager_var poa_manager =
    poa->the_POAManager ();
poa_manager ()->activate ();
orb->run ();
```

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## Additional Information on the POA

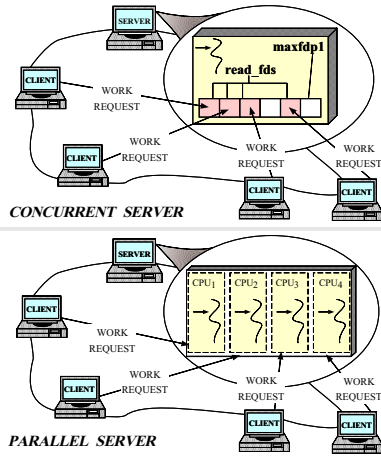
- See POA specification for some examples:
  - One Servant for all Objects
  - Single Servant, many objects and types, using DSI
- See Vinoski/Henning book for even more examples
- See Schmidt/Vinoski C++ Report columns
  - [www.cs.wustl.edu/~schmidt/report-dc.html](http://www.cs.wustl.edu/~schmidt/report-dc.html)
  - [\\$TAO\\_ROOT/examples/POA/](http://$TAO_ROOT/examples/POA/)
- See TAO release to experiment with working POA examples

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## Motivation for Concurrency in CORBA



- *Leverage hardware/software*
  - e.g., multi-processors and OS thread support
- *Increase performance*
  - e.g., overlap computation and communication
- *Improve response-time*
  - e.g., GUIs and network servers
- *Simplify program structure*
  - e.g., sync vs. async

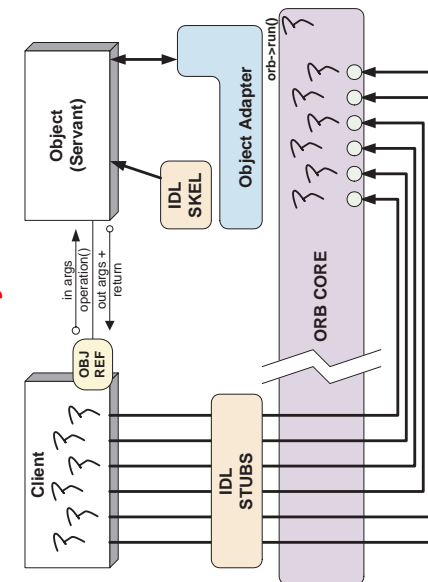
## Threading in TAO

- An application can choose to ignore threads and if it creates none, it need not be thread-safe
- TAO can be configured with various concurrency strategies:
  - *Thread-per-Connection*
  - *Thread Pool*
  - *Thread-per-Endpoint*
- TAO also provides many locking strategies
  - TAO doesn't automatically synchronize access to application objects
  - Therefore, applications must synchronize access to their own objects

## TAO Multi-threading Examples

- Each example implements a concurrent CORBA stock quote service
  - Show how threads can be used on the server
- The server is implemented in two different ways:
  1. *Thread-per-Connection* → Every client connection causes a new thread to be spawned to process it
  2. *Thread Pool* → A fixed number of threads are generated in the server at start-up to service all incoming requests
- Note that clients are unaware which concurrency model is being used...

## TAO's Thread-per-Connection Concurrency Architecture



### Pros

- Simple to implement and efficient for long-duration requests

### Cons

- Excessive overhead for short-duration requests
- Permits unbounded number of concurrent requests

**Thread-per-Connection Main Program**  
 The server creates a single Quoter factory and waits in ORB's event loop

```
int main (void)
{
  ORB_Manager orb_manager (argc, argv);

  const char *factory_name = "my_quoter_factory";

  // Create the servant, which registers with rootPOA and Naming Service implicitly.
  My_Quoter_Factory factory (factory_name);

  // Block indefinitely waiting for incoming invocations and dispatch upcalls.
  orb_manager.run ();

  // After run() returns, the ORB has shutdown.
}
```

### The ORB's svc. conf file

```
static Resource_Factory "-ORBResources global -ORBReactorType select_mt"
static Server_Strategy_Factory "-ORBConcurrency thread-per-connection"
```

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## Thread-per-Connection Quoter Implementation

Implementation of multi-threaded Quoter callback invoked by the CORBA skeleton

```
long My_Quoter::get_quote (const char *stock_name)
{
  Guard<Thread_Mutex> guard (lock_);

  // Increment the request count.
  ++My_Quoter::req_count_;

  // Obtain stock price (beware...).
  long value = Quote_Database::instance ()->
    lookup_stock_price (stock_name);

  if (value == -1)
    // Skeleton handles exceptions.
    throw Stock::Invalid_Stock ();

  return value;
}
```

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## Thread-per-Connection Quoter Interface

Implementation of the Quoter IDL interface

```
typedef u_long COUNTER; // Maintain request count.

class My_Quoter :
  virtual public POA_Stock::Quoter,
  virtual public PortableServer::RefCountServantBase
{
public:
  // Constructor.
  My_Quoter (const char *name);

  // Returns the current stock value.
  long get_quote (const char *stock_name);
  throw (CORBA::SystemException,
    Quoter::InvalidStock);

private:
  // Serialize access to database.
  Thread_Mutex lock_;

  // Maintain request count.
  static COUNTER req_count_;
};
```

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## Thread Pool

- This approach creates a thread pool to amortize the cost of dynamically creating threads
- In this scheme, before waiting for input the server code creates the following:
  1. A Quoter\_Factory (as before)
  2. A pool of threads based upon the command line input
- Note the use of the ACE spawn\_n method for spawning multiple pool threads

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## Thread Pool Configuration

The run\_orb adapter function

```
void run_orb (void *arg)
{
    try {
        CORBA::ORB_ptr orb =
            ACE_reinterpret_cast (CORBA::ORB_ptr, arg);

        // Block indefinitely waiting for incoming
        // invocations and dispatch upcalls.
        orb->run ();

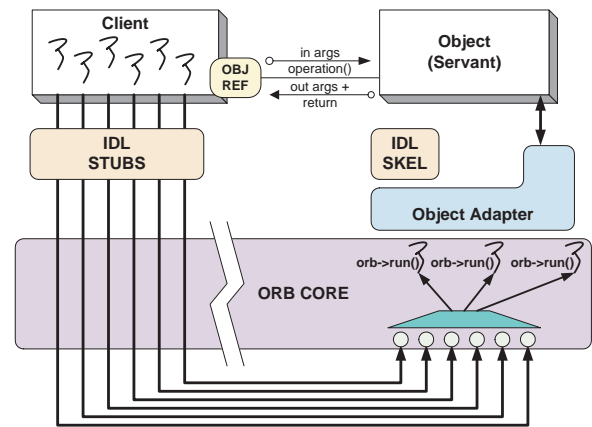
        // After run() returns, the ORB has shutdown.
    } catch (...) { /* handle exception ... */ }
}
```

The ORB's svc.conf file

```
static Resource_Factory "-ORBReactorType tp"
```



## TAO's Thread Pool Concurrency Architecture



### Pros

- Bounds the number of concurrent requests
- Scales nicely for multi-processor platforms, *e.g.*, permits load balancing

### Cons

- May Deadlock



- See Real-time CORBA 1.0 specification
  - [www.cs.wustl.edu/~schmidt/RT-ORB-std-new.pdf.gz](http://www.cs.wustl.edu/~schmidt/RT-ORB-std-new.pdf.gz)
- See our papers on CORBA Threading
  - [www.cs.wustl.edu/~schmidt/PDF/CACM-arch.pdf](http://www.cs.wustl.edu/~schmidt/PDF/CACM-arch.pdf)
  - [www.cs.wustl.edu/~schmidt/PDF/RT-perf.pdf](http://www.cs.wustl.edu/~schmidt/PDF/RT-perf.pdf)
  - [www.cs.wustl.edu/~schmidt/PDF/COOTS-99.pdf](http://www.cs.wustl.edu/~schmidt/PDF/COOTS-99.pdf)
  - [www.cs.wustl.edu/~schmidt/PDF/orc.pdf](http://www.cs.wustl.edu/~schmidt/PDF/orc.pdf)
  - [www.cs.wustl.edu/~schmidt/report-doc.html](http://www.cs.wustl.edu/~schmidt/report-doc.html)
- See TAO release to experiment with working threading examples
  - [\\$TAO\\_ROOT/tests/](#)



## Thread Pool Main Program

```
int main (int argc, char *argv[]) {
    try {
        ORB_Manager orb_manager (argc, argv);

        const char *factory_name = "my quoter factory";

        // Create the servant, which registers with
        // the rootPOA and Naming Service implicitly.
        My_Quoter_Factory factory (factory_name);

        int pool_size = // ...

        // Create a thread pool.
        ACE_Thread_Manager::instance ()->spawn_n
            (pool_size,
             &run_orb,
             (void *) orb_manager.orb ());
        // Block indefinitely waiting for other
        // threads to exit.
        ACE_Thread_Manager::instance ()->wait ();

        // After run() returns, the ORB has shutdown.
    } catch (...) { /* handle exception ... */ }
}
```

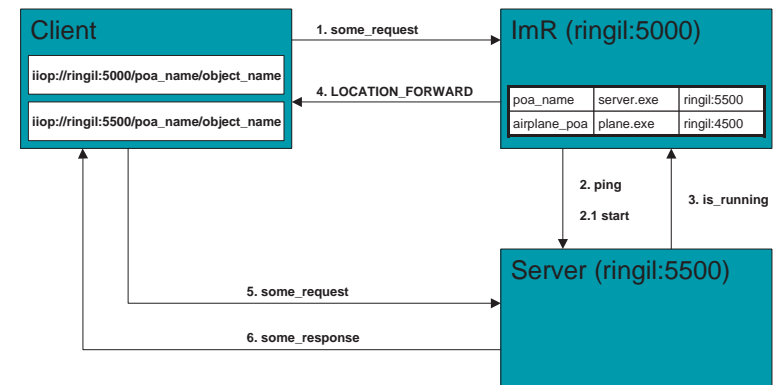




## Implementation Repository

- Allows the ORB to activate servers to process operation invocations
- Store management information associated with objects
  - *e.g.*, resource allocation, security, administrative control, server activation modes, etc.
- Primarily designed to work with *persistent* object references
- From client's perspective, behavior is portable, but administrative details are highly specific to an ORB/OS environment
  - *i.e.*, not generally portable
- [www.cs.wustl.edu/~schmidt/PDF/binding.pdf](http://www.cs.wustl.edu/~schmidt/PDF/binding.pdf)

## Typical Implementation Repository Use-case



## Server Activation via Implementation Repository

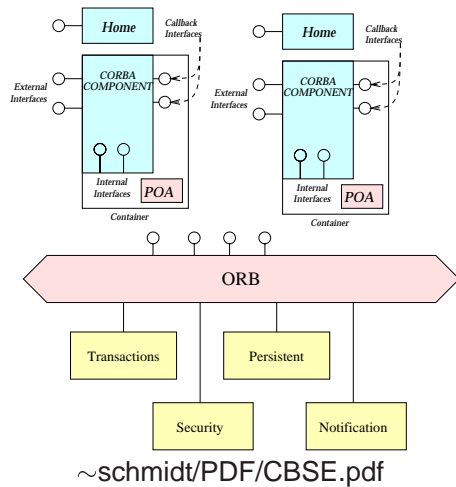
- If the server isn't running when a client invokes an operation on an object it manages, the Implementation Repository automatically starts the server
- Servers can register with the Implementation Repository
  - *e.g.*, in TAO
 

```
% tao_imr add airplane_poa -c "plane.exe"
```
- Server(s) may be installed on any machine
- Clients may bind to an object in a server by using the Naming Service or by explicitly identifying the server

## Server Activation Modes

- An idle server will be automatically launched when one of its objects is invoked
- TAO's Implementation Repository supports four types of activation
  1. *Normal* → one server, started if needed but not running
  2. *Manual* → one server, will not be started on client request, *i.e.*, pre-launched
  3. *Per-client call* → one server activated for each request to the Implementation Repository
  4. *Automatic* → like normal, except will also be launched when the Implementation Repository starts

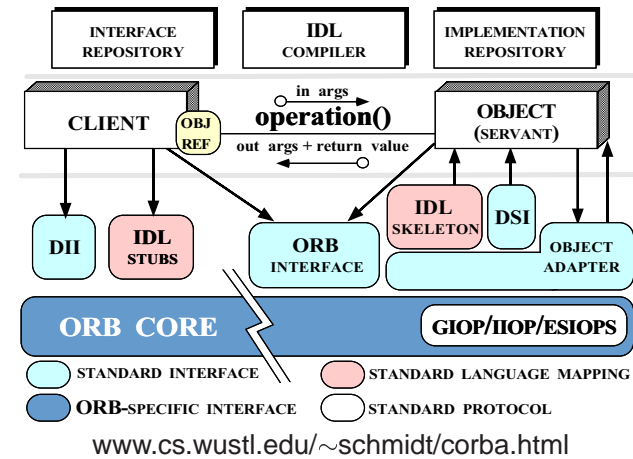
## The CORBA Component Model



### • Features

- Navigation among interfaces supported by components
- Standardized system-component interaction
- Standardized component life-cycle management
- Component interconnections
- Standardized component configuration
- Standardized ORB services interfaces

## Evaluating CORBA



### Criteria

- Learning curve
- Interoperability
- Portability
- Feature Limitations
- Performance

## Learning Curve

- CORBA introduces the following:
  1. **New concepts**
    - e.g., object references, proxies, and object adapters
  2. **New components and tools**
    - e.g., interface definition languages, IDL compilers, and object-request brokers
  3. **New features**
    - e.g., exception handling and interface inheritance
- Time spent learning this must be amortized over many projects

## Interoperability

- The first CORBA 1 spec was woefully incomplete with respect to interoperability
  - The solution was to use ORBs provided by a single supplier
- CORBA 2.x defines a useful interoperability specification
  - Later extensions deal with portability issues for server-side
    - \* i.e., the POA spec
- Most ORB implementations now support IOP or GIOP robustly...
  - However, higher-level CORBA services aren't covered by ORB interoperability spec...

## Portability

- To improve portability, the latest CORBA specification standardizes
  - IDL-to-C++ language mapping
  - Naming service, event service, lifecycle service
  - ORB initialization service
  - Portable Object Adapter API
  - Servant mapping
  - Server thread pools (Real-time CORBA)
- Porting applications from ORB-to-ORB is greatly simplified by `corbaconf`
  - <http://corbaconf.kiev.ua>



## Feature Limitations

- Standard CORBA doesn't yet address all the "inherent" complexities of distributed computing, *e.g.*,
  - *Latency*
  - *Causal ordering*
  - *Deadlock*
- It does address
  - *Service partitioning*
  - *Fault tolerance*
  - *Security*



## Feature Limitations (cont'd)

- Many ORBs do not yet support passing objects-by-value (OBV)
  - However, CORBA 2.3 OBV spec. defines a solution for this
- Most ORBs still support only the following semantics:
  - Object references are passed by-reference
    - \* However, all operations are routed to the originator
  - C-style structures and discriminated unions may be passed by-value
    - \* However, these structures and unions do *not* contain any methods
- Until OBV spec is ubiquitous, objects can be passed by value using hand-crafted "factories"



## Feature Limitations (cont'd)

- Many ORBs do not yet support AMI and/or standard CORBA timeouts
  - However, these capabilities are defined in the OMG Messaging Specification
- Most ORBs do not yet support fault tolerance
  - This was standardized by the OMG recently, however
    - [www.omg.org/techprocess/meetings/schedule/Fault\\_Tolerance\\_RFP.html](http://www.omg.org/techprocess/meetings/schedule/Fault_Tolerance_RFP.html)
- Versioning is supported in IDL via `pragmas`
  - Unlike Sun RPC or DCE, which include in language



## Performance Limitations

- Performance may not be as good as hand-crafted code for some applications due to
  - Additional remote invocations for naming
  - Marshaling/demarshaling overhead
  - Data copying and memory management
  - Endpoint and request demultiplexing
  - Context switching and synchronization overhead
- Typical trade-off between extensibility, robustness, maintainability → *micro-level efficiency*
- Note that a well-crafted ORB may be able to automatically optimize *macro-level efficiency*



## CORBA Implementations

- Many ORBs are now available
  - Orbix2000 from IONA
  - Visibroker from Borland
  - BEA Web Logic Enterprise
  - Component Broker from IBM
  - eORB from Vertel, ORB Express from OIS, and HighComm from Highlander/Borland
  - Open-source ORBs → TAO, ORBacus(\*), omniORB, MICO, and JacORB
- In theory, CORBA facilitates vendor-independent and platform-independent application collaboration
  - In practice, heterogeneous ORB interoperability and portability still an issue...



## CORBA Services

- Other OMG documents (*e.g.*, COSS) specify higher level services
  - **Naming service**
    - \* Mapping of convenient object names to object references
  - **Event service**
    - \* Enables decoupled, asynchronous communication between objects
  - **Lifecycle service**
    - \* Enables flexible creation, copy, move, and deletion operations via factories
- Other CORBA services include transactions, trading, relationship, security, concurrency, property, A/V streaming, etc.



## Summary of CORBA Features

- CORBA specifies the following functions to support an Object Request Broker (ORB)
  - Interface Definition Language (IDL)
  - A mapping from IDL onto C++, Java, C, COBOL, etc.
  - A Static Invocation Interface, used to compose operation requests via proxies
  - A Dynamic Invocation Interface, used to compose operation requests at run-time
  - Interface and Implementation Repositories containing meta-data queried at run-time
  - The Portable Object Adapter (POA), allows service programmers to interface their code with an ORB



## Concluding Remarks

- Additional information about CORBA is available on-line at the following WWW URLs
  - [Doug Schmidt's CORBA page](#)
    - \* [www.cs.wustl.edu/~schmidt/corba.html](http://www.cs.wustl.edu/~schmidt/corba.html)
  - [OMG's WWW Page](#)
    - \* [www.omg.org/](http://www.omg.org/)
  - [CETUS CORBA Page](#)
    - \* [www.cetus-links.org/oo\\_corba.html](http://www.cetus-links.org/oo_corba.html)