

# CORBA

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Cpt. S 464/564 Lecture

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# Overview

- Lots of details here, very few testable
- Goal is to let you understand better middleware plumbing
- I will carefully articulate in the last lecture what you are responsible for on the final exam

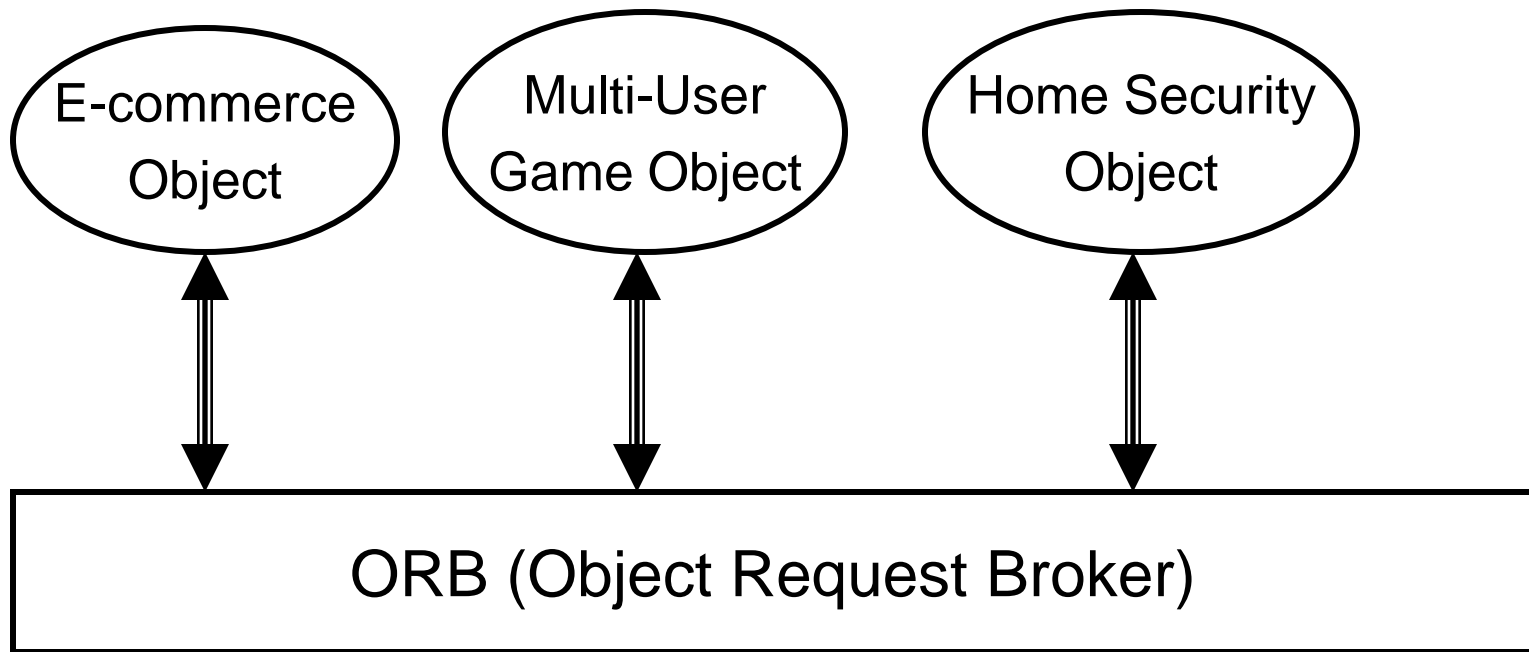
# CORBA Features

- **Transparencies**
  - Programming language
  - CORBA vendor
  - Operating Systems
  - Location
  - Network HW/SW
  - Access
- **Dynamic Binding**
- **Dynamic Typing**
- **Object Orientation**
  - Encapsulation
  - Polymorphism
  - Inheritance
- **Instantiation**
- **Extended Services**
  - Naming/trader
  - Events/notification
  - Transactions
  - Security, domains
  - .....

In an open specification with multivendor support

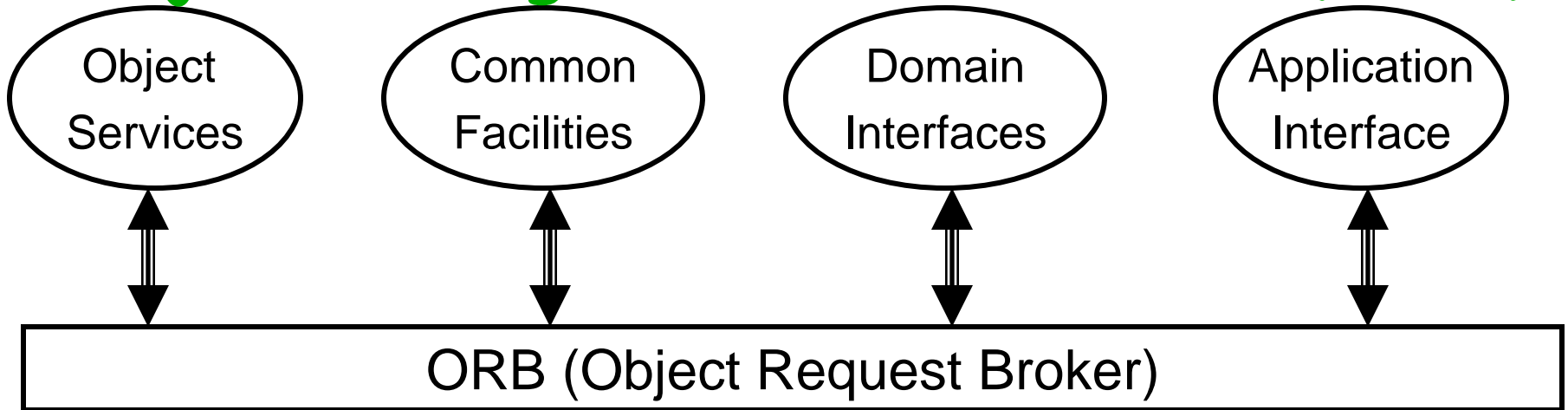
See Object Management Group (OMG) site, [www.omg.org](http://www.omg.org)

# CORBA: A "Software Bus"



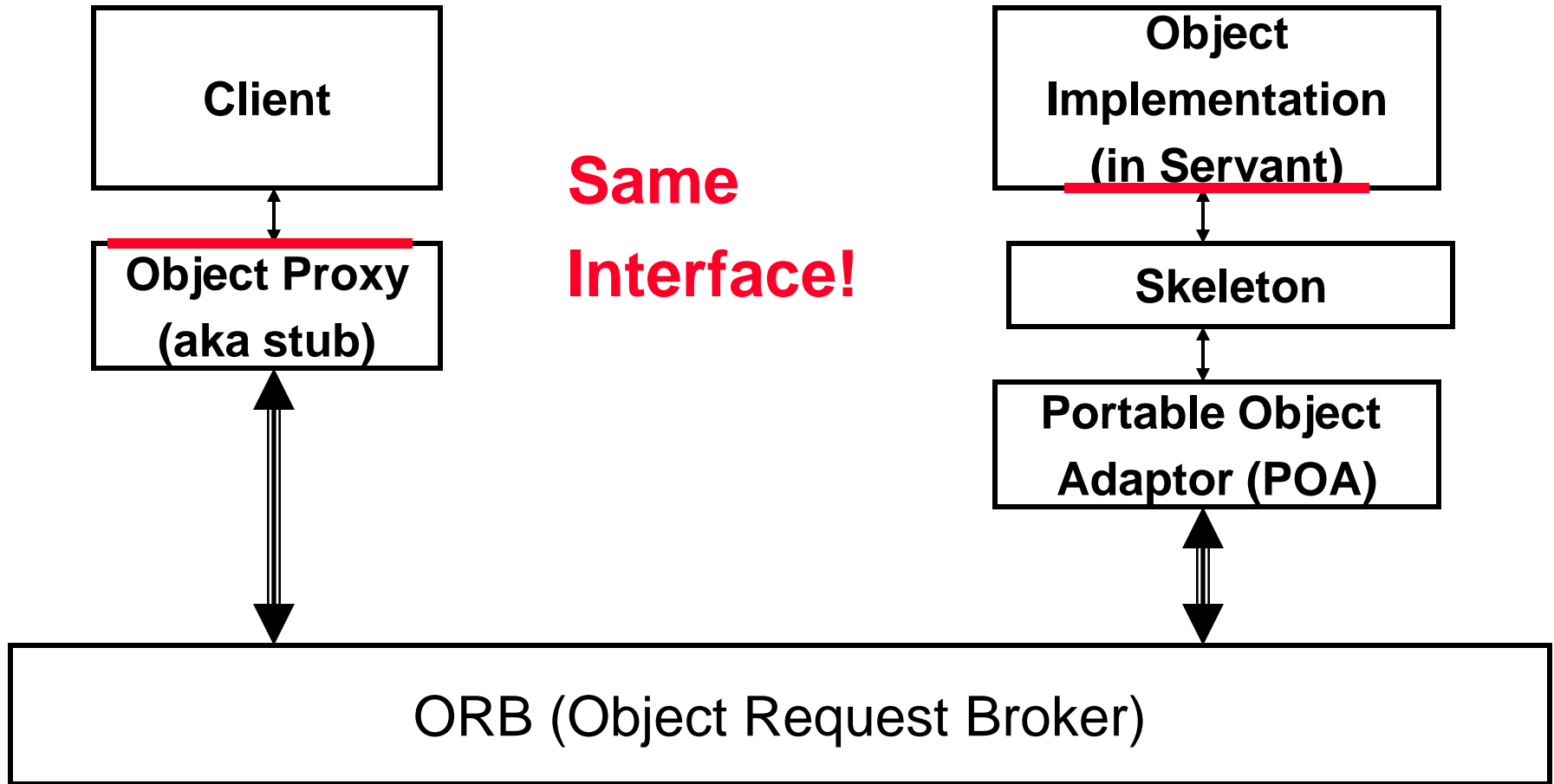
- Hardware bus: lets chips "plug and play" in a standard way
- Software bus: same idea but for software objects

# Object Management Architecture (OMA)



- Object Services: useable by all objects
  - Events, Trader, Security, Naming, Transactions, ...
- Common Facilities: useable by all applications
  - Scripting, compound documents, ....
- Domain interfaces: industry-specific APIs
  - Finance, telecom, ....
- Application Interface:
  - What you provide....

# ORB, Proxies, and POA

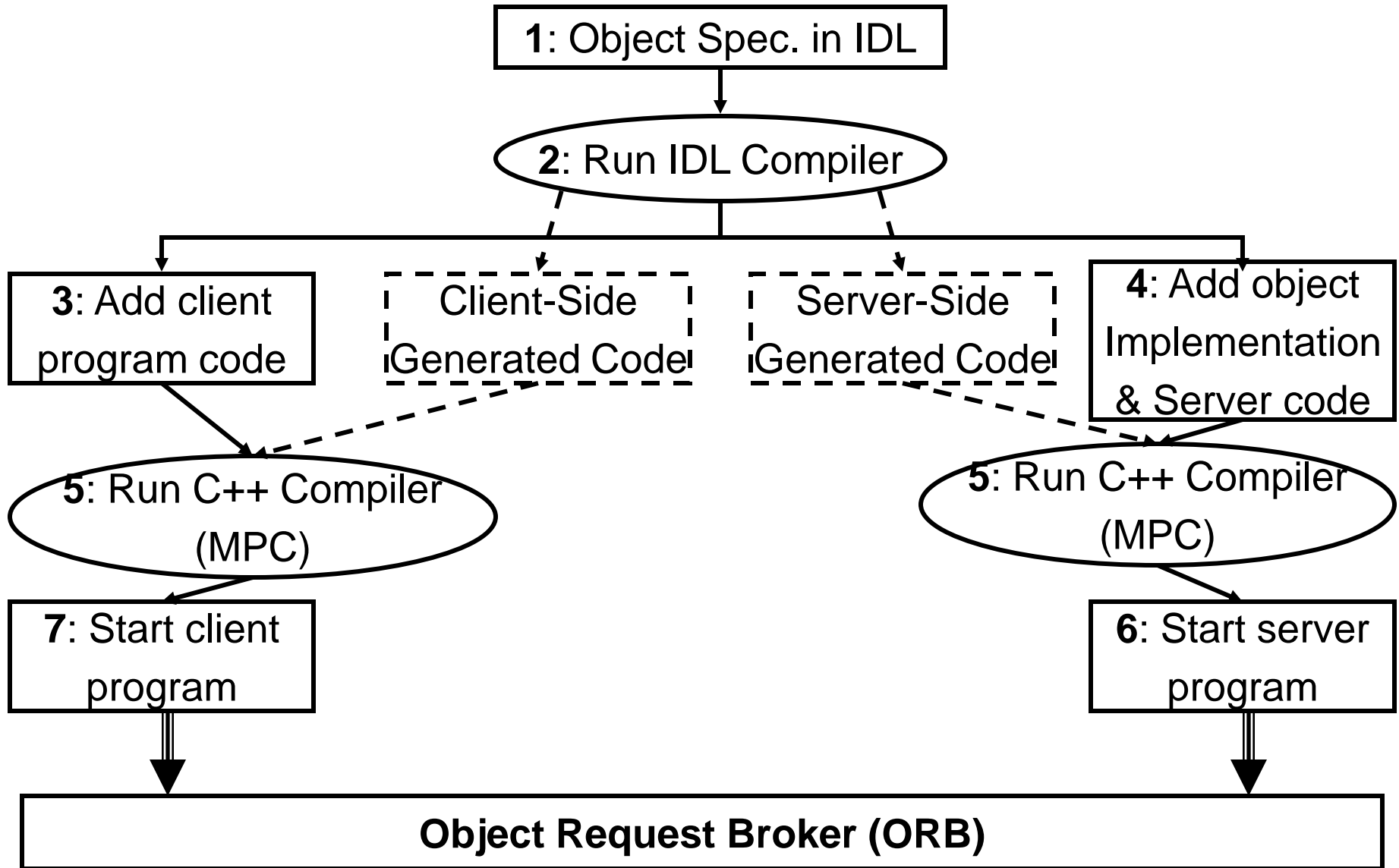


- Note: POA has a tree of objects, starting with root “/” (more later...)

# Notes on this Example

- Showing generic CORBA application
  - Should work with any CORBA vendor's implementation
  - Exact steps, command names, etc. for TAO are mentioned in documentation (Chapter.3)
- Lots of low-level details, esp. on server side
  - You will just mimic code fragments for the different steps (startup, etc)
  - Basically the same, just the interface/class name is different, for almost all of what you will do here

# CORBA C++ App. Development Steps



# 1: Object Spec. in IDL

```
// messenger.idl
```

```
interface Messenger
```

```
{
```

```
    boolean send_message (
```

```
        in    string user_name,
```

```
        in    string subject,
```

```
        inout string message );
```

```
};
```

# Another IDL Example (no more details...)

```
module BankExample {  
  interface Account {  
    exception BadCheck {float fee;};  
  
    float deposit(in float amount);  
    float writeCheck(in float amount, in long checknum)  
      raises (BadCheck);  
  };  
  interface AccountManager {  
    Account openAccount(in string name);  
  };  
};
```

Note 1) Module-namespace control 2) exceptions 3) Obj ref

## 2: Run IDL Compiler

- Compiles Messenger.idl
- Generates client-side code
- starter implementation class in MessengerI.\*
- Client-side stubs in MessengerC.\*
- Server-side skeletons in MessengerS.\*
- Reminder: “server” is a process/program, “servant” is a running piece of code that provides functionality for an object reference

# IDL to C++ mapping notes

- IDL isolates implementation from interface
  - Allows clients and servants to be in different languages
  - Allows for an interface to not be bound to a single implementation
    - Useful for many server-side optimizations
    - E.g., multiple servants can service requests to a single object reference
  - Allows for code to be inserted above ORB while still meeting stub API
    - E.g., QuO delegates
    - Caching
- Mappings of Basic IDL types (see CORBA manual for details)

# IDL to C++ mapping notes

<u>IDL type</u>	<u>Java</u>	<u>C++</u>	<u>CORBA C++</u>
<b>short</b>	<b>short</b>	<b>short</b>	CORBA::Short
<b>long</b>	<b>int</b>	--- <sup>1</sup>	CORBA::Long
<b>unsigned long</b>	<b>int</b>	<b>unsigned long</b>	CORBA::ULong
<b>float</b>	<b>float</b>	<b>float</b>	CORBA::Float
<b>double</b>	<b>double</b>	<b>double</b>	CORBA::Double
<b>boolean</b>	<b>boolean</b>	<b>unsigned char</b>	CORBA::Boolean
<b>long long</b>	<b>long</b>	--- <sup>1</sup>	CORBA::LongLong

1: Platform dependent: use the standardized CORBA types for portability

# 3: Add client program code (MessengerClient.cpp)

// C++

```
#include "MessengerC.h"
```

```
#include <iostream>
```

```
int main(int argc, char* argv[])
```

```
{
```

```
try {
```

// Initialize the ORB.

```
CORBA::ORB_var orb =
```

```
    CORBA::ORB_init(argc, argv);
```

// Read Messenger object's IOR.

```
CORBA::Object_var obj = orb-
```

```
    >string_to_object("file://Messenger.io  
r");
```

```
if( CORBA::is_nil(obj.in())) {
```

```
std::cerr << "Could not get Messenger  
IOR." << std::endl;
```

```
return 1;
```

```
}
```

// Narrow the IOR to object reference.

```
Messenger_var messenger =
```

```
    Messenger::_narrow(obj.in());
```

```
if( CORBA::is_nil(messenger.in())) {
```

```
std::cerr << "IOR was not a Messenger  
object reference." << std::endl;
```

```
return 1;
```

```
}
```

// Send a message

```
CORBA::String_var msg =
```

```
    CORBA::string_dup("Hello!");
```

```
messenger->send_message("TAO User",  
"Test", msg.inout());
```

// Print the Messenger's reply.

```
..
```

```
}
```

```
catch (CORBA::Exception& ex) {...}
```

```
}
```

# 4A: Add Object Implementations (Messenger\_impl.h)

2: Run IDL Compiler

Client-Side Generated Code

Includes Messenger  
class in MessengerC.h

Server-Side Generated Code

Includes POA\_Messenger  
class in MessengerS.h

MessengerI class  
written by programmer (4A)  
and used by server

## •4A: Add Object Implementations (cont.)

```
#include "Messenger_i.h" // renamed from MessengerI.h
#include <iostream>
CORBA::Boolean Messenger_i::send_message (
const char* user_name,
const char* subject,
char*& message)
ACE_THROW_SPEC ((CORBA::SystemException))
{
    std::cout << "Message from: " << user_name << std::endl;
    std::cout << "Subject: " << subject << std::endl;
    std::cout << "Message: " << message << std::endl;
    CORBA::string_free(message);
    message = CORBA::string_dup("Thanks for the message.");
    return 1;
}
```

## 4B: Implement the Server(Server.cpp)

1. Initializes the ORB
2. Creates a Portable Object Adaptor (POA).
3. Creates a (C++) MessengerI object. Note that this is not yet CORBA object.
4. Instantiates a CORBA object from the local one
5. Writes the IOR for the impl objects to a file.
6. Activates the POA manager (and the POA)
7. Waits for incoming requests

Note: Lotsa details, you will be just copying and changing..

# 4B: Implement the Server (Server.cpp)

```
#include "Messenger_i.h"

int main(int argc, char* argv[])
{
  try {
    // Initialize the ORB.
    CORBA::ORB_var orb =
      CORBA::ORB_init(argc, argv);

    //Get POA
    PortableServer::POA_var poa =
      PortableServer::POA::_narrow(obj.in());

    // Activate the POAManager.
    PortableServer::POAManager_var mgr = poa-
      >the_POAManager();
    mgr->activate();

    // Create a servant.
    Messenger_i servant; a reference to the
      RootPOA.
```

```
// Register the servant & write it to a file.
PortableServer::ObjectId_var oid = poa-
  >activate_object(&servant);
obj = poa->id_to_reference(oid.in());
CORBA::String_var str = orb-
  >object_to_string(obj.in());
ofstream iorFile("Messenger.ior");
iorFile << str.in() << std::endl;
iorFile.close();

std::cout << "IOR written to file
  Messenger.ior" << std::endl;

// Accept requests from clients.
orb->run();
orb->destroy();
return 0;}
catch (CORBA::Exception& ex) { }
return 1;
}
```

# TAO Notes

- Cross platform make solution
  - Supports multiple build environment (VC++, GNU Make, etc)
- Based on using Make Project Creator (MPC)
  - Just create a .mpc file for each project
- Example:

```
project(*Server): taoexe, portableserver {
    Source_Files {
        Messenger_i.cpp
        MessengerServer.cpp
    }
}
project(*Client): taoexe {
    Source_Files {
        MessengerC.cpp // prevents implicit MessengerS.cpp
        MessengerClient.cpp
    }
}
```

# More CORBA Topics

- Example with naming service
- User-defined exceptions
- Overview of CORBA hooks and architectural modules
- CORBA hooks
- ORB core
- CORBA:Object
- Dynamic Invocation Interface (DII)
- Object References
- Interface Repository
- Implementation Repository
- GIOP and IIOP

# Messenger Server Finding the Naming Service

// Note – you will ALWAYS just copy and tweak this code.

// For more info see TAO manual section 24.3.3

// Find the Naming Service

CORBA::Object\_var naming\_obj =

**orb->resolve\_initial\_references( "NameService" );**

CosNaming::NamingContext\_var root =

CosNaming::NamingContext::\_narrow( naming\_obj.in() );

if( CORBA::is\_nil( root.in() ) ) {

cerr << "Nil Naming Context reference" << endl;

**throw 0;**

}

# Messenger Server Binding a Name

```
// Bind the example Naming Context, if necessary
CosNaming::Name name;
name.length( 1 );
name[0].id = CORBA::string_dup( "example" ); // use userid
try {
    CORBA::Object_var dummy = root->resolve( name );
}
catch ( const CosNaming::NamingContext::NotFound & ) {
    CosNaming::NamingContext_var dummy =
        root->bind_new_context( name );
}

// ... continued on next slide...
```

# Messenger Server Binding a Name

```
// Bind the Messenger object
name.length( 2 );
name[1].id = CORBA::string_dup( "Messenger" );
PortableServer::ObjectId_var oid =
    poa->activate_object( messenger_servant );
CORBA::Object_var messenger_obj =
    poa->id_to_reference( oid.in() );
try {
    root->rebind( name, messenger_obj.in() );
}
catch ( const CosNaming::NamingContext::NotFound & ) {
    cout << "Can't bind example/Messenger" << endl;
}
cout << "Messenger obj bound in Naming Service" << endl;
```

# Messenger Client Using the Naming Service

```
// ... find naming service just like server did, same code
// Resolve the Messenger object
CosNaming::Name name;
name.length( 2 );
name[0].id = CORBA::string_dup( "example" );
name[1].id = CORBA::string_dup( "Messenger" );
CORBA::Object_var obj = root->resolve( name );
// Narrow
Messenger_var messenger = Messenger::_narrow( obj.in() );
if ( CORBA::is_nil( messenger.in() ) ) {
    cerr << "Not a Messenger reference" << endl;
    throw 0;
}
```

# User-Defined Exceptions

- CORBA has >20 pre-defined system exceptions that **you should catch with every CORBA call of any kind**
  - UNKNOWN, BAD\_PARAM, NO\_MEMORY, IMPL\_LIMIT, COMM\_FAILURE, INV\_OBJREF, NO\_PERMISSION, ...
  - Thrown by ORB implementation
- Programmers can also declare exceptions in IDL
  - Thrown by server side

# Messenger IDL with Exceptions

```
// messenger.idl
```

```
interface Messenger {
```

```
    exception ImNotHere {
```

```
        string reason;
```

```
    };
```

```
    boolean send_message (
```

```
        in   string user_name,
```

```
        in   string subject,
```

```
        inout string message ) raises (ImNotHere);
```

```
};
```

# Messenger Catching User-Level Exceptions

```
// MessengerClient.cpp
try {
    // .... Init ORB, get IOR from file or name service, make invocations ...
}
catch( const Messenger::ImNotHere &inhEx ) {
    cerr << "Caught an ImNotHere exception: " << inhEx << endl;
    cerr << "reason: " << inhEx.reason << endl;
    return 1;
}
catch( const CORBA::COMM_FAILURE &commEx ) {
    cerr << "Caught a COMM_FAILURE: " << commEx << endl;
    return 1;
}
catch( const CORBA::SystemException &sysEx) {.....}
```

# Messenger Throwing User-Level Exceptions

CORBA::Boolean

```
Messenger_impl::send_message(const char* user_name,  
                             const char* subject, char*& message)
```

```
    throw(Messenger::ImNotHere,  
          CORBA::SystemException)
```

```
{
```

```
    if (strcmp(user_name, "The_Professor") == 0) {
```

```
        // ...
```

```
    } else if (strcmp(user_name, "Joe_Freshman") == 0) {
```

```
        // don't want to talk to a freshman--send him the ImNotHere exception
```

```
        // and tell him to talk to someone else
```

```
        cerr << "Throw ImNotHere" << endl;
```

```
        cerr << endl;
```

```
        CORBA::String_var reason =
```

```
            CORBA::string_dup("Go talk to someone else");
```

```
        throw Messenger::ImNotHere(reason);
```

```
    } else {
```

```
        // ...
```

# Major CORBA Design Principles

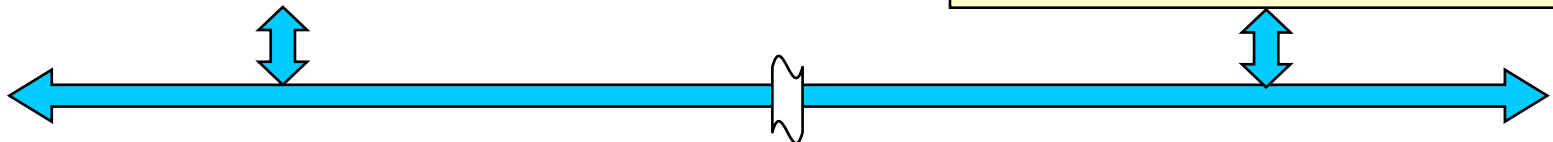
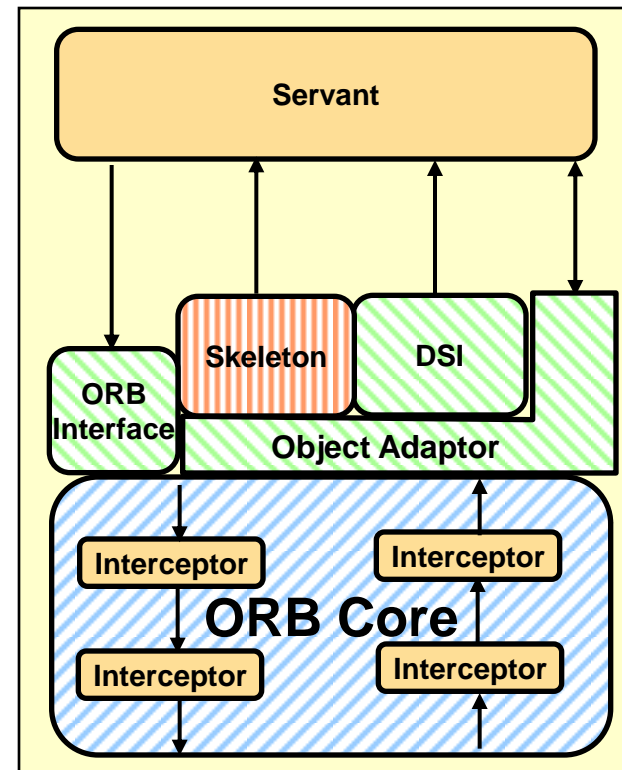
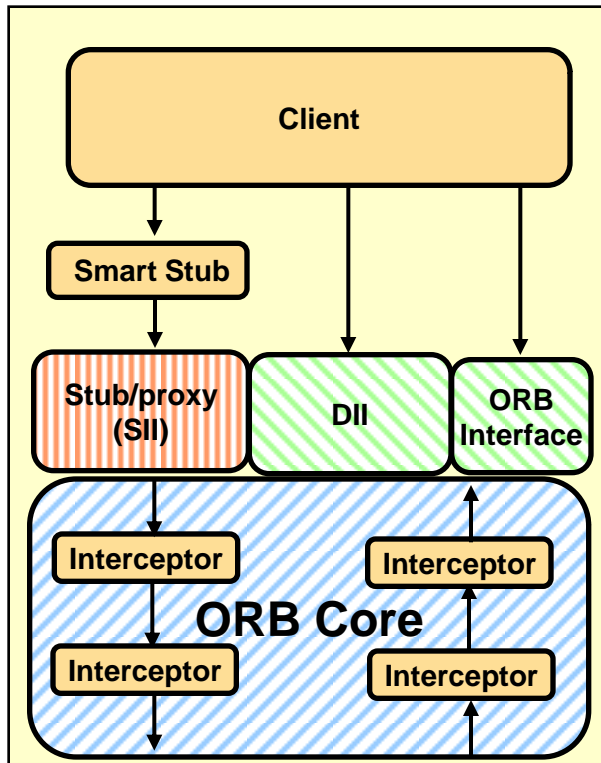
- Separation of interface and implementation
  - Clients depend on interfaces, not implementations
- Location transparency
  - Service use is orthogonal to service location
- Access transparency
  - Invoke CORBA objects just like local ones
- Typed interfaces
  - Object references are typed by interfaces
- Support of multiple inheritance of interfaces
  - Inheritance extends, evolves, and specialized behavior
  - Note: not implementation of multiple implementations!
- Support of multiple interaction styles
  - Client/server
    - Some support for mobile code, too, with Objects by Value (OBV)
  - Peer processes
  - Publish/Subscribe (aka “push”)

# CORBA Modules & System Builders' Hooks

Interface Repository

IDL Compiler

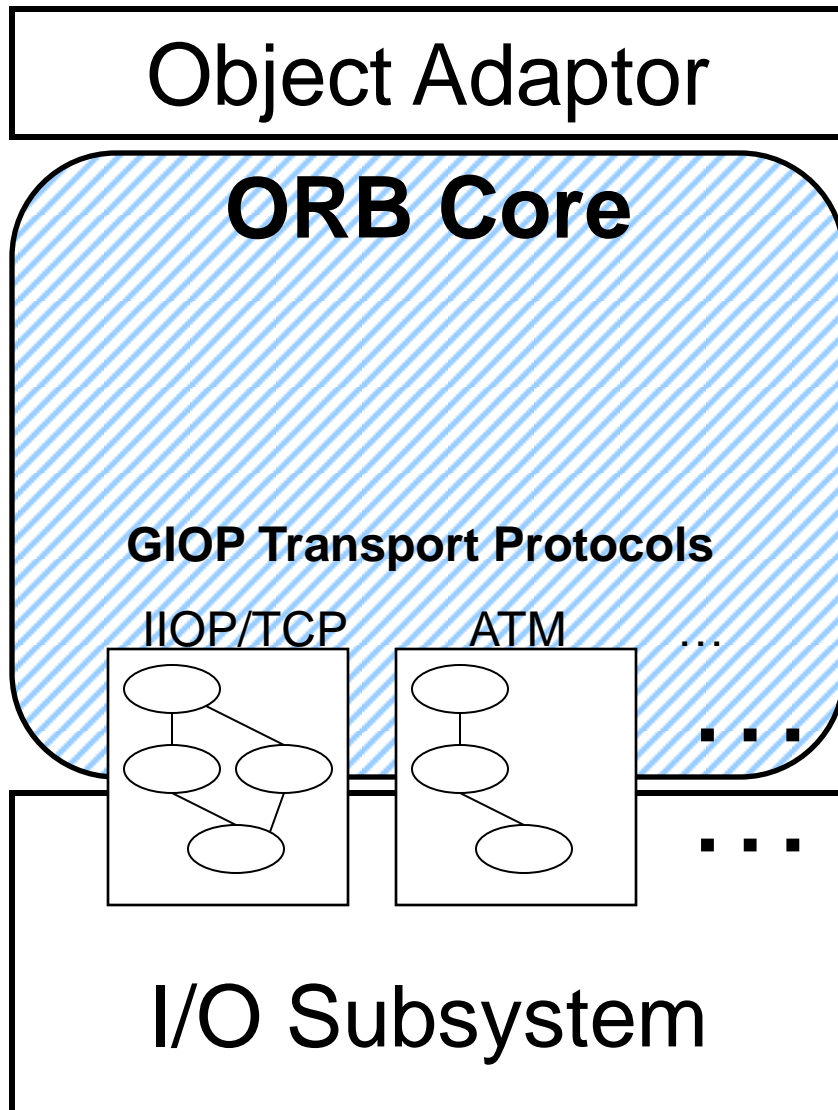
Implementation Repository



Standard Interfaces
  IDL-generated
  ORB-Specific

(This slide adapted from FTCS-29 Tutorial by Shalini Yajnik of Lucent Technologies)

# ORB Core Overview



## Features (server-side)

- Connection management
- Memory management
- Request transfer
- Endpoint demuxing
- Concurrency control

## Other utility methods

- `object_to_string()` and `string_to_object()`
- Etc.

# CORBA:Object class

- Base class for all proxies
- Useful utility methods:
  - `_is_a()`
  - `_is_equivalent()`
  - `_duplicate()`
  - `_release()`
  - `_is_local()`
  - `_is_remote()`
- Request methods for DII (more soon...)

# SII

- Static Invocation Interface (SII)
  - Most common way to use IDL
  - All operations specified in advance and known to client (by proxies/stubs) and server (by skeletons)
  - Simple
  - Typesafe
  - Efficient
  - Its what you used so far in this class

# DII

- Dynamic Invocation Interface (DII)
  - Less common way to use IDL
  - Lets clients invoke operations on objects whose IDL is not known to them at compile time (main advantage of DII)
    - Browsers of all sorts (interface browser, etc)
    - Debuggers
  - Also can use `send_deferred()` and `poll_response()`
    - asynchronous (non-blocking) APIs for sending request and getting reply
  - Clients construct a `CORBA::Request` (local) object, “pushing” arguments and operation name etc. on it like a stack
    - Exactly what a proxy does: same API to ORB Core

# DII Example

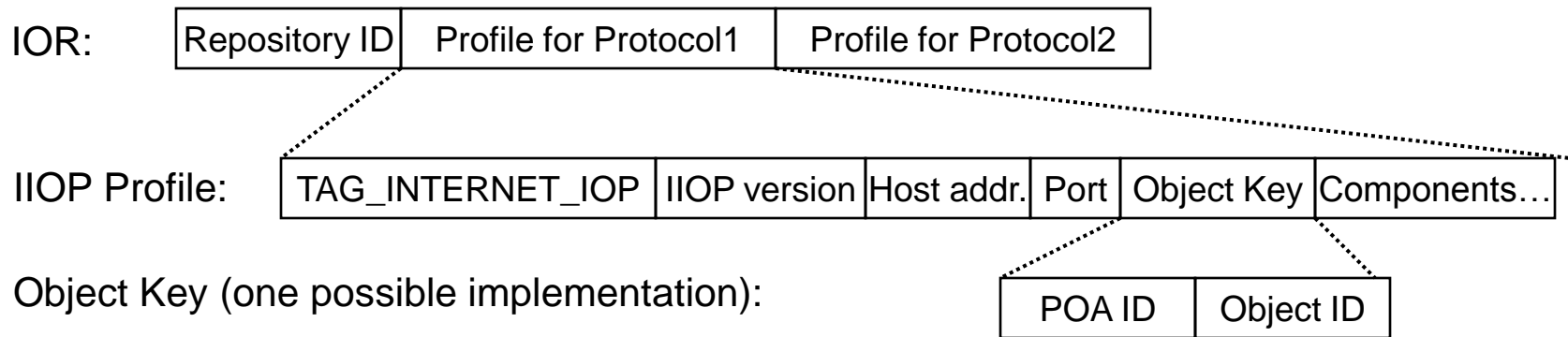
- Notes (**don't need to memorized gory details....** )
  - CORBA::Request object represents one invocation of one method of one CORBA object
  - CORBA::Any encapsulates any CORBA type

```
// Create request that will be sent to the manager object
CORBA::Request_var request = manager->_request("open");
// Create argument to request
CORBA::Any customer;
customer <<= (const char *) name;
CORBA::NVList_ptr arguments = request->arguments();
arguments->add_value( "name" , customer, CORBA::ARG_IN );
// Set result type
request->set_return_type(CORBA::_tc_Object);
// Invoke operation. NOTE: Could have used send_deferred()
request->invoke();
// Get the return value
CORBA::Object_var account;
CORBA::Any& open_result = request->return_value();
open_result >>= CORBA::Any::to_object(account.out());
```

# Object References

- Object reference
  - Opaque handle for client to use
  - Identifies exactly one CORBA object
  - IOR == “Interoperable Object Reference”
- References may be passed among processes on different hosts
  - As parameters or “stringified”
  - ORB will convert into form suitable for transmission over network
  - ORB on receiver side will create a proxy and return a pointer to it
  - Basically functions as a remote “pointer” that works across heterogeneity in language, OS, net, vendor, ...

# Object References (cont.)



- Object Key
  - Opaque to client
  - ORB-specific
- Object ID
  - Can be created by user or POA (more in POA slides...)

# Interface Repository

- Stores information on interfaces which can be looked up later by others at runtime. Tells about
  - Interface names
  - Method signatures
  - ...
  - Exactly the information in an IDL file.
- Allows for runtime discovery of interfaces.
  - Can be used by other useful hooks, such as the DII, DSI, and Interceptors.

# Implementation Repository (IR)

- Stores information on the implementations available for a given interface
  - Mainly bindings between interface names and executable files that implement them
- This allows the ORB to
  - activate servants to process object invocations
  - Construction of remotely accessible **factory objects**

# General Interoperability Protocol (GIOP)

**Abstract** protocol to allow for interoperability between different vendors' ORBs. To do this, it defines:

- **Interoperable Object Reference (IOR) format**
- **Inter-ORB message formats (and their protocol state machine for interacting)**
  1. **Request**: from client, sending an invocation. Contains
    - `GIOP.MessageHeader`
    - `GIOP.RequestHeader`
    - `GIOP.RequestBody`
  2. **Reply**: from server, responding to Request.
  3. **CancelRequest**: from client, telling it to ignore a Request already sent.
  4. **LocateRequest**: from client, to find out if a server can service a particular request, or if it has a forwarding IOR to the actual server implementation.
  5. **LocateReply**: from server, in response to `LocateRequest`.
  6. **CloseConnection**: from server, indicating it is closing the connection.
  7. **MessageError**: by both...
- **Wire protocol (data transfer syntax): Common Data Representation (CDR)**. A coding for all IDL types, structured types, exceptions, object references. Covers coding into an octet stream, alignment boundaries, how to indicate byte ordering used.

# Example of GIOP Format

```
module GIOP {  
  enum MsgType {Request, Reply, CancelRequest, LocateRequest,  
    LocateReply, CloseConnection, MessageError};  
  struct MessageHeader {  
    char magic[4];  
    Version GIOP_version;  
    octet byte_order;  
    octet message_type;  
    unsigned long message_size;  
  };  
  struct RequestHeader {  
    IIOp::ServiceContextList service_context;  
    unsigned long request_id;  
    boolean response_requested;  
    sequence<octet> object_key;  
    string operation;  
    Principal requesting_principal;  
  }  
  ...  
}
```

# GIOP Transport Layer Assumptions

- Connection-oriented
  - I.e., transport management deals with opening and closing and using connections
- Connections are like
  - Two roles
    - Clients: open connections to servers
    - Servers: listen for connections
  - Clients and servers may only send a subset of the message types
  - Can be closed in an orderly fashion, or abortive close (both clearly defined)

# IIOP

- IIOP is simply GIOP (an abstract protocol, remember) implemented over TCP/IP
- Must be implemented by every ORB
  - Gives a universal way for ORBs to communication
  - A given ORB may implement different transports underneath GIOP, also
- CommunicationID = {IP address, TCP port}

# QuO project: The Overarching Challenge

*The overarching challenge is to provide COTS middleware support for developing distributed applications for these widely differing environments*

- Middleware support for building integrated QoS, adaptive applications (with varying requirements on granularity of changing behavior):
  - adaptable: change at runtime while application/service running
  - reconfigurable: change at runtime while application/service halted
  - evolvable: change at development time
  - rehostable: move from environment to environment, platform to platform, and domain to domain with minimum effort and maximum reuse.

# The Quality Objects (QuO) Framework Supports Development of Distributed Applications with QoS

The QuO framework provides

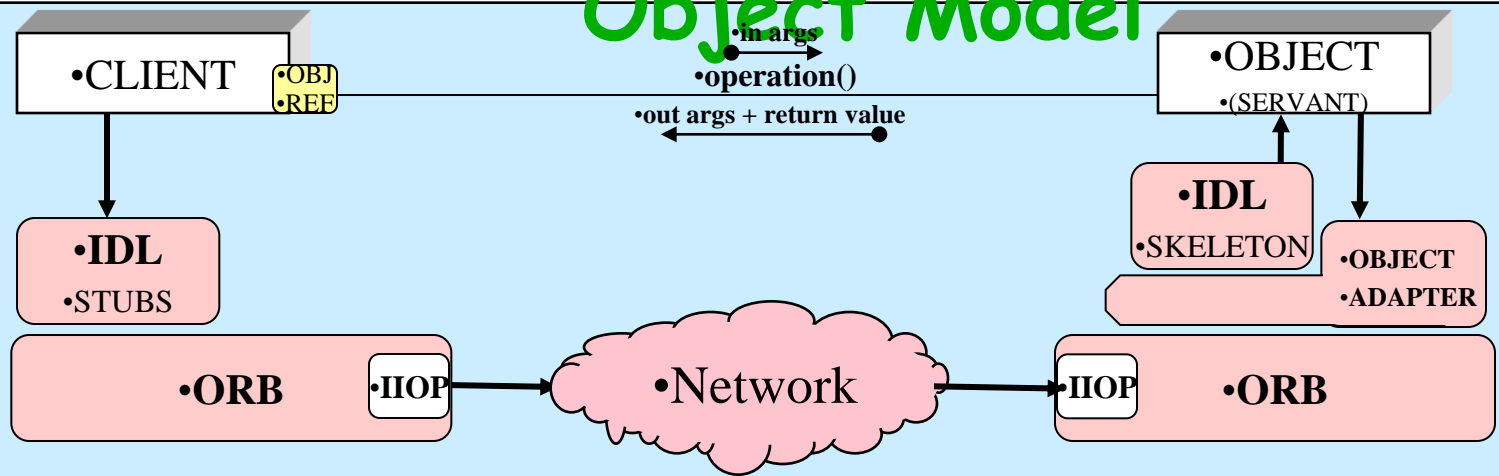
- Separation of concerns between software functional properties and QoS needs
- Consistent interfaces for QoS measurement and resource management control
- Standard middleware interfaces between application and QoS-provider layers
- Facilities to enable application- and system-level adaptation

QuO is being developed as a common approach to adaptable QoS for a number of projects focusing on different QoS dimensions:

- Dependability, replication, group communication (U.Illinois, Cornell, UCSB)
- Managed bandwidth, resource reservation (CMU, Columbia Univ.)
- Real-time behavior (Washington Univ in St. Louis)
- Security, access control, survivability, intrusion detection (TIS)
- Integrating different dimensions in an application, e.g., real-time and dependability
- Suitability for supporting different approaches to a dimension

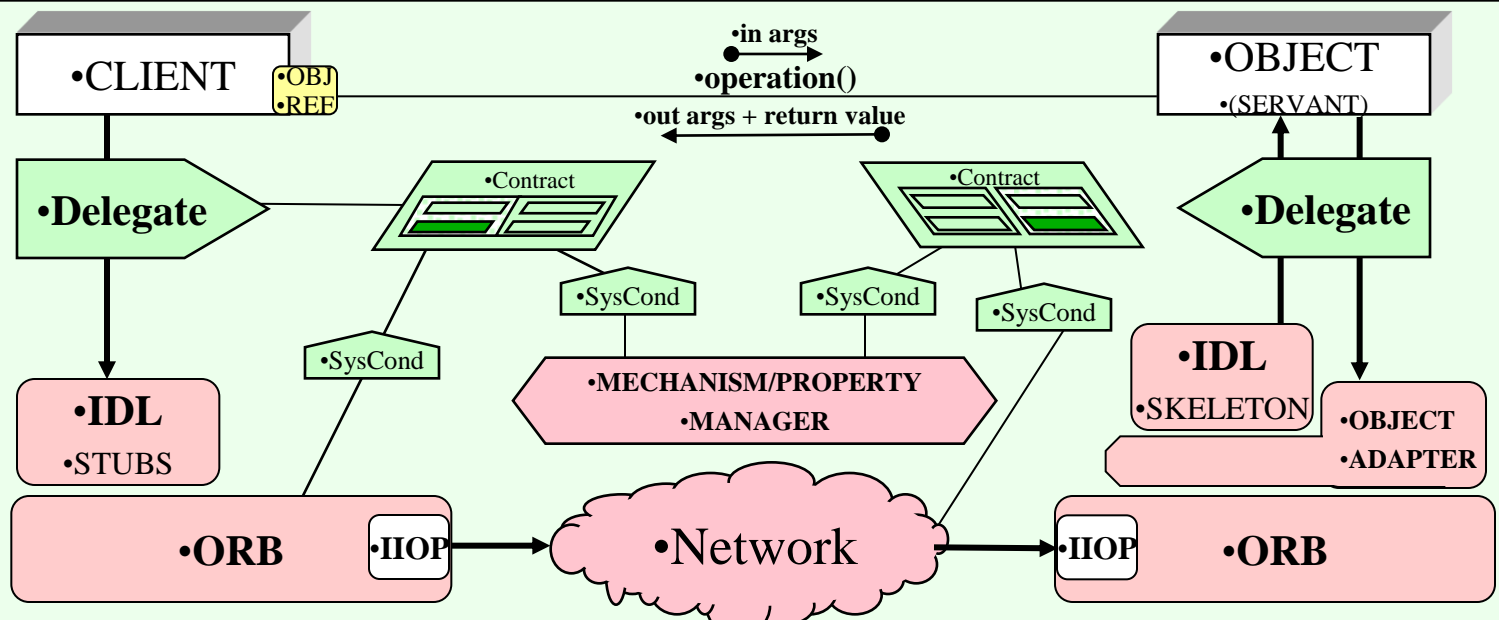
# QuO Adds Specification, Measurement, and Adaptation into the Distributed Object Model

•CORBA DOC MODEL



•Application Developer  
•Mechanism Developer

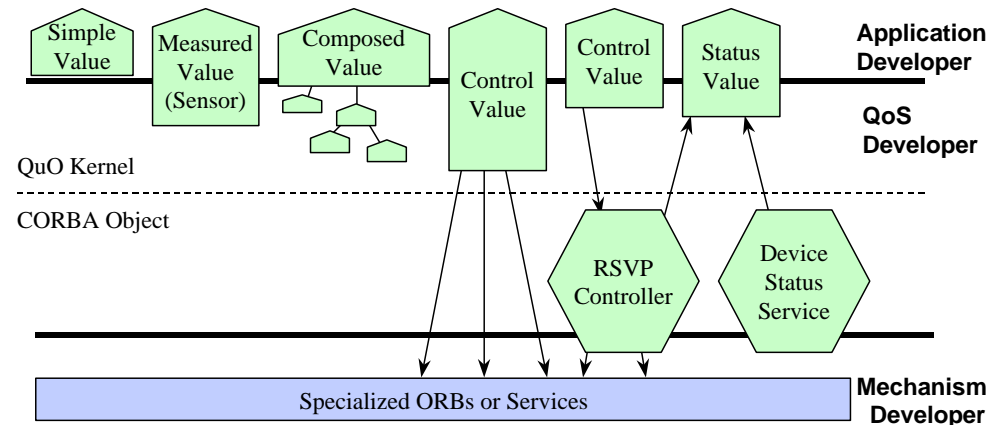
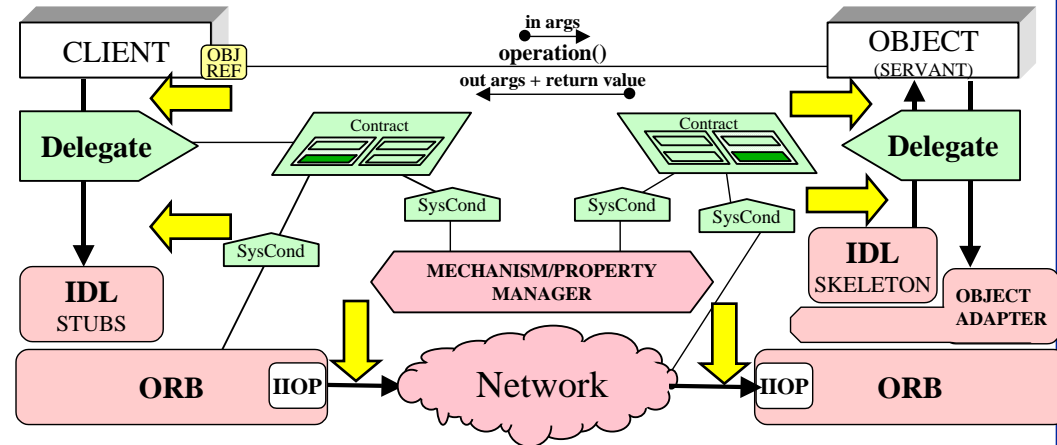
•QUO/CORBA DOC MODEL



•Application Developer  
•QuO Developer  
•Mechanism Developer

# Measurement in QuO

- *In-band* measurement handled by instrumentation
  - A structure is transparently passed along with the method call/return
  - Information can be inserted, read, and processed to record and evaluate method call statistics (e.g., the time spent in



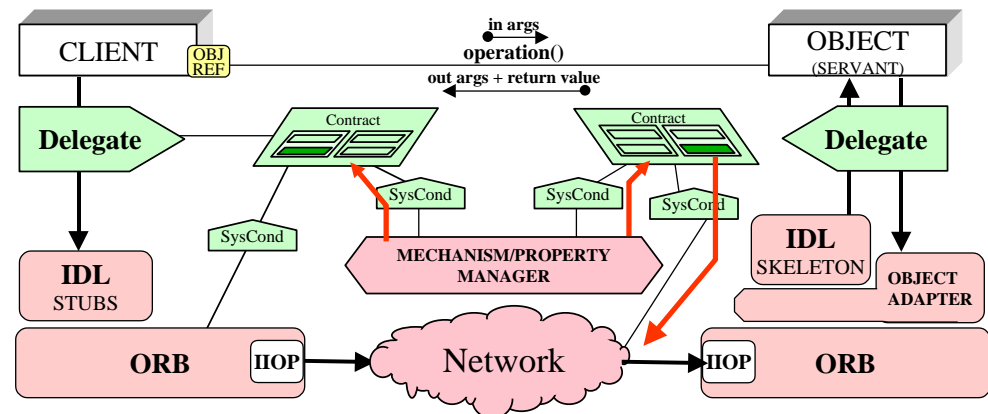
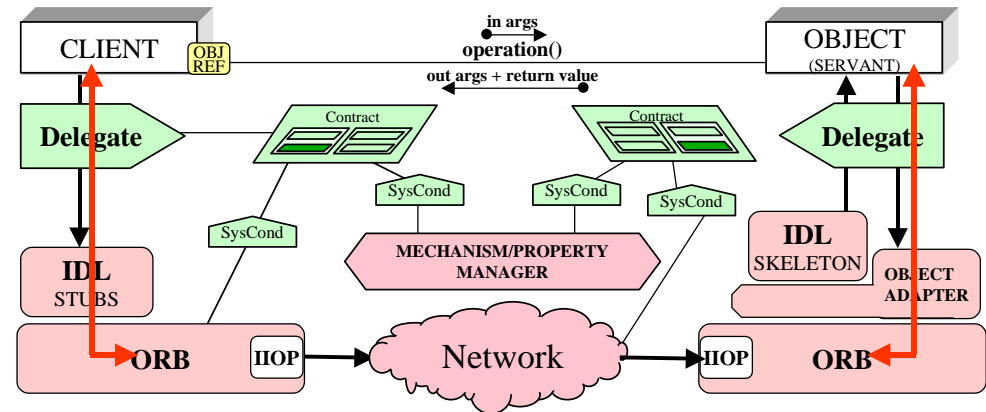
# Adaptation and Control in QuO

- *In-band* adaptation provided by the delegate and gateway

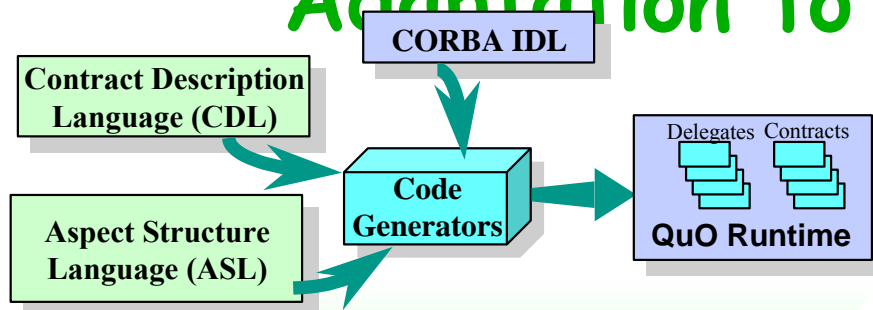
- A delegate decides what to do with a method call or return based upon the state of its contract

- Gateway enables control and adaptation at the transport layer

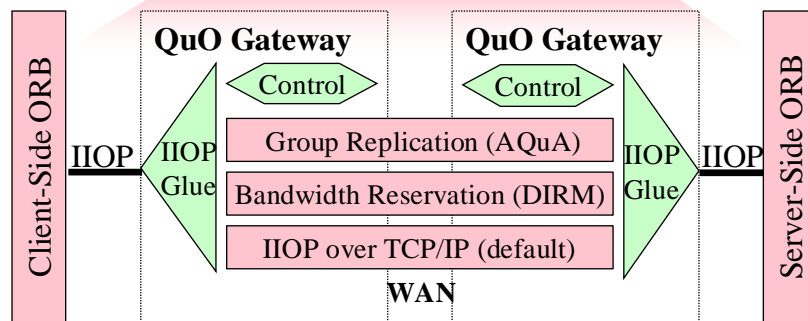
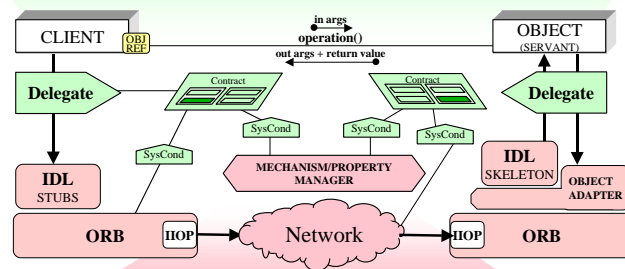
- *Out-of-band* adaptation triggered by transitions in



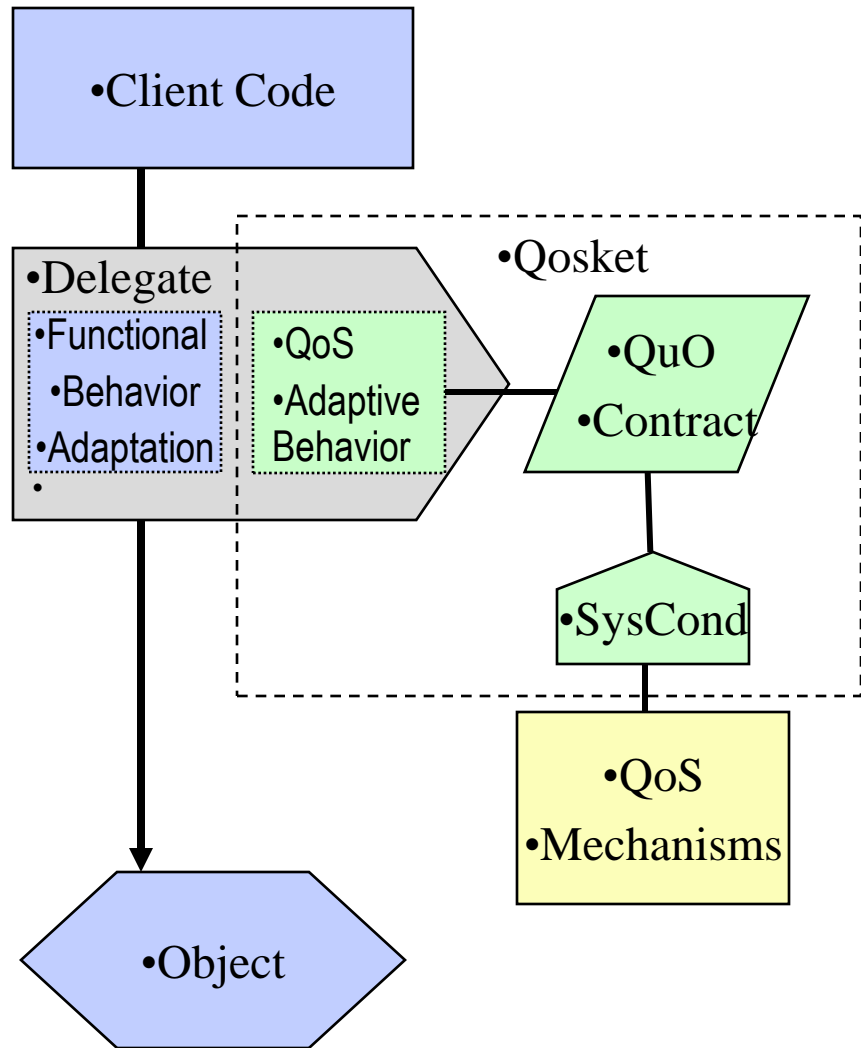
# The QuO Toolkit Supports Building Adaptive Applications or Adding Adaptation to Existing Apps



- QuO aspect languages
  - Contract description language and adaptive behavior description language
  - Code generators that weave QuO code into Java and C++ applications
- System Condition Objects
  - Provide interfaces to resources, managers, and mechanisms
- QuO Runtime Kernel
  - Contract evaluator
  - Factory object which instantiates contract and system condition objects
- Instrumentation library
- QuO gateway
  - Insertion of special purpose transport layers and adaptation below the ORB



# Bundles of "Systemic Behavior" Called Qoskets



- The Qosket encapsulates a set of contracts (CDL), system condition objects (IDL), and QoS adaptive behavior (ASL)
- The Qosket exposes interfaces to access QuO controls and information (specified in IDL)
- The Qosket separates the functional adaptive behavior (business logic) from the QoS adaptive behavior and the middleware controls from the QoS mechanisms