Real-time and Embedded CORBA Technology Update for Ada

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Disclaimer

- Objective Interface is an ORB vendor
- On the positive side:
  - This talk is based on first hand from experience
  - OIS is part of the group that created the Ada mapping for the CORBA standard
    - We've been in the ORB business since 1995
  - OIS is one of the co-authors of the Real-Time and Fault Tolerant CORBA standards
- On the negative side:
  - We are not "neutral"

Discussions in this talk describe CORBA standard technology only. No product plans, features, or release dates are described or implied

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Topics

- Brief Review of CORBA Fundamentals (in two minutes)
- Changes in the IDL → Ada mapping
- Real-Time CORBA
- Asynchronous Messaging
- Fault Tolerant CORBA
- Other New Technologies ("CORBA 3.0")

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Brief Review of CORBA Fundamentals

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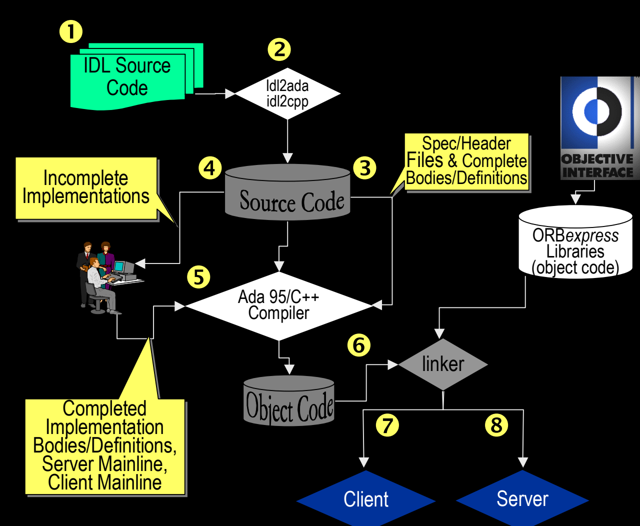
IDL is the Key

- **Provides the glue to attach the object to the software bus**
- **OMG's Interface Definition Language (IDL)**
  - Specifies interfaces to remote objects
  - Part of the CORBA specification
  - Fully Object-Oriented
- **A declarative language mapped to modern programming languages**
  - Ada 95, C, C++, Java, Smalltalk, OO Cobol, Eiffel...

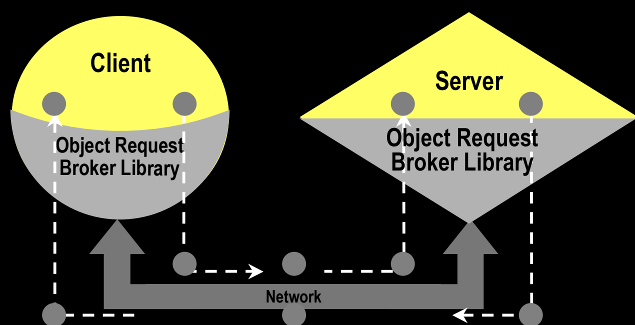
Language Neutral Interface (API)

CORBA Development Process



CORBA Runtime View Overview

Basic CORBA Runtime Architecture (Diagram)



- ❶ Client sends a request to the server
- ❷ Server receives request from Client
- ❸ Server sends a reply to the Client
- ❹ Client gets reply from the Server

Changes in the IDL → Ada mapping

Latest Revision Approved
April 2000

RFP Requirements

- Mandatory - Update the mapping of OMG IDL to the Ada language
  - Reflect additions and changes to the CORBA "core"
  - As of deadline for LOIs (1 June 1999)
- Optional - additional server-side mapping based on delegation

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Outline of Mapping Changes and Additions

- Helper Packages
- Value Types
- Value Boxes
- Abstract Interfaces
- Additions and Changes to Pseudo-Interface
- Delegating Servants
- Local Interfaces
- Import
- Repository Identity Declaration
- Exception Clauses for Attributes

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Helper Packages

- **Interfaces are currently mapped to**
  - An interface package containing
    - A “Ref” type derived from CORBA.Object.Ref
    - Mapped “set_*attribute*” and “get_*attribute*” subprograms
    - Mapped operation subprograms
    - “To_Ref” function that supports widening and narrowing
    - Type any support
      - TypeCode constant
      - “From_Any” and “To_Any” functions
  - An implementation package containing
    - An “Object” type derived from PortableServer.Servant
    - Subprograms mapped from IDL attributes and operations

Helper Packages (cont.)

- **Revision defines a “.Helper” package – moves in**
  - Widening and narrowing support
  - Type Any support
  - Forward reference conversion, if needed
- **Rationale**
  - Cleaner, more direct interface package
  - Consistent with other language mappings
- **This packaging pattern is used in mapping of new constructs (value types, etc.)**

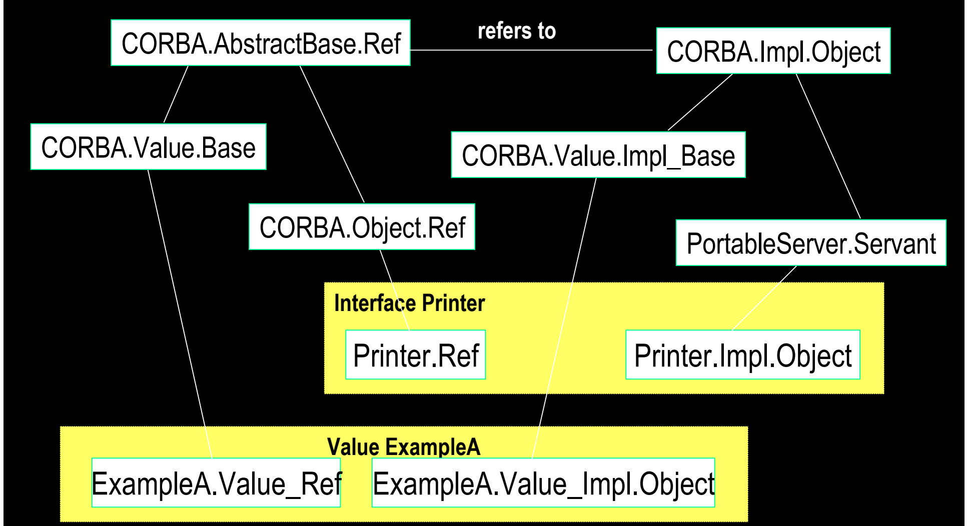
Example Interface Mapping

```
interface Feed {
    typedef long measure;
    attribute measure weight; };
package Feed is
    type Ref is new CORBA.Object.Ref with null record;
    type measure is new CORBA.Long;
    procedure Set_weight (Self : in Ref; To : in measure);
    function Get_weight (Self : in Ref) return measure;
end Feed;
package Feed.Helper is
    function To_Ref (From : in CORBA.Object.Ref'CLASS) return Ref;
    function To_Any (From : in Ref) return CORBA.Any;
    function From_Any (From : in CORBA.Any) return Ref;
    TC_Feed : constant CORBA.TypeCode.Object;
end Feed.Helper;
package Feed.Impl is
    type Object is new PortableServer.Servant with ...
    function Get_weight (Self : access Object) return measure;
    procedure Set_weight (Self : access Object; To : measure);
end Feed.Impl;
```


Objects by Value

- IORs and Interfaces are an OO construct that is always passed (around the network) by *reference*
- There is a need/desire for an OO construct that is always passed (around the network) by *value*
- ValueTypes is the result
  - First order approximation Ada equivalent is: tagged record that can be inherited and extended
  - However, due to additional semantics in the standard, these actually map to a smart pointer
- Unfortunately, Java RMI interoperability perturbs the simplicity of the result

Inheritance of Base Types



Value Types Basic Mapping

- **A value type is mapped to 3 packages**
  - 1.) Value Interface package containing
    - A Value_Ref type derived from CORBA.Value.Base
    - Accessor functions and set procedures for the public state members
    - Functions and procedures mapped from the operations on the value type
    - Functions returning a Value_Ref mapped from the initializers of the value
    - A null value constant.

Value Types
Basic Mapping

- **A value type is mapped to 3 packages**
  2.) Value implementation package specification containing
  - An Object type
    - Derived from CORBA.Value.Impl_Base
    - Contains components for each public and private state member
  - An Object_Ptr type - general access to Object type
  - Specifications of functions and procedures mapped from the operations on the value type
  - Factory functions returning an Object_Ptr mapped from the initializers of the value type

Value Types
Basic Mapping

- **A value type is mapped to 3 packages**
  3.) Value Helper package containing
  - TypeCode constants
  - To_Any, From_Any converters
  - A widening converter

Other CORBA 2.3 Changes

- Escaped Identifiers
  - Lexical mapping rules were adjusted to account for escaped identifiers
- Additional operations in CORBA standard pseudo-interfaces
  - These have now been mapped into Ada 95 according to the rules for mapping pseudo-interfaces

Delegating Servants

- Current servant mapping using inheritance
  - Delegation is an alternative design approach (known as the "tie" approach in the C++ mapping)
- Additional implementation delegation package may be generated for each interface. Generic package
  - With formal parameters specifying
    - Type to be wrapped
    - Functions and procedures with the same signature as
      - Mapped attribute accessors and settors
      - Mapped operations
      - Including signatures of all inherited interfaces
  - Defines
    - the servant type - Object
    - Create function

Local Interfaces (from CORBA Components Specification)

- **Mapping of local interfaces differs from mapping of "unconstrained" interfaces in only minor ways**
- **Interface package**
  - Reference type is named "Local_Ref"
  - Semantics of CORBA.Object operations altered
- **Implementation package**
  - Object type inherits from CORBA.Local.Object
- **Helper package**
  - No need for type any support
- **LocalObject - mapped to type Object in CORBA.Local package**

Import (from CORBA Components Specification)

- **New statement introduces unit visibility rules into IDL**
- **Visibility rules from IDL import statements are incompatible with visibility rules for Ada's "with" statements**
  - No explicit mapping rules for import
  - Instead, general visibility mapping rules
- **Visibility mapping rules**
  - IDL visibility according to IDL visibility rules
  - Generate Ada "with" statements to reflect visibility required by Ada compilation

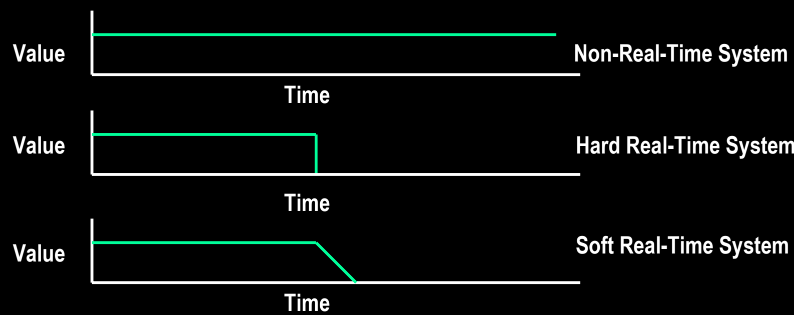
Other CORBA Components based Changes

- Repository Identity Declaration
  - Explicit typeID and typePrefix statements replace pragma
  - Affects string values used in TypeCode constants only
- Exception clauses for attributes
  - Adds “getRaises” and “setRaises” clauses to attributes
  - No explicit mapping needed for Ada

Real-Time CORBA

Definition of Real-Time for this Discussion

- A real-time system is one which ensures time constraints are met
- A real-time system produces a value to the overall system which is a function of time

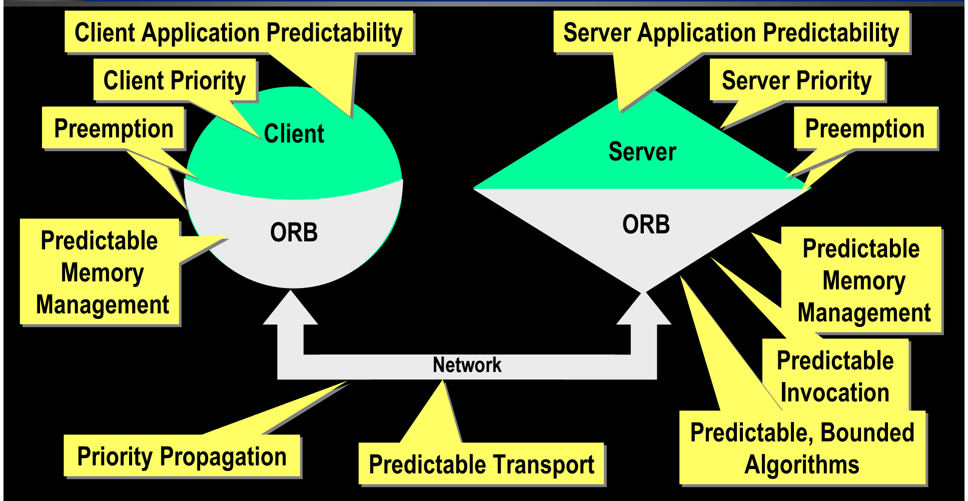


A Truism

- Real-Time $\neq$ Real Fast!

- However, that being said, people usually want real-time systems to be very fast!

Real-Time System Predictability



CORBA is an important part of the solution!

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Why Use CORBA in a Real-Time System? [1]

- **… for flexibility**
  - Many real-time systems must run on multiple computers & are written in mixed languages
  - CORBA solves many real-time system integration problems if the ORB is:
    - fast
    - predictable
    - small
    - has native support for embedded transports

CORBA doesn't have to be slow, bulky or indeterminate

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Why Use CORBA in a Real-Time System? [2]

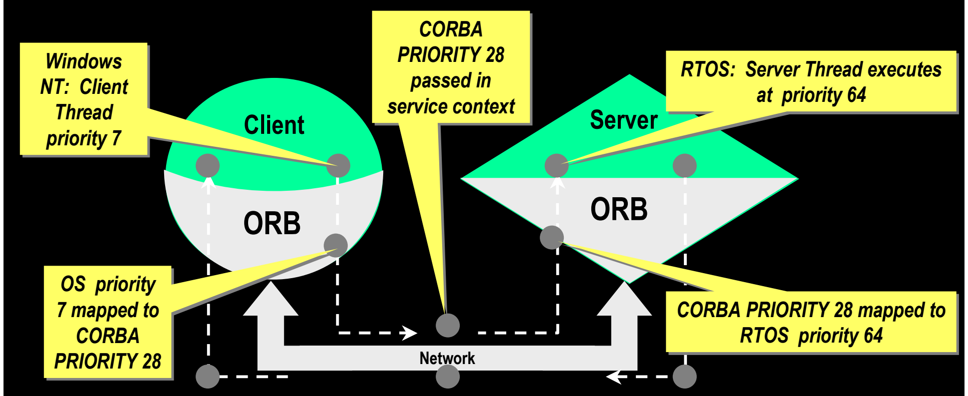
- **... to save money!**
  - Future system changes are much easier
    - change CPU type
    - change O/S
    - change transport (bus or network)
  - Upgrade components one at a time
    - New components can interoperate with old components

Ingredients of a Real-Time ORB

Key: Support Predictability in the full End-to-End Round Trip

- **Predictable ORB infrastructure**
  - Predictable memory management, etc.
  - Use of predictable, bounded algorithms
  - Analysis and documentation of behavior
- **Priority Propagation & Distributed Priority Inheritance**
- **Predictable transport (i.e. not TCP)**
  - Native ATM (ANI) Reflective Memory FDDI
  - FireWire (IEEE 1394) Shared Memory VME/PCI
- **ORB must understand and use deterministic transports & Quality of Service (QoS) metrics**
- **ORB must allow designer to control QoS and map them from client → network → server**

CORBA Priority Propagation



History and Standardization

- **CORBA Evolution:**
  - Introduced in 1991 by the Object Management Group (OMG)
  - OMG is an international consortium of over 800 companies
    - Users, Suppliers, Academics, Government
    - Industry spends 30M each year to participate in OMG
  - CORBA Specification continues to evolve
- **Real-Time CORBA Evolution:**
  - Effort to *extend* the CORBA specification to meet real-time requirements
  - Produced over a period of 1 ½ years
  - Based on experience of vendors and users with existing implementations
  - Real-Time CORBA 1.0 standard accepted 7/99

Overview of Real-Time CORBA Standard

- **The basic concepts described earlier are embodied in the Real-Time CORBA standard**
- **In addition to the mandatory elements, ORB vendors can/will offer additional capabilities**
- **Some specific additional aspects of the Real-Time CORBA standard**
  - Objective
  - Threads and Priorities
  - Threadpools
  - Mutex
  - Priority Banded Connections

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Objective

- **End-to-End Predictability =**
  - Respecting thread priorities between client and server for resolving resource contention during the processing of CORBA invocations;
  - Bounding the duration of thread priority inversions during end-to-end processing;
  - Bounding the latencies of operation invocations.
- **Support both “Hard” and “Soft” Real-Time Applications**
  - Tools in the standard for predictability for Hard Real-Time Systems
  - Tools in the standard for resource control and management for Soft Real-Time systems where these can be scarce

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Threads and Priorities

- "Thread" is the schedulable entity
- POSIX Threads
- Native (RTOS) Priorities
  v.s.
- CORBA Priorities
  - 0 .. 32767
  - 32767 is the "highest" priority
  - Universal priority scheme
  - User installable mapping functions

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Threadpools

- Threadpool abstraction is used to manage threads on server- side of real- time CORBA ORB
  - Pre- allocation, partitioning, bounding usage: predictability
- • Threadpool parameters
  - Number of static threads
  - Dynamic thread limit
    - 0 = no limit. Same value as static = no dynamic threads
  - Thread stacksize
  - Default thread priority
    - Thread priority will change as required
- Laned Threadpools also exist

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Mutex

- The Essential Abstraction for Resource Protection
- Context for Priority Inheritance Discussions
- Makes the mutex used by the ORB available to the application developer

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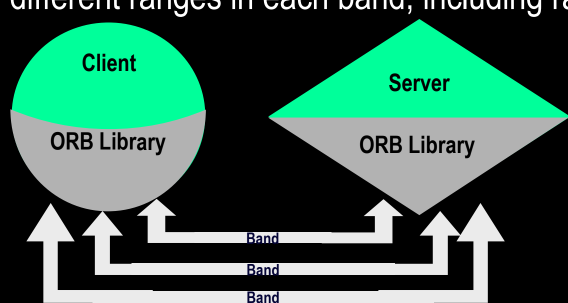
Priority Banded Connections

- Multiple connections, to reduce priority inversion
  - Each connection handling different priority invocations
- Banding
  - Each connection may represent a range of priorities, to allow resources to be traded off against limited inversion
  - May have different ranges in each band, including range of 1



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Asynchronous Messaging

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AMI Concepts

- **Current CORBA supports only Synchronous calls**
  - Oneway isn't really what is wanted for Asynchronous calls
  - It is limited to in parameters only and no exceptions
    - AMI does define new, additional semantics to oneway operations
  - There were no delivery guarantees
- **AMI defines two new Asynchronous modes:**
  - Callback
    - Caller hands callee an IOR for a callback interface
    - Callee invokes callback interface when reply
    - Callback interface is automatically determined from IDL (ReplyHandler)
  - Polling
    - Invocation returns an IOR to an interface which may be periodically polled for the pending result(s)

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AMI Concepts [2]

- Message Quality of Service Characteristics
  - Delivery Characteristics including:
    - Birth and Expiry times for request and reply
    - Reliability
    - Scope of synchronization with target
  - Server Side Queue Management or Ordering:
    - Temporal based
    - Priority based

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Fault Tolerant CORBA

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Fault Tolerant CORBA Concepts

- **Wide range of systems exist that might want/need this functionality**
  - Compromises have been made in creating the FT CORBA specification
  - Once experience has been gained, revisions might happen
- **Objectives:**
  - Provide robust support for applications that require a high level of reliability
    - No single point of failure
  - Depends on entity redundancy, fault detection and recovery
    - Redundancy is based on Object replication and groups of Objects

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FT CORBA Concepts [2]

- **Objectives (continued):**
  - Range of fault tolerance strategies, including:
    - Request retry
    - Redirection to an alternative server
    - Passive (primary/backup) replication and
    - Active replication (which provides more rapid recovery from faults)
  - Developer control of
    - Creation of replicas
    - Automation of replication of state
  - Support of Fault detection, notification and analysis
  - Minimal modification of programs
  - Transparency of replication and faults
  - No Single Point of Failure

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Other New Technologies ("CORBA 3.0")

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CORBA 3.0

- Some Highlights:
  - Support for distributed components
  - New messaging support
  - Quality of Service (QoS) features (covered previously)
    - Invocation ordering and time outs
    - Real-Time, Minimum and Fault Tolerant CORBA
  - Enhanced Java and Internet integration

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CORBA Components

- Specifies a framework for the development of "plug and play" CORBA objects:
  - Encapsulates the creation, lifecycle, methods, and events for a single object
  - Meant to decrease learning curve for development and us of CORBA clients and servers
  - Scripting language
  - Multiple interfaces for a single object
  - Pass Objects by Value
- Leverage and extend the existing Enterprise Java Beans specification for Java

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Java and Internet Integration

- Java-to-IDL Reverse Mapping
  - Unifies Java Remote Machine Interface (RMI) and CORBA IIOP
  - We are aware of a background effort to create an Ada to IDL mapping
- Java objects become CORBA-accessible:
  - Write JAVA server object
  - Automatically generate the interface in OMG IDL
  - Access its methods from a CORBA client written in any language
  - No longer a single-language distributed environment
- Firewall specification – allows secure use of CORBA with the internet

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Minimum CORBA

- New specification for embedded CORBA environment
- Based on the idea that an ORB "must have at least" these features to comply
- Does not discuss memory footprint or dynamic memory constraints
- Designed for fixed, predictable systems
  - Eliminates dynamic aspects of CORBA
    - DII, DSI, Dynamic Any
    - Interface Repository
    - Some POA features and policies
  - Supports ALL OMG IDL types

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