DISTRIBUTED SYSTEMS (COMP9243)

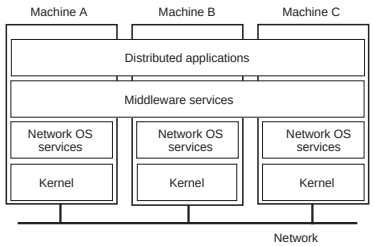
Lecture 8c: Middleware

Slide 1

① Introduction
② Publish/Subscribe Middleware
③ Distributed Object Middleware
- Remote Objects & CORBA
- Distributed Shared Objects & Globe

MIDDLEWARE

Slide 2

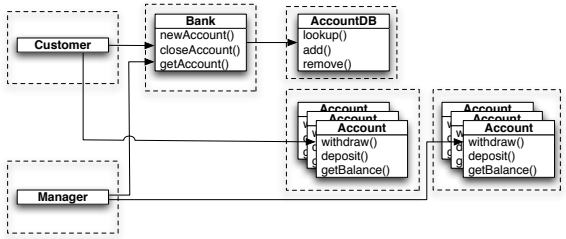


KINDS OF MIDDLEWARE

Distributed Object based:

➜ Objects invoke each other's methods

Slide 3



Message-oriented:

➜ Messages are sent between processes

➜ Message queues

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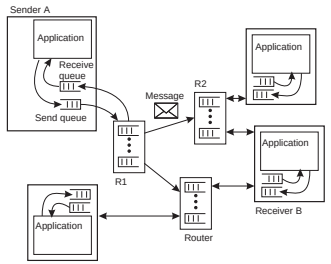

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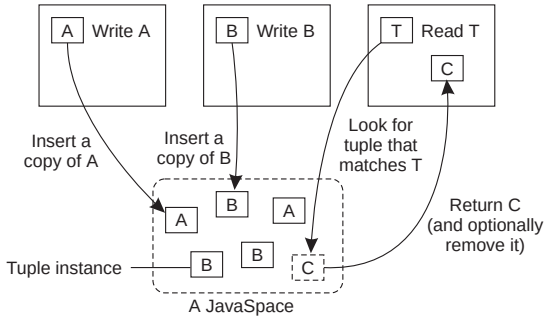
Coordination-based:

➜ Tuple space



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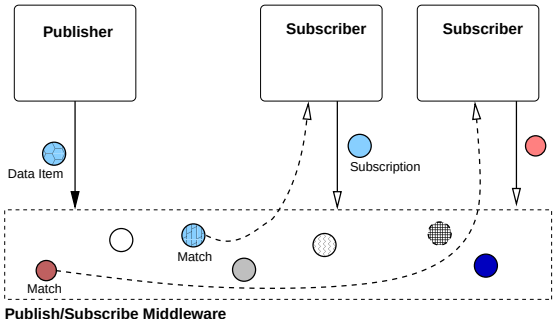
➜ Publish/Subscribe



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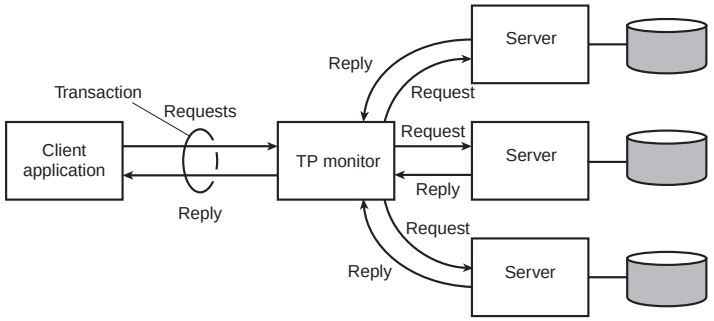
Transaction Processing Monitors:



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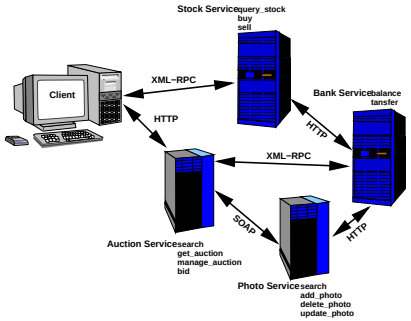
Web Services:



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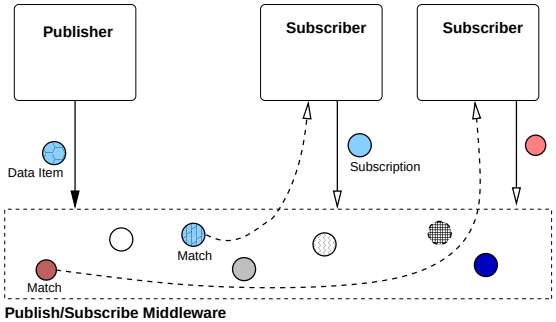
Publish/Subscribe (Event-Based) Middleware



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Challenges

Transparency:
- ➜ loose coupling → good transparency

Scalability:
- ➜ Potentially good due to loose coupling
- ✗ In practice hard to achieve
- ➜ Number of subscriptions
- ➜ Number of messages

Flexibility:
- ➜ Loose coupling gives good flexibility
- ➜ Language & platform independence
- ➜ Policy separate from mechanism

Programmability:
- ➜ Inherent distributed design
- ➜ Doesn't use non-distributed concepts

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Examples

Real-time Control Systems:
- ➜ External events (e.g. sensors)
- ➜ Event monitors

Stock Market Monitoring:
- ➜ Stock updates
- ➜ Traders subscribed to updates

Network Monitoring:
- ➜ Status logged by routers, servers
- ➜ Monitors screen for failures, intrusion attempts

Enterprise Application Integration:
- ➜ Independent applications
- ➜ Produce output as events
- ➜ Consume events as input
- ➜ Decoupled

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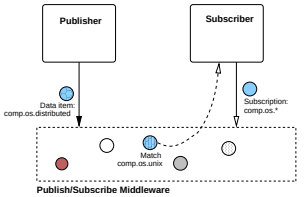
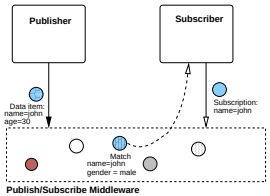
Message Filtering

Topic-based



Content-based



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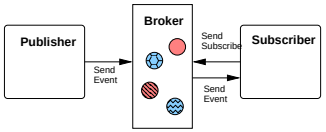
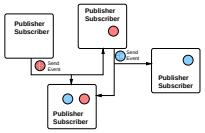
Architecture

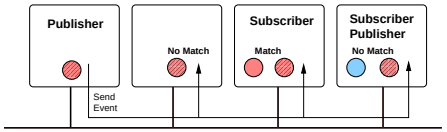
Centralised:



Peer-to-Peer:



Multicast-based:



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Communication

- ➜ Point-to-point
- ➜ Multicast
  - hard part is building appropriate multicast tree
- ➜ Content-based routing
  - point-to-point based router network
  - make forwarding decisions based on message content
  - store subscription info at router nodes

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Replication

Replicated Brokers:

- ➜ Copy subscription info on all nodes
- ➜ Keep nodes consistent
- ➜ What level of consistency is needed?
- ➜ Avoid sending redundant subscription update messages

Partitioned Brokers:

- ➜ Different subscription info on different nodes
- ➜ Events have to travel through all nodes
- ➜ Route events to nodes that contain their subscriptions

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Fault Tolerance

Reliable Communication:

- ➜ Reliable multicast

Process Resilience (Broker):

- ➜ Process groups
- ➜ Active replication by subscribing to group messages

Routing:

- ➜ Stabilise routing if a broker crashes
- ➜ Lease entries in routing tables

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Example Systems

TIB/Rendezvous:

- ➜ Topic-based
- ➜ Multicast-based

Java Message Service (JMS):

- ➜ API for MOM
- ➜ Topic-based
- ➜ centralised or peer-to-peer implementations possible

Scribe:

- ➜ Topic-based
- ➜ Peer-to-peer architecture, based on Pastry (DHT)
- ➜ Topics have unique IDs and map onto nodes
- ➜ Multicast for sending events
  - Tree is built up as nodes subscribe

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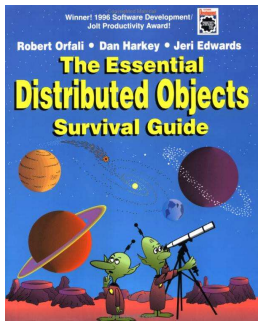
Distributed Objects



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Challenges

- ➜ Transparency
  - Failure transparency
- ➜ Reliability
  - Dealing with *partial failures*
- ➜ Scalability
  - Number of clients of an object
  - Distance between client and object
- ➜ Design
  - Must take distributed nature into account from beginning
- ➜ Performance
- ➜ Flexibility

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Object Model

- ➜ Classes and Objects

  Class: defines a type
  Object: instance of a class
- ➜ Interfaces
- ➜ Object references
- ➜ Active vs Passive objects
- ➜ Persistent vs Transient objects
- ➜ Static vs Dynamic method invocation

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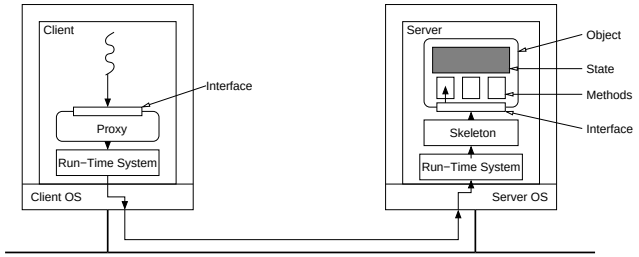
Remote Object Architectural Model



Remote Objects:

- Single copy of object state (at single object server)
- All methods executed at single object server
- All clients access object through proxy
- Object's location is location of state

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Client

Client Process:

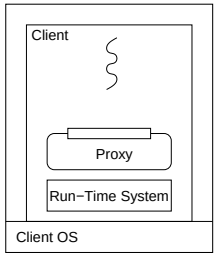
- Binds to distributed object
- Invokes methods on object

Proxy:

- Proxy: RPC stub + destination details
- Binding causes a proxy to be created
- Responsible for marshaling
- Static vs dynamic proxies
- Usually generated

Run-Time System:

- Provides services (translating references, etc.)
- Send and receive



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Object Server

Object:

- State & Methods
- Implements a particular interface

Skeleton:

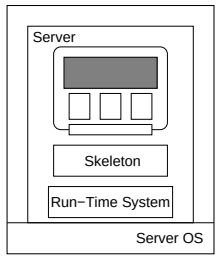
- Server stub
- Static vs dynamic skeletons

Run-Time System:

- Dispatches to appropriate object
- Invocation policies

Object Server:

- Hosts object implementations
- Transient vs Persistent objects
- Concurrent access
- Support legacy code



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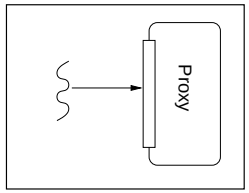
Object Reference

Local Reference:

- Language reference to proxy



OBJECT REFERENCE

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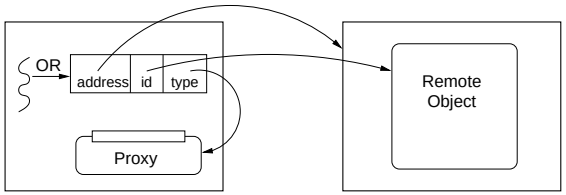
Remote Reference:

- Server address + object ID



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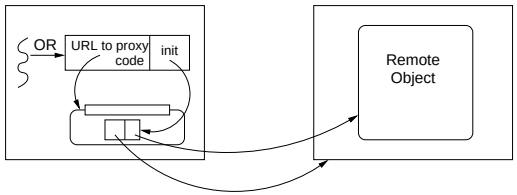
- Reference to proxy code (e.g., URL) & init data



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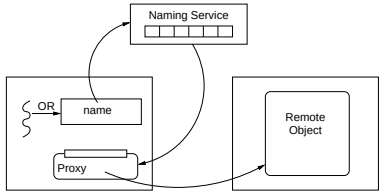
- Object name (human friendly, object ID, etc.)



What are the drawbacks and/or benefits of each approach?

REMOTE METHOD INVOCATION (RMI)

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Standard invocation (synchronous):

- Client invokes method on proxy
- Proxy performs RPC to object server
- Skeleton at object server invokes method on object
- Object server may be required to create object first

Other invocations:

- Asynchronous invocations
- Persistent invocations
- Notifications and Callbacks

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CORBA

Features:

- ➜ Object Management Group (OMG) Standard (version 3.1)
- ➜ Range of language mappings
- ➜ Transparency: Location & some migration transparency
- ➜ Invocation semantics: at-most-once semantics by default; maybe semantics can be selected
- ➜ Services: include support for naming, security, events, persistent storage, transactions, etc.

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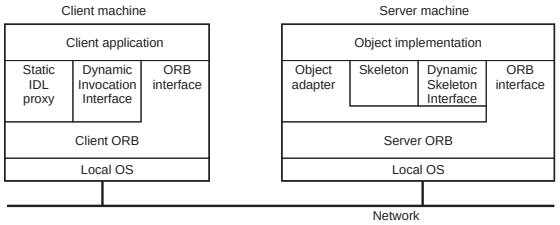
CORBA Architecture



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INTERFACES: OMG IDL

Example: A Simple File System:

```
module CorbaFS {
  interface File;       // forward declaration

  interface FileSystem {
    exception CantOpen {string reason;};
    enum OpenMode {Read, Write, ReadWrite};
    File open (in string fname, in OpenMode mode)
      raises (CantOpen);
  };

  interface File {   // an open file
    string read  (in long   nchars);
    void   write (in string data);
    void   close ();
  };
};
```

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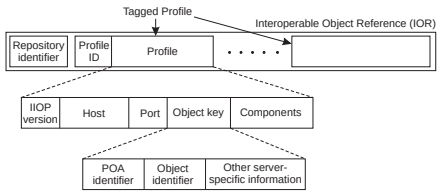
OBJECT REFERENCE (OR)

Object Reference (OR):

- ➜ Refers to exactly one object, but an object can have multiple, distinct ORs
- ➜ ORs are implementation specific

Interoperable Object Reference (IOR)

- ➜ Can be shared between different implementations



Object Request Broker (ORB)

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- Provides run-time system
- Translate between remote and local references
- Send and receive messages
- Maintains interface repository
- Enables dynamic invocation (client and server side)
- Locates services

Interceptors

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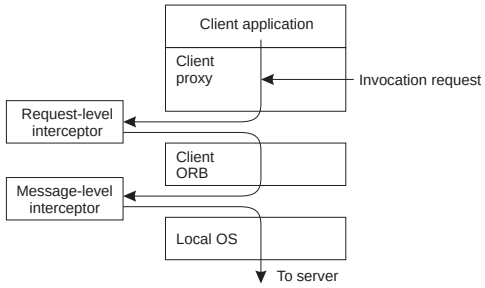

Binding

Direct Binding:

- Create proxy
- ORB connects to server (using info from IOR)
- Invocation requests are sent over connection

Indirect Binding:

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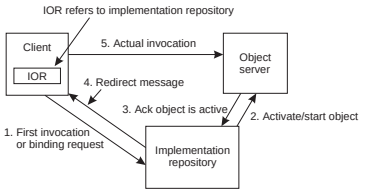

CORBA Services

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Some of the standardised services are the following:

- Naming Service
- Event Service
- Transaction Service
- Security Service
- Fault Tolerance

CORBA Bibliography

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(1) *IIOP Complete*, W. Ruh, T. Herron, and P. Klinker, Addison Wesley, 1999.

(2) *The Common Object Request Broker: Architecture and Specification (2.3.1)*, Object Management Group, 1999.

(3) *C Language Mapping Specification*, Object Management Group, 1999.

(4) *CORBAservices: Common Object Services Specification*, Object Management Group, 1998.

Play with CORBA. Many implementations available, including ORBit: `http://www.gnome.org/projects/ORBit2/`

Distributed Shared Object (DSO) Model

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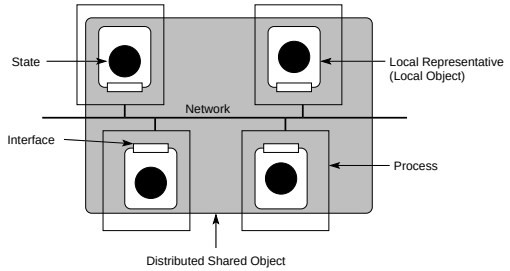

Distributed Shared Objects:

- ➜ Object state can be replicated (at multiple object servers)
- ➜ Object state can be partitioned
- ➜ Methods executed at some or all replicas
- ➜ Object location no longer clearly defined

Client

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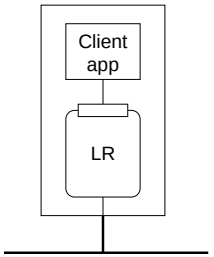
- ➜ Client has local representative (LR) in its address space
- ➜ Stateless LR
  - Equivalent to proxy
  - Methods executed remotely
- ➜ Statefull LR
  - Full state
  - Partial state
  - Methods (possibly) executed locally



Object

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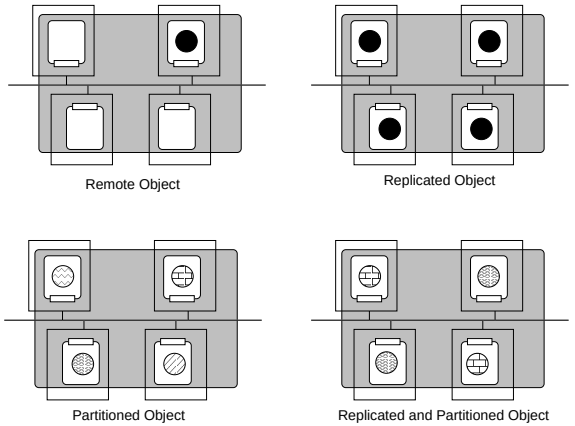

Object Server

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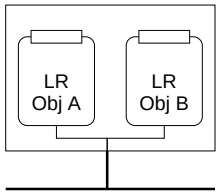
- Server dedicated to hosting LRs
- Provides resources (network, disk, etc.)
- Static vs Dynamic LR support
- Transient vs Persistent LRs
- Security mechanisms



Location of LRs:

- LRs only hosted by clients
- Statefull LRs only hosted by object servers
- Statefull LRs on both clients and object servers

Globe (Global Object Based Environment)

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Scalable wide-area distributed system:

- Wide-area scalability requires replication
- Wide-area scalability requires flexibility

Features:

- Per-object replication and consistency
- Per-object communication
- Mechanism not policy
- Transparency (replication, migration)
- Dynamic replication

Homework

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- Could you turn CORBA into a distributed shared object middleware using interceptors?

Hacker's edition:

- Implement the simple filesystem presented using a freely available version of CORBA (or other middleware if you prefer).

Reading List

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Globe: A Wide-Area Distributed System An overview of Globe

CORBA: Integrating Diverse Applications Within Distributed Heterogeneous Environments An overview of CORBA

New Features for CORBA 3.0 More CORBA