DISTRIBUTED SYSTEMS (COMP9243)

Lecture 8c: Middleware

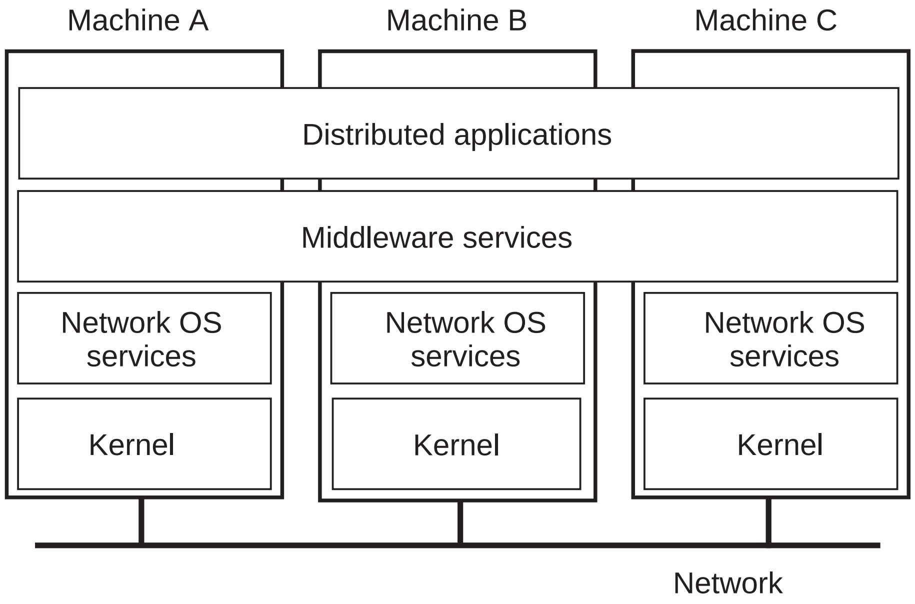
① Introduction

② Publish/Subscribe Middleware

③ Distributed Object Middleware

- Remote Objects & CORBA
- Distributed Shared Objects & Globe

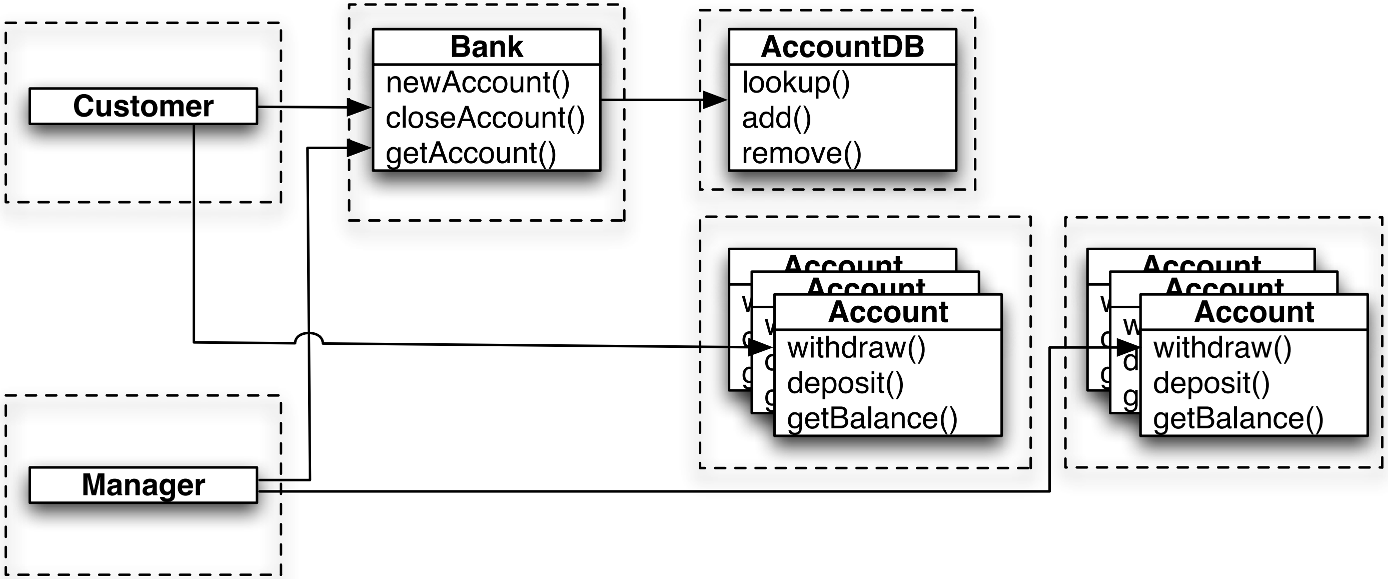
Middleware


Machine A
Machine B
Machine C
Distributed applications
Middleware services
Network OS services
Kernel
Network OS services
Kernel
Network OS services
Kernel
Network

KINDS OF MIDDLEWARE

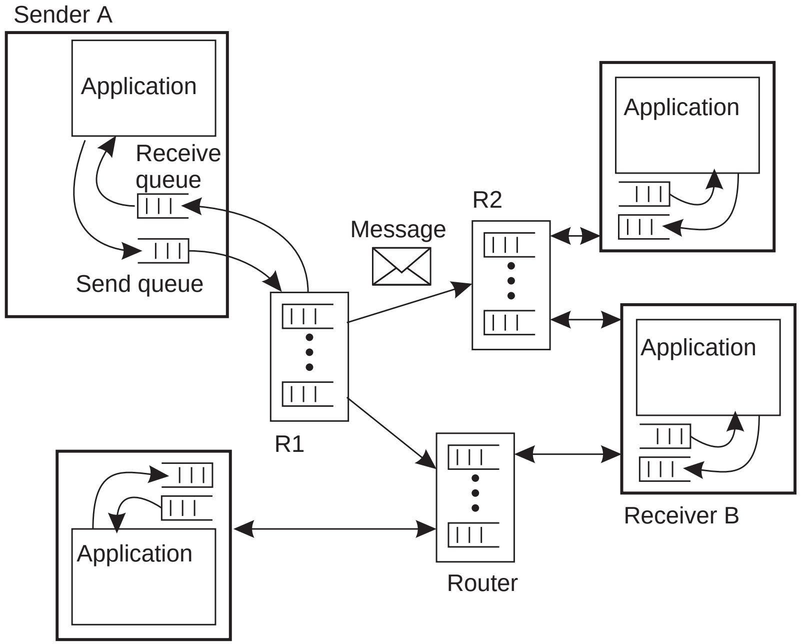
Distributed Object based:

➜ Objects invoke each other's methods



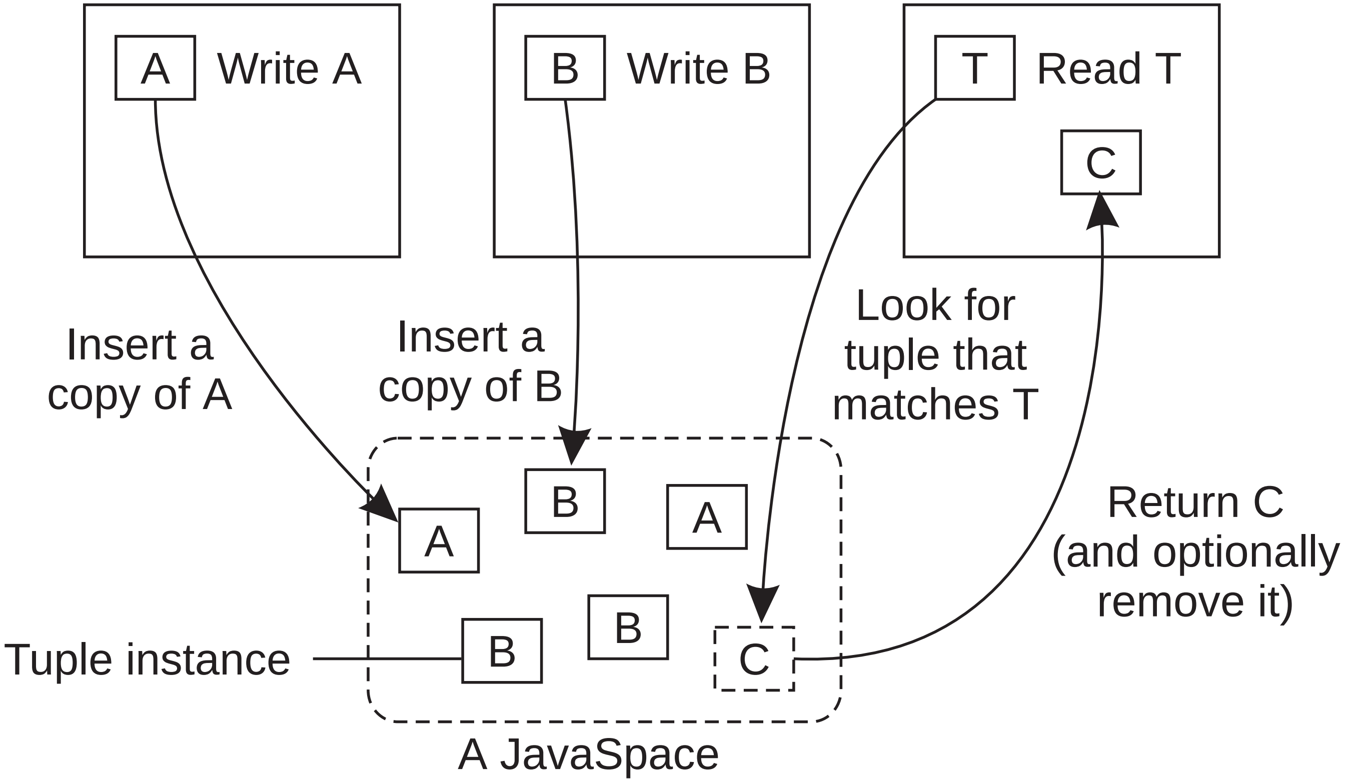
Message-oriented:

- ➜ Messages are sent between processes
- ➜ Message queues

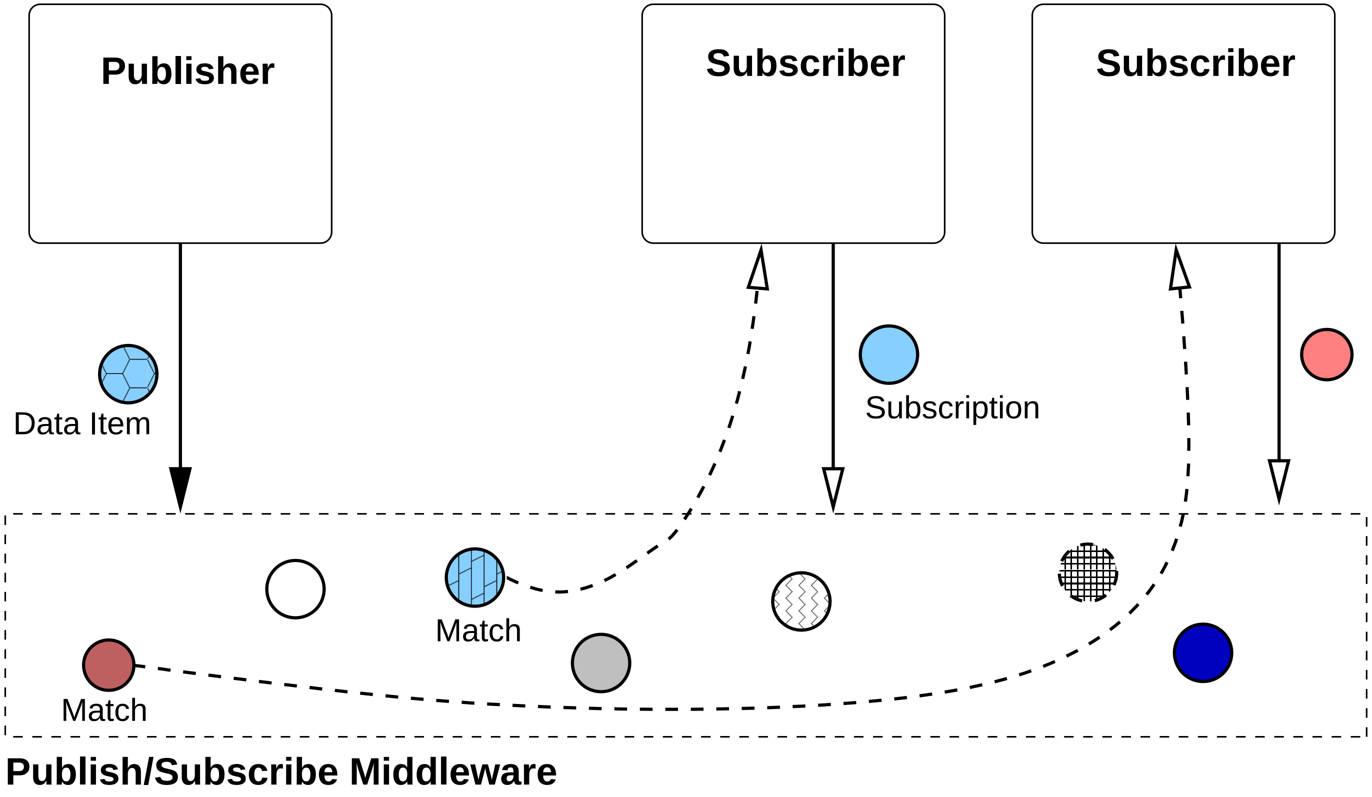


Coordination-based:

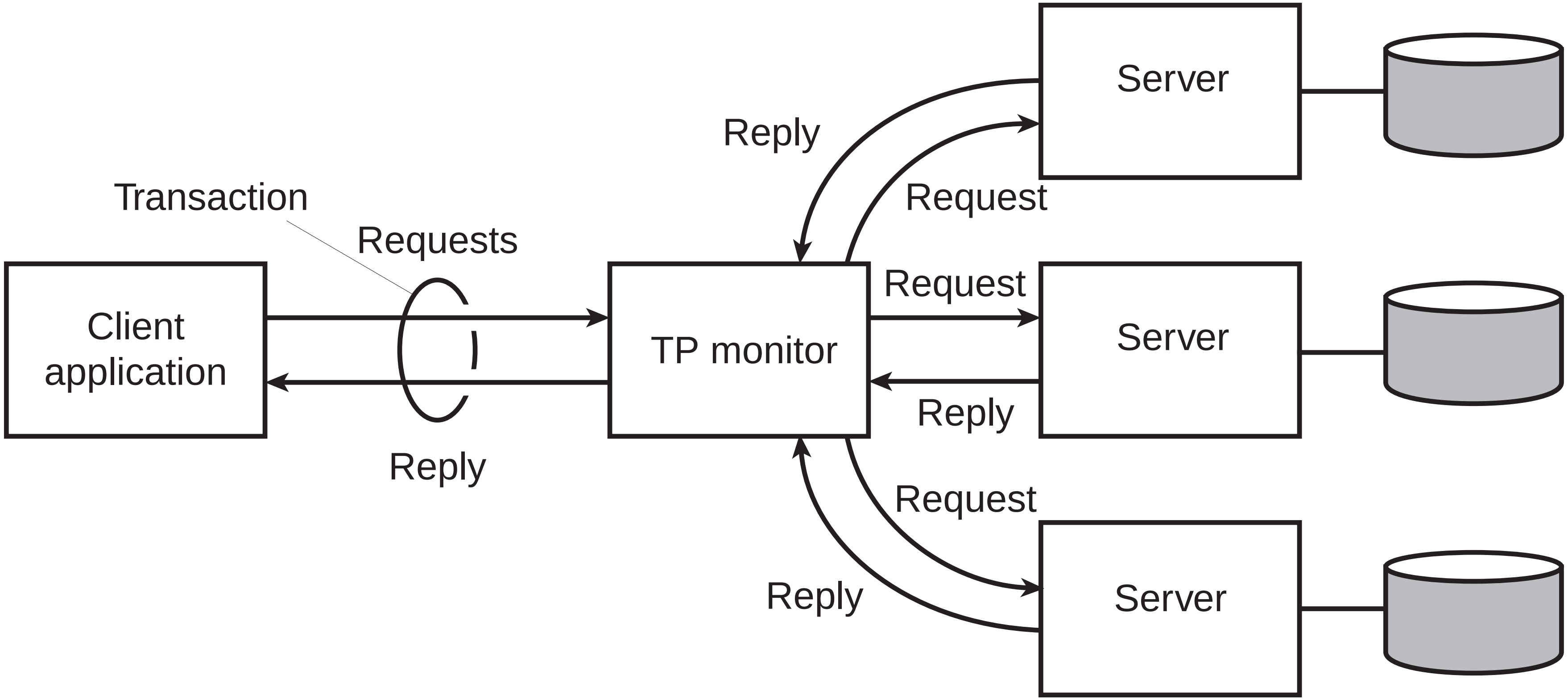
- ➜ Tuple space



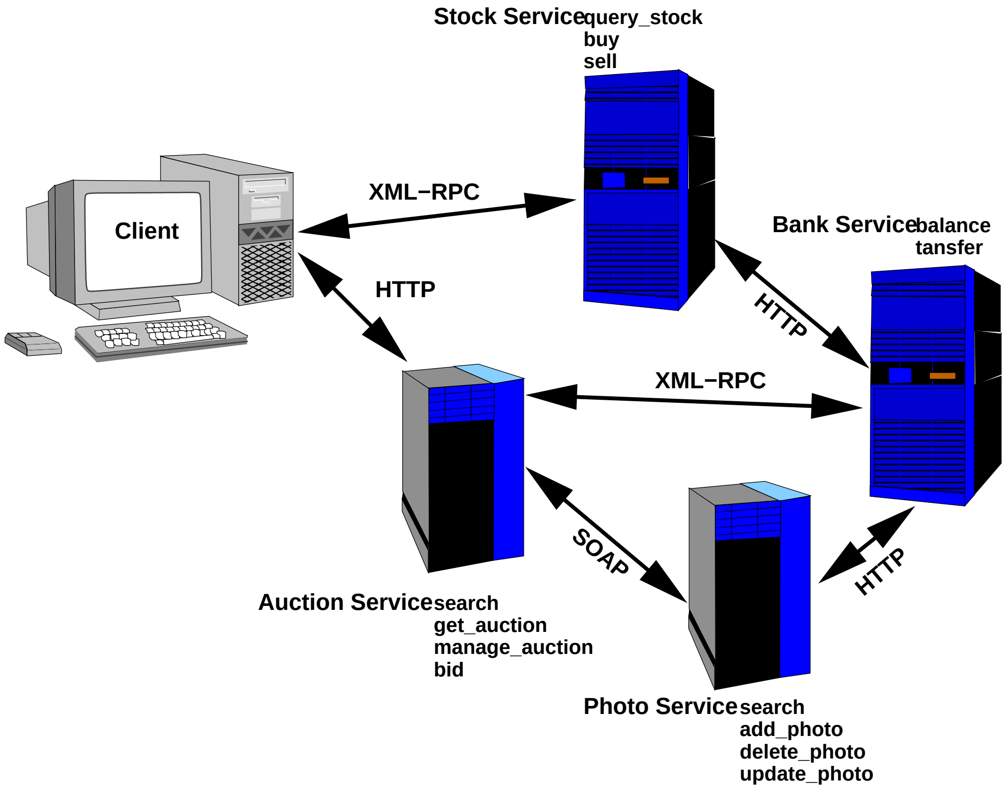
➜ Publish/Subscribe



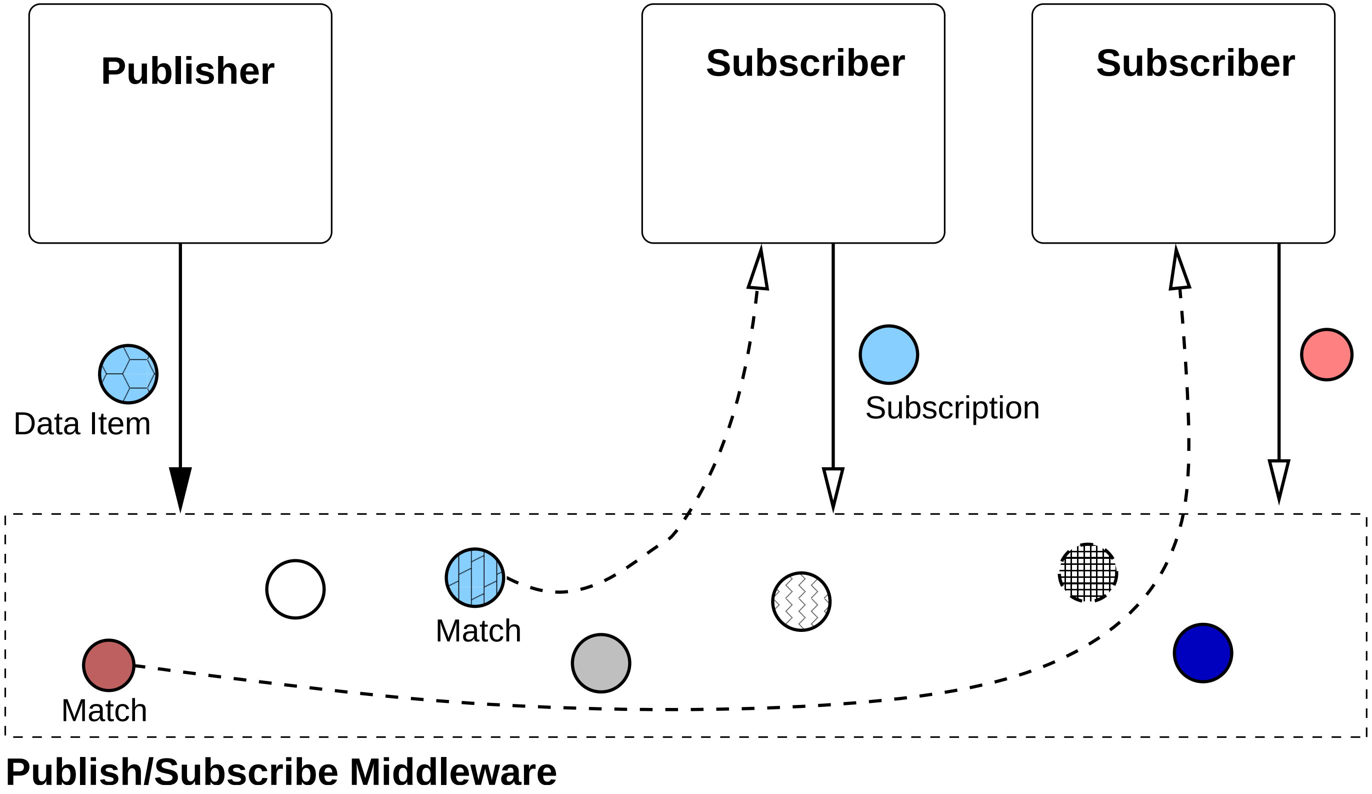
Transaction Processing Monitors:



Web Services:



Publish/Subscribe (Event-Based) Middleware



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

EXAMPLES

Real-time Control Systems:

- ➜ External events (e.g. sensors)
- ➜ Event monitors

Stock Market Monitoring:

- ➜ Stock updates
- ➜ Traders subscribed to updates

Network Monitoring:

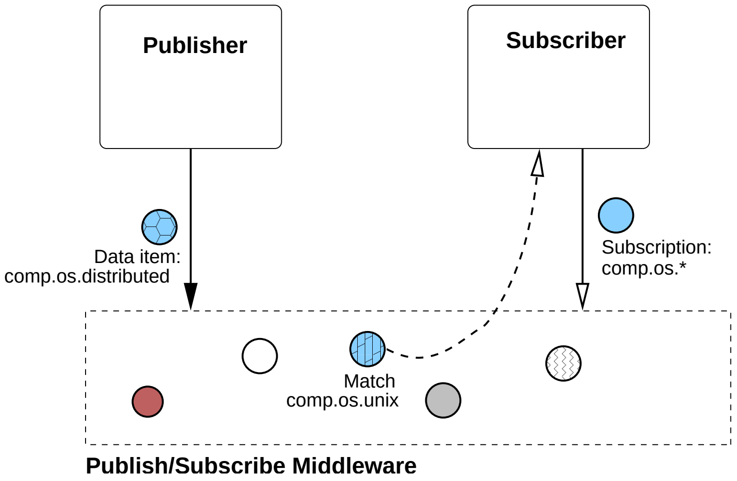
- ➜ Status logged by routers, servers
- ➜ Monitors screen for failures, intrusion attempts

Enterprise Application Integration:

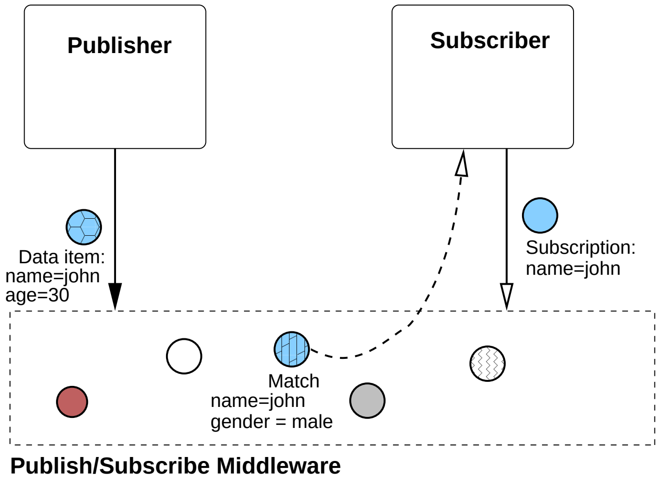
- ➜ Independent applications
- ➜ Produce output as events
- ➜ Consume events as input
- ➜ Decoupled

MESSAGE FILTERING

Topic-based

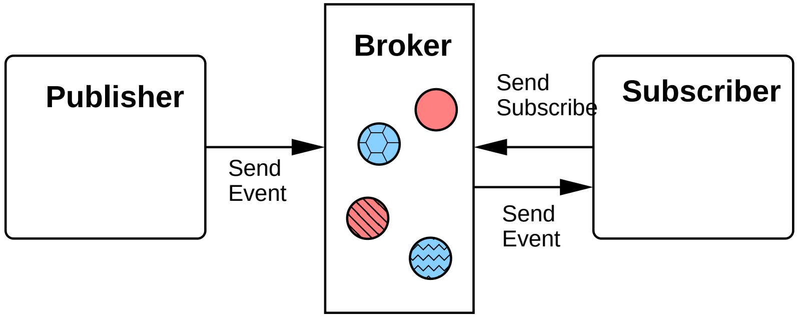


Content-based

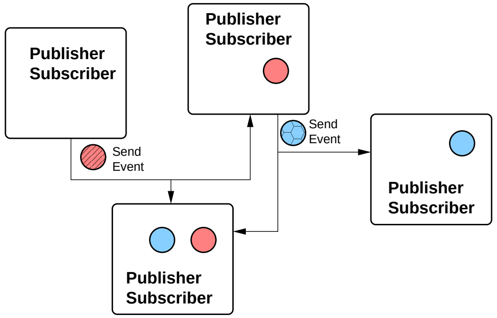


ARCHITECTURE

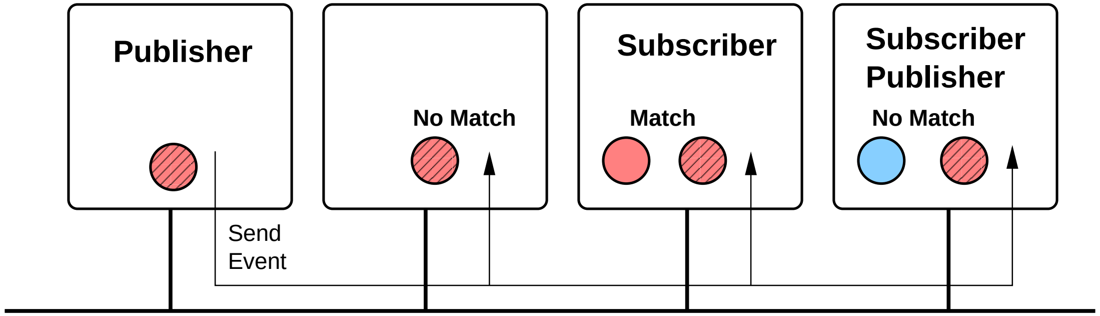
Centralised:



Peer-to-Peer:



Multicast-based:



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

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

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

EXAMPLE SYSTEMS

TIB/Rendezvous:

- ➜ Topic-based
- ➜ Multicast-based

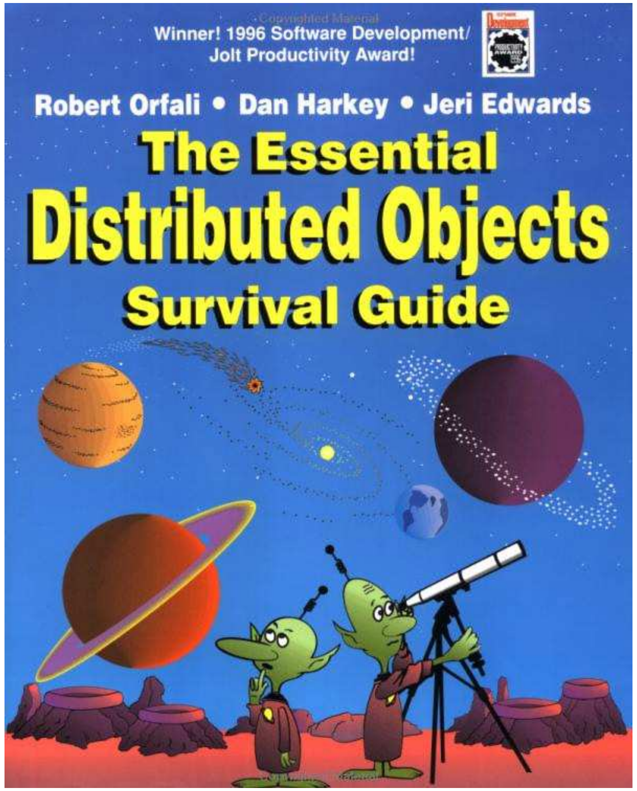
Java Message Service (JMS):

- ➜ 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

Distributed Objects



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

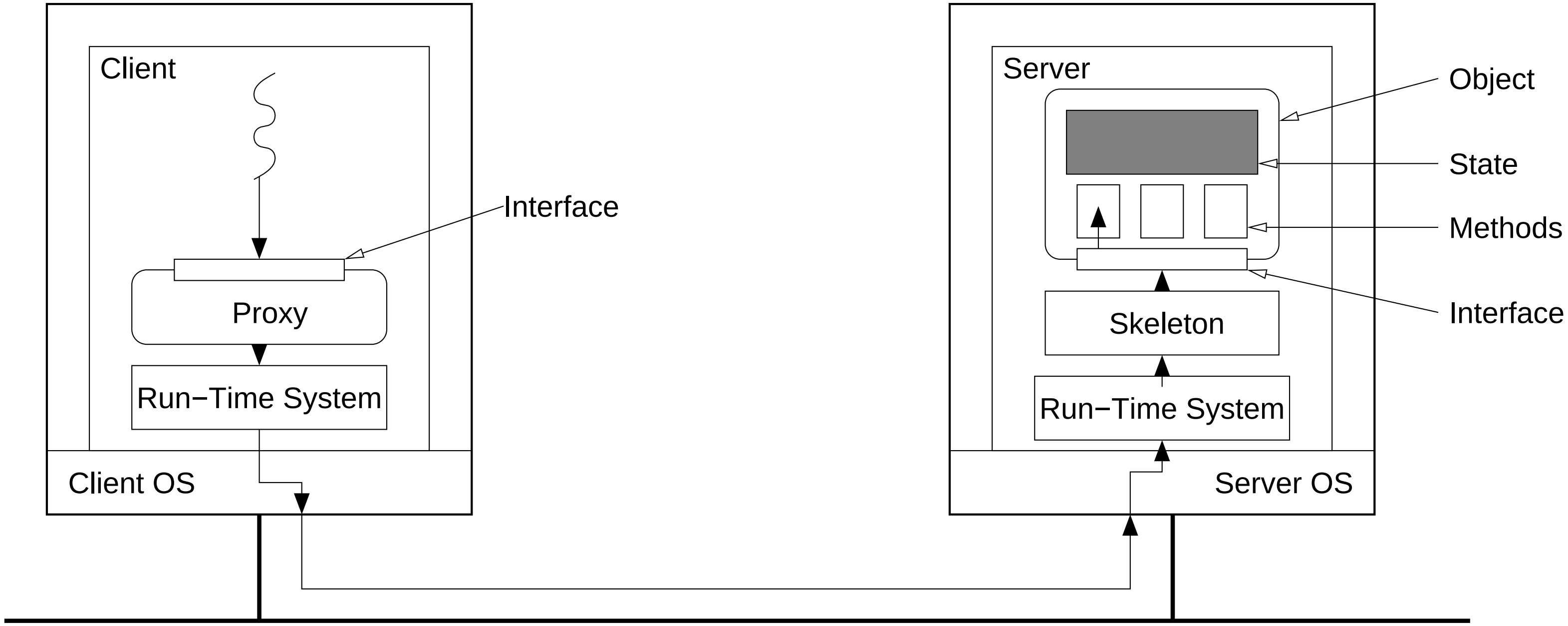
OBJECT MODEL

- ➜ 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

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

CLIENT

Client Process:

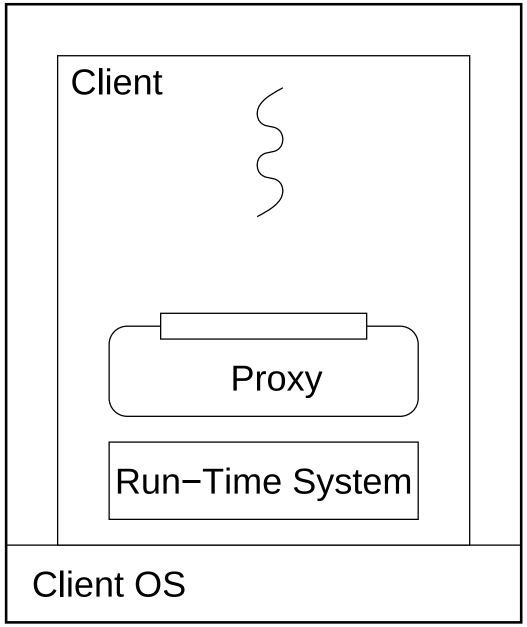
- ➜ Binds to distributed object
- ➜ Invokes methods on object

Proxy:

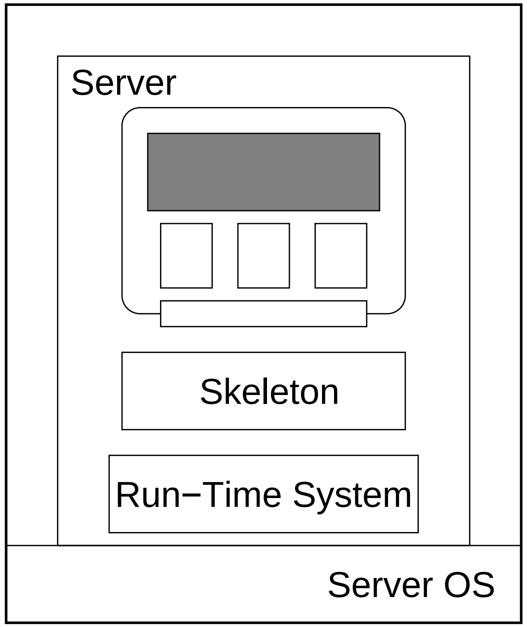
- ➜ Proxy: RPC stub + destination details
- ➜ Binding causes a proxy to be created
- ➜ Responsible for marshaling
- ➜ Static vs dynamic proxies
- ➜ Usually generated

Run-Time System:

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



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

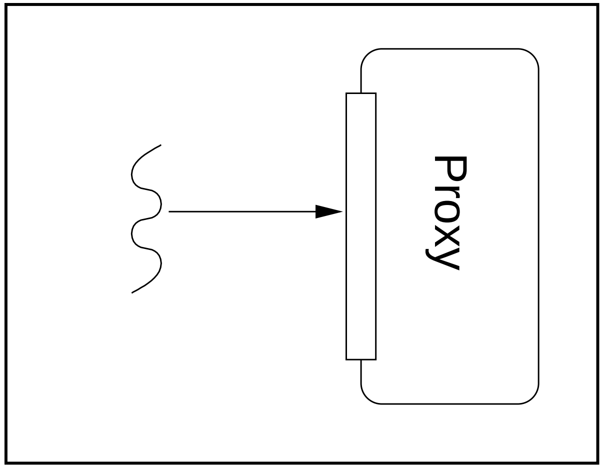
Object Server:

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

OBJECT REFERENCE

Local Reference:

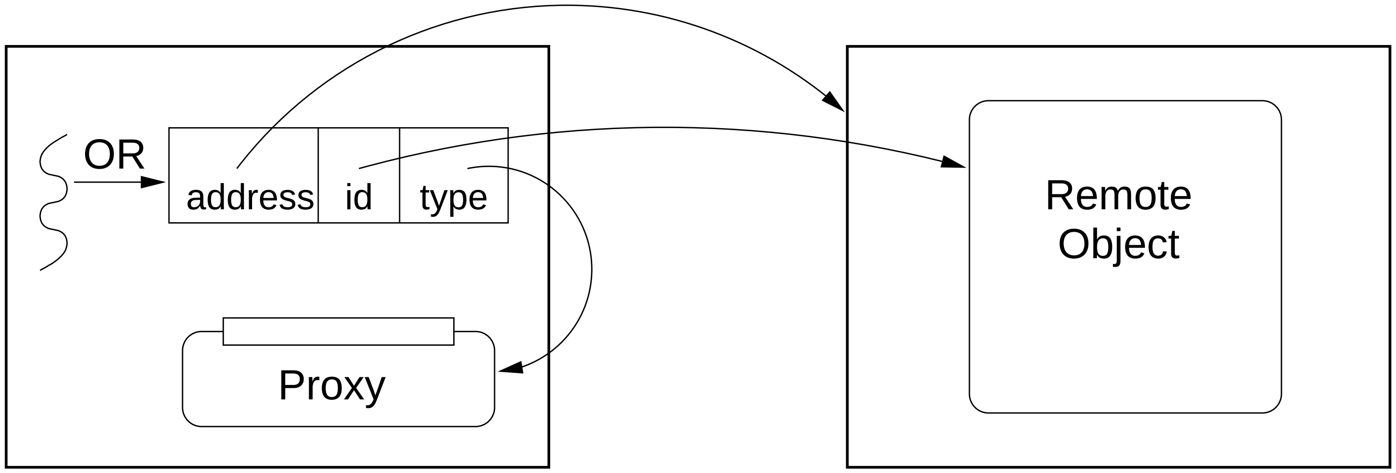
- ➜ Language reference to proxy



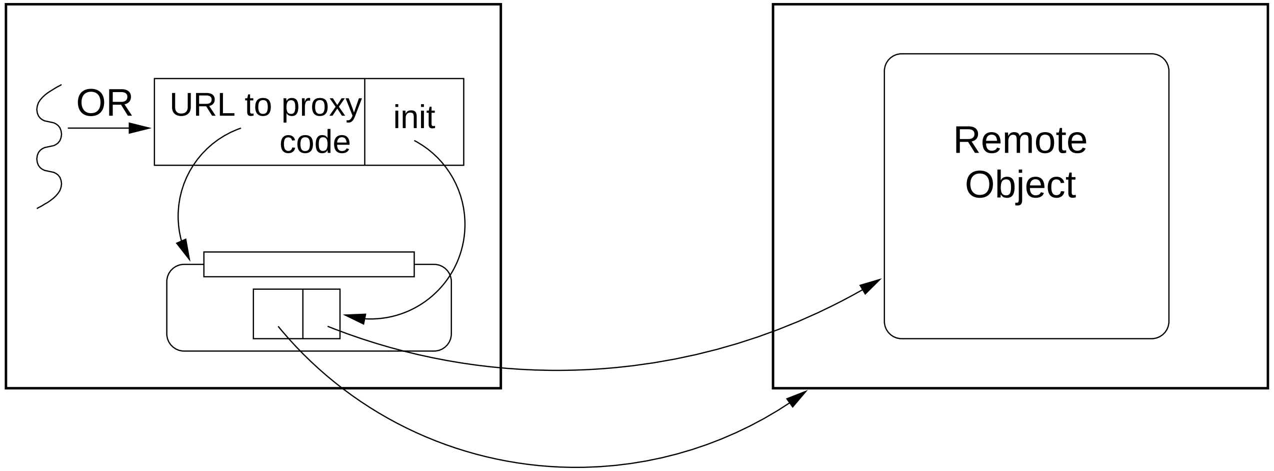
Object Reference

Remote Reference:

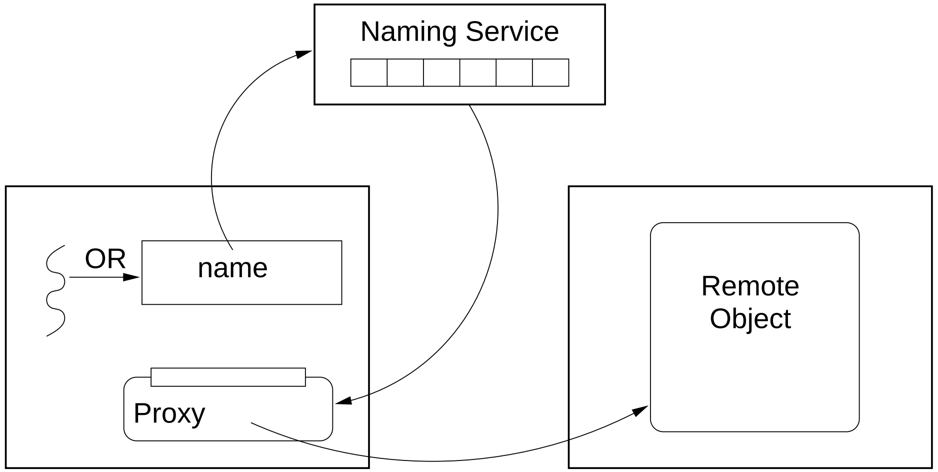
➜ Server address + object ID



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



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



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

REMOTE METHOD INVOCATION (RMI)

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:

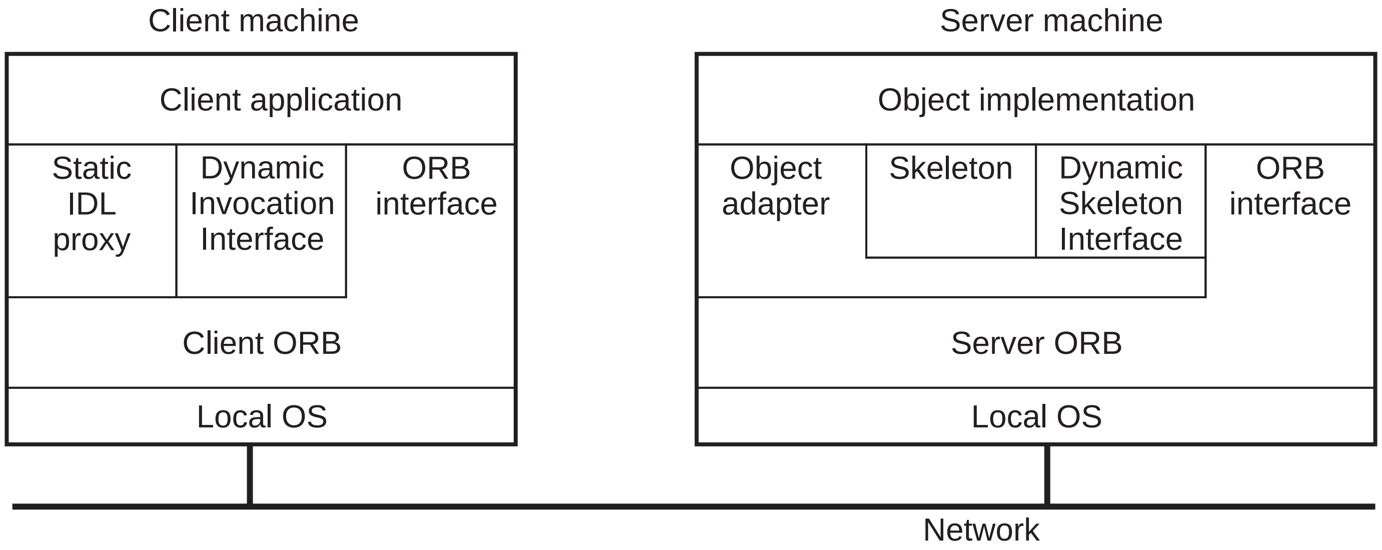
- ➜ Asynchronous invocations
- ➜ Persistent invocations
- ➜ Notifications and Callbacks

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.

CORBA ARCHITECTURE



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 ();
  };
};
```

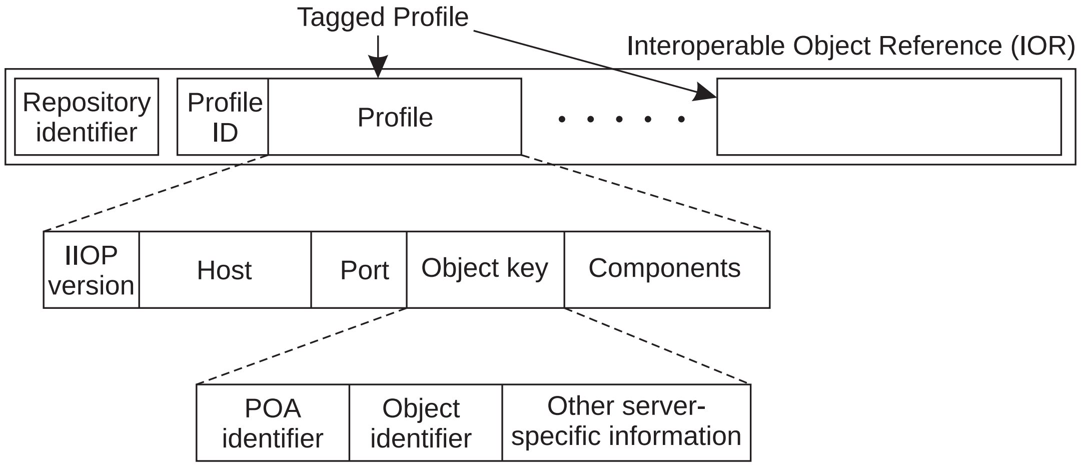
Object Reference (OR)

Object Reference (OR):

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

Interoperable Object Reference (IOR)

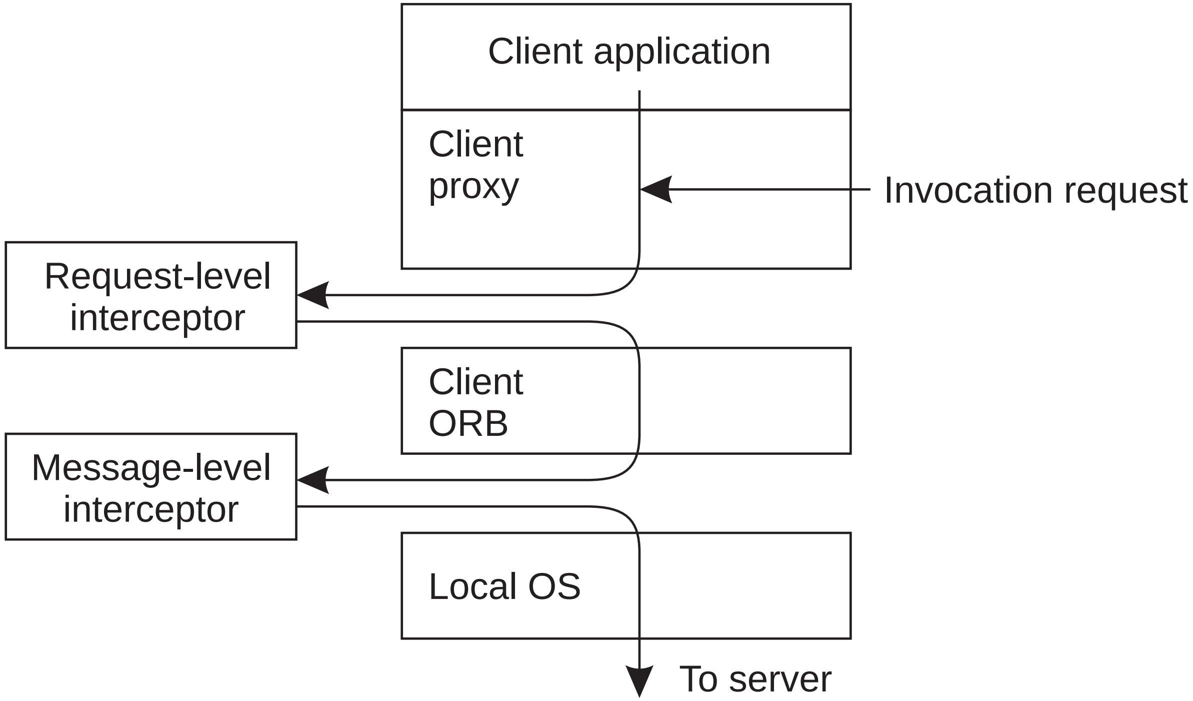
- ➜ Can be shared between different implementations



OBJECT REQUEST BROKER (ORB)

- ➜ 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

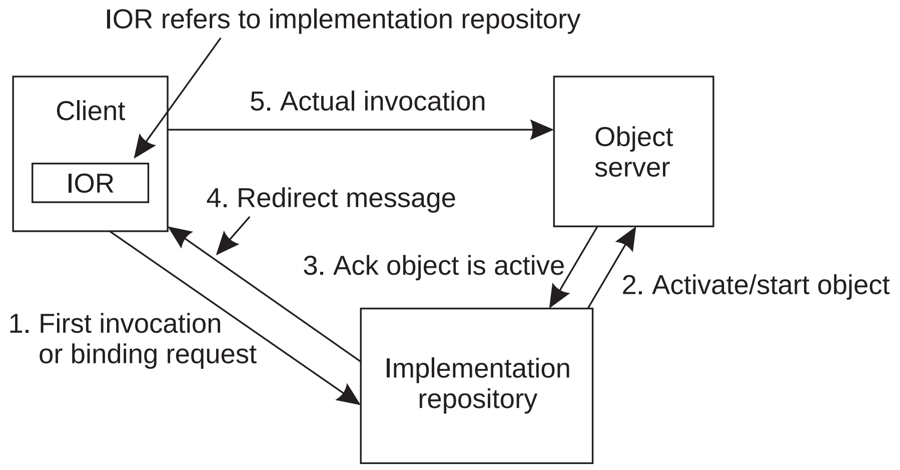


BINDING

Direct Binding:

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

Indirect Binding:



CORBA SERVICES

Some of the standardised services are the following:

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

CORBA Bibliography

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

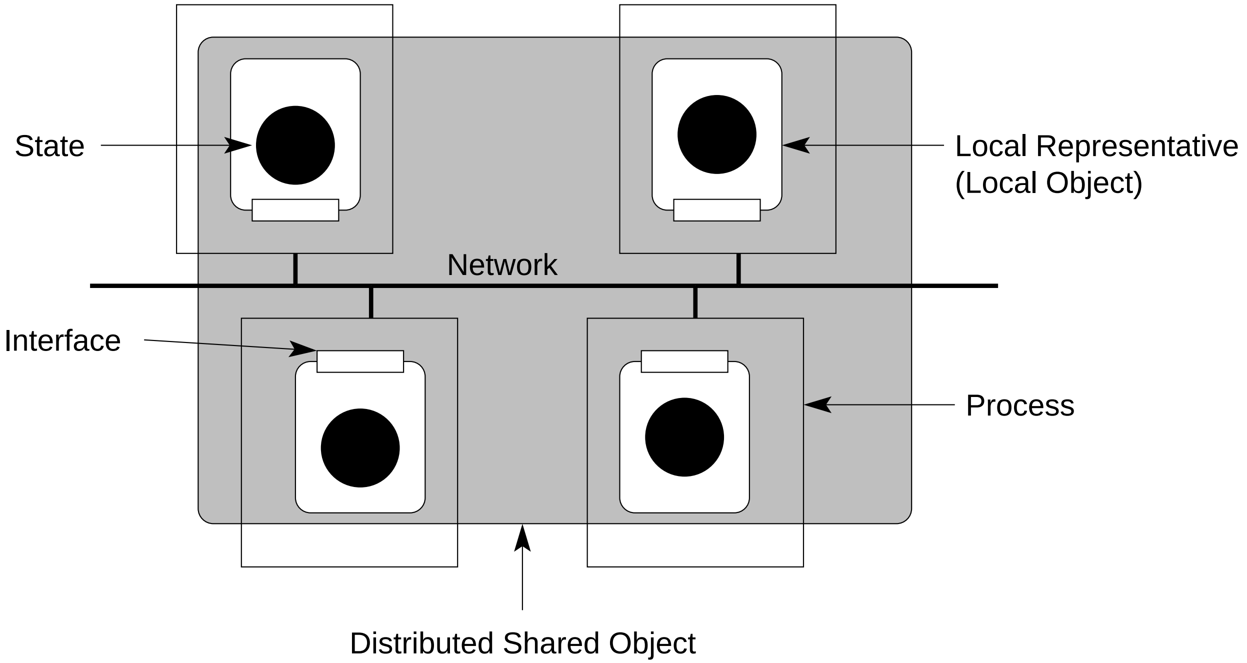
(2) *The Common Object Request Broker: Architecture and Specification (2.3.1)*, Object Management Group, 1999.

(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

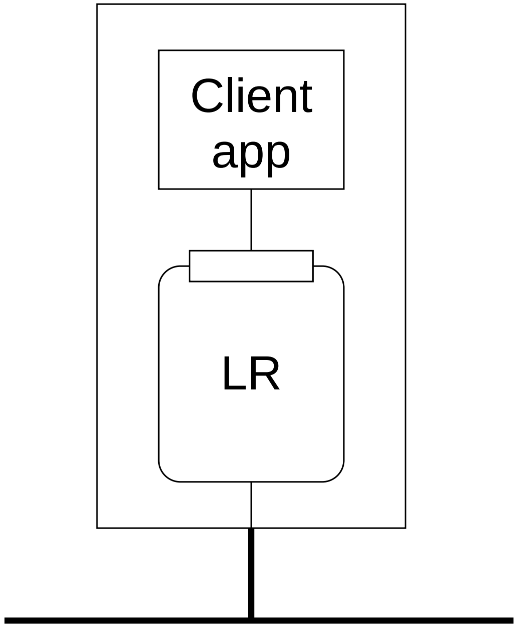


Distributed Shared Objects:

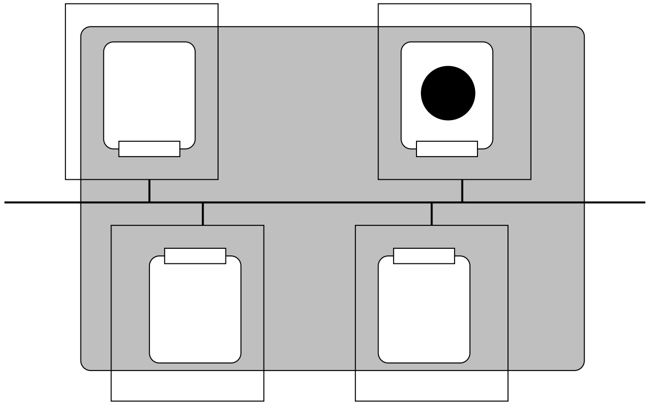
- ➜ Object state can be replicated (at multiple object servers)
- ➜ Object state can be partitioned
- ➜ Methods executed at some or all replicas
- ➜ Object location no longer clearly defined

CLIENT

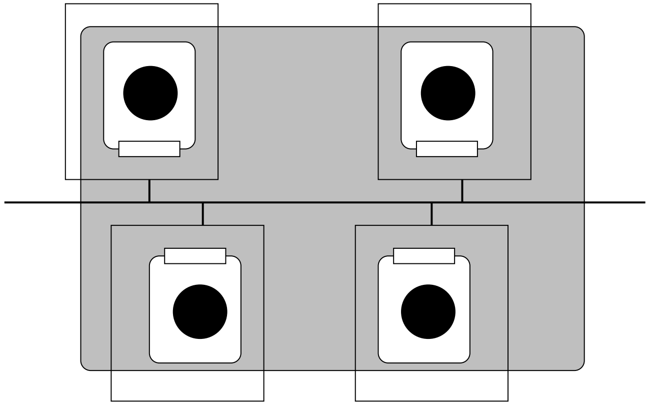
- ➜ Client has local representative (LR) in its address space
- ➜ Stateless LR
  - Equivalent to proxy
  - Methods executed remotely
- ➜ Statefull LR
  - Full state
  - Partial state
  - Methods (possibly) executed locally



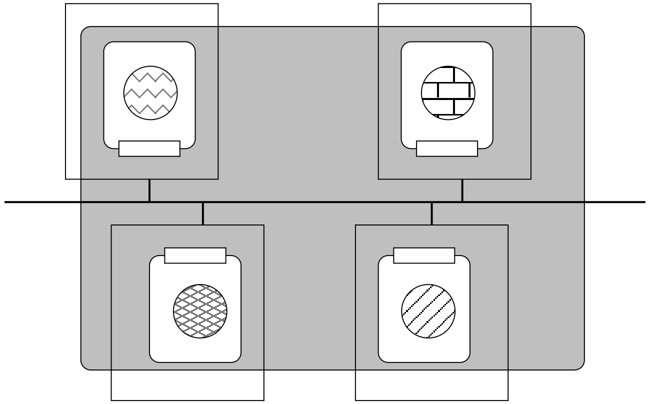
Object



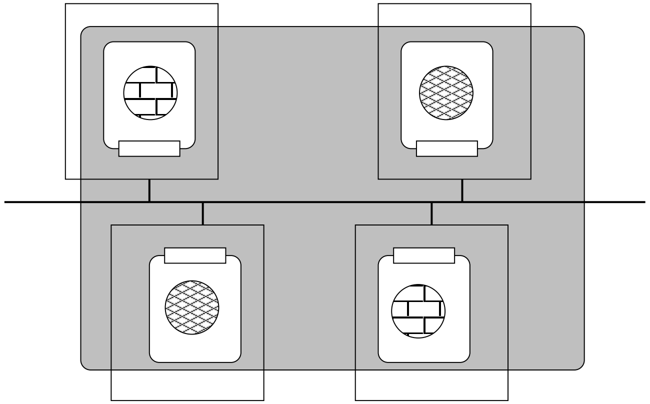
Remote Object



Replicated Object



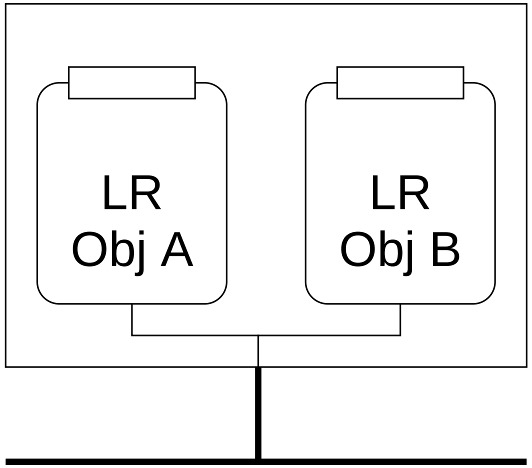
Partitioned Object



Replicated and Partitioned Object

OBJECT SERVER

- ➜ 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)

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

- ➜ 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

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