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Distributed Objects and Remote Invocation

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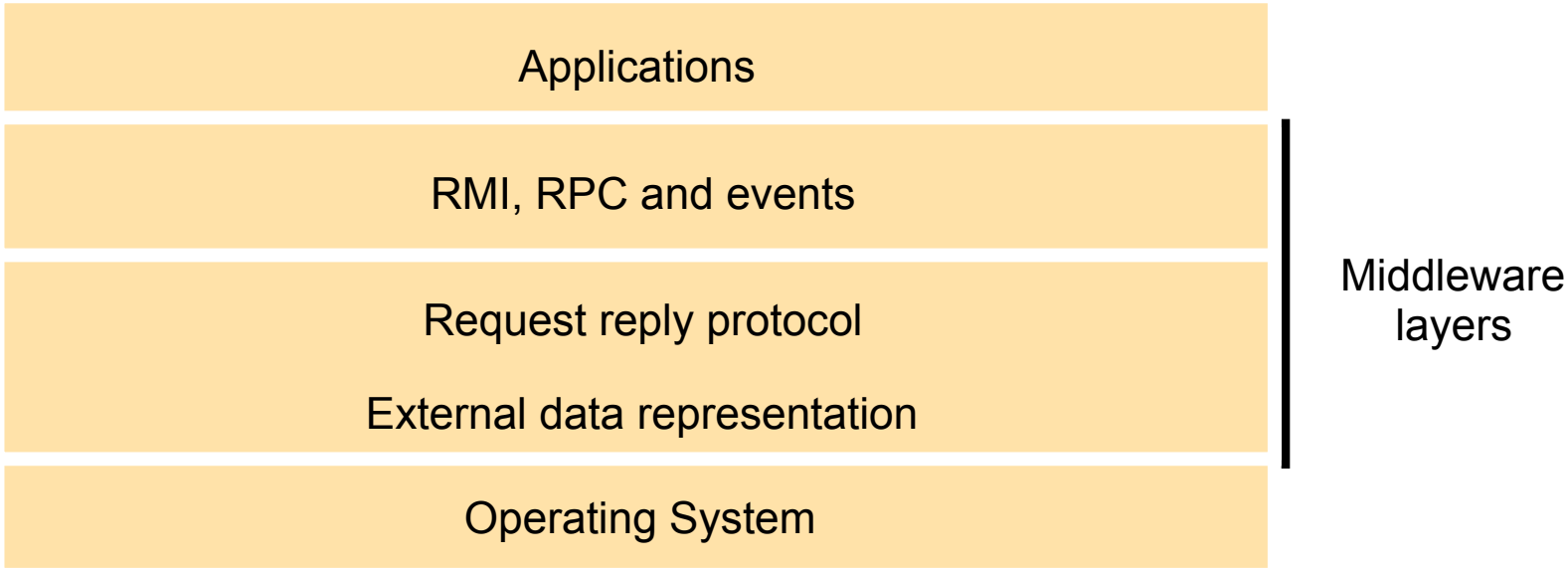
Middleware layer



1. Location transparency
2. Communication protocols
3. Computer hardware
4. Operating systems
5. Use of several programming languages

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Middleware layer

- *"Middleware is the slash in the term client/server"*
- *"Middleware is software that allows elements of applications to interoperate across network links, despite differences in underlying communication protocols, system architectures, OSes, databases, and other application services"*
- *"Middleware succeeds by providing five main services: hardware independence, interchangeability of key software components (e.g., DBMSs), network independence, operational savings, and administrative savings"*
- *"Middleware is software that no one wants to pay for"*

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The object model

1. Object references
2. Interfaces
3. Actions
4. Exceptions
5. Garbage collection

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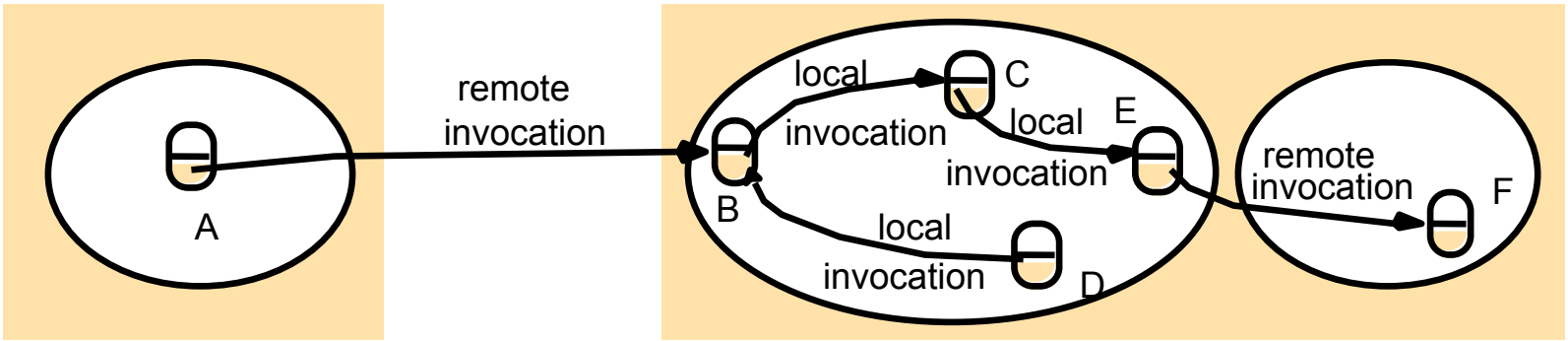
Distributed objects

- Local method invocation: within the same process
- Remote method invocation: different processes (different machines)



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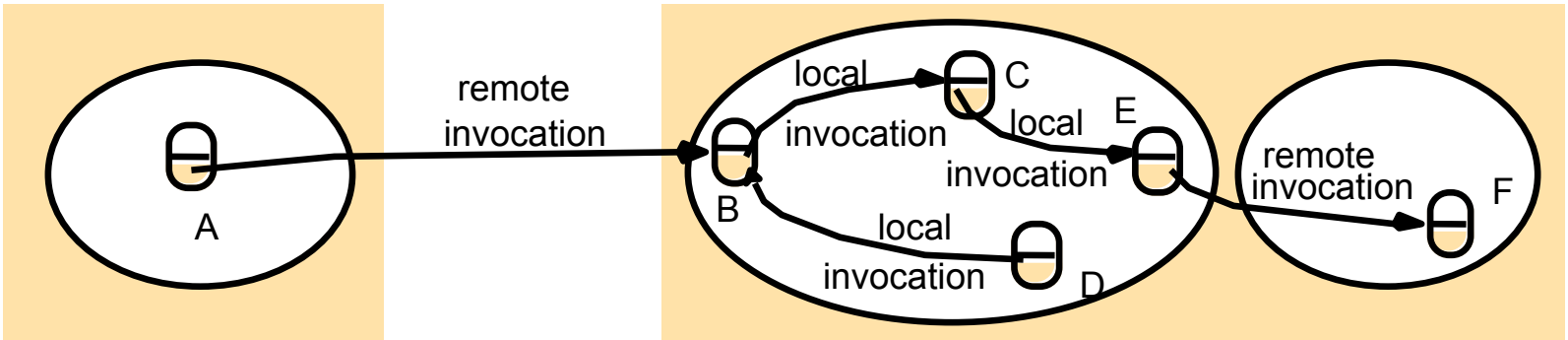
Distributed objects



- Remote object reference
- Remote interface

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Distributed object model

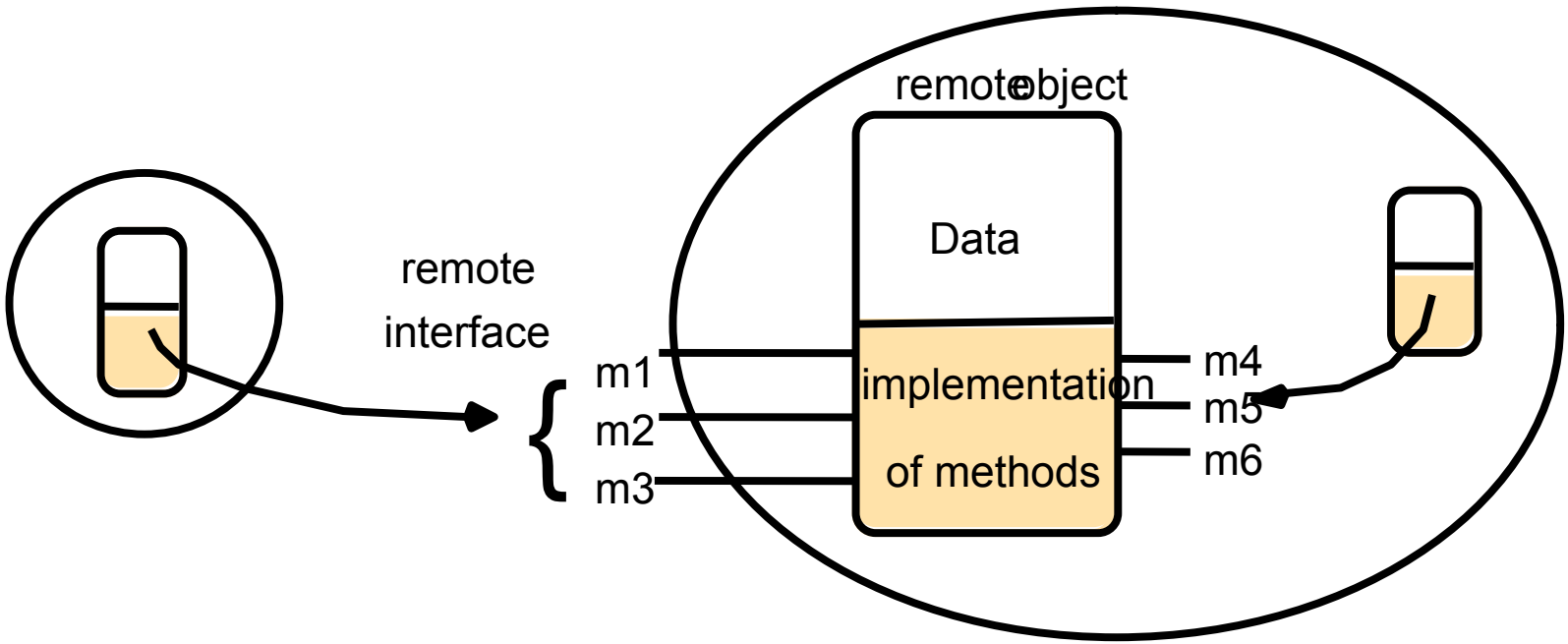
Remote Object reference

- other objects can invoke the methods of a remote object if they have access to its remote object reference
- it is an identifier throughout a distributed system
- can be passed as arguments and results of remote method invocations

Distributed object model

Remote interfaces

- every remote object has a remote interface that specifies which of its methods can be invoked remotely
- name, arguments, return type
- IDL



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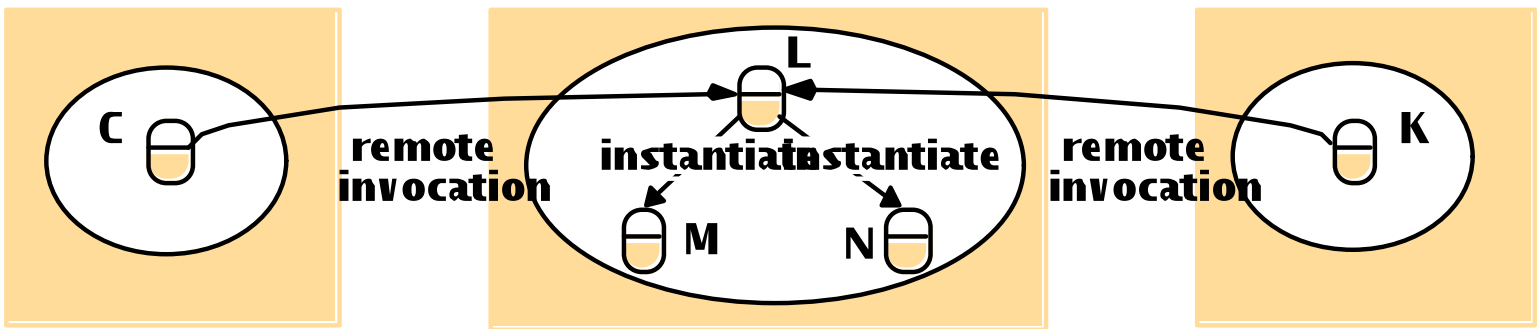
Java RMI: A remote object must implement an interface that extends `java.rmi.Remote`

Distributed object model

Actions

- Needs remote object reference
- Calling of methods of objects in another process/host
- Remote objects might have methods for instantiation (hence remote instantiation)



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Distributed object model

Garbage collection

- local garbage collector
- additional module to coordinate

Exceptions

- unexpected events or errors
- more and different exceptions from local methods

Java RMI: All methods of remote objects must throw
`java.rmi.RemoteException`

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RMI design issues

Error handling

- Retry request message
- Duplicate filtering
- Retransmission of results

Invocation semantics

- Maybe
- At-least-once
- At-most-once

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RMI: Invocation semantics

Fault tolerance measures			*Invocation semantics*
Retransmit request message	*Duplicate filtering*	*Re-execute procedure or retransmit reply*	
No	Not applicable	Not applicable	*Maybe*
Yes	No	Re-execute procedure	*At-least-once*
Yes	Yes	Retransmit reply	*At-most-once*

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RMI: Transparency

- Like a local call:
  - marshalling/unmarshalling
  - locating remote objects
  - access/syntax
- Latency
- Vulnerability to failures

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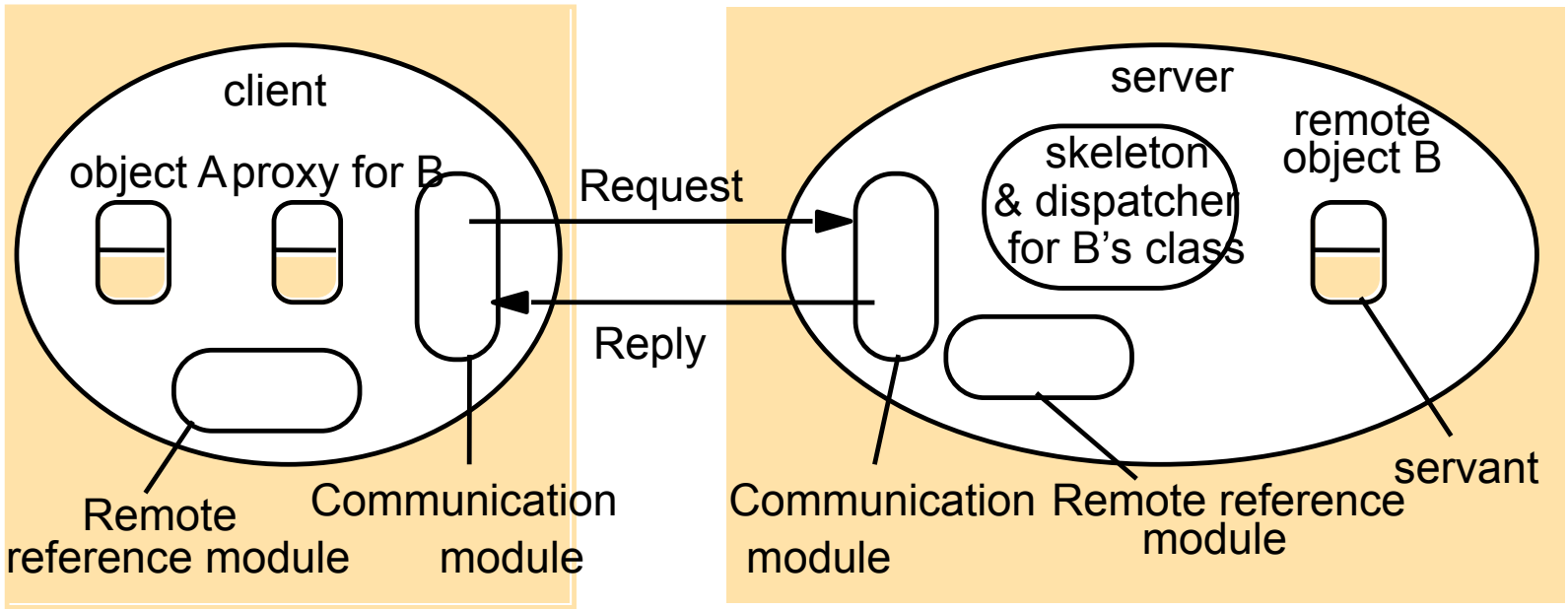
RMI Implementation



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RMI Implementation

Communication module

- request-reply
- Client side: message type, requestID, remote object reference
- implements specific invocation semantics
- Server side: selects the dispatcher, passes on local reference from remote reference module

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RMI Implementation

Remote reference module

- translate between local and remote object references
- create remote object references
- remote object table
  - remote objects held by the process (B on server)
  - local proxy (B on client)
- remote object (first time): add to the table, create proxy

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RMI Implementation

RMI software

- Proxy: behaves like a local object, but represents the remote object
- Dispatcher: look at the methodID and call the corresponding method in the skeleton
- Skeleton: implements the method

Generation of proxies, dispatchers and skeletons

- IDL (RMI) compiler
  Java RMI: `rmic`

Dynamic invocation

- Proxies are static - interface compiled into client code
- Dynamic - interface available during runtime
  -Dynamic downloading of classes (Java RMI)

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RMI Implementation

Server initialization

- Server creates the first object for remote access
- Usually clients are not allowed to create servers

Binder: locating service/object by name

- Table mapping for names and remote object references

Java RMI: `RMIregistry`

Server threads

- concurrency

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RMI Implementation

Activation of remote objects

- many server objects, all running?
- active and passive status
  - active: available for invocation in a running process
  - passive: not running, state is stored on disk
- Activation
  - create an active object from a passive object
  - register the new active object
- Java RMI: objects can be activatable

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RMI Implementation

Persistent object stores

- stored in marshalled from on disk for retrieval
- saved those that were modified
- persistent or not:
  - persistent root: any descendent objects (reachable from the root) are persistent
  -certain classes are declared persistent

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RMI Implementation

Object location

- ip address, port #, ...

- location service for migratable objects
  - map remote object references to their probable current locations
  - Cache/broadcast scheme
    - Cache locations
    - If not in cache, broadcast to find it
  - Improvement: forwarding

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RMI Implementation

Distributed garbage collection

- Reference count
- Java's approach
  - the server of an object (B) keeps track of proxies
  - addRef(B) is called when a proxy is created for a remote object
  - addRef(B) tells the server to add an entry
  - when the local host's garbage collector removes the proxy
  - removeRef(B) tells the server to remove the entry
  - when no entries for object B, the object on server is deallocated
- Race condition
  - removeRef(B) from client X
  - addRef(B) from client Y
- Communication failures
  - addRef() didn't return successfully
  - removeRef() will be issued
- Client process failures
  - leases from server
  - renew before expiration
  - entry removed if not renewed before expiration