# Last Class: RPCs

- RPCs make distributed computations look like local computations
- Issues:
  - Parameter passing
  - Binding
  - Failure handling



# Today:

- Lightweight RPCs
- Remote Method Invocation (RMI)
  - Design issues

# Lightweight RPCs

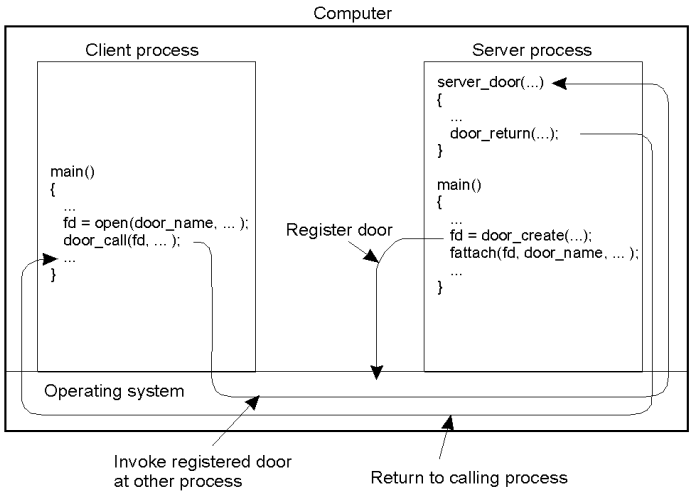
- Many RPCs occur between client and server on same machine
  - Need to optimize RPCs for this special case => use a lightweight RPC mechanism (LRPC)
- Server *S* exports interface to remote procedures
- Client *C* on same machine imports interface
- OS kernel creates data structures including an argument stack shared between *S* and *C*



# Lightweight RPCs

- RPC execution
  - Push arguments onto stack
  - Trap to kernel
  - Kernel changes mem map of client to server address space
  - Client thread executes procedure (OS upcall)
  - Thread traps to kernel upon completion
  - Kernel changes the address space back and returns control to client
- Called “doors” in Solaris

# Doors



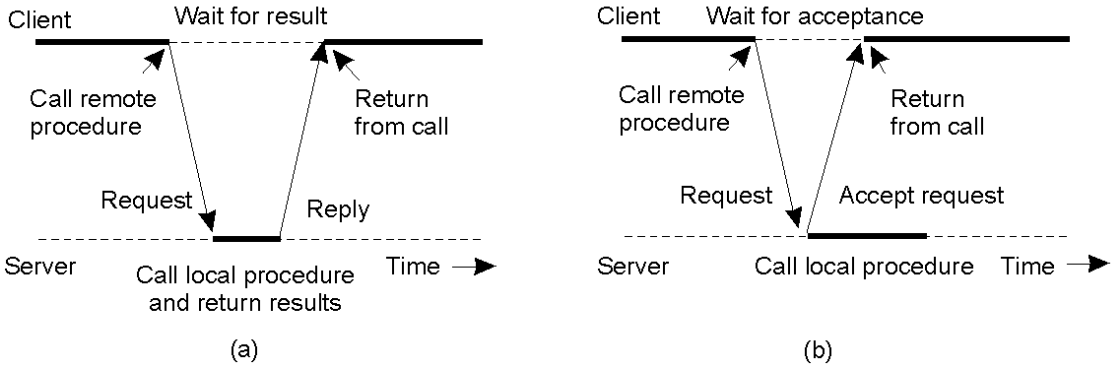

- Which RPC to use? - run-time bit allows stub to choose between LRPC and RPC



# Other RPC Models

- Asynchronous RPC
  - Request-reply behavior often not needed
  - Server can reply as soon as request is received and execute procedure later
- Deferred-synchronous RPC
  - Use two asynchronous RPCs
  - Client needs a reply but can't wait for it; server sends reply via another asynchronous RPC
- One-way RPC
  - Client does not even wait for an ACK from the server
  - Limitation: reliability not guaranteed (Client does not know if procedure was executed by the server).

# Asynchronous RPC



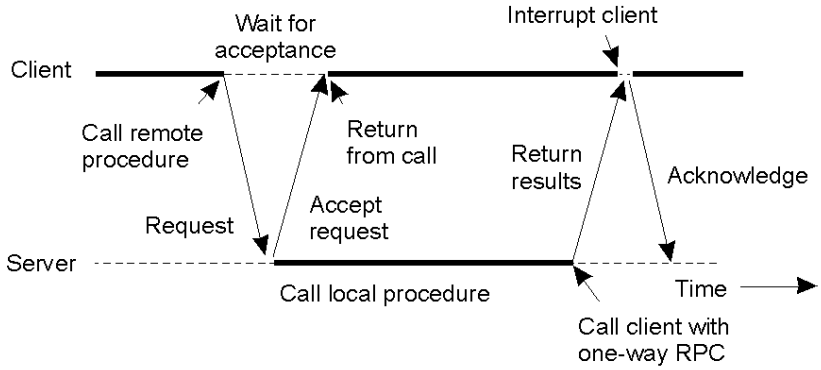

a) The interconnection between client and server in a traditional RPC

b) The interaction using asynchronous RPC



# Deferred Synchronous RPC

- A client and server interacting through two asynchronous RPCs

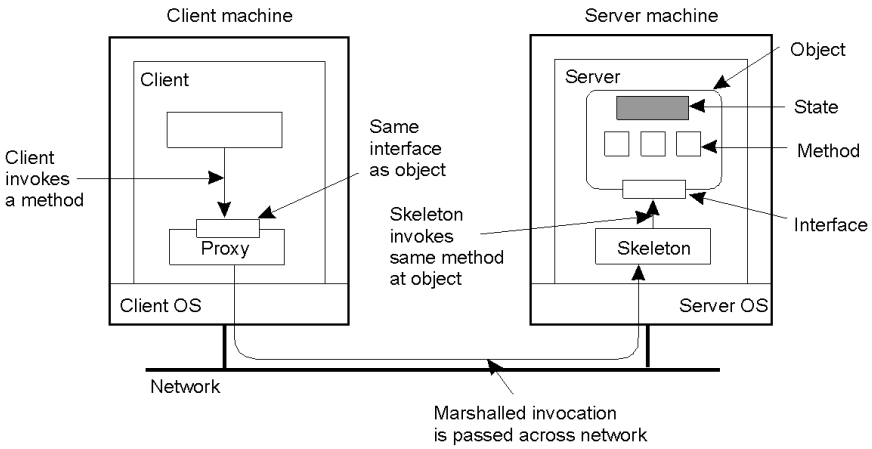


# Remote Method Invocation (RMI)

- RPCs applied to *objects,* i.e., instances of a class
  - *Class:* object-oriented abstraction; module with data and operations
  - Separation between interface and implementation
  - Interface resides on one machine, implementation on another
- RMIs support system-wide object references
  - Parameters can be object references



# Distributed Objects




- When a client binds to a distributed object, load the interface ("proxy") into client address space
  - Proxy analogous to stubs
- Server stub is referred to as a skeleton

# Proxies and Skeletons

- Proxy: client stub
  - Maintains server ID, endpoint, object ID
  - Sets up and tears down connection with the server
  - [Java:] does serialization of local object parameters
  - In practice, can be downloaded/constructed on the fly (why can't this be done for RPCs in general?)
- Skeleton: server stub
  - Does deserialization and passes parameters to server and sends result to proxy



# Binding a Client to an Object

```
Distr_object* obj_ref;                  //Declare a systemwide object reference
obj_ref = …;                            // Initialize the reference to a distributed object
obj_ref-> do_something();               // Implicitly bind and invoke a method
```

(a)

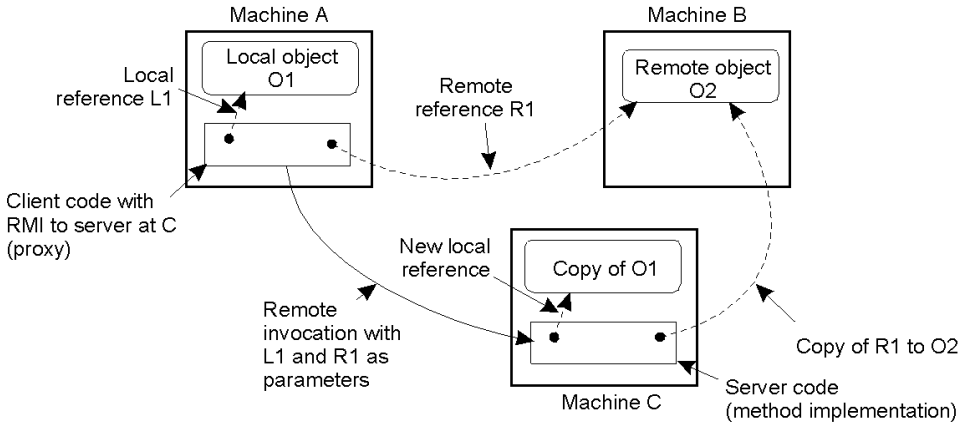
```
Distr_object objPref;                   //Declare a systemwide object reference
Local_object* obj_ptr;                  //Declare a pointer to local objects
obj_ref = …;                            //Initialize the reference to a distributed object
obj_ptr = bind(obj_ref);                //Explicitly bind and obtain a pointer to the local proxy
obj_ptr -> do_something();              //Invoke a method on the local proxy
```

(b)

a) (a) Example with implicit binding using only global references
b) (b) Example with explicit binding using global and local references

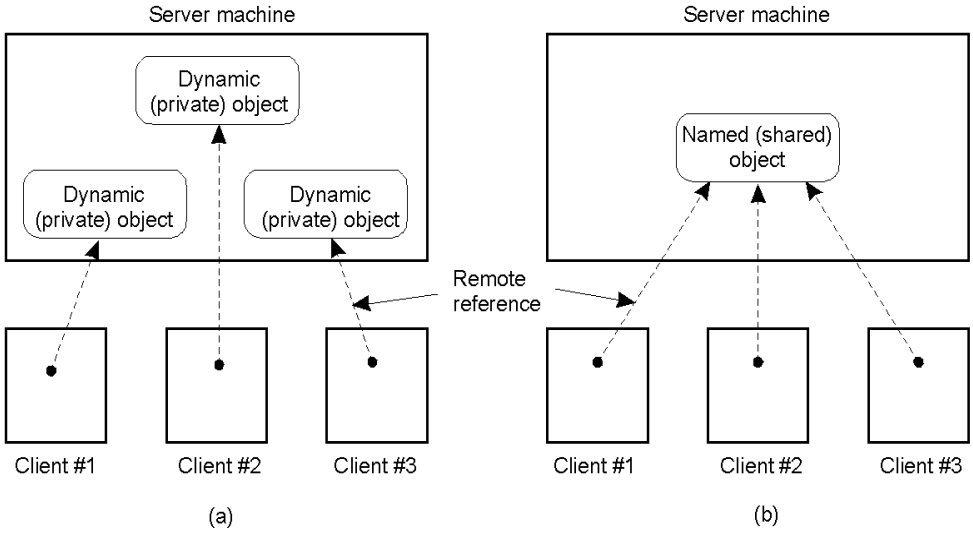
# Parameter Passing

- Less restrictive than RPCs.
  - Supports system-wide object references
  - [Java] pass local objects by value, pass remote objects by reference






# DCE Distributed-Object Model




a) Distributed dynamic objects in DCE.
b) Distributed named objects

# Java RMI

- Server
  - Defines interface and implements interface methods
  - Server program
    - Creates server object and registers object with "remote object" registry
- Client
  - Looks up server in remote object registry
  - Uses normal method call syntax for remote methods
- Java tools
  - Rmiregistry: server-side name server
  - Rmic: uses server interface to create client and server stubs

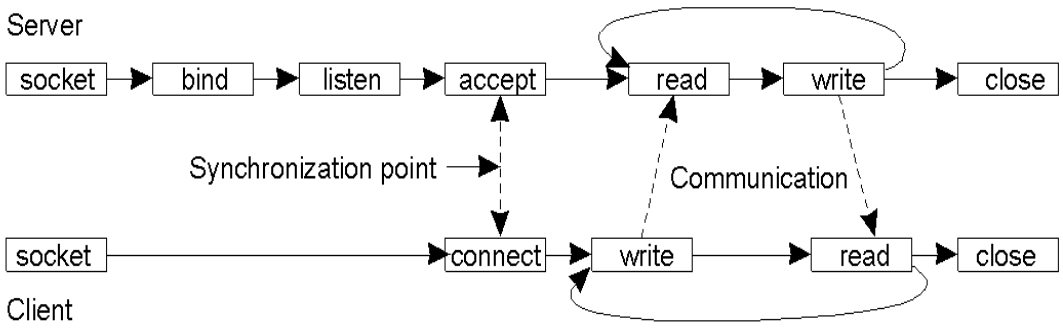


# Java RMI and Synchronization

- Java supports Monitors: synchronized objects
  - Serializes accesses to objects
  - How does this work for remote objects?
- Options: block at the client or the server
- Block at server
  - Can synchronize across multiple proxies
  - Problem: what if the client crashes while blocked?
- Block at proxy
  - Need to synchronize clients at different machines
  - Explicit distributed locking necessary
- Java uses proxies for blocking
  - No protection for simultaneous access from different clients
  - Applications need to implement distributed locking

# Message-oriented Transient Communication

- Many distributed systems built on top of simple message-oriented model
  - Example: Berkeley sockets






# Berkeley Socket Primitives

| Primitive | Meaning |
|---|---|
| Socket | Create a new communication endpoint |
| Bind | Attach a local address to a socket |
| Listen | Announce willingness to accept connections |
| Accept | Block caller until a connection request arrives |
| Connect | Actively attempt to establish a connection |
| Send | Send some data over the connection |
| Receive | Receive some data over the connection |
| Close | Release the connection |

# Message-Passing Interface (MPI)

- Sockets designed for network communication (e.g., TCP/IP)
  - Support simple send/receive primitives
- Abstraction not suitable for other protocols in clusters of workstations or massively parallel systems
  - Need an interface with more advanced primitives
- Large number of incompatible proprietary libraries and protocols
  - Need for a standard interface
- Message-passing interface (MPI)
  - Hardware independent
  - Designed for parallel applications (uses ***transient communication***)
- Key idea: communication between groups of processes
  - Each endpoint is a *(groupID, processID)* pair



# MPI Primitives

| Primitive | Meaning |
|---|---|
| MPI_bsend | Append outgoing message to a local send buffer |
| MPI_send | Send a message and wait until copied to local or remote buffer |
| MPI_ssend | Send a message and wait until receipt starts |
| MPI_sendrecv | Send a message and wait for reply |
| MPI_isend | Pass reference to outgoing message, and continue |
| MPI_issend | Pass reference to outgoing message, and wait until receipt starts |
| MPI_recv | Receive a message; block if there are none |
| MPI_irecv | Check if there is an incoming message, but do not block |