COMMUNICATION

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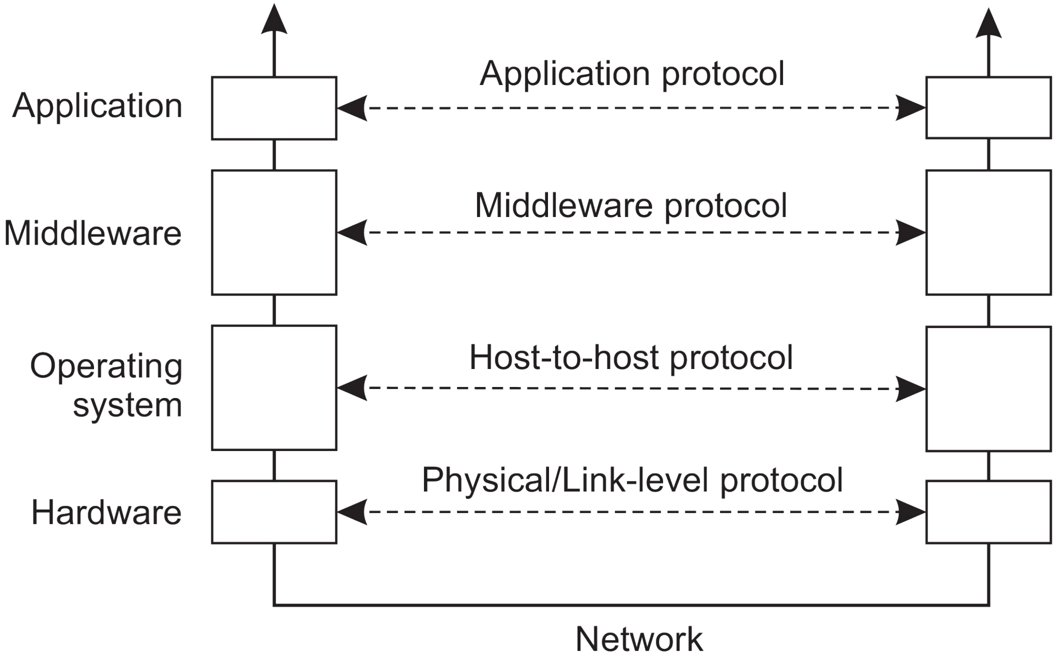
- Interprocess communication is at the heart of distributed computing.
- In distributed systems communication is achieved using messages (shared memory not an option).
- Low-level communication facilities of computer networks do not offer **distribution transparency**.
- Therefore higher level middleware solutions are typically used.



An adapted reference model for networked communication.

Connection-oriented and connectionless communication

Connection-oriented communication:

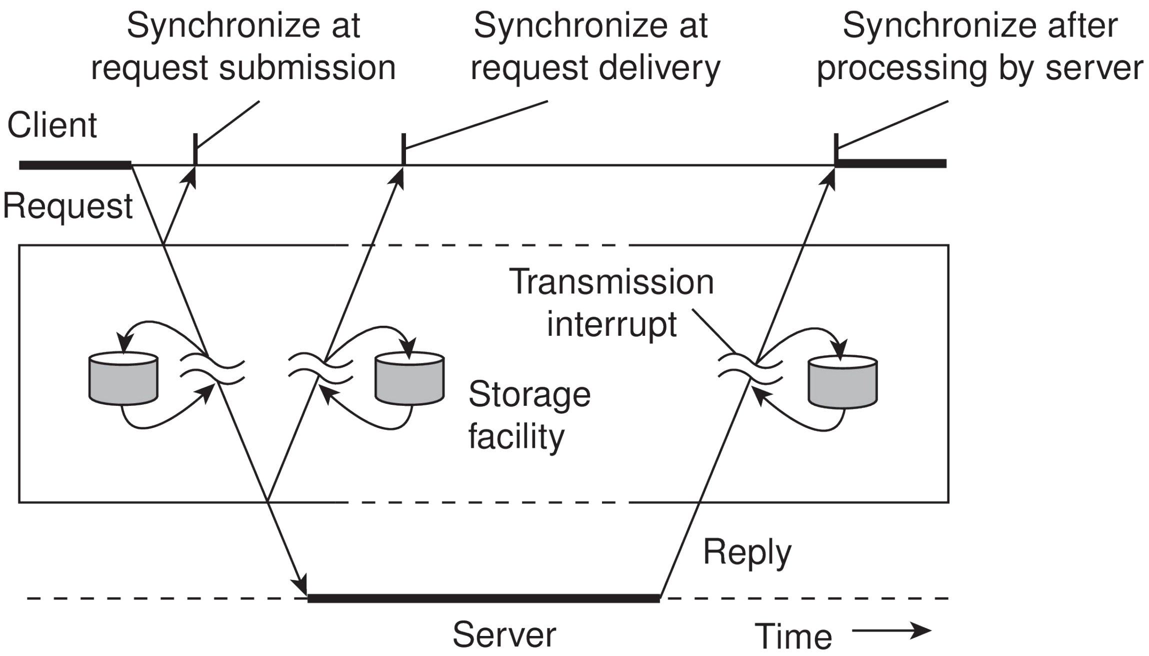
- Before exchanging data the sender and receiver first explicitly establish a connection.
- When they are done, they release (terminate) the connection.
- The telephone is a connection-oriented communication service.

Connectionless communication:

- No setup in advance is needed.
- The sender just transmits the first message when it is ready.
- Dropping a letter in a mailbox is an example of a connectionless communication service.

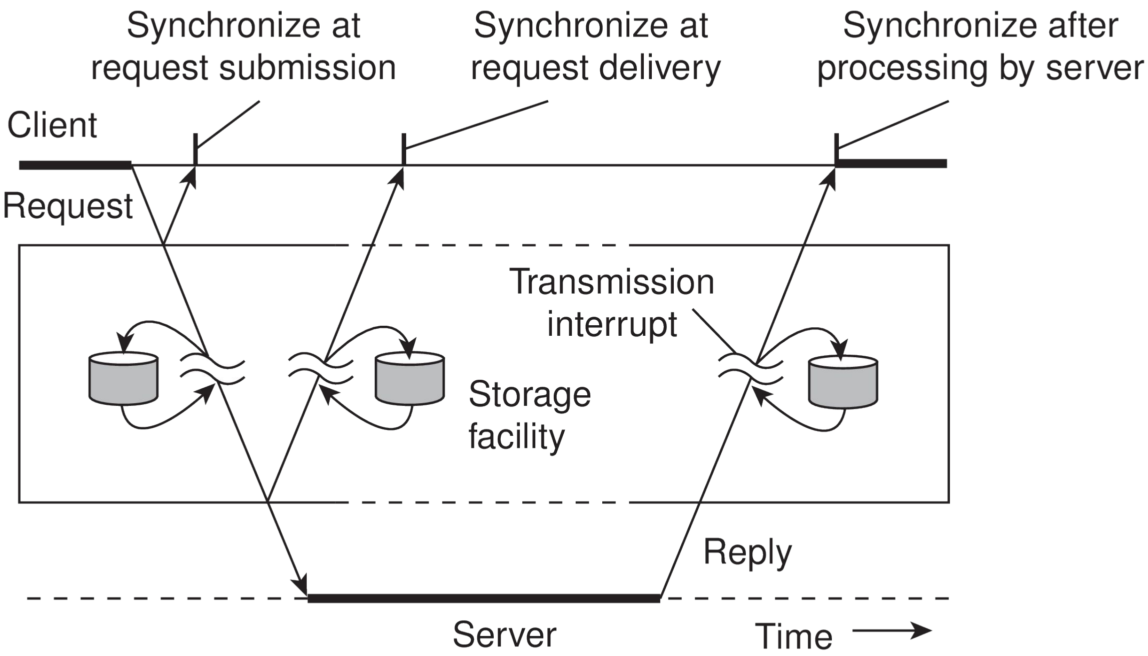
Persistent and transient communication

- **Persistent communication** - message submitted for transmission is stored by communication system as long as it takes to deliver it to the receiver.
- **Transient communication** - message stored by communication system only as long as the sender and receiver executing.


Synchronize at request submission
Synchronize at request delivery
Synchronize after processing by server
Client
Request
Transmission interrupt
Storage facility
Reply
Server
Time

Asynchronous and synchronous communication

- **Asynchronous communication** - sender continues immediately after it has submitted its message for transmission.
- **Synchronous communication** - sender is blocked until its request is known to be accepted.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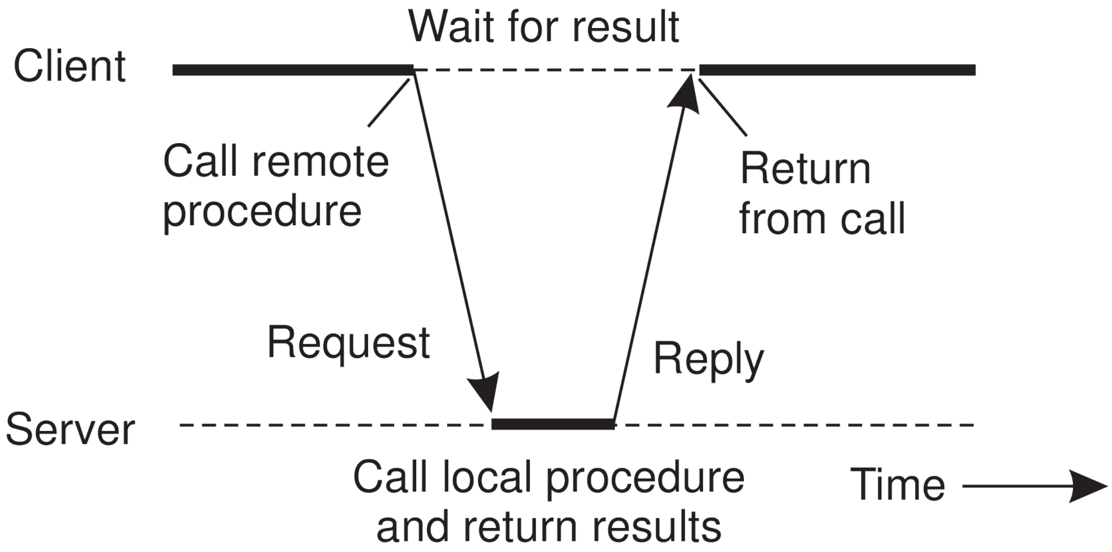
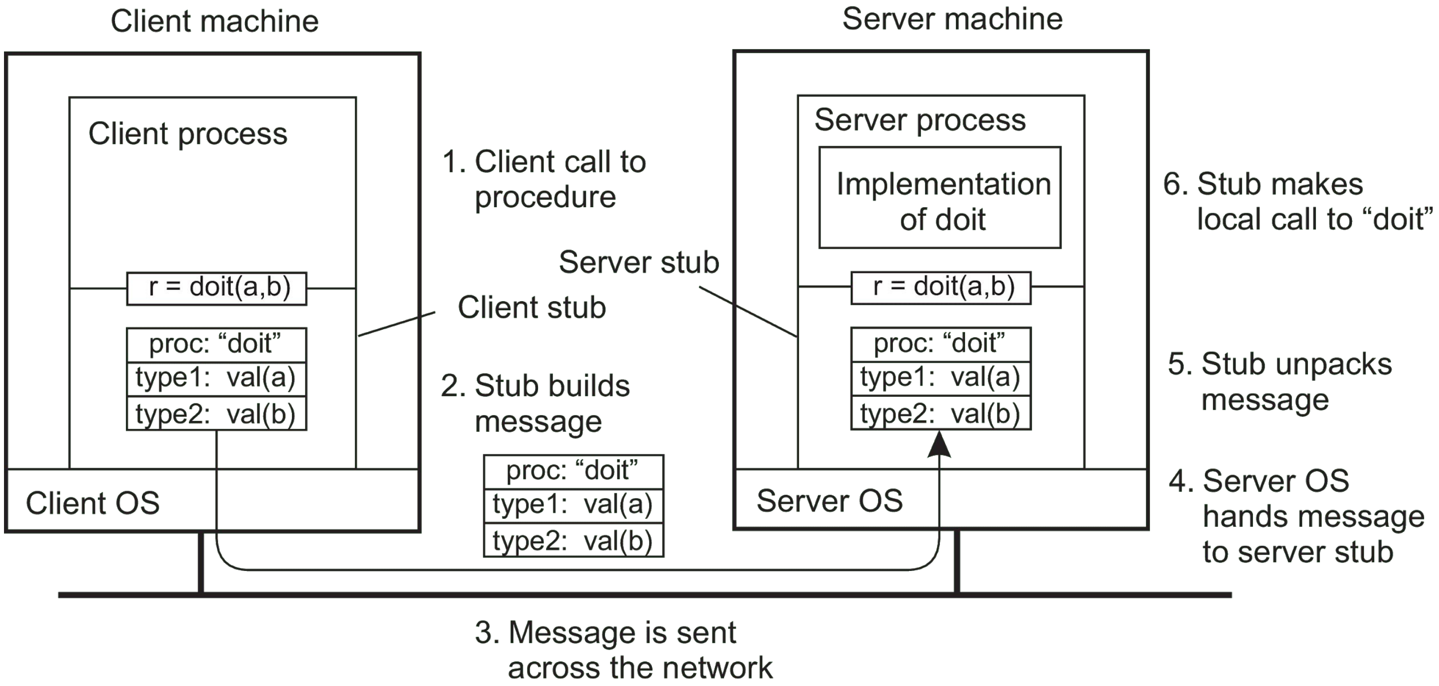
Remote Procedure Call (RPC)

- **Locally** call a procedure (aka a function) that is implemented on a **remote** machine.
- Parameters and results are transported but no message passing is visible to the programmer.
- Achieves **access** and **location** transparency.



The principle of RPC between a client and server program.

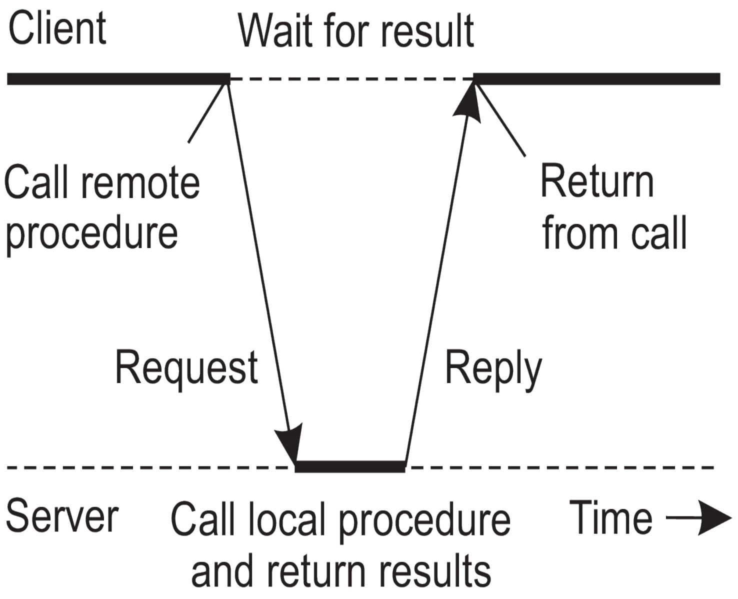
- Client calls directed to a **client stub** which provides the local procedure call interface to the remote function.
- A **server stub** transforms calls coming in over the network into local calls.



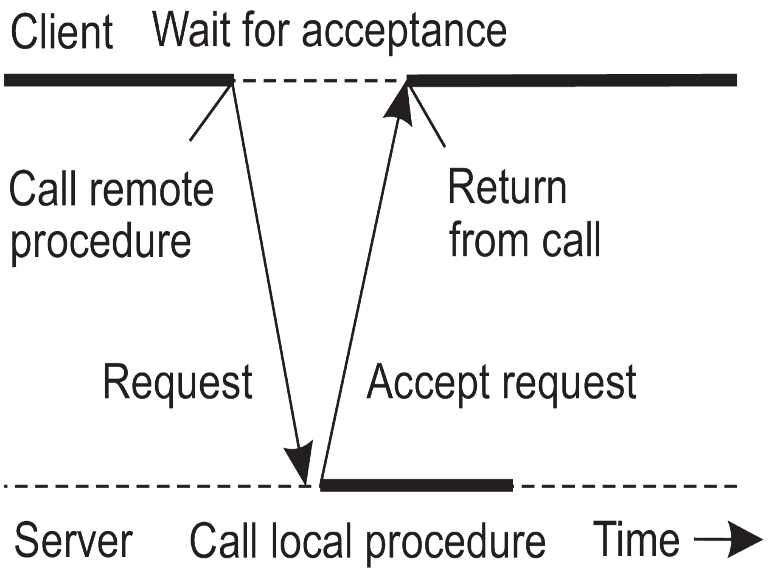
The steps involved in calling a remote procedure doit(a,b). The return path for the result is not shown

- RPC challenges include:
  - Handling different data representations (e.g. little endian vs. big endian).
  - Handling pointers or references which refer to local memory.

Asynchronous RPC

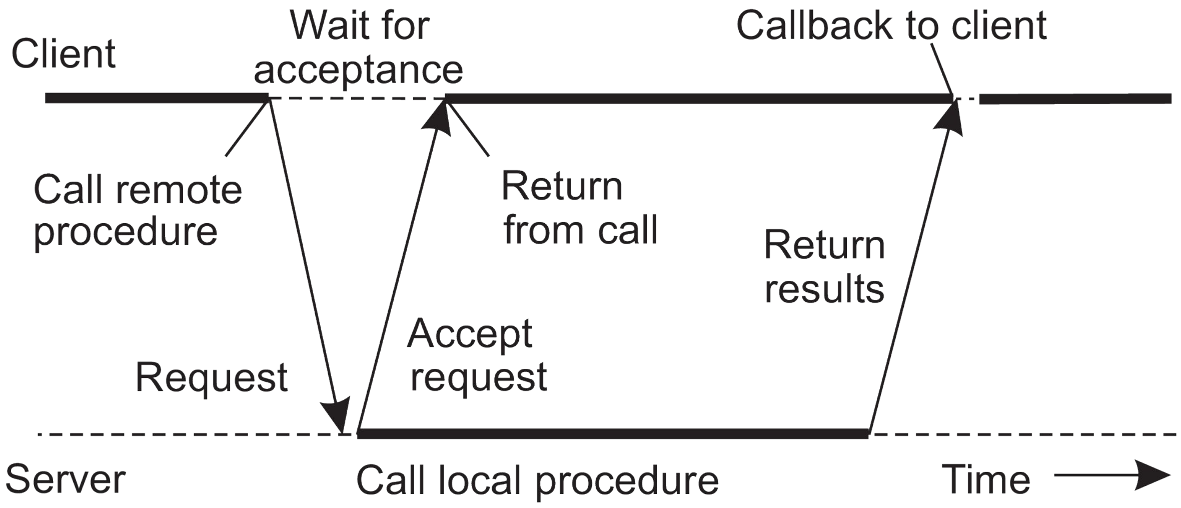


The interaction between client and server in a traditional RPC.



The interaction using asynchronous RPC.

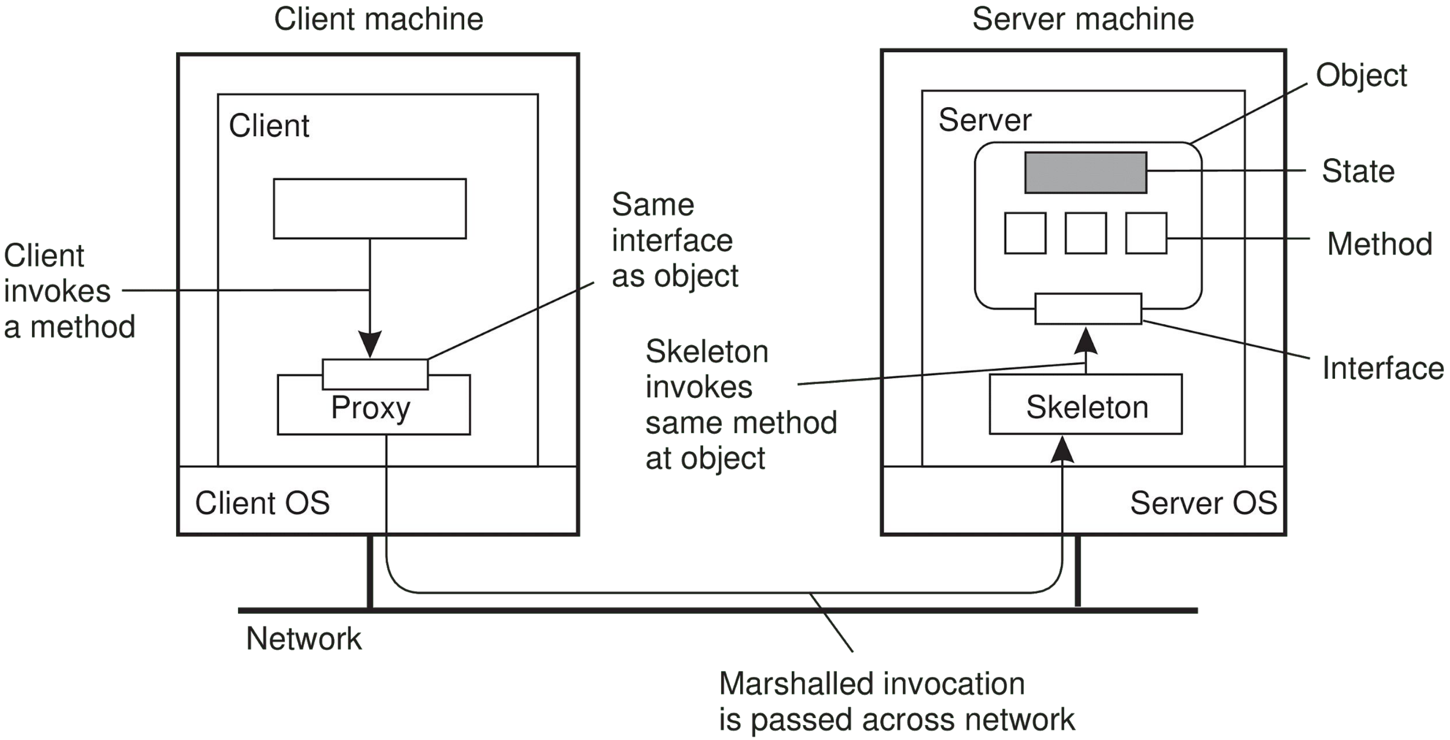
Asynchronous RPC combined with a callback



A client and server interacting through asynchronous RPCs.

Remote Method Invocation (RMI)

- RMI is the object-oriented equivalent of (RPC).



Common organisation of a remote object with client-side proxy.

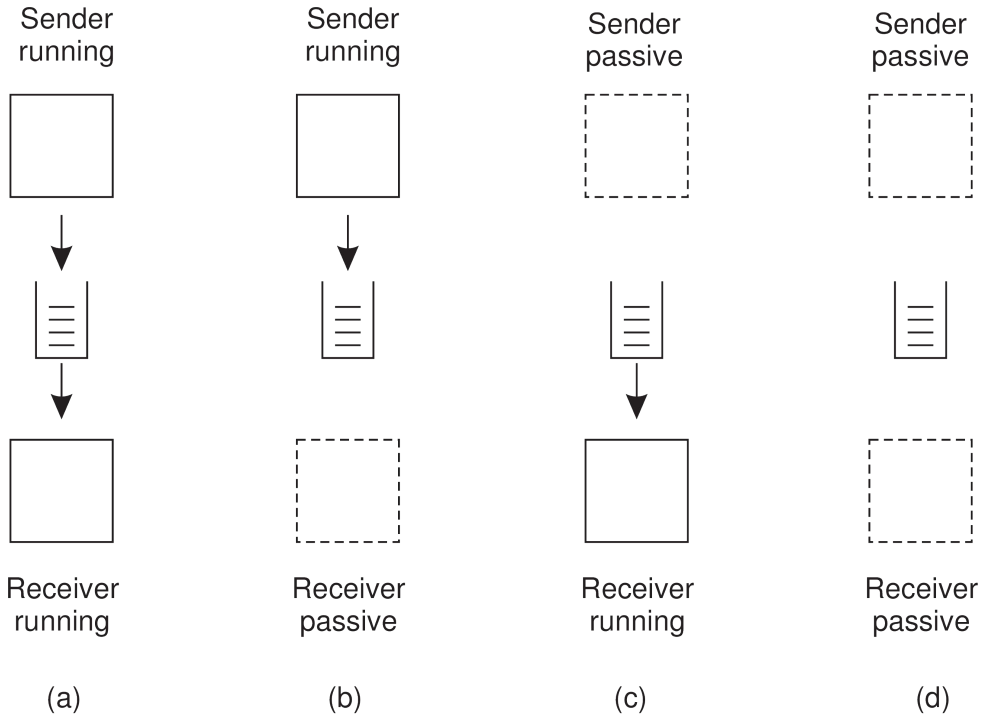
- The object resides on the server’s machine and is known as a *remote object*.
- An object for which the instance of the data associated with it is distributed across machines is known as a *distributed object* (e.g. a distributed database).

Message Oriented Middleware (MOM)

- RPC and RMI require client and server to be running at time of communication (transient communication).
- RPC and RMI block the client until its request has been processed (synchronous communication).

- **Message Oriented Middleware** offers intermediate storage for messages, without requiring sender or receiver to be active during transmission.
- Applications communicate by inserting messages in specific queues.
- Sender is given only the guarantees that its message will eventually be inserted in the recipient’s queue.
- No guarantees are given about when, or even if the message will actually be read.
- Achieves **persistent** and **asynchronous** communication.

- Four combinations with respect to the execution mode of the sender and receiver.



Four combinations with respect to the execution mode of the sender and receiver.

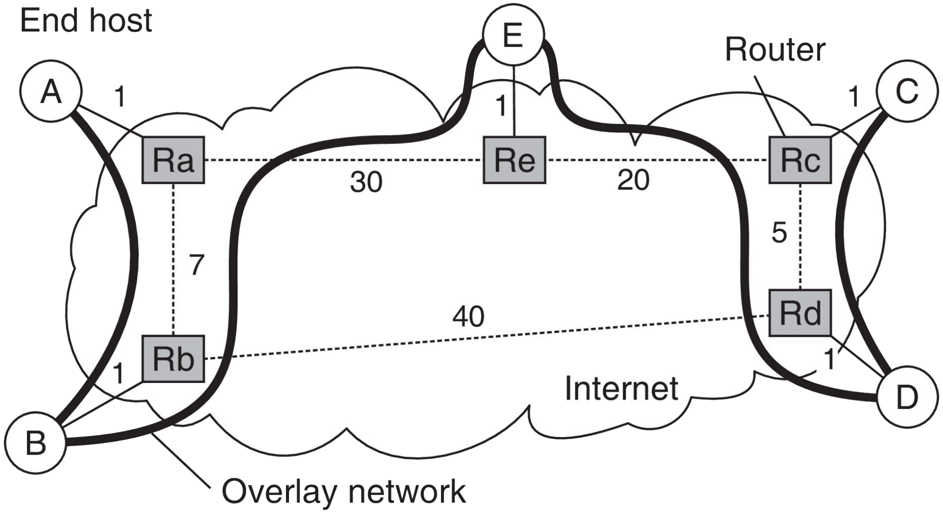
- *Advanced Message Queuing Protocol* (AMQP) is a protocol for MOM.

Multicast Communication

- Multicast communication concerns sending data to multiple receivers.
- Many specialized algorithms to perform this task including **application-level tree-based multicasting**.

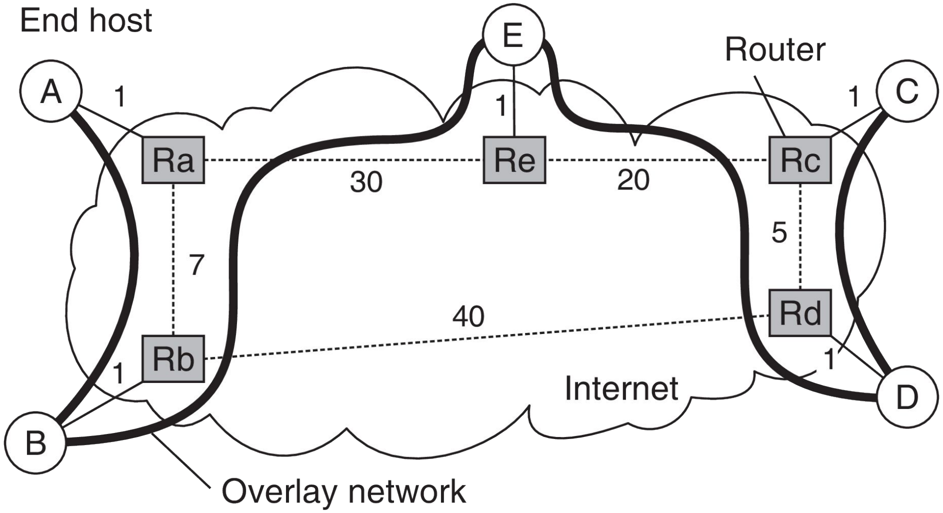
Application-level tree-based multicasting

- Nodes organize as overlay network with tree topology; unique (overlay) path between every pair of nodes.
- Each node forwards a message m to each of its neighbors, except to the one from which it received.



The relation between links in an overlay and actual network-level routes.

- Building an efficient tree is challenging.
- A message multicast by A will traverse the links (B, Rb), (Ra, Rb), (E, Re), (Rc, Rd), and (D, Rd) twice.



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