Distributed Systems Lecture 4

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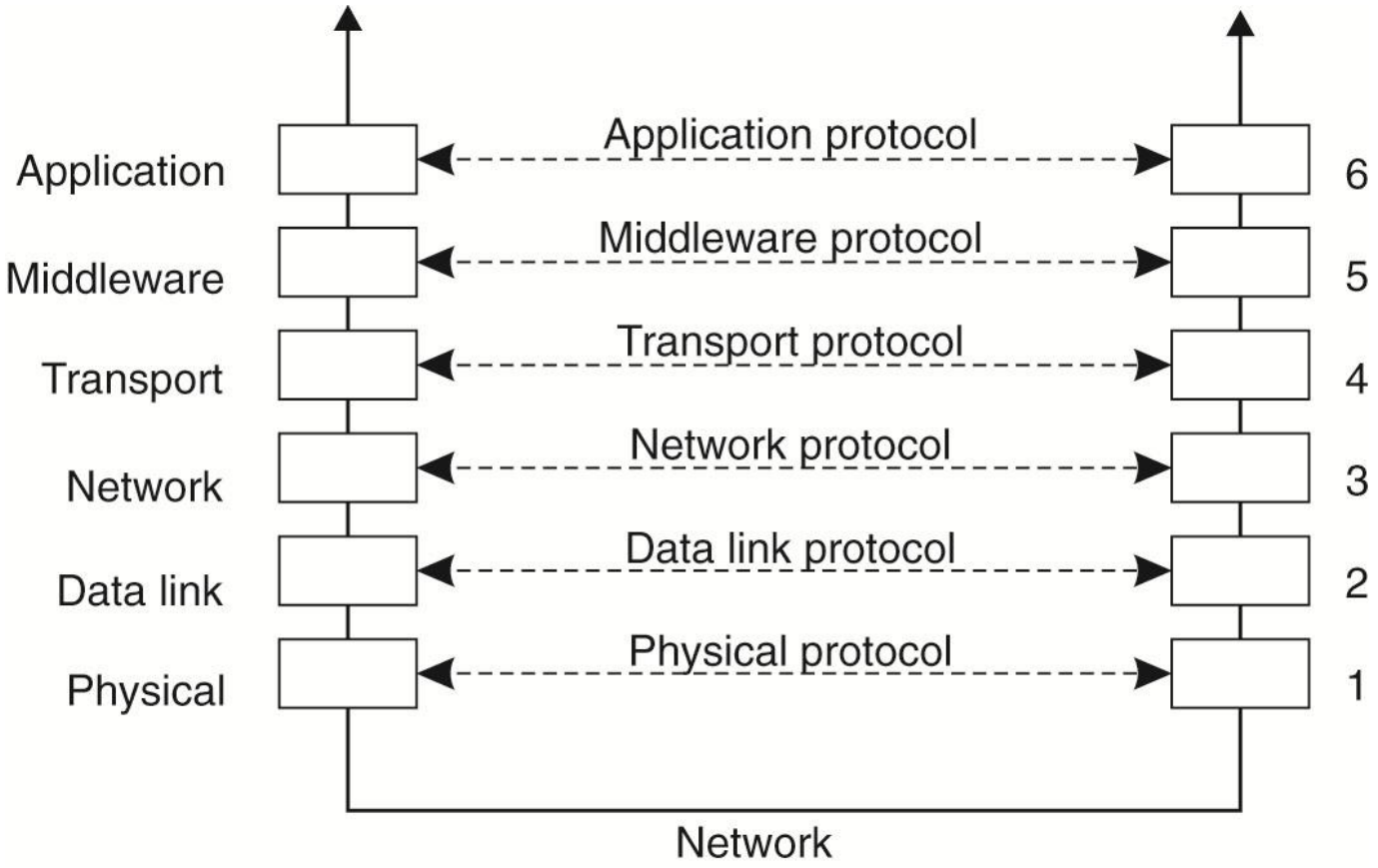
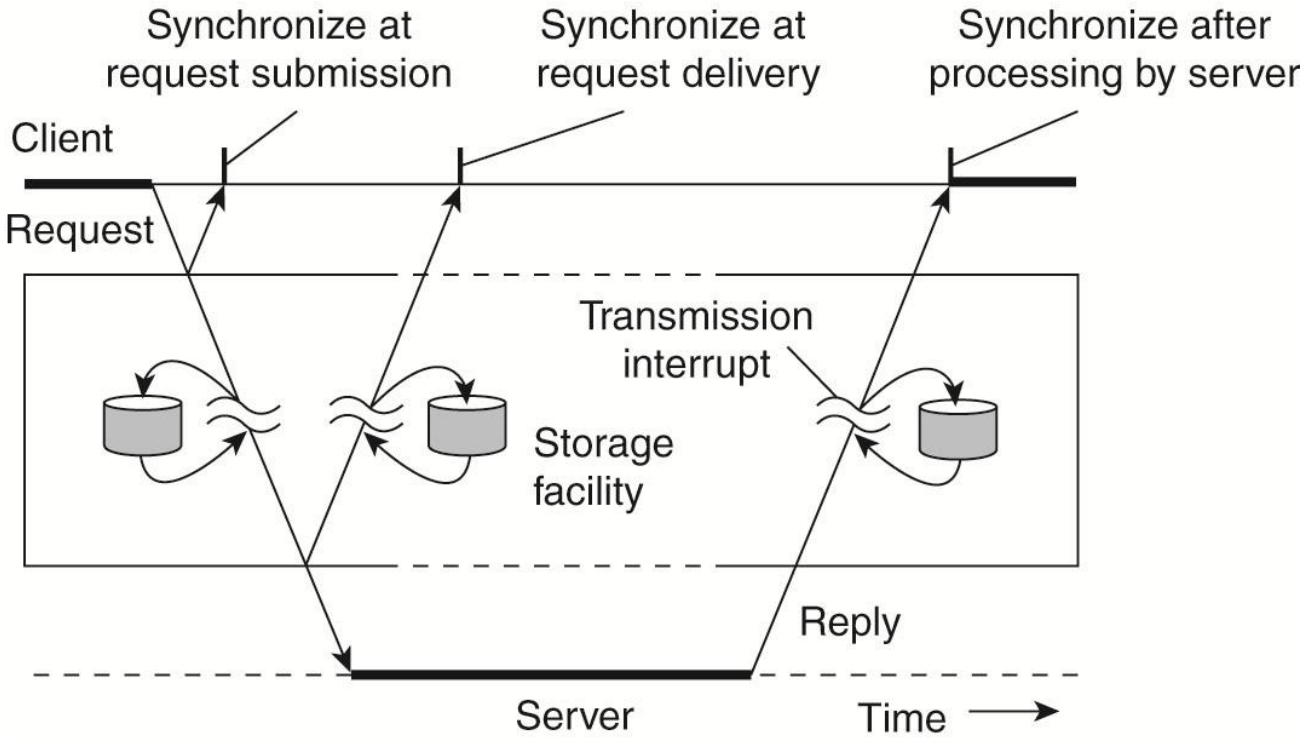
Layered Protocols

- A reference model for distributed systems, adapted from the ISO/OSI model



Middleware in the Communication Path

- Middleware as an intermediate (distributed) service in application-level communication
- Persistent communication in an e-mail system

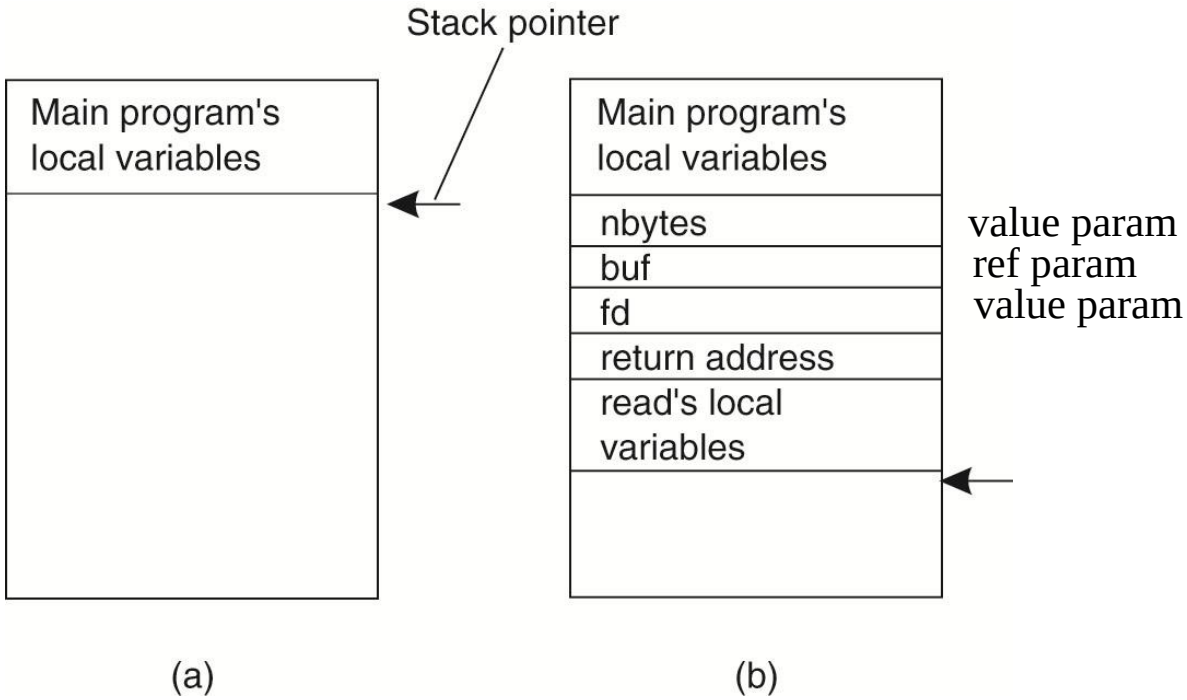


Conventional Local Procedure Call

- Parameter passing in a local procedure call *read(fd, buf, nbytes)*

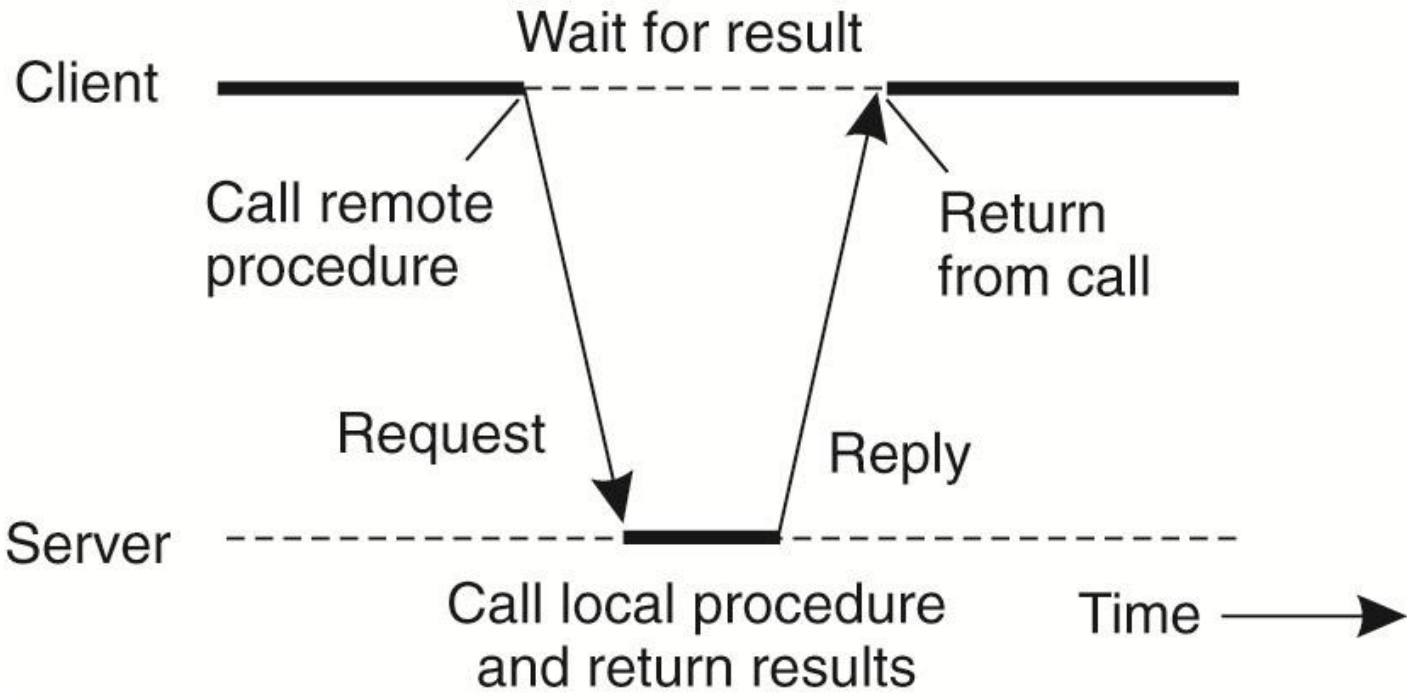
(a) The stack before the call to read

(b) The stack while the called procedure is active



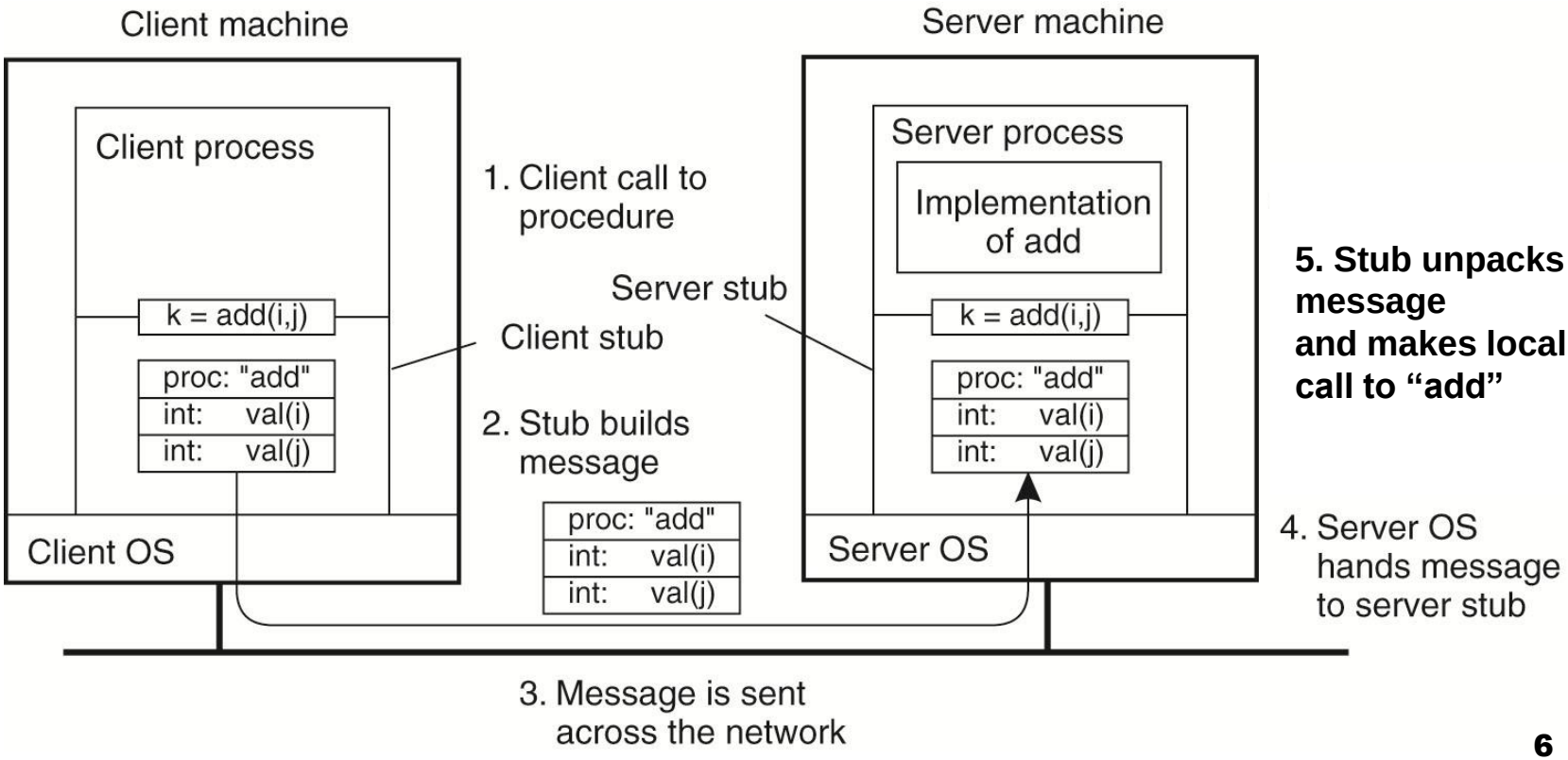
Remote Procedure Call

- Principle of **Remote Procedure Call (RPC)** between a client program and a server program



Remote Procedure Call

- The steps involved in doing a remote computation using RPC



Remote Procedure Call

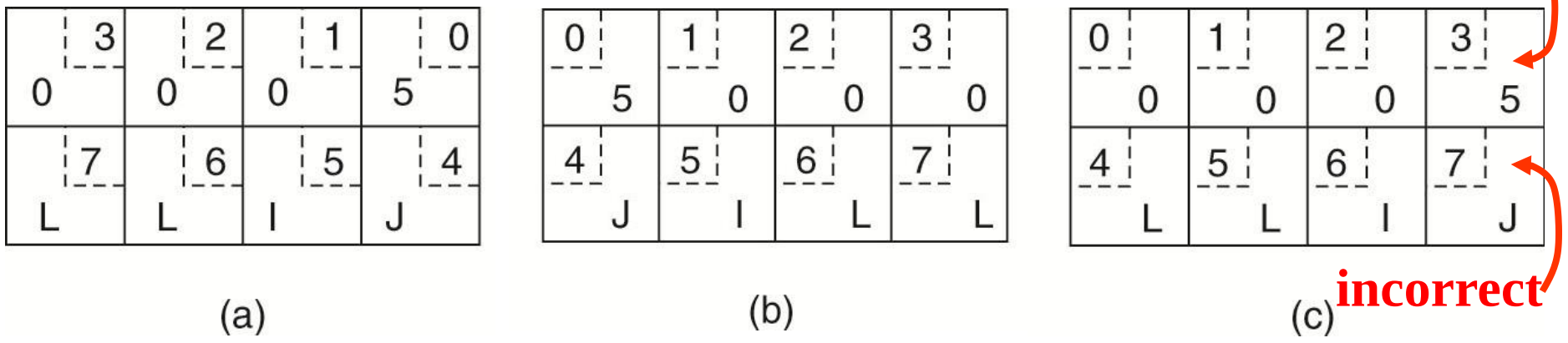
- A remote procedure call involves the following steps:
  1. **The client procedure calls the client stub**
  2. **The client stub builds a message and calls its local OS**
  3. **The client OS sends the message to the remote server OS**
  4. **The server OS passes the message to the server stub**
  5. **The server stub unpacks the parameters and calls the server**
  6. **The server executes the procedure and returns the result to the server stub**
  7. **The server stub packs the result in a message and calls its local OS**
  8. **The server OS sends the message to the client OS**
  9. **The client OS passes the message to the client stub**
  10. **The client stub unpacks the result and returns the result to the client**

Passing Value Parameters

(a) The original message on the Pentium (little endian - most significant digit in low address byte)

(b) The message after receipt on the SPARC

(c) The message after being inverted on the SPARC (big endian - most significant digit in high address byte)



- The numbers in the small boxes indicate the address of each byte
- **Integers must be reversed, but strings must not be reversed**

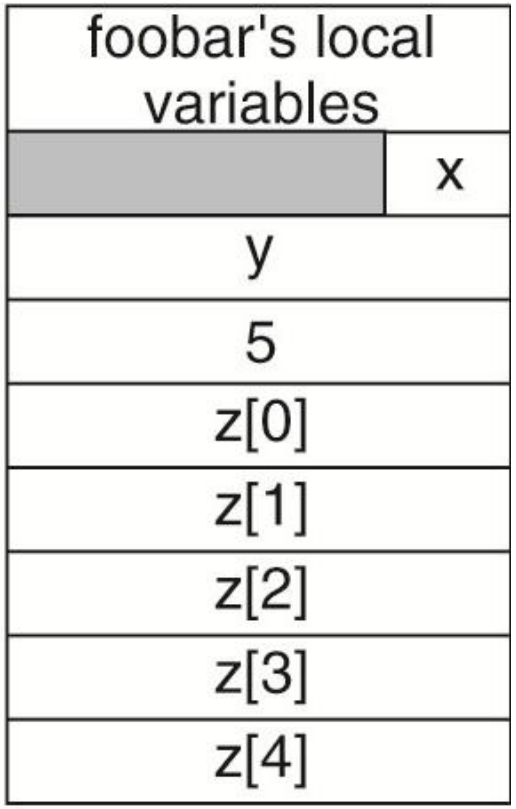
Parameter Specification and Stub Generation

(a) A procedure

(b) The corresponding message

```
foobar( char x; float y; int z[5] )
{
   ....
}
```

(a)

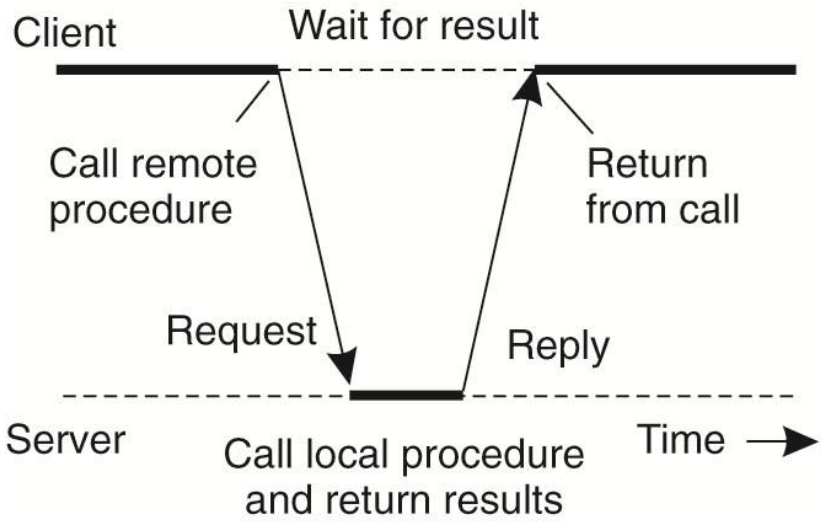


(b)

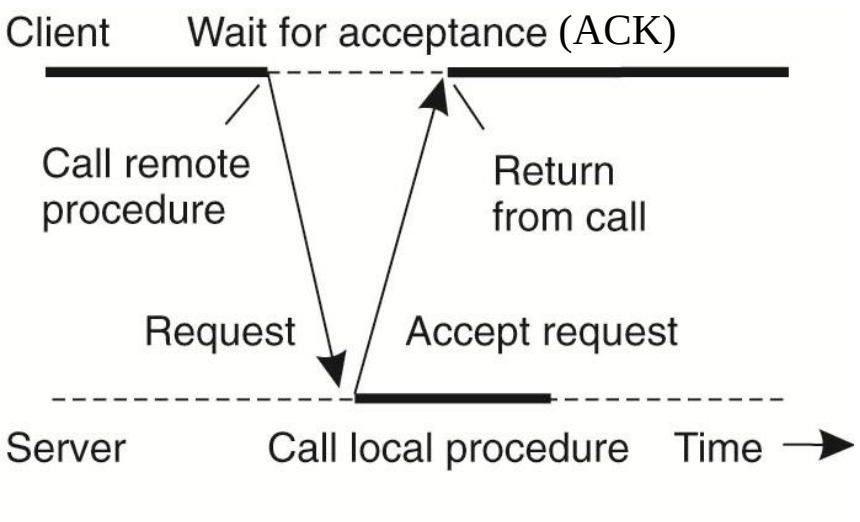
Asynchronous RPC

(a) Traditional Synchronous RPC: Client calls remote procedure and waits (blocks) until it receives the result from the server

(b) Asynchronous RPC: Client calls remote procedure and waits until it receives an ACK of its request from the server (see next slide)



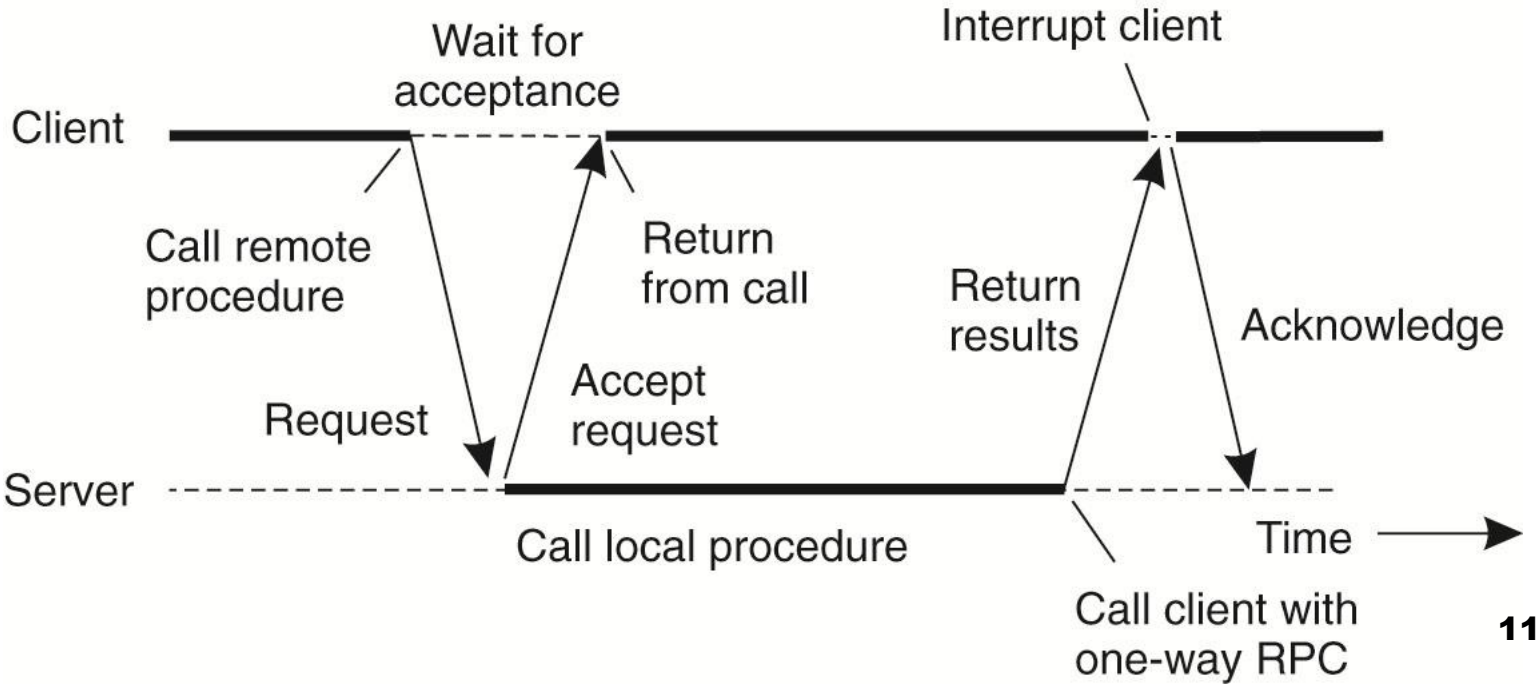
(a)



(b)

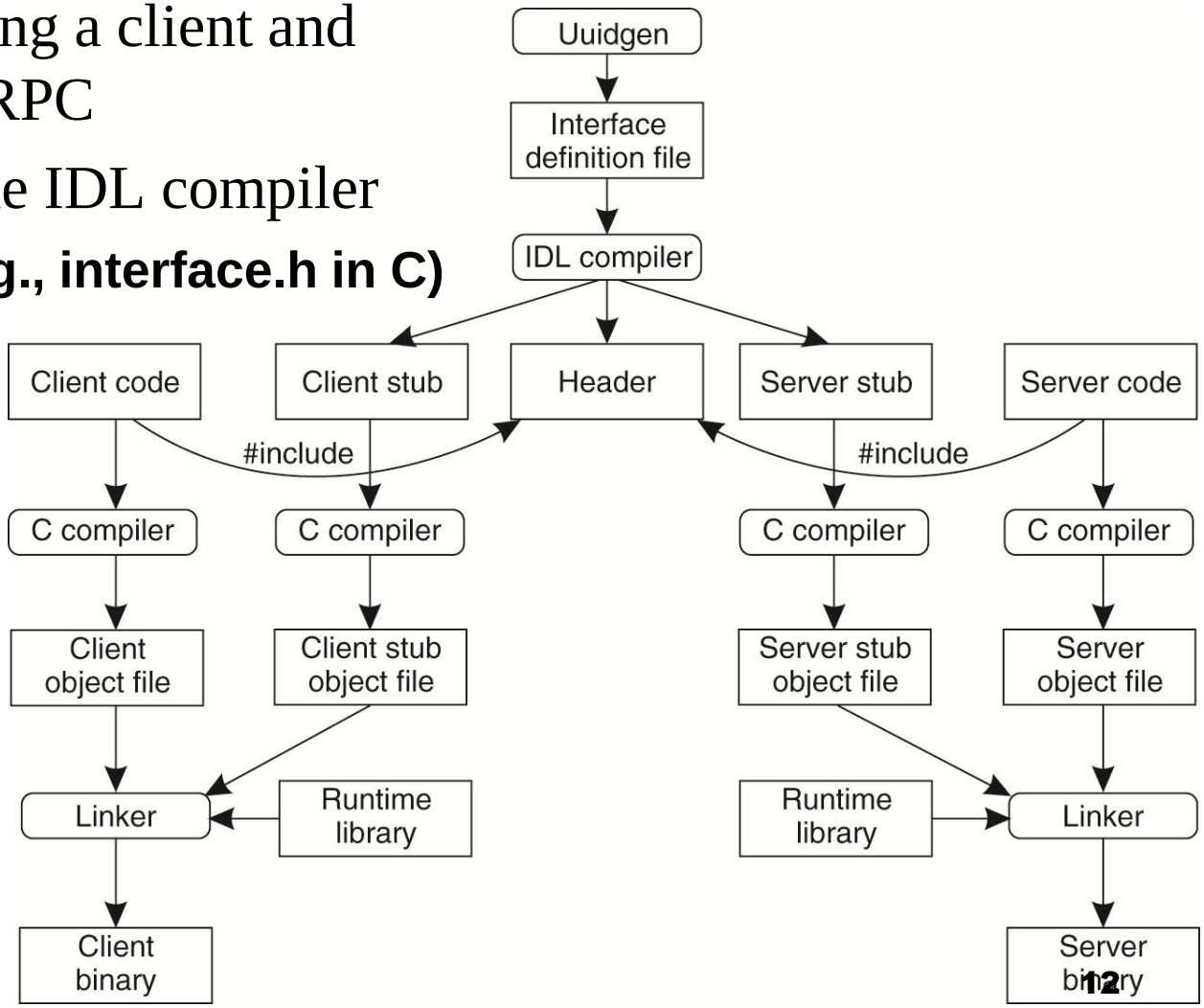
Asynchronous RPC

- Using two asynchronous (one-way) messages
  - **Client calls remote procedure and waits until it receives an ACK of its request from the server**
  - **Server performs the computation and returns the results to the client and waits until it receives an ACK for its response from the client**



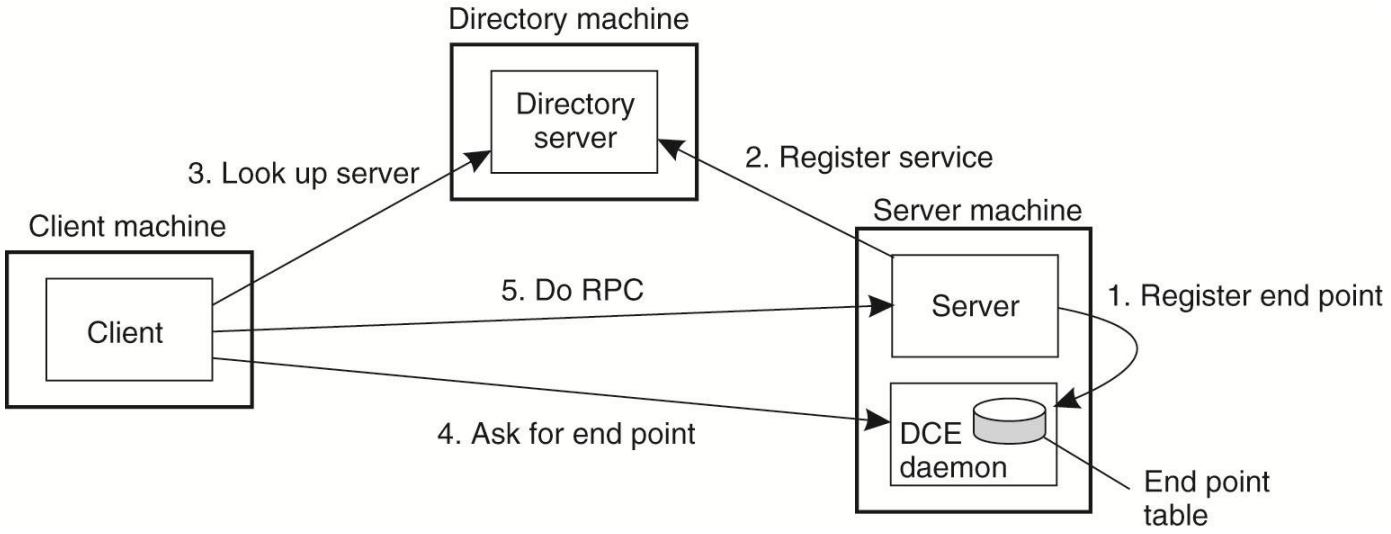
Writing a Client and a Server

- The steps in writing a client and a server in DCE RPC
- Files output by the IDL compiler
  - **Header file (e.g., interface.h in C)**
  - **Client stub**
  - **Server stub**



Binding a Client to a Server in DCE

- Registration of a server is done in two steps
  1. **Server registers its endpoint with the DCE daemon**
  2. **Server registers its service with the Directory server**
- Location of the server is done in two steps
  3. **Client locates the server machine using the Directory server**
  4. **Client locates the server on that machine using the DCE daemon**



Message Oriented Communication

- Synchronous vs. Asynchronous Communication
- Message Queueing Systems
- Message Brokers
- Example: IBM's MQSeries

Synchronous Communication

- Client-server computing is based on a **synchronous** communication model
  - **Client and server must be active at the time of the communication**
  - **Server waits passively for incoming requests, and processes them when they arrive**
  - **Client issues request and blocks until it receives a reply from the server**
- **Drawbacks of synchronous communication**
  - **Client cannot do any other work while waiting for the server's reply**
  - **Failures in the server must be dealt with immediately (the client is waiting)**
  - **In many cases, the model is not appropriate (e.g., e-mail, news)**

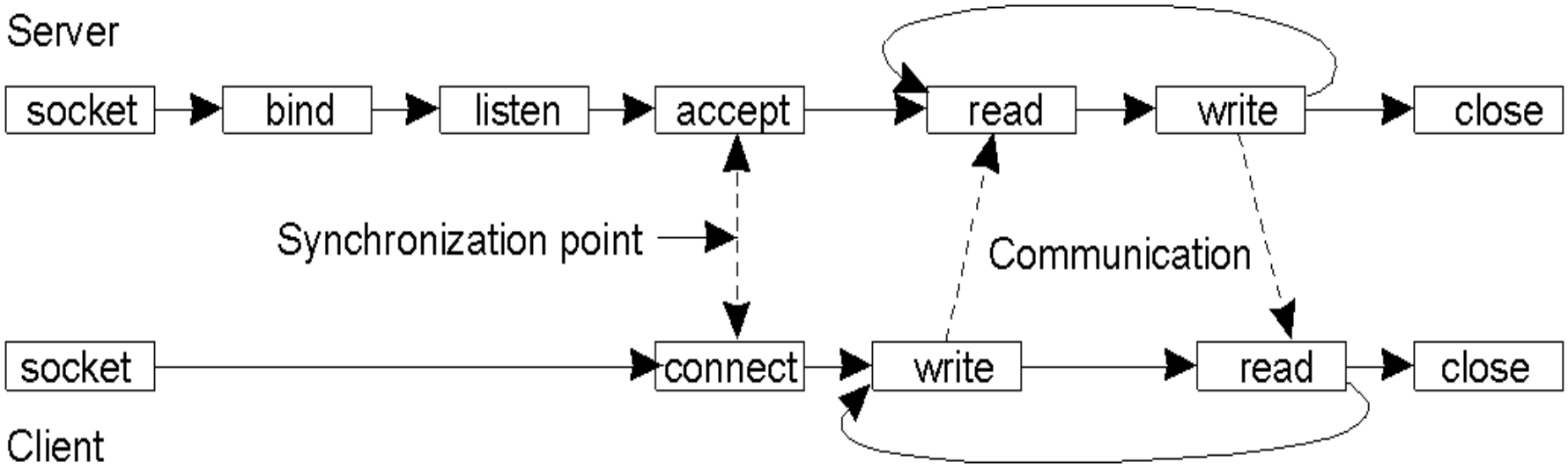
Berkeley Sockets

- Socket primitives for the Transmission Control Protocol (TCP)

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 (Write)	Send some data over the connection
Receive (Read)	Receive some data over the connection
Close	Release the connection

Berkeley Sockets

- Connection-oriented communication pattern using sockets



Message Passing Interface

- Primitives for the Message Passing Interface (MPI), used for parallel applications in high-performance clusters

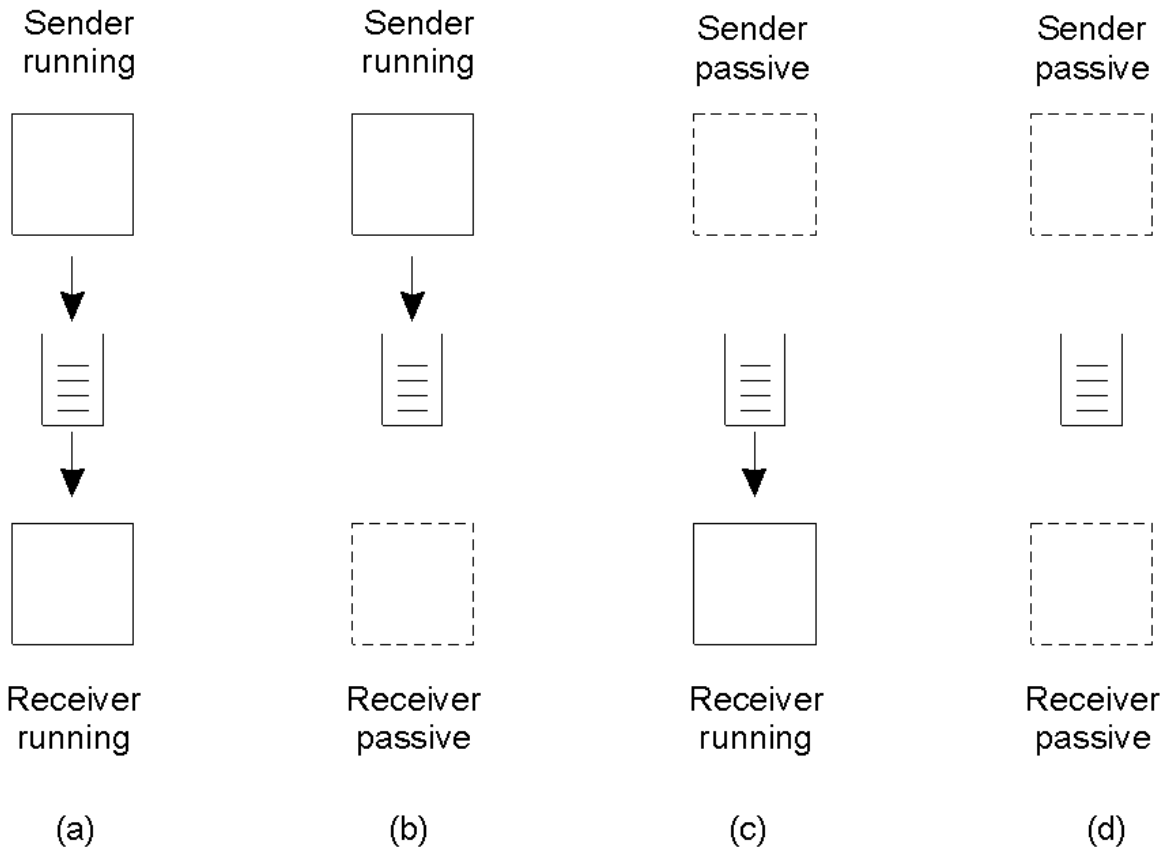
Primitive	Meaning
MPI_bsend	Append outgoing message to a local send buffer
MPI_send	Send a message and wait until copied to local or remote buffer
MPI_ssend	Send a message and wait until receipt starts
MPI_sendrecv	Send a message and wait for reply
MPI_isend	Pass reference to outgoing message, and continue
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

Asynchronous Communication

- **Message Oriented Middleware (MOM)** provides high-level **asynchronous** communication
  - **Processes send messages to each other**
  - **Messages are queued**
  - **Sender does not need to wait for an immediate reply, but can do other processing**
- Message oriented middleware facilitates fault tolerance

Message Queueing Model

- Four combinations for loosely-coupled communication using message queues



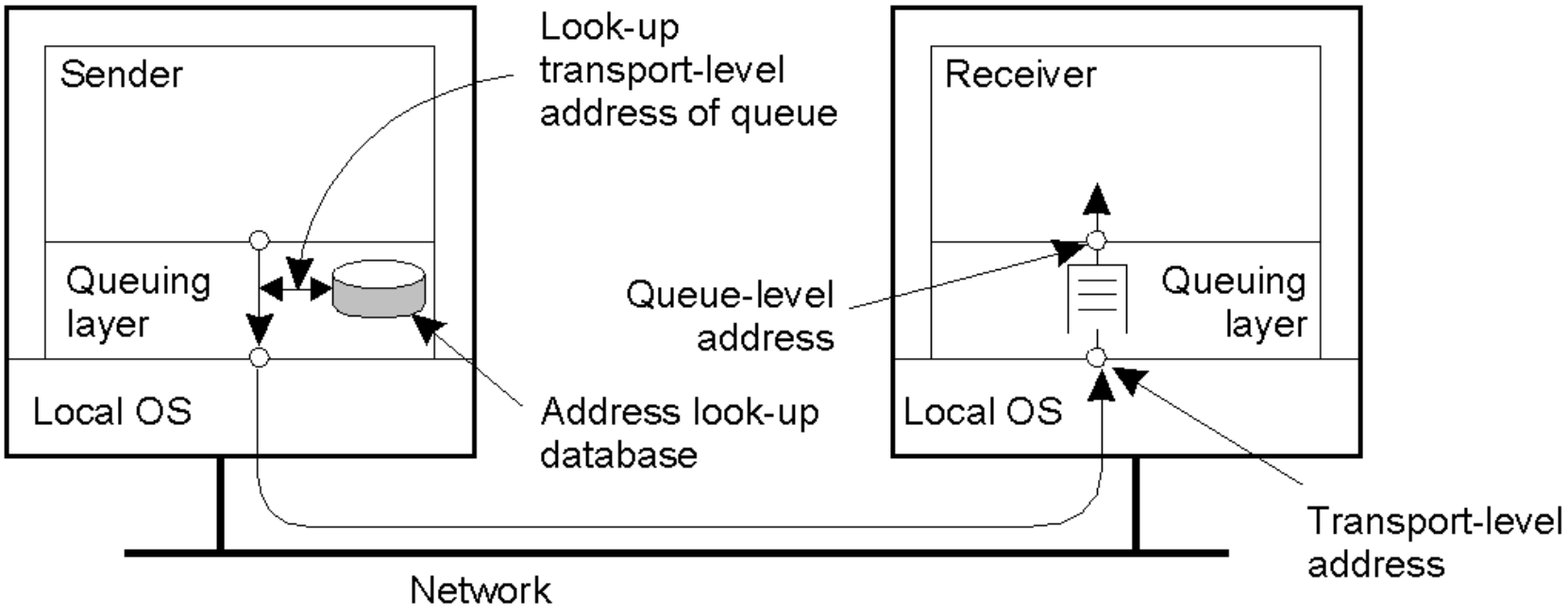
Message Queueing Model

- Basic primitives that provide access to a queue in a message queueing system

Primitive	Meaning
Put	Append a message to a specified queue
Get	Block until the specified queue is nonempty, and remove the first message from the queue
Poll	Check a specified queue for messages, and remove the first message. Never blocks
Notify	Install a handler to be called when a message is put into the specified queue

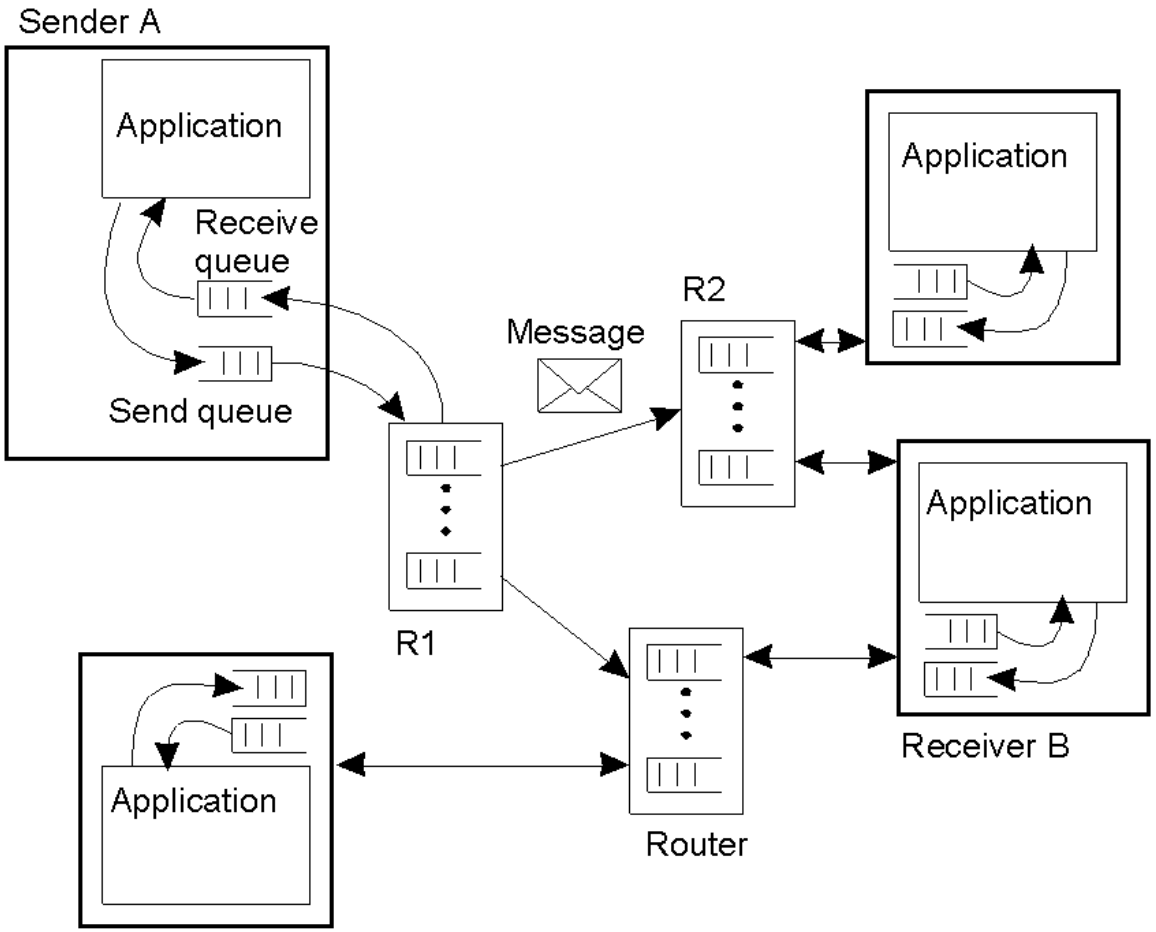
Architecture of a Message Queueing System

- The relationship between Transport-level addressing and queue-level addressing in the middleware



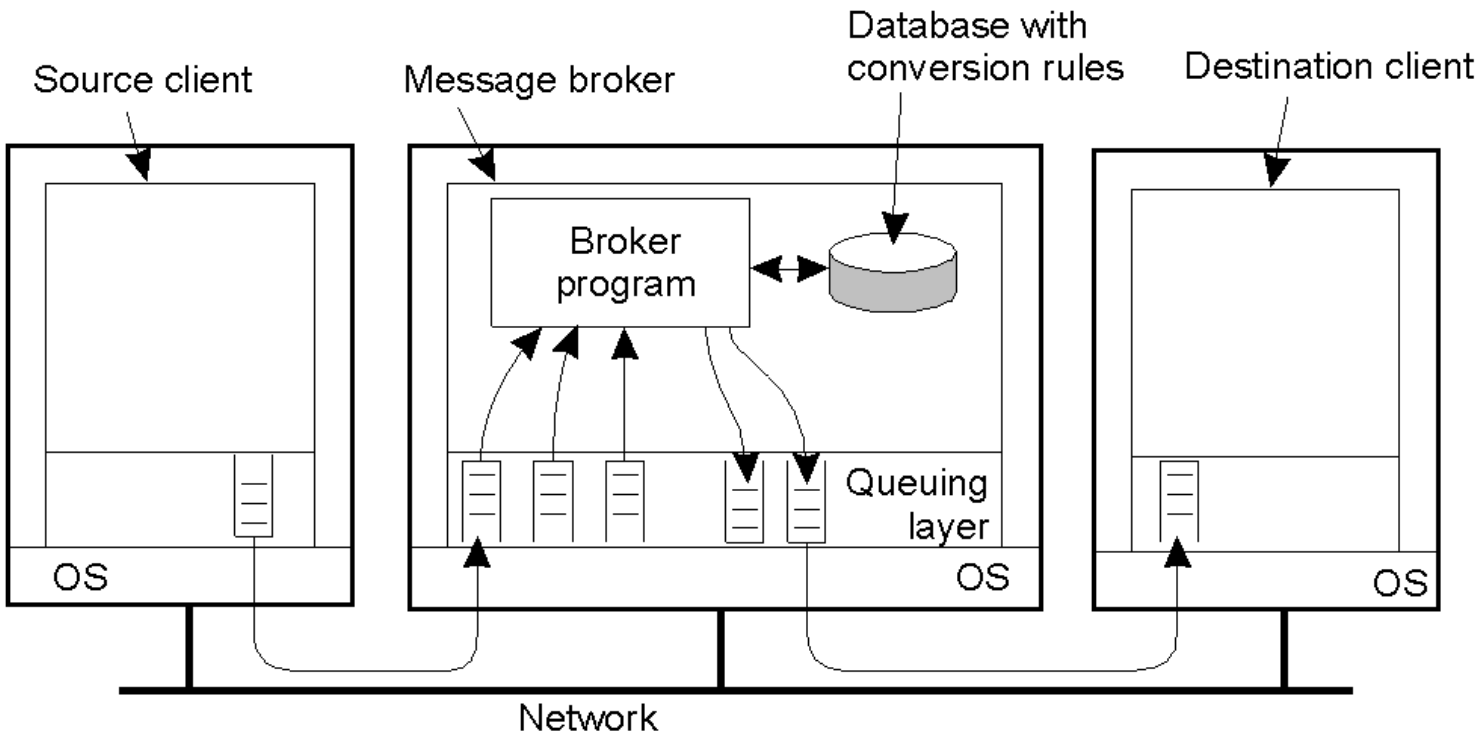
Architecture of a Message Queueing System

- A message queueing system with routers



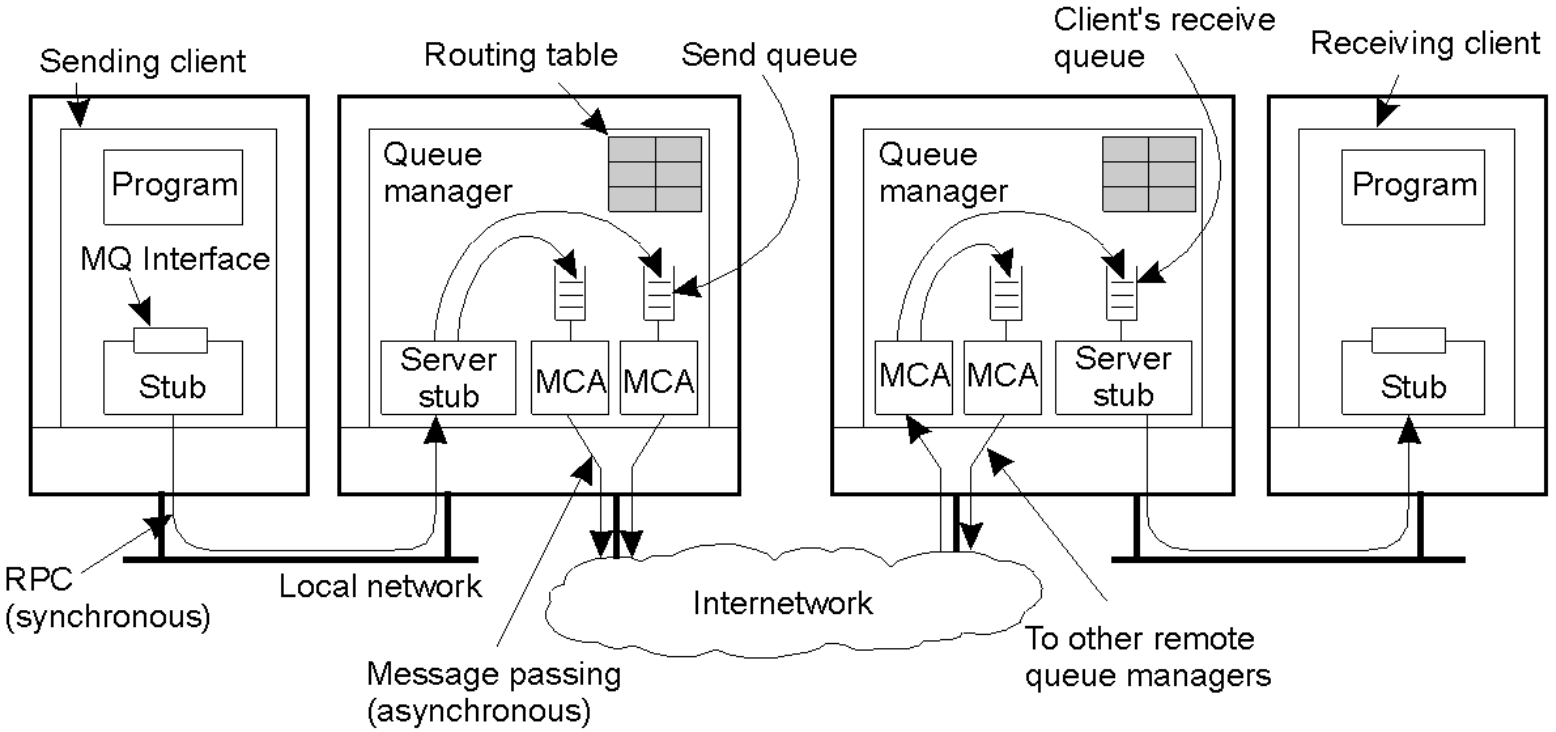
Message Brokers

- A message broker (middleman) in a message queueing system, e.g., for reformatting a message or transforming a message from one type to another



Example: IBM's MQSeries

- IBM's MQSeries message queueing system



- Queue Manager
  - **Removes messages from send queue and forwards to other Queue Managers**
  - **Receives incoming messages and stores them in receive queue**

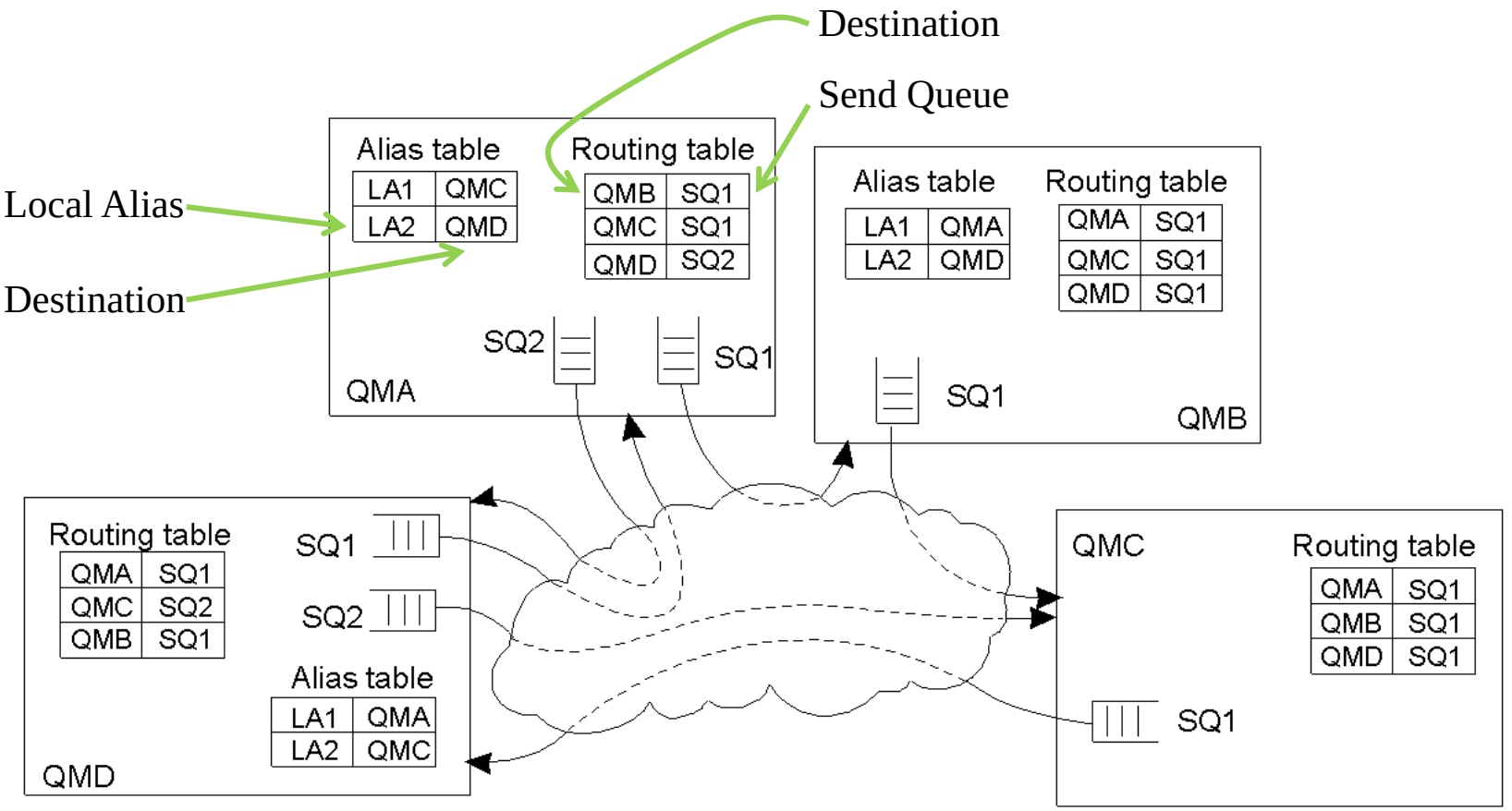
MQSeries: Message Channels

- Message Channel – Unidirectional, reliable connection between sending and receiving Message Queue Managers, through which queued messages are transported
- Message Channel Agent (MCA) – Manages one end of a message channel
  - **Attributes associated with Message Channel Agents**

Attribute	Description
Transport type	Determines the Transport protocol to be used
FIFO delivery	Indicates that messages are to be delivered in the order sent
Message length	Maximum length of a single message
Setup retry count	Specifies maximum number of retries to start up the remote MCA
Delivery retries	Maximum times MCA will try to put received message into queue

MQSeries: Message Transfer

- An MQSeries queueing network using Alias and Routing tables



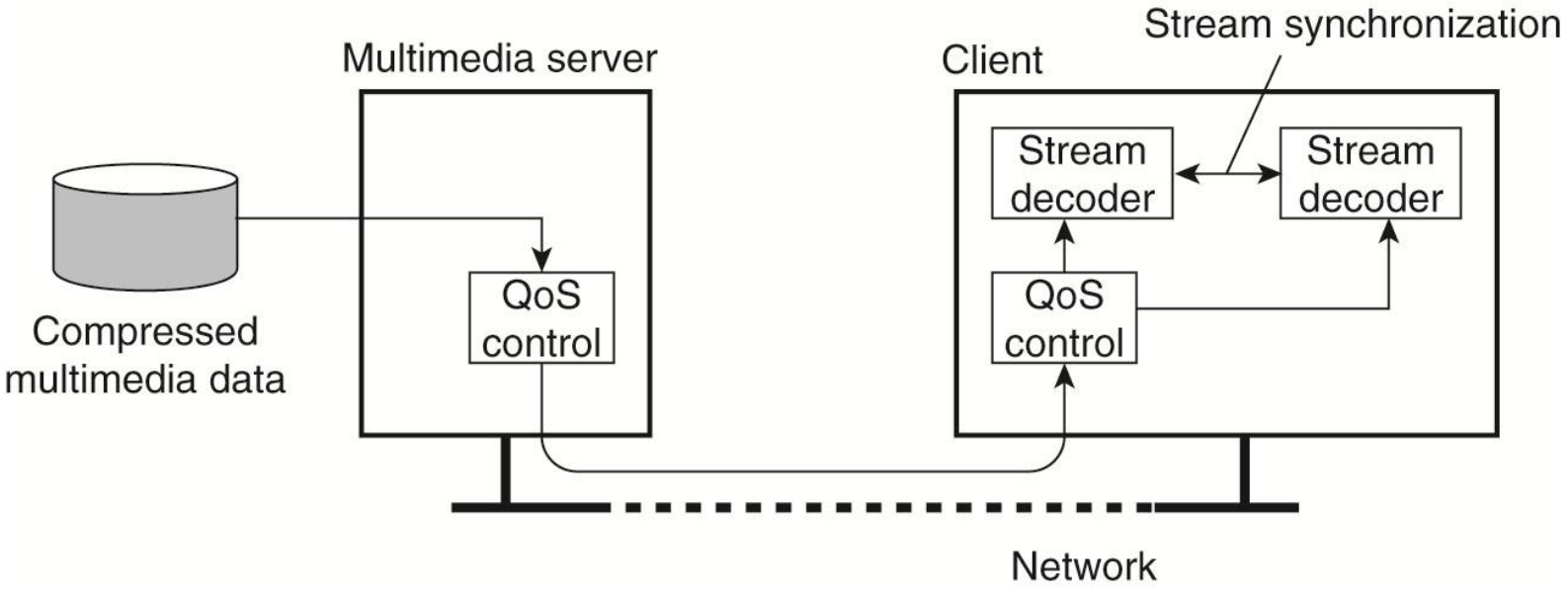
MQSeries: Message Queue Interface

- Primitives for the Message Queue Interface (MQI)

Primitive	Description
MQopen	Open a (possibly remote) queue
MQclose	Close a queue
MQput	Put a message into an opened queue
MQget	Get a message from a (local) queue

Multimedia Data Streams

- An architecture for streaming stored (rather than live) multimedia data over a network
  - **Storing provides more opportunity for fine tuning**

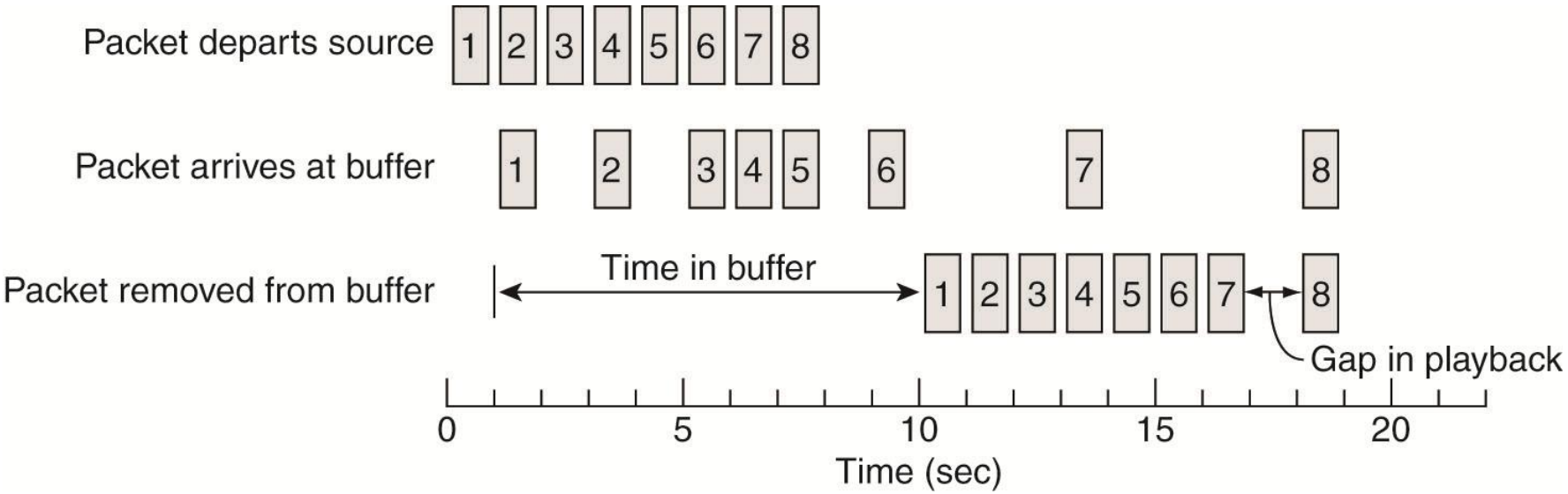


Quality of Service

- Quality of Service (QoS) metrics
  - **Required bit rate at which data should be transported**
  - **Maximum delay (latency) until a session has been set up**
  - **Maximum end-to-end delay (latency)**
  - **Maximum delay variance (jitter)**
  - **Maximum round-trip delay (latency)**

Enforcing QoS

- Using a buffer to store packets before delivering them to the destination in order to reduce jitter



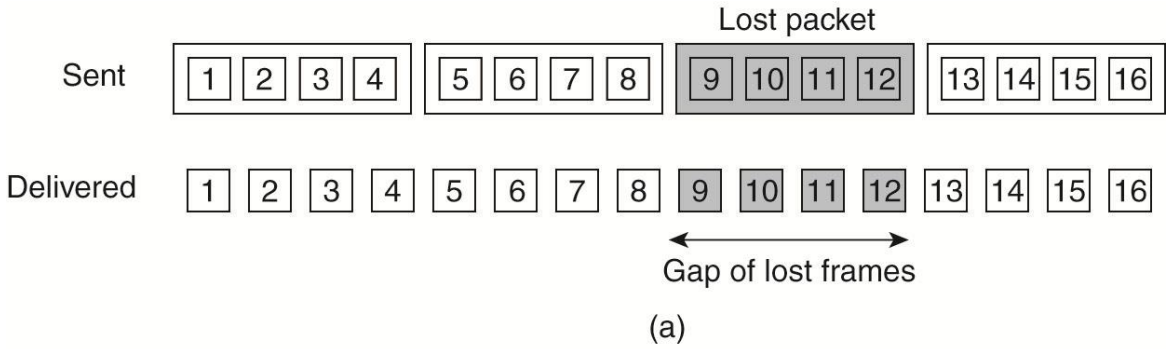
- Gap in playback results because
  - **Size of receiver's buffer corresponds to 9 sec**
  - **Packet 8 took 11 sec to reach the destination**

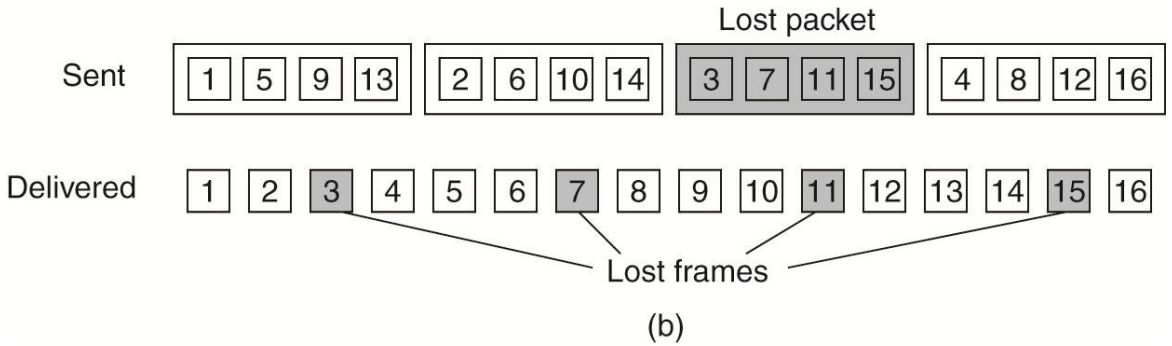
Enforcing QoS

- Effect of packet loss

  (a) Non-interleaved transmission of frames

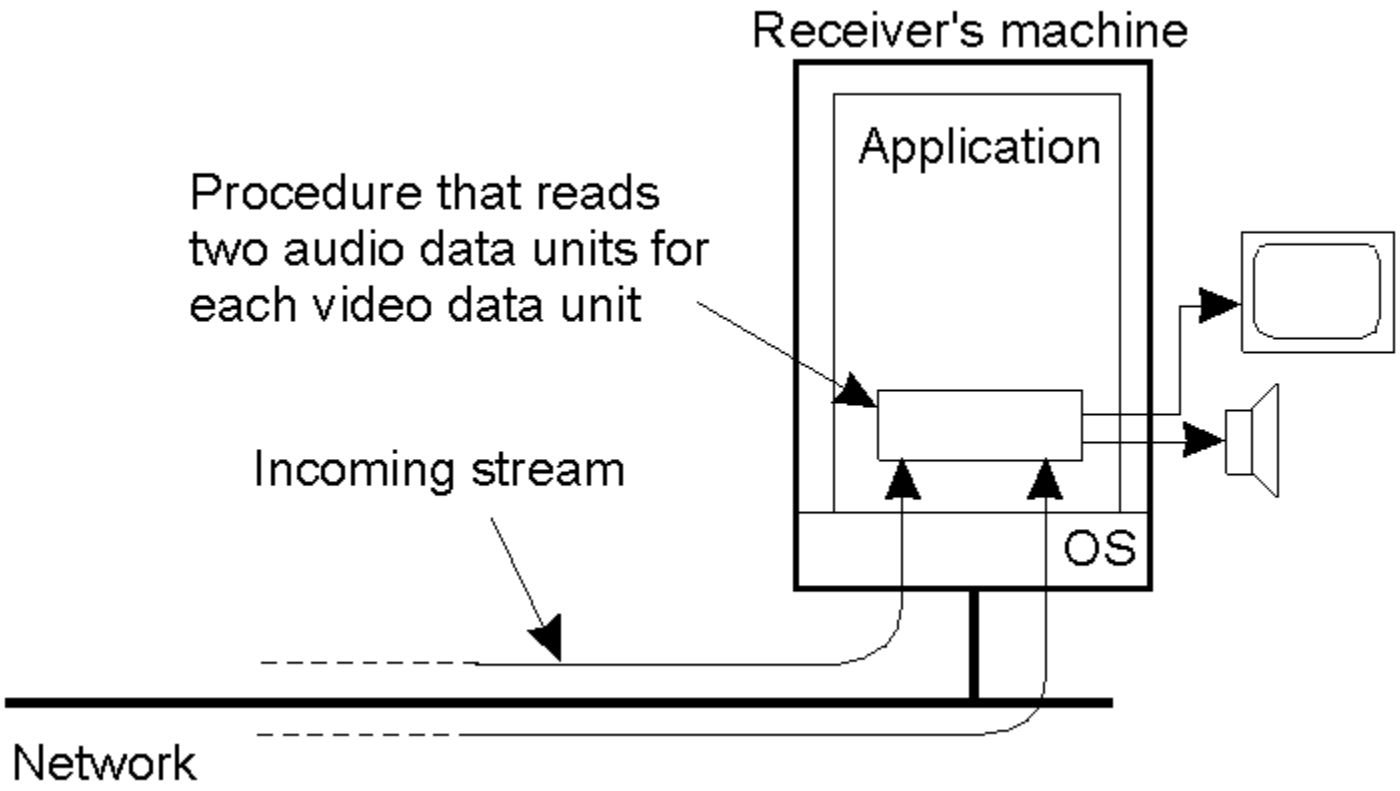
  (b) Interleaved transmission distributes gap over time, but requires a larger buffer at receiver





Synchronization Mechanisms

- Explicit synchronization at the level of data units



Synchronization Mechanisms

- Synchronization supported by high-level interfaces