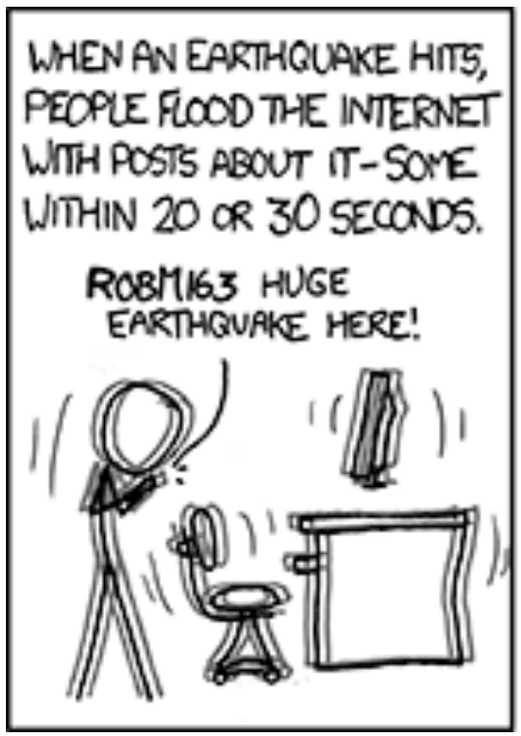
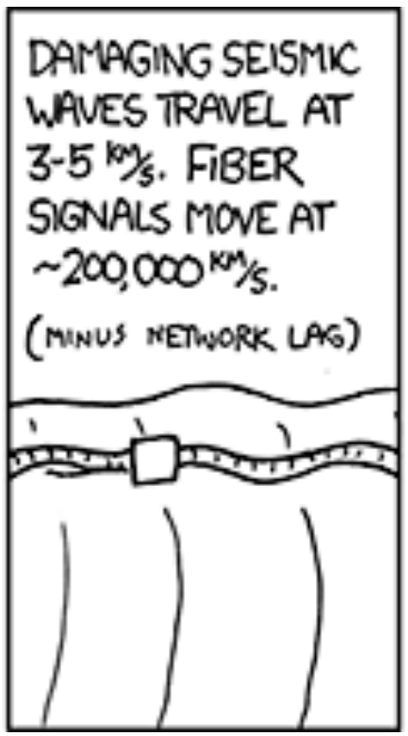
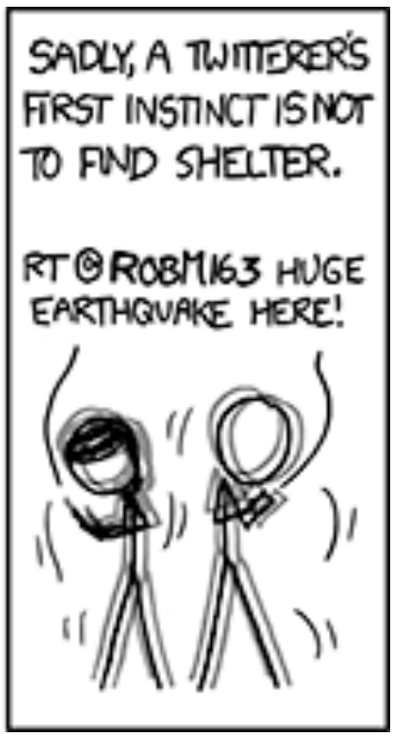
xkcd.com


WHEN AN EARTHQUAKE HITS, PEOPLE FLOOD THE INTERNET WITH POSTS ABOUT IT - SOME WITHIN 20 OR 30 SECONDS.
ROB1163 HUGE EARTHQUAKE HERE!


DAMAGING SEISMIC WAVES TRAVEL AT 3-5 KM/S. FIBER SIGNALS MOVE AT ~200,000 KM/S.
(MINUS NETWORK LAG)


THIS MEANS WHEN THE SEISMIC WAVES ARE ABOUT 100 KM OUT, THEY BEGIN TO BE OVERTAKEN BY THE WAVES OF POSTS ABOUT THEM.
QUAKE
TWEETS


PEOPLE OUTSIDE THIS RADIUS MAY GET WORD OF THE QUAKE VIA TWITTER, IRC, OR SMS BEFORE THE SHAKING HITS.
WHOA! EARTHQUAKE!


SADLY, A TWITTERER'S FIRST INSTINCT IS NOT TO FIND SHELTER.
RT @ROB1163 HUGE EARTHQUAKE HERE!

End To End Protocols

COS 460 & 540

End to End Protocols

This section is about

Process to Process

communications.

or the **how** applications can talk to each other.

Requirements

- **Guarantee** Delivery
- Deliver **in order**
- Deliver at most **one copy**
- **Any size**
- Flow control & Synchronization

The Network May...

- Drop messages
- Reorder messages
- Deliver duplicate copies
- Limit message size
- Delay messages

End To End Protocols

The network provides a **best-effort** service

This layer needs to provide
high level services

End To End Protocols

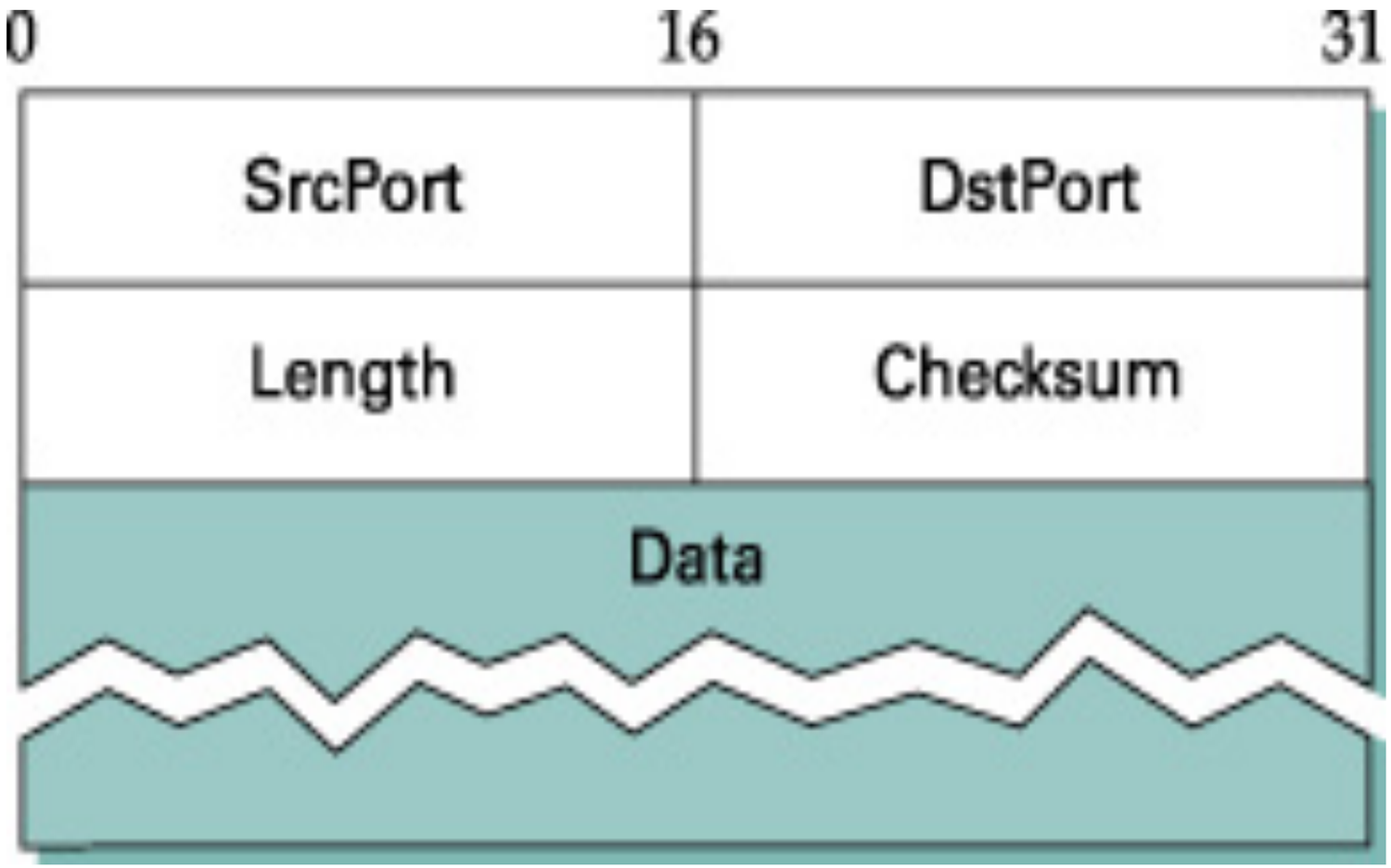
★Simple Demultiplexer (UDP)

- Reliable Stream (TCP)
- Remote Procedure Call (RPC)
- Real-time Applications (RTP)
- Performance

User Datagram Protocol (UDP)

- Thin layer over Network Layer
  (unreliable, best-effort service)
- Simple demultiplexing; Adds **Process Address** or **port**
- Checksum (packet correctness)

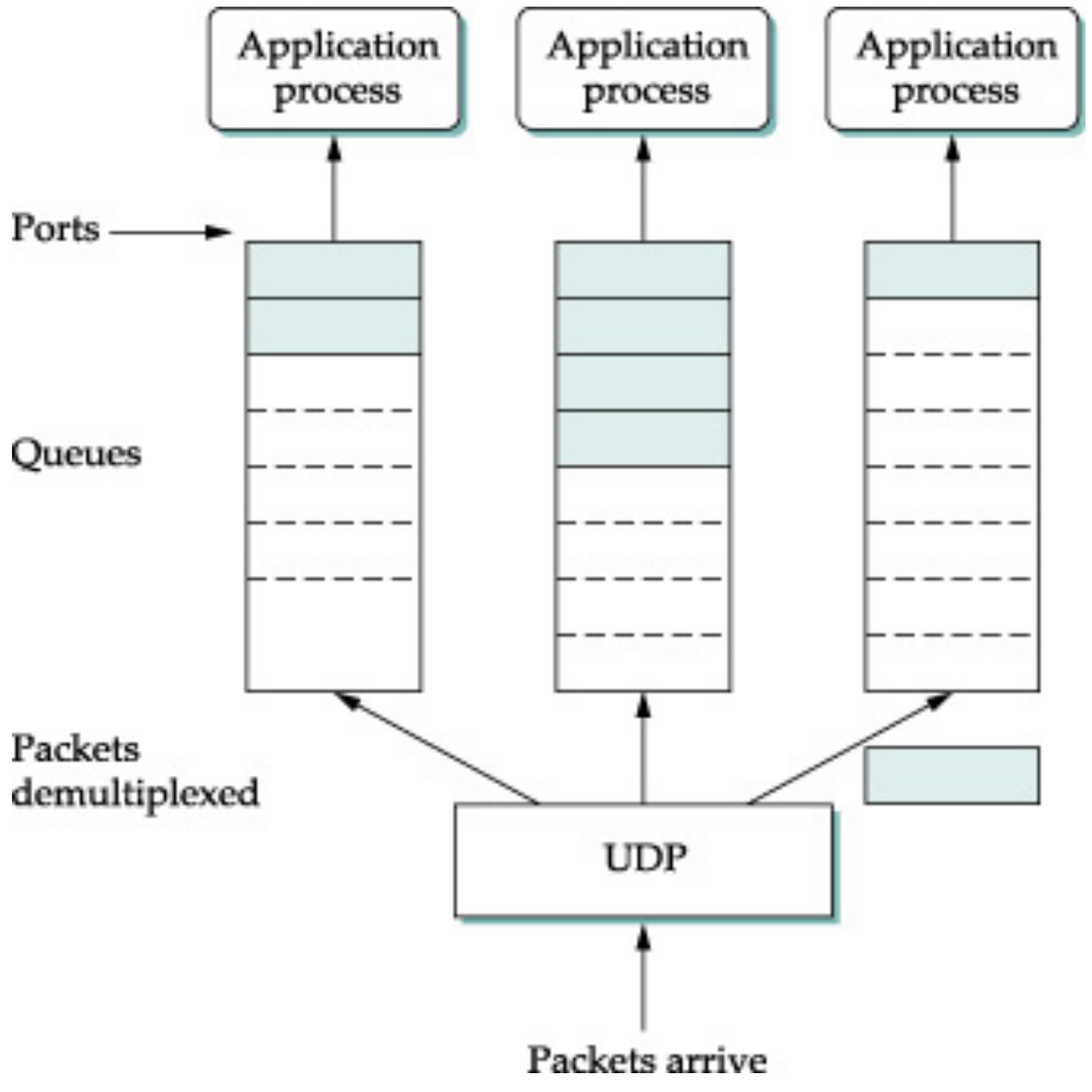
UDP



Ports

- 16 bit port number = 64,536 ports
- Unique to a host (IP address)
  - for example: 192.168.1.2:80
- *well-known* ports
  - 22, 25, 80, ...
- <1,024 usually requires administrator

UDP Demultiplexing



Socket Pairs

Every datagram has a unique “pairing”

- source ip address
- source port
- destination ip address
- destination port

End To End Protocols

✓Simple Demultiplexer (UDP)

★Reliable Stream (TCP)

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- Real-time Applications (RTP)
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Reliable Byte Stream

Provide a reliable, in-order, at most once delivery mechanism with flow control and synchronization.

... sounds easy right?

Transmission Control Protocol (TCP)

- Byte-oriented
- Connection-oriented
- Reliable, guaranteed delivery
- In-order delivery
- full-duplex channel

End-To-End Issues

- Logical connections over the great unknown network
- No “single path,” each packet is routed individually.
- Solve by using Sliding Window Protocol with connection setup and teardown

End-To-End Issues

- Round Trip Time (RTT) varies widely
  - even over short-lived connections

- Solve by using *adaptive retransmission*

End-To-End Issues

- Packets are likely to get delivered out of order
- TTL removes packets from the network
- Old packets suddenly show up later
- Solve using Sliding Window w/sequence numbers

End-To-End Issues

- Bandwidth at endpoints and links between them may be vastly different

- Solve by using a flow control mechanism

End-To-End Issues

- The Sender may be able to generate large amounts of data
- Intermediate links can become congested
- Solve using congestion control mechanisms

Segmentation

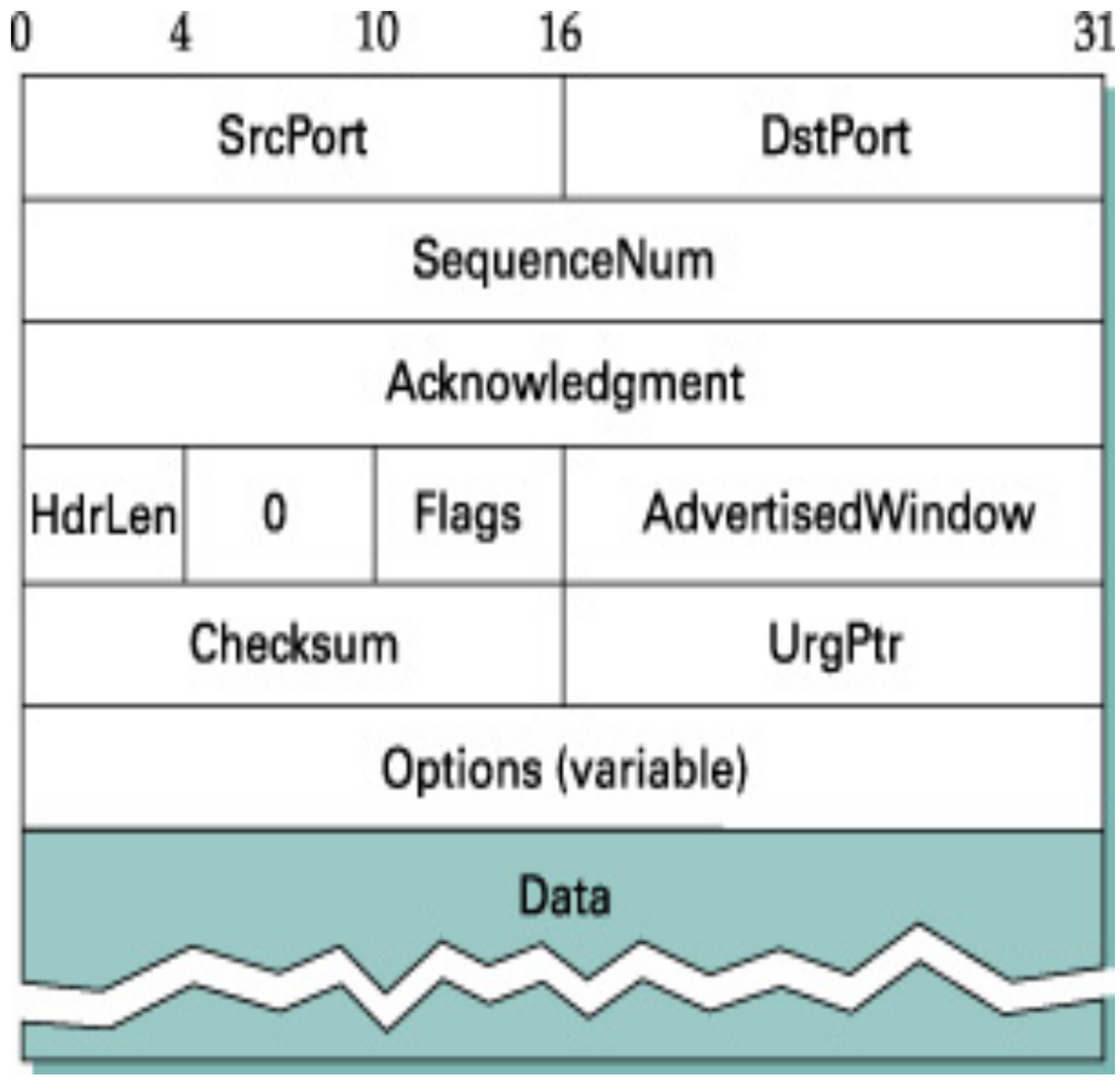
TCP may be a ***byte-stream*** protocol...

...but the network is ***packet based***.

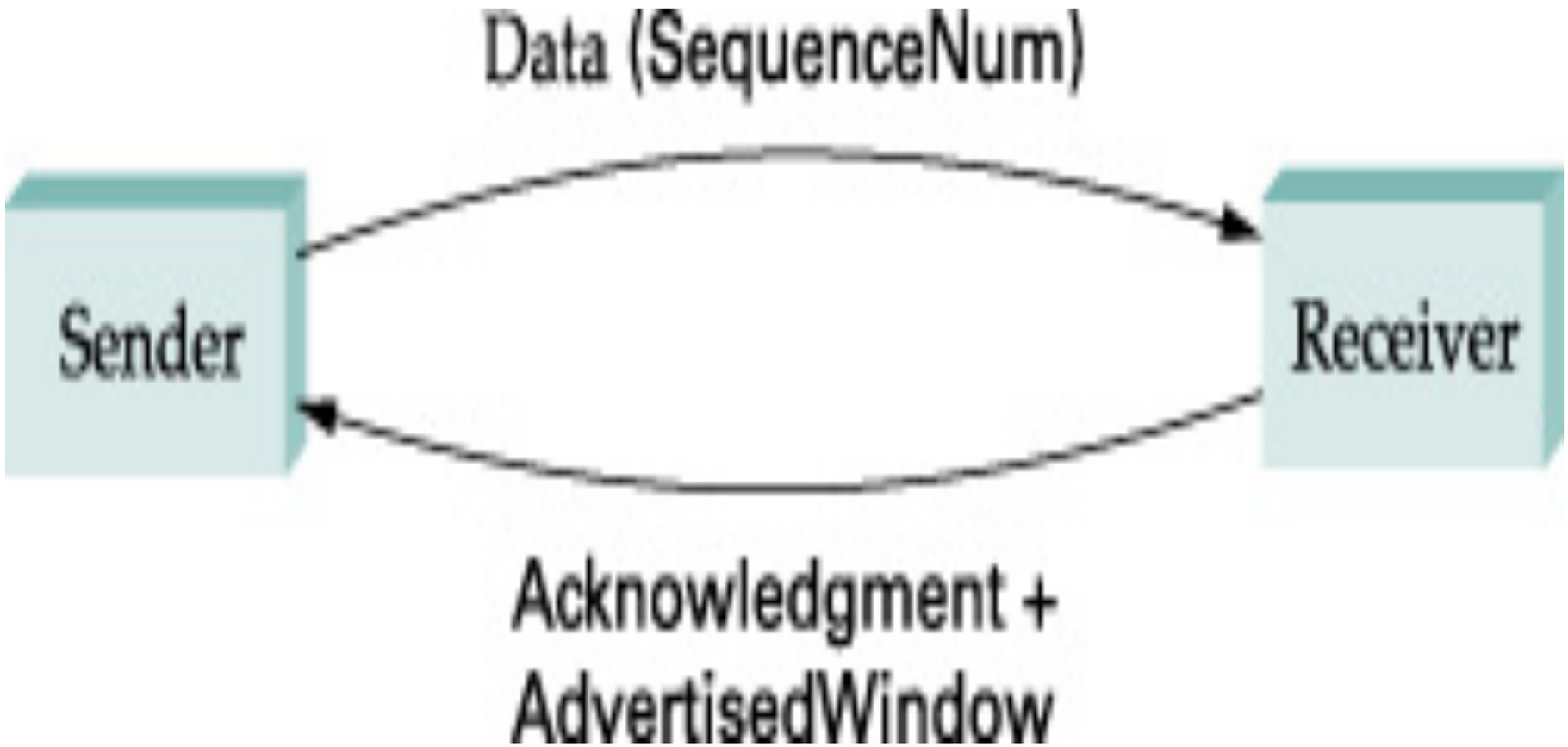
TCP Segment Format

- TCP is byte-oriented
  - buffers bytes for transmission
    - send when full or flushed
- Send bytes in **segments**
- **Acknowledgments** and **windows**

TCP Segment Format



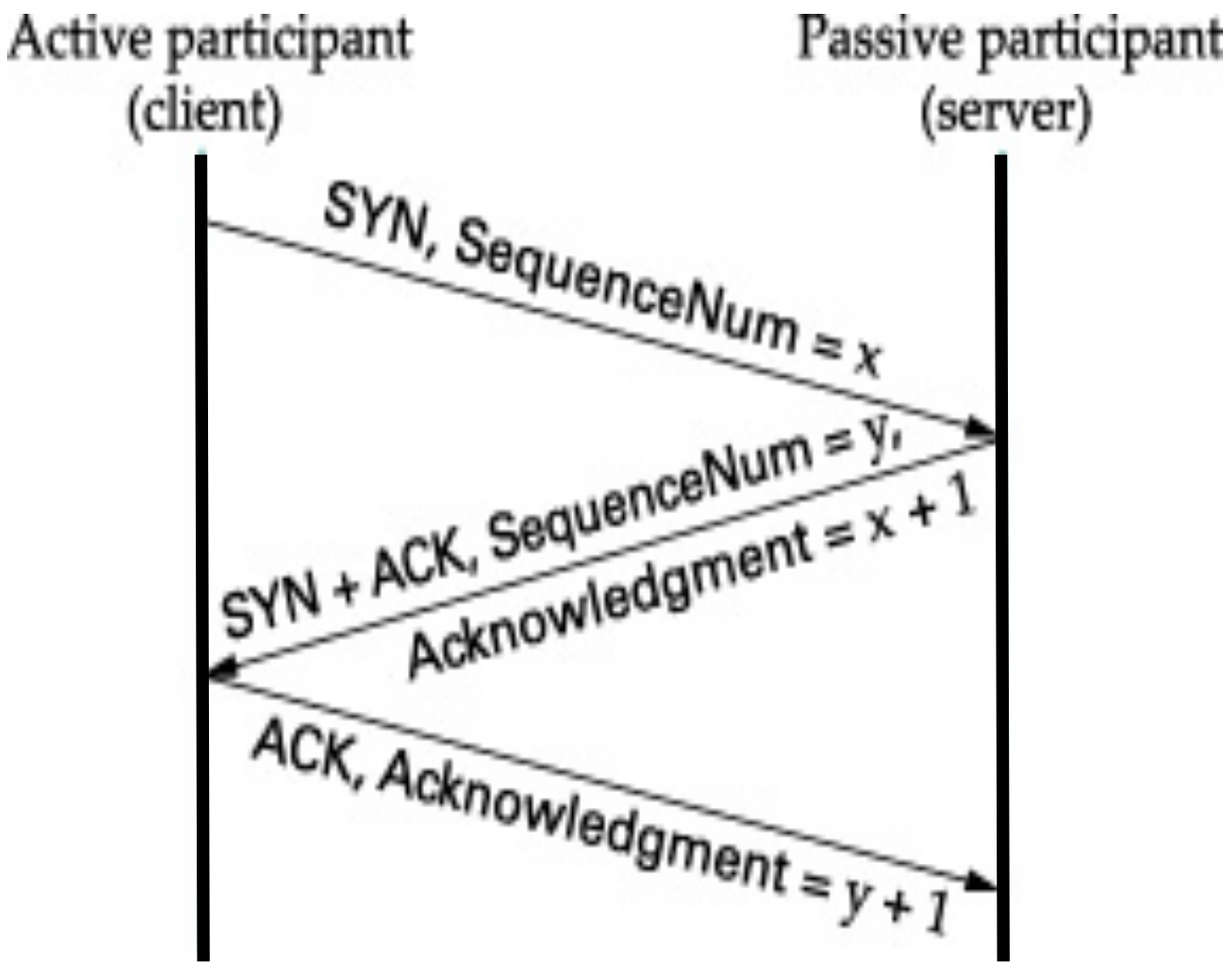
TCP Flow


Data (SequenceNum)
Sender
Receiver
Acknowledgment +
AdvertisedWindow

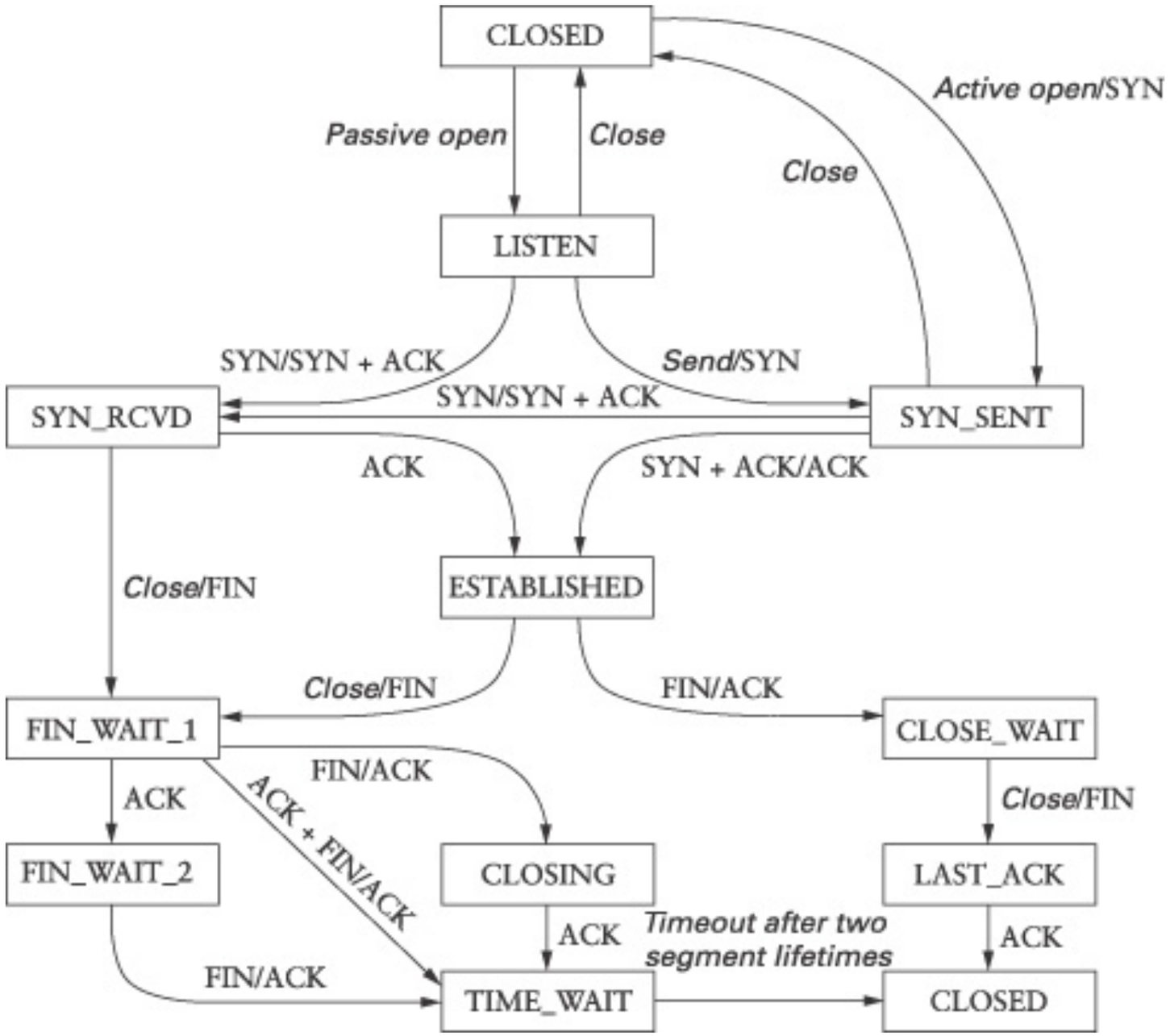
TCP Segment

- Two way communication
- SequenceNum = first byte in segment
- Acknowledgement = next seq. expected
- AdvertisedWindow = buffer size left

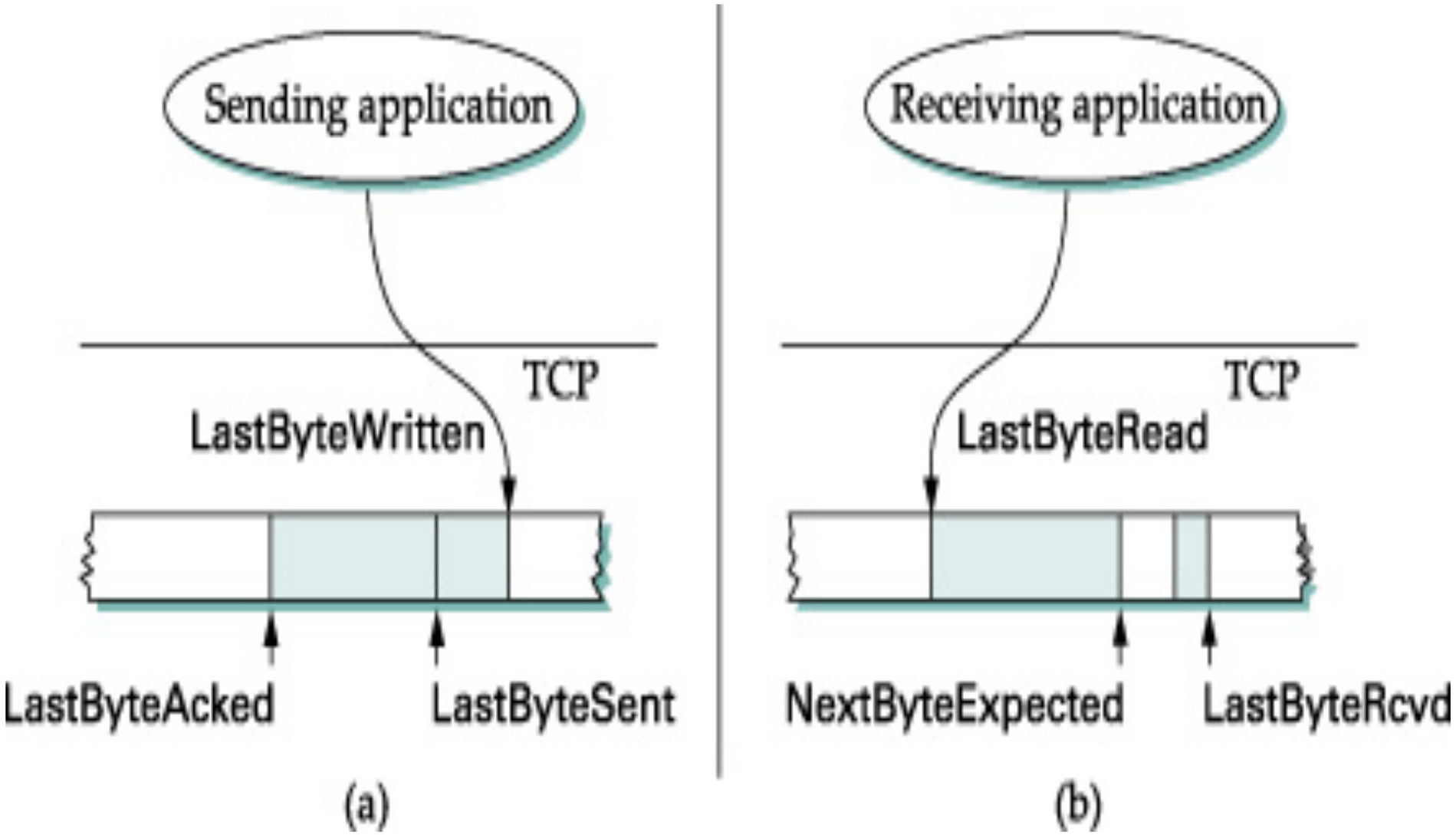
Connection Establishment



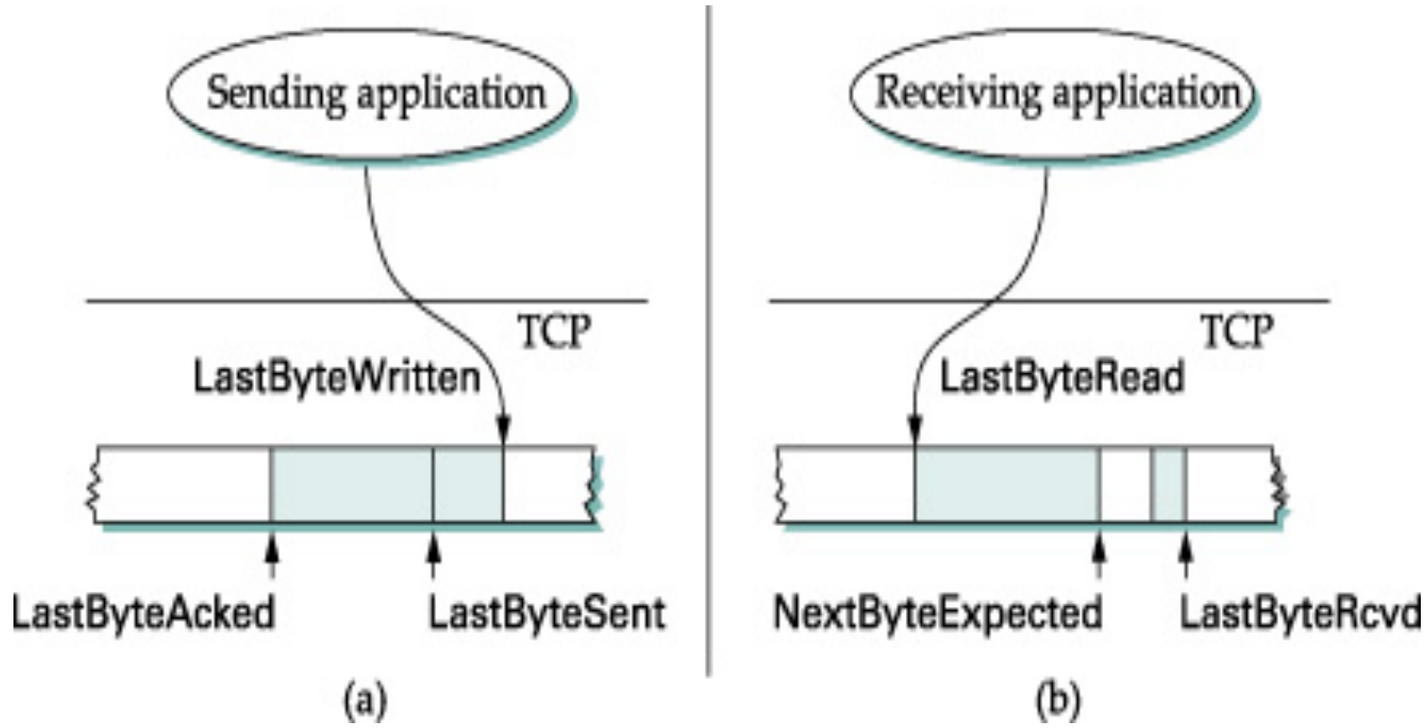
TCP Lifecycle



TCP Sliding Window



TCP Flow Control



Advertised Window

LastByteRcvd - LastByteRead <= MaxBuff =

MaxB - ((NextByte - 1) - LastBytRead)

Advertised Window = 0

Sender “pings” with 1 byte segments

Triggering Transmission

- When segment is full (MSS = MTU)
- *push* operation
- Timeout expires

Record Boundaries

How would we send a set of database records?

- <name, address, phone,...>, <...>, ...
- UDP = 1 record per datagram

Record Boundaries

In TCP we could....

- Encode special characters, recall ETX?
- Encode the dataset, e.g. XML
- Urgent data flag
- push operation

End To End Protocols

✓Simple Demultiplexer (UDP)

✓Reliable Stream (TCP)

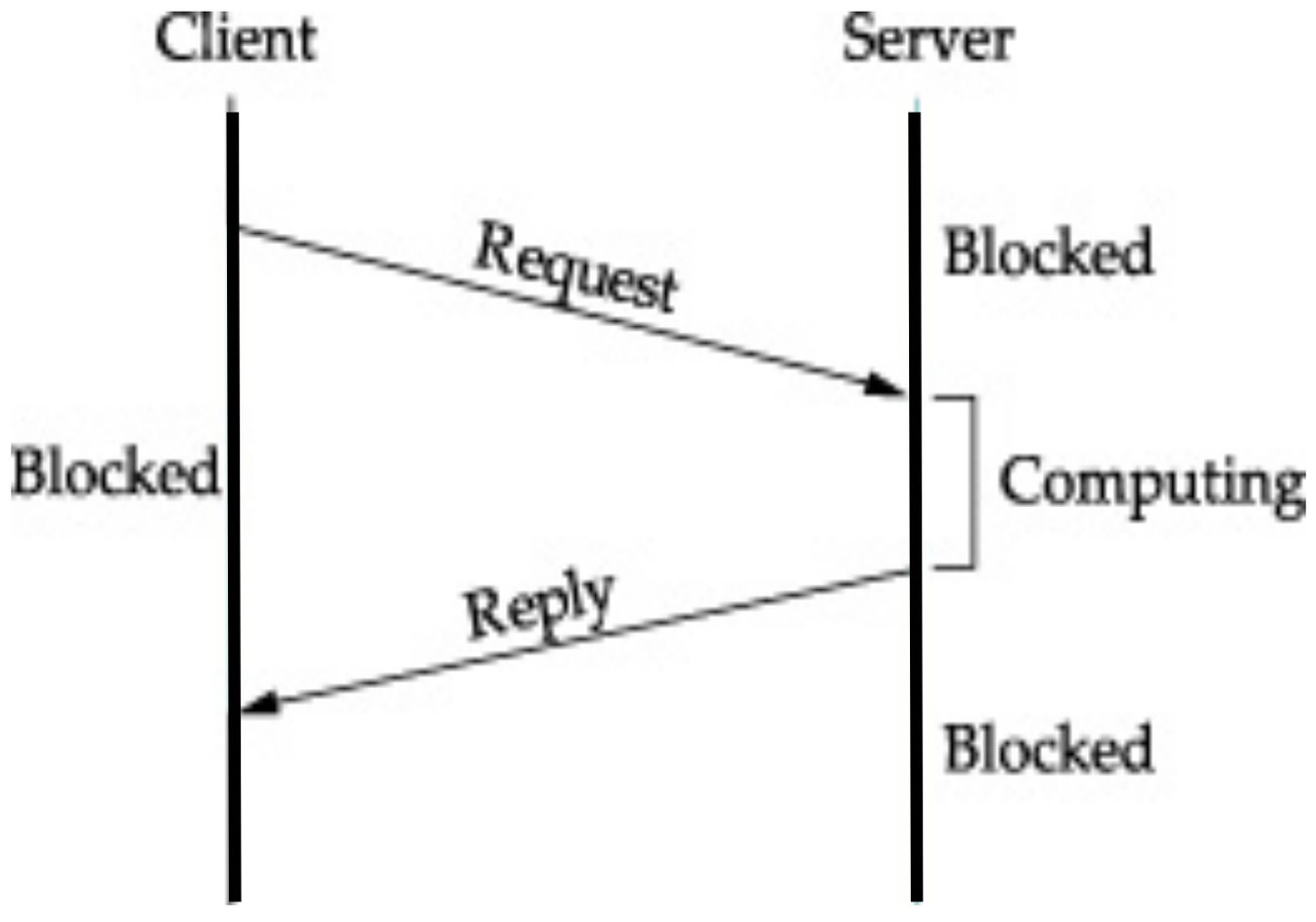
★Remote Procedure Call (RPC)

- Real-time Applications (RTP)
- Performance

Remote Procedure Call

- Request/Reply Protocol
- Different from UDP?
  - Reliable
  - Sequencing

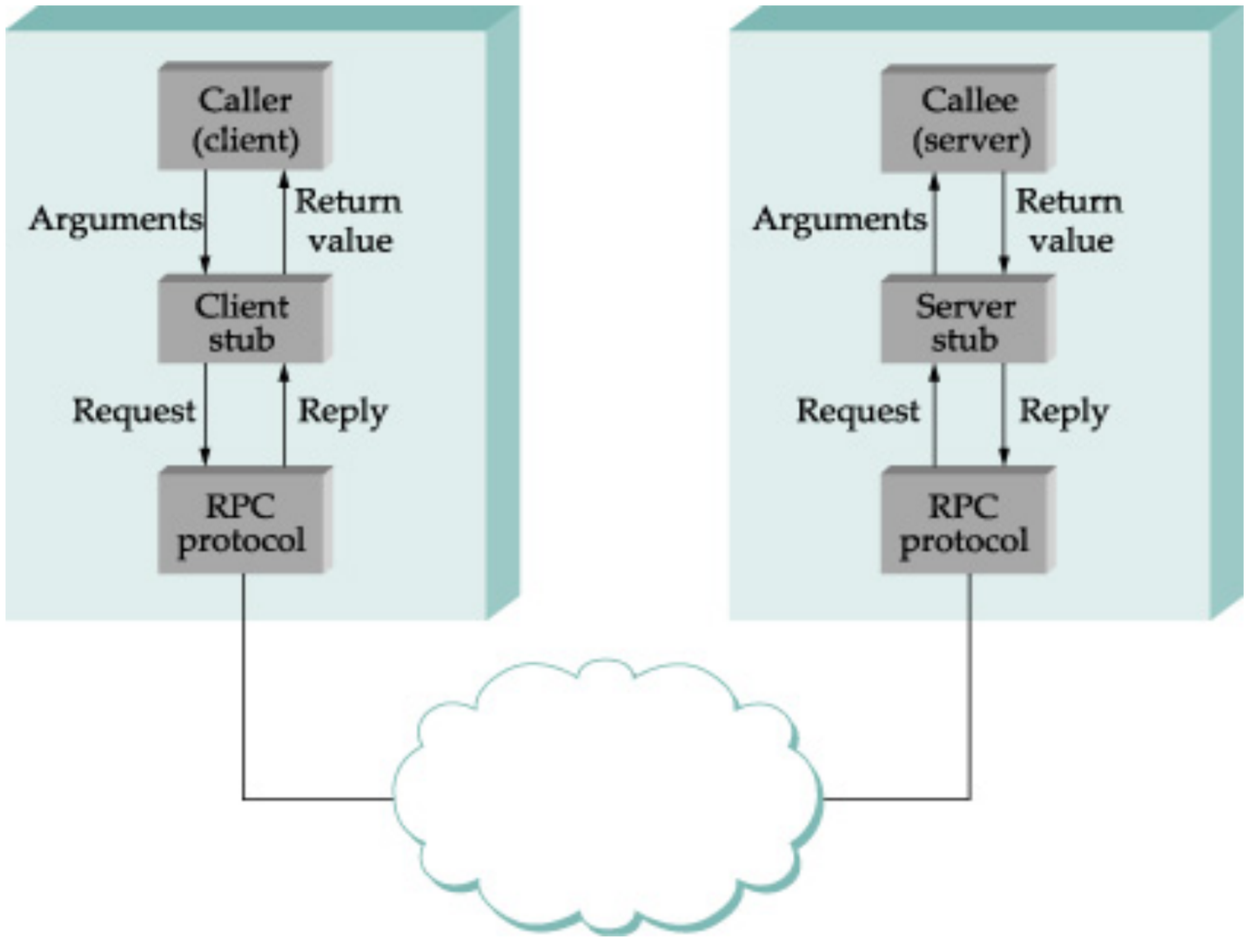
Request Reply



RPC Stack

- Client-Side
  - Generates “stubs”
  - Developer calls stubs
- Server-Side
  - Generates “server”
  - Server calls developers routines

RPC Stack


Caller
(client)
Arguments
Return
value
Client
stub
Request
Reply
RPC
protocol
Callee
(server)
Arguments
Return
value
Server
stub
Request
Reply
RPC
protocol

Serializing Data

- byte, word, character
- string
- array
- tree
- ... more complex data structures

RPC Questions

- RPC over UDP or over TCP or over IP?
- Textual data representation or binary
  - e.g. XML vs XDR

Other RPC-like Protocols

- Common Object Request Broker (CORBA)
- Distributed Component Object Module (DCOM)
- Remote Method Invocation (RMI)
- Simple Object Access Protocol (SOAP)

End To End Protocols

✓Simple Demultiplexer (UDP)

✓Reliable Stream (TCP)

✓Remote Procedure Call (RPC)

★Real-time Applications (RTP)

- Performance

Real-Time Applications

- Encodings… (mp3, aac, etc..)
- Timing of data at receiver
    - Synchronization
- Packet loss
- Frame boundaries

Real-Time Applications

- TCP
  - Has it’s own reliable transmission
  - Does not “know” the data
- UDP
  - Does very little, works well

End To End Protocols

✓Simple Demultiplexer (UDP)

✓Reliable Stream (TCP)

✓Remote Procedure Call (RPC)

✓Real-time Applications (RTP)

★Performance

End To End Protocols

✓ Simple Demultiplexer (UDP)

✓ Reliable Stream (TCP)

✓ Remote Procedure Call (RPC)

✓ Real-time Applications (RTP)

✓ Performance

End

End To End Protocols