CSC4200/5200 – COMPUTER NETWORKING

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CONGESTION CONTROL

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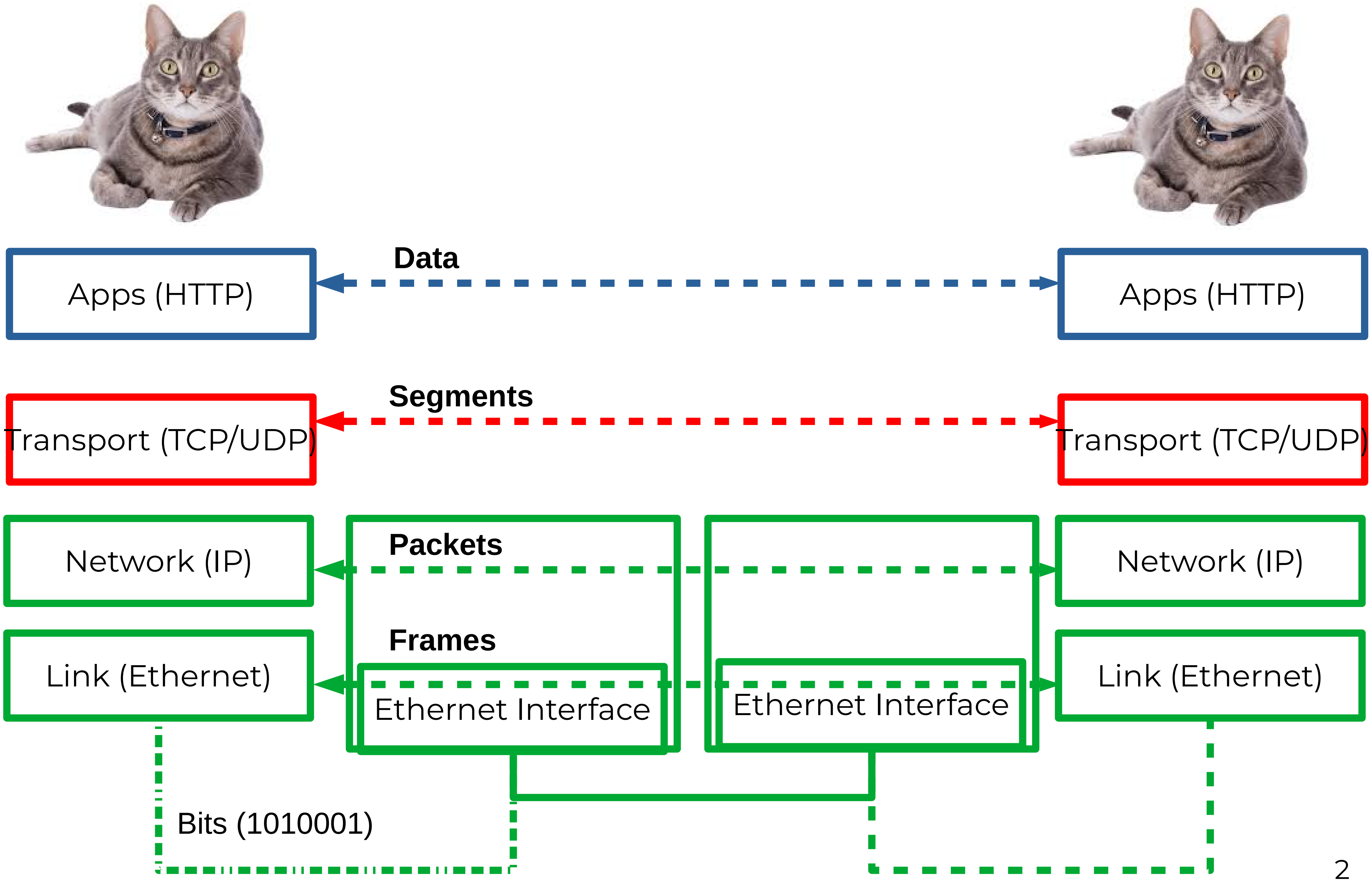
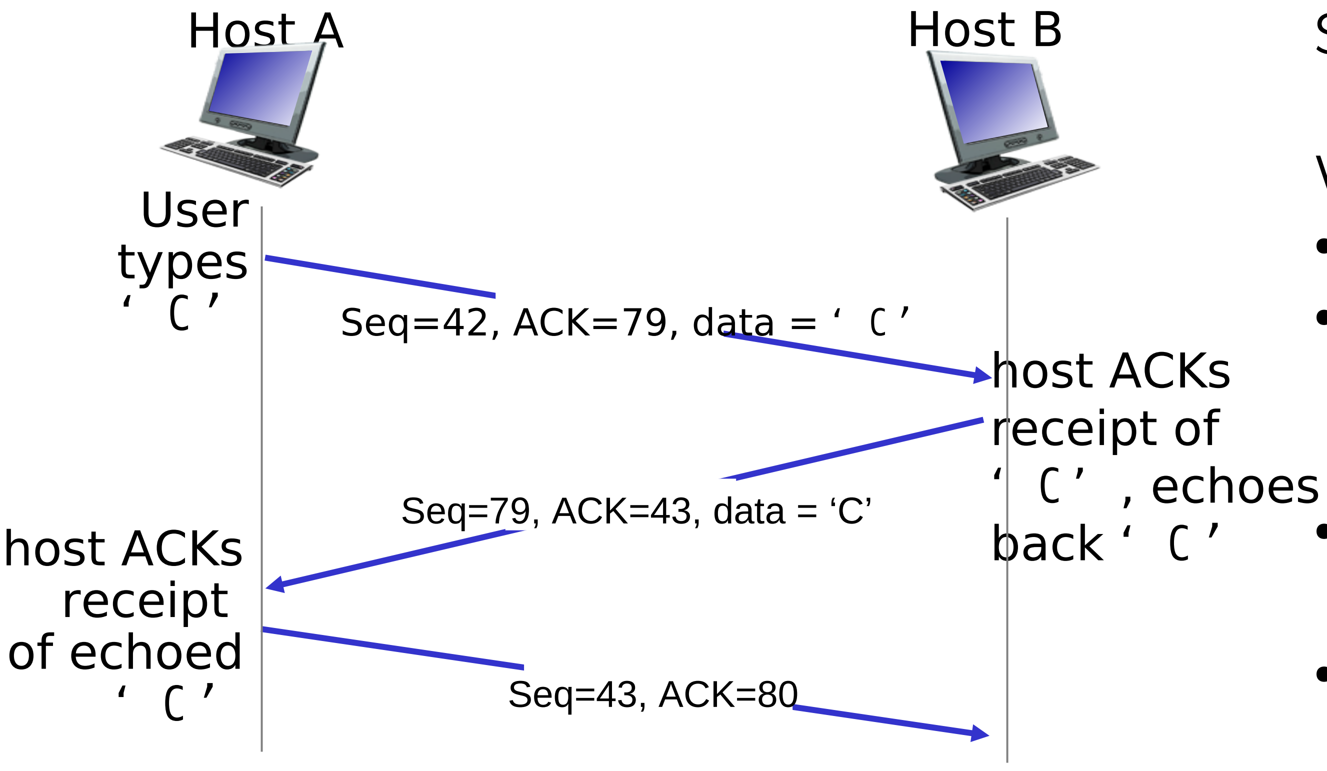
Tennessee TECH


Data
Apps (HTTP)
Apps (HTTP)
Segments
Transport (TCP/UDP)
Transport (TCP/UDP)
Packets
Network (IP)
Network (IP)
Frames
Link (Ethernet)
Ethernet Interface
Ethernet Interface
Link (Ethernet)
Bits (1010001)

TCP seq. numbers, ISNs



simple telnet scenario

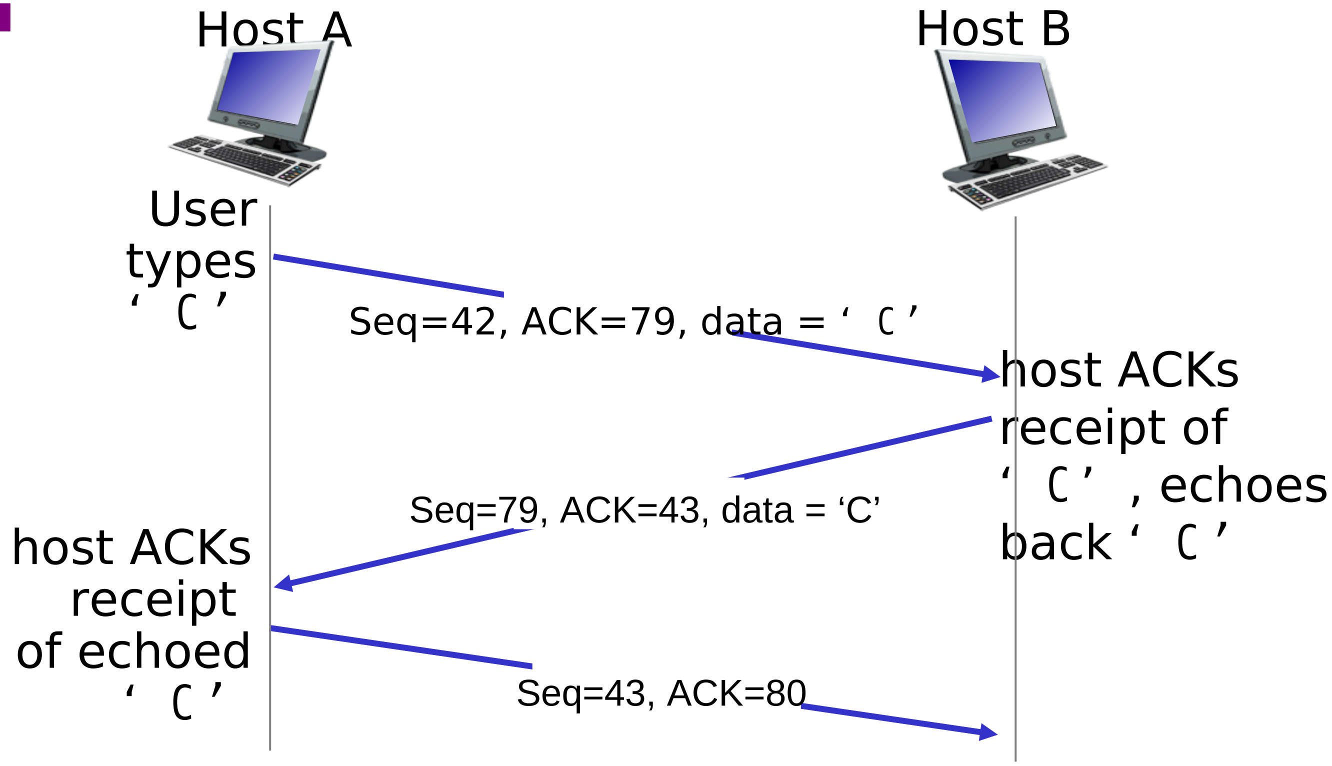
Sequence number for the first byte

Why not use 0 all the time?

- Security
- Port are reused, you might end up using someone else’s previous connection
- Phone number analogy

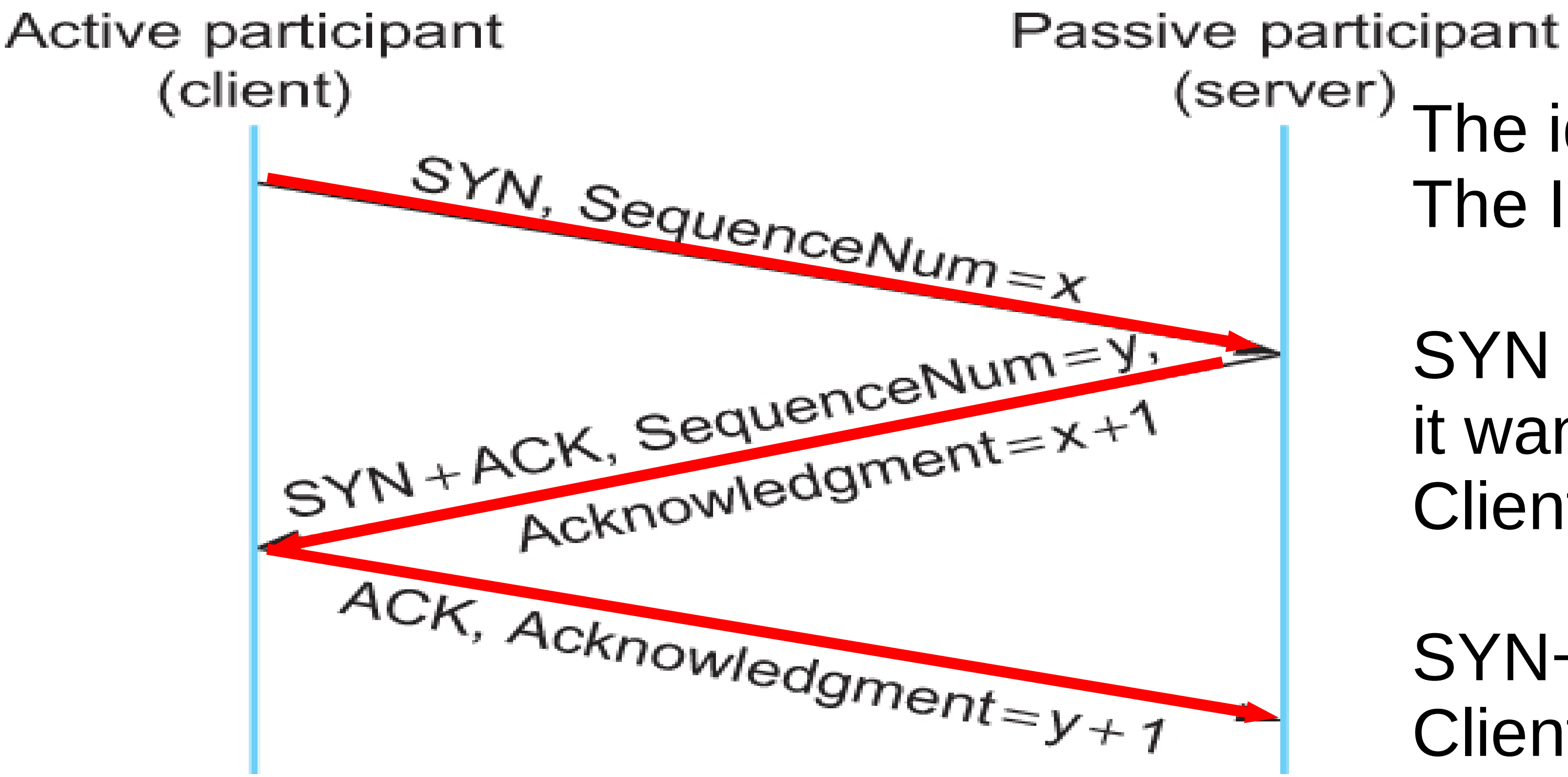
- TCP ISNs are clock based
  - 32 bits, increments in 4 microseconds
  - 4.55 hours wrap around time

TCP seq. numbers, ACKs



simple telnet scenario

TCP Three-way Handshake



Timeline for three-way handshake algorithm

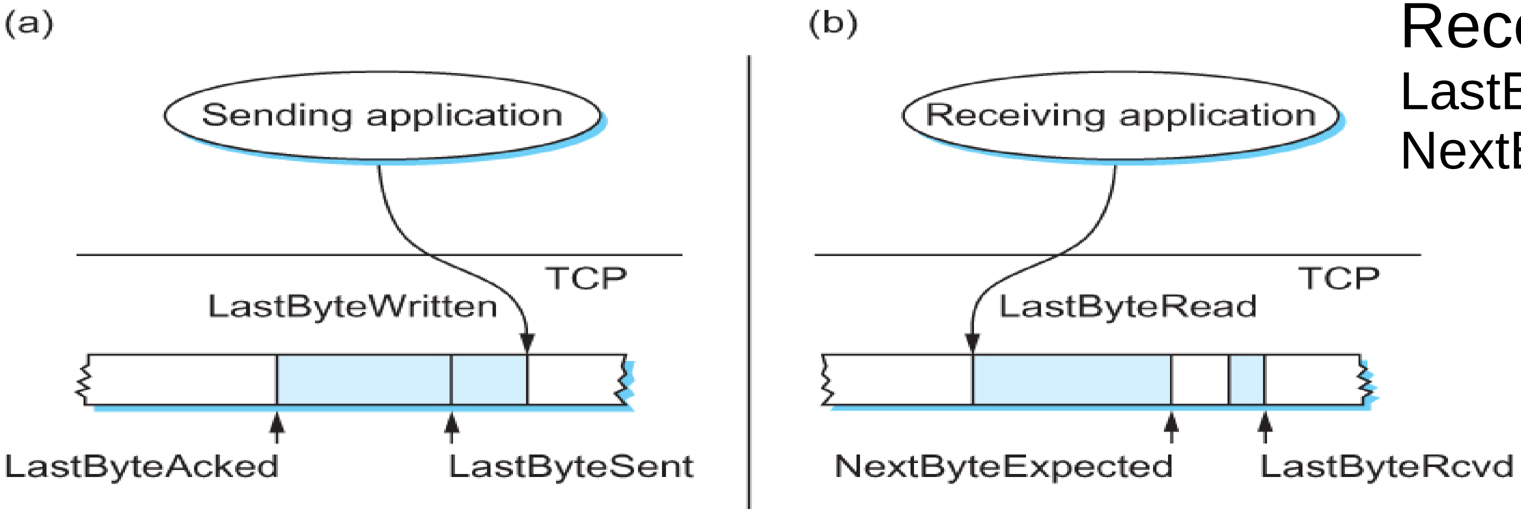
The idea is to tell each other
The ISNs

SYN → Client tells server that it wants to open a connection, Client's ISN = x

SYN+ ACK → Server tells Client → Okay → Server's ISN = y, ACK = CLSeq + 1

Why increment by 1?

Sliding Window Revisited



Sending Side

LastByteAcked ≤ LastByteSent

LastByteSent ≤ LastByteWritten

Receiving Side

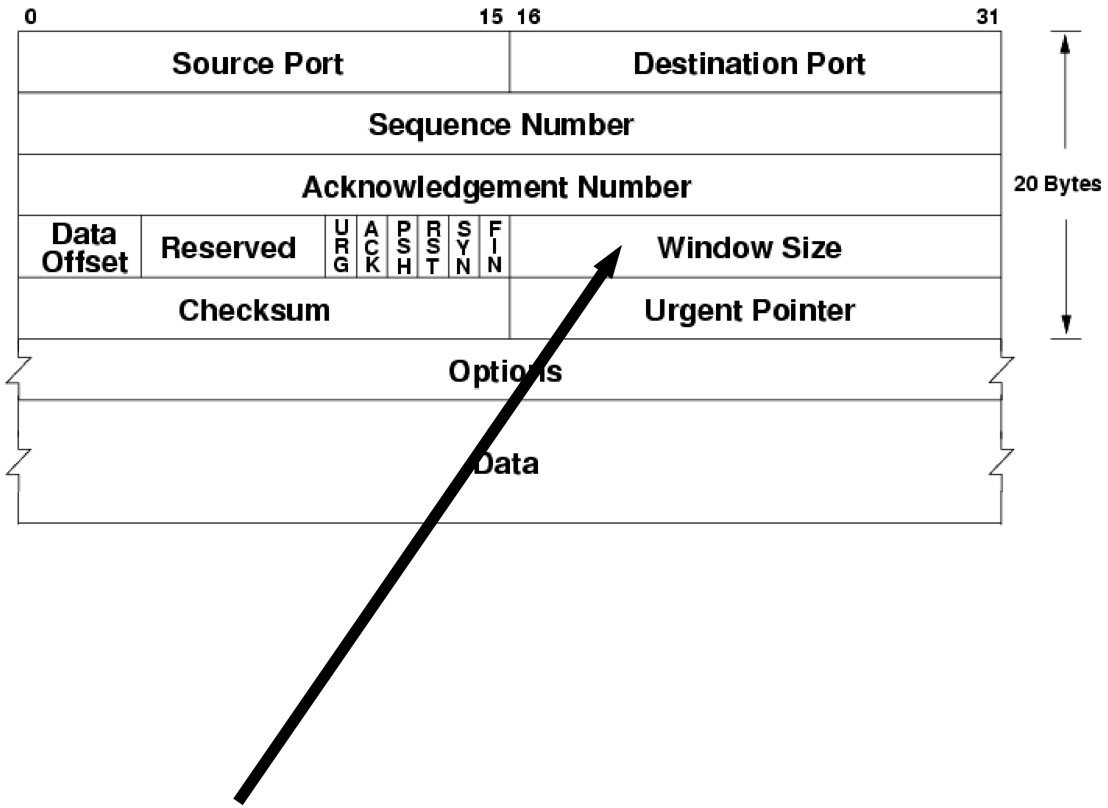
LastByteRead < NextByteExpected

NextByteExpected ≤ LastByteRcvd + 1

Relationship between TCP send buffer (a) and receive buffer (b).

TCP flow control

- receiver "advertises" free buffer space in the header
- sender limits amount of unacked ("in-flight") data to receiver's **`rwnd`** value
- guarantees receive buffer will not overflow

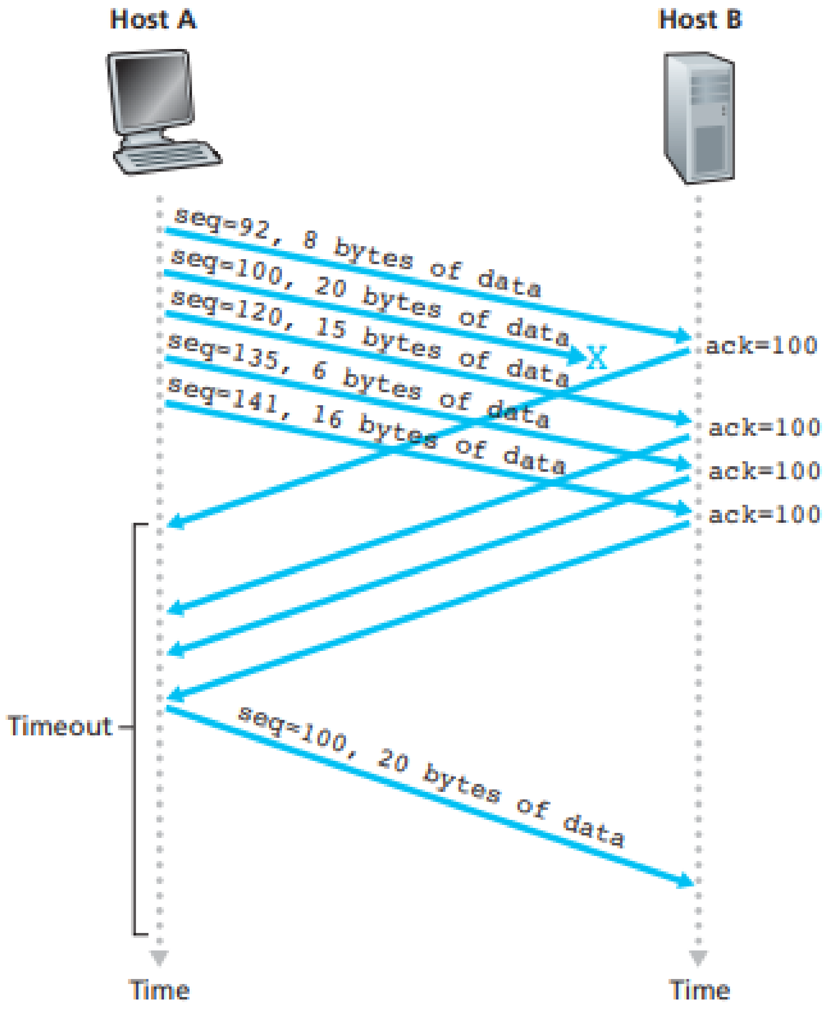


TCP Fast Retransmission

Timeouts are wasteful

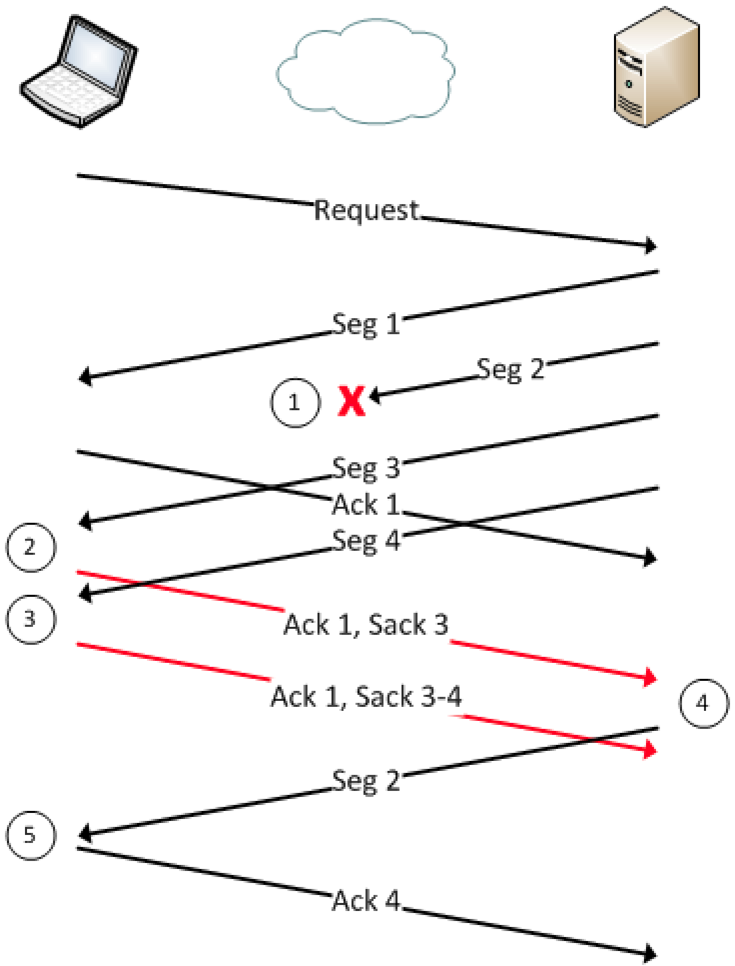
Triple duplicate ACKs

Retransmits before timeout



TCP Fast Retransmission - SACK

What if multiple segments are lost?

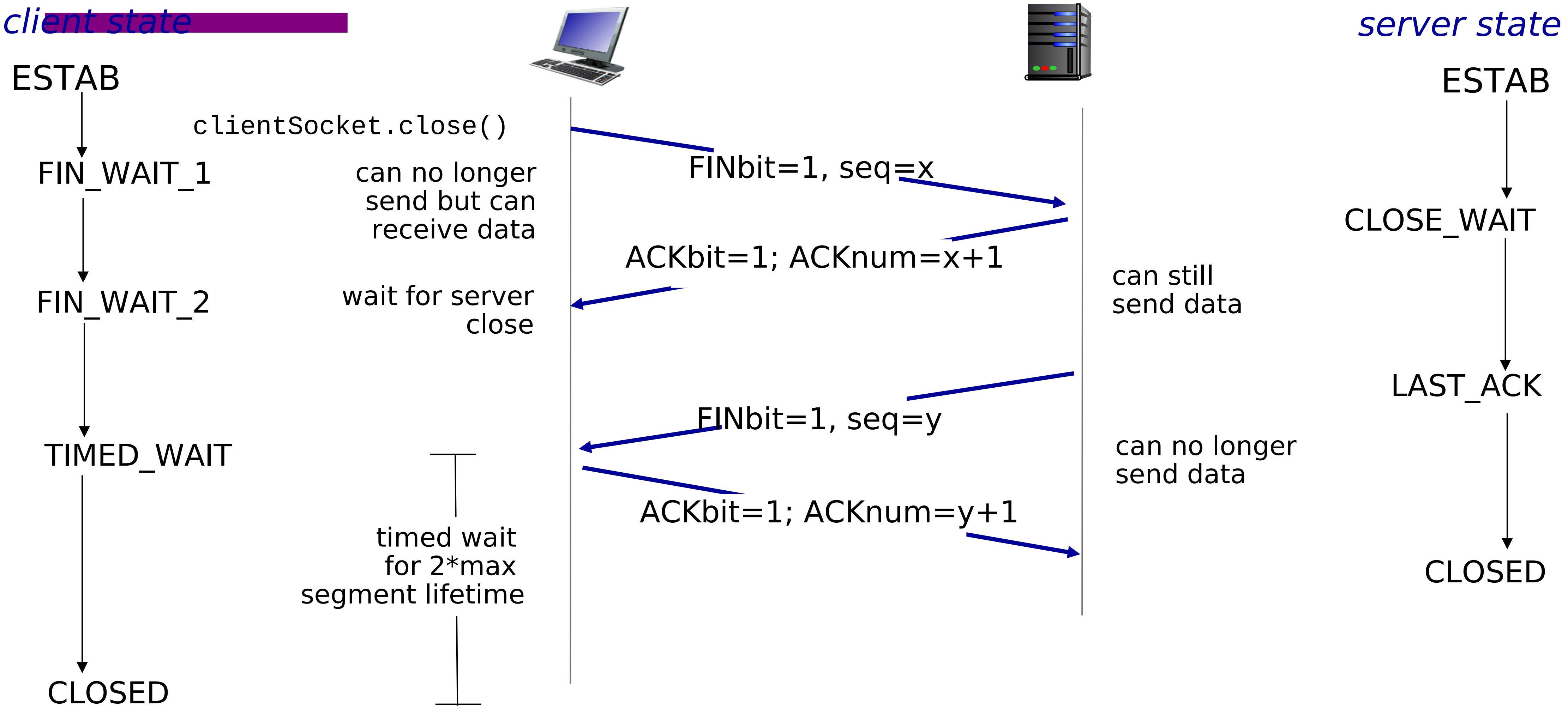


Very good explanation:
https://packetlife.net/blog/2010/jun/17/tcp-selective-acknowledgments-sack/

TCP: closing a connection

- client, server each close their side of connection
  - send TCP segment with FIN bit = 1
- respond to received FIN with ACK
  - on receiving FIN, ACK can be combined with own FIN
- simultaneous FIN exchanges can be handled

TCP: closing a connection



Why do we need ack for closing?

- Data in-flight

Congestion Control

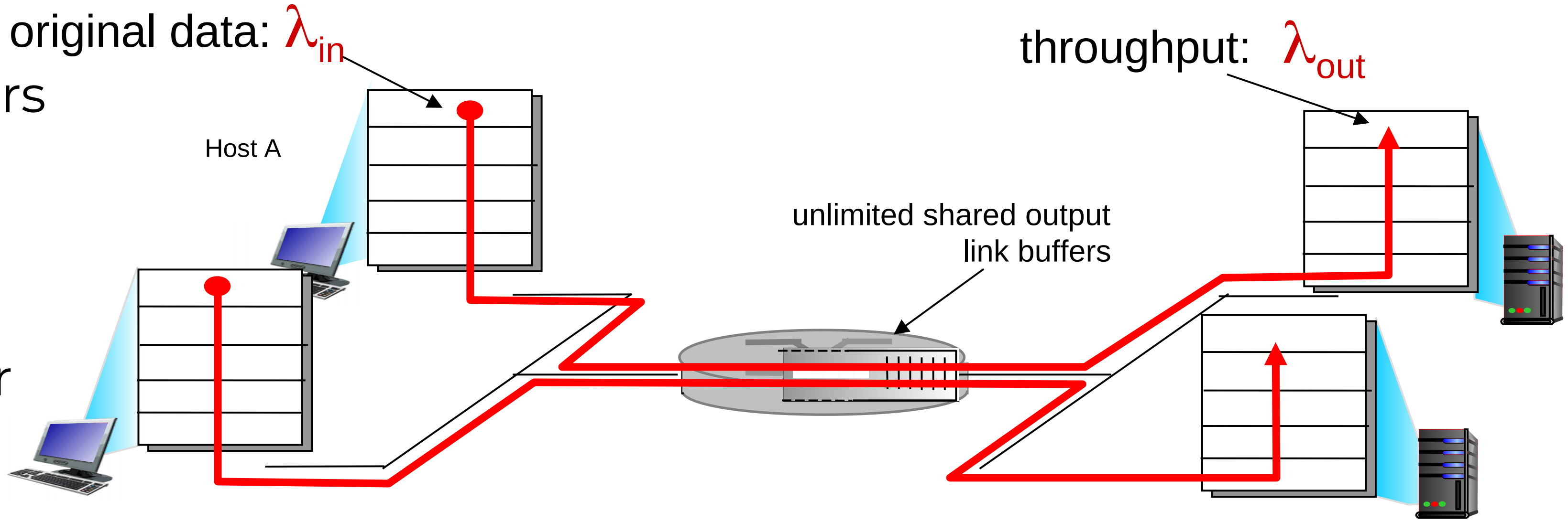
Principles of congestion control

congestion:

- informally: "too many sources sending too much data too fast for *network* to handle"
- different from flow control!
- manifestations:
  - lost packets (buffer overflow at routers)
  - long delays (queueing in router buffers)
- a top-10 problem!

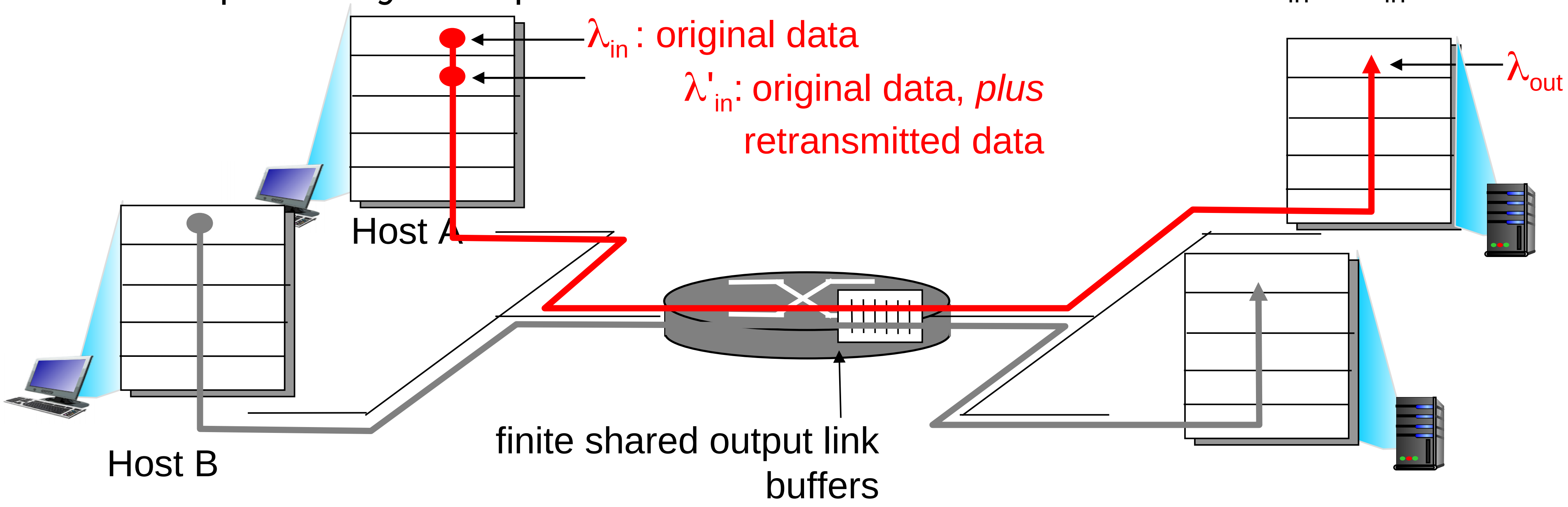
Congestion: scenario 1

- three senders, two receivers
- one router, infinite buffers
- output link capacity: R
- The router can only transmit one –... and either buffer or drop the other
- If many packets arrive,
- Buffer overflow



Causes/costs of congestion: scenario 2

- one router, *finite* buffers
- sender retransmission of timed-out packet
  - application-layer input = application-layer output: $\lambda_{in} = \lambda_{out}$
  - transport-layer input includes *retransmissions* : λ_{in} λ_{in}



Metrics: Throughput vs Delay

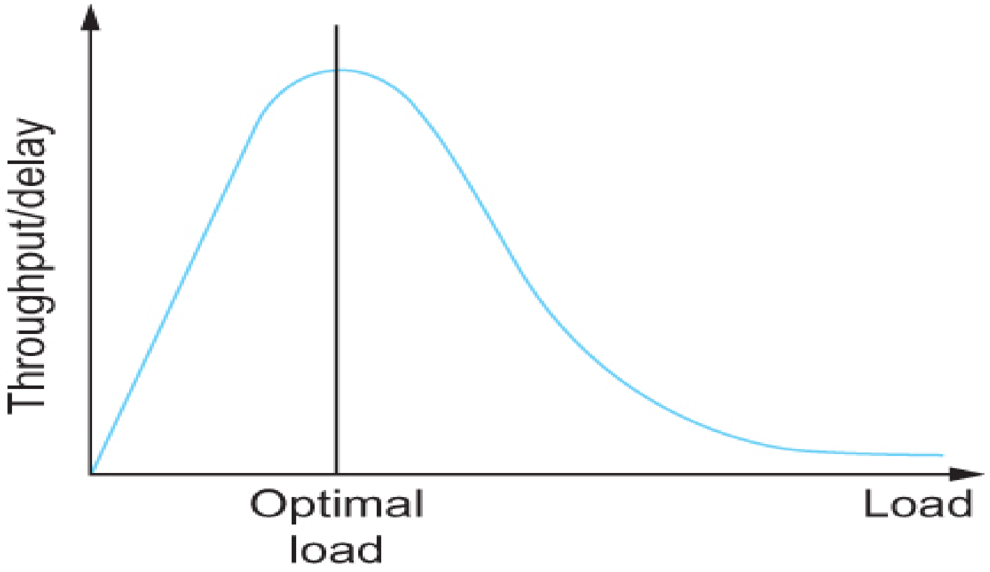
High throughput –

- Throughput: measured performance of a system –E.g., number of bits/second of data that get through
- Low delay –
- Delay: time required to deliver a packet or message –E.g., number of ms to deliver a packet •
- These two metrics are sometimes at odds –
  - More packets = more queuing

Issues in Resource Allocation

- Evaluation Criteria
  - Effective Resource Allocation

power of the network.
Power = Throughput/Delay



Ratio of throughput to delay as a function of load

Issues in Resource Allocation

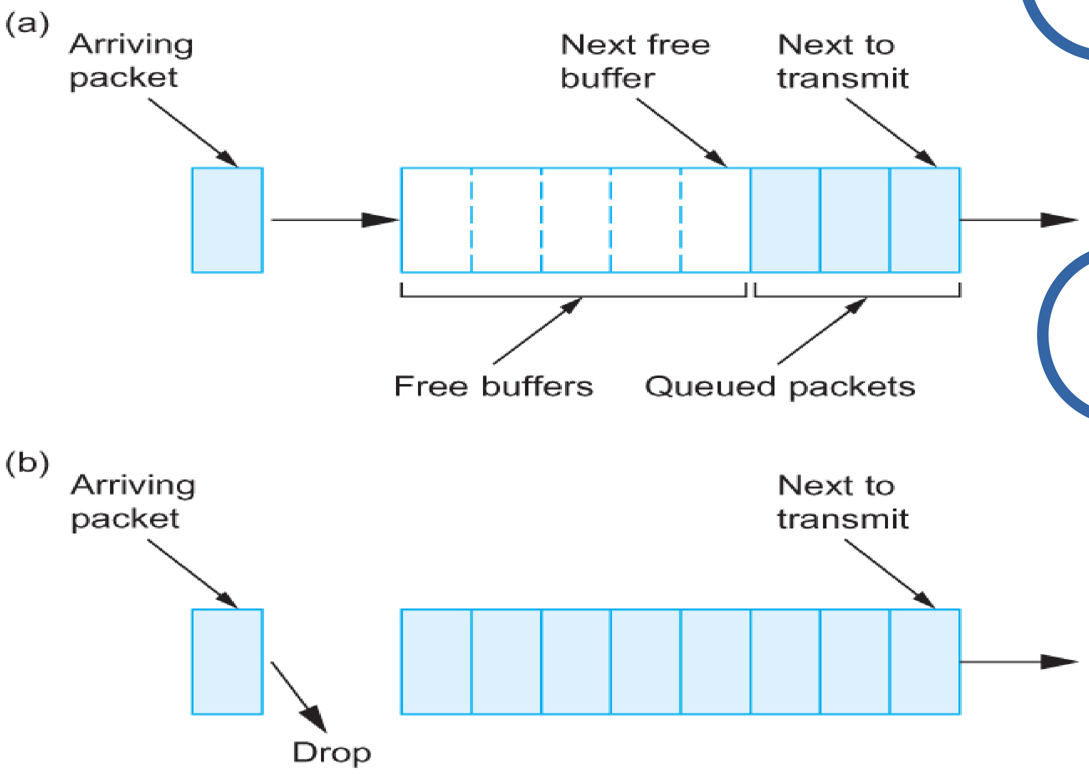
- Evaluation Criteria
  - Fair Resource Allocation
    - The effective utilization of network resources is not the only criterion for judging a resource allocation scheme.
    - We want to be “fair”
    - Equal share of bandwidth

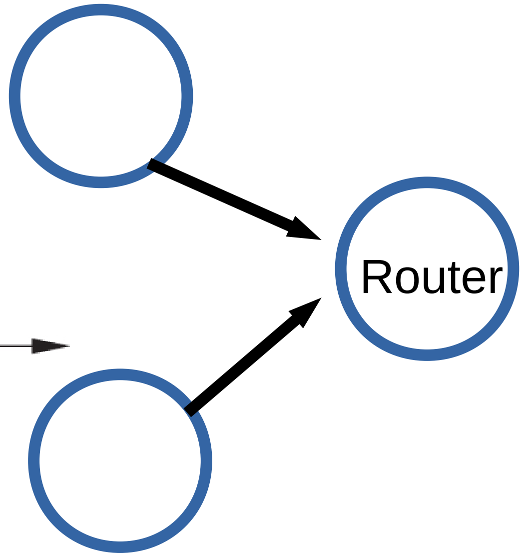
But, what if the flows traverse different paths?

Open problem, often determined by economics

Queuing Disciplines

Simplest – FIFO
and drop tail





(a) FIFO queuing; (b) tail drop at a FIFO queue.

What are the problems?

Defining Fairness: Flows

“fair” to whom?   – Should be Fair to a Flow

What is a flow?

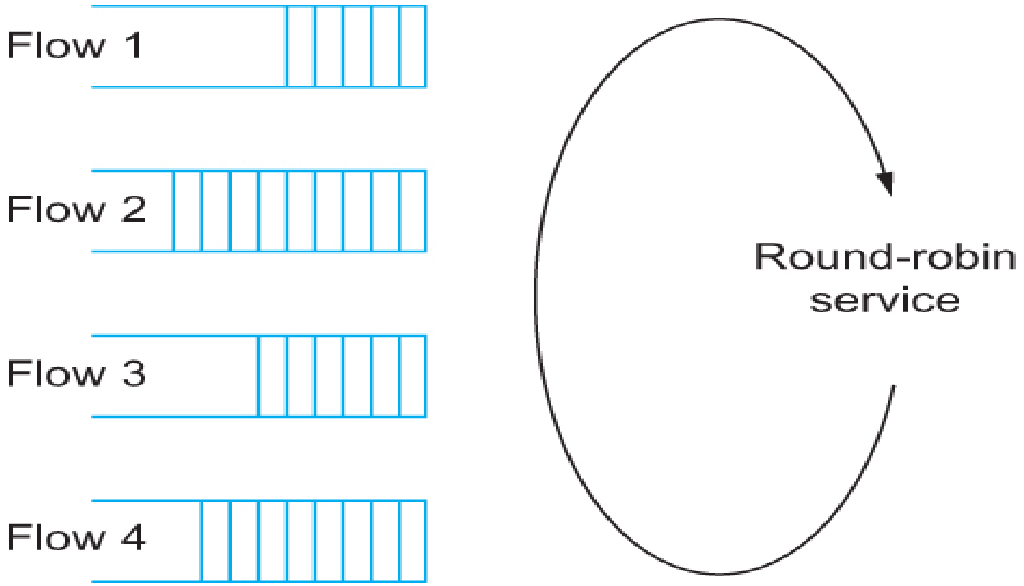
Combination of <Src IP, Src Port, Dst IP, Dst Port>

Fair Queuing

- Fair Queuing
  - FIFO does not discriminate between different traffic sources, or
  - it does not separate packets according to the flow to which they belong.
  - Fair queuing (FQ) maintains a separate queue for each flow

Queuing Disciplines

- Fair Queuing



Round-robin service of four flows at a router

Next steps

MaxMin algorithm and TCP Congestion control