Transport Layer 4

ELEC3227/ELEC6255

Alex Weddell
asw@ecs.soton.ac.uk

University of Southampton
School of Electronics and Computer Science

Photo by Alvaro Reyes on Unsplash

UNIVERSITY OF Southampton
School of Electronics and Computer Science

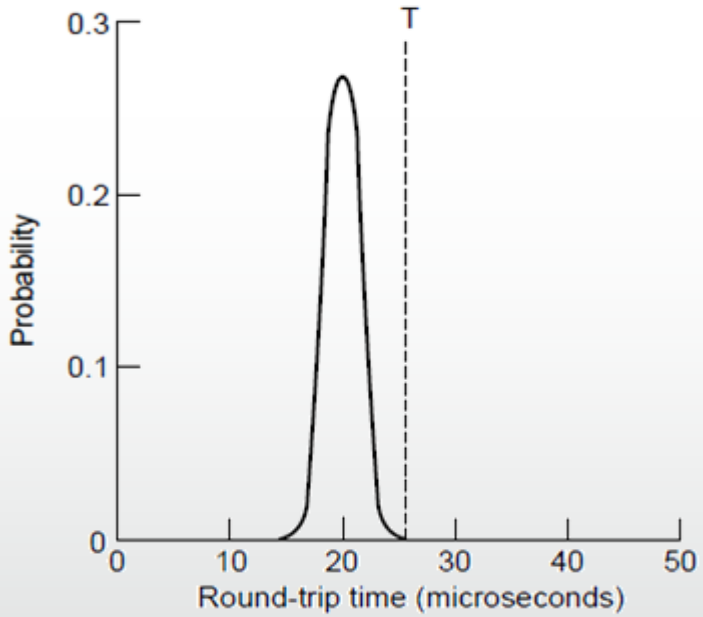
Overview

- TCP Congestion Control
- Real-time Transport
- Questions

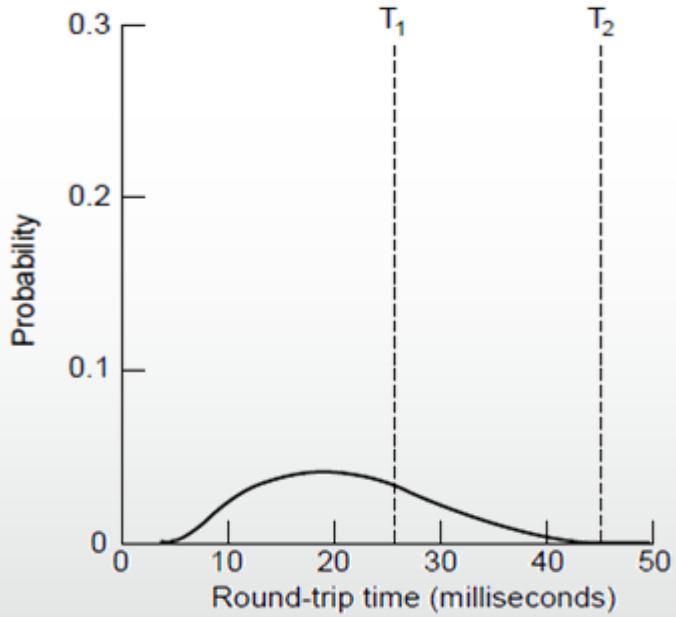
UNIVERSITY OF Southampton
School of Electronics and Computer Science

TCP Timer Management

- TCP estimates retransmit timer from segment RTTs
  - Tracks both average and variance (for Internet case)
  - Timeout is set to average plus 4 x variance



LAN case – small, regular RTT



Internet case – large, varied RTT

UNIVERSITY OF Southampton
School of Electronics and Computer Science

TCP Congestion Control

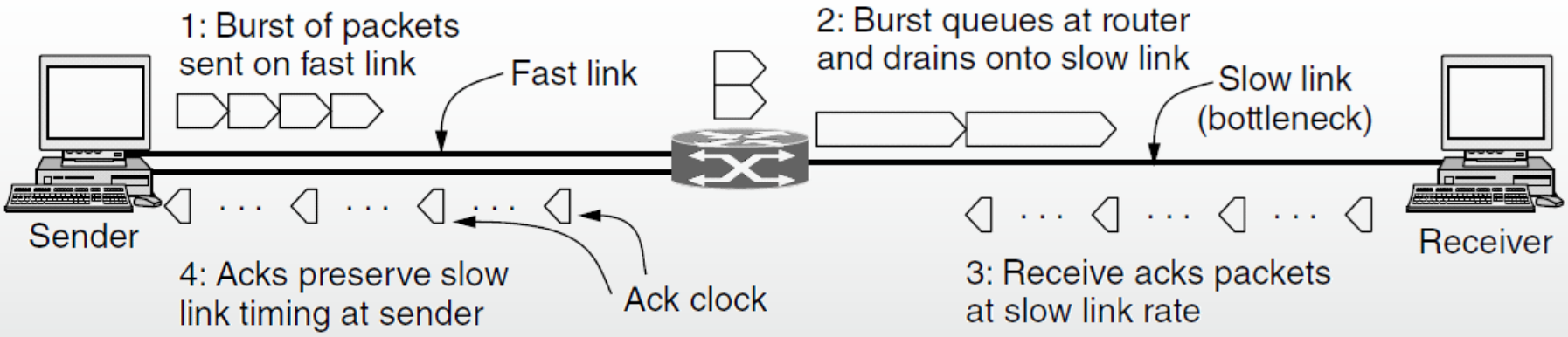
TCP uses AIMD with loss signal to control congestion

- Implemented as a congestion window (cwnd) for the number of segments that may be in the network
- Uses several mechanisms that work together

Name	Mechanism	Purpose
ACK clock	Congestion window (cwnd)	Smooth out packet bursts
Slow-start	Double cwnd each RTT	Rapidly increase send rate to reach roughly the right level
Additive Increase	Increase cwnd by 1 packet each RTT	Slowly increase send rate to probe at about the right level
Fast retransmit / recovery	Resend lost packet after 3 duplicate ACKs; send new packet for each new ACK	Recover from a lost packet without stopping ACK clock

TCP Congestion Control

- Congestion window controls the sending rate
  - Rate is cwnd / RTT; window can stop sender quickly
  - ACK clock (regular receipt of ACKs) paces traffic and smoothes out sender bursts

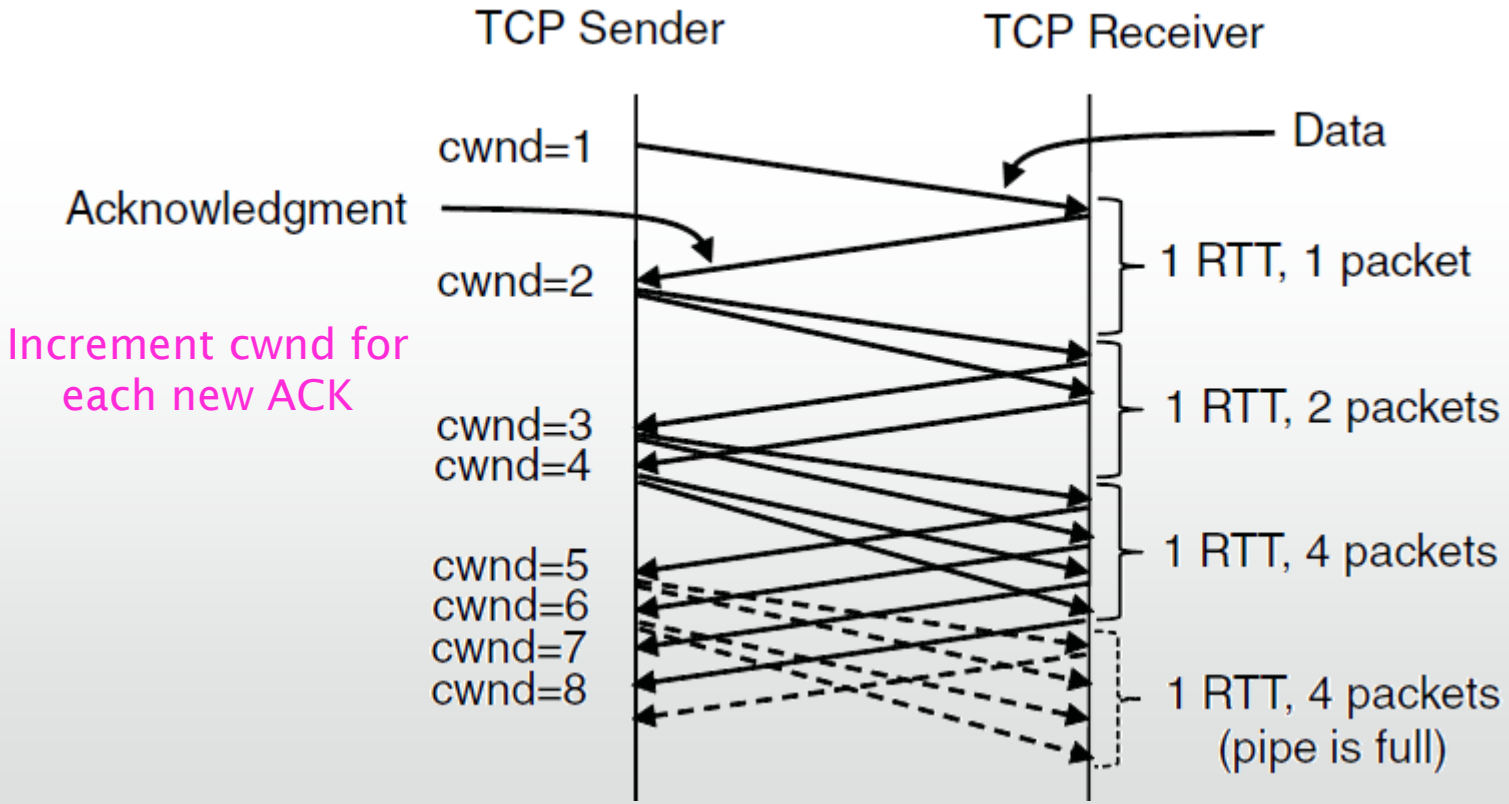


ACKs pace new segments into the network and smooth bursts

UNIVERSITY OF Southampton
School of Electronics and Computer Science

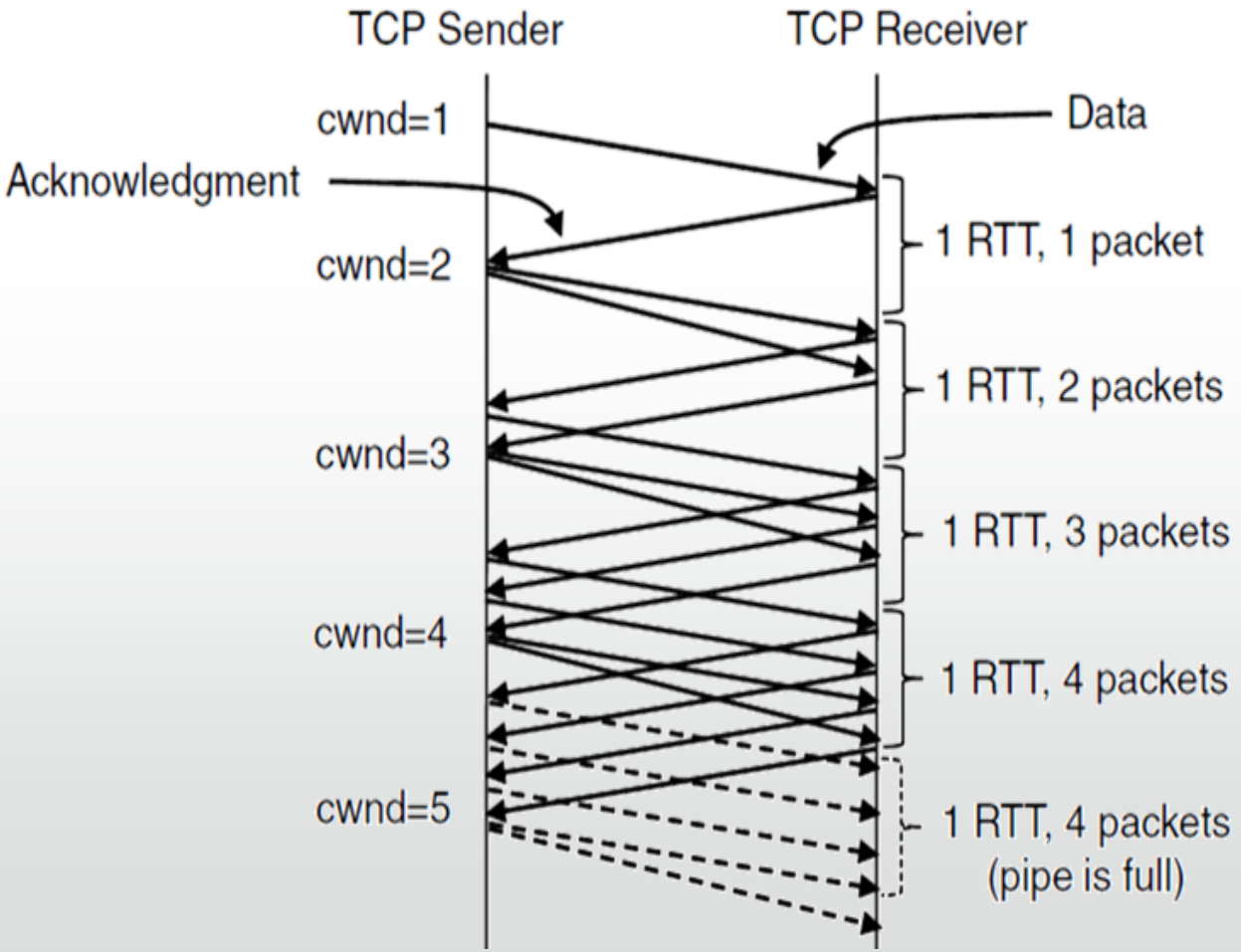
TCP Congestion Control

- Slow start grows congestion window exponentially
  - Doubles every RTT while keeping ACK clock going



TCP Congestion Control

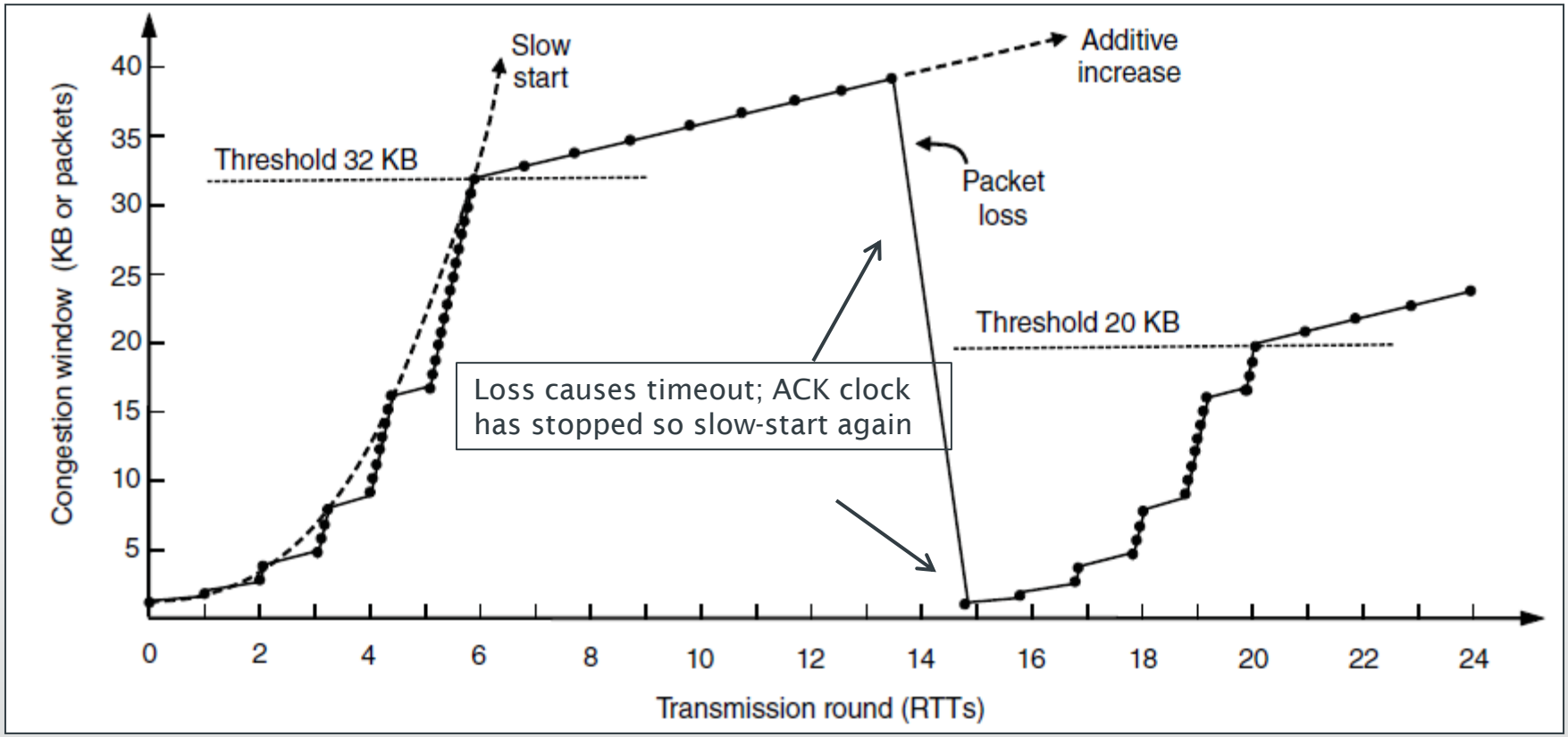
- Additive increase grows cwnd slowly
  - Adds 1 every RTT
  - Keeps ACK clock



UNIVERSITY OF Southampton
School of Electronics and Computer Science

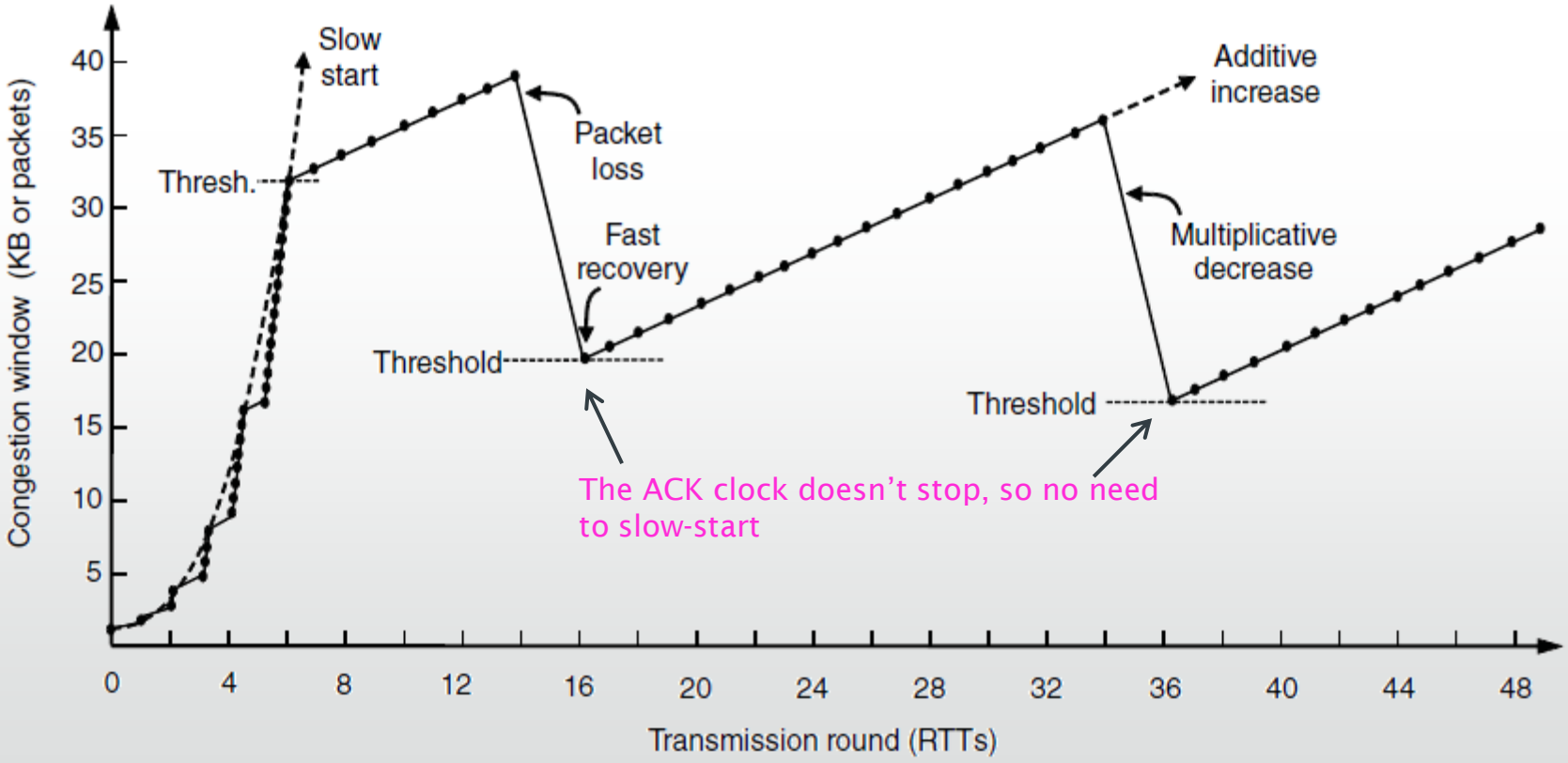
TCP Congestion Control

- Slow start followed by additive increase (TCP Tahoe)
  - Threshold is half of previous loss cwnd



TCP Congestion Control

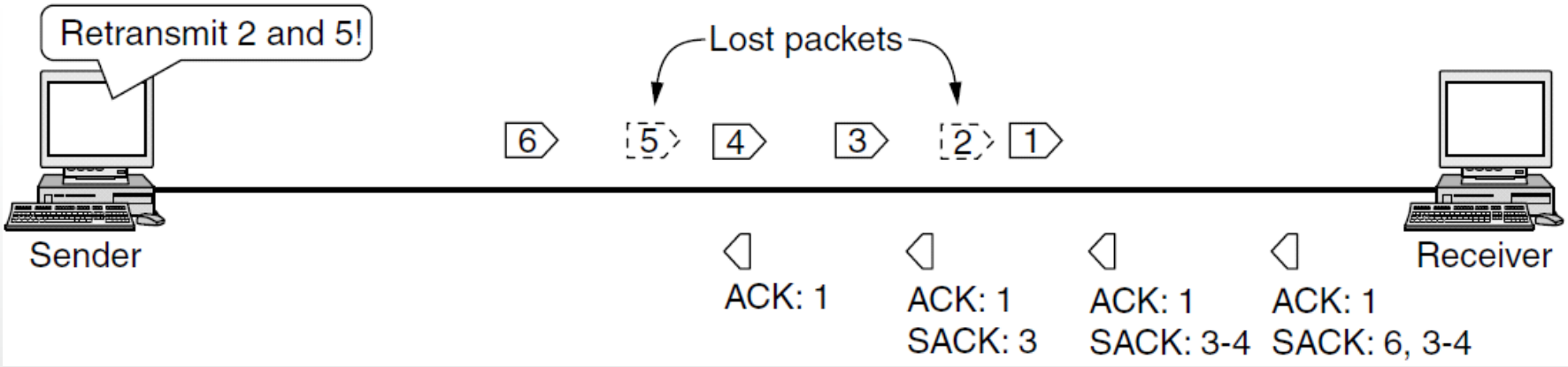
- With fast recovery, we get the classic sawtooth (TCP Reno)
  - Retransmit lost packet after 3 duplicate ACKs
  - New packet for each dup. ACK until loss is repaired



UNIVERSITY OF Southampton
School of Electronics and Computer Science

TCP Congestion Control

- SACK (Selective ACKs) extend ACKs with a vector to describe received segments and hence losses
  - Allows for more accurate retransmissions / recovery

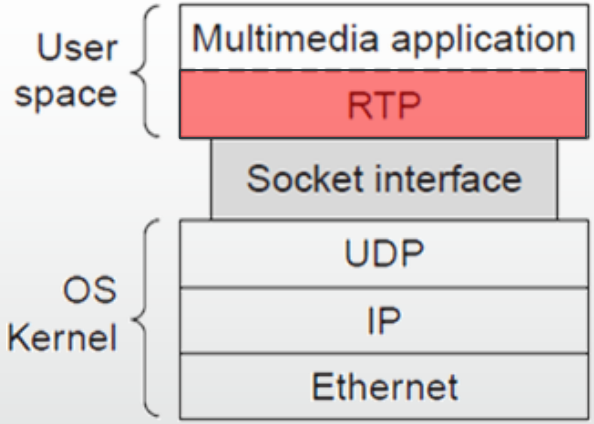


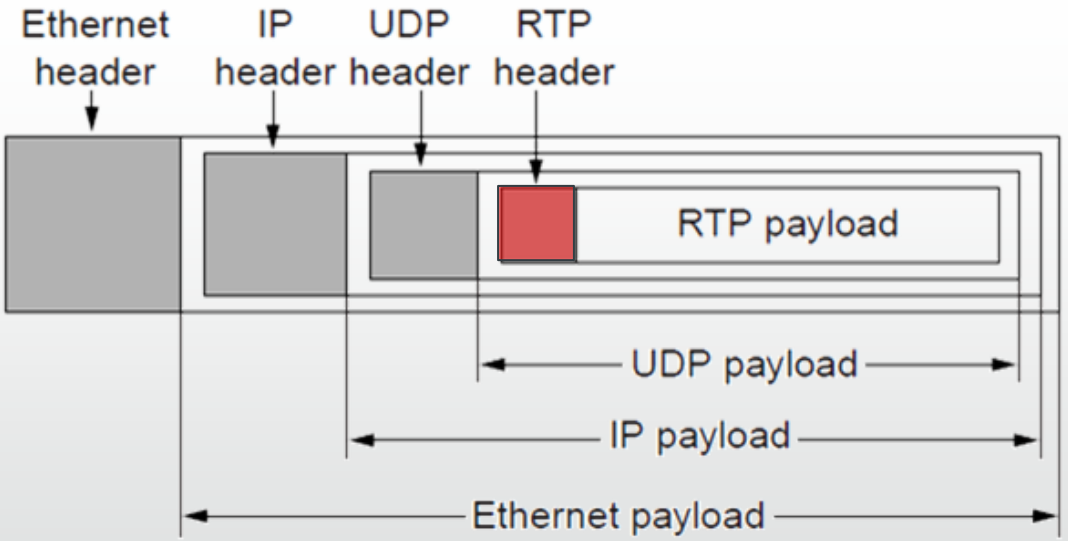
No way for us to know that 2 and 5 were lost with only ACKs

UNIVERSITY OF Southampton
School of Electronics and Computer Science

Real-Time Transport

- RTP (Real-time Transport Protocol) provides support for sending real-time media over UDP
  - Often implemented as part of the application

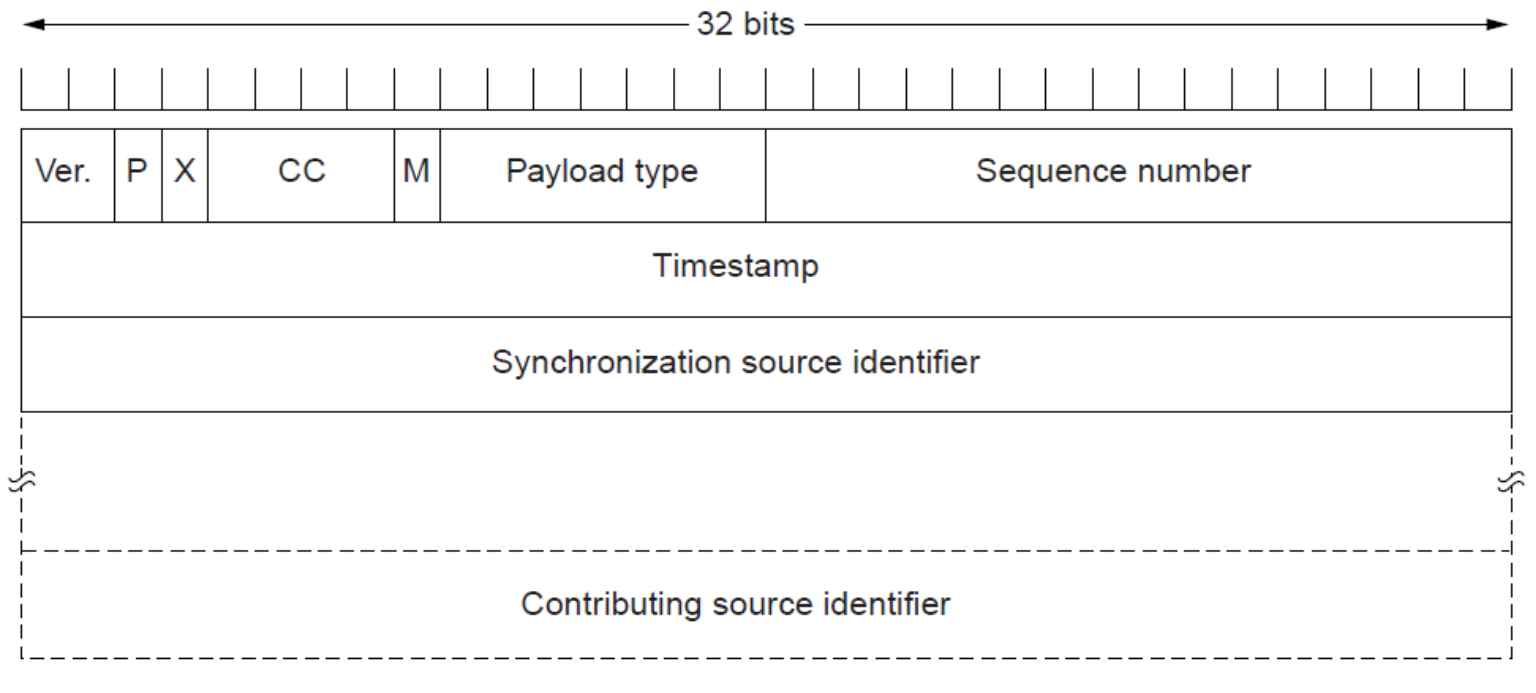




UNIVERSITY OF Southampton
School of Electronics and Computer Science

Real-Time Transport

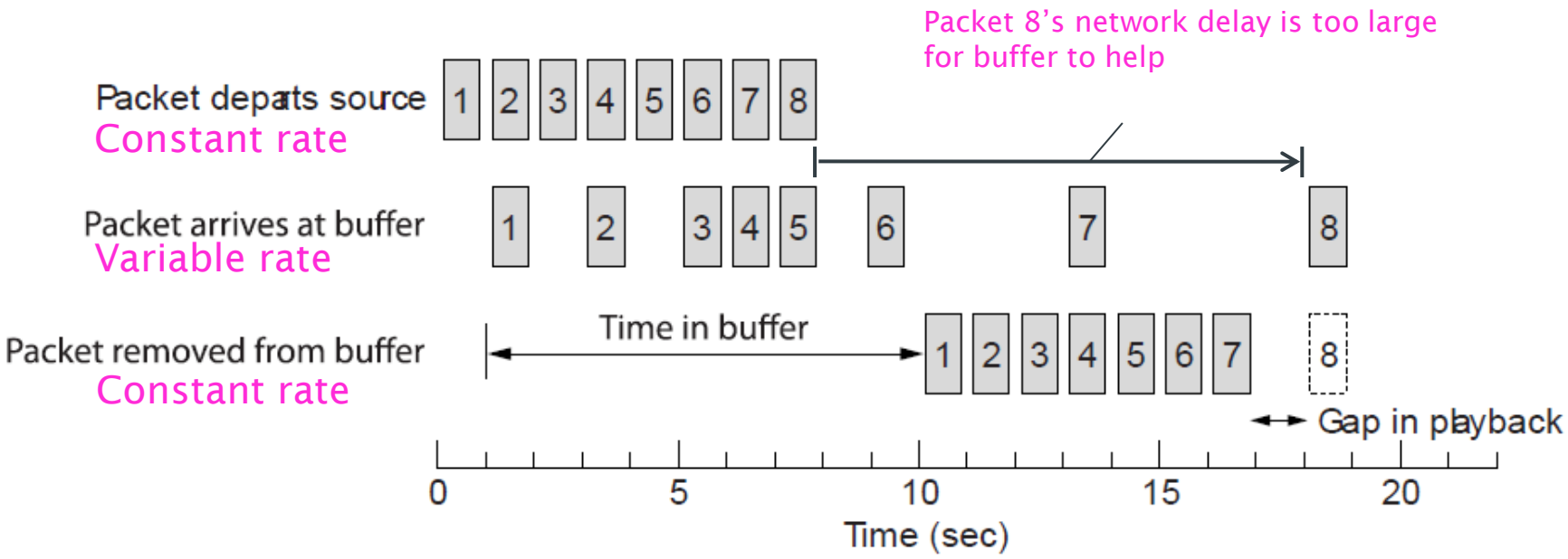
- RTP header contains fields to describe the type of media and synchronize it across multiple streams



UNIVERSITY OF Southampton
School of Electronics and Computer Science

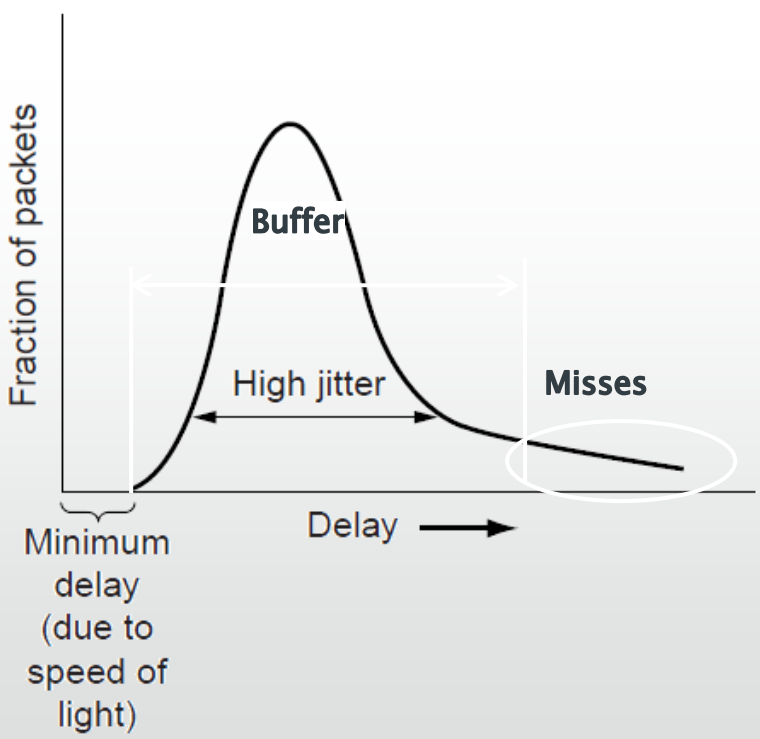
Real-Time Transport

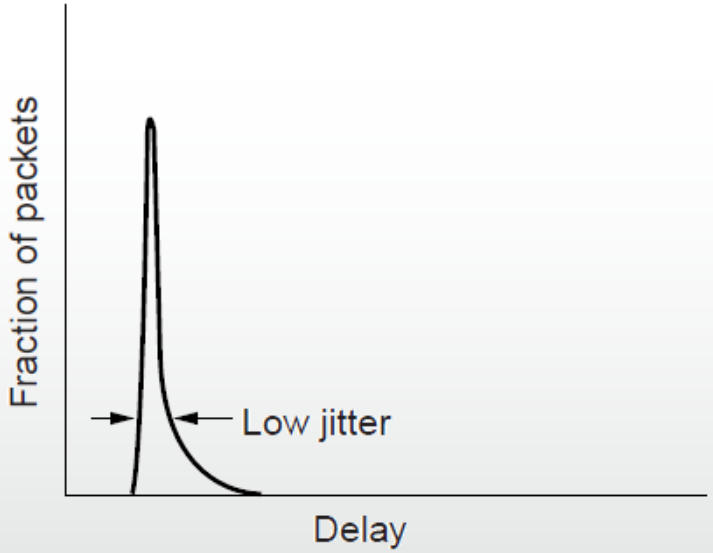
- Buffer at receiver is used to delay packets and absorb jitter so that streaming media is played out smoothly



Real-Time Transport

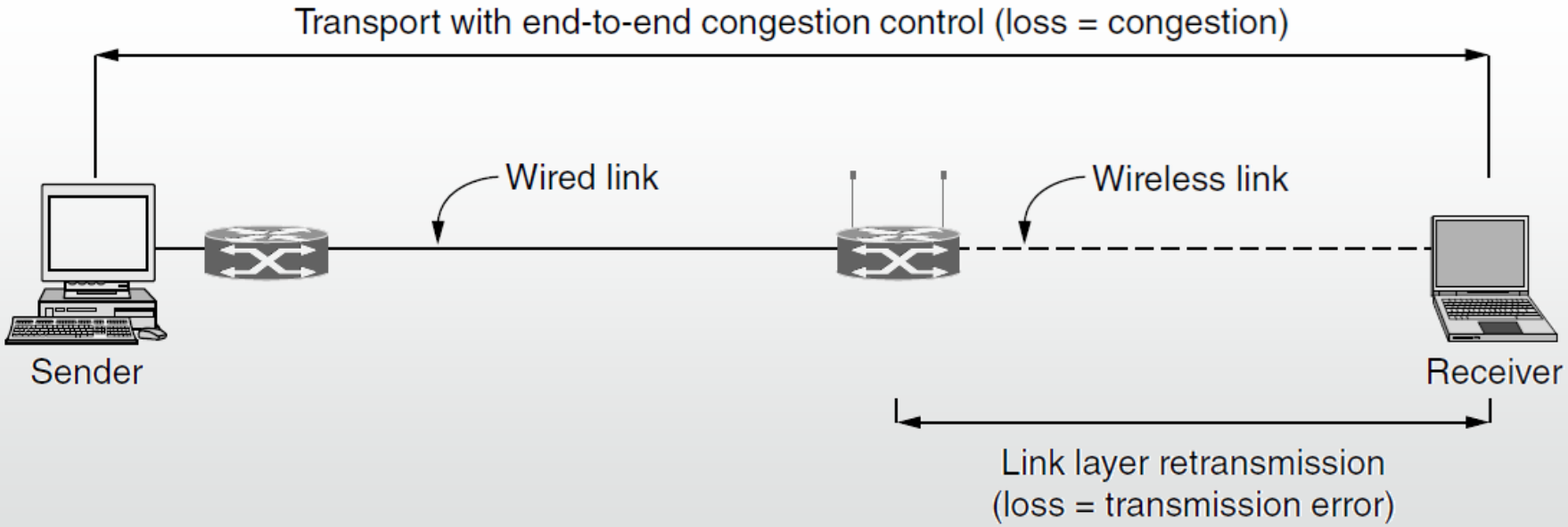
- High jitter, or more variation in delay, requires a larger playout buffer to avoid playout misses
  - Propagation delay does not affect buffer size





Wireless Issues

- Wireless links lose packets due to transmission errors
  - Do not want to confuse this loss with congestion
  - Or connection will run slowly over wireless links!
- Strategy:
  - Wireless links use ARQ (Automatic Repeat Request), which masks errors



Summary

- Regulating the Sending Rate
- TCP Connection State
- TCP Sliding Window
- TCP Congestion Control

Questions

UNIVERSITY OF Southampton
School of Electronics and Computer Science

Question 1

In both parts of the Internet File Server example, there is a comment that the value of SERVER PORT must be the same in both client and server.

Why is this so important?

UNIVERSITY OF Southampton
School of Electronics and Computer Science

Question 2

Suppose that the clock-driven scheme for generating initial sequence numbers is used with a **15-bit wide clock counter**. The clock **ticks** once every **100 msec**, and the maximum packet lifetime is **60 sec**. How often need resynchronization take place:

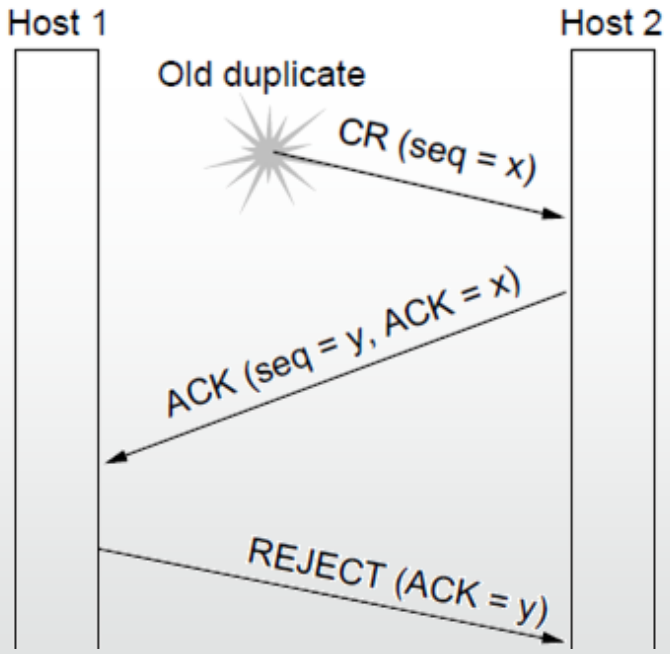
(a) in the worst case?

(b) when the data consumes 240 sequence numbers/min?

UNIVERSITY OF Southampton
School of Electronics and Computer Science

Question 3

Why does the **maximum packet lifetime, T,** have to be large enough to ensure that not only the packet but also its acknowledgements have vanished?



UNIVERSITY OF Southampton
School of Electronics and Computer Science

Question 4

Why does **UDP** exist? Would it not have been enough to just let user processes send **raw IP packets**?

UNIVERSITY OF Southampton
School of Electronics and Computer Science

Question 5

Both **UDP** and **TCP** use **port numbers** to identify the destination entity when delivering a message. Give two reasons why these protocols invented a **new abstract ID (port numbers), instead of using process IDs**, which already existed when these protocols were designed.

UNIVERSITY OF Southampton
School of Electronics and Computer Science

Question 6

A process on host 1 has been assigned port p, and a process on host 2 has been assigned port q.

Is it possible for there to be **two or more TCP connections** between these two ports at the same time?

UNIVERSITY OF Southampton
School of Electronics and Computer Science

Question 7

In a network whose **max segment** is **128 bytes**, max **segment lifetime** is **30 sec**, and has **8-bit sequence numbers**, what is the maximum data rate per connection?

UNIVERSITY OF Southampton
School of Electronics and Computer Science

Question 8

To get around the problem of sequence numbers wrapping around while old packets still exist, one **could use 64-bit sequence numbers**.

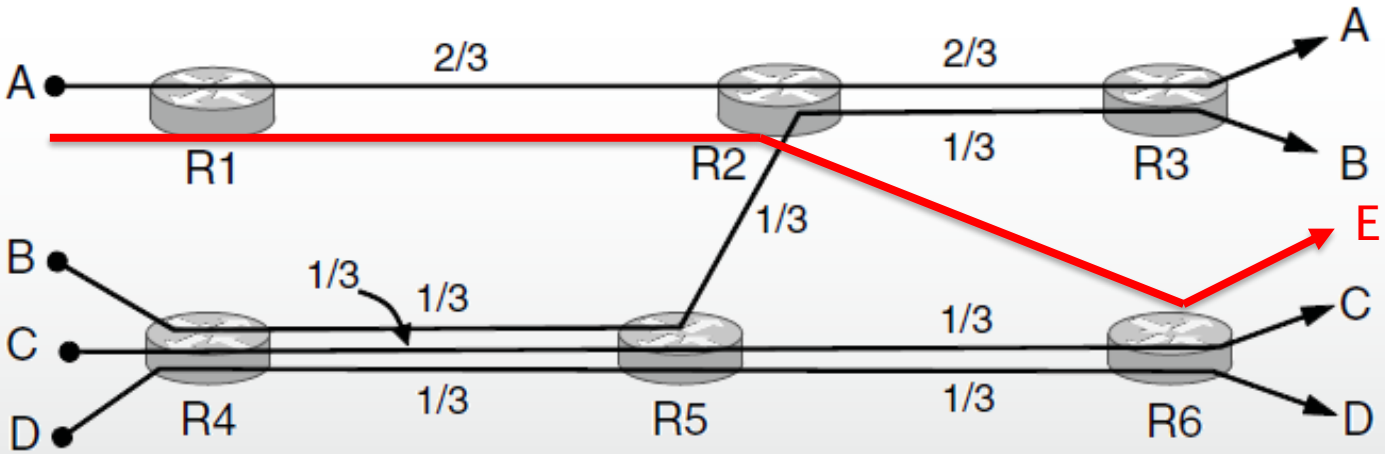
However, theoretically, an **optical fiber can run at 75 Tbps**. What **maximum packet lifetime** is required to make sure that future 75-Tbps networks do not have wraparound problems even with 64-bit sequence numbers?

Assume that **each byte has its own sequence number**, as TCP does.

UNIVERSITY OF Southampton
School of Electronics and Computer Science

Question 9

Suppose a new flow *E* is added that takes a path from *R1* to *R2* to *R6*. How does the max-min bandwidth allocation change for the five flows?



Question 10

Some policies for fairness in congestion control are:

1. Additive Increase Additive Decrease (AIAD)
2. Multiplicative Increase Additive Decrease (MIAD)
3. Multiplicative Increase Multiplicative Decrease (MIMD)

What are their convergence and stability properties?