National University of Computer & Emerging Sciences

CS 3001 - COMPUTER NETWORKS

Lecture 05

Chapter 1

6th September, 2022

Nauman Moazzam Hayat

nauman.moazzam@lhr.nu.edu.pk

Office Hours: 02:30 pm till 06:00 pm (Every Tuesday & Thursday)

Chapter 1: roadmap

1.1 what *is* the Internet?

1.2 network edge

- end systems, access networks, links

1.3 network core

- packet switching, circuit switching, network structure

1.4 delay, loss, throughput in networks

1.5 protocol layers, service models

1.6 networks under attack: security

1.7 history

How do we evaluate a network?

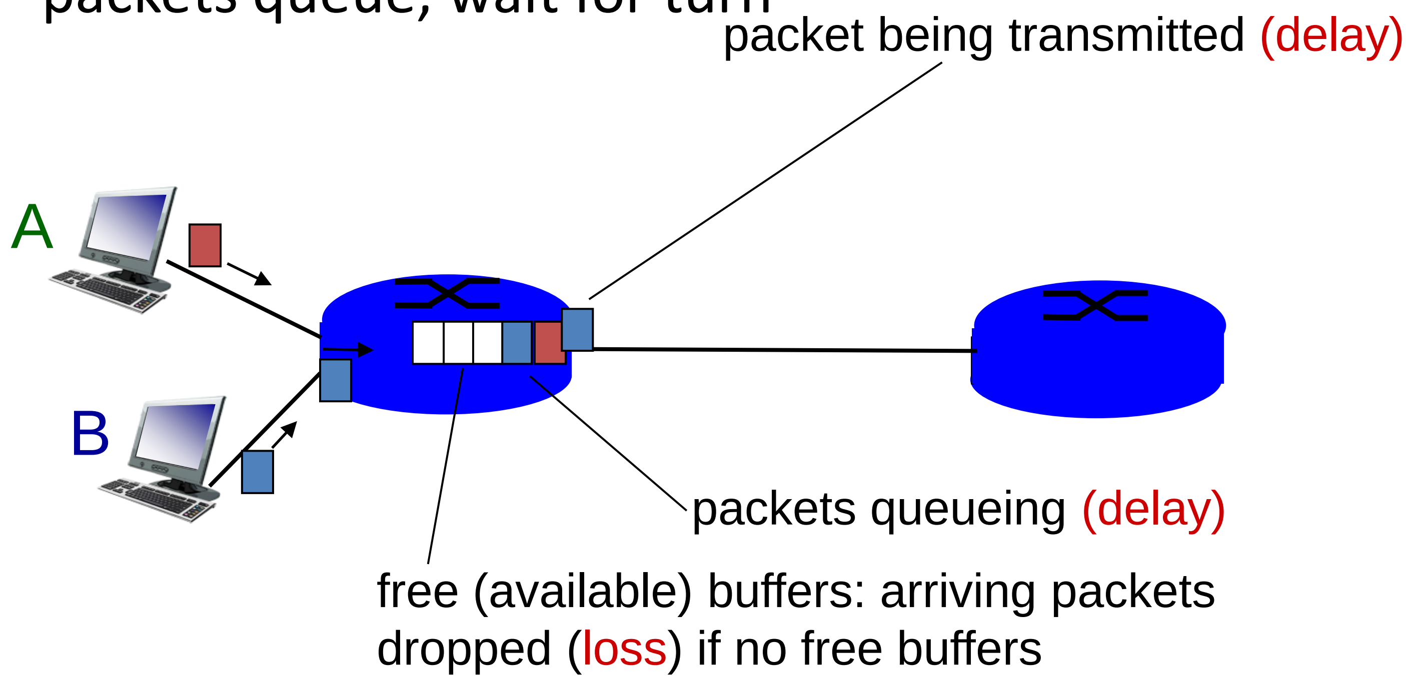
Performance Metrics

- Delay
- Loss
- Throughput

How do loss and delay occur?

packets *queue* in router buffers

- packet arrival rate to link (temporarily) exceeds output link capacity
- packets queue, wait for turn



Delay

- How long does it take to send a packet from its source to destination?

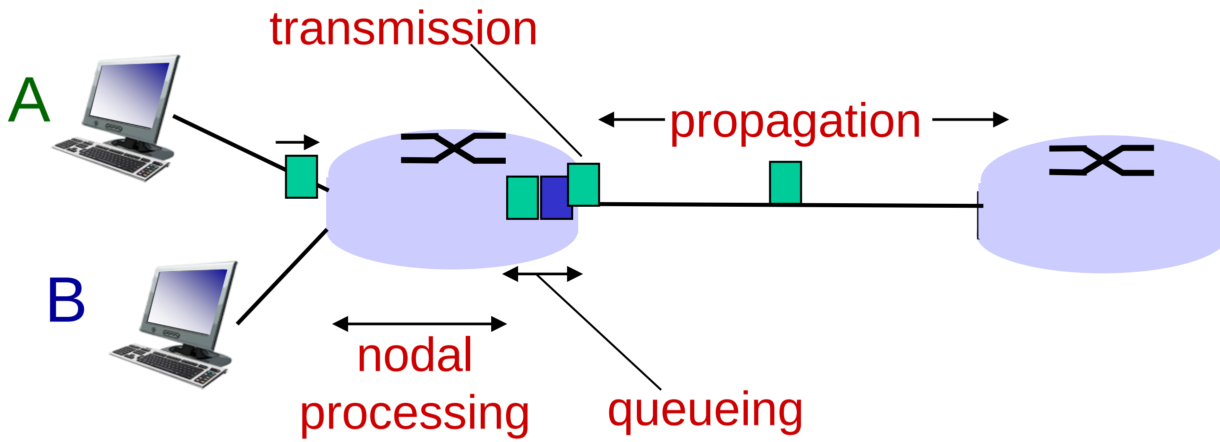
Delay

- Consists of four components
  - *queuing delay*
  - *processing delay*
  - *transmission delay*
  - *propagation delay*

due to traffic mix and Switch / router internals (queuing delay, processing delay)

due to link properties (transmission delay, propagation delay)

Four sources of packet delay



$$d_{nodal} = d_{proc} + d_{queue} + d_{trans} + d_{prop}$$

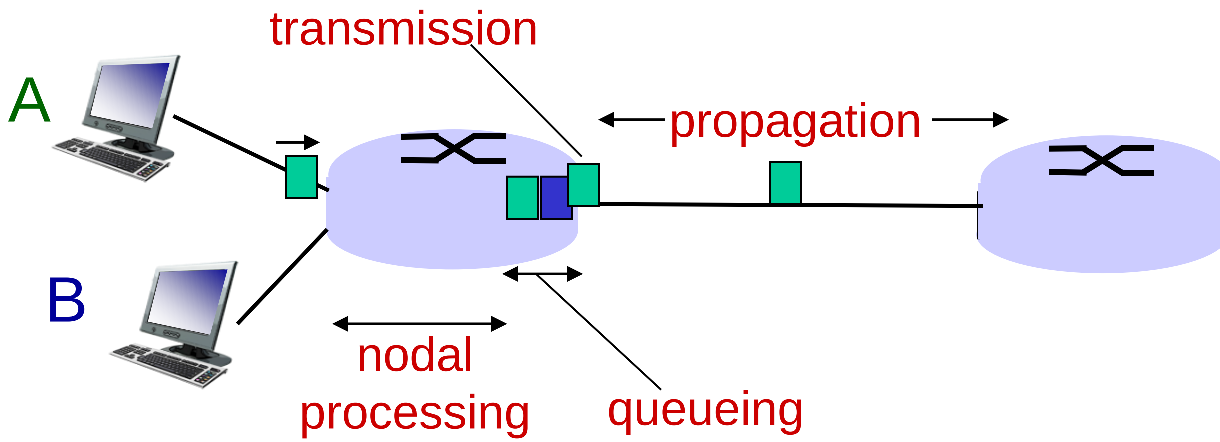
d_{proc}: **nodal processing**

- Packet header inspection & determination of output link
- check bit errors
- typically < micro secs

d_{queue}: **queueing delay**

- time waiting at output link for transmission
- depends on congestion level of router

Four sources of packet delay



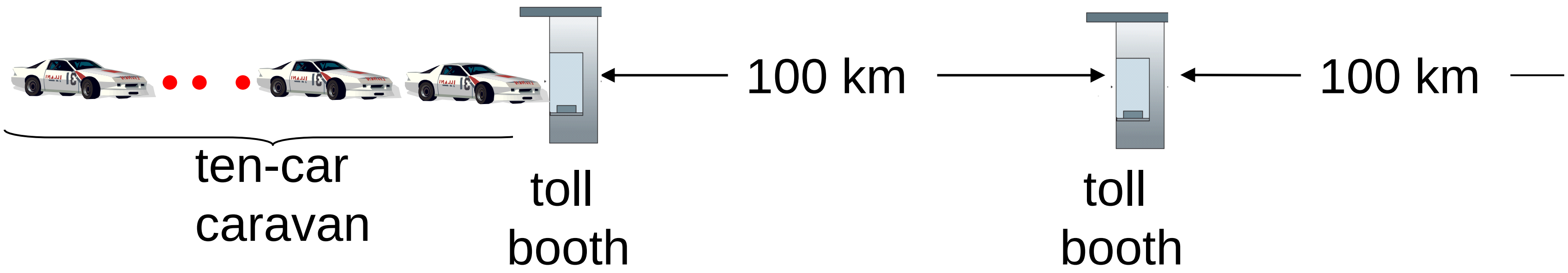
$$d_{nodal} = d_{proc} + d_{queue} + d_{trans} + d_{prop}$$

d_{trans}: transmission delay:
- L: packet length (bits)
- R: link *bandwidth (bps)*
- $d_{trans} = L/R$

d_{trans} and d_{prop}
very different

d_{prop}: propagation delay:
- d: length of physical link
- s: propagation speed in medium ($\sim 2 \times 10^8$ m/sec)
- $d_{prop} = d/s$

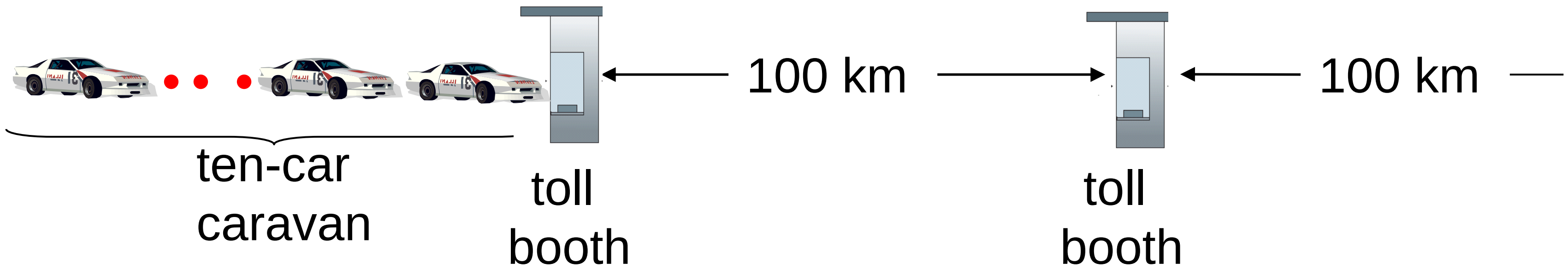
Caravan analogy



- cars "propagate" at 100 km/hr
- toll booth takes 12 sec to service car (bit transmission time)
- car~bit; caravan ~ packet
- *Q*: How long until caravan is lined up before 2nd toll booth?

- time to "push" entire caravan through toll booth onto highway = 12*10 = 120 sec (Transmission Delay)
- time for last car to propagate from 1st to 2nd toll both: 100km/(100km/hr)= 1 hr = 60 minutes (Propagation Delay)
- *A*: 62 minutes

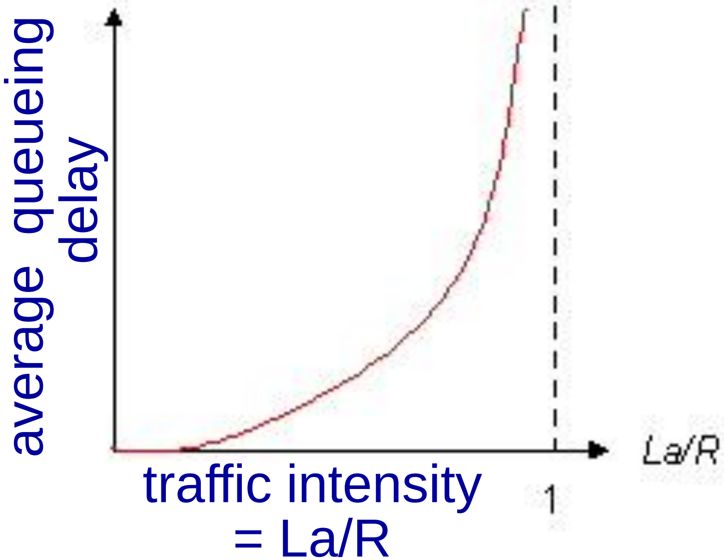
Caravan analogy (more)



- suppose cars now "propagate" at 1000 km/hr
- and suppose toll booth now takes one min to service a car
- *Q:* Will cars arrive to 2nd booth before all cars serviced at first booth?
  - *A: Yes!* after 7 min, 1st car arrives at second booth; three cars still at 1st booth.

Traffic Intensity

- *R:* link bandwidth (bps)
- *L:* packet length (bits)
- a: average packet arrival rate
- Traffic Intensity = La/R



- *La/R* ~ 0: avg. queueing delay small
- *La/R* -> 1: avg. queueing delay large
- *La/R* > 1: more "work" arriving

  than can be serviced, average delay infinite!
- *Thus system should be designed with traffic intensity <= 1*

La/R ~ 0

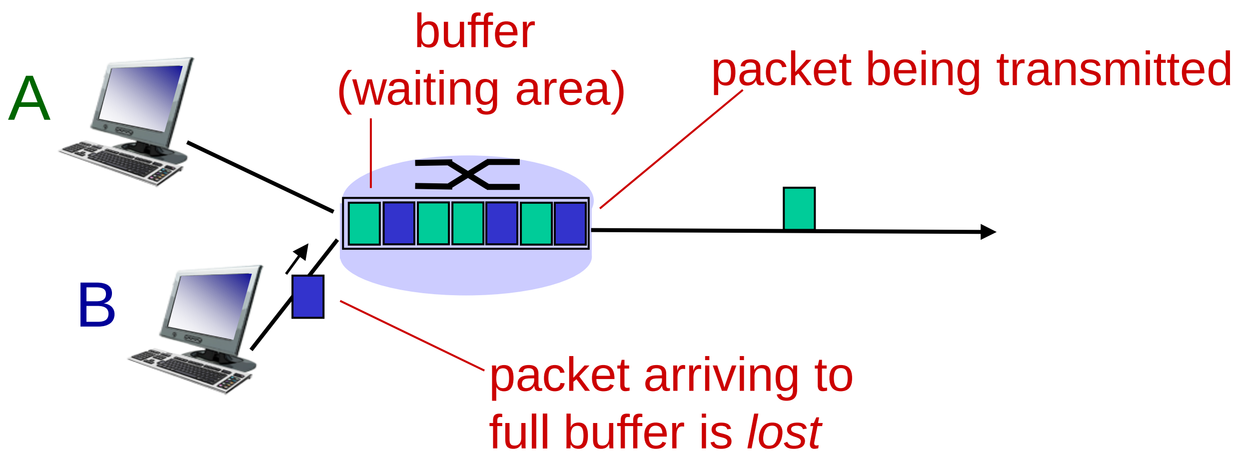
La/R -> 1

Loss

- What fraction of the packets sent to a destination are dropped?

Packet loss

- queue (aka buffer) preceding link in buffer has finite capacity
- packet arriving to full queue dropped (aka lost)
- lost packet may be retransmitted by previous node, by source end system, or not at all

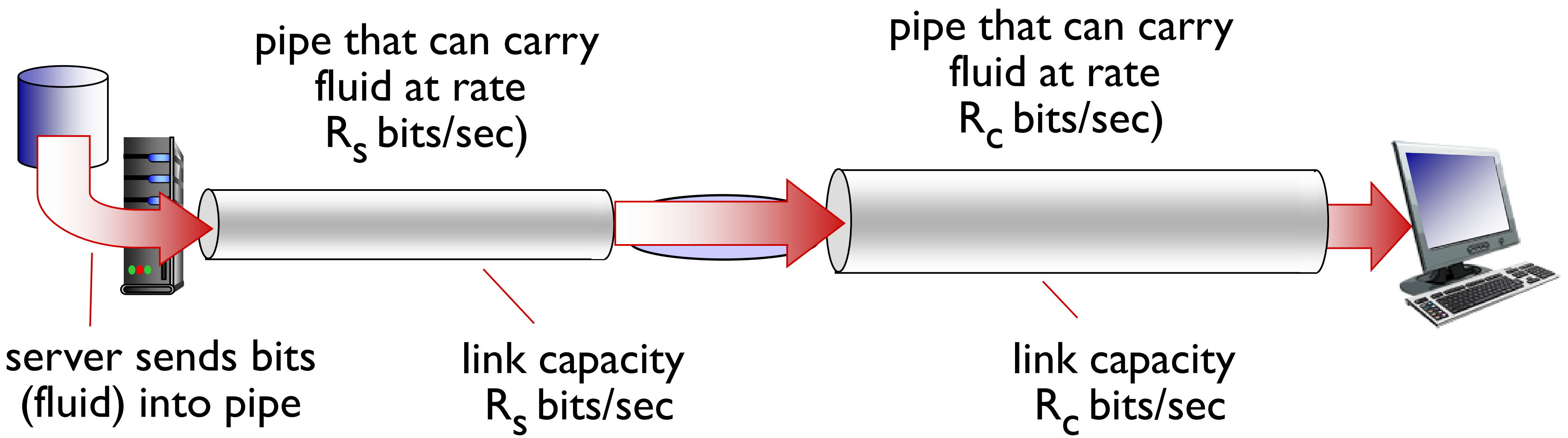


Throughput

- At what rate is the destination receiving data from the source?

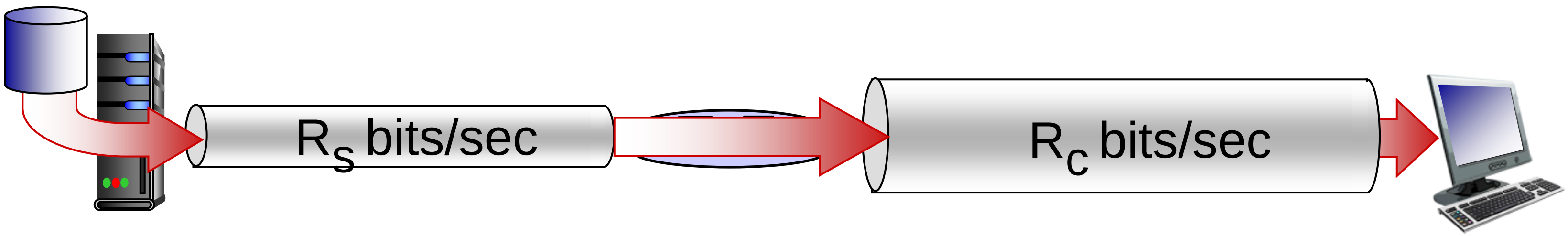
Throughput

- *throughput:* rate (bits/time unit) at which bits transferred between sender/receiver
  - *instantaneous:* rate at given point in time
  - *average:* rate over longer period of time



Throughput (more)

- $R_s < R_c$ What is average end-end throughput?



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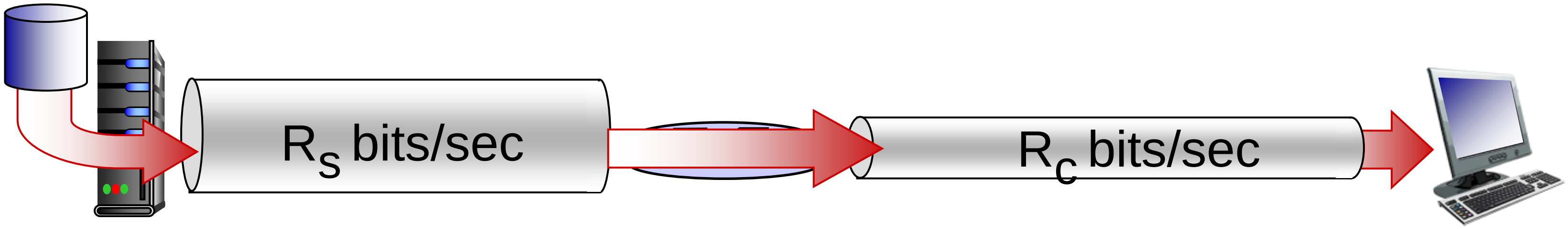
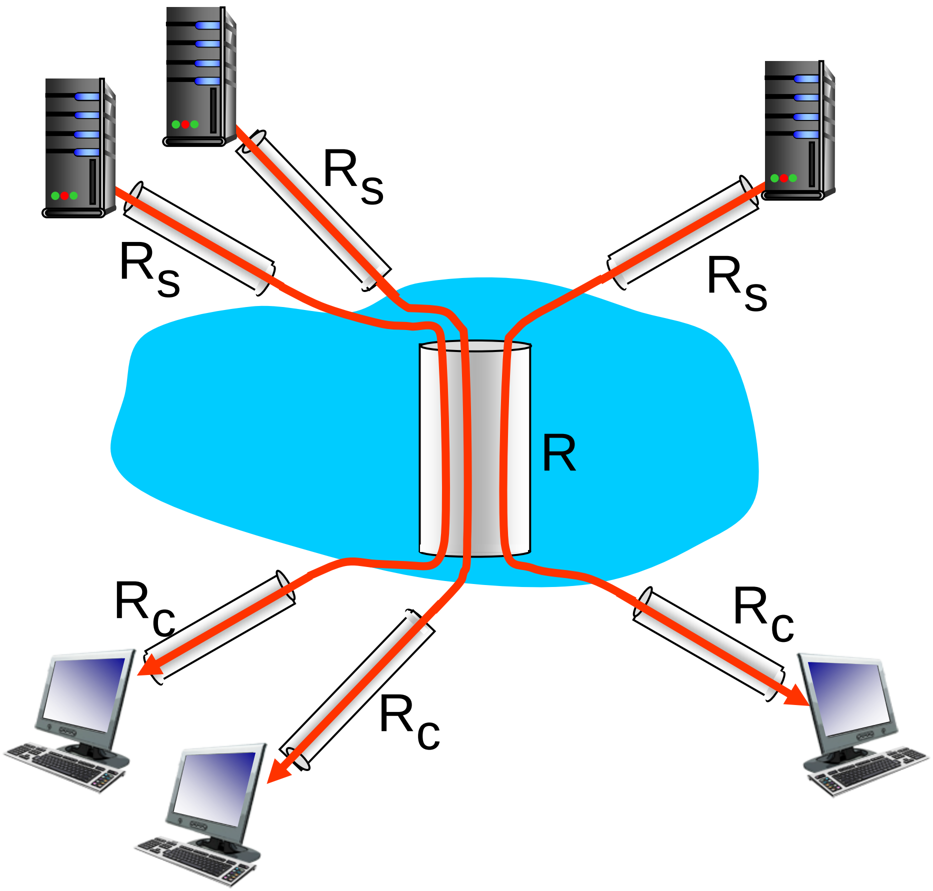


bottleneck link

link on end-end path that constrains end-end throughput

Throughput: Internet scenario

- per-connection end-end throughput: $\min(R_c, R_s, R/10)$
- in practice: R_c or R_s is often bottleneck



10 connections (fairly) share backbone bottleneck link R bits/sec

Bandwidth Delay Product

- The bandwidth-delay product is the product of a link's capacity (in bits per second) and its round-trip delay time (in seconds)

- The result, an amount of data measured in bits (or bytes), is equivalent to the maximum amount of data on the network circuit at any given time

- i.e., data that has been transmitted but not yet acknowledged. (Maximum number of bits that can be inserted into the pipe (link) in a given interval of time.)

- The bandwidth-delay product was originally proposed as a rule of thumb for sizing router buffers in conjunction with congestion avoidance algorithm Random Early Detection (RED).

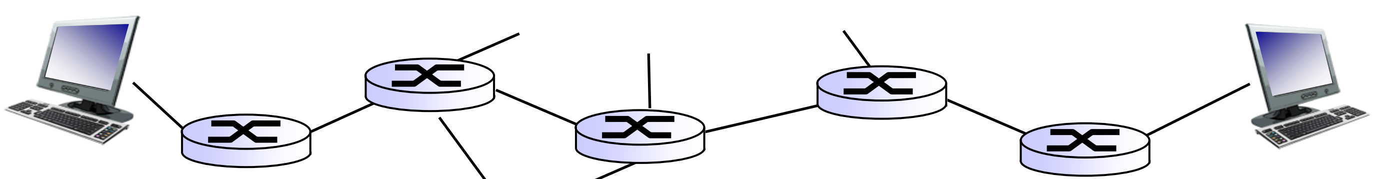
Examples

- Moderate speed satellite network: 512 kbit/s, 900 ms round-trip time (RTT)
  B x D = (512×10^3 bits/s) x (900×10^{-3} s) = 460,800 bits = 460.8 kbit = 57.6kB

- Residential DSL: 2 Mbit/s, 50 ms round-trip time (RTT)
  B x D = (2×10^6bits/s) x (50×10^{-3} s) = 100×10^3 bits = 100 kbit = 12.5kB

"Real" Internet delays and routes

- what do "real" Internet delay & loss look like?
- `ping` program: provides a basic reachability test between end hosts.
- Uses ICMP protocol to send a basic echo request and awaits for an echo reply.
- Reports packet loss, round-trip time and statistical summary: *standard deviation, mean and average of results.*



Ping (echo request) →

← echo reply

“Real” Internet delays and routes

C:\Users\E5080>ping www.google.com

Pinging www.google.com [216.58.205.164] with 32 bytes of data:
Reply from 216.58.205.164: bytes=32 time=177ms TTL=54
Reply from 216.58.205.164: bytes=32 time=172ms TTL=54
Reply from 216.58.205.164: bytes=32 time=186ms TTL=54
Reply from 216.58.205.164: bytes=32 time=174ms TTL=54

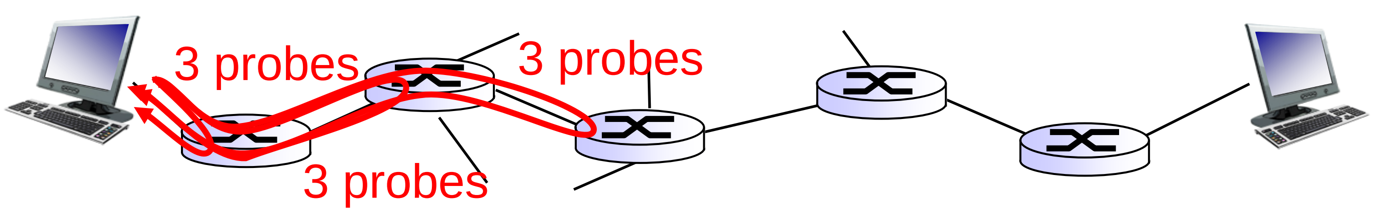
Ping statistics for 216.58.205.164:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 172ms, Maximum = 186ms, Average = 177ms

TTL

- TTL means "Time to Live"
- It is a value on an ICMP packet that prevents that packet from propagating back and forth between hosts ad infinitum.
- Each router that touches the packet decrements the TTL.
- If the TTL ever reaches zero, the packet is discarded.
- It's also a measure of how many hops the packet took. (For Example, if the TTL value started at, say, 128 and you see a value of 28, then there were 100 hops between the system where the packet originated and the final destination.

"Real" Internet delays and routes

- `traceroute` program: provides delay measurement from source to router along end-end Internet path towards destination. For all *i:*
  - sends three packets that will reach router *i* on path towards destination
  - router *i* will return packets to sender
  - sender times interval between transmission and reply.



“Real” Internet delays, routes

traceroute: gaia.cs.umass.edu to www.eurecom.fr

3 delay measurements from gaia.cs.umass.edu to cs-gw.cs.umass.edu

```
1  cs-gw (128.119.240.254)  1 ms  1 ms  2 ms
2  border1-rt-fa5-1-0.gw.umass.edu (128.119.3.145)  1 ms  1 ms  2 ms
3  cht-vbns.gw.umass.edu (128.119.3.130)  6 ms 5 ms 5 ms
4  jn1-at1-0-0-19.wor.vbns.net (204.147.132.129)  16 ms 11 ms 13 ms
5  jn1-so7-0-0-0.wae.vbns.net (204.147.136.136)  21 ms 18 ms 18 ms
6  abilene-vbns.abilene.ucaid.edu (198.32.11.9)  22 ms  18 ms  22 ms
7  nycm-wash.abilene.ucaid.edu (198.32.8.46)  22 ms  22 ms  22 ms
8  62.40.103.253 (62.40.103.253)  104 ms 109 ms 106 ms
9  de2-1.de1.de.geant.net (62.40.96.129)  109 ms 102 ms 104 ms
10  de.fr1.fr.geant.net (62.40.96.50)  113 ms 121 ms 114 ms
11  renater-gw.fr1.fr.geant.net (62.40.103.54)  112 ms  114 ms  112 ms
12  nio-n2.cssi.renater.fr (193.51.206.13)  111 ms  114 ms  116 ms
13  nice.cssi.renater.fr (195.220.98.102)  123 ms  125 ms  124 ms
14  r3t2-nice.cssi.renater.fr (195.220.98.110)  126 ms  126 ms  124 ms
15  eurecom-valbonne.r3t2.ft.net (193.48.50.54)  135 ms  128 ms  133 ms
16  194.214.211.25 (194.214.211.25)  126 ms  128 ms  126 ms
17  * * *
18  * * *
19  fantasia.eurecom.fr (193.55.113.142)  132 ms  128 ms  136 ms
```

trans-oceanic link

* means no response (probe lost, router not replying)

* Do some traceroutes from exotic countries at www.traceroute.org

Assignement # 1 (Chapter – 1)

- *1st Assignment will be uploaded on Google Classroom after the lecture in the Stream Section, on 8th September, 2022*

- *Due Date: Tuesday, 13th September, 2022 (During the lecture)*

- *Hard copy of the handwritten assignment to be submitted directly to the Instructor during the lecture.*

- *Please read all the instructions carefully in the uploaded Assignment document, follow & submit accordingly*

Quiz # 1 (Chapter - 1)

- *Quiz # 1 for Chapter 1 to be taken in the class on Thursday, 15th September, 2022 during the lecture time*

No Retake

Be on time