



# Network Fundamentals for Cloud

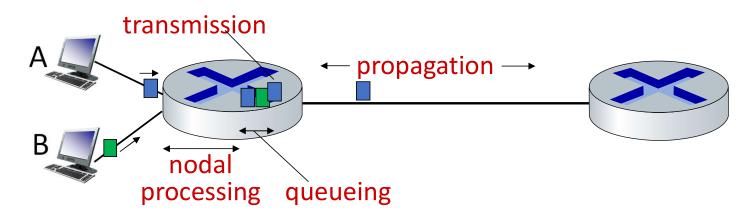
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CC ZG503: Network Fundamentals for Cloud Lecture No. 3: Fundamentals of Networking (Contd.)

### RECAP: Packet delay: four sources



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

#### $d_{\text{trans}}$ : transmission delay:

- L: packet length (bits)
- R: link transmission rate (bps)

$$d_{trans} = L/R$$

$$d_{trans} \text{ and } d_{prop}$$

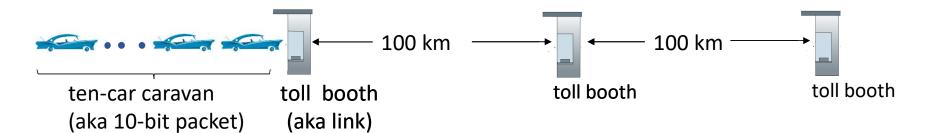
$$very \text{ different}$$

### $d_{prop}$ : propagation delay:

- *d*: length of physical link
- s: propagation speed (~2x10<sup>8</sup> m/sec)

$$d_{\text{prop}} = d/s$$

### **RECAP: Caravan analogy**

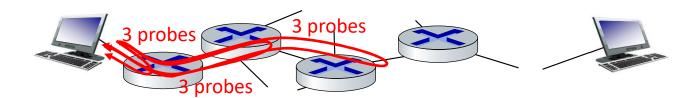


- car ~ bit; caravan ~ packet; toll service ~ link transmission
- toll booth takes 12 sec to service car (bit transmission time)
- "propagate" at 100 km/hr
- Q: How long until caravan is lined up before 2nd toll booth?

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

### "Real" Internet delays and routes

- what do "real" Internet delay & loss look like?
- 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 (with time-to-live field value of *i*)
  - router i will return packets to sender
  - sender measures time interval between transmission and reply



### Real Internet delays and routes

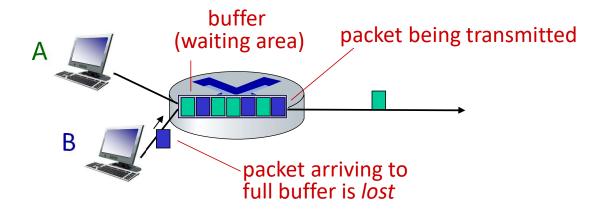
traceroute: gaia.cs.umass.edu to www.eurecom.fr

```
3 delay measurements from
                                                                                                                       gaia.cs.umass.edu to cs-gw.cs.umass.edu
2 border1-rt-fa5-1-0.gw.umass.edu (128.119.3.145) 1 ms 1 ms 2 ms 4 ip1 at1 0 0 10 warvibra mat (024.117.118) 2 ms 4 ip1 at1 0 0 10 warvibra mat (024.117.118) 2 ms 4 ip1 at1 0 0 10 warvibra mat (024.117.118) 2 ms 4 ip1 at1 0 0 10 warvibra mat (024.117.118) 2 ms 4 ip1 at1 0 0 10 warvibra mat (024.117.118) 2 ms 4 ip1 at1 0 0 10 warvibra mat (024.117.118) 2 ms 4 ip1 at1 0 0 10 warvibra mat (024.117.118) 2 ms 4 ip1 at1 0 0 10 warvibra mat (024.117.118) 2 ms 4 ip1 at1 0 0 10 warvibra mat (024.117.118) 2 ms 4 ip1 at1 0 0 10 warvibra mat (024.117.118) 2 ms 4 ip1 at1 0 0 10 warvibra mat (024.117.118) 2 ms 4 ip1 at1 0 0 10 warvibra mat (024.117.118) 2 ms 4 ip1 at1 0 0 10 warvibra mat (024.117.118) 2 ms 4 ip1 at1 0 0 10 warvibra mat (024.117.118) 2 ms 4 ip1 at1 0 0 10 warvibra mat (024.117.118) 2 ms 4 ip1 at1 0 0 10 warvibra mat (024.117.118) 2 ms 4 ip1 at1 0 0 10 warvibra mat (024.117.118) 2 ms 4 ip1 at1 0 0 10 warvibra mat (024.117.118) 2 ms 4 ip1 at1 0 0 10 warvibra mat (024.117.118) 2 ms 4 ip1 at1 0 0 10 warvibra mat (024.117.118) 2 ms 4 ip1 at1 0 0 10 warvibra mat (024.117.118) 2 ms 4 ip1 at1 0 0 10 warvibra mat (024.117.118) 2 ms 4 ip1 at1 0 0 10 warvibra mat (024.117.118) 2 ms 4 ip1 at1 0 0 10 warvibra mat (024.117.118) 2 ms 4 ip1 at1 0 0 10 warvibra mat (024.117.118) 2 ms 4 ip1 at1 0 0 10 warvibra mat (024.117.118) 2 ms 4 ip1 at1 0 0 10 warvibra warvibra mat (024.117.118) 2 ms 4 ip1 at1 0 0 10 warvibra wa
 1 cs-qw (128.119.240.254) 1 ms 1 ms 2 ms
                                                                                                                                                                                                            to border1-rt-fa5-1-0.gw.umass.edu
4 jn1-at1-0-0-19.wor.vbns.net (204.147.132.129) 16 ms 11 ms 13 ms 5 jn1-so7-0-0.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 trans-oceanic link
 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
                                                                                                                                                                                                                             looks like delays
 11 renater-gw.fr1.fr.geant.net (62.40.103.54) 112 ms 114 ms 112 ms 4
                                                                                                                                                                                                                             decrease! Why?
 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
                                                   * means no response (probe lost, router not replying)
 19 fantasia.eurecom.fr (193.55.113.142) 132 ms 128 ms 136 ms
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<sup>\*</sup> Do some traceroutes from exotic countries at www.traceroute.org

### Packet loss

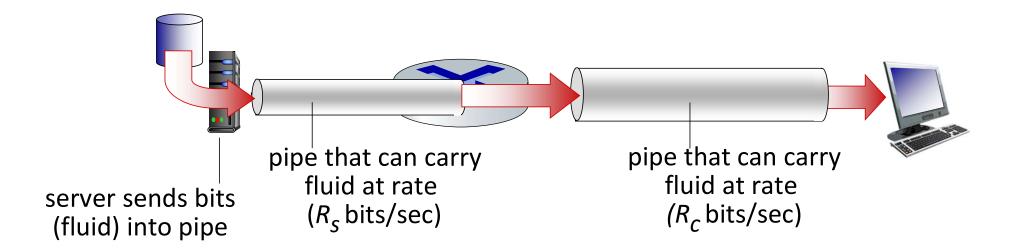
- queue (aka buffer) preceding link in buffer has finite capacity
- packet arriving to full queue dropped (aka lost)
- lost packet may be retransmitted by previous node, by source end system, or not at all



<sup>\*</sup> Check out the Java applet for an interactive animation (on publisher's website) of queuing and loss

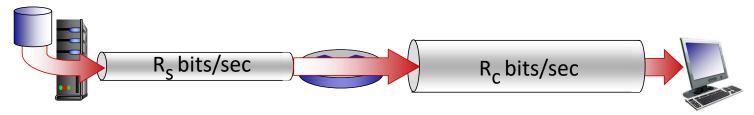
### Throughput

- throughput: rate (bits/time unit) at which bits are being sent from sender to receiver
  - instantaneous: rate at given point in time
  - average: rate over longer period of time

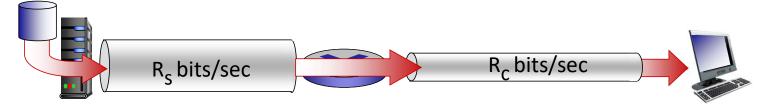


### Throughput

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



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



#### bottleneck link

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

## Protocol "layers" and reference models

# Networks are complex, with many "pieces":

- hosts
- routers
- links of various media
- applications
- protocols
- hardware, software

Question: is there any hope of organizing structure of network?

and/or our discussion of networks?

### Example: organization of air travel

end-to-end transfer of person plus baggage

ticket (purchase) ticket (complain)

baggage (check) baggage (claim)

gates (load) gates (unload)

runway takeoff runway landing

airplane routing airplane routing

airplane routing

How would you define/discuss the system of airline travel?

a series of steps, involving many services

### Example: organization of air travel

ticket (purchase)	ticketing service	ticket (complain)	
baggage (check)	baggage service	baggage (claim)	
gates (load)	gate service	gates (unload)	
runway takeoff	runway service	runway landing	
airplane routing	routing service	airplane routing	

layers: each layer implements a service

- via its own internal-layer actions
- relying on services provided by layer below

## Why layering?

### Approach to designing/discussing complex systems:

- explicit structure allows identification, relationship of system's pieces
  - layered reference model for discussion
- modularization eases maintenance, updating of system
  - change in layer's service *implementation*: transparent to rest of system
  - e.g., change in gate procedure doesn't affect rest of system

### Layered Internet protocol stack

- application: supporting network applications
  - HTTP, IMAP, SMTP, DNS
- transport: process-process data transfer
  - TCP, UDP
- network: routing of datagrams from source to destination
  - IP, routing protocols
- link: data transfer between neighboring network elements
  - Ethernet, 802.11 (WiFi), PPP
- physical: bits "on the wire"

application
transport
network
link
physical

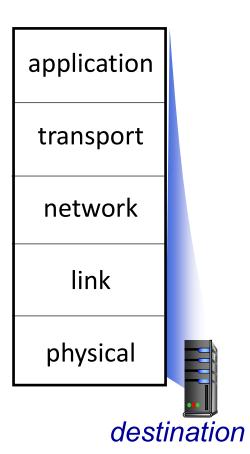
application
transport
network
link
physical

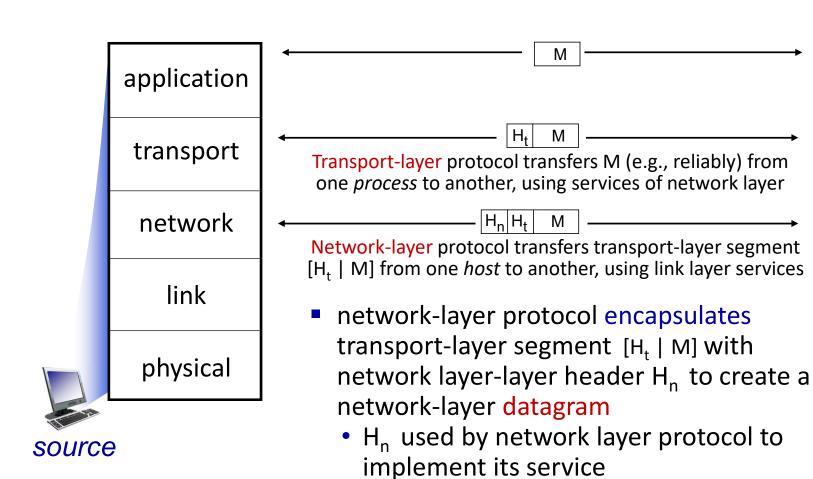
source

Application exchanges messages to implement some application service using services of transport layer

Transport-layer protocol transfers M (e.g., reliably) from one *process* to another, using services of network layer

- transport-layer protocol encapsulates application-layer message, M, with transport layer-layer header H<sub>t</sub> to create a transport-layer segment
  - H<sub>t</sub> used by transport layer protocol to implement its service





application transport network link physical destination

