Qualifying Packet Switching Networks

Delay, Loss and Throughput

School of Software Engineering
South China University of Technology
Dr. Chunhua Chen
chunhuachen@scut.edu.cn
2018 Spring

Quantitative and Qualitative Analysis

- Qualitative (定性分析) **Subjective**
  - Question you should ask: is it heavy?
  - Answers:
    - By me: no, not at all!
    - By my little daughter: Dad, it is too heavy!
- Quantitative (定量分析) **Objective**
  - Question you should ask: what is it Weight?
  - Answers:
    - By me: it is 2kg!
    - By my little daughter: Dad, what is Weight, and of course, it should not have another weight!

Delay happens and is unpredictable

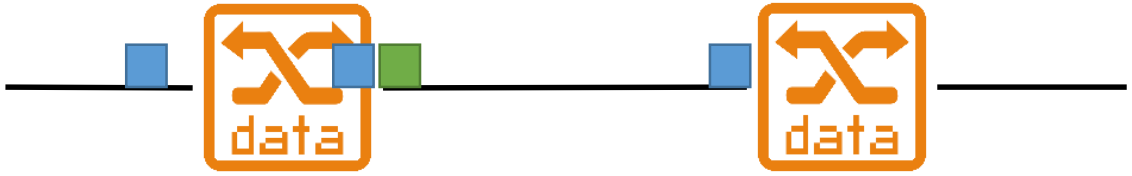
the Most Elusive Part

- Packets queue in router buffers
  - Packet arrival rate exceeds output link capacity
  - Hence, packets queue, wait for turn

  - Other kinds of delay?

The nodal delay model

- Nodal processing delay
  - Check bit errors and determine output link
- Queuing delay
  - Wait for turn, depends on congestion level of router
- Transmission delay
  - R=link bandwidth (bps)
  - L=packet length (bits)
  - L/R=time to send bits into link
- Propagation delay
  - d = length of physical link
  - s = propagation speed in medium (~2x108 m/sec)
  - d/s=propagation delay



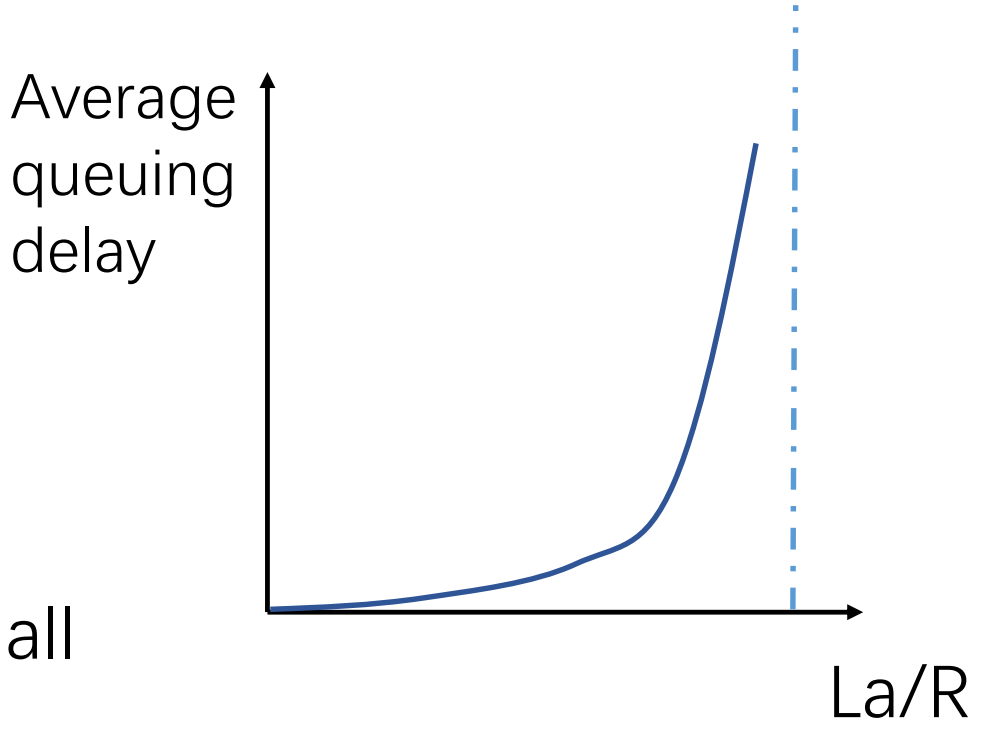
$$d_{\text{nodal}} = d_{\text{proc}} + d_{\text{queue}} + d_{\text{trans}} + d_{\text{prop}}$$

The end-to-end delay model

- We have many intermediate nodes, just sum all the nodal delays!

Queuing Delay and Traffic Intensity

- R=link bandwidth (bps)
- L=packet length (bits)
- a=average packet arrival rate



Traffic Intensity = La/R

- La/R ~ 0: average queuing delay small
- La/R -> 1: delays become large
- La/R > 1: more “work” arriving than can be serviced, average delay infinite!

Packet Loss

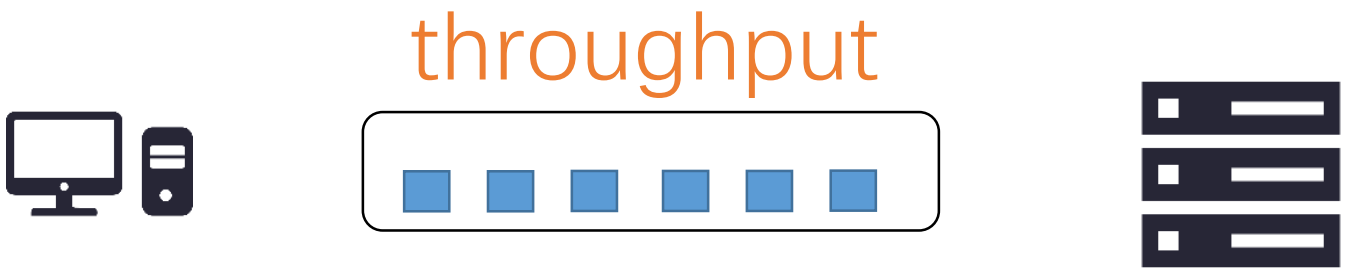
without feekback from the network infrastructure

- 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

look at what you actually get

- Throughput: rate (R bits/time unit) at which bits transferred between sender/receiver
  - instantaneous: rate at given point in time
  - average: rate over long(er) period of time



The Throughput Bottleneck

Link on end-end path that constrains end-end throughput

- R1 < R2, what about the average end-to-end throughput?

- R1 > R2, what about the average end-to-end throughput?

Throughput: Internet scenario

- Per-connection end-end throughput: min(R1,R2,R/10)
- In practice: R1 or R2 is often bottleneck!
  - Ri << R
- If you want to improve the throughput, kill the bottleneck!
  - Fiber to your home! (光纤到户)