Delay, Loss Throughput, OSI Layers

Chapter 1.4-1.7 to accompany slides.

# 1.4 Delay Loss and Throughput



Slide: Figure 1.16

## 1.4.1 Delay overview

Trivia: There exists Delay Loss and constraints on throughput such that 100s of Ph.D. dissertations have been written on these topics.

Def: Nodal Delay starts when a packet arrives at a node (router) and ends when that packet has arrived at the next node (router | host). Nodal Delay is made up of:

1. (Nodal) Processing Delay (usually on the order of microseconds e.g. 5 microseconds = 5x10^-6 seconds)
2. Queuing Delay (how long is the line? Micro to milli seconds)
3. Transmission delay
4. Propagation delay

**Processing delay** is a property of the router and is given usually in microseconds. This is denoted$ d\_{proc}$.

**Queuing delay** depends on the amount of traffic. We will use a measure called traffic intensity, but more on traffic intensity later. This is denoted$ d\_{queue}$.

**Transmission delay** is the amount of time it takes for the router or host to push out the packet onto the wire. If a packet has L bits in it, and the transmission rate is R, then

$$d\_{trans}=\frac{L}{R}$$

**Propagation delay** is simply a rate and distance question. How long does it take to get from here to there (the length of the wire) if you are traveling at wire speed.

$$d\_{prop}=\frac{d}{s}$$

Usually the speed is $2×10^{8}$ meters per second for electricity or $3×10\^8$ meters per second for light or electromagnetic radiation such as wireless.

So we have that **nodal delay** is given as

$$d\_{nodal}=d\_{proc}+d\_{queue}+d\_{trans}+d\_{prop}$$

Q: In what situations can you think of that each of these might dominate? Is there one that will probably never dominate?

## 1.4.2 Queuing delay and packet loss

The most complicated and interesting delay is $d\_{queue}$.

Several books have been written on this topic alone!

**Queuing delay varies from packet to packet.**

**Q: If ten packets arrive simultaneously to the same queue, the first packet has** $d\_{queue}=0$**. If the packets are all of length** $L$ **and the transmission rate is** $R$**, what is the delay of the 10th packet?**

**A: Packet number 10 has to wait for each packet to be transmitted. Since each packet takes** $L/R$ **time to transmit (we don’t care about the propagation time), the wait time is** $9L/R$**.**

**Q: If there were** $n$ **packets?**

**A:** $\left(n-1\right)L/R$**.**

Clearly at this point you can see that the amount of wait time depends on the arrival rate and the transmission rate.

Let $a$ denote the arrival rate of packets (units = packets / second), then the average rate at which bits arrive is $La$, where $L$ is bits/packet such that $La$ has units of bits/second. The way to determine traffic intensity is to look at the ratio of incoming bits to outgoing bits. We denote traffic intensity by

$$I=\frac{La}{R}$$

If incoming bits are arriving faster than outgoing bits, then $I>1$ and you will eventually fill up the queue and the **router will drop packets for queues that are full**.

If $I<1$ we will shrink the queue and life is good.

If $I=1$, watch out, no mistakes can be made and life is frantic.

## 1.4.3 End-to-end delay

Example: $N-1$ routers separate two hosts where the network is *uncongested*, then

$$d\_{end-to-end}=N(d\_{proc}+d\_{trans}+d\_{prop})$$

Example: Short trace route end-to-end example.

Other end-to-end delays: For dialup: modulation encoding delays, for VoIP: packetization delay…

## 1.4.4 Throughput in computer networks (use slides 56-58 of the publisher)

Def: Instantaneous throughput at any instant of time is the rate (in bits/sec) at which the receiving host is receiving the file.

Def: Average throughput for a large file of size $F$ which takes a total of time $T$ to receive is $F/T$.

# 1.5 Protocol Layers and service models (use slides 60-66 of the publisher)

# 1.6 Not covered – join network security

# 1.7 Time permitting

Internet turns 40 Labor day 2009!