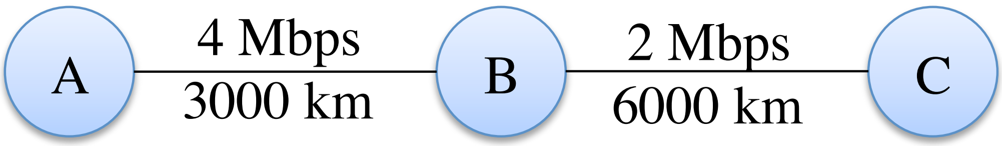
CS168 Fall 2014 Discussion Section 1

Packet Delay Constants

1 Mbps = 10^6 bits per second
1 ms = 10^{-3} seconds
Speed of light (c) = $3 \cdot 10^5$ km/second



Problem 1: Delays in Packet Switching

For this problem, assume all packets are sent using packet switching, and intermediate nodes use store-and-forward when forwarding packets.

(a) What is the transmission delay if A sends a 500 byte packet to B?

$500 \text{ bytes} \cdot \frac{8 \text{ bits}}{1 \text{ byte}} = 4,000 \text{ bits}$
$4,000 \text{ bits} / \left(4 \cdot 10^6 \text{bits/second}\right) = 1 \cdot 10^{-3} \text{ second} = 1 \text{ millisecond}$

(b) What is the propagation delay if A sends a 500 byte packet to B?

$3000 \text{ km} / \left(3 \cdot 10^5 \text{ km/s}\right) = 1 \cdot 10^{-2} \text{ seconds} = 10 \text{ milliseconds}$

(c) What is the end-to-end delay if A sends a 500 byte packet to B?

$1 \text{ millisecond} + 10 \text{ milliseconds} = 11 \text{ milliseconds}$

(d) What is the end-to-end delay if A sends a 1000 byte packet to B? Which component of delay is affected by packet size?

The propagation delay is unchanged, because it is independent of packet size. The new transmission delay is:

$$1000 \text{ bytes} \cdot \frac{8 \text{ bits}}{1 \text{ byte}} = 8,000 \text{ bits}$$
$$8,000 \text{ bits} / \left(4 \cdot 10^6 \text{bits/second}\right) = 2 \cdot 10^{-3} \text{ seconds} = 2 \text{ milliseconds}$$

The total delay is 10 milliseconds + 2 milliseconds = 12 milliseconds.

(e) What is the end-to-end delay if A sends a 500 byte packet to C?

The end-to-end delay from A to C is:

transmission $\text{delay}_{A\to B}$ + propagation $\text{delay}_{A\to B}$ + transmission $\text{delay}_{B\to C}$ + propagation $\text{delay}_{B\to C}$

We computed the first two terms above.

$$\begin{aligned}\text{transmission delay}_{B\to C} &= 4,000 \text{ bits}/\left(2\cdot 10^6 \text{bits/second}\right)\\ &= 2\cdot 10^{-3} \text{ seconds}\\ &= 2 \text{ milliseconds}\\ \text{propagation delay}_{B\to C} &= 6000 \text{ km}/\left(3\cdot 10^5 \text{ km/s}\right)\\ &= 2\cdot 10^{-2} \text{ seconds}\\ &= 20 \text{ milliseconds}\end{aligned}$$

The total delay is 1 millisecond + 10 milliseconds + 2 milliseconds + 20 millseconds = 33 milliseconds.

(f) What is the end-to-end delay if A sends two 500 byte packets, one afer the other, to C?

Let's call the time A begins sending the first packet $t = 0$, and we'll specify all times in milliseconds. First, A transmits the first packet onto the wire towards B; the transmission delay is 1 millisecond, so A will finish transmitting the first packet at $t = 1$. Next, A will begin transmitting the second packet at $t = 1$; A finishes transmitting the second packet at $t = 2$, and the second packet will finish arriving at B at $t = 12$ (2 plus the 10 millisecond propagation delay).

B finishes receiving the first packet from A at $t = 11$, at which point B will begin transmitting that packet to C. It takes B 2 milliseconds, as computed in the previous problem, to transmit a 500 byte packet, so B finishes transmitting the first packet at $t = 11 + 2 = 13$. B receives the second packet from A at $t = 12$, as described above, but it can't start transmitting that packet to C yet, because at $t = 12$, B is still transmitting the first packet. So, B does not begin transmitting the second packet until $t = 13$. B will finish transmitting the second packet at $t = 15$; propagation delay from B to C is 20 milliseconds, so the end-to-end delay is $15 + 20 = 35$ milliseconds.

Problem 2: Delays in Circuit Switching

Now, suppose all packets are sent using circuit switching. Assume we're using virtual circuit switching, where we set up a circuit on a packet-switched network by first using a setup packet.

(a) How long does it take to establish a circuit from A to C? Assume intermediate nodes can process the setup message instantaneously, and that the setup and confirmation messages are 100 bytes.

The setup packet is sent from A to C like a normal packet, so the total delay is:

transmission $\text{delay}_{A\to B}$ + propagation $\text{delay}_{A\to B}$ + transmission $\text{delay}_{B\to C}$ + propagation $\text{delay}_{B\to C=30.6 \text{ ms}}$

$$(100\cdot 8)\div(4\cdot 10^6)\cdot 1000 + 10 + (100\cdot 8)\div(2\cdot 10^6)\cdot 1000 + 20 = 30.6$$
$$0.2 + 10 + 0.4 + 20 = 30.6 \text{ ms}$$

When the setup packet returns from C back to A (to signal that the circuit has been established), the intermediate switches do not use store and forward, because resources have already been allocated for the circuit. Thus, the total delay is the transmission delay along the lowest bandwidth link (in this case, the link from C to B) plus the total propagation delay:

$$0.4 \text{ milliseconds} + 10 \text{ milliseconds} + 20 \text{ milliseconds} = 30.4 \text{ milliseconds}$$

Therefore, total circuit setup time is 61ms.

(b) Once the circuit is set up, what is the end-to-end delay if A sends a 500 byte packet to C?

All the required numbers were computed in Problem 1. It's the total propagation delay (10ms + 20ms), plus the transmission delay of the bottleneck link (2ms).

32 milliseconds

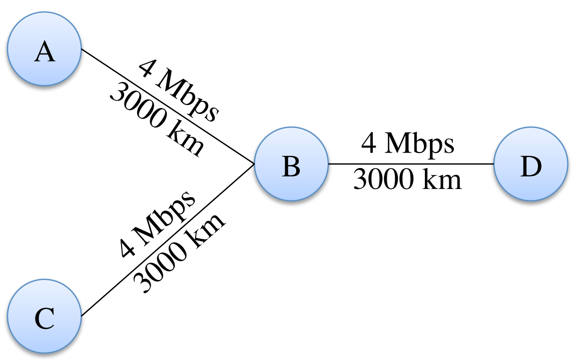
(c) Now, suppose that A needs to send a 1MB (megabyte) packet to C. What is the total delay with circuit switching, including the time to set up the circuit (under the same assumptions as in (a)).

The transmission delay for the larger packet is:

$$1 \cdot 10^6 \text{ bytes} \cdot \frac{8\text{bits}}{1\text{byte}} / \left(2 \cdot 10^6 \text{bits/second}\right) = 4 \text{ seconds (4000ms)}$$

The propagation delay is the same (10ms + 20ms).
The time to set up the circuit is the same as above (61ms), since the setup packet is the same size.
Add those together... 4000ms + 10ms + 20ms + 61ms = 4091ms

Problem 3: Contention



In the above topology, suppose that A sends two 500 byte packets to D at $t = 0$ and that C sends a single 500 byte packet to D 1.5 milliseconds later. What is the end-to-end delay of the first packet from A? What about the packet from C?

Propagation times are all 10ms. Transmission times are all 1ms.

A transmits its first packet from t=0 to t=1ms, and the packet arrives at B at t=11ms
A transmits its second packet from t=1 to t=2ms, and the packet arrives at B at t=12ms
C transmits its only packet from t=1.5 to t=2.5ms, and the packet arrives at B at t=12.5ms

Thus, B sends out the first packet from A, then the second packet from A. While half way though transmitting the second packet from A, the packet from C finishes arriving and must be queued.

Since neither of the packets from A were queued on B, B finishes transmitting them at t=12ms and t=13ms respectively. They arrive at D at t=22ms and t=23ms respectively.

Since the packet from C was queued, it begins being transmitted immediately after the second packet from A finishes transmitting – at t=13ms. It completes transmitting at t=14ms, and arrives at D at t=24ms.

Thus, end-to-end delay of the first packet from A is 22ms; and the end-to-end delay of the packet from C is 24 - 1.5 = 22.5ms.