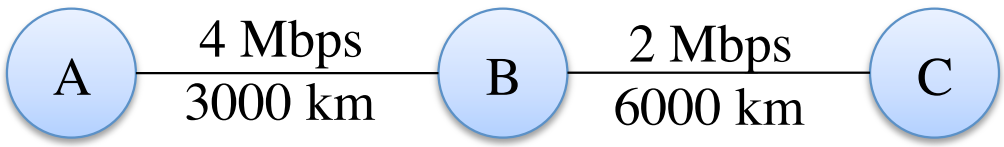
EE122 Fall 2013 Discussion Section 1

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 millisecond + 10 milliseconds = 11 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:

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

We computed the first two terms above.

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

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 message is 100 bytes.

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

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

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:

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

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?

32 milliseconds

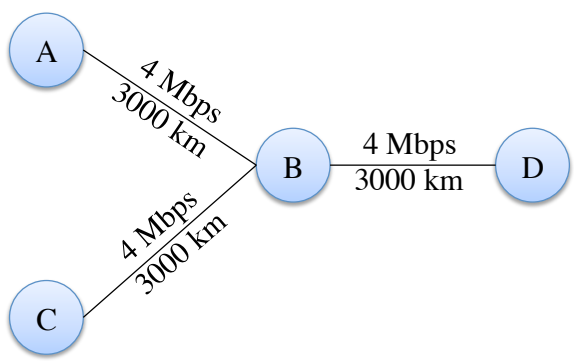
(c) Now, suppose that A needs to send a 1MB packet to C. What is the total delay with circuit switching, including the time to setup the circuit (under the same assumptions as in (a)).

The time to setup the circuit is the same as above, since the setup packet is the same size. The transmission delay for the larger packet is:

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

The total propagation delay is 30ms and the time to setup the circuit is 61ms from part a. So, the total delay with circuit switching is 4.091 seconds.

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 of the packet from C?

A finishes transmitting the first packet at $t = 1$ms and starts transmitting the second packet. The first packet from reaches B at $t = 11$ms which starts transmitting it to D. The second packet from A reaches B at $t = 12$ms and the packet from C reaches B at $t = 12.5$ms. Thus, B first sends out the second packet from A and then the packet from C. B finishes transmission of A's first packets at $t = 12$ms and C's packet at $t = 14$ms. Therefore, A's first packet reaches D at $t = 22$ms and C's packet reaches D at $t = 24$ms.
Thus, end-to-end delay of the first packet from $A = 22$ms; and the end-to-end delay of the first packet from C is 24 - 1.5 = 22.5ms.