1 Understanding Delays in Data Transfer

Two computers, Host A and Host B, are connected by a link with speed R bits per second. They are m meters apart, and signals travel at s meters per second. Host A sends a packet of L bits to Host B. We need to answer questions about delays and packet locations.

1.1 Part (a): Time to Travel the Distance

The propagation delay, d_{prop}, is how long it takes a bit to travel from A to B:

$$d_{\text{prop}} = \frac{m}{s}$$

1.2 Part (b): Time to Send the Packet

The transmission delay, d_{trans}, is the time to send all L bits onto the link:

$$d_{\text{trans}} = \frac{L}{R}$$

1.3 Part (c): Total Time for Delivery

The end-to-end delay is the time from when A starts sending until B gets the whole packet. Its the sum of transmission and propagation delays:

$$\text{Total delay} = \frac{L}{R} + \frac{m}{s}$$

1.4 Part (d): Where is the Last Bit at $t = d_{\text{trans}}$?

At $t = 0$, Host A starts sending. At $t = d_{\text{trans}} = \frac{L}{R}$, the last bit is just sent. Its still at Host A, just entering the link.

1.5 Part (e): First Bit When $d_{\text{prop}} > d_{\text{trans}}$

If $d_{\text{prop}} > d_{\text{trans}}$, the first bit, sent at $t = 0$, travels for time d_{trans}. It covers a distance:

$$\text{Distance} = s \cdot \frac{L}{R}$$

Since $\frac{m}{s} > \frac{L}{R}$, the first bit hasnt reached Host B yet. Its on the link, $s \cdot \frac{L}{R}$ meters from Host A.

1.6 Part (f): First Bit When $d_{\text{prop}} < d_{\text{trans}}$

If $d_{\text{prop}} < d_{\text{trans}}$, the first bit reaches Host B at $t = d_{\text{prop}} = \frac{m}{s}$, before $t = d_{\text{trans}}$. So, at $t = d_{\text{trans}}$, the first bit is already at Host B.

1.7 Part (g): Distance Where Delays Are Equal

Given $s = 2.5 \times 10^8\,\mathrm{m\,s^{-1}}$, $L = 1500\,\mathrm{B} = 12000\,\mathrm{bit}$, and $R = 10\,\mathrm{Mbit\,s^{-1}}$, we find m where $d_{\text{prop}} = d_{\text{trans}}$:

$$\frac{m}{s} = \frac{L}{R}$$

$$m = s \cdot \frac{L}{R} = 2.5 \times 10^8 \cdot \frac{12000}{10 \times 10^6} = 300000\,\mathrm{m} = 300\,\mathrm{km}$$

1.8 Final Answer

1. Propagation delay: $\frac{m}{s}$
2. Transmission delay: $\frac{L}{R}$
3. Total delay: $\frac{L}{R} + \frac{m}{s}$
4. Last bit at $t = d_{\text{trans}}$: At Host A.
5. If $d_{\text{prop}} > d_{\text{trans}}$, first bit at $t = d_{\text{trans}}$: On the link, $s \cdot \frac{L}{R}$ meters from Host A.
6. If $d_{\text{prop}} < d_{\text{trans}}$, first bit at $t = d_{\text{trans}}$: At Host B.
7. Distance: $300\,\mathrm{km}$