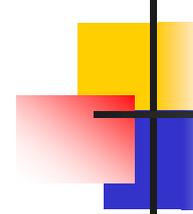


## 3-6 PERFORMANCE

*One important issue in networking is the **performance** of the network—how good is it? We discuss quality of service, an overall measurement of network performance, in greater detail in Chapter 24. In this section, we introduce terms that we need for future chapters.*

### **Topics discussed in this section:**

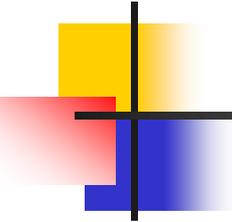
- **Bandwidth - capacity of the system**
- **Throughput - no. of bits that can be pushed through**
- **Latency (Delay) - delay incurred by a bit from start to finish**
- **Bandwidth-Delay Product**



*Note*

*In networking, we use the term bandwidth in two contexts.*

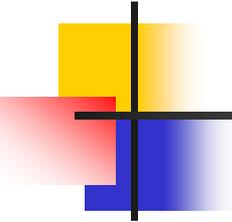
- The first, bandwidth in hertz, refers to the range of frequencies in a composite signal or the range of frequencies that a channel can pass.
- The second, bandwidth in bits per second, refers to the speed of bit transmission in a channel or link. Often referred to as Capacity.



## *Example 3.42*

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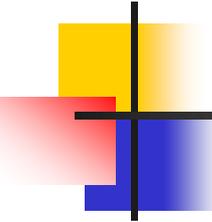
*The bandwidth of a subscriber line is 4 kHz for voice or data. The bandwidth of this line for data transmission can be up to 56,000 bps using a sophisticated modem to change the digital signal to analog.*



## *Example 3.43*

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*If the telephone company improves the quality of the line and increases the bandwidth to 8 kHz, we can send 112,000 bps by using the same technology as mentioned in Example 3.42.*



## *Example 3.44*

*A network with bandwidth of 10 Mbps can pass only an average of 12,000 frames per minute with each frame carrying an average of 10,000 bits. What is the throughput of this network?*

### *Solution*

*We can calculate the throughput as*

$$\text{Throughput} = \frac{12,000 \times 10,000}{60} = 2 \text{ Mbps}$$

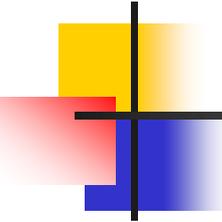
*The throughput is almost one-fifth of the bandwidth in this case.*

# Propagation & Transmission delay

- Propagation speed - speed at which a bit travels through the medium from source to destination.
- Transmission speed - the speed at which all the bits in a message arrive at the destination. (difference in arrival time of first and last bit)

# Propagation and Transmission Delay

- Propagation Delay = Distance/Propagation speed
- Transmission Delay = Message size/bandwidth bps
- Latency = Propagation delay + Transmission delay + Queueing time + Processing time



## *Example 3.45*

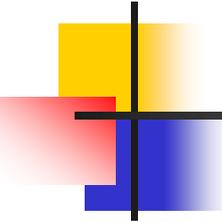
*What is the propagation time if the distance between the two points is 12,000 km? Assume the propagation speed to be  $2.4 \times 10^8$  m/s in cable.*

### *Solution*

*We can calculate the propagation time as*

$$\text{Propagation time} = \frac{12,000 \times 1000}{2.4 \times 10^8} = 50 \text{ ms}$$

*The example shows that a bit can go over the Atlantic Ocean in only 50 ms if there is a direct cable between the source and the destination.*



## *Example 3.46*

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*What are the propagation time and the transmission time for a 2.5-kbyte message (an e-mail) if the bandwidth of the network is 1 Gbps? Assume that the distance between the sender and the receiver is 12,000 km and that light travels at  $2.4 \times 10^8$  m/s.*

### *Solution*

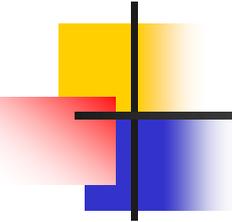
*We can calculate the propagation and transmission time as shown on the next slide:*

## *Example 3.46 (continued)*

$$\text{Propagation time} = \frac{12,000 \times 1000}{2.4 \times 10^8} = 50 \text{ ms}$$

$$\text{Transmission time} = \frac{2500 \times 8}{10^9} = 0.020 \text{ ms}$$

*Note that in this case, because the message is short and the bandwidth is high, the dominant factor is the propagation time, not the transmission time. The transmission time can be ignored.*



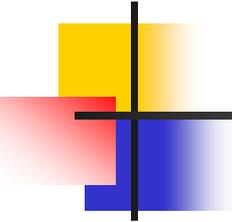
## *Example 3.47*

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*What are the propagation time and the transmission time for a 5-Mbyte message (an image) if the bandwidth of the network is 1 Mbps? Assume that the distance between the sender and the receiver is 12,000 km and that light travels at  $2.4 \times 10^8$  m/s.*

### *Solution*

*We can calculate the propagation and transmission times as shown on the next slide.*



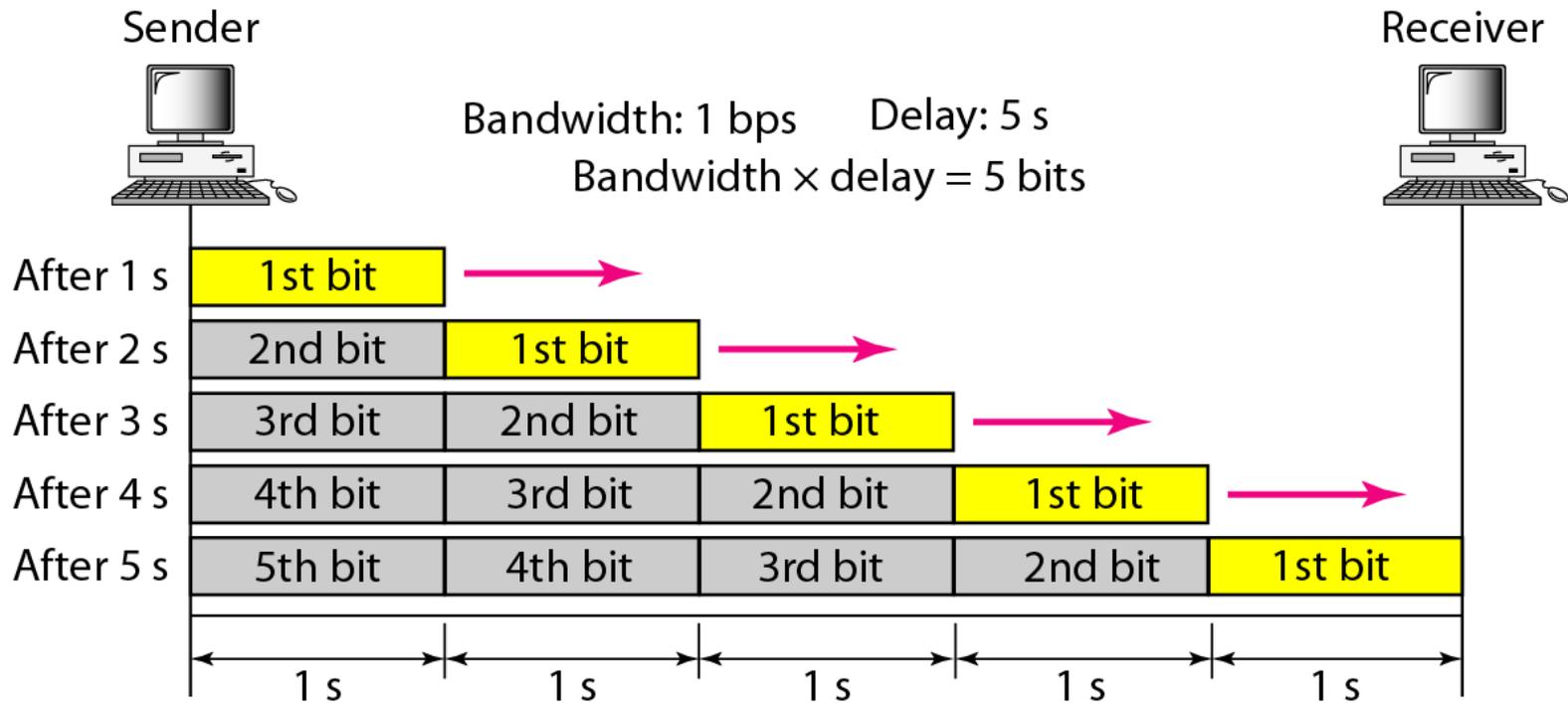
## *Example 3.47 (continued)*

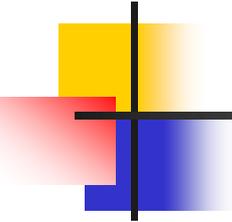
$$\text{Propagation time} = \frac{12,000 \times 1000}{2.4 \times 10^8} = 50 \text{ ms}$$

$$\text{Transmission time} = \frac{5,000,000 \times 8}{10^6} = 40 \text{ s}$$

*Note that in this case, because the message is very long and the bandwidth is not very high, the dominant factor is the transmission time, not the propagation time. The propagation time can be ignored.*

**Figure 3.31** *Filling the link with bits for case 1*



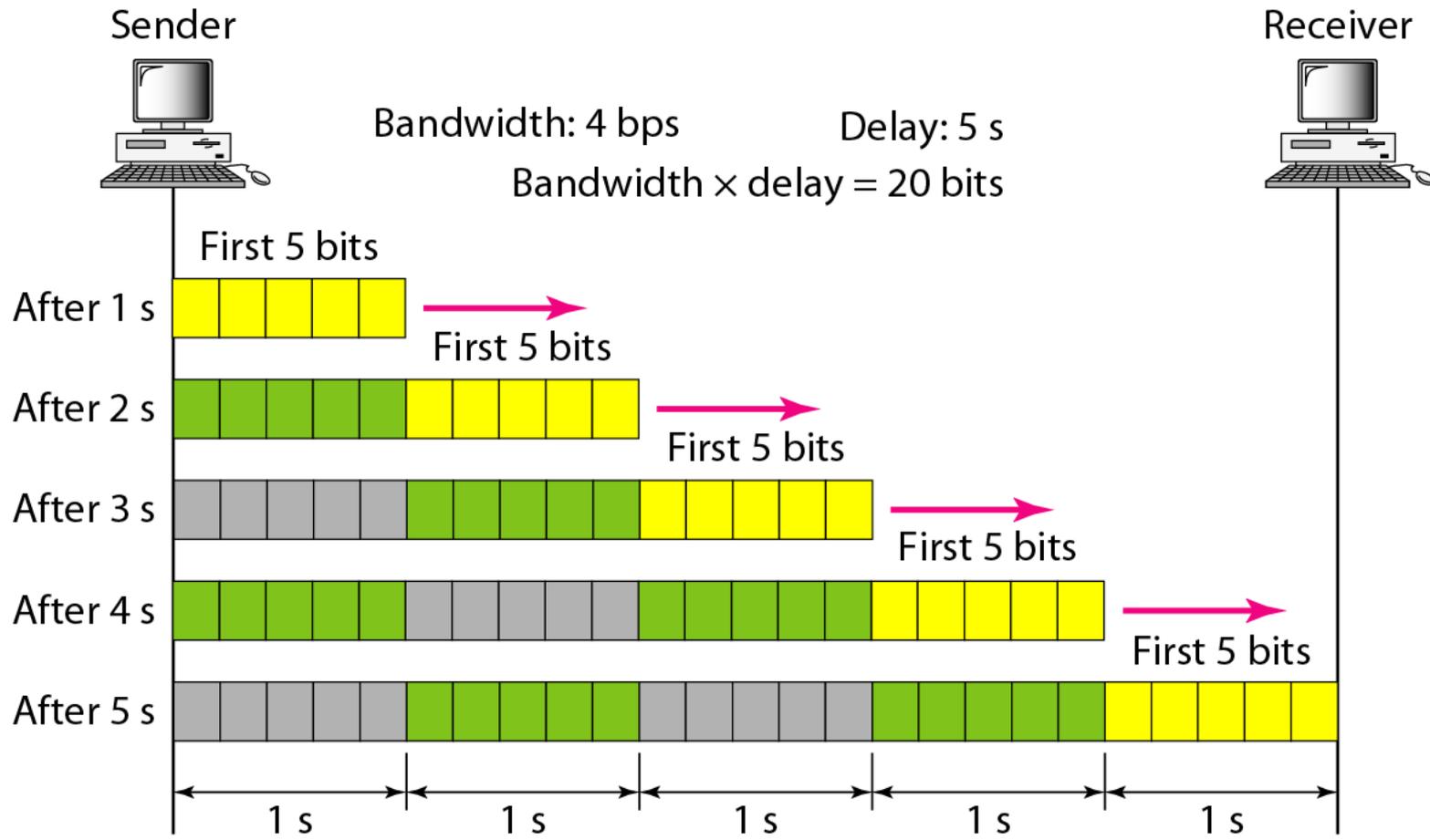


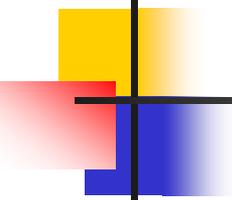
## *Example 3.48*

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*We can think about the link between two points as a pipe. The cross section of the pipe represents the bandwidth, and the length of the pipe represents the delay. We can say the volume of the pipe defines the bandwidth-delay product, as shown in Figure 3.33.*

**Figure 3.32** *Filling the link with bits in case 2*





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*Note*

**The bandwidth-delay product defines the number of bits that can fill the link.**

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**Figure 3.33** *Concept of bandwidth-delay product*

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