NETWORK PERFORMANCE

ECE 525E – WIRELESS & MOBILE COMMUNICATION

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NETWORK PERFORMANCE PARAMETERS

The following parameters can be used to measure network performance:

1. Bandwidth
2. Throughput
3. Latency
4. Jitter
5. Error Rate
6. Bandwidth Utilization
7. Network Availability (or Uptime)
8. Response Time
9. Round Trip Time (RTT)

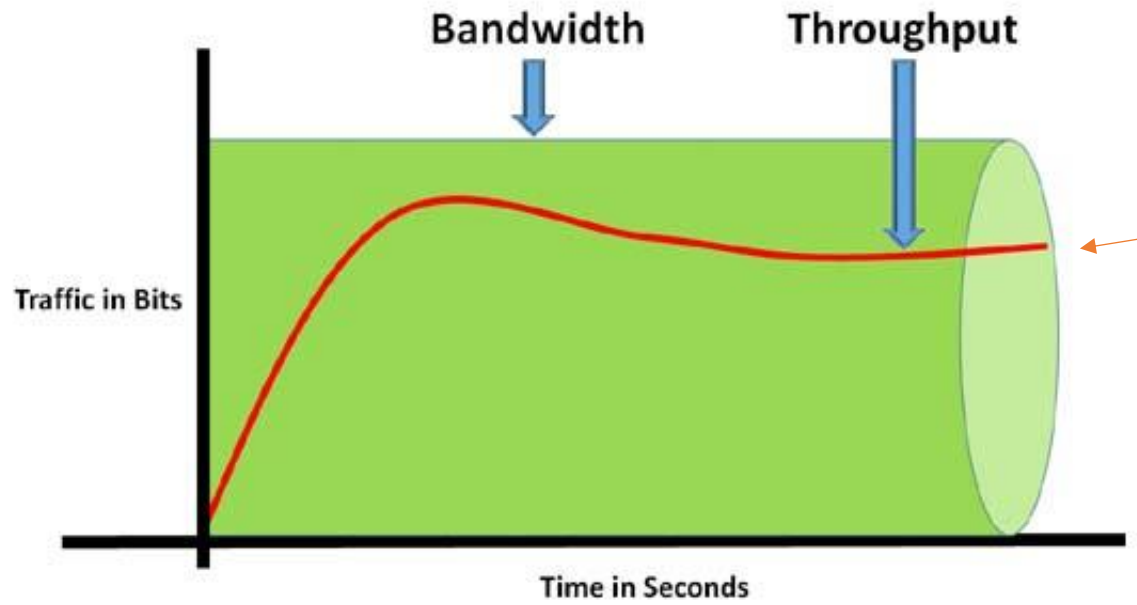
BANDWIDTH

1. **Bandwidth is one the fundamental characteristic used to measure network performance.**
2. **Bandwidth can be stated in hertz or in bits per second** as follows:
   a) **Bandwidth in hertz** is the range of frequencies contained in a composite signal or the range of frequencies a channel can pass. For example, we can say the bandwidth of telephone line is 4 kHz.

   b) **Bandwidth in Bits/s** refers to the maximum number of bits per second that a channel, a link, or a network can transmit, e.g. bandwidth of a Fast Ethernet network is a maximum of 100 Mbps.

THROUGHPUT

1. **Throughput** is a measure of how fast we can send data through a network.
2. Bandwidth in bits per second and throughput are different.
3. **Bandwidth** is a potential measurement of a link; the **throughput** is an actual measurement of how fast we can send data.
4. For example, we can have a link with a bandwidth of 1 Mbps, but the devices connected to the end of the link may handle only 200 kbps.



Throughput measures how many packets arrive at their destinations successfully.

WORKED THROUPUT EXAMPLE

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 1,200 bits. What is the throughput of this network?

Throughput $= No\ of\ Frames/\sec \times Frame\ size\ in\ bits = \frac{No\ of\ Frames/\min \times Frame\ size\ in\ bits}{60}$

$$= \frac{12000 \times 1200}{60}$$

$$= 240\ Kb/s$$

LATENCY

Latency defines how long it takes for an entire message to completely arrive at the destination from the time the first bit is sent out from the source to the time the last bit arrives.

Propagation

Time required for a bit to travel from the source to the destination.

Propagation time = $\frac{Distance}{Propagation\ Speed}$

Transmission time

The time required to send the entire message.

Transmission time = $\frac{Message\ size}{Bandwidth\ in\ MB/s}$

Latency =Propagation time +Transmission time +Queuing time + Processing delay

Queuing time

The time used by each intermediate or end device to hold the message before it can be processed.

Processing Delay

The time take by intermediate and terminal equipment to process data.

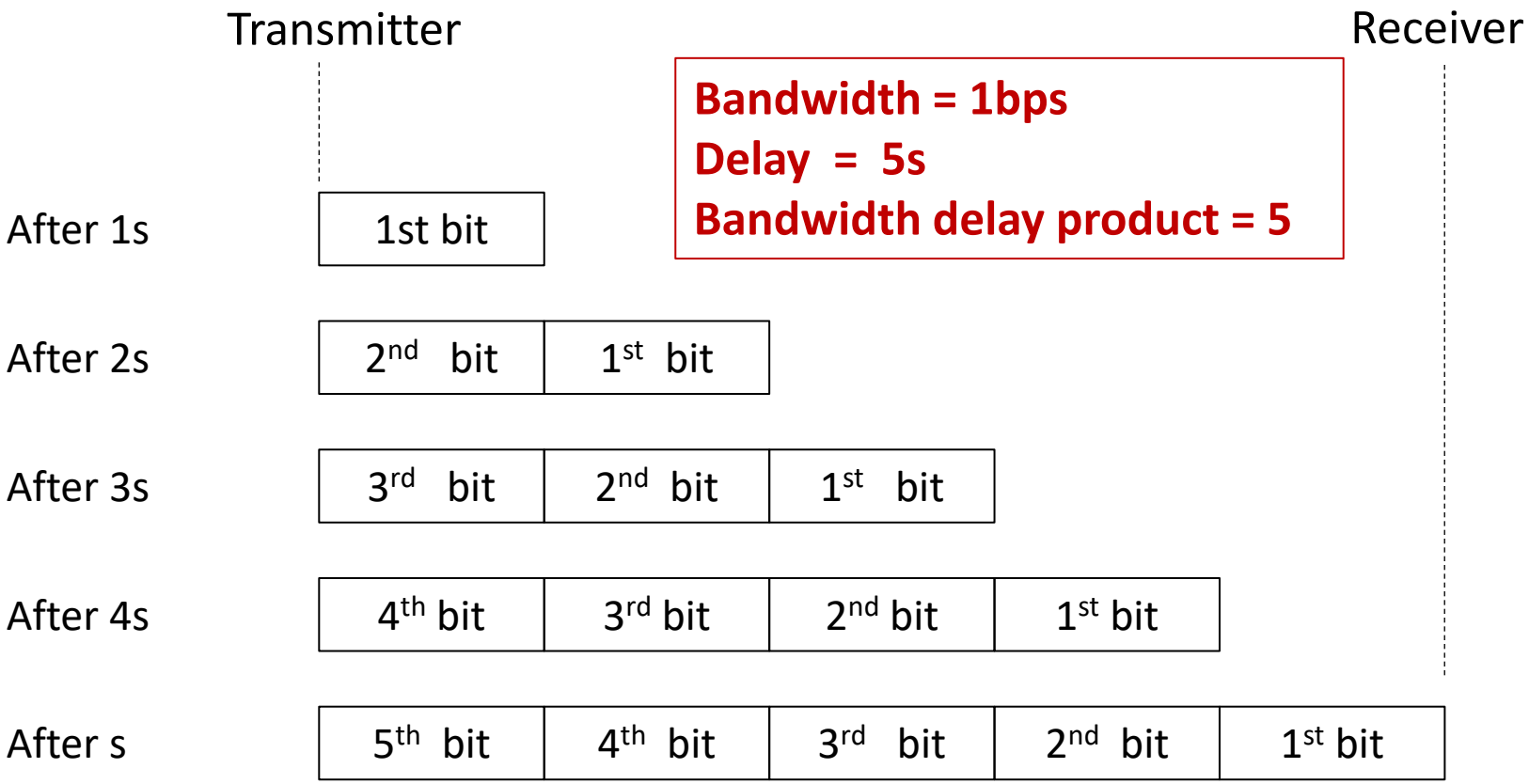
BANDWIDTH-DELAY PRODUCT

1. **Bandwidth-delay product** is the product of a data link's capacity (in bits per second) and its round-trip delay time (in seconds).

2. **Bandwidth-delay product gives the maximum amount of data that can be on the network at any given time** (or the amount that can be transmitted by the sender at a given time before receiving acknowledgment).

EXAMPLE – BANDWIDTH DELAY PRODUCT

A link is of bandwidth 1bps and the delay of the link is 5s.
Calculate its bandwidth delay product.



The product 1 x 5 is the maximum number of bits that can fill the link.
Or, there can be close to 5 bits at any time on the link.

LONG FAT NETWORK (LFN)

1. **A network with a large bandwidth-delay product is commonly known as a Long Fat Network (LFN).**
2. **Internet RFC 1072**, defines LFN as a network with bandwidth-delay product is significantly larger than 12,500 bytes.
3. **A "long fat network" (LFN) is characterized by high bandwidth and long latency.**
4. **LFN presents challenges for TCP's efficient operation**, potentially leading to decreased throughput due to the protocol's reliance on acknowledgements and its window-based flow control.

TYPICAL BANDWIDTH DELAY PRODUCTS

Network	Bandwidth (bits/sec)	Round-trip time (ms)	Bandwidth-delay product (bytes)
Ethernet LAN	10,000,000	3	3,750
T1 telephone line, transcontinental	1,544,000	60	11,580
T1 telephone line, satellite	1,544,000	500	96,500
T3 telephone line, transcontinental	45,000,000	60	337,500
gigabit, transcontinental	1,000,000,000	60	7,500,000

LFNs

1. **The TCP window size is a 16-bit field** in the TCP header, limiting the window to $2^{16} = 65{,}535$ bytes.
2. **Packet loss in an LFN can therefore reduce throughput drastically**.

JITTER

1. **Jitter in computer networks** is the variation in time delay between when a signal is transmitted and when it's received over a network connection, measuring the variability in ping.
2. Jitter is caused by:
   a) Congestion
   b) Poor hardware performance
   c) Low priority given to packets in routers

- High jitter can lead to problems in real-time applications like video conferencing, online gaming, and VoIP calls, **causing choppy audio, delayed video, or even dropped connections**.

WORKED EXAMPLE - LATENCY

- What are the latency for a 5-byte message if the bandwidth of the network is 1 Mbps? Assume that the distance between the sender and the receiver is 12,000 m.

Propagation time = $\frac{12{,}000}{3\times10^8} = 40\ Microseconds$

Transmission time = $\frac{5\times8}{1\times10^6} = 40 Microseconds$

Latency = 2x transmission time = 80 microseconds