Delay and Energy Consumption

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Outline I

1 Delay and Energy Consumption
- Delay
- Energy Consumption

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Delay I

- The latency or delay 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.
- We can say that latency is made of four components: propagation time, transmission time, queuing time and processing delay.

$$\begin{aligned} \textit{Delay} \quad = \quad & \textit{Propagation time} + \textit{Transmission time} + \\ & \textit{Processing time} + \textit{Queuing time} \end{aligned} \tag{1}$$

Propagation time I

- Propagation time measures the time required for a bit to travel from the source to the destination.
- The propagation time is calculated by dividing the distance by the propagation speed.

$$Propagation\ time = \frac{Distance}{Propagation\ Speed} \tag{2}$$

Transmission time I

- In data communications we don't send just 1 bit, we send a message.
- The first bit may take a time equal to the propagation time to reach its destination; the last bit also may take the same amount of time.
- However, there is a time between the first bit leaving the sender and the last bit arriving at the receiver.
- The first bit leaves earlier and arrives earlier; the last bit leaves later and arrives later.
- The time required for transmission of a message depends on the size of the message and the bandwidth of the channel.

$$\textit{Transmission time} = \frac{\textit{Message Size}}{\textit{Bandwidth}} \tag{3}$$

Processing time I

- Processing time is purely depend on the node's architecture and hardware components.

Queuing time I

- The fourth component in latency is the queuing time, the time needed for each intermediate or end device to hold the message before it can be processed.
- The queuing time is not a fixed factor; it changes with the load imposed on the network.
- When there is heavy traffic on the network, the queuing time increases.
- An intermediate device, such as a router, queues the arrived messages and processes them one by one.
- If there are many messages, each message will have to wait.

1 Delay and Energy Consumption
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Energy Consumption I

Accordind to Friis transmission equation :

$$\frac{P_t}{P_r} = \frac{(4\pi d)^2}{G_t G_r \lambda^2} \tag{4}$$

$$P_t = P_r \frac{(4\pi d)^2}{G_t G_r \lambda^2} = P_r \frac{(4\pi df)^2}{G_t G_r c^2} \approx 17.53 \times 10^{-16} \times P_r (df)^2 \tag{5}$$

where, P_t = signal power at the transmitting antenna
P_r = signal power at the receiving antenna
λ = carrier wavelength
f = carrier frequency
G_t = gain of the transmitting antenna
G_r = gain of the receiving antenna
d = propagation distance between antennas
c = speed of light (3×10^8 m/s)
where d and λ are in the same units (e.g., meters).

Energy Consumption II

Thus, we can say,

$$Energy\ Consumption = P_t \times \frac{Number\ of\ bits\ transmitted}{Bit\ Rate} \quad (6)$$