# Transmission Rate, Transmission Delay, Propagation Delay, and Queuing Delay

## Introduction

When a packet travels through a computer network, it experiences multiple types of delays before reaching its destination. These delays depend on:

- Packet size and link bandwidth
- Physical distance between sender and receiver
- Router load and congestion

The four key performance measures are:

Transmission Rate, Transmission Delay, Propagation Delay, Queuing Delay.

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## Transmission Rate (Bandwidth)

### Definition

The **Transmission Rate** $R$ is the speed at which bits are transmitted over a link, measured in **bits per second (bps)**.

$$R = \frac{\text{Number of bits transmitted}}{\text{Time (s)}}$$

### Example

If $R = 100\,\text{Mbps}$, the link can transmit $100 \times 10^6$ bits every second.

**Analogy**

Think of a water pipe. The **width of the pipe** corresponds to the **transmission rate**. A wider pipe allows more water (bits) per second.

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# Transmission Delay

## Definition

The time required to *push all the bits of a packet* into the link:

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

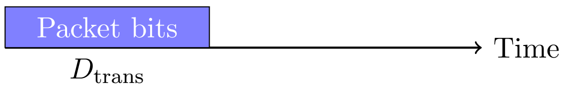
## Example

If packet size $L = 8 \times 10^6$ bits and $R = 10\,\text{Mbps}$:

$$D_{\text{trans}} = \frac{8 \times 10^6}{10 \times 10^6} = 0.8\,\text{s}$$

**Analogy**

Filling a water tank with a pump. The time taken to push *all the water* into the pipe is like transmission delay.

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# Propagation Delay

## Definition

The time for a bit to physically travel across the medium:

$$D_{\text{prop}} = \frac{d}{s}$$

## Example

If $d = 3000\,\text{km}$ and $s = 2 \times 10^8\,\text{m/s}$:

$$D_{\text{prop}} = \frac{3 \times 10^6}{2 \times 10^8} = 0.015\,\text{s}$$

**Analogy**

The time taken for the **first drop of water** to travel through a long pipe is like propagation delay.


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# Queuing Delay

## Definition

The time a packet spends waiting in a router's buffer before transmission.

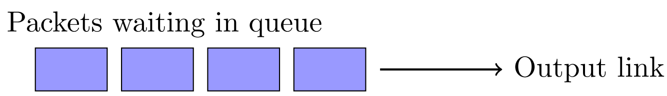
## Example

If 4 packets are ahead, each needing 0.8 seconds to transmit:

$$D_{\text{queue}} = 4 \times 0.8 = 3.2\,\text{s}$$

**Analogy**

Cars waiting at a toll booth. Each car must wait until the cars ahead pass. This waiting time is the queuing delay.

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# Summary Table

| Concept | Formula | Analogy |
|---|---|---|
| Transmission Rate | $R$ (bps) | Pipe width |
| Transmission Delay | $D_{\text{trans}} = L/R$ | Filling a tank |
| Propagation Delay | $D_{\text{prop}} = d/s$ | First drop in pipe |
| Queuing Delay | Depends on traffic | Cars at toll booth |