CS2105
Introduction to Computer Networks

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1 Introduction

1.1 Network Edge

Hosts (end systems) access the Internet through **access networks**, running network applications, and communicating over **links**.

Wireless access network use access points to connect hosts to routers, either via wireless LANs, e.g. Wi-Fi, or wide-area wireless access, e.g. 4G.

Hosts can connect directly to an access network physically via guided media, e.g. twisted pair cables and fiber optic cables, or over-the-air via unguided meia, e.g. radio.

1.2 Network Core

A mesh of interconnected routers which forward data in a network.

Transmitting data through a network takes place via **circuit switching** or **packet switching**.

1.2.1 Circuit Switching

Circuits along the path are reserved before transmission can begin, which mean that no other circuit can use the same path, but performance can be guaranteed.

However, there is a finite number of circuits, so the network is limited in its capacity. This approach is used in telephone networks.

1.2.2 Packet Switching

Messages are broken into smaller chunks, called **packets**. Packets are transmitted onto a link at a **transmission rate**, also known as **link capacity** or **bandwidth**.

The **packet transmission delay** (d_{trans}) is the time needed to transmit an L-bit packet into the link at a transmission rate R.

$$d_{\text{trans}} = \frac{L \text{ in bits}}{R \text{ in bits/sec}} \text{ seconds}$$

Packets are passed from one **router** to the next across links on the path from the source to the destination.

This incurs a **propagation delay** (d_{prop}), which depends on the length d of the physical link, and the propagation speed s in the medium.

$$d_{\text{prop}} = \frac{d}{s \approx 2 \times 10^8 \ m/s}$$

At each router, packets are **stored and forwarded**, which means an entire packet must arrive before being transmitted onto the next link.

Therefore, with P packets and N routers, the **end-to-end delay**:

$$d_{\text{end-to-end}} = (P + N - 1) \cdot \frac{L}{R}$$

At the router, packets are checked for bit errors and the output link is determined using **routing algorithms**. This incurs a **nodal processing delay** (d_{proc}).

Therefore, packets have to **queue** in a **buffer** at each router, also incurring a **queueing delay** (d_{queue}), which is the time spent waiting in the queue before transmission.

In general,

$$d_{\text{end-to-end}} = d_{\text{trans}} + d_{\text{prop}} + d_{\text{queue}} + d_{\text{proc}}$$

1.2.3 Packet Loss

Router buffers have a finite capacity and packets arriving to a full queue will be **dropped**, resulting in **packet loss**. This is known as **buffer overflow**.

Packets can be corrupted in transit or due to noise.

1.2.4 Throughput

The number of bits that can be transmitted the per unit time.

Each link has its own **bandwidth** R, so throughput is measured for end-to-end communication.

$$\text{throughput} = \frac{1}{\sum_{i=1}^{n} \frac{1}{R_i}} \text{ where } n \text{ is the number of links}$$

Peak throughput and other throughput calculations are not covered in this module.

1.3 Network Protocols

The format and order of messages exchanged, and the actions taken after messages are sent and received.

The protocols in the Internet are arranged in a stack of **5 layers**:

1. **application**, e.g. HTTP, SMTP
2. **transport**, e.g. TCP, UDP
3. **network**, e.g. IP
4. **link**, e.g. ethernet, 802.11
5. **physical**, e.g. bits on the wire