Chapter 1

Definition 1.0.1: Key points

1. Networks allow computers to communicate information. Communication requires a shared medium, a common language, and a protocol.
2. Protocols are used at all network layers to define the structure, content, timing, and actions involved in communicating between systems.
3. Understand the difference between packet switching and circuit switching and the fundamental Internet components.
4. The Internet supports two transmission protocols: TCP (connection-oriented reliable service) and UDP (connectionless unreliable service).

Definition 1.0.2: Communication

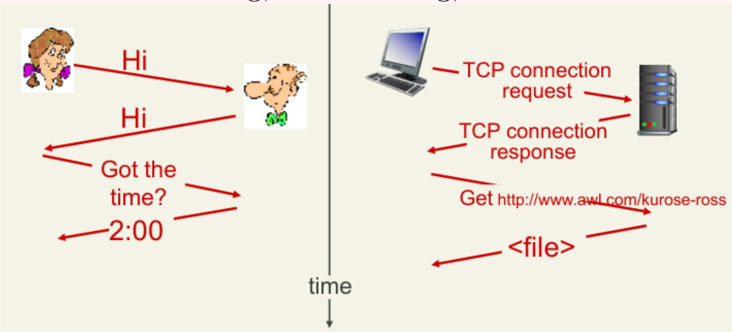
- The act of sending information from one party to another
- Sender transmits the info to one or more receivers
- For effective communication we need
  - Shared medium accessible to both sender and receiver
  - Language or encoding representing the information sent
  - Protocol or set of rules explaining how the medium is used by both the sender and receiver

Types of communication

- Broadcast communication: there is a single sender and multiple receivers
- Point-to-point communication: there is a single sender and single receiver

Definition 1.0.3: Protocol

Defines the format and order of messages exchanged between communicating parties and the actions associated with receiving, transmitting, and other events



Basically a ruleset, there are network protocols that function at various layers such as

- Physical layer protocols - define how bits are represented, encoded/decoded, and transmitted on the medium.
- Link layer protocols - define how bits are segmented and grouped into frames or packets.
- Protocols in upper layers define various services such as connections, error-handling, addressing, and routing.

Definition 1.0.4: TCP/IP (Transmission Control Protocol/Internet Protocol)

The structure/language and protocol used for communicating between computers on the internet
How it works

- Information is broken into sequential fixed-size units called **packets**
- Each packet has space for the unit of data, and also the destination IP address, and it's number in the sequence for reconstruction
- Packets are sent over the internet one at a time with whatever route is available, **this is called packet switching**
- Due to the fact that packets can take multiple routes, congestion and service interruptions do not delay transmissions

Note:-
Standards for internet protocols are created by the **Internet Engineering Task Force (IETF)**. The documents are called **Requests for comments (RFCs)**

Corollary 1.0.1 User datagram protocol (UDP)

Provides connectionless service that performs no handshaking thus is faster than TCP, but also does not provide reliability, flow control or congestion control

Theorem 1.0.1 Sending packets of data: host perspective

- Gets application message
- Breaks into packets of length L bits
- Transmits packets into access network at *transmission rate/link capacity,link bandwidth* R

$$\text{Packet transmission delay} = \text{Time needed to transmit L-bit to link} = \frac{L}{R\text{bits/sec}}$$

Corollary 1.0.2 Packet Switching: Store-and-Forward

- Transmission delay: takes L/R seconds to transmit L-bit packet into link at R bps
- Store and forwared: The entire packet must arrive at router before it can be transmitted on next link
- End-to-end Delay: $2\frac{L}{R}$(assuming zero propogation delay)

If the arrival rate is higher than the transmission rate of link then

- Packets will be queued and wait to be transmitted on link
- Packets can be dropped if memory buffer fills up

Packet Vs Circuit Switching

- Circuit switching: Networks reserve the resources needed for the duration of a communication before sending the data. These resources include buffers at switches and bandwidth on the links. Each communication link is divided among the number of circuits and the bandwidth is $\frac{1}{n}$ of the total bandwidth supported on the link. This is devided up either by a fixed value (FDM), or each circuit gets the full bandwidth for a set block of time and rotates between them (TDM)
- Packet switching: Networks don't reserve resources and the communicated data use the necessary resources on demand. Due to the store-forward method, there is a delay at *every link* the packet traverses; therefore the delay is $\frac{L}{R}$ bps. Also incurs **queue delays** when waiting for the buffer to free up, depends on network traffic; if very busy could result in packet loss

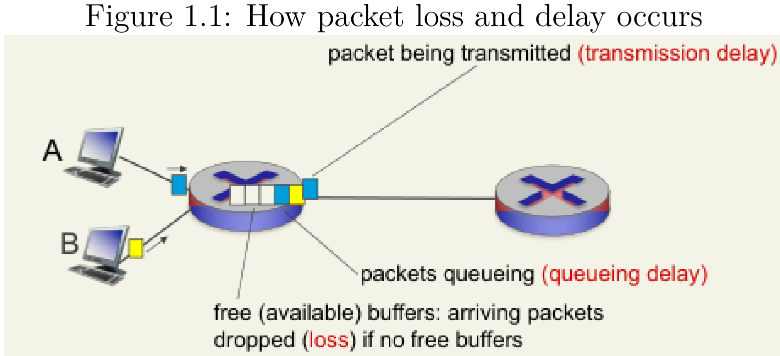
Note:-

There are two main issues with circuit switching

1. They waste bandwidth and resources during idle times as each circuit is garanteed a dedicated bandwidth at all times whether it uses it or not
2. There is a significant overhead and complexity to setup circuits and the associated resources. This setup time introduces an initial delay that may be significant for short communications

1.1 Packet Delay and Loss

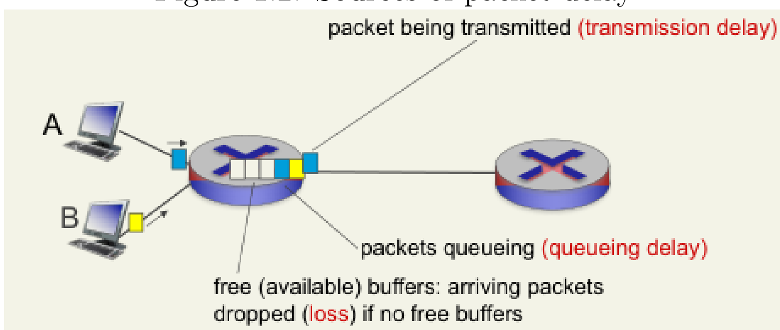
Figure 1.1: How packet loss and delay occurs



Sources of Packet delay

1. Processing delay: Time to read header and direct packet
2. Queuing delay: Time waiting in queue to be transmitted (depends on congestion/load)
    - It's traffic delay can be characterized by $\frac{La}{R}$ where a is the **average packet arrival time**
    - $\frac{La}{R}0$: Average queueing delay small
    - $\frac{La}{R} \to 1$: Average queueing delay large
    - $\frac{La}{R} > 1$: More work than can be serviced at once
3. Transmission delay: Time to transmit packet on link
4. Propogation delay: Time to propogate from one end of link to the other (near speed of light)

Figure 1.2: Sources of packet delay



These delays add up to a total delay called $d_{\textbf{nodal}}$

$$d_{\text{nodal}} = d_{\text{queue}} + d_{\text{trans}} + d_{\text{prop}}$$

- d_{proc}:
    - Checks for bit errors
    - Determine the output link
    - Typically under a milisec
- d_{queue}:
    - Time waiting for output link for transmission
    - Depends on congestion level of router
- d_{trans}:
    - L: Packet length (bits)
    - R: Link **bandwidth** (bps)
    - $d_{\textbf{trans}}$=$\frac{L}{R}$
- d_{prop}
    - d: Length of physical link
    - s: Propogation speed ($2 * 10^8 \frac{m}{\text{sec}}$)
    - $d_{\textbf{prop}}$=$\frac{d}{s}$

Theorem 1.1.1 Throughput

The rate $\frac{\text{bits}}{\text{time}}$unit at which bits transferred between sender and receiver

- Instantaneous: Rate at any given time
- Average: Rate over a longer period of time

Note:-

Bottlenecking: Our throughput is bottlenecked to what the **lowest throughput** of any link in the chain is