CS 456/656 - Computer Networks **Fall 2018**

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2.1 What's the Internet

- A Network Billions of connected computing devices
- Hosts are the end systems
- Communication links are the result of a network established by complex physical infrastructure.
- Packet switches help forwards packets (chunks of data) between systems on the internet

2.2 Network Structure

Network structure consist of multiple components

- **Network Edges** : A collection of hosts which are clients and servers
- **Access Networks and Physical Media** : Various wired and wireless communication links (Provide Access to the Internet)
- **Network Core** : A series of interconnected routers and a network of networks

2.3 Access Networks

Definition 2.1 ***Capacity Bandwidth*** *: The physical limit of amount of data carried by a access network*

Definition 2.2 ***Frequency Division Multiplexing (FDM)*** *- Splits a access connection into multiple parts to allow multiple connection by modulating the frequency of each connection*

Definition 2.3 ***Time Division Multiplexing (TDM)*** *- Allocates the full capacity of a access network for one connection for a small period of time before swapping for another connection*

- Digital Subscriber Line (DSL)
  - DSL Utilizes existing telephone lines to central office DSLAM.
  - Upstream has a theoretical max of 2.5Mbps, but typically is 1Mbps in practice
  - Downstream has a ideal max of 24Mbps, but typically 10Mbps
- Cable Networks

- Due to the concentric nature of the cable network, there is less noise which allows for more data to be transferred.
- **Frequency Division Multiplexing** allows for different channels transmitted in different frequency band. This can be utilized to data in addition to regular tv signals.
- The difference from DSL is that the cable is not dedicated. Coxial Cable are shared by multiple homes along the network.
- HFC (Hybrid Fiber Coax) can typically achieve an asymmetric 30Mbps downstream and 2Mbps upstream

2.4 Core Networks

- A mesh of interconnected routers
- packet switching: hosts break application layer messages into packets
- Access networks connect users to the core and the core forwards connections along to their correct locations
- Two key functions is routing and fowarding

Definition 2.4 ***Routing*** *- Determines source destintaion route taken by packets*

Definition 2.5 ***Forwarding*** *- Move packets from routers input to appropriate routers output*

- There are two types of core switching, Circuit and Packet Switching

2.4.1 Circuit Switching

- end-end resources are allocated to ensure there is a dedicated link between each user and the end point.
- circuit segments are unused if let idle.
- Circuit switching can use FDM or TDM to divide the singular physical connection

2.4.2 Packet Switching

- Hosts break application-layer messages into packets and forward packets from one router to the next. Each of the packets are transmitted at full link capacity
- `L` = bits per packet and `R` = bits per second
- Methods for forwarding
  - Store-And-Forward
    - Entire packet must arrive at router before it can be transmitted on the next link
    - Takes $\frac{L}{R}$ seconds to transmit L-bit packet into link at R bps
    - end-end delay is $2\frac{L}{R}$ assuming no propagation delay
  - Cut-Through

    - Switch starts forwarding a frame before the whole frame has been received
    - This technique reduces latency through the switch and relies on teh destination devices for error handling
    - Only possible if the speed of the outgoing network is equal to /greater than the incoming network

- Probability of success of a connection on a packet switch network can be modelled via a binomial distribution
  -
  $$p(X = r) = \binom{n}{r} p^r q^r$$
  - r = number of failures

Definition 2.6 ***Queuing and Loss*** *- If arrival rate to link exceed transmission rate of link for a period of time*

- *Packets will queue, wait to be transmitted on link*
- *packets can be dropped if memory fills up*

2.4.3 Packet Delays

There are four sources of packet delays

- d_{proc} - Nodal processing delay
  - Occurs on the core and is the result of validating data and determining output link.
  - Typically is in the milliseconds
- d_{queue} - Queuing delay
  - Time spent waiting at the output link for transmission.
  - Wait times depend on congestion level of router
- d_{trans} - Transmission Delay
  - Amount of time required for the router to push out the packet
  - $d_{trans} = \frac{L}{R}$
- d_{prop} - Propagation Delay.
  - Time it takes a bit to propagate from one router to the next.
  - Typically insignificant and irrelevant as the propagation speed is ($\approx 2 \times 10^8$m/sec)
  - $d_{prop} = \frac{d}{s}$

Definition 2.7 ***Throughput*** *: rate (bits/time unit) at which bits transferred between sender/receiver*

- ***instantaneous:*** *rate at given point in time*
- ***average:*** *rate over longer period of time*

2.4.4 Encapsulation

On most modern systems there is a series of information added onto a packet to help direct data and abstract network control.

- M - **Application** Layer provides the message
- H_t - **Transport** Layer adds IP address
- H_n - **Network** Layer is a physical hardware layer that appends its own identifiable information (Black box for now)
- H_i - **Link** Layer adds system MAC. address (Media Access Control Address)
- **Physical** Layer adds no additional data, but is responsible for physically sending off data across a network.