CS2105 Live Class Lec1: Overview of Internet Structure

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1 Overview of the internet

1.1 nuts and bolts view

Hosts/end systems: devices running network apps
Communication links: fiber, copper, radio, stallite
Transmission rate: bandwidth(the rate at which the data can be transmitted)
Packet switches: forward packets (chunks of data) (routers and switches)

1.1.1 Difference between router and switch

1. switch is designed to connect computers within a network

2. a router is designed to connect multiple networks together

1.2 network edge

Hosts: client and servers
The servers are oftern in data center(e.g. google has local data center in Singpore, the Apple Chinese data center is Gui Zhou)

1.3 access networks, physical media

media wired, wireless communication links

2 network core

2.1 interconnected routers

1. Packet-switching: hosts break application-layer message into packets
2. forward packets from one router to the next, across links on path from source to destination
3. each packet transmitted at full link capacity(if a link has 5Mg/s capacity, when wen want to transmit one pkt, we transmit that pkt at that rate

2.1.1 The step flow of transmitting message

1. takes the application messages and break them into smaller chunks or pkt of length L bits
2. transmits pkt into access network at transmission rate R
The "link transmission rate"=="capacity"=="link band width"
pkt transmission delay=time needed to transmit L-bit pkt into link $=\frac{L(bits)}{R(bits/sec)}$

2.1.2 Packet-switching: store-and-forward

Takes L/R seconds to transmit L-bit packet into link at R bps
store and forward: entire packet must arrive at router before it can be transmitted on next link

2.1.3 Packet Switching: queueing delay, loss

Queueing and loss:
if arrival rate(in bits) to link exceeds(>) transmission rate of link for period of time:
* packets will queue, wait to be transmitted on link
* pkts can be dropped if memory fills up

2.2 Two key network-core functions

2.2.1 routing

determines source-destination route taken by pkts

2.2.2 forwarding

move pkets from router's input to appropriate router output

3 circuit switching

End-end resources allocated to, reserved for "call" between resource and dest

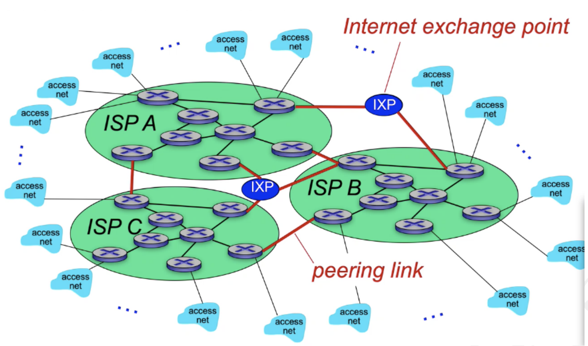
The traditional call(perhaps the private telephone between countries' presidents nowaday

4 Internet structure

End systems connect to Internet via access ISPs(Internet Service Providers)

The ISPs are interconnected so that any two hosts can send pkts to each other

The complex resulting network of networks is very complex (driven by tech, economics and national policies)

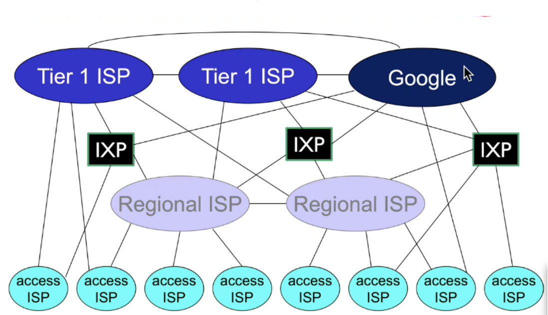


peering link: the ISP connects with each other in one-to-one manner(there r negotiations)

The IXP: internet exchange points connecting ISPs, ISPs post their link there and ISP can visit via the link there(but no guarantee for quality and compacity)

Regional net: provide services regionally

Content provider network(google, facebook, instegram)



5 The algorithm of sending a packet in a packet switching network

1. Sender transmit a packet onto the link as a sequence of bits.
2. Bits are propagated to the next node(e.g. a router) on the link.
3. Router stores, processes and forwards the segments to the next link.
4. Steps 2 and 3 repeat till the packet arrives at the receiver.

6 packet arrive delay

$D_{nodal} = D_{proc} + D_{queue} + D_{trans} + D_{prop}$

6.1 D_{proc}

Process Delay(D_{proc})
1. check bit errors
2. determine output link(divide the message into packets
3. typically<msec
4. determined by the hosts

6.2 D_{queue}

queueing delay
1. time waiting at output link for transmission
2. depends on congestion level of router and the transmission rate

6.3 D_{trans}

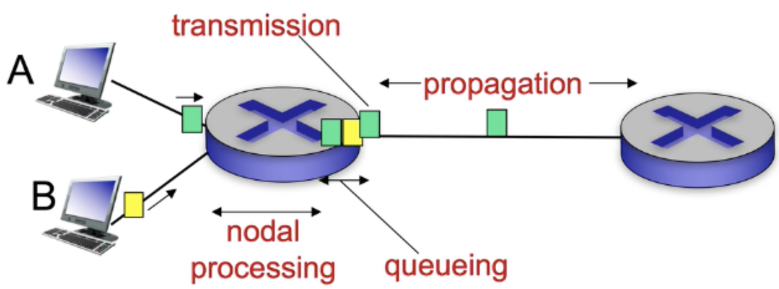
transmission delay
transmission delay (or store-and-forward delay) is the amount of time required to push all of the packet's bits into the wire
Most packet switched networks use store-and-forward transmission at the input of the link. A switch using store-and-forward transmission will receive (save) the entire packet to the buffer and check it for CRC errors or other problems before sending the first bit of the packet into the outbound link. Thus store-and-forward packet switches introduce a store-and-forward delay at the input to each link along the packet's route.
hence it's determined by the router(luyouqi in Chinese) L: packet length(bits)

R: link bandwidth(bps)
$D_{trans} = \frac{L}{R}$

6.4 D_{prop}

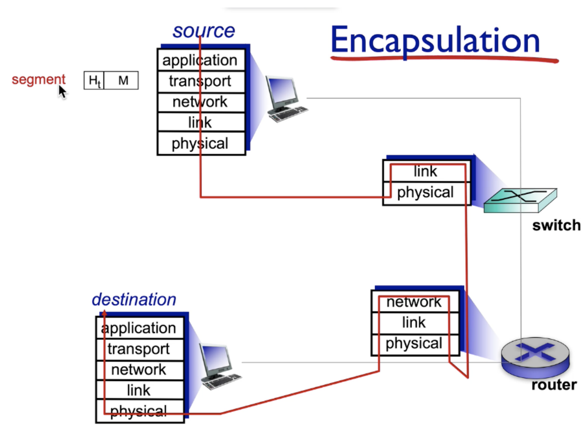
propagation delay
The time required for a signal to pass through a given complete operating circuit. The time it takes to transmit a signal from one place to another.

d:length of physical link
s: propagation speed(2 $\times 10^8$m/sec) $D_{prop} = \frac{d}{s}$
Usually in unit of nanosecond
Propagation delay is dependent solely on distance and two thirds the speed of light. Signals going through a wire or fiber generally travel at two thirds the speed of light.
In unit of d/s



6.5 Exercise

6.5.1 End-to-end delay



Two hosts A and B are connected via a router. The link rate is 1 Mbps and propagation delay is 40 ms per link. The maximum size of a packet is 1 Kb and packet header is 80 bits. Suppose sender sends as much data as possible in a packet, packets are sent continuously and no packet is corrupted or lost during transmission.

How long (in milliseconds) does it take to send a 400 Kb file from A to B (from when the first bit of the first packet leaves A to when last bit of the last packet arrives at B)?

# of pkt = $\left\lceil \frac{400*10^3}{1000-80} \right\rceil = 435$

Total # of bits sent = 435*80 + 400,000 = 434,800

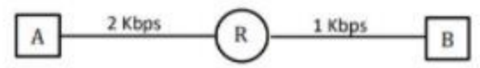
Length of first 434 packets: 1,000

Length of last packet: 800

End-to-end delay = $\frac{1000}{10^3} + 40 + \frac{434{,}800}{10^3} + 40 = 515.8$ **ms**

6.5.2 queuing delay

Two hosts **A** and **B** are separated by a router **R** in between. The bandwidth of the links between **A** and **R** and between **R** and textbfB are 2Kbps and 1Kbps respectively. The propagation delay is 500 msper link. Ignore all other kinds of unmentioned delays. Suppose **A** sends 80000 bits to **B** as a series of consecutive packets of 1000 bits each, what is the queueing delay (in seconds) of the 15^{th} packet in **R**?



For A to R:

1. $D_trans = 1000bits/2000Kbps = 0.5s$
2. $D_prop = 0.5s$

For R to B:

1. $D_trans = 1000bits/1000Kbps = 1s$
2. $D_prop = 0.5s$

1.0s:

1. 1^{st} pkt arrive R
2. the 2^{nd} pkt leaves A
3. from when, every 0.5 s, there is one pkt arrive R

Hence when 15^{th} pkt arrive R, it's 1.0s+(15-1)*0.5=8s
2.0s:

1. The 1^{st} pkt leave R
2. from when, every 1 s, there is one pkt leaves R
3. there is 2 pkg left at 2.0s
4. because since 1s, there is 1pkt arrive R every 0.5s(i.e. 2 pkt every second), and 1 pkt leave every second, the R buffer will add 2-1=1 pkt every second)

8.0s:

1. there are 2+(8-2)*1=8 pkt(includes $15^{th}pkt$
2. for the first 7 pkt, every pkt takes 1 second of D_trans

Hence the $15^{th}pkt$ should wait for 7s, $D_queue = 7s$

6.5.3 Conclusion for these delay related problem

1. RTT are two-direction while end-to-end delay is one direction
2. First clarify/calculate how many pkt should be sent and the size of each pkt; Usually only the last pkt size would possibly be different

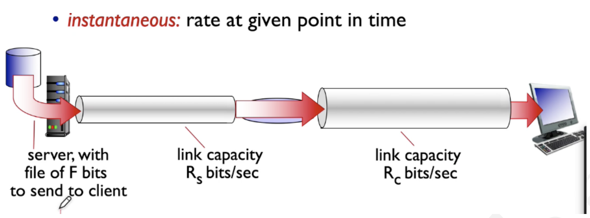
3. Understand the state of the first pkt, when it leaves the node, and when it arrives certain node, when it reaches the destination
4. Understand the state relationship of the second pkt(or some other key pkt) with pkt 1, which can be further inducted to the relationship between i+1 and i

7 Throughput

Rate(bits/time unit) at which bits transferred between sender/receiver

7.1 Two types of throughput

1. average: rate over longer period of time
2. instantaneous: rate at given point in time



Assume there is a file with size of F, the rate of the first pipeline is R1 and the rate of the second pipeline is R2

Throughput=$\frac{F}{\frac{F}{R1}+\frac{F}{R2}}$

7.2 difference between throughput and link capacity

Throughput is measured for end-to-end communication.
Link capacity(bandwidth) is meant for a specific link.

8 service view of Internet

8.1 infrastructure that provides services to applications

Web,VoIP,Email,game, e-commerce, social nets

8.2 provide programming interfaces to apps

hooks that allows sending and receiving app programs to "connect" to internet
provides service options analogous(like) to postal service

9 protocols

Protocols define **format,order** of **message sent and received** among network entities, and **actions taken** on message transmission, receipt

10 protocols structure

10.1 Layers Structure

1. performing actions within that layer
2. relying on the services provided the layer below it (Hide details from each other)
3. explicit structure allows identification, relationship of complex system's pieces(which means can better and more easily describe the functionality and state of each part)
4. modularization eases maintenance , updating of system
5. Simple interfaces between layers

10.2 Internet protocol stack

10.2.1 Application: supporting network applications

FTP,SMTP, HTTP

10.2.2 Transport: process-process data transfer

TCP, UDP

10.2.3 Network: routing of datagrams from source to destination

IP, routing protocols

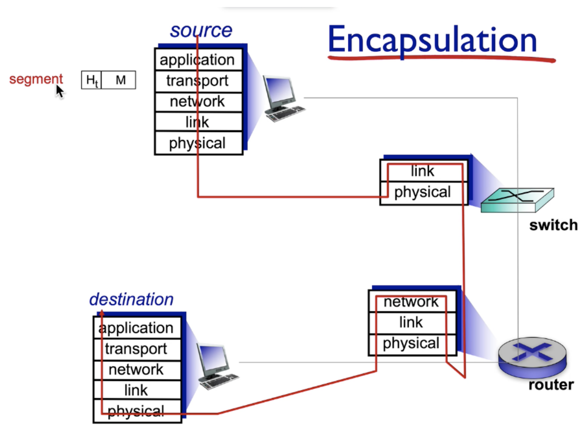
10.2.4 link: data transfer between neighboring network elements

Ethernet, 802.111(Wifi),PPP

10.2.5 physical: bits "on the wire"

IMPORTANT: Above(inclusively) transport layer r purely software, below(inclusively) link layer r purely hardware

10.3 Internet step flow



1. data packet will go through all the protocol/stages from the source
2. At the transport layer, will break the packets into segment
3. In the network layer: data was handled from segment into datagram
4. At the link layer, packets are called frame
5. The touter will implement network layer while switch does not
6. When the packets arrive, they will go through the five layer in upward manner