**CS 456 Computer Networks**

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Grading

* Midterm (25%) June 14th 7:00-8:50pm TBD
* Final (35%)
* Assignments (30%):
* Two programming assignments (15% each)
* Tentative important dates on LEARN/Calendar
* Quizzes (10%)

**Chapter 1: roadmap**

**1.1 what is the Internet?**

What's the Internet: "nuts and bolts" view

- Switches are used in access networks and routers are used in core networks

- End systems access the internet through ISPs such as the local cable or telephone companies, university ISPs,..

- An ISP is a network of packets switches and communication links.

- ISPs provide a variety of types of network access like wireless, DSL, dial up, high speed LAN. They also provide access to content developers

- TCP: Transmission Control Protocol

- IP: Internet Protocol (defines the formats of the packets)

* millions of connected computing devices:
* hosts = end systems
* running network apps
* communication links
* fiber, copper, radio, satellite
* transmission rate: bandwidth
* packet switches: forward packets (chunks of data)
* routers and switches
* Internet: “network of networks”
* Interconnected ISPs
* protocols control sending, receiving of msgs
* e.g., TCP, IP, HTTP, Skype, 802.11
* Internet standards
* RFC: Request for comments
* IETF: Internet Engineering Task Force

"Fun" internet appliances

Computer networks is a little outdated given that now some non traditional devices are being hooked up to the internet

* IP picture frame
* Web-enabled toaster + weather forecaster
* Tweet-a-watt: monitor energy use
* Internet refrigerator
* Slingbox: watch, control cable TV remotely
* Internet phones

What's the Internet: a service view

- Application Programming Interface (API): set of rules that the sending program must follow so that the internet can deliver its data to the destination program

- Like the postal service API is put data which is letter in an envelop, seal, stamp, write address and drop at mailbox

* Infrastructure that provides services to applications:
* Web, VoIP, email, games, e-commerce, social nets, …
* provides programming interface to apps
* hooks that allow sending and receiving app programs to “connect” to Internet
* provides service options, analogous to postal service

What's a protocol?

* human protocols:
* "what's the time?"
* "i have a question"
* introductions
* network protocols:
* machines rather than humans
* all communication activity in Internet governed by protocols

... specific msgs sent

... specific actions taken when msgs received, or other events

* protocols define format, order of msgs sent and received among network entities, and actions taken on msg transmission, receipt
* a human protocol and a computer network protocol:

**1.2 network edge (end systems, access networks, links)**

A closer look at network structure

* network edge:
* hosts: clients and servers
* servers often in data centres
* access networks, physical media
* wired, wireless communication links
* network core
* interconnected routers
* network of networks

Access networks and physical media

In home the 2 most popular broadband residential access is DSL (digital subscriber line) and cable

*Q: How to connect end systems to edge router?*

- residential access nets

- institutional access networks (school, company)

- mobile access networks

* keep in mind:
* bandwidth (bits per second) of access network?
* shared or dedicated?

Access net: digital subscriber line (DSL)

- Typically DSL is obtained from the same local telephone company. It uses twisted pair coper wire

- DSLAM: Digital subscriber line access multiplexer

- DSL provider might limit max rate due to tiered services, distance might limit, electrical interference,..

- DSL is used for short distances if the residential access is not within 10miles from the CO alternative methods must be seeked

* use existing telephone line to central office DSLAM
* data over DSL phone line goes to Internet
* voice over DSL phone line goes to telephone net
* < 2.5 Mbps upstream transmission rate (typically < 1 Mbps)
* < 24 Mbps downstream transmission rate (typically < 10 Mbps)

Access net: cable network

- Cable modem termination system (CMTS): turns analog signal to digital

- One junction serves 500 to 5000 homes

- Cable makes use of the existing television’s company cable.

frequency division multiplexing: different channels transmitted in different frequency bands

* HFC: hybrid fiber coax
* asymmetric: up to 42.8Mbps downstream transmission rate, 30.7 Mbps upstream transmission rate
* network of cable, fiber attaches homes to ISP router
* homes share access network to cable headend
* unlike DSL, which has dedicated access to central office

Access net: home network

Access net: fiber to the home

ONT: Optical network terminator

OLT: Optical Line terminator

Splitter combines up to 100 homes

* Optical Distribution Network Architecture
* Active (AON)
* Passive (PON)
* Rates can be up to gigabit per second

Enterprise access networks (Ethernet)

* typically used in companies, universities, etc
* 10 Mbps, 100Mbps, 1Gbps, 10Gbps transmission rates
* today, end systems typically connect into Ethernet switch

Wireless access networks

* shared wireless access network connects end system to router
* via base station aka “access point”
* wireless LANs:
* within building (100 ft)
* 802.11b/g/n/ac (WiFi): up to 300Mbps transmission rate
* wide-area wireless access
* provided by telco (cellular) operator, 10’s km
* between 1 and 40 Mbps
* 3G, 4G: LTE

Host: sends packets of data

host sending function:

* takes application message
* breaks into smaller chunks, known as packets, of length L bits
* transmits packet into access network at transmission rate R
* link transmission rate, aka link capacity, aka link bandwidth

Physical media

Bit is sent by propagating electromagnetic waves or optical pulses across a physical medium

* bit: propagates between transmitter/receiver pairs
* physical link: what lies between transmitter & receiver
* guided media:
* signals propagate in solid media: copper, fiber, coax
* unguided media:
* signals propagate freely, e.g., radio, satellite

twisted pair (TP)

* two insulated copper wires
* Category 5: 100 Mbps, 1 Gpbs Ethernet
* Category 6: 10Gbps

Physical media: coax, fiber

* coaxial cable:
* two concentric copper conductors
* bidirectional
* broadband:
* multiple channels on cable
* fiber optic cable:
* glass fiber carrying light pulses, each pulse a bit
* Used mostly in overseas links
* high-speed operation:
* high-speed point-to-point transmission (e.g., 10’s-100’s Gpbs transmission rate)
* low error rate:
* repeaters spaced far apart
* immune to electromagnetic noise

Physical media: radio

* signal carried in electromagnetic spectrum
* no physical “wire”
* bidirectional
* propagation environment effects:
* reflection
* obstruction by objects
* interference

radio link types:

* terrestrial microwave
* e.g. up to 45 Mbps channels
* LAN (e.g., WiFi)
* 11Mbps, 300 Mbps
* wide-area (e.g., cellular)
* 3G cellular: ~ few Mbps
* satellite
* Kbps to hundreds Mbps channel (or multiple smaller channels)
* 270 msec end-end delay
* geosynchronous versus low altitude

**1.3 network core (packet switching, circuit switching, network structure)**

The network core

* mesh of interconnected routers
* packet-switching: hosts break application-layer messages into packets
* forward packets from one router to the next, across links on path from source to destination
* each packet transmitted at full link capacity

Packet-switching: store-and-forward

* takes L/R seconds to transmit (push out) 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
* end-end delay = 2L/R (assuming zero propagation delay) -> more on delay shortly ...
* one-hop numerical example:
* L = 7.5 Mbits
* R = 1.5 Mbps
* one-hop transmission delay = 5 sec

Packet Switching: queueing delay, loss

queuing and loss:

* If arrival rate (in bits) to link exceeds transmission rate of link for a period of time:
* packets will queue, wait to be transmitted on link
* packets can be dropped (lost) if memory (buffer) fills up

Two key network-core functions

* routing: determines source-destination route taken by packets
* routing algorithms
* forwarding: move packets from router's input to appropriate router output