Networks

What we have done so far

- Information Privacy and HIPAA
- How do computers work?
- So now moving onto network of computers

Topics

- Point to point connections
- Data Representation
  - Numbers, Characters, Documents, Pictures
- Networks
  - LANs vs WANs
  - Circuit switched vs. packet switched
- Example: The Internet
- Network protocols
- Example: Looking at a web page
- Wi-Fi and Bluetooth (Optional)

A simple point-to-point connection

- Processor convert data into signals
  - Example: Modem, Ethernet card
- Signals are transported through channels
- Channels utilize one or more connection media

Signal/Data: Analog vs. Digital

- Analog data
  - Can take on any value within a continuous range
  - Examples:
    - Human voice
    - Temperature
- Digital data
  - Can take on only a finite set of discrete values
  - Examples:
    - Data stored in binary computers
    - The US standard size of clothes

Old Network: Now Mostly Digital

Movement Towards Digital

Connection media – Examples

Medium	Speed	Cost
Twisted wire	30 BPS – 10 MBPS	Low
Microwave	256 KBPS – 100 MBPS	
Coaxial cable	56 KBPS – 200 MBPS	
Optical fiber	500 KBPS – 10 GBPS	High

BPS = bits per second
All digital channels
Phone line: used to be analog channel

What is bandwidth

- Technically:
  - The range of usable frequencies in a communications medium
- Practically:
  - The amount of information that can be carried by a communications medium per unit of time
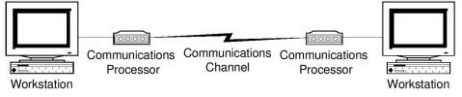
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Representing Numbers

$$1\ 0\ 1\ 1$$
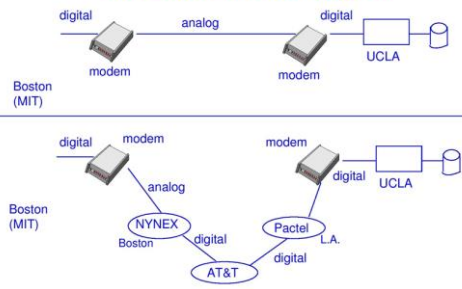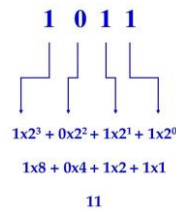
$$1 \times 2^3 + 0 \times 2^2 + 1 \times 2^1 + 1 \times 2^0$$

$$1 \times 8 + 0 \times 4 + 1 \times 2 + 1 \times 1$$

$$11$$

Number	4-bit binary representation
1	0001
2	0010
3	0011
…	…

Representing Characters

- ASCII: 7 bits
- UTF-8 (Universal Character Set Transformation Format)
  - variable length and uses 8 bit-code units (1 byte)
- Content-Type: text/html; charset=UTF-8

Character	ASCII/UTF-8 (Decimal)	Representation (Binary = 1 byte)	Representation (Hex = 2 byte)
A	65	0100 0001	0041
B	66	0100 0010	0042
C	67	0100 0011	0043
…	…	…	…
a	97	0110 0001	0061
b	98	0110 0010	0062
…	…	…	…
0	48	0011 0000	0030
1	49	0011 0001	0031
…	…	…	…

Formatted Documents

- In addition to text, must contain information about how it appears on paper
  - Bold, italic, underlined text
  - Different sizes of type
  - Page breaks
- "Invisible" formatting characters are embedded in text
  - Special "begin formatting" character
  - Format specification character (i.e. "bold type")
  - Text string for which formatting applies
  - Special "end formatting" character
- Same character codes have different meaning when interpreted as letters and when as format specifications
  - 65 could mean either 'A' or 'bold' depending on context

Formatted Documents (cont'd)

- Example:
  - This is <u>nicely</u> formatted line.
- Could be stored internally as:
  - <BG PAR> 'T' 'h' 'i' 's' ' ' 'i' 's' ' ' 'a' <BG UNDERLINE> 'n' 'i' 'c' 'e' 'l' 'y' ' ' <EN UNDERLINE> <BG COLOR>1 'f' 'o' 'r' 'm' 'a' 't' 't' 'e' 'd' <EN COLOR> 'l' 'i' 'n' 'e' '.' <CR>
- Where:
  - <BG PAR>, <BG UNDERLINE>, <EN UNDERLINE>, <BG COLOR><EN COLOR><CR> are special byte sequences that denote the beginning and end of various formatting features
  - Different word processors use different byte sequences, that's why documents require conversion to be used by a different word processors

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```
<meta http-equiv="content-type" content="text/html; charset=UTF-8">
<meta charset="utf-8">
```

Pictures (Images)

- Numbers, letters, and words are not enough: we want pictures
- Representing a picture
  - Draw a very fine grid on it
    - Grid cells are called pixels or dots
  - See what is in each grid cell
    - Bitmap: is cell empty or full?
    - Grayscale: how dark is the cell?
    - Color: what color is the cell?
  - Represent each cell with a pre-specified # of bits (RGB=256+256+256=8+8+8=24 bits)
  - Store the bits for the cells in a pre-specified order
    - e.g. all the cells for the top row, then the next row, etc.

Color Representation (Pixel)

- http://upload.wikimedia.org/wikipedia/commons/thumb/c/c2/AdditiveColor.svg/220px-AdditiveColor.svg.png
- http://en.wikipedia.org/wiki/File:Hsl-hsv_models.svg

Videos

- Many images (frames)
- Frame frequency
  - Frames per second (FPS)
- Compression: Video Codec
  - Only slight changes between consecutive frames
  - Same as previous frame EXCEPT …
  - Device or software to compress/decompress
  - Lossless compression

Audio

- ADC: Analog-to-Digital converter
- DAC: Digital-to-Analog converter

- http://en.wikipedia.org/wiki/File:4-bit-linear-PCM.svg
- http://upload.wikimedia.org/wikipedia/commons/8/84/A-D-A_Flow.svg

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Why build networks?

Full Connectivity doesn't scale!

Networks are about sharing

- The network allows an entity to switch its attention among a large number of others
- Permits sharing of resources attached to the network, including the resources of the network itself

Local and Wide Area Networks

- Local Area Networks (LANs)
  ◦ Short distances
  ◦ Within organizations
  ◦ Typical technology: Ethernet or Token Ring
- Wide Area Networks (WANs)
  ◦ Long distances
  ◦ Across organizations (typically multiple LANs)
  ◦ Typical technology: Public Switched, Leased Line

Two forms of network connection

- Circuit switching
  ◦ A dedicated end-to-end connection is established for the duration of the connection
  ◦ Used in telephone network
- Packet switching
  ◦ Messages are divided into small packets
  ◦ Each packet is separately routed to the destination
  ◦ Different packets can take different paths and times
  ◦ Missing or garbled packets are retransmitted, if necessary
  ◦ Packets are reassembled into messages at the destination

Packet switching
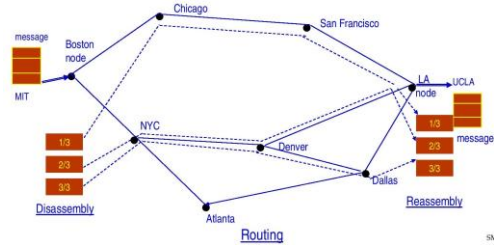
Packet switching

| Circuit switching	Packet switching
Minimum delay	Variable delay
Very inefficient use of connection capacity	Much more efficient use of connection capacity
When overloaded, unable to make connection at all	Can almost always connect, but may be long delays
Both ends of connection must use same data rate	Data-rate conversion is easy

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The Internet

- What is the Internet?
  ◦ Outgrowth of ARPANET
  ◦ Based on TCP/IP
  ◦ A collection of interconnected networks
  ◦ Provides appearance of widespread connectivity
- What is it used for?
  ◦ E-mail, file transfer, terminal access, client-server traffic, information browsing (aka Web), distributed work, electronic commerce, cloud computing etc.

Hierarchy of networks

Internet Address (IP address)
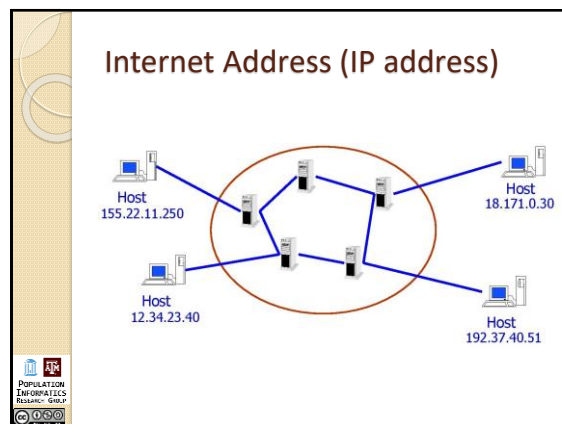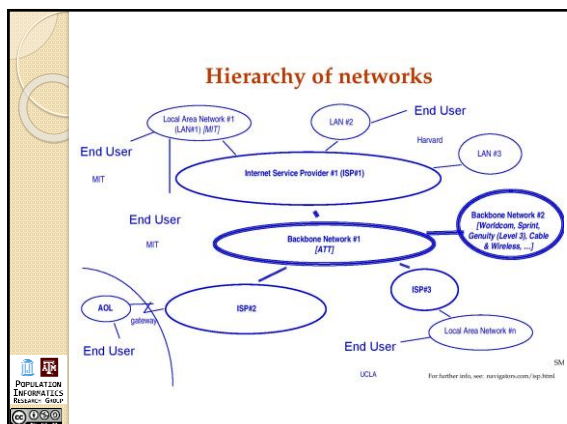
Understanding Internet Addresses
18.154.0.27

- Uniquely assigned to a specific Internet connection point
- 32-bit address
- Each number between dots is the decimal representation of 8 bits in the address
- In this case:
  ◦ 18 specifies MIT (MIT owns all addresses 18.xxx.yyy.zzz)
  ◦ 154 specifies the subnet corresponding to building E56
  ◦ 0.27 is host number within the subnet
- Every internet address can optionally have a descriptive host name (e.g. LASAGNA.MIT.EDU)
  ◦ DNS (Domain Name Server) maps host name to IP

Port number & Socket

- Socket: IP address + port number
  ◦ www.tamhsc.edu:443
- Port number: within a computer (IP address), what service (software)
  ◦ Each software (e.g. email client) is "listening" to a particular port: receives TCP/IP packets that are sent to a particular port
  ◦ One software could listen to more than one port. Different ports, for different processes
- Default Port Numbers
  ◦ Data stream to/from email client: port 587 (SMTP)
  ◦ Data stream to browser: port 80 (http)
  ◦ Encrypted data stream to browser: port 443 (https)
  ◦ http://pinformatics.org:80
  ◦ https://pinformatics.org:443

What does it mean to be on the Internet?

- Have an IP address
  ◦ Have a reachable address from the Internet
- Run TCP/IP protocol
  ◦ Be able to communicate with other computers (servers) on the Internet
- Have ability to send IP packets to other machines on the Internet

Connect your PC to the Internet

- Establish an IP address
  ◦ OLD: a point-to-point link with the provider's machine using PPP (Point-to-Point Protocol)
  ◦ Your PC receives a "temporary IP address"
    · Using DHCP (Dynamic Host Configuration Protocol)
    · Rents an IP address from ISP (DHCP server)
    · If using home wireless device
      · Wireless router is assigned the real IP address
      · Router assigns virtual IP addresses to individual device.
      · Home networking: Private IP address space. Can not be transmitted through the public Internet (192.168.x.x)
  ◦ Your PC receives the address of a Domain Name Server (DNS)

Who controls the Internet?

- The **Internet Corporation for Assigned Names and Numbers (ICANN)**
  - Nonprofit organization, founded in September 18, 1998
  - September 29, 2006, ICANN signed a new agreement with the United States Department of Commerce (DOC) that moves the organization further towards a solely multi-stakeholder governance model
  - Responsible for the coordination of maintenance and methodology of several databases of unique identifiers related to the namespaces of the Internet, and ensuring the network's stable and secure operation
  - Policy development for internationalization of the DNS system
  - Operation of root DNS
  - Introduction of new generic top-level domains (e.g., *.edu:Educause, *.gov)
  - Manages numbering facilities including the Internet Protocol address spaces for IPv4 and IPv6
  - Assignment of address blocks to regional Internet domain registries
- **Internet Engineering Task Force (IETF)**
  - Develops and promotes voluntary Internet standards, in particular the standards that comprise the Internet protocol suite (TCP/IP).
  - An open standards organization
  - No formal membership or membership requirements
  - All participants and managers are volunteers, though their work is usually funded by their employers or sponsors.
  - An international membership-based non-profit organization

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Network Protocols

- Rules of behavior
  - What, when, and how should A send messages to B and vice versa?
- Protocol layers
  - Each layer uses the layers below it and can be used by the layers above it
  - Often, multiple alternatives can be substituted at one layer without affecting the other layers

Example: TCP/IP protocol architecture

Application layer
Provides communication between applications on separate machines
(e.g. email, file transfer, web browsing)

Transport layer
Provides end-to-end reliable data transfer across multiple networks
(e.g. TCP – Transmission Control Protocol)

Internet layer
Routes data from source to destination through
one or more networks (IP – Internet Protocol)

Network access layer
Manages logical interface between a machine and its local network
(e.g. Ethernet, X.25)

Physical Layer
Converts bits to signals and back (e.g. wires, radio, etc.)

Example: Email

- A collection of Email servers
- Internet layer: Protocol (TCP/IP) for sending and receiving email
- Application layer: Protocol
  - SMTP
  - IMAP, POP
- Interoperate
  - outlook email server to outlook email server
  - gmail server to outlook email server

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Example: The World Wide Web

- A collection of interlinked documents stored on computer servers all over the world and accessible to user clients via the Internet
  ◦ Documents communicated in HTML (Hyper Text Markup Language)
  ◦ Rules for requesting and providing documents (and other interactions between clients and servers) are defined by HTTP (Hyper Text Transfer Protocol)
- Documents may contain easily "clickable" links to other documents.
  ◦ Documents are identified by "web addresses" called URLs (Uniform Resource Locators)
- "Hypertext" means text documents that contain embedded links to other documents.

Looking at a Web Page

- User request from a browser a page via URL
- Browser asks DNS for the IP address of the MIT Server using the domain name of URL
- DNS replies with 18.170.0.167
- Browser opens TCP connection to 18.170.0.167
- Browser sends the command
  ◦ GET/class/syllabus.htm
  ◦ file path and HTTP method used
- The MIT Server sends file syllabus.htm
- TCP connection is released
- Browser displays the contents of syllabus.htm

Take Away I
Data Representation

- Numbers: Binary
- Characters: ASCII, UTF-8 encoding
- Documents: Content + layout
- Pictures (Images): pixels
  ◦ RGB
  ◦ HSL/HSV
- Video: Frames per second, codec
- Audio: ADC & DAC

Take Away II: Networks

- Analog vs Digital signal
- Bandwidth
- LAN vs WAN
- How does packet switching work and how does it compare to circuit switching
- What is an IP address? socket?
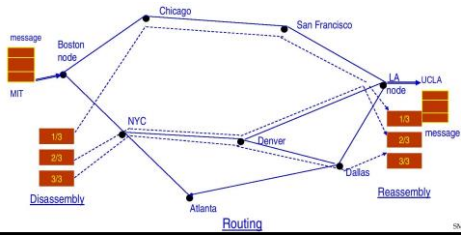
Take Away III

http://en.wikipedia.org/wiki/File:Internet_Key_Layers.png

Internet of Things (IoT)

early milestones	Key Layers of the Internet	milestones
email@-1971 Ray Tomlinson	CONTENT	1991-.html Berners-Lee & Cailliau
Archie-1990 Emtage & Deutsch	SEARCH ENGINE	1998-Google Brin & Page
DOS Houdini-1986 Neil Larson	BROWSERS	1993-Mosaic Marc Andreessen
Vannevar Bush, Ted Nelson, Douglas Engelbart	WORLD WIDE WEB	1990-http:// Tim Berners-Lee
ARPANET-1969 J.C.R. Licklider	INTERNET	1975-TCP/IP Cerf & Kahn
SAGE-1956 George Valley	NETWORKS	1973-Ethernet Robert Metcalfe
Z3-1941 Konrad Zuse	COMPUTERS	1976-Apple Jobs & Wozniak

A Sample LMC Program

① ASSEMBLY LANG ➝② MACHINE LANG.
(Source Program) (Object Program)

INSTRUCTIONS

op-code	symbolic	STEP	INSTRUCTION		LOC	INSTRUCTION
		00	get		00	901
		01	store w		01	398
000	stop	02	get		02	901
1xx	add	03	store b		03	399
2xx	subtract	04	load w		04	598
3xx	store	05	add b		05	199
5xx	load	06	put		06	902
901	get	07	s		07	000
902	put					

No space
(X: Billed Amount
O: BilledAmount or Billed_Amount)

Correct variable memory
w: 98 (398); b:99 (399)
O: 598 199; X: 534 103

Lab 3

- Week 1: ?
- Week 2: ?
- Assignment: ?
- Considering learning a little CSS
  ◦ Write a few lines of CSS
- Considering learning a little Javascript
  ◦ Write a few lines of Javascript