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

<table>
<thead>
<tr>
<th>Medium</th>
<th>Speed</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Twisted wire</td>
<td>30 BPS – 10 MBPS</td>
<td>Low</td>
</tr>
<tr>
<td>Microwave</td>
<td>256 KBPS – 100 MBPS</td>
<td></td>
</tr>
<tr>
<td>Coaxial cable</td>
<td>56 KBPS – 200 MBPS</td>
<td></td>
</tr>
<tr>
<td>Optical fiber</td>
<td>500 KBPS – 10 GBPS</td>
<td>High</td>
</tr>
</tbody>
</table>

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

1011

\[1*2^3 + 0*2^2 + 1*2^1 + 1*2^0\]

\[1*8 + 0*4 + 1*2 + 1*1\]

11

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

<table>
<thead>
<tr>
<th>Character</th>
<th>ASCII/LATF-8</th>
<th>Representation (Hex / Binary)</th>
<th>Representation (Hex / Bytes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>65</td>
<td>0010 0001</td>
<td>0041</td>
</tr>
<tr>
<td>B</td>
<td>66</td>
<td>0010 0010</td>
<td>0042</td>
</tr>
<tr>
<td>C</td>
<td>67</td>
<td>0100 0011</td>
<td>0043</td>
</tr>
<tr>
<td>a</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>b</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>0</td>
<td>48</td>
<td>0011 0000</td>
<td>0030</td>
</tr>
<tr>
<td>l</td>
<td>49</td>
<td>0011 0001</td>
<td>0031</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

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 nicely 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>` 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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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.

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Color Representation (Pixel)

- [AdditiveColor](http://upload.wikimedia.org/wikipedia/commons/thumb/c/c2/AdditiveColor.svg/220px-AdditiveColor.svg.png)

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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

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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

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

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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.
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
  - 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 number

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)

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

- 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.

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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: 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


Key Layers of the Internet

Internet of Things (IoT)

CONTENT

1991-Meta
Berners-Lee & Callau

SEARCH ENGINE

1999-Google
Brin & Page

BROWSERS

1993-Mosaic
Marc Andreesen

WORLD WIDE WEB

1990-http://
Tim Berners-Lee

INTERNET

1975-ARPANET
J.C.R. Licklider

NETWORKS

1976-Ethernet
Robert Metcalfe

COMPUTERS

Z3-1941
Kernighan

A Sample LMC Program

Correct variable memory

w: 98 (398); b:99 (399)

No space

(X: Billed Amount
O: Billed_Amount or Billed_Amount)

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

- Considering learning a little CSS
  - Write a few lines of CSS

- Considering learning a little Javascript
  - Write a few lines of Javascript

- Considering learning a little CSS
  - Write a few lines of CSS