Making the connection
(or: how does the Internet work?)
Learning Goals

• Tell whether a communication technology (Internet, radio, LAN, etc.) is synchronous or asynchronous; broadcast or point-to-point
• Explain the roles of Internet addresses, domain names, and DNS servers in networking
• Explain how data is transferred from one location to another across networks, such as the Internet
• Understand some of the design features of TCP/IP networks, such as packets, routing, domain names, and hierarchical structure
Delivering things on the internet is a bit like delivering in snail mail

- How do you address a letter?
- Where must you put stamps on a letter?
- How much does sending a letter cost?
- How does the post office determine if you have paid enough for your letter?
- How does your letter get from you to the recipient?
- What language is the letter in?
The Internet is like sending a novel to your publisher using postcards

The novel is broken into small units that fit on a postcard
Layered Systems

- The postal system is divided into *layers* to help all users of the system work with it…
- “*you and me*” layer: a letter, labeled with address or recipient, is placed in a postbox, arrives at destination
- “*mail carrier*” layer: a letter is brought to a distribution centre, bar-coded, and sent to the receiving centre
- “*wings and wheels*” layer: bins of letters are transferred by a combination of plane, truck, and train to their destination centre
Layered Systems

Ideally (and in many cases), users at a given layer:
• view the layer below as “the whole system”
• need not think about the layer above/outer layer

Why is that a good thing? (break into groups: discuss on paper with student names and ID #s)
the Internet looks very complex!

- Internet access:
  - phone line (dial-up modem at each end)
  - DSL (digital subscriber line) or TV cable

- Network components:
  - router/gateway
  - commercial grade link
  - wireless access point
  - intranet router
  - personal computers
  - servers
How do two computers communicate?

Taken altogether, this would be very complex. The Internet uses layers to make this simpler!
Layers in the Internet’s Architecture

- **application layer**: web browsers, e-mail readers, and other “applications” provide ways to send and receive data.
- **transport layer**: puts the data into the right format for routing by the network.
- **network layer**: routes data from source to destination.
- **link/physical layers**: moves data along one step through the network.

Not so different from the postal service!
Layers of the Internet

Hosts (our computers) communicate through a chain of routers (network computers).

Each layer pretends that it is the whole Internet to the layer above.

Each layer ignores the details that make the lower layers work.
Layers in the Internet’s Architecture

- **application layer**: web browsers, e-mail readers, and other “applications” provide ways to send and receive data
- **transport layer**: puts the data into the right format for routing by the network.
- **network layer**: routes data from source to destination
- **link/physical layers**: moves data along one step through the network
Application Layer

What are communications tasks on computers?
What are communications tasks on computers?
- send e-mail
- open web pages
- ...?

Addresses are key to performing these tasks:
- e-mail addresses: identify *people*
- URLs: identify *web pages*
- domain names: identify *computers*

Let's start with *domain names*
A blast from the past: domain names

Example: ugrad.cs.ubc.ca

The name of the computer is **ugrad**
Which is part of the Computer Science and Engineering Department domain (**cs**)
Which is part of the University of British Columbia domain (**UBC**)
Which is part of Canada (**ca**)
Domain Names Pictorially

These names form a *hierarchy*

**example names:**
- cs.ubc.ca,
- google.com,
- ugrad.cs.ubc.ca

(Remember: we store these as trees.)
E-mail Addresses

two parts, separated by “@”:

userID (processed at the receiving computer)
destination domain name (processed at the sending computer)

example: rap@cs.ubc.ca
Uniform Resource Locators (URLs) also known as: web addresses

A URL identifies a web page

Example: http://www.google.ca/index.html

http is a way to transferring files (a protocol)
www.google.ca is … what?
index.html is the name of the file that contains the webpage
That's it for the application layer

Past you (the casual user) thinks about things only in the application layer. But now that we understand that, we're ready for the next layer… the *transport* layer
Layers in the Internet’s Architecture

*application layer:* web browsers, e-mail readers, and other “applications” provide ways to send and receive data

*transport layer:* puts the data into the right format for routing by the network.

*network layer:* routes data from source to destination

*link/physical layers:* moves data along one step through the network
Where in the World is rap@cs.ubc.ca

rap is a user ID; the computer addressed by cs.ubc.ca will figure it out for us

cs.ubc.ca is an address... but it’s designed for humans

the transport layer switches from human-readable domain names to machine-friendly “IP addresses”
IP Addresses

• Each computer connected to the Internet is given a unique address called its **IP address** (short for Internet Protocol address)
• This address is either temporarily or permanently assigned by an Internet Service Provider (ISP)
• An IP address is a series of four numbers separated by dots
• The range of each of these numbers (0–255) allows for billions of IP addresses
• New IP addresses are in short supply
What do you think will happen when all of the possible IP addresses are used? Will they add more numbers? Or will they reuse old websites that are unused?

IPV4 → 4.3 billion addresses or $4.3 \times 10^{10}$

IPV6 → $3.4 \times 10^{38}$ represented as eight groups of four hexadecimal digits

OLD: 8a3e:3a32:1232:0001
NEW: 2001:0db8:85a3:0042:1000:8a2e:0370:7334
Domain Name Servers: bridging the application and network layers

- Domain name servers (DNSs) keep a directory connecting domain names to IP addresses.
- Every computer connected to the internet needs the IP address of its “nearest” DNS.
- This DNS is used to resolve, or translate, a domain name to an IP address.
- DNS names need to be constantly updated.

You can play with this:
http://ip-lookup.net/domain-lookup.php
Layers in the Internet’s Architecture

- **application layer**: web browsers, e-mail readers, and other “applications” provide ways to send and receive data.
- **transport layer**: puts the data into the right format for routing by the network.
- **network layer**: routes data from source to destination.
- **link/physical layers**: moves data along one step through the network.
the internet is a collection of nodes and links

data is routed along links from node to node in the network

Going from one node to another is called a "hop"
Client/Server Structure

Most interactions over the Internet use the client/server interaction protocol:

- When you click a Web link, your computer gets the page for you...beginning the client/server interaction
- Your computer is the client computer and the computer with the Web page is the server (Web server)
- The client, gets services from the server

When the page is returned, the operation is completed and the client/server relationship ends
Client/Server Structure

The client/server structure is fundamental to Internet interactions. A key aspect is that only a single service request and response are involved. The *relationship* is very brief relationship, lasting from the moment the request is sent to the moment the service is received.
Many Brief Relationships

This approach means that the server can handle many clients at a time.

For example, between two consecutive client requests from your browser (getting a page and asking for another) that server could have serviced hundreds of other clients.

The server is busy only for as long as it takes to perform your request.
The Internet is asynchronous

Synchronous communication:
Both the sender and the receiver are active at the same time (think of talking on a telephone)

Asynchronous communication:
The sending and receiving occur at different times (think of email and answering machines)
TCP/IP Postcard Analogy

Sooner or later, your publisher received the postcards, but not necessarily in sequential order.
Nor do they take the same route.
The cards are finally arranged in order.

These “postcards” are really **IP packets**

They hold: one unit of information, the destination IP, and their sequence number
(which packet they are)
Packets Are Independent

Because each packet can take a different route, congestion and service interruptions do not delay transmissions

Each TCP/IP packet is *independent*

The TCP/IP protocol works under adverse conditions

If traffic is heavy and the packet progress is slow, the protocol allows the packet to be thrown away
Point-to-Point Routing

• The network layer communicates “point-to-point” (like the postal network)
  • computers send data to their neighbours, which send data to their neighbours, ...
  • somehow, data gets from one computer across the network to another

• How?
Back to the postcard analogy again

Each postcard (packet) is sent along a path based on a routing algorithm.

Let's imagine we're trying to go from the pink node to the purple node. What would you do?
How long do we expect these paths to be?

Let's say that we're starting from remote.ugrad.cs.ubc.ca

How many hops do you think it'd take to get to:

• remote.ugrad.cs.ubc.ca?
• www.ugrad.cs.ubc.ca?
• www.cs.ubc.ca?
• www.google.ca?
• www.google.com?
• www.theaustralian.com.au?
• australia.gov.au?
You can try this on your Unix account

Traceroute is a command that will allow you to trace the route from your computer to another computer

Similar commands exist on other platforms
Broadcast “Routing”

Unlike a point-to-point system, in a broadcast system, each message is delivered to all recipients within range (as with voice and radio).

Norm Abramson at U. Hawaii linked together a computer and terminals on the Hawaiian islands using a radio channel in 1970.

Today, ethernet channels (wires or optical fibres) link together computers in a small area.
Ethernet and wireless Ethernet networks provide broadcast communication... but how do we decide who gets to talk when?

hosts "talk" to the WAP with radio waves; just like talking in class, everyone can hear
RQ: the NSA

How does the NSA could monitor people's online/wireless information and interactions?
Layers in the Internet’s Architecture

**application layer:** web browsers, e-mail readers, and other “applications” provide ways to send and receive data

**transport layer:** puts the data into the right format for routing by the network.

**network layer:** routes data from source to destination

**link/physical layers:** moves data along one step through the network
Layers of the Internet

Message to domain name cs.ubc.ca

Sent to IP address: 142.103.6.5

Routed step by step through the network

Transferred as electrical signals (or light or radio waves or...) from one router to the next.
the Internet looks very complex!

But it's understandable if you look at it a bit at a time

phone line (dial-up modem at each end)

ISP gateway

DSL (digital subscriber line) or TV cable

wireless access point

Intranet router

commercial grade link

personal computers

servers
Suggested additional material

http://www.youtube.com/watch?v=7_LPdttKXPc&feature=related

http://www.youtube.com/watch?v=i5oe63pOhLI&feature=related

(These do not explain all you need to know, but they illustrate some important Internet concepts covered in the textbook.)
Learning Goals revisited

• Tell whether a communication technology (Internet, radio, LAN, etc.) is synchronous or asynchronous; broadcast or point-to-point
• Explain the roles of Internet addresses, domain names, and DNS servers in networking
• Explain how data is transferred from one location to another across networks, such as the Internet
• Understand some of the design features of TCP/IP networks, such as packets, routing, domain names, and hierarchical structure