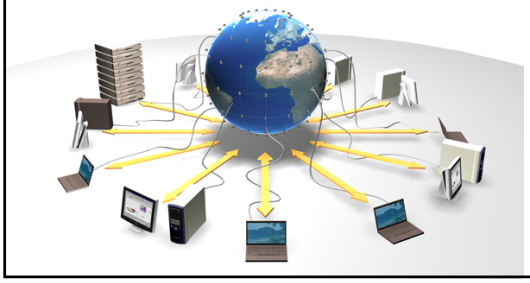
91.113 Exploring the Internet, Fall 2011

Lecture 3 Internet Basics, part I



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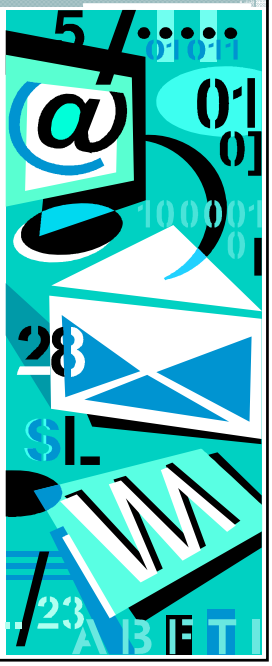
Objectives

1. Understand how the Internet works.
2. Describe the binary number system.
3. Study how to Identify and Analyze an IP address.
4. Hands-on Exercise



How does the Internet work?

Video

- http://youtu.be/qv0XCaUkfNk

Sharing Saves Money

- Computer networks do not usually dedicate a single wire to each pair of communicating computers.
- Typically, multiple computers share the underlying hardware facilities to lower cost.
  - Uses fewer wires
  - Uses fewer switching machines

Sharing Reduces Performance

- Granting one party exclusive access of a shared transport path can be impractical because it can delay all other parties.
  - Sharing temporarily prevents other applications from using the wire

Communicating On Wires

- In a computer network, the transmission path between two computers consists of wires.
- Because only one data transfer can occur on a given wire at a given time, multiple devices that share a wire must wait to use it.
  - In some early telephone systems, subscribers on a street all shared one telephone line. If someone was using the line, their conversation prevented their neighbors from making a call.
  - When two computers on a given network transfer data, all other computers must wait until the transfer completes.

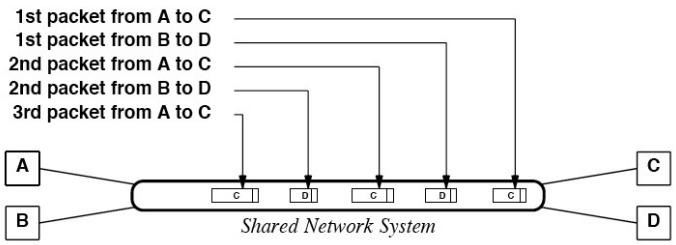
- One solution to sharing is the use of ***channels***.
- Cable television systems send multiple signals using multiple channels.
  - Each channel is assigned a unique frequency, and a carrier at that frequency is modulated to encode the information.
  - All the signals are mixed together and sent over the cable
  - The television receiver extracts the signal for the selected channel and ignores the other channels.

Packet Switching

- Most network technologies use a different approach. They share by taking turns.
- In the 1960s, ***packet switching*** was invented where (to avoid long delays) the amount of data that can be transferred on a turn is limited.
- The unit of data that can be transferred at one time is called a ***packet***.

Example: Two messages are sent.

- A sends a message to C.
- B sends a message to D.
- Messages are split into packets which are interleaved.



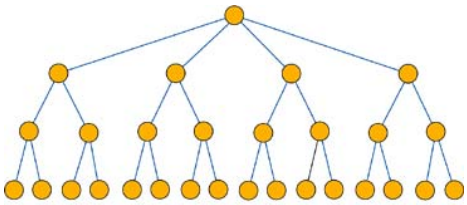
Packet Switching Is General

- Many different kinds of devices can connect to a packet switching network.
  - cash registers
  - video cameras
  - bar code scanners
  - magnetic strip readers
  - printers

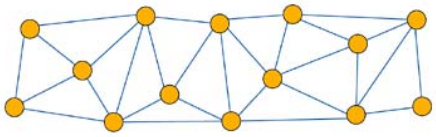
Internet Organization

- The Internet is a ***network of networks*** that are spread all over the world
- Networks that are geographically close are called Local Area Networks (LANs)
  - Often in the same building
  - The university's network is a prime example
- The Internet is organized in both hierarchical and heterarchical

- A **hierarchical** network contains a tree-like structure where some nodes are superior to others.
- A **heterarchical** network contains many nodes that are interconnected.
  - Dynamic routing
  - Robust

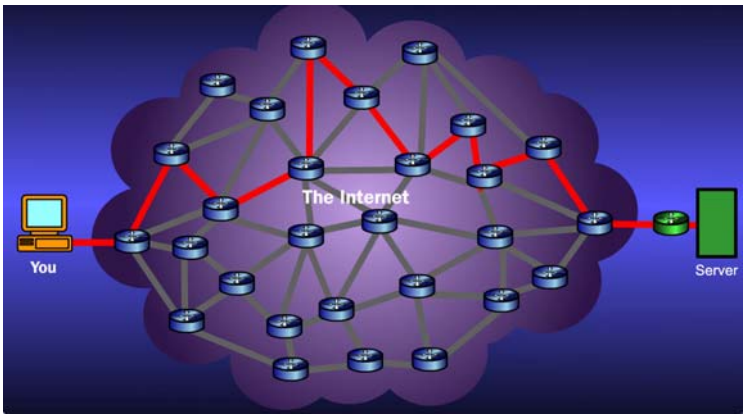


Hierarchical Structure



Heterarchical Structure

- A characteristic of a heterarchical network is that it is a robust network.
- If some nodes are removed, data can still be sent between nodes
- Hierarchical networks do not lend themselves to robustness
- The Internet also has dynamic routing, where the route of the data is determined at the time of transmission based on current network conditions.



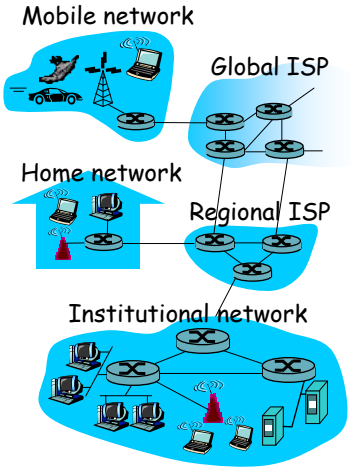
Routers determine the path between you and an Internet server

Internet, Intranet, Extranet

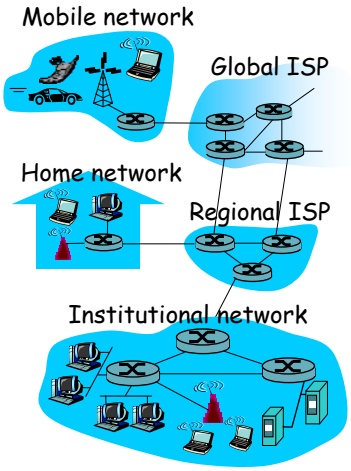
- Internet
  - A world-wide network of public and private networks based on the TCP/IP protocol. The web is built on top of the Internet.
- Intranet
  - An internal network that uses the same technologies as the Internet.
- Extranet
  - A network that uses Internet technologies to provide information internally to a corporation or other entity and to selected outside participants.

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

- millions of connected computing devices:
  - *hosts = end systems*
  - running *network apps*
- *communication links*
  - fiber, copper, radio, satellite
  - transmission rate = *bandwidth*
- *routers:* forward packets (chunks of data)



- *protocols* control sending, receiving of msgs
  - e.g., TCP, IP, HTTP, Skype, Ethernet
- *Internet:* "network of networks"
  - loosely hierarchical
  - public Internet versus private intranet
- Internet standards
  - RFC: Request for comments
  - IETF: Internet Engineering Task Force



What's a protocol?

human protocols:

- "what's the time?"
- "I have a question"
- introductions

… specific msgs sent

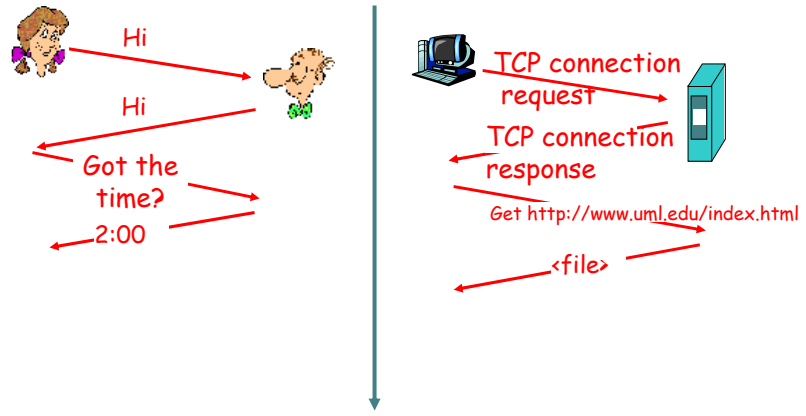
… specific actions taken when msgs received, or other events

network protocols:

- machines rather than humans
- all communication activity in Internet governed by protocols

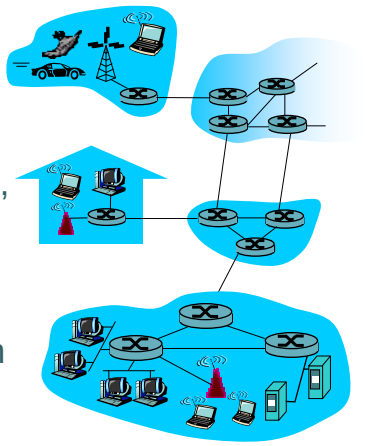
protocols define format, order of msgs sent and received among network entities, and actions taken on msg transmission, receipt

a human protocol and a computer network protocol:



What's the Internet: a service view

- communication *infrastructure* enables distributed applications:
  - Web, VoIP, email, games, e-commerce, file sharing
- communication services provided to apps:
  - reliable data delivery from source to destination
  - "best effort" (unreliable) data delivery



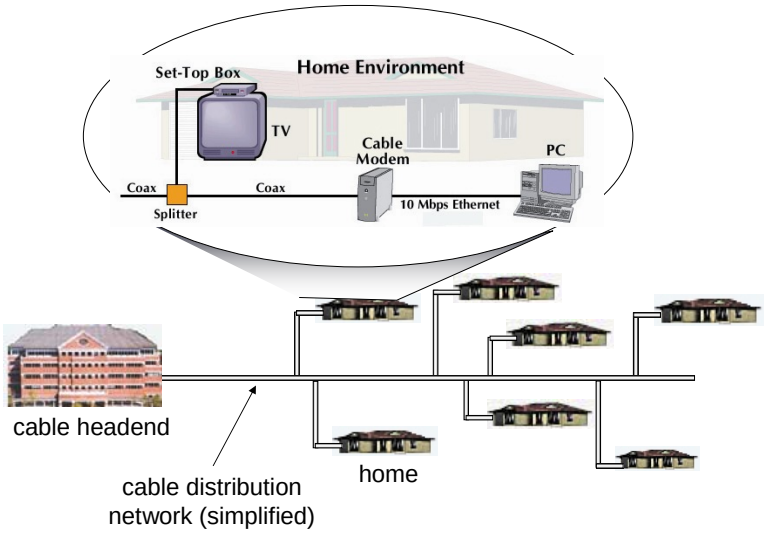
How To Access the Internet

- Residential
  - ISP: Internet Service Provider
  - www.thelist.com
  - Connection choices
    - Dial-up: use telephone line – 56 kbps
      - Need modem
    - Dedicated
      - DSL (Digital Subscriber Line) – 1~6 Mbps
      - FIOS
    - Shared
      - Cable – 6~12 Mbps
    - Wireless
      - Satellite

Dial-up	56 Kbps	Inexpensive	Slow
DSL	1.5 Mbps		
Cable	10 Mbps		
DSS (Direct Satellite System)	0.5 Mbps	Remote area	Connection quality varies
Wireless-Fidelity (Wi-Fi)	11, 54 Mbps		Has to be near a hotspot

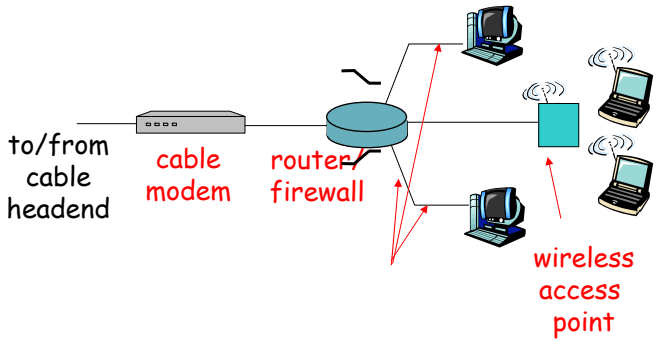
Cable Network

Typically 500 to 5,000 homes



Wireless Network

- Access Point – Base Station



- Institutional
  - Campus, company
- Wireless
  - Wifi (IEEE802.11b/g) – 11 Mbps
    - Find a local Wireless Hotspot
      - » www.wi-fihotspotlist.com
  - Broadband (WiMax) – 50 Mbps

802.11a	1999	5GHz	54M	OFDM	120ft
.11b	1999	2.4G	11M	DSSS	120ft
.11g	2003	2.4G	54M	OFDM	120ft
.11n	2009	2.4/5G	248M		220ft

What's binary?

Introduction to Numbering Systems

- We are all familiar with the decimal number system (Base 10). Some other number systems that we will work with are:
  - **Binary → Base 2**
  - **Octal → Base 8**
  - **Hexadecimal → Base 16**

Characteristics of Numbering Systems

1) The digits are consecutive.
2) The number of digits is equal to the size of the base.
3) Zero is always the first digit.
4) The base number is never a digit.
5) When 1 is added to the largest digit, a sum of zero and a carry of one results.

Significant Digits

Binary: 11101101

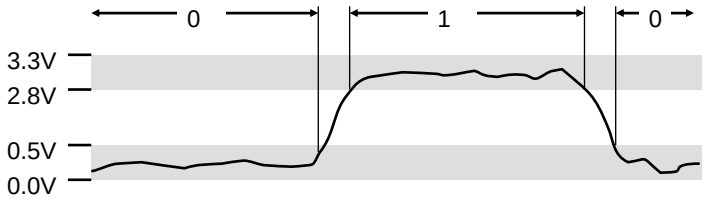
Most significant digit ***Least significant digit***

Hexadecimal: 1D63A7A

Most significant digit ***Least significant digit***

Binary Number System

- Also called the **"Base 2 system"**
- The binary number system is used to model the series of electrical signals computers use to represent information
- 0 represents the no voltage or an **off state**
- 1 represents the presence of voltage or an **on state**



Binary Numbering Scale

Base 2 Number	Base 10 Equivalent	Power	Positional Value
000	0	2^0	1
001	1	2^1	2
010	2	2^2	4
011	3	2^3	8
100	4	2^4	16
101	5	2^5	32
110	6	2^6	64
111	7	2^7	128

Binary Addition

4 Possible Binary Addition Combinations:

(1)
```
  0
 +0
 --
 00
```
Carry → 00 ← Sum

(2)
```
  0
 +1
 --
 01
```

(3)
```
  1
 +0
 --
 01
```

(4)
```
  1
 +1
 --
 10
```

Note that leading zeroes are frequently dropped.

Decimal to Binary Conversion

- The easiest way to convert a decimal number to its binary equivalent is to use the ***Division Algorithm***
- This method repeatedly divides a decimal number by 2 and records the quotient and remainder
  - ***The remainder digits (a sequence of zeros and ones) form the binary equivalent in least significant to most significant digit sequence***

Division Algorithm

Convert 67 to its binary equivalent:

$67_{10} = x_2$

Step 1: 67 / 2 = 33 R 1 — *Divide 67 by 2. Record quotient in next row*

Step 2: 33 / 2 = 16 R 1 — *Again divide by 2; record quotient in next row*

Step 3: 16 / 2 = 8 R 0 — *Repeat again*

Step 4: 8 / 2 = 4 R 0 — *Repeat again*

Step 5: 4 / 2 = 2 R 0 — *Repeat again*

Step 6: 2 / 2 = 1 R 0 — *Repeat again*

Step 7: 1 / 2 = 0 R 1 — **STOP *when quotient equals 0***

$1\,0\,0\,0\,0\,1\,1_2$

Binary to Decimal Conversion

- The easiest method for converting a binary number to its decimal equivalent is to use the ***Multiplication Algorithm***
- Multiply the binary digits by increasing powers of two, starting from the right
- Then, to find the decimal number equivalent, sum those products

Multiplication Algorithm

Convert $(10101101)_2$ to its decimal equivalent:

Binary →	1	0	1	0	1	1	0	1
	X	X	X	X	X	X	X	X
Positional Values →	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
Products →	128	+ 32	+ 8	+ 4	+ 1			

173_{10}

How to Identify and Analyze an IP address?

IP address

- Goals:
  - Identify networks on Internet
  - Identify hosts on network
- IP address: 4 bytes
  - Each machine in a (IP) network has its own IP address
    - Examples: 10000000 0100000 00000001 00000001

- IP address contains 2 parts
  - Prefix: network prefix OR net id
  - Postfix: host id
- Example: 128.64.1.1/24 , 128.64.1.5/24

All machines in the same network have the same NET ID, and different host ids

Netmask

- How to specify the length of netid in IP address? Solution: Netmask.
- Configure IP address for a machine:
  - IP Address + Netmask
- Netmask: 32 bits = 4 bytes
  - Prefix of netmask = 111…1
  - Postfix of netmask = 00…0
- Examples: 11111111 11111111 11111111 00000000

  255 . 255 . 255 . 0
- NetworkID = IP address “AND” NETMASK

IP address	128. 64. 1.1	10000000 01000000 00000001 00000001
Netmask	255.255.255.0	11111111 11111111 11111111 00000000
NetworkID	128. 64. 1.0	10000000 01000000 00000001 00000000

Ways to represent IP address

- For host
  - 192.168.1.5
  - Combination of IP address and netmask
    - IP address: 192.168.1.5
    - Netmask: 255.255.255.0
  - In binary.
- For network
  - 192.168.1.0/24
  - Combination of Network ID and netmask
    - Network ID: 192.168.1.0
    - Netmask: 255.255.255.0

Range in an IP network

- Assume that we have an IP network:
  - 200.100.1.0 /24
  Network ID = 200.100.1.0
  Netmask = 255.255.255.0
- Broadcast ID (by filling 1 to all bits for hostid)
  = 200.100.1.255
- Range: (254 host)
  - 200.100.1.1 -> 200.100.1.254

Class A, B, C on Internet

- For INTRANET, we can assign “ANY” IP addresses
- For INTERNET, we should follow the RULES

	Net ID	Host ID
Class A	0xxxxxxx .	xxxxxxxx . xxxxxxxx . xxxxxxxx
Class B	10xxxxxx . xxxxxxxx .	xxxxxxxx . xxxxxxxx
Class C	110xxxxx . xxxxxxxx . xxxxxxxx .	xxxxxxxx
Multicast	111xxxxx . xxxxxxxx . xxxxxxxx . xxxxxxxx	

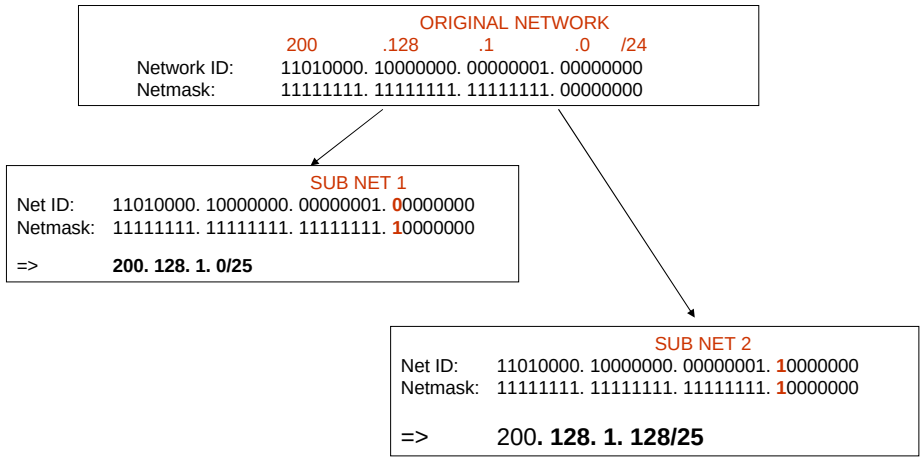
- How many hosts are there in a class C network?

  2^8 – 2 = 254 hosts

  !!! Don’t count the IP address for NetworkID (host id = 00…0) and broadcast address (host id = 11..1)

Subneting

- Example: You buy a class C network from an ISP, e.g 200.128.1.0/24, and you want to divide the network into 2 subnets for 2 offices.
- Method:



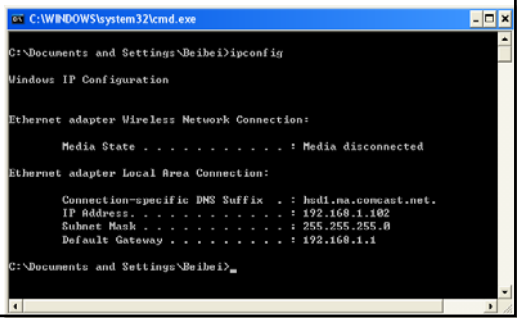
Further Reading

- How Internet works:
  1) http://computer.howstuffworks.com/internet-infrastructure.htm/printable
  2) http://www.theshulers.com/whitepapers/internet_whitepaper/index.html
  3) http://en.wikipedia.org/wiki/Subnetwork

Hands-on Exercises

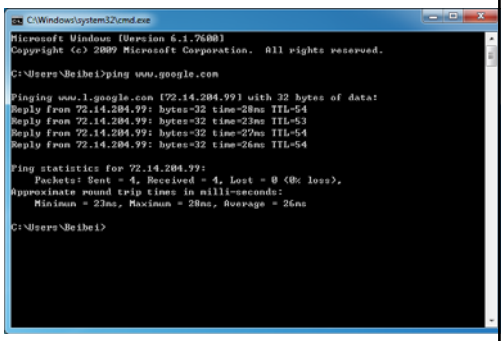
Hands-on Exercise (1)

- Identify your IP address and netmask
  - In Windows, click “Run…” in the start menu,
  - type “cmd”, and enter,
  - in the pop-up window, input “ipconfig” and enter,
  - You will see the IP adress and netmask of your computer.
  - If you input “ipconfig /all” instead in the 3rd step, you’ll see more information appearing.



Hands-on Exercise (2)

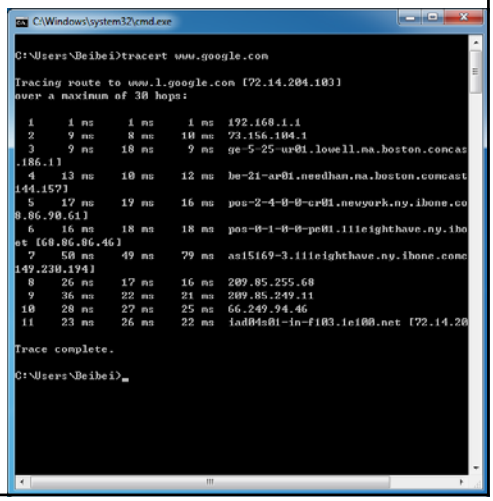
- Detect if you can connect to an address.
  - In Windows, click “Run…” in the start menu,
  - type “cmd”, and enter,
  - in the pop-up window, input “ping www.google.com” and enter,
  - You will see if your computer is connected to the Google web server.



Example: ping www.google.com

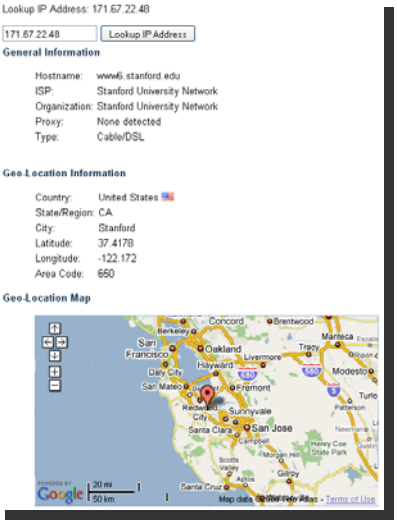
Hands-on Exercise (3)

- Trace the route between two addresses
  - In Windows, click “Run…” in the start menu,
  - type “cmd”, and enter,
  - in the pop-up window, input “tracert www.google.com” and enter,
  - You will see the each hop from your computer to the Google web server.



Hands-on Exercise (4)

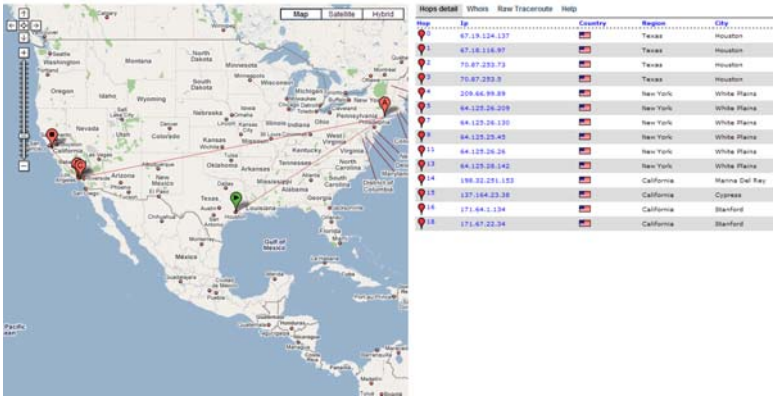
- Find the geographic information of an IP address:
  http://whatismyipaddress.com/



The result of querying IP address 171.67.22.48

Hands-on Exercise (5)

- http://www.mapulator.com/



The result of “tracert www.stanford.edu” from the mapulator.com server.

Hands-on Exercise (6)

- Add 0011 1010 and 0010 0101 in binary and double check the result by converting the numbers into decimals.