COMP 206 – Intro to Software Systems

Lecture 18 – Internet 2

November 9th, 2018

Outline

- More details about how the internet works:
  - More details on how we manage addresses
  - Ports and port ranges
  - Network standardization conventions
- Looking at an internet socket in detail:
  - The 3-way handshake
- Ideas about writing internet software:
  - Sending and receiving on the same socket

Brief history of the internet

- Early network ideas in the 60's: break data into packets, how to organize connections, clients and servers, simple transmission
- 1970's: Early versions of ARPANET (The Advanced Research Projects Agency Network) completed and demonstrated. Ethernet @ Xerox.
- 1980's: First implemented versions of modern TCP/IP.
- 1989: World Wide Web proposed, public in 1991

McGill and the Internet

- Canada on the net: around 1985 with NetNorth
  - McGill is an early member, with researchers at what is now called "Centre for Intelligent Machines" (CIM) having many of the first connected devices
  - Historical information: the NetNorth Polcies circa 1990: http://retirees.uwaterloo.ca/~rwwatt/nnpp.html

- The first search engine Archie, written by Alan Emtage, Bill Heelan, and Mike Parker at McGill University in Montreal Canada is released on September 10, 1990

How to keep track of all of these addresses?

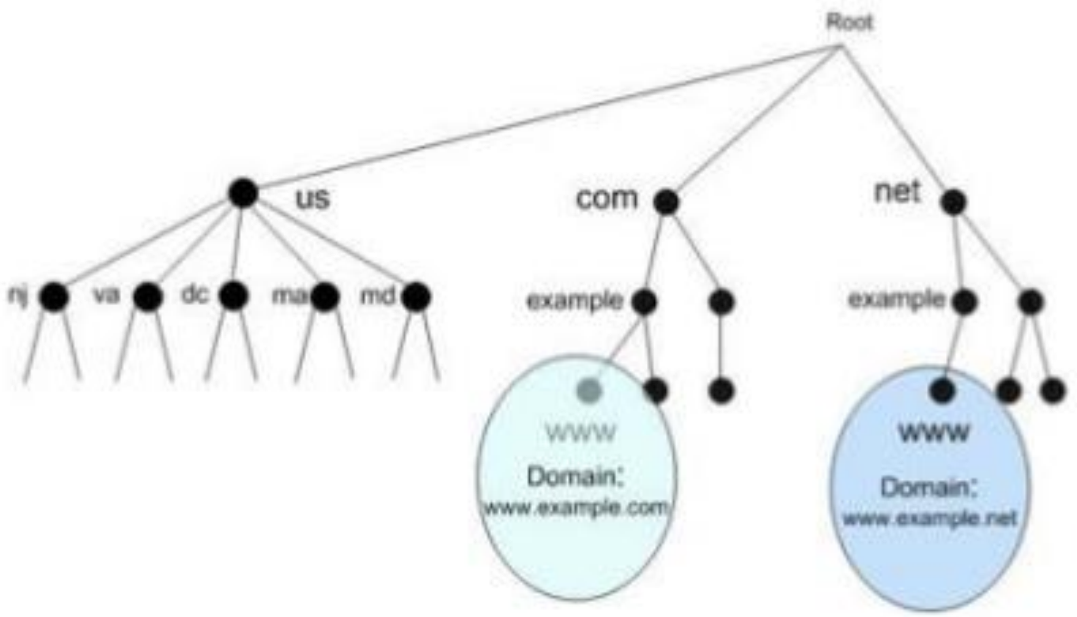
- IPv6 allows close to 2^128 devices to be online and uniquely addressable:
  - Log in to every device from your laptop to your toaster!
  - Each address is 16 bytes... hard to even type correctly, let alone remember!

- Routers and servers are organized into a hierarchy and direct traffic

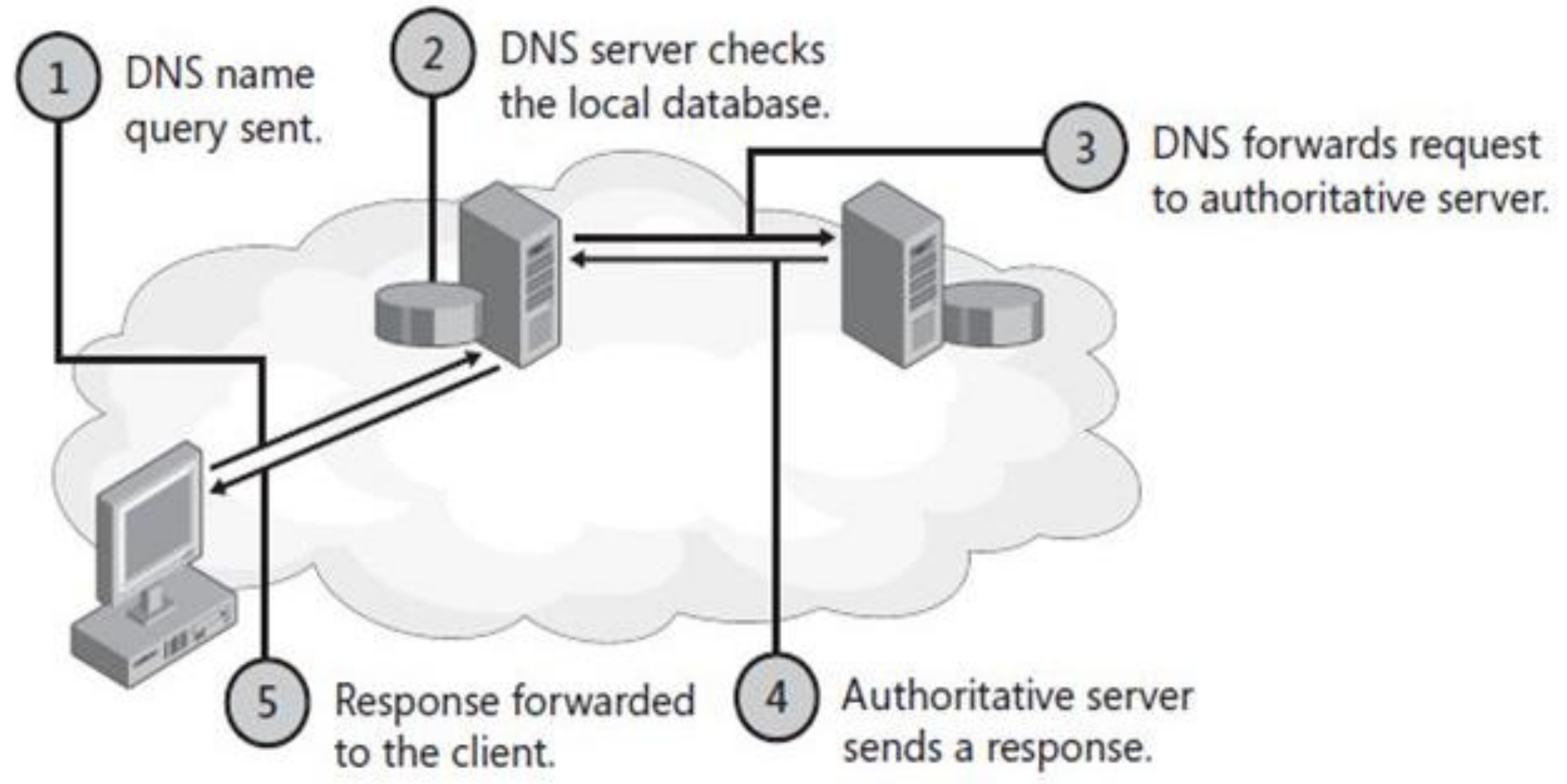
- Domain Name Service (DNS) is the book-keeper:
  - Each human readable name is mapped to a unique address (it can change over time)
  - Each computer and server can offer ***name resolution***, the ability to look-up addresses in the part of the internet that it's responsible for

The DNS Hierarchy

- Each part of the name-space is recorded by a master server (along with redundancy)
- That either holds the entry, or knows where to look
- DNS queries go "up-then-down"
  - Originates at a leaf, checks if parent knows, if not, sends upwards
  - Once reach a level with the knowledge (maybe root), go downwards to ask the authority



DNS Dataflow


1 DNS name query sent.
2 DNS server checks the local database.
3 DNS forwards request to authoritative server.
4 Authoritative server sends a response.
5 Response forwarded to the client.

Networking Tools in Linux

- Commands:
    - ssh, ftp, scp, etc : Command-line networking
    - ifconfig : Report on network interfaces
    - ping : Send trivial packets to <source>, useful to look-up DNS addresses
    - iwconfig : Manage wireless connections
    - iptables, route, etc : Turn your PC into a network traffic switch
- Security:
    - Enforced through protected port ranges, optional firewalls (e.g., ufw), user authentication (e.g. LDAP)

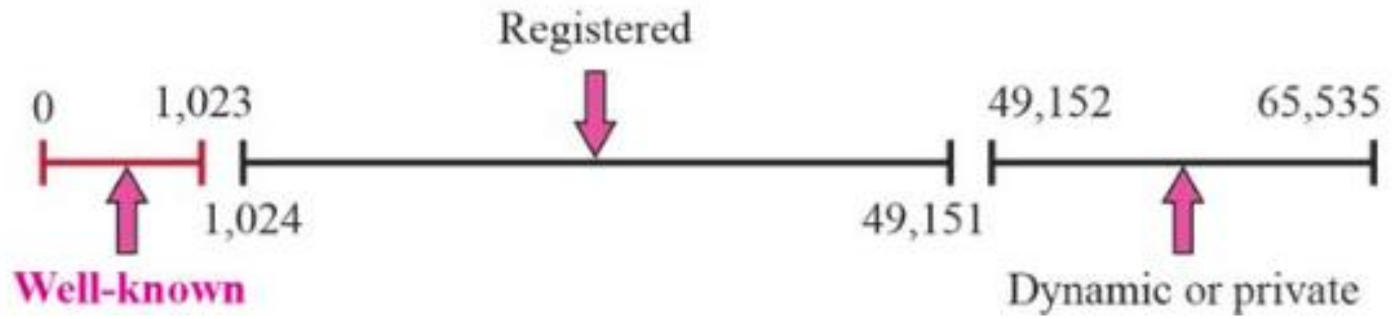
Beyond Addresses: Ports

- A computer must often maintain multiple connections
  - E.g. A web server streaming video to multiple users
  - E.g., Any computer at all since so many apps and resources live on the "cloud" currently

- But, we can only have one single address per device, so isn't this a collision?

ICANN Ranges

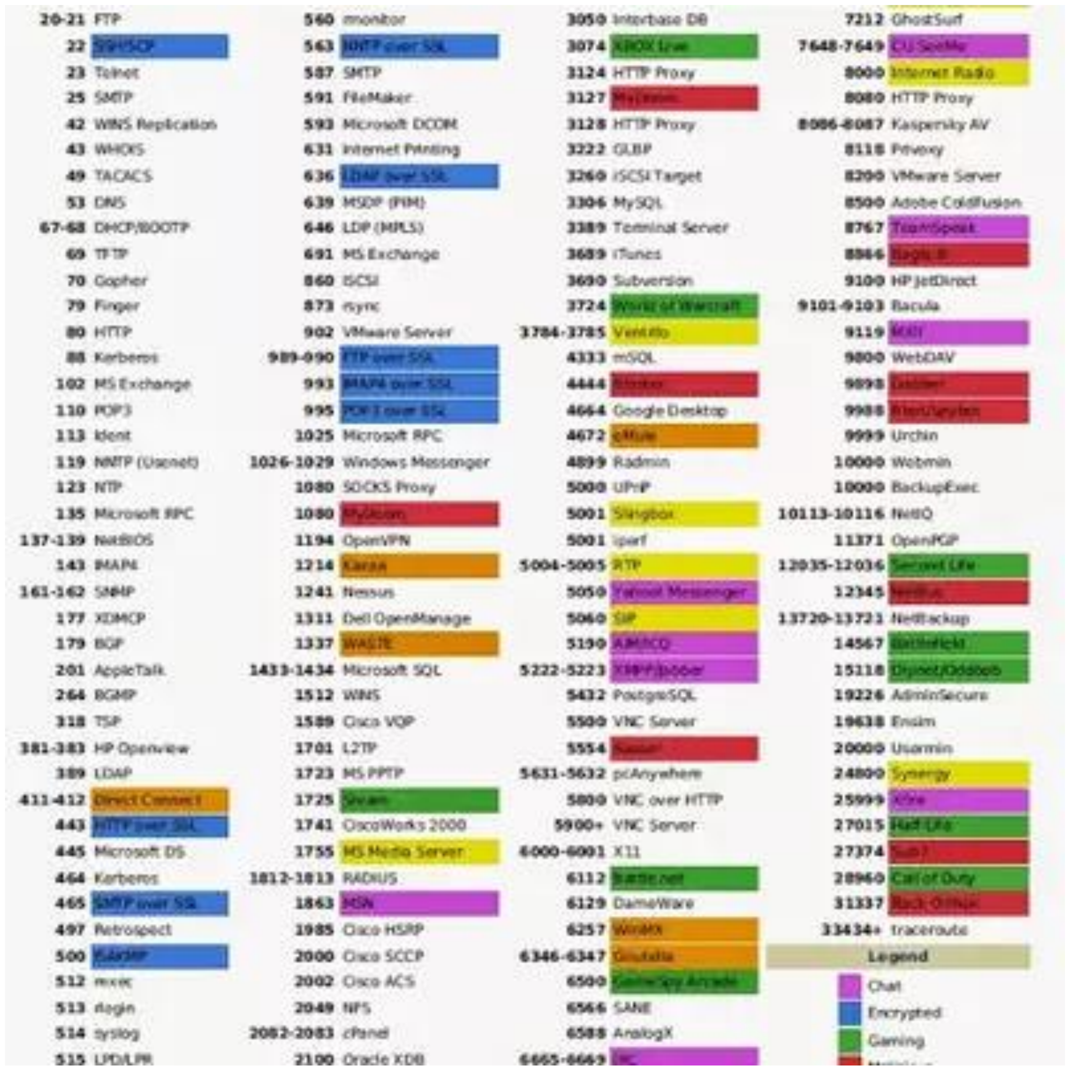
- Well-known ports : 0 ~ 1,023
  - Assigned and controlled by ICANN
- Registered ports : 1,024 ~ 49,151
  - Not assigned and controlled by ICANN
  - Can be registered with ICANN to prevent duplication
- Dynamic ports : 49,152 ~ 65,535
  - Can be used as temporary or private port number



A 2-byte integer: max value (2^16)

Within the standard range, known applications

- On the right is a standard list, but it can differ over time
- Constant ones to know for 206:
    - 20 & 21: FTP
    - 22 SSH/SCP
    - 25 SMTP (mail)
    - 53 DNS
    - 80 HTTP
    - 443 HTTPS



20-21	FTP	560	rmonitor	3050	Interbase DB	7212	GhostSurf
22	SSH/SCP	563	NNTP over SSL	3074	XBOX Live	7648-7649	CU-SeeMe
23	Telnet	587	SMTP	3124	HTTP Proxy	8000	Internet Radio
25	SMTP	591	FileMaker	3127	MyDoom	8080	HTTP Proxy
42	WINS Replication	593	Microsoft DCOM	3128	HTTP Proxy	8086-8087	Kaspersky AV
43	WHOIS	631	Internet Printing	3222	GLBP	8118	Privoxy
49	TACACS	636	LDAP over SSL	3260	iSCSI Target	8200	VMware Server
53	DNS	639	MSDP (PIM)	3306	MySQL	8500	Adobe ColdFusion
67-68	DHCP/BOOTP	646	LDP (MPLS)	3389	Terminal Server	8767	TeamSpeak
69	TFTP	691	MS Exchange	3689	iTunes	8866	Bagle.B
70	Gopher	860	iSCSI	3690	Subversion	9100	HP JetDirect
79	Finger	873	rsync	3724	World of Warcraft	9101-9103	Bacula
80	HTTP	902	VMware Server	3784-3785	Ventrilo	9119	MXit
88	Kerberos	989-990	FTP over SSL	4333	mSQL	9800	WebDAV
102	MS Exchange	993	IMAP4 over SSL	4444	Blaster	9898	Dabber
110	POP3	995	POP3 over SSL	4664	Google Desktop	9988	Rbot/Spybot
113	Ident	1025	Microsoft RPC	4672	eMule	9999	Urchin
119	NNTP (Usenet)	1026-1029	Windows Messenger	4899	Radmin	10000	Webmin
123	NTP	1080	SOCKS Proxy	5000	UPnP	10000	BackupExec
135	Microsoft RPC	1080	MyDoom	5001	Slingbox	10113-10116	NetIQ
137-139	NetBIOS	1194	OpenVPN	5001	iperf	11371	OpenPGP
143	IMAP4	1214	Kazaa	5004-5005	RTP	12035-12036	Second Life
161-162	SNMP	1241	Nessus	5050	Yahoo! Messenger	12345	NetBus
177	XDMCP	1311	Dell OpenManage	5060	SIP	13720-13721	NetBackup
179	BGP	1337	WASTE	5190	AIM/ICQ	14567	Battlefield
201	AppleTalk	1433-1434	Microsoft SQL	5222-5223	XMPP/Jabber	15118	Dipnet/Oddbob
264	BGMP	1512	WINS	5432	PostgreSQL	19226	AdminSecure
318	TSP	1589	Cisco VQP	5500	VNC Server	19638	Ensim
381-383	HP Openview	1701	L2TP	5554	Sasser	20000	Usermin
389	LDAP	1723	MS PPTP	5631-5632	pcAnywhere	24800	Synergy
411-412	Direct Connect	1725	Steam	5800	VNC over HTTP	25999	Xfire
443	HTTP over SSL	1741	CiscoWorks 2000	5900+	VNC Server	27015	Half-Life
445	Microsoft DS	1755	MS Media Server	6000-6001	X11	27374	Sub7
464	Kerberos	1812-1813	RADIUS	6112	Battle.net	28960	Call of Duty
465	SMTP over SSL	1863	MSN	6129	DameWare	31337	Back Orifice
497	Retrospect	1985	Cisco HSRP	6257	WinMX	33434+	traceroute
500	ISAKMP	2000	Cisco SCCP	6346-6347	Gnutella	Legend	
512	rexec	2002	Cisco ACS	6500	GameSpy Arcade	🟪	Chat
513	rlogin	2049	NFS	6566	SANE	🟦	Encrypted
514	syslog	2082-2083	cPanel	6588	AnalogX	🟩	Gaming
515	LPD/LPR	2100	Oracle XDB	6665-6669	IRC	🟥	

Which ports can I access?

- Access to ports enables the good internet functionality that we want, but it's also an opening for unwanted access
- A "firewall" is a software system designed to monitor internet communication and restrict dangerous activities.
- Firewalls can be implemented in the backbone, such as in a wifi router or McGill's central internet connection, as well as by each end-point device (client and server)

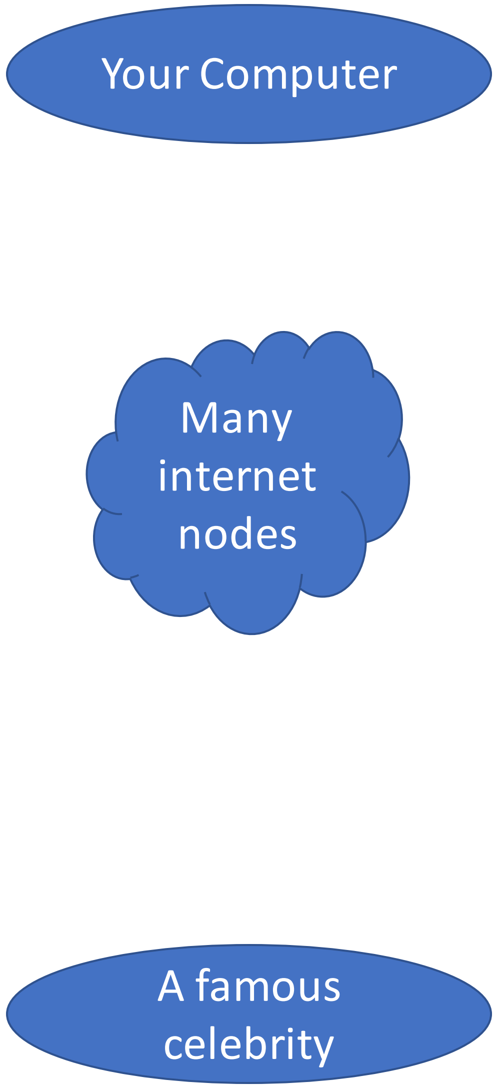
Typical firewall restrictions

- It is common that all ports outside those used for named applications are closed to traffic outside the "trusted" network
- For McGill, this can mean some functions do not work connecting to mimi from home.
  - VPN'ing is one way to fix this, it means your computer is now "virtually" part of the trusted network, but it still may not allow everything
- Because we cannot entirely change the networking settings everywhere, we oftentimes use "localhost", or 127.0.0.1 to demonstrate low-level functions. Do not be fooled, this still uses the "internet", but only the local implementation on a single computer.
- We will look at a few creative "work-arounds" in a while

Endianness on the internet

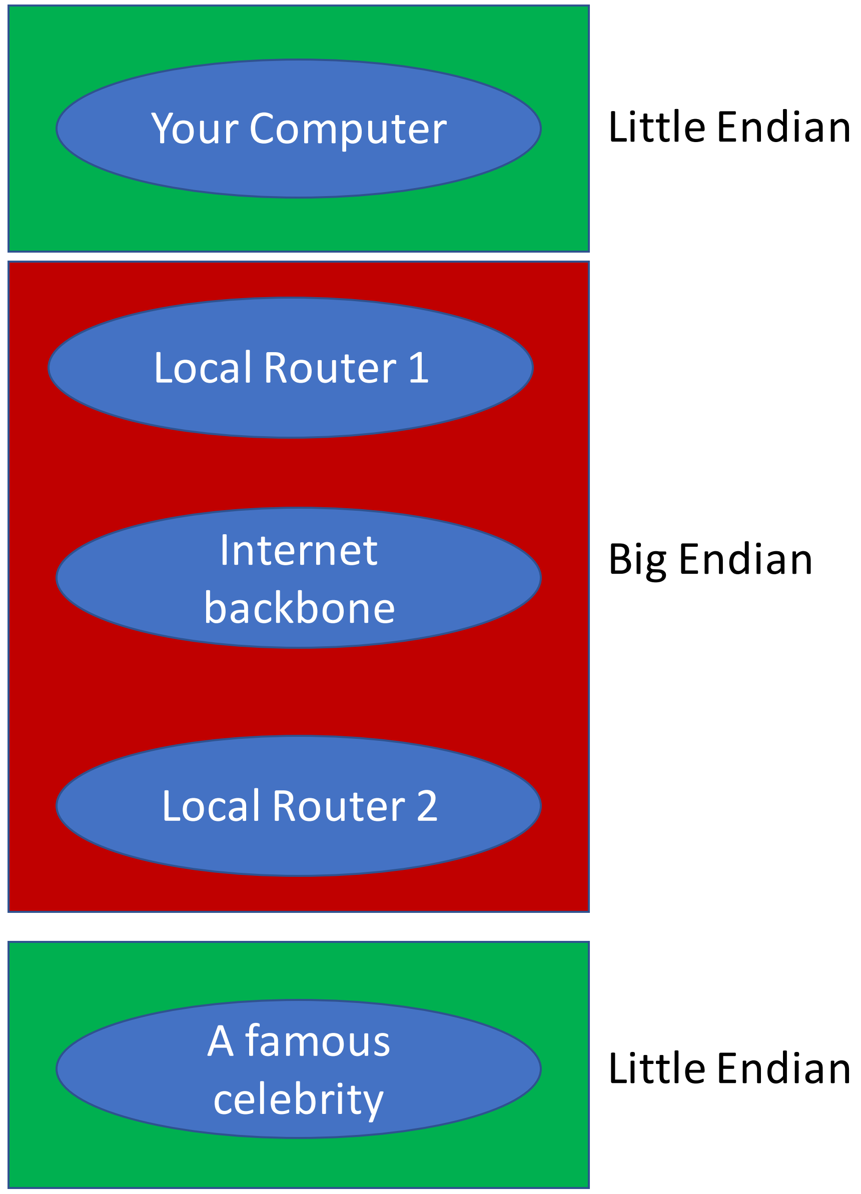
- Each device that hops our traffic through the internet needs to read the destination address to decide where to send the packet next

- What if those computers do not have the same endianness?

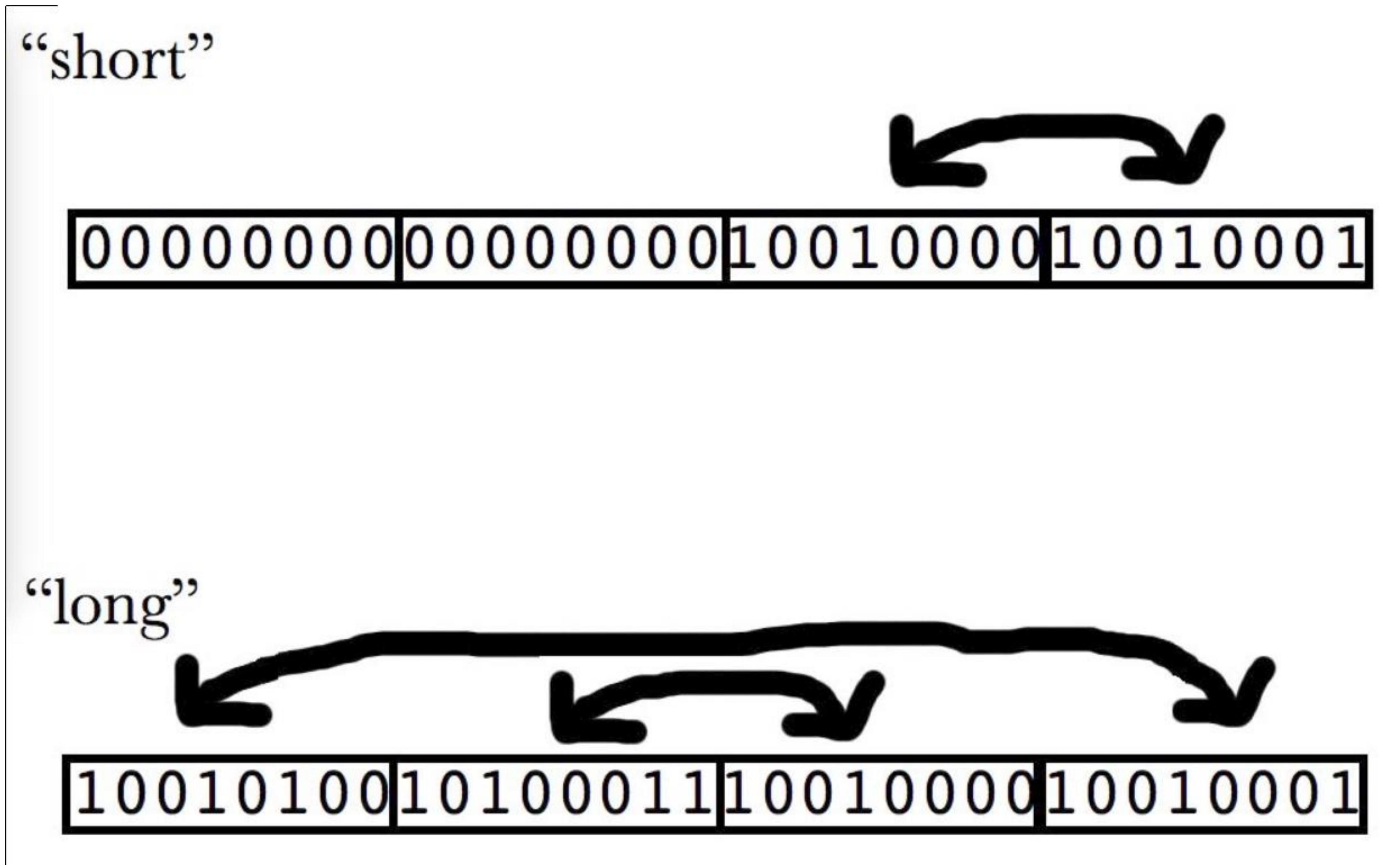


Endianness on the internet

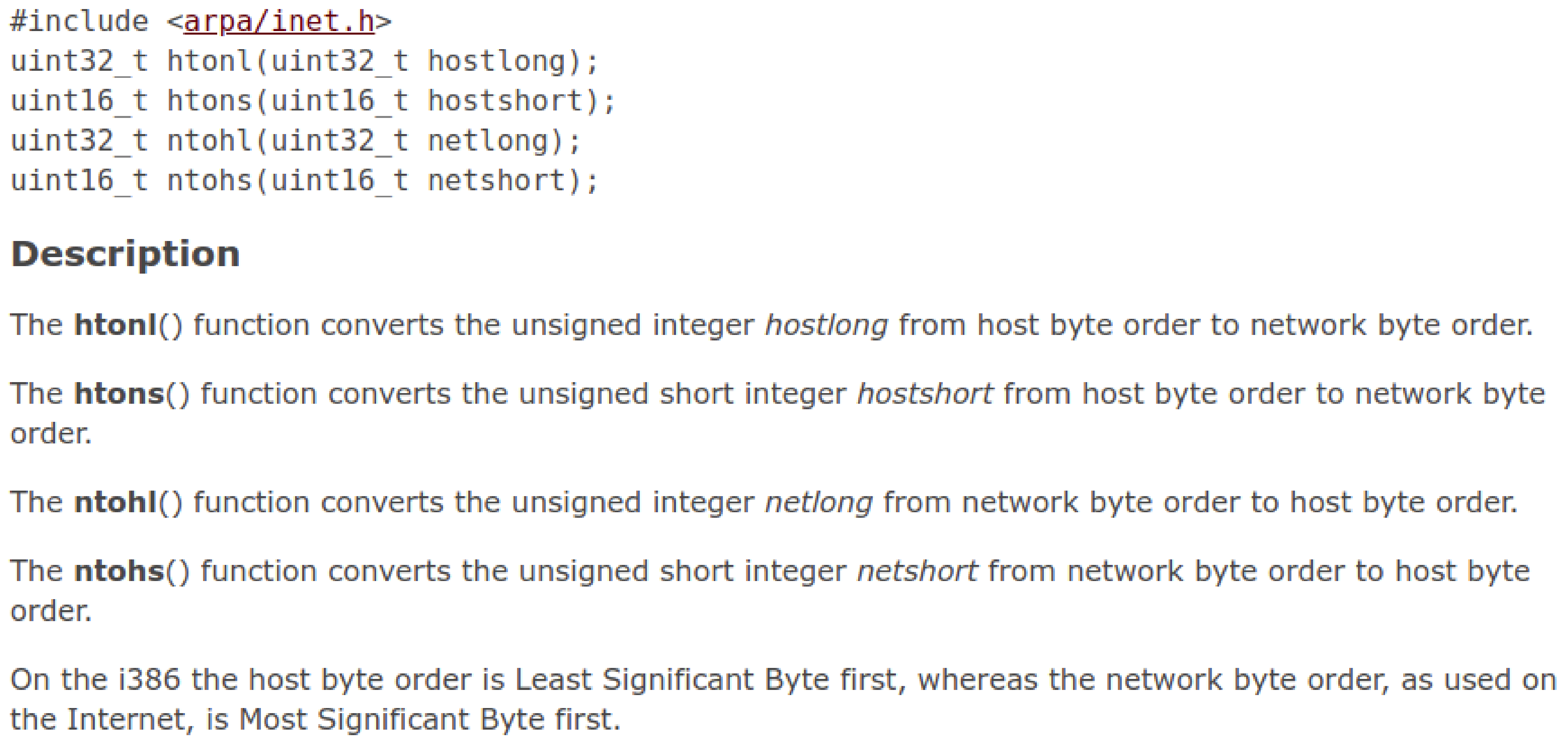
- Each device that hops our traffic through the internet needs to read the destination address to decide where to send the packet next
- What if those computers do not have the same endianness?
  - In fact they very rarely will all agree.
  - Therefore, we must choose a standard: Big Endian is "network byte order". Everyone converts to that when the message is sent



Converting means swapping the right bytes



How to convert in a cross-platform way?



```
#include <arpa/inet.h>
uint32_t htonl(uint32_t hostlong);
uint16_t htons(uint16_t hostshort);
uint32_t ntohl(uint32_t netlong);
uint16_t ntohs(uint16_t netshort);
```

Description

The **htonl**() function converts the unsigned integer *hostlong* from host byte order to network byte order.

The **htons**() function converts the unsigned short integer *hostshort* from host byte order to network byte order.

The **ntohl**() function converts the unsigned integer *netlong* from network byte order to host byte order.

The **ntohs**() function converts the unsigned short integer *netshort* from network byte order to host byte order.

On the i386 the host byte order is Least Significant Byte first, whereas the network byte order, as used on the Internet, is Most Significant Byte first.

What else must be standardized?

- Anything important that we could inerpret differently between any 2 computers on the net. What have we seen so far that's important?
  - \0 ends C strings
  - \t means tab

  - \n means newline (or does it?)
  - \r means carriage-return (which carriage?)
  - \r\n means carriage-return then newline (...wait...)

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  - \0 ends C strings
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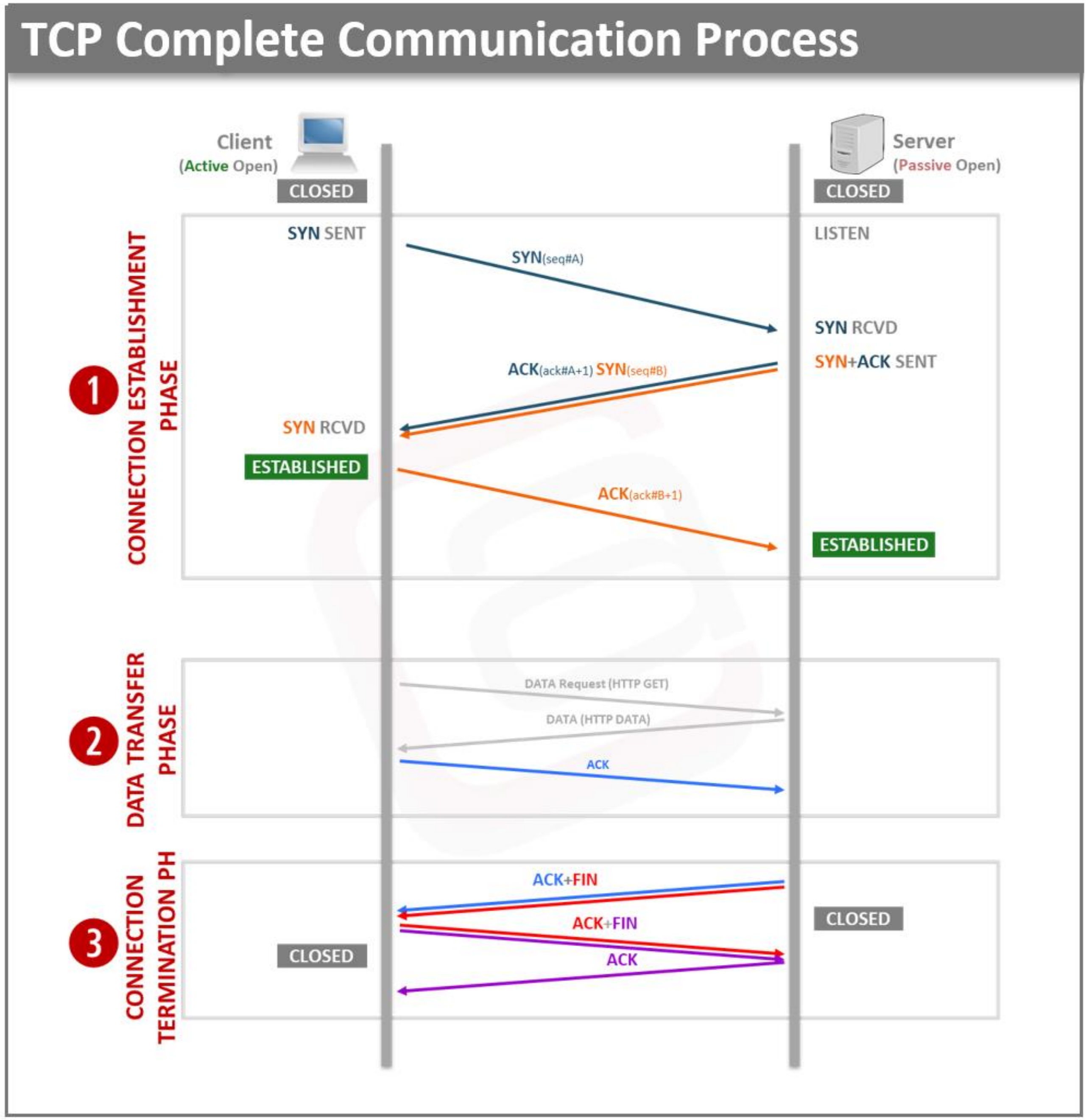
  - \n means newline (or does it?)
  - \r means carriage-return (which carriage?)
  - \r\n is the network "newline"

Thinking about a connection

- We said that 2 communicating generals could never coordinate, so how can we get data across a socket?
- #1: We don’t need to attack anyone, so the constraints on success are easier to meet
- #2: The Internet's idea is "best effort" in that we will always acknowledge the possibility of failure and move on eventually
- But within these bounds, do everything we get to get the data across

TCP Phases to know

- 1) 3-way handshake establishes the communication link, sets up parameters, agrees on plan to re-send, control congestion, etc
- 2) Each side is now able to send and receive
- 3) 3-way tear-down, ensures that both sides know the session is ending.



Next example: both send and receive

- We will look at the echo_server and echo_client in ExampleCode/Lecture18
- We'll use this code as a boot-strap towards our full chat functionality:
- Explore changing some of the parameters
  - Send a lot of data. Does it all arrive?
  - Try to run it on a different server. Which ports are OK and not?

Further Reading

- A sockets tutorial from RPI:
  - http://www.cs.rpi.edu/~moorthy/Courses/os98/Pgms/socket.html