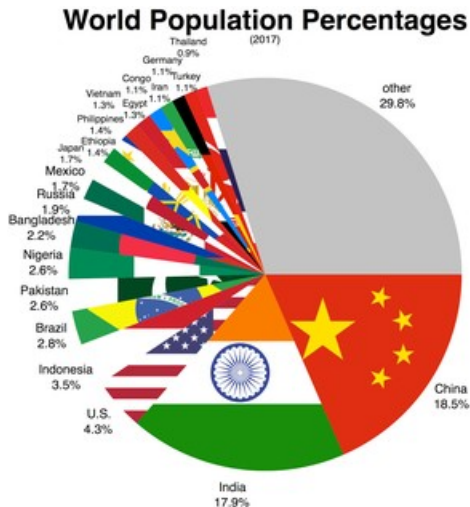
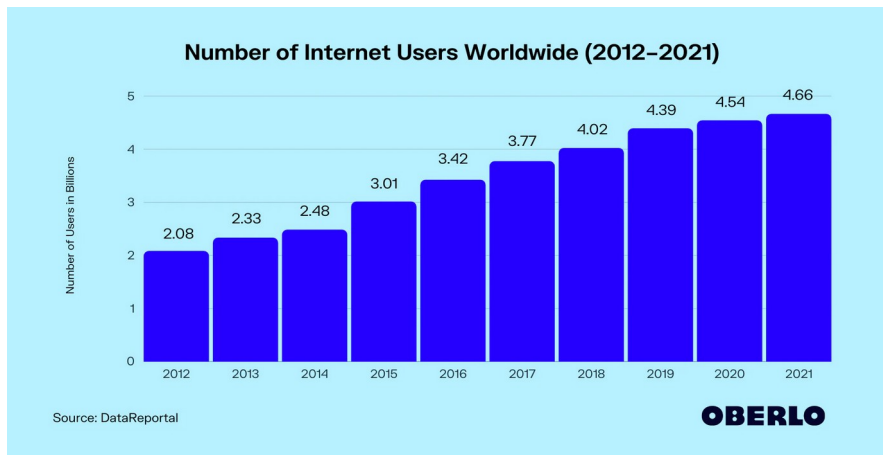


TCI/IP Networking Review

- Internet users (acc. to multiple statistical sites) – 4.66 billion.
- World population – 7.8 billion in 195 countries.
 - Which continent has the largest number of countries?
 - Which continent has the smallest number of countries?
- Internet users in USA – 93%.



Img src: Wikipedia.com



TCP/IP

- Networking system underlying the internet
- Independent of hardware, OSs, nw size, topologies, or connectivity.
- Contributed largely to the success of the internet.
- Consists of a suite of open and non-proprietary protocols.
- Progenitor – ARPANET of 1969 by DoD.

- By 1980s became commercial.

Internet – collection of networks interconnected at peering-points, owned by ISPs.

What devices can be connected to Internet?

Internet of Things (IoT) - a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction (Wikipedia).

Who runs Internet?

- ICANN (Internet Corporation for Assigned Names and Numbers), icann.org
 - Non-profit corporation, hq in Ca
 - The only group with any enforcement capability
 - Controls allocation of Internet addresses, port numbers, and domain names.

From their webpage: “This is a community-based consensus-driven approach to policy-making. The idea is that Internet governance should mimic the structure of the Internet itself- borderless and open to all.”

- ISOC (Internet Society)
 - International non-profit organization, offices in D.C. and Geneva, isoc.org
 - Open membership organization that represents Internet users
 - Has educational and policy functions
 - The umbrella organization for technical development of internet
 - Parent of IETF (ietf.org) that oversees technical work.
- IGF (Internet Governance Forum)
 - Created by UN in 2006, intgovforum.org.
 - Home of international and policy-oriented discussion related to Internet
 - Structured as annual conference series

Network Standards and Documentation

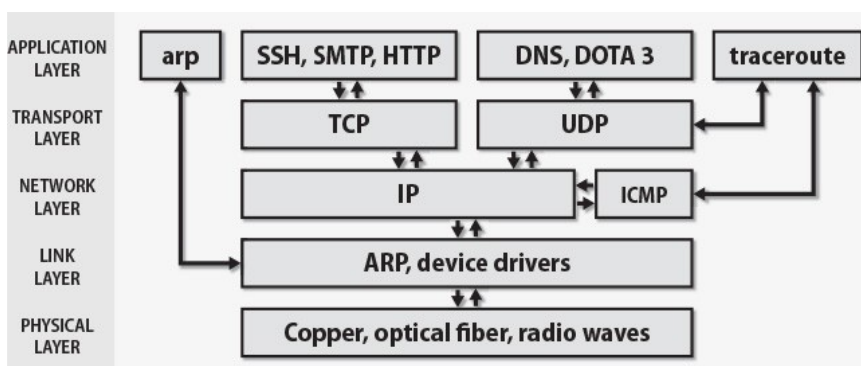
- Net admins must know how to access information and where to find it!!!
- RFC (Request for comments) – protocol standards and changes, info bulletins.

- Start as a draft, and after a lot of work and IETF meetings either die or become RFCs.
- Standardize Internet protocols.
- Authoritative, concise, free.
- Sometimes just document or explain aspects of existing practice.
- Numbered sequentially, have descriptive titles.
- 8,200 already in existence.
- Contents never change, if revisions are necessary, new RFCs will be created.
- rfc-editor.org is the most up-to-date source.
- Internet standards process itself is described in RFC2026.
- RFC5540 (40 years of RFCs) describes cultural and technical context of the system, 2009.
- RFC 2555 (30 years of RFCs) , 1999.
- RFC1 S. Crocker “Host Software”, 1969.
 - The Interface Message Processor (IMP) was the packet switching node used to interconnect participant networks to the ARPANET from the late 1960s to 1989. It was the first generation of gateways, which are known today as routers. (Wikipedia)
- Some are fun to read (RFC7511, RFC1925).
- RFC can also be assigned special numbers:
 - FYI – info for broad audience.
 - RFC 1713 = FYI127.
 - BCP (best current practice) – recommended procedures for internet sites, and administrative suggestions.
 - STD – Internet protocols that have completed IETF review and were adopted as standards.

Networking Basics

TCP/IP consists of a protocol suite:

- IP - routes data packets from one machine to another (RFC791).
- ICMP - defines low-level support for IP, error msgs, routing assistance, debugging (RFC792).
- ARP - address resolution protocol, translates IP address to MAC address (RFC826).
- UDP - user datagram protocol, unverified, best-effort delivery (RFC768).
- TCP - reliable, full duplex, flow-controlled, error-corrected (RFC793).



Img src: textbook.

IPv4 and IPv6

- IPv4 = 4 B = 32 bits addresses. How many devices can we address?
 $4,294,967,296 = 4.3 * 10^9$
 - Africa still has addresses available, Asia-Pacific first to run out.
 - How does it still work?
 - We learned to be more efficient
 - NAT
 - CIDR
 - Some sites are not reachable via IPv6: amazon, ebay, pinterest, dropbox
- IPv6 = 16B = 128 bits addresses. How many devices can we address?
 $340282366920938463463374607431768211456 = 3 * 10^{38}$
- On 03/2017 14% hosts contacting Google had IPv6, 30% in US.
- IPv6 integrates security and authentication, and removes some IPv4 features.
- Most mobile devices default to IPv6 on carrier's data network.
- Most home and enterprise networks are IPv4.
- Choices - IPv4 and IPv6, or IPv6 alone ?
- IPv6 is still the future, not the present.
- Data Centers are using IPv6.
- IPv6 mandatory for all new devices with nw capabilities.

Packets and encapsulation

- TCP/IP supports Ethernet, token ring, MPLS (multiprotocol label switching), wireless Ethernet, and serial systems) - link layer manages hw.
- Link layer determines max packet size. Packet = header + payload.
- Data unit terminology:
 - LL - frame;
 - IP layer - packet;
 - TCP layer - segment;
- Each protocol adds its own header on sending end, and removes their header on receiving end.

Ethernet header	IPv4 header	UDP header	Application data	Ethernet CRC
14 bytes	20 bytes	8 bytes	100 bytes	4 bytes
UDP packet (108 bytes)				
IPv4 packet (128 bytes)				
Ethernet frame (146 bytes)				

Img src: textbook.

Ethernet Framing

Link Layer:

- Adds headers and puts separators between packets.
- Logical Link layer – handles framing.
- MAC layer – transmits bits on to the medium (wire, optical, etc.)
- Maximum Transfer Unit (MTU).
- Size determined by HW specs and protocol (Ethernet = 1500 B).

Packet Addressing scheme

- MAC addresses for use by hardware.
 - Media Access Control address identifies machines on physical network.
 - Unique addresses 6 B long written as series of 2-digit hex bytes with colons.
 - Assigned during manufacturing process.
 - First 3 bytes id manufacturer, IEEE Organizationally Unique Identifier (OUI)
 - Vendor ID can be found here:
<https://www.wireshark.org/tools/oui-lookup.html>
 - Second 3 bytes are a unique serial number.
 - Permanent addresses, BUT....
 - Many will allow you to override it (switches or routers may use it, or sw licensing).
- IP addresses are hardware independent.
 - Globally unique, BUT.... not globally unique: NAT, anycast addressing, private subnets.
 - Link layer maps IP address to MAC address. (nw service, or /etc/hosts)
 - Hostnames are associated with IP address and can be used by humans.
 - IP address can have 1 or more hostnames associated with it.
 - Ports (16 bit number in range 1-65,535) id specific processes or services.
 - Ports are assigned by iana.org (Internet Assigned Numbers Authority)
 - Well-known ports are in /etc/services.
 - Do not modify /etc/services file!
 - Address types:
 - Unicast – one host.
 - Multicast – group of hosts.
 - Internet Group Management Protocol (IGMP) manages sets of hosts.
 - Broadcast – all hosts on the local subnet.
 - Anycast – deliver packets to one of the group of hosts.
 - Several routers will have the same address.

- Closest of several destinations is determined by routing protocol.
- Load balancing function.
- Hostnames by use by people

IPv4 Addresses

- 32 bit (4 bytes) dotted decimal notation.
- Have network and host identifiers.
- Loopback address – no network interface, and only 1 host – self: 127.0.0.1 (not unique).
- Historically has a “class” based on the leftmost byte.
- Class determined which bits id nw, and which id host.

Class	1 st byte ^a	Format	Comments
A	1-127	N.H.H.H	Very early networks, or reserved for DoD
B	128-191	N.N.H.H	Large sites, usually subnetted, were hard to get
C	192-223	N.N.N.H	Were easy to get, often obtained in sets
D	224-239	–	Multicast addresses, not permanently assigned
E	240-255	–	Experimental addresses

a. The value 0 is special and is not used as the first byte of regular IP addresses. The value 127 is reserved for the loopback address.

- Most networks of class B do not have this many hosts.
- To make better use of the address bits we can create subnetting.
- “Subnet masks” or “netmasks” are used to reassign host portion to networks:
 - 1 = desired nw portion (min 8 bits), 0 = desired host portion (min 2 bits).
 - 22 netmask bits are reassignable.
 - Hard to decode when not on byte boundary.

IP address	128	.	138	.	243	.	0
Decimal netmask	255	.	255	.	255	.	192
Hex netmask	f f	.	f f	.	f f	.	c 0
Binary netmask	1111 1111	.	1111 1111	.	1111 1111	.	1100 0000

- CIDR uses prefixed notation for net bits.
- Uses prefix to indicate network portion.
128.138.243.0/26 have mask 255.255.255.192 has 4 networks 128.138.243.
Two left bits of the 2nd left byte can be used for “subnetting”

128.138.243.0/26 (0 in decimal is 00000000 in binary)

128.138.243.64/26 (0 in decimal is 01000000 in binary)
 128.138.243.128/26 (0 in decimal is 10000000 in binary)
 128.138.243.192/26 (0 in decimal is 11000000 in binary)

IP address	Netmask	Network	Broadcast
128.138.243.100/16	255.255.0.0	128.138.0.0	128.138.255.255
128.138.243.100/24	255.255.255.0	128.138.243.0	128.138.243.255
128.138.243.100/26	255.255.255.192	128.138.243.64	128.138.243.127

- Subnetting - a single big network is divided into multiple smaller subnetworks. Network portion is greater than implied by the network's explicit class. For example, in class C addresses, nw portion will be greater than 24 bits, in B - greater than 16, in A greater than 8.

CIDR

- Direct extension of subnetting, but...
- Host portion can be smaller than the one defined by class rules.
- Allows networks to be supernetted - aggregated for the purpose of routing.
- In *Supernetting*, multiple networks are combined into a bigger network called supernet or supernet. Network portion here will be smaller number of bits than the network's explicit class. For example, for class A it can be smaller than 8, for B - smaller than 16, c - smaller than 24.
- All hosts must have the same netmask.

192.144.0.0 thru 192.144.7.0 (CIDR 192.144.0.0 /21)

1 nw with /21 with 2046 hosts, mask 255.255.248.0
 8 nw with /24 with 254 hosts, mask 255.255.255.0
 16 nw with /25 with 126 hosts, mask 255.255.255.128
 32 nw with /26 with 62 hosts, mask 255.255.255.192

Address Allocation

- Only network numbers are assigned.
- Sites define their own host addresses.
- ICANN allocated blocks of addresses to 5 regional Internet Agencies.
- Agencies give out addresses to ISPs.
- ISPs assign addresses to clients.

NAT

- Private IP addresses (RFC1918)

- Used internally, not globally visible.
- Router translates between private and address assigned by ISP.
- Routing table is usually involved with internal port numbers to differentiate between hosts.
- IPv6 Addresses
 - Identify network interfaces on the global Internet.
 - RFC1884, RFC1924
 - IPv6 is 128 bits long with fixed network/host portion of /64.
 - True subnetting no longer exists in IPv6 world.
 - 8 groups of 16 bits separated by colons ":"
 - Each group of 16 bits (2bytes) is represented by 4 hex digits.
 - Leading zeros are removed.
 - :: used for any number of 0 groups once per address (longest group).
 - :: can appear at first or last component.
 - 2607:f8b0:000a:0806:0000:0000:0000:200e → 2607:f8b0:a:806::200e
 - 0:0:0:0:0:0:0:1 → ::1 (loopback)
 - RFC5952 explains notation of an IPv6 address and how to simplify it.
 - Searching is difficult because addresses have to be normalized.

Linux Specific Network Management

- Sysadmin may need to add a machine to network.
- Several steps:
 1. Assign unique IP address and hostname.
 2. Configure NW interfaces and IP addresses.
 3. Setup default route as minimum.
 4. Point to DNS server to allow access to the rest of internet.
- If use DHCP for basic provisioning, DHCP server will do most configuring.

Assigning hostnames

- **/etc/hosts** - maps names to IP addresses. Below is a sample hosts file from CU SoC nw:

```
127.0.0.1      localhost
::1           localhost ip6-localhost ip6-loopback
ff02::1       ip6-allnodes
ff02::2       ip6-allrouters
130.127.255.249 clemsonuldap.clemson.edu
```

Use **hostname** command to find out what the name of a machine is.

```
$ hostname -- this command displays the hostname
LatitudeD630
```

```
$ sudo hostname newName -- this command changes hostname
$ hostname
LatitudeD630
```

- Every system has at least 2 network interfaces
 - Loopback virtual interface
 - Physical network card/s (Ethernet, wireless, virtual, etc.)
- Display all interfaces:

```
$ ip link show -- cs computers
1: lo: <LOOPBACK,UP,LOWER_UP> mtu 65536 qdisc noqueue state
UNKNOWN mode DEFAULT group default
    link/loopback 00:00:00:00:00:00 brd 00:00:00:00:00:00
2: eth0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc pfifo_fast
state UP mode DEFAULT group default qlen 1000
    link/ether 36:85:7b:c5:a7:36 brd ff:ff:ff:ff:ff:ff
```

Routing configuration

ip route command display routing table

```
default via 130.127.201.193 dev eth0
130.127.201.192/26 dev eth0 proto kernel scope link src 130.127.201.252
```

ip route add -- adds a routing entry via adjacent gateway or host

ip route del -- deletes an entry

ip route flush -- flushed the table and makes it rebuild it

/etc/networks maps names to network numbers

```
default      0.0.0.0
loopback     127.0.0.0
link-local   169.254.0.0
localnet     10.20.33.0
```

Configuring a machine as a DNS client

- Set up **/etc/resolv.conf** file to list domains to be searched to resolve incomplete names
- Amend IP addresses of the name servers for name lookups.

```
nameserver 130.127.255.250
nameserver 130.127.255.251
domain computing.clemson.edu
search computing.clemson.edu cs.clemson.edu fx.clemson.edu
clemson.edu
```

options ndots:2

- Linux default is Network Manager (2004)
 - Runs continuously || with system tray app for configuring nw interfaces
 - Handles transient networks, wifi, vpn
 - Does not handle statically configured ip addresses, but works in ||
- Legacy commands still work: **ipconfig, netstat, route**
- Replaced by package iproute2 with commands: **ip** and **ss**:
 - **ip link show, ip route show, ip address show**
- Ubuntu config files:
 - **/etc/hostname** sets fully qualified hostname:
ada11.computing.clemson.edu
 - **/etc/network/interfaces** sets IP address, netmask, default route

```
auto lo
iface lo inet loopback
```

```
auto eth0
iface eth0 inet static
address 130.127.201.252
netmask 255.255.255.192
network 130.127.201.192
broadcast 130.127.201.255
dns-nameservers 130.127.255.250 130.127.255.251
dns-search cs.clemson.edu
gateway 130.127.201.193
```

```
auto eth0
iface eth0 inet6 static
address 2620:103:a004:e::252
netmask 64
dns-search cs.clemson.edu
gateway 2620:103:a004:e::1
```

- Hardware options:
 - **ethtool eth0** - queries and sets the media-specific interface parameters for a network: link speed and duplex.
 - Not installed by default

TCP/IP options

- **/proc/sys/net/ipv4** and **/proc/sys/net/ipv6** contain network variables, such as congestion window, retransmit protocol (Reno on most machines), etc.

- UDP and TCP are version dependent and define more params in ipv4

Network Troubleshooting

- Useful tools: **ping, traceroute, tcpdump, Wireshark**
- Checklist on pp 428-429.
- **ping** and **ping6** check if machine is alive.
 - Used for connectivity debugging.
 - Send ICMP_ECHO_PACKET to target host and wait for reply.
 - Some hosts block it.
 - If DNS is not working, use numeric addresses to ping.
 - Can send packets of specified size:
 - `ping -s 1500 computing.clemson.edu`
- **traceroute** discovers the path packets travel to destination.
 - **traceroute google.com**
 - works by setting ttl – hop count to live.