Network Computing courses

Maël Auzias

ENSIBS - UBS

October 2014

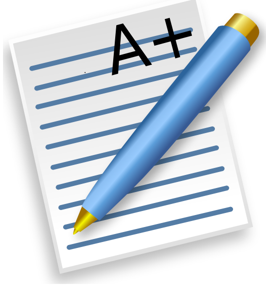
Figure: teaching.auzias.net

Course details

Objectives

- How do *computers* communicate?
- What are the mechanisms **under** an HTTP request or a telegram message?
- Networks are all around us, better study them!

Course details



Evaluation

- Short test at the beginning of every lesson (5 min) ?
- Project
- Final exam (1 hour)
- All same weighting

Material

- Slides available at teaching.auzias.net (github too)

Presentation Outline

Definitions

- **Network:** an **interconnected** group or system
- **Internet:** world wide **interconnected system of networks** RFC791 (September 1981)
- **IP:** Internet **Protocol** provides the functions necessary to deliver a package of bits from a source to a destination over a network
- **(world wide) Web: network** consisting of a collection of Internet websites using HTTP

Definitions

- **HTTP:** Hypertext Transfer **Protocol**, application-level protocol for distributed, collaborative, hypermedia information systems draft HTTP2 (July 2014)
- **FTP:** File Transfer **Protocol** promotes sharing of files, encourages the use of remote computers RFC959 (October 1985)
- **TCP:** Transmission Control **Protocol** is intended for use as a highly reliable host-to-host RFC761 (January 1980)
- **UDP:** User Datagram **Protocol** provides a procedure for application programs to send messages to other programs with a minimum of protocol mechanism RFC768 (August 1980)
- **RFC:** Request For Comments (Internet Draft (ID), RFC, Internet Standard)

Definitions

- **Router:** network **hardware** providing routing services
- **Routing: algorithm processed** to decide where to forward a packet
- **Forwarding: action** of moving a packet from one NIC to another
- **NIC:** Network Interface Card
- **Switch (hub):** network **hardware** connecting systems using packet switching
- **Packet switching:** forward-like method regardless of the content (destination-based)
- **NAT:** Network Address Translation, router modifying IP address into another IP address.

Definitions

- **Node (network):** any entity that can send packets to/receive packets from a network through a NIC
- **Client: computer** able to send requests to a server
- **Request: application message** destined for a server (*order*)
- **Server: computer** able to respond a client's requests
- **Response: application message** destined for a client (*result*)
- **Fat client: application** where most functions are processed by the client itself
- **Thin client: application** where most functions are carried out on a central server

What kind of network is it?

- **BAN:** Body Area Network
- **PAN:** Personal Area Networks
- **(W)LAN:** (Wireless) Local Area Networks (home, office, school or airport)
- **MAN:** Metropolitan Area Networks, can cover a whole city
- **WAN:** Wide Area Networks cover a broad area (Internet)

Topologies

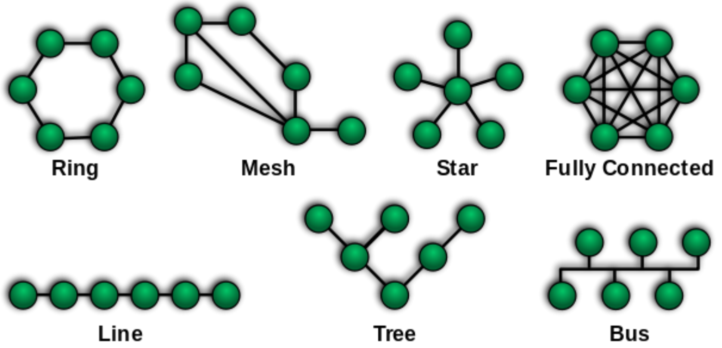


Figure: upload.wikimedia.org

Topologies

- **Point-to-point:** two entities directly connected to each other (tunnel).
- **Ring:** data go around the ring, unidirectional way network.
- **Mesh:** all nodes cooperate in the distribution of data in the network[1].
- **Star:** all messages go through the same central node, reducing network failure.
- **Fully connected:** all nodes are connected to all other nodes.
- **Line:** bidirectional link between two nodes. Node can only send packet going through its neighbors.
- **Bus:** all nodes are connected to the same media. Only one can send a packet at a time, which all others then receive.
- **Tree:** hierarchical topology, such as a binary tree.

[1] Hong Kong protesters use a mesh network to organize

Bonus

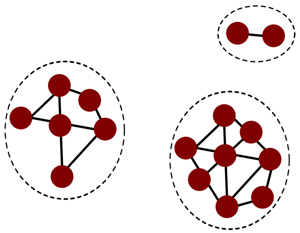


Figure: Disconnected MANET illustration [?]

Bonus

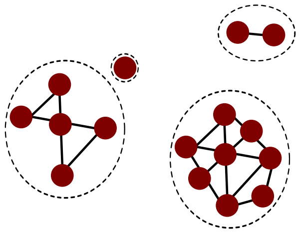


Figure: Store-carry-and-forward [?]

Bonus

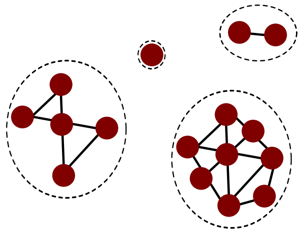


Figure: Store-carry-and-forward [?]

Bonus

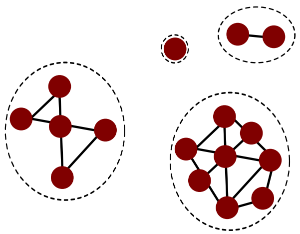


Figure: Store-carry-and-forward [?]

Bonus

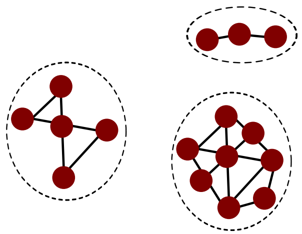


Figure: Store-carry-and-forward [?]

HTTP request/response example

Enter getbootstrap.com in your browser

Source	Destination	Protocol	Length	Info
192.168.0.48	208.67.222.222	DNS	76	Standard query 0x4797 A getbootstrap.com
208.67.222.222	192.168.0.48	DNS	108	Standard query response 0x4797 A 192.30.252.154 A 192.30.252.153

Figure: DNS request/response

Source	Destination	Protocol	Length	Info
127.0.0.1	127.0.0.13	TCP	74	36159 > http [SYN] Seq=0 Win=43690 Len=0 MSS=65495 SACK_PERM=1 TSval=12
127.0.0.13	127.0.0.1	TCP	74	http > 36159 [SYN, ACK] Seq=0 Ack=1 Win=43690 Len=0 MSS=65495 SACK_PERM
127.0.0.1	127.0.0.13	TCP	66	36159 > http [ACK] Seq=1 Ack=1 Win=43776 Len=0 TSval=122257 TSecr=12225
127.0.0.1	127.0.0.13	HTTP	356	GET /index.html HTTP/1.1
127.0.0.13	127.0.0.1	TCP	66	http > 36159 [ACK] Seq=1 Ack=291 Win=44800 Len=0 TSval=122259 TSecr=122
127.0.0.13	127.0.0.1	HTTP	354	HTTP/1.1 200 OK (text/html)
127.0.0.1	127.0.0.13	TCP	66	36159 > http [ACK] Seq=291 Ack=289 Win=44800 Len=0 TSval=122259 TSecr=1
127.0.0.1	127.0.0.13	HTTP	357	GET /favicon.ico HTTP/1.1
127.0.0.13	127.0.0.1	HTTP	565	HTTP/1.1 404 Not Found (text/html)
127.0.0.1	127.0.0.13	TCP	66	36159 > http [ACK] Seq=582 Ack=788 Win=45952 Len=0 TSval=122269 TSecr=1

Figure: HTTP request/response

How do messages reach their destination?

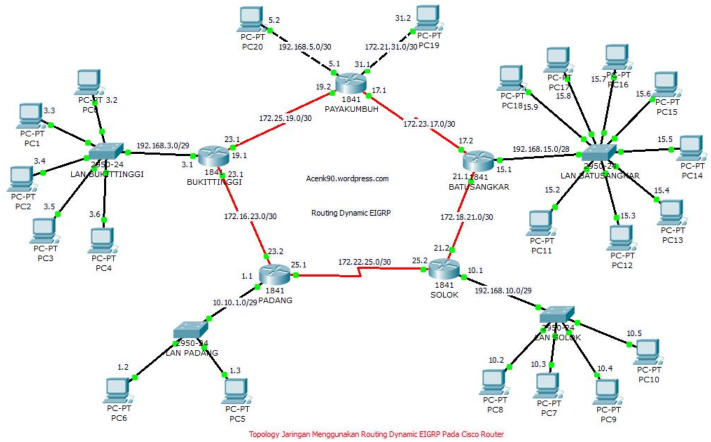


Figure: acenk90.files.wordpress.com

More like this...

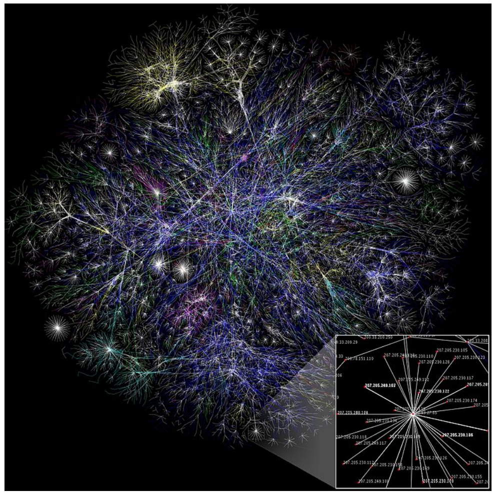


Figure: wikimedia.org

How does it work? From signal to application...

- 7 Application
- 6 Presentation
- 5 Session
- 4 Transport
- 3 Network
- 2 Data Link
- 1 Physical

Figure: OSI model

Nth layer communicate with Nth layer..

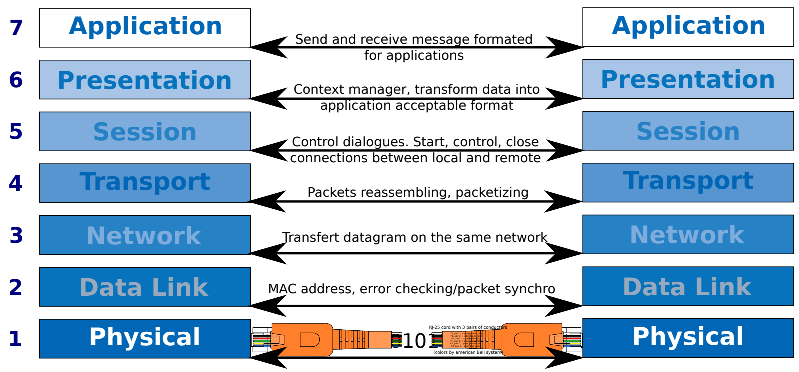


Figure: layer to layer

.. thanks to 3-th layers

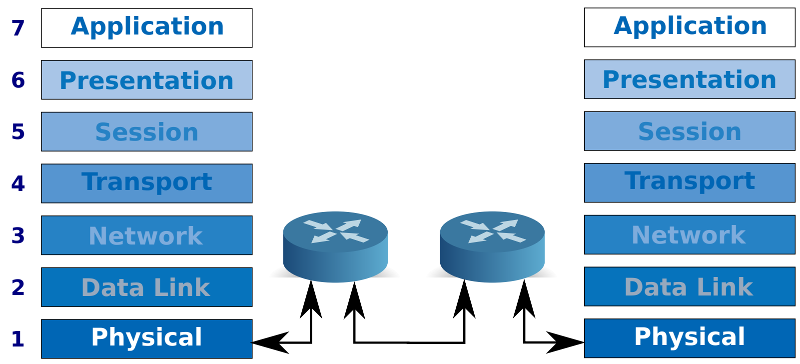
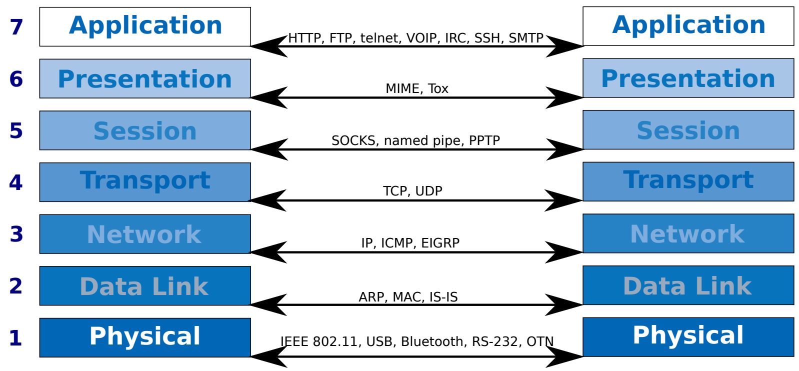


Figure: layers and routing

One single protocol, one single layer



Encapsulation

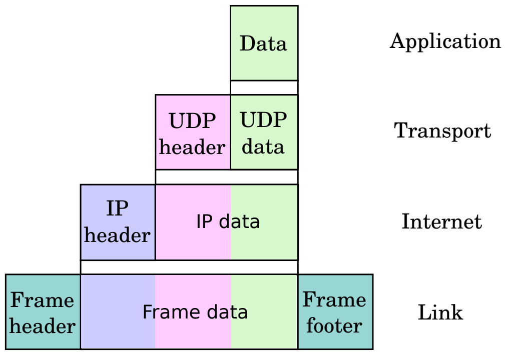


Figure: Encapsulation

Presentation Outline

Aims

- Interface data link layer,
- (De)Encode,
- Transmit: 1 after 0 (after 0 or 1, after 0... or 1)

Hardware medium

- IEEE 802.3 (a.k.a. Ethernet): <100Gbit/s
- IEEE 802.11 (a.k.a. Wi-Fi): <50 Mbit/s (802.11ad goes up to 6.75 Gbit/s)
- IEEE 802.15.1 (a.k.a. Bluetooth): <1 Mbit/s
- IEEE 802.15.4 (a.k.a. ZigBee): <250 kbit/s
- IEEE 802.16 (a.k.a. Wi-Max): <40 Mbit/s
- IEEE 1394 (a.k.a. Firewire): <3200 Mbit/s
- USB, serial port such as RS-232...

Hardware medium: IEEE 802.3 (Ethernet)

Figure: RJ45 connector

Hardware medium: IEEE 802.15.1 (Bluetooth)

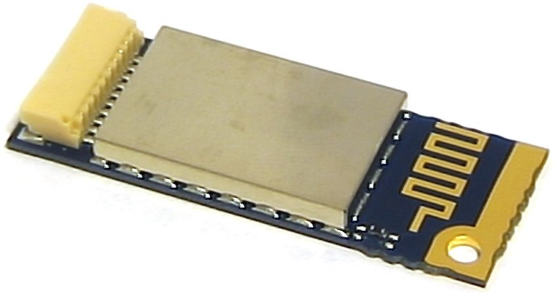


Figure: Bluetooth card

Hardware medium: IEEE 802.15.4 (ZigBee)

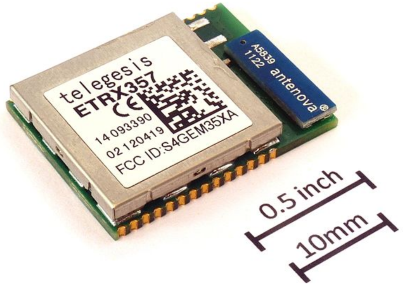


Figure: ZigBee card

Hardware medium: IEEE 802.16 (Wi-Max)

Figure: Wi-Max antenna

Hardware medium: IEEE 1394 (Firewire)

Figure: Firewire connector

Encoding

- **MLT3 (Multi-Level Transmit):** state change for 1s over 3 levels, stay in the same state for 0s
- **AMI (Alternate Mark Inversion):** state 0 for 0s, state +/-1 for 1s
- **Manchester:** voltage transition (rising/falling edge mean 1/0)
- **BMC (Biphase Mark Code):** change its state for 1s, stay on the same state for 0s
- and so on...

Encoding: Multi-Level Transmit

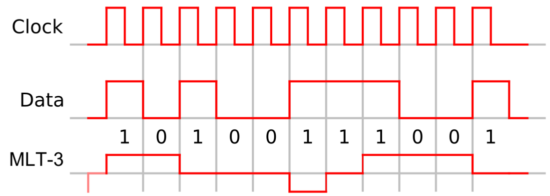


Figure: Multi-Level Transmit

Encoding: Alternate Mark Inversion

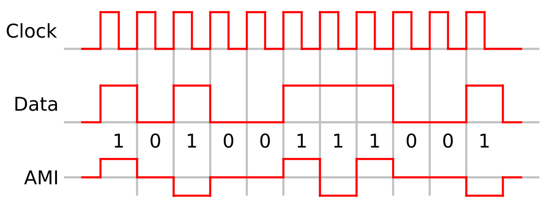


Figure: Alternate Mark Inversion

Encoding: Manchester

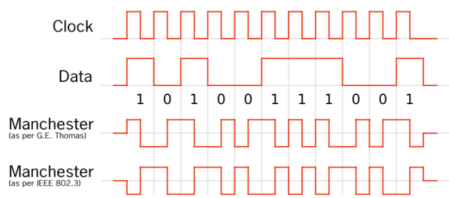


Figure: Manchester

Encoding: Biphase Mark Code

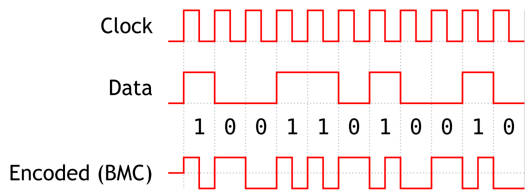


Figure: Biphase Mark Code

Transmitting

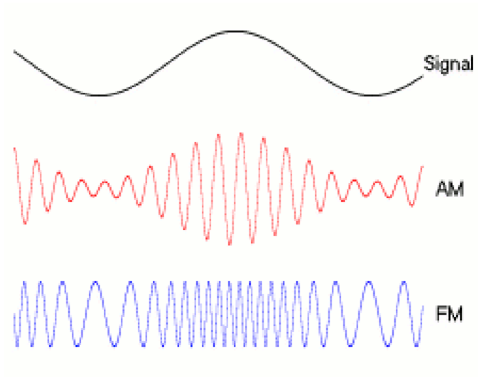


Figure: Amplitude and phase modulation

Error detection

- Repetition (hum...)
- Parity (XOR)
- Checksum
- CRC (Cyclic redundancy check): with a polynomial divison
- Hash
- and so on...

Error correcting

- Repetition (again)
- Hamming
- MDPC (Multidimensional parity-check code)

Correction: MDPC

Raw data to send: 0x01 02 03 04

0x01	0x02	0x03
0x03	0x04	0x07
0x04	0x06	

Figure: Data received with MDPC

Data sent (with MDPC): 0x01 02 03 03 04 07 04 06

Aims

- Interface network layer,
- Delivery to unique(?) hardware addresses,
- Framing,
- Data transfer

Layer composition (of its two sublayers)

1. Logical Link Control (LLC):
   - end to end flow control
   - end to end error control
   - (transmitting/receiving) protocols, over MAC sublayer, multiplexing
2. Media Access Control (MAC):
   - physical (hardware) addressing
   - collision detection and retransmission
   - data packet scheduling (and queuing)
   - QoS
   - VLAN

Carrier Sense Multiple Access with Collision Avoidance

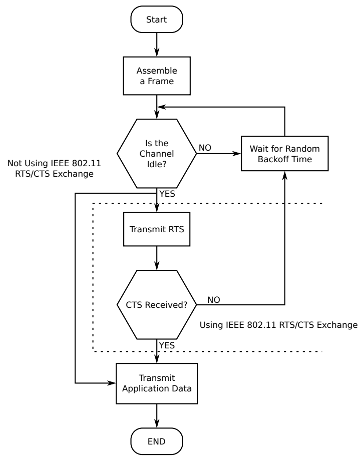


Figure: CSMA CA

Layer 2 Ethernet packet

MAC dest. (6)	MAC src. (6)	VLAN tag* (4)	Ethertype (2)
Payload (42-1500)		Frame check sequence (4)	

Figure: Layer 2 Ethernet packet

optional, Content (size in bytes)

Ethertype 0x	Protocol
0800	IPv4
0806	ARP
0842	Wake-on-LAN
86dd	IPv6

Figure: Data received with MDPC

ARP example

0000	ff	ff	ff	ff	ff	ff	fa	ba	00	ab	ab	af	08	06	00	01
0010	08	00	06	04	00	01	fa	ba	00	ab	ab	af	ac	11	22	37
0020	00	00	00	00	00	00	ac	11	00	f9	00	00	00	00	00	00
0030	00	00	00	00	00	00	00	00	00	00	00	00				

Figure: ARP request

MAC address destination MAC address source Ethertype Hardware type Protocol type OpCode (1 request, 2 reply) IP address source IP address destination

ARP example

0000	ff	ff	ff	ff	ff	ff	fa	ba	00	ab	ab	af	08	06	00	01
0010	08	00	06	04	00	01	fa	ba	00	ab	ab	af	ac	11	22	37
0020	00	00	00	00	00	00	ac	11	00	f9	00	00	00	00	00	00
0030	00	00	00	00	00	00	00	00	00	00	00	00				

Figure: ARP request

MAC address destination MAC address source Ethertype Hardware type Protocol type OpCode (1 request, 2 reply) IP address source IP address destination

ARP example

0000	fa	ba	00	ab	ab	af	be	be	00	00	eb	eb	08	06	00	01
0010	08	00	06	04	00	01	be	be	00	00	eb	eb	ac	11	00	f9
0020	fa	ba	00	ab	ab	af	ac	11	22	37	00	00	00	00	00	00
0030	00	00	00	00	00	00	00	00	00	00	00	00				

Figure: ARP reply

MAC address destination MAC address source Ethertype Hardware type Protocol type OpCode (1 request, 2 reply) IP address source IP address destination

ARP example

0000	fa	ba	00	ab	ab	af	be	be	00	00	eb	eb	08	06	00	01
0010	08	00	06	04	00	01	be	be	00	00	eb	eb	ac	11	00	f9
0020	fa	ba	00	ab	ab	af	ac	11	22	37	00	00	00	00	00	00
0030	00	00	00	00	00	00	00	00	00	00	00	00				

Figure: ARP reply

MAC address destination MAC address source Ethertype Hardware type Protocol type OpCode (1 request, 2 reply) IP address source IP address destination

Aims

- Interface transport layer,
- Host addressing,
- End-to-end packet transmission (data link? Connectionless? Switch? Router?),
- Routing, load balancing

Concepts

- IP addressing fundamentals,
- Classfull IP addressing,
- Subnet and VLSM (Variable length subnet masks),
- CIDR (Classless inter-domain routing),
- Routing,
- IPv6.

IP addressing fundamentals

IP address

32 bits (4x4 bytes)

mask	
Networks part	Host part

Figure: IP address parts

IP addressing fundamentals

Masks

- Separates network and host bits,
- MSB **always** are ones and then zeros! 255.254.255.0 is not possible,
- Indicates how many bits are used for the network part:
  - A 8-bit mask leaves 24 bits for the hosts,
  - A 16-bit mask leaves 16 bits for the hosts,
  - A 24-bit mask leaves 8 bits for the hosts,
  - A N-bit mask leaves 32-N bits for the hosts.
- Two different masks (differences seen further):
  - Network mask,
  - Subnet mask.

IP addressing fundamentals

IP address

32 bits (4x4 bytes)	
ones mask	zeros mask
Networks part	Host part

Figure: IP address parts and mask

IP addressing fundamentals

Is that an address?

- Network address,
- Hosts,
- Broadcast address.

Within the same network

- All addresses have the same network bits,
- Network address has zeros for host bits: x.x.x.0*,
- All hosts have different host bits: x.x.x.[0-1]*,
- Broadcast address has ones for host bits: x.x.x.1*.

IP addressing fundamentals

Mask /24 254 hosts	255 11111111	255 11111111	255 11111111	0 00000000
Network address	192 11000000	168 10101000	1 00000001	0 00000000
First host	192 11000000	168 10101000	1 00000001	1 00000001
Last host	192 11000000	168 10101000	1 00000001	254 11111110
Broadcast address	192 11000000	168 10101000	1 00000001	255 11111111

Figure: IP address example 1

IP addressing fundamentals

Mask /16 65.534 hosts	255 11111111	255 11111111	0 00000000	0 00000000
Network address	172 10101100	64 01000000	0 00000000	0 00000000
First host	172 10101100	64 01000000	0 00000000	1 00000001
Last host	172 10101100	64 01000000	255 11111111	254 11111110
Broadcast address	172 10101100	64 01000000	255 11111111	255 11111111

Figure: IP address example 2

IP addressing fundamentals

Formula: how many hosts with a N-bit mask?

$2^{32-N} - 2$, the -2 moves out network and broadcast addresses which are not hosts.

- 24-bit mask: $2^{32-24} - 2 = 2^{8} - 2 = 254$ hosts
- 16-bit mask: $2^{32-16} - 2 = 2^{16} - 2 = 65.534$ hosts
- 8-bit mask: $2^{32-8} - 2 = 2^{24} - 2 = 16.777.214$ hosts

IP addressing fundamentals

Public addresses

- Most of IP addresses
- Registered ISP and large organizations inherit blocks of public addresses from IANA[2]
- Usage of not registered public addresses is forbidden.

Private addresses

- Privates addresses are A, B and C classes (not all, see after)
- No registration needed
- Not routed across the Internet
- Proxy, NAT and private addresses solved IPv4 shortage.

[2] Internet Assigned Numbers Authority

Classful IP Addressing

Class	A	B	C
First octet	1 - 126	128 - 191	192 - 223
First octet 0b	0*	10*	110*
Network mask	255.0.0.0 /8	255.255.0.0 /16	255.255.255.0 /24
IP addresses range	1.0.0.0 126.0.0.0	128.0.0.0 191.255.0.0	192.0.0.0 223.255.255.0
Private range	10.0.0.0 10.255.255.255	176.16.0.0 176.31.255.255	192.168.0.0 192.168.255.0
Number of hosts	16.777.214	65.534	254

Figure: Three main classes

Where did 127.0.0.0/8 go ?!

Classful IP Addressing

Class D

- First octet: 224 - 239
- First octet pattern: 1110*
- Theses IP addresses are multicast addresses.

Class E

- Everything left
- Experimental class.

Classful IP Addressing

Reserved addresses

- 0.0.0.0 used in routing (seen further)
- 127.0.0.0/8: loopback addresses (127.0.0.1 - 127.255.255.254).

Classful IP Addressing

- Class A (16 m-addresses) and B (65 k-adresses) are too large!
- Class C (254 addresses) is manageable. A and B are not, and then not fully utilized... That's a waste of IP addresses!

Means to limit the number of nodes on a network (regardless of the class) and, thus, improve the manageability, are needed. Three means for it:

- Subnet,
- VLSM (Variable Length Subnet Mask),
- CIDR (Classless Inter-Domain Routing).

Subnet and VLSM

- Class A (16 m-addresses) and B (65 k-adresses) are too large!
- Class C (254 addresses) is manageable. A and B are not, and then not fully utilized... That's a waste of IP addresses!

Subnet and VLSM

Mask /16 65.534 hosts	255 11111111	255 11111111	0 00000000	0 00000000
Network address	172 10101100	64 01000000	0 00000000	0 00000000
First host	172 10101100	64 01000000	0 00000000	1 00000001
Last host	172 10101100	64 01000000	255 11111111	254 11111110
Broadcast address	172 10101100	64 01000000	255 11111111	255 11111111

Figure: IP address example 2

Subnet and VLSM

Mask /12 1.048.574 hosts	255 11111111	240 11110000	0 00000000	0 00000000
Network address	172 10101100	64 01000000	0 00000000	0 00000000
First host	172 10101100	64 01000000	0 00000000	1 00000001
Last host	172 10101100	79 01001111	255 11111111	254 11111110
Broadcast address	172 10101100	79 01001111	255 11111111	255 11111111

Figure: IP address example 3

Subnet and VLSM

Mask /10 4.194.302 hosts	255 11111111	192 11000000	0 00000000	0 00000000
Network address	172 10101100	64 01000000	0 00000000	0 00000000
First host	172 10101100	64 01000000	0 00000000	1 00000001
Last host	172 10101100	127 01111111	255 11111111	254 11111110
Broadcast address	172 10101100	127 01111111	255 11111111	255 11111111

Figure: IP address example 4

Subnet and VLSM

Mask /31 0 host	255 11111111	255 11111111	255 11111111	254 11111110
Network address	172 10101100	64 01000000	0 00000000	254 11111110
First host	172 10101100	64 01000000	0 00000000	? 1111111?
Last host	172 10101100	64 01000000	255 00000000	? 1111111?
Broadcast address	172 10101100	64 01000000	255 00000000	255 11111111

Figure: IP address example 5

Subnet and VLSM

Mask /30 2 hosts	255 11111111	255 11111111	255 11111111	252 11111100
Network address	172 10101100	64 01000000	0 00000000	252 11111100
First host	172 10101100	64 01000000	0 00000000	253 11111101
Last host	172 10101100	64 01000000	255 00000000	254 11111110
Broadcast address	172 10101100	64 01000000	255 00000000	255 11111111

Figure: IP address example 6

Netmask		CIDR	hosts
255.255.255.255	11111111.11111111.11111111.11111111	/32	single address
255.255.255.254	11111111.11111111.11111111.11111110	/31	Unusable
255.255.255.252	11111111.11111111.11111111.11111100	/30	2
255.255.255.248	11111111.11111111.11111111.11111000	/29	6
255.255.255.240	11111111.11111111.11111111.11110000	/28	14
255.255.255.224	11111111.11111111.11111111.11100000	/27	30
255.255.255.192	11111111.11111111.11111111.11000000	/26	62
255.255.255.128	11111111.11111111.11111111.10000000	/25	126
255.255.255.0	11111111.11111111.11111111.00000000	/24	254
255.255.254.0	11111111.11111111.11111110.00000000	/23	510
255.255.252.0	11111111.11111111.11111100.00000000	/22	1.022
255.255.248.0	11111111.11111111.11111000.00000000	/21	2.046
255.255.240.0	11111111.11111111.11110000.00000000	/20	4.094
255.255.224.0	11111111.11111111.11100000.00000000	/19	8.190
255.255.192.0	11111111.11111111.11000000.00000000	/18	16.382
255.255.128.0	11111111.11111111.10000000.00000000	/17	32.766
255.255.0.0	11111111.11111111.00000000.00000000	/16	65.534
255.254.0.0	11111111.11111110.00000000.00000000	/15	131.070
255.252.0.0	11111111.11111100.00000000.00000000	/14	262.142
255.248.0.0	11111111.11111000.00000000.00000000	/13	524.286
255.240.0.0	11111111.11110000.00000000.00000000	/12	1.048.574
255.224.0.0	11111111.11100000.00000000.00000000	/11	2.097.152
255.192.0.0	11111111.11000000.00000000.00000000	/10	4.194.302
255.128.0.0	11111111.10000000.00000000.00000000	/9	8.388.606
255.0.0.0	11111111.00000000.00000000.00000000	/8	16.777.214
254.0.0.0	11111110.00000000.00000000.00000000	/7	33.554.430
252.0.0.0	11111100.00000000.00000000.00000000	/6	67.108.862
248.0.0.0	11111000.00000000.00000000.00000000	/5	134.217.726
240.0.0.0	11110000.00000000.00000000.00000000	/4	268.435.454
224.0.0.0	11100000.00000000.00000000.00000000	/3	536.870.910
192.0.0.0	11000000.00000000.00000000.00000000	/2	1.073.741.822
128.0.0.0	10000000.00000000.00000000.00000000	/1	2.147.483.646
0.0.0.0	00000000.00000000.00000000.00000000	/0	IP space

Figure: Subnet mask cheat sheet

CIDR

Classless Inter-domain Routing?

- Wait! What is routing?

Routing Principles

Algorithm processed to decide where to forward a packet

Any router must

- know where any packet should be directed
- send directly the packets to the packet's destination if the router and the destination are on the same network

Any node

- on any network can communicate directly with all the nodes within the same network
- can connect to any node using its gateway
- needs to be aware of its gateway to communicate with nodes on other networks

Routing Principles

Route

- Destination
- Gateway
- Masks
- Metric

```
>sudo route -n
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
0.0.0.0         192.168.0.254   0.0.0.0         UG    0      0        0 eth0
192.168.0.0     0.0.0.0         255.255.255.0   U     0      0        0 eth0
```

Figure: Routing table

Network Computing courses
└ Layers
└ Network

Routing Principles

```
>sudo route -n
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
0.0.0.0         192.168.0.254   0.0.0.0         UG    0      0        0 eth0
192.168.0.0     0.0.0.0         255.255.255.0   U     0      0        0 eth0
```

Figure: Routing table

0.0.0.0 ?

- Default address
- Default route
- Default gateway

Network Computing courses
└ Layers
└ Network

Routing Principles

Example

What would the routing table of this router will look like?

Network Computing courses
└ Layers
└ Network

Routing Principles

Static or dynamic ?

We will see this later

CIDR

Combine 2+ networks' into one bigger to facilitate routing.

Classless Inter-domain Routing?

- Does a routing table having both (192.168.0.0/24, E0), (192.168.1.0/24, E0), (10.0.0.0/8, S0) can be shorten?
- Does a routing table having both (192.168.0.0/24, E0), (192.168.1.0/24, E0), (192.168.8.0/24, E0), (10.0.0.0/8, S0) can be shorten?
- Does a routing table having both (192.168.0.0/24, E0), (192.168.4.0/24, E0), (192.168.1.0/24, E1), (10.0.0.0/8, S0) can be shorten?

Routing Protocol

- RIP: Routing Information Protocol
- OSPF: Open Shortest Path First
- EIGRP: Enhanced Interior Gateway Routing Protocol

Routing Protocol

RIP v1

- Classful routing
- Periodic updates (30 sec) ..
- ..by broadcasting (!)
- Metric is hop-count (max = 15, infinite = 16)
- Timer (180 sec) to tag route as invalid (metric = 16)
- no subnet, no VLSM, no CIDR, no router authentication

Routing Protocol

RIP v2

- Classless routing
- Multicast (224.0.0.9)
- VLSM support
- Route summarization
- "Authentication" (MD5)

RIPng is the next RIP version for support of IPv6

Routing Protocol

1. Router getting online broadcasts Request message
2. RIP Router send broadcasts Response message with their routing table
3. When Update timers (from other routers) expire routing table[3] is sent again
4. When Invalid timer expires, the metric of the route is set to 16 (unreachable)
5. When Flush timer expires, the 16-metric routes are removed from the routing table
6. When a new router (or new metric) is sent, a Hold-down timer is started to stabilize the network.

[3] not always all the routing table

Routing Protocol

OSPF

- Classless
- IPv4 and IPv6
- VSLM
- CIDR
- Build a topology of the network
- Dijkstra
- Metric = f(hop-count, bandwidth, link reliability)
- Subdivided into area (a 32-bit number)
- Multicast
- Authentication support (update only from trusted routers)

Routing Protocol

EIGRP

- Enhanced IGRP (to support classless routing)
- IPv4 and IPv6
- VSLM
- CIDR
- Build a topology of the network
- Dijkstra
- Metric = f(bandwidth, load, delay, reliability)
- Authentication support

IPv6

Aims

- Support billions of hosts (even with inefficient IP addressing)
- Reduce routing table size
- Simplified protocol to allow routers to process packets faster
- Better security
- Better real-time QoS
- Better multicast diffusion (scope)
- Being able to move, without changing IP address
- Make the protocol able to evolve
- Make the protocol able to coexist with newer version

IPv6

IPv4 vs IPv6

- not compatible
- IPv4 address: 4 octets, IPv6: 16 octets ($2^{128} = 3 \times 10^{138}$)
- Packet Header, IPv6: 7 fields, IPv4:13 (faster to process)
- IP options: some required options are now optionals (faster to process)
- Notation:
  - 8000:0000:0000:0000:0123:4567:89AB:CDEF
  - 8000::0123:4567:89AB:CDEF
  - ::192.168.2.3
- Unicast address format:

bits	48 (or more)	16 (or fewer)	64
field	routing prefix	subnet id	interface identifier

Figure: Unicast IPv6 address format

IPv6

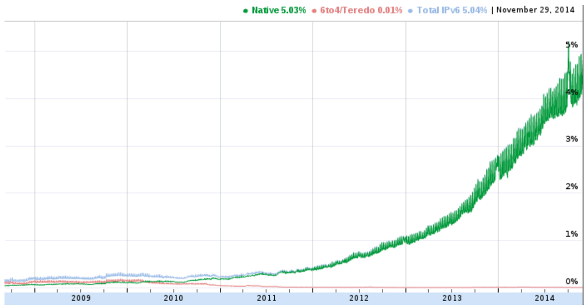


Figure: IPv6 adoption (among Google users)[4]

Belgium: 28%, USA and Germany: 11%

[4] https://www.google.com/intl/en/ipv6/statistics.html

Lessons are going on!

To be continued... ;)

Hope you liked it and learnt about networking!

Figure: teaching.auzias.net