Computer network architectures and protocols

laboratory

Imre Varga

University of Debrecen, Faculty of Informatics

04 September 2017

General information

Subject, course:

Computer network architectures and protocols
INHK721 (Computer Science Engineering BSc)
Computer networks (Architectures and protocols)
INJK711-K5 (Business Information BSc)

Wednesday 10:00-12:00, TEOKJ II/106B room (Lecture, I.V.)
Tuesday 12:00-14:00, IF03 room (Practice, INJK711L, I.V.)
Tuesday 16:00-18:00, IF03 room (Practice, INHK721L, A.K.)

subject credit: 5 (INJK711-K5), 4 (INHK721)

General information

Teachers:

Dr. Varga, Imre (Tuesday 10, Tuesday 12)
Department of Informatics Systems and Networks
email: varga.imre@inf.unideb.hu
www: irh.inf.unideb.hu/user/vargai
room: IF13

Karsai, Andrea (Tuesday 16)
Network and Telecommunication Supplier Unit
email: karsai.andrea@it.unideb.hu
room: Chemistry Building, C stairway 4/3

General information

Requirements, conditions for **practice** (INJK711L):

maximum number of absences: 3

late arrival (more than 20 minutes) means absent from class

2 midterm tests (+1 retake)

to pass a test: reach **at least 50%**

if a test failed: retake is necessary with extra conditions

retake test: covers the whole semester

result overwrites the worse test result

General information

Requirements, conditions for **lecture** (INJK711-K5):

written exam

to pass: reach **at least 50%**

signature + passed theoretical test: suggested grade

theoretical and practical results together determine the final grade (50%-50%)

Readings:

Andrew S. Tanenbaum: *Computer Networks*, Prentice-Hall, 2003.

Numeral systems

Decimal number system

10 different symbols: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9

How do we count in decimal?

…	…	…	…	…
08	18	098	598	0998
09	19	099	599	0999
10	20	100	600	1000
11	21	101	601	1001
12	22	102	602	1002
…	…	…	…	…

Binary systems

Why binary systems are so important?

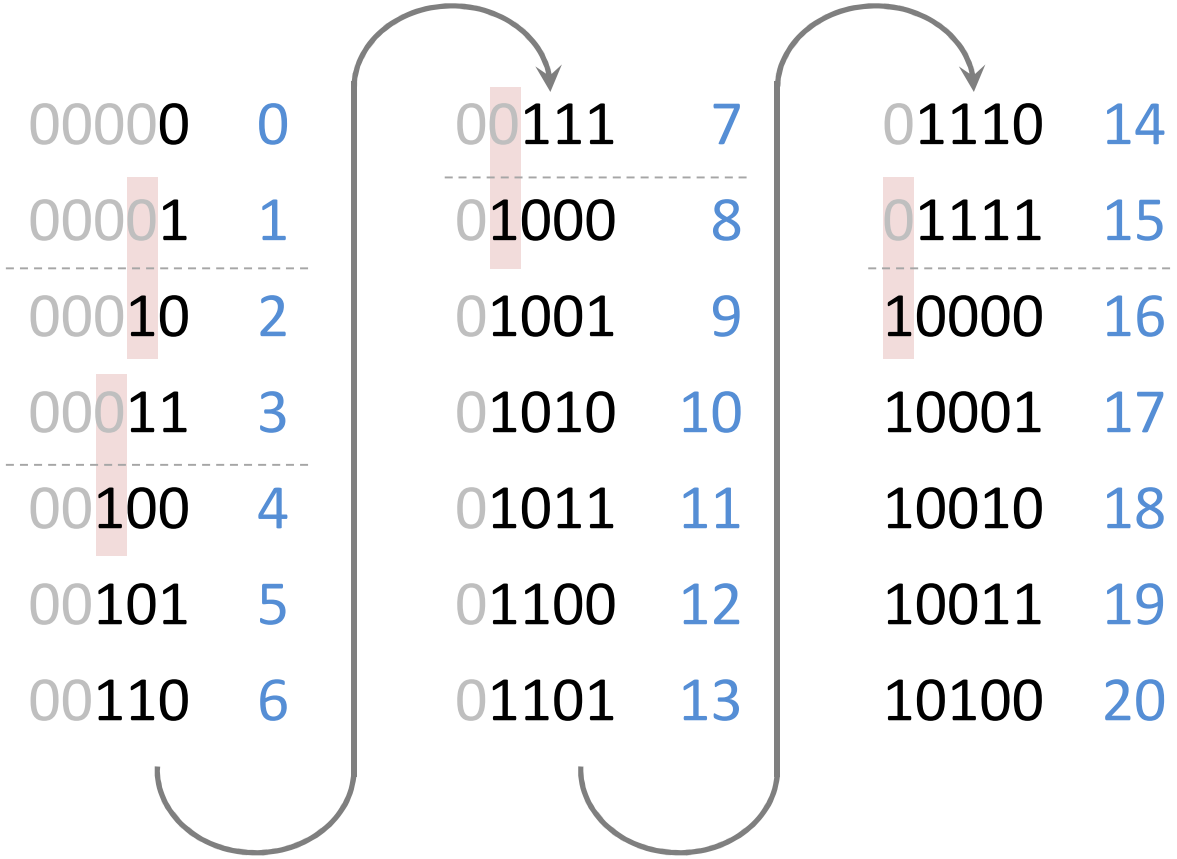
- There are many binary systems in our environment.
- The computer is binary.

no	yes
false	true
absent	present
close	open
switched off	switched on
insulator	conductor
electric current flows	no electric current
0	**1**

Binary number system

Only 2 different symbols: 0, 1

How do we count using binary?



Conversion from decimal to binary

conversion of 217:

	217	**2**
217 = 2*108+1	108	1
108 = 2*54+0	54	0
54 = 2*27+0	27	0
27 = 2*13+1	13	1
13 = 2*6+1	6	1
6 = 2*3+0	3	0
3 = 2*1+1	1	1
1 = 2*0+1	0	1

$217_{10} = 11011001_2$

Conversion from binary to decimal

Decimal (10):

$2495 = 2*1000+4*100+9*10+5*1$

$2495 = 2*10^3 + 4*10^2 + 9*10^1 + 5*10^0$

Binary (2):

$1010011_2 = 1*2^6 + 0*2^5 + 1*2^4 + 0*2^3 + 0*2^2 + 1*2^1 + 1*2^0$

$1010011_2 = 1*64 + 0*32 + 1*16 + 0*8 + 0*4 + 1*2 + 1*1$

$1010011_2 = 64+16+2+1 = 83_{10}$

Hexadecimal number system

16 different symbols: 0,1,2,3,4,5,6,7,8,9,A,B,C,D,E,F

How do we count in hexadecimal?

…	…	…	…	…
08	0E	0FE	9FE	0FFE
09	0F	0FF	9FF	0FFF
0A	10	100	A00	1000
0B	11	101	A01	1001
0C	12	102	A02	1002
…	…	…	…	…

Conversion to hexadecimal

conversion of 3564_{10}:

	3564	**16**
3564= 16*222+12	222	C
222= 16*13+14	13	E
13 = 16*0+13	0	D

$3564_{10} = DEC_{16}$

conversion of $10111111110110011_2 = 17FB3_{16}$

1 7 F B 3

Conversion from hexadecimal

conversion of $2BA5_{16}$ to decimal (10):

$2BA5_{16} = 2*4096+B*256+A*16 +5*1$

$2BA5_{16} = 2*16^3 +B*16^2 +A*16^1+5*16^0$

$2BA5_{16} = 8192+2816+160+5 = 11173_{10}$

conversion of $2BA5_{16}$ to binary (2):

$2BA5_{16} = 0010\,1011\,1010\,0101_2$

Numbers in computer

- Bit is similar to a digit of a binary number. (0 or 1)
- Byte is 8 bit (a maximum 8 digit long binary number).
- Numbers on a byte (8 bit):
  00000000 - 11111111
  (0-255)
  256 different values
- Numbers on 4 bytes (32 bit):
  00000000000000000000000000000000 - 11111111111111111111111111111111
  (0-4294967295)
  4.294.967.296 different values

Logical operations

Logical values:

- true: 1
- false: 0

Logical operations:

- **AND** (&)
- OR (|)
- NOT (!)

Table of truth of AND (X & Y = Z):

X	Y	Z
0	0	0
0	1	0
1	0	0
1	1	1

Elephant is a fruit	and	it is small.	False statement.
Elephant is a fruit	and	it is large.	False statement.
Elephant is an animal	and	it is small.	False statement.
Elephant is an animal	and	it is large.	True statement.

Logical operations

Logical values:

- true: 1
- false: 0

Logical operations:

- AND (&)
- **OR** (|)
- NOT (!)

Table of truth of OR (X | Y = Z):

X	Y	Z
0	0	0
0	1	1
1	0	1
1	1	1

Elephant is a fruit	or	it is small.	False statement.
Elephant is a fruit	or	it is large.	True statement.
Elephant is an animal	or	it is small.	True statement.
Elephant is an animal	or	it is large.	True statement.

Logical operations

Logical values:

- true: 1
- false: 0

Logical operations:

- AND (&)
- OR (|)
- **NOT** (!)

Table of truth of NOT (!X = Z):

X	Z
0	1
1	0

Elephant is not small. True statement.

Elephant is not large. False statement.

Logical ‘AND’ operation on bytes

Example 1:

```
  1 0 0 1 0 1 1 0        150
& 0 0 0 0 0 0 0 0      &   0
  0 0 0 0 0 0 0 0          0
```

Example 2:

```
  1 0 0 1 0 1 1 0        150
& 1 1 1 1 1 1 1 1      & 255
  1 0 0 1 0 1 1 0        150
```

Example 3:

```
  1 0 0 1 0 1 1 0        150
& 1 1 1 1 0 0 0 0      & 240
  1 0 0 1 0 0 0 0        144
```

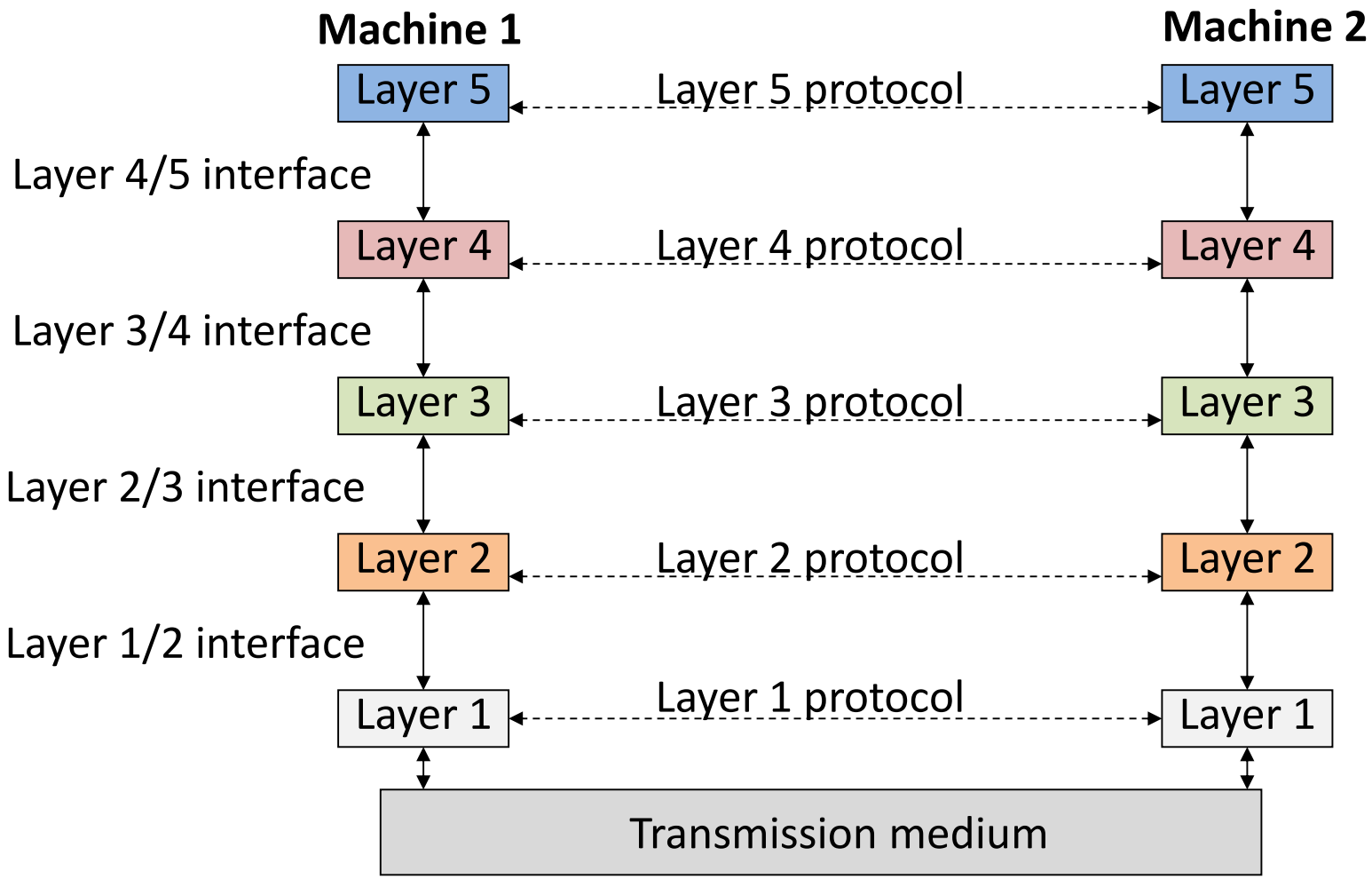
Layered Network Architecture

Layered Network Architecture

Why we use layered network architecture?

- To describe a huge protocol is complex and difficult.
- A hierarchical protocol system can be easier implemented.
- The change tracking is easier.
- Layers can cooperate also in case of different producers.

Layers (Levels), Protocols, Interfaces



Encapsulation

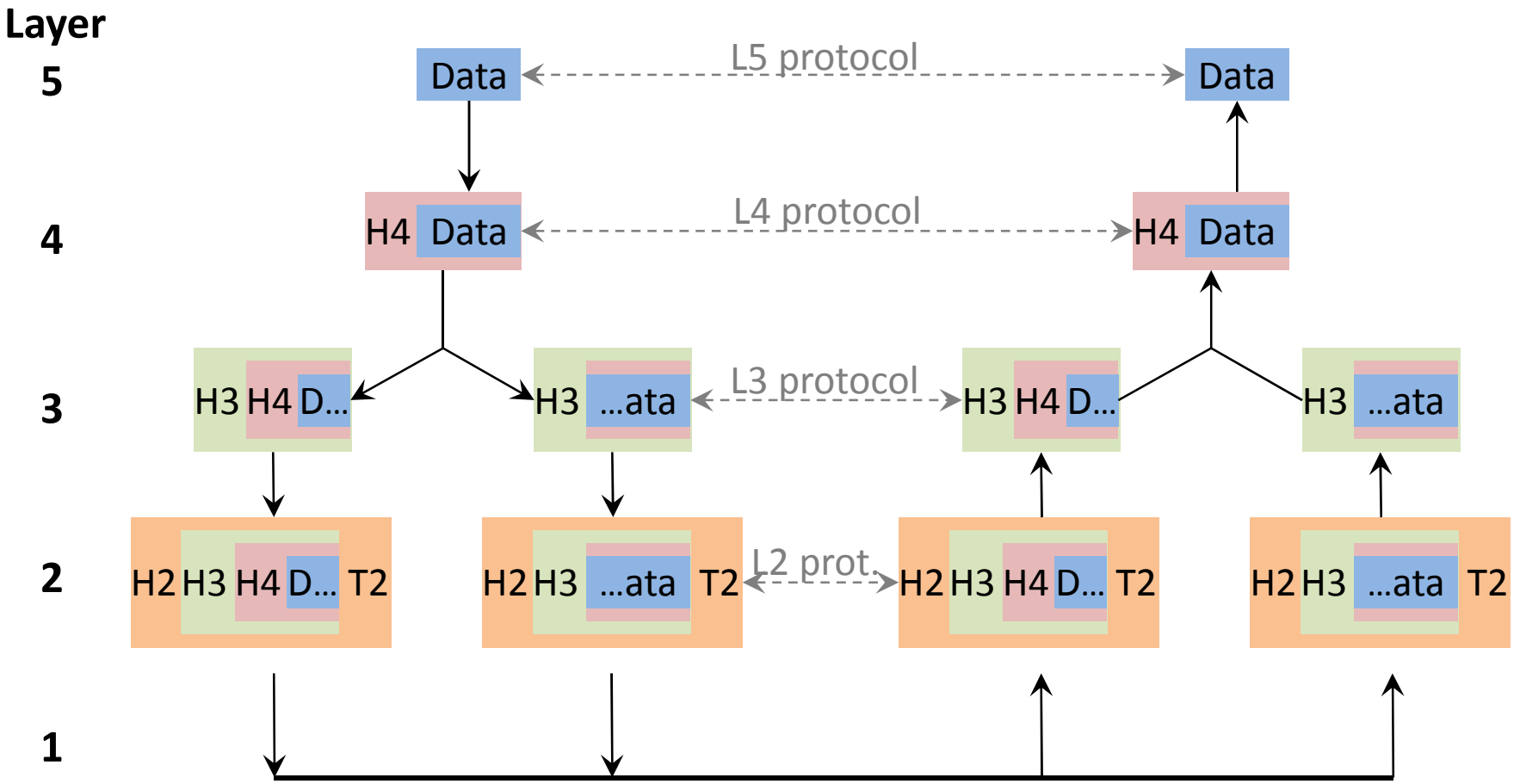
Encapsulation:

Packaging the information arrived from a higher level with a header of a specific protocol (it is similar when a traditional mail letter is put in an envelope and the envelope is addressed).

Protocol Data Unit (PDU):

Entity (contains header and data) handled by the considered protocol. (It is frequently mentioned as packet.)

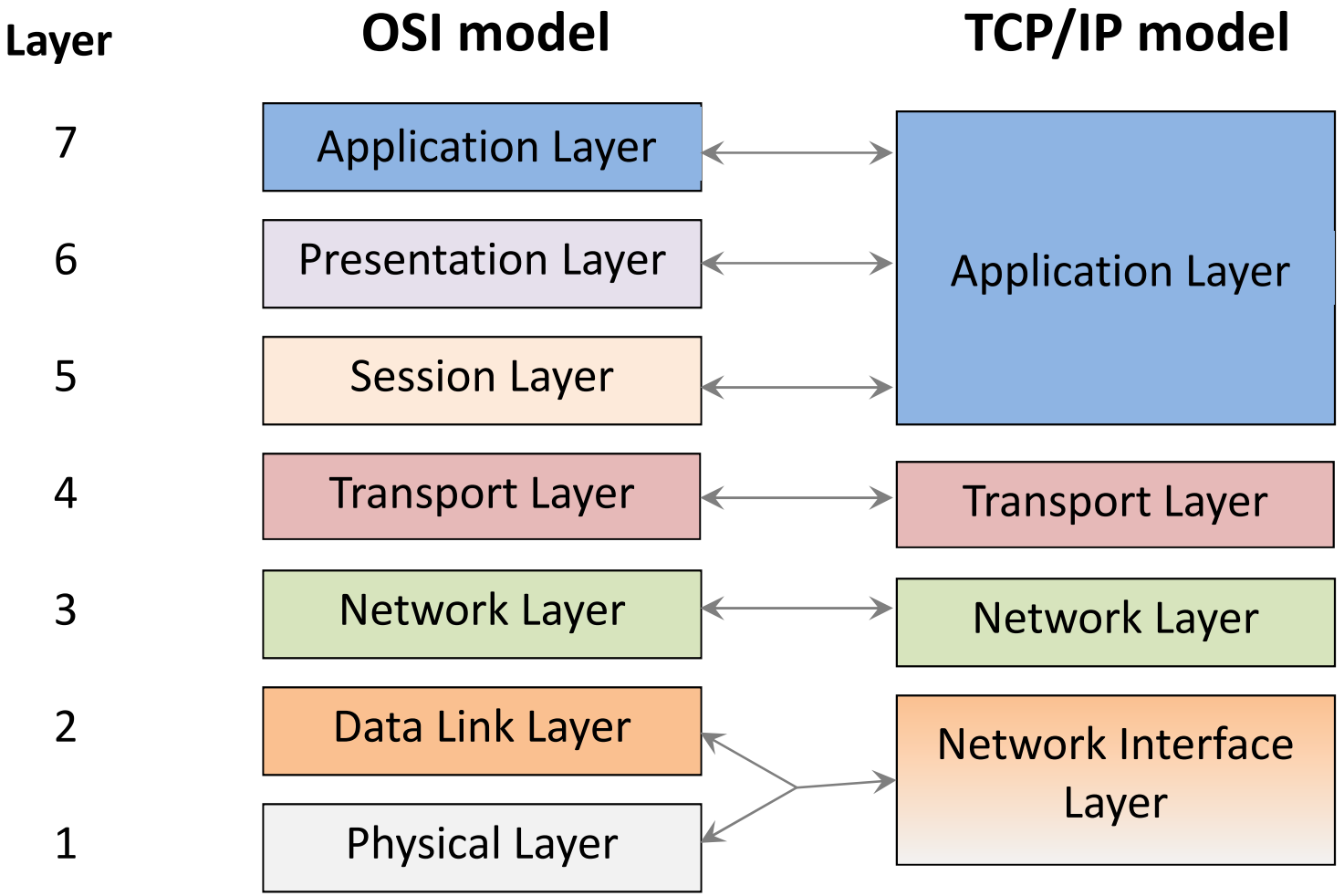
Scheme of Network Communication



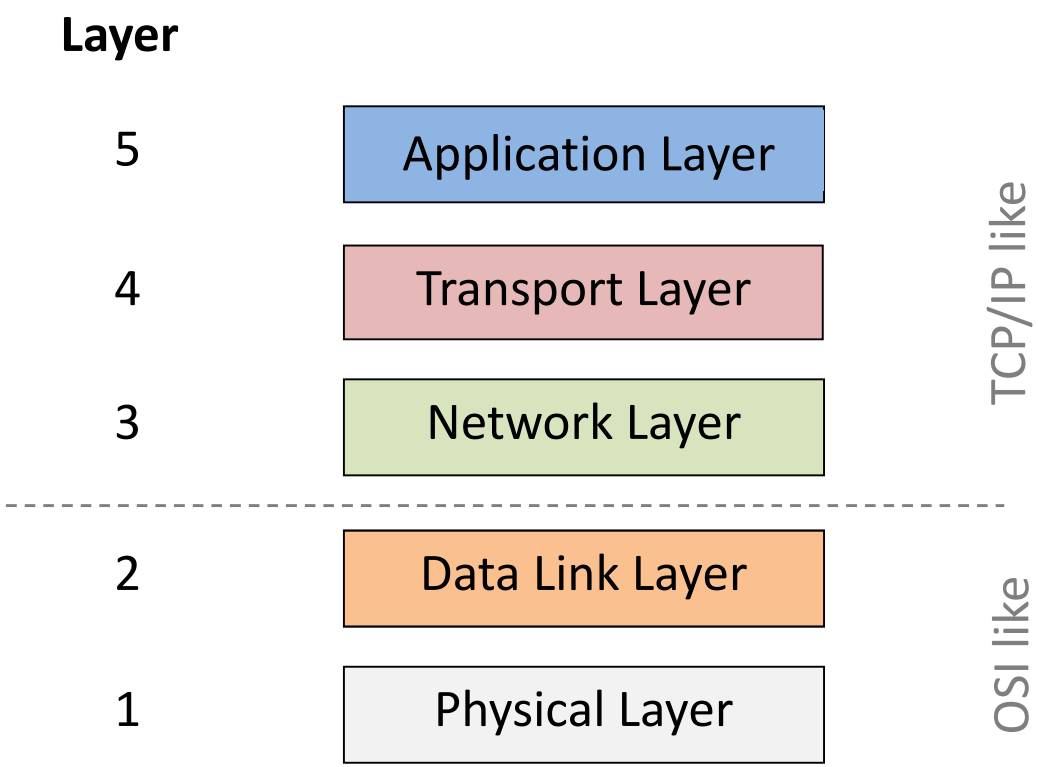
OSI Reference Model

Layer		Name of PDU
7	Application Layer	APDU
6	Presentation Layer	PPDU
5	Session Layer	SPDU
4	Transport Layer	TPDU, Segment
3	Network Layer	Packet
2	Data Link Layer	Frame
1	Physical Layer	Bit

Mapping of TCP/IP - OSI Model



Hybrid Reference Model



Layers of hybrid model

Physical Layer (L1):

Specification and properties of different transmission mediums in order to implement signal transmission.

- Cables, connectors, modulation, signal coding, etc.

Data Link Layer (L2):

Reliable transmission between two directly connected devices. Two sublayers: LLC, MAC.

- Physical addressing, media access, logical topology, etc.

Layers of hybrid model

Network Layer (L3):

Connection between any two network nodes (not just dirrectly connected).

- Routing, traffic control, network addressing, etc.

Transport Layer (L4):

Reliable connection between softwares on two nodes. Protocols may connectionless or connection-oriented.

- Error detection/correction, order guarantee, etc.

Layers of hybrid model

Application Layer (L5):

Interface between applications and users. Provides same interpretation of information (different nodes can use different data structures, data representation). Encryption, compression, etc.

- DNS, http, ftp, e-mail, bittorrent, etc.

Network interconnection

Network Interconnection - Basics

Collision domain; Bandwidth domain:

Part of a network, where collisions can be detected (a common communication channel that is shared by multiple nodes).

In a collision domain only one information transmission can be performed at a time.

Broadcast domain:

Part of a network, where information transmitted with a broadcast address can be detected.

Network Interconnection Devices

Repeater:

Amplifies and repeats the signals sent on transmission media.

Does not separate the connected subnetworks.

Repeaters with multiple ports is called a HUB.

Bridge:

Working in Data Link Layer it performs selective connection („Only those packets goes through the bridge, who tends to other side”).

The interconnected subnets form separate collision domains.

Usually transmits the broadcasting towards all interconnected subnets.

Network Interconnection Devices

Switch:

A multiple port device with bridge functionality between any two ports.

Router:

Working in Network Layer it performs selective connection, routing, and traffic control.

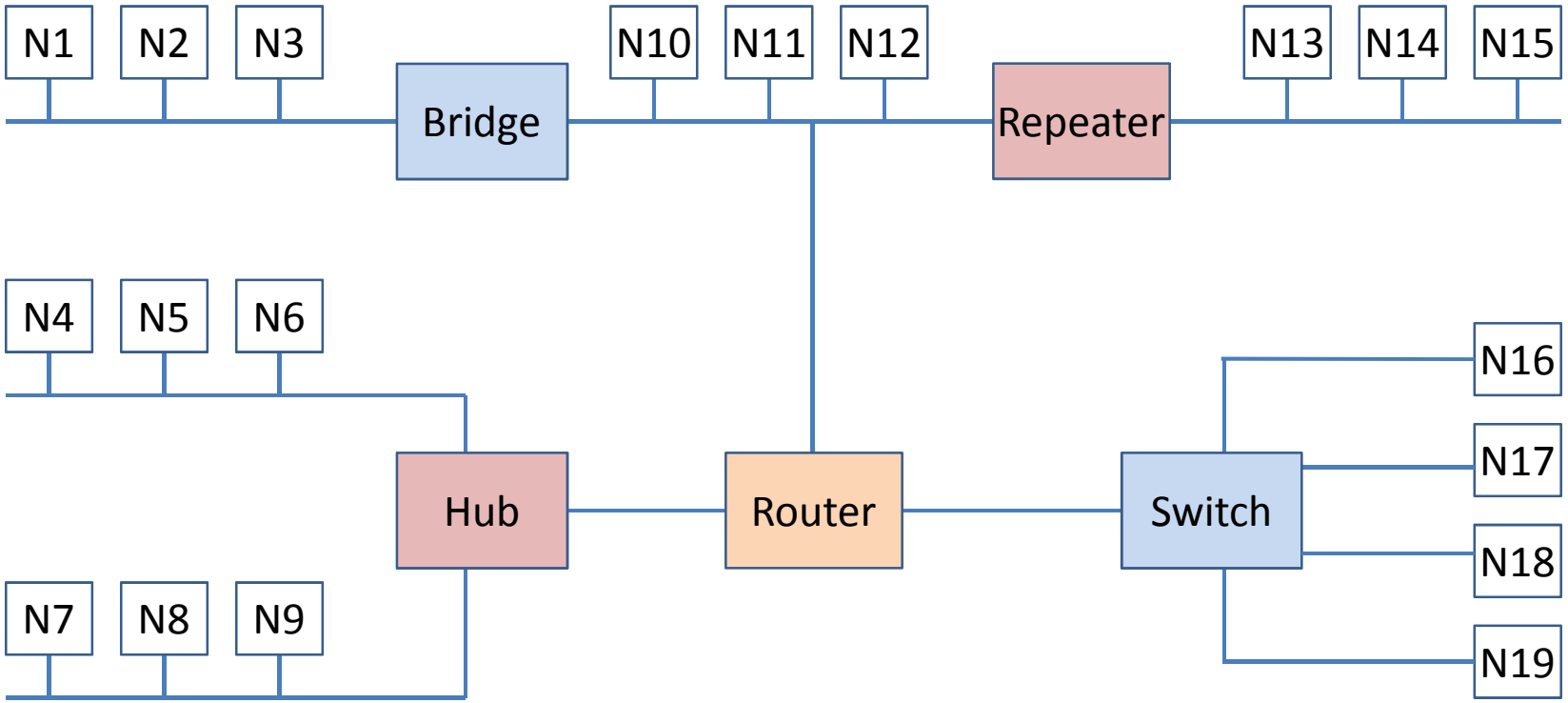
The interconnected subnets form separate collision domains and separate broadcast domains.

It is a node with own IP address.

Sometimes it is also called a gateway in Network Layer (default gateway).

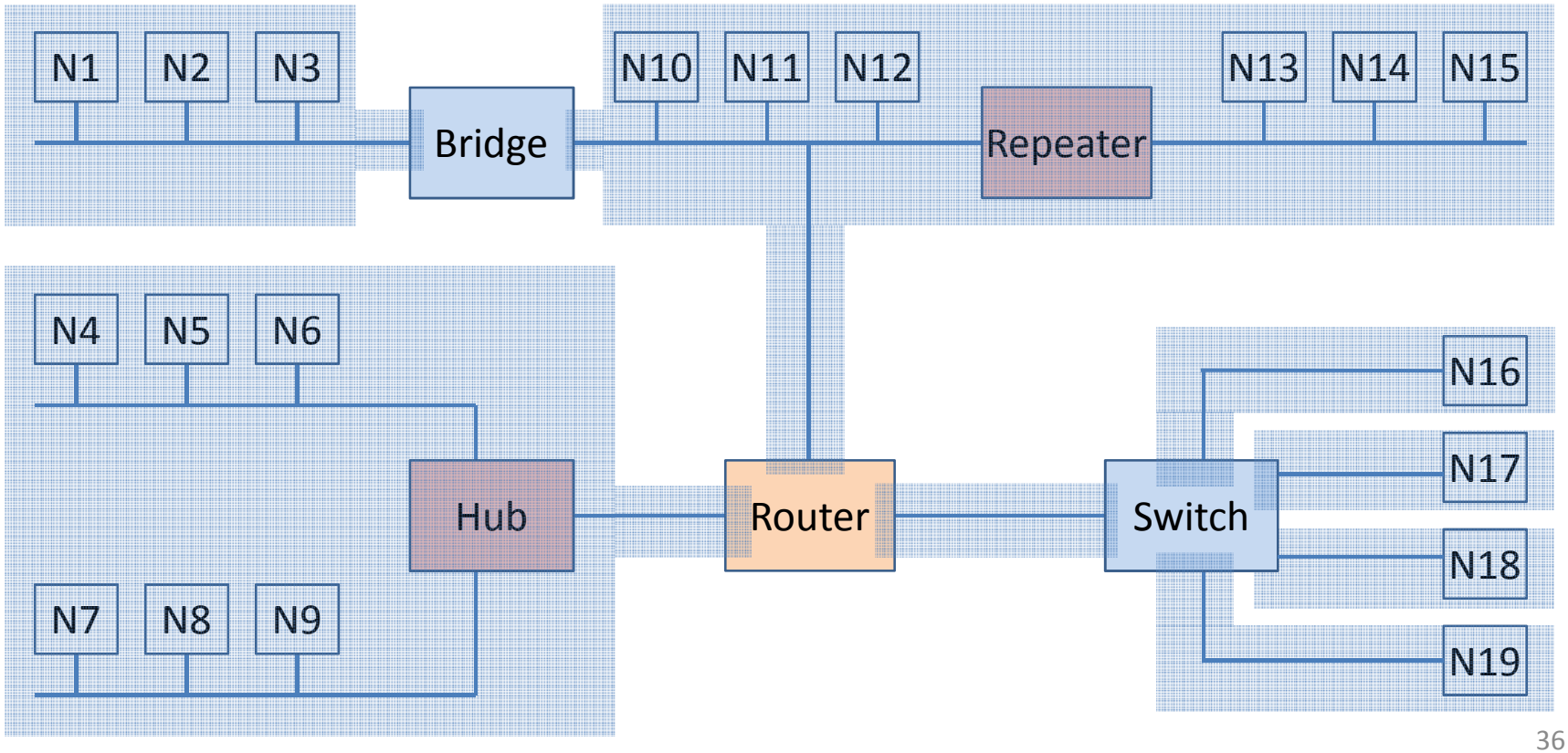
Network Interconnection Devices

- Which node-pairs don't disturb each other?
- Who is available form where by broadcast?



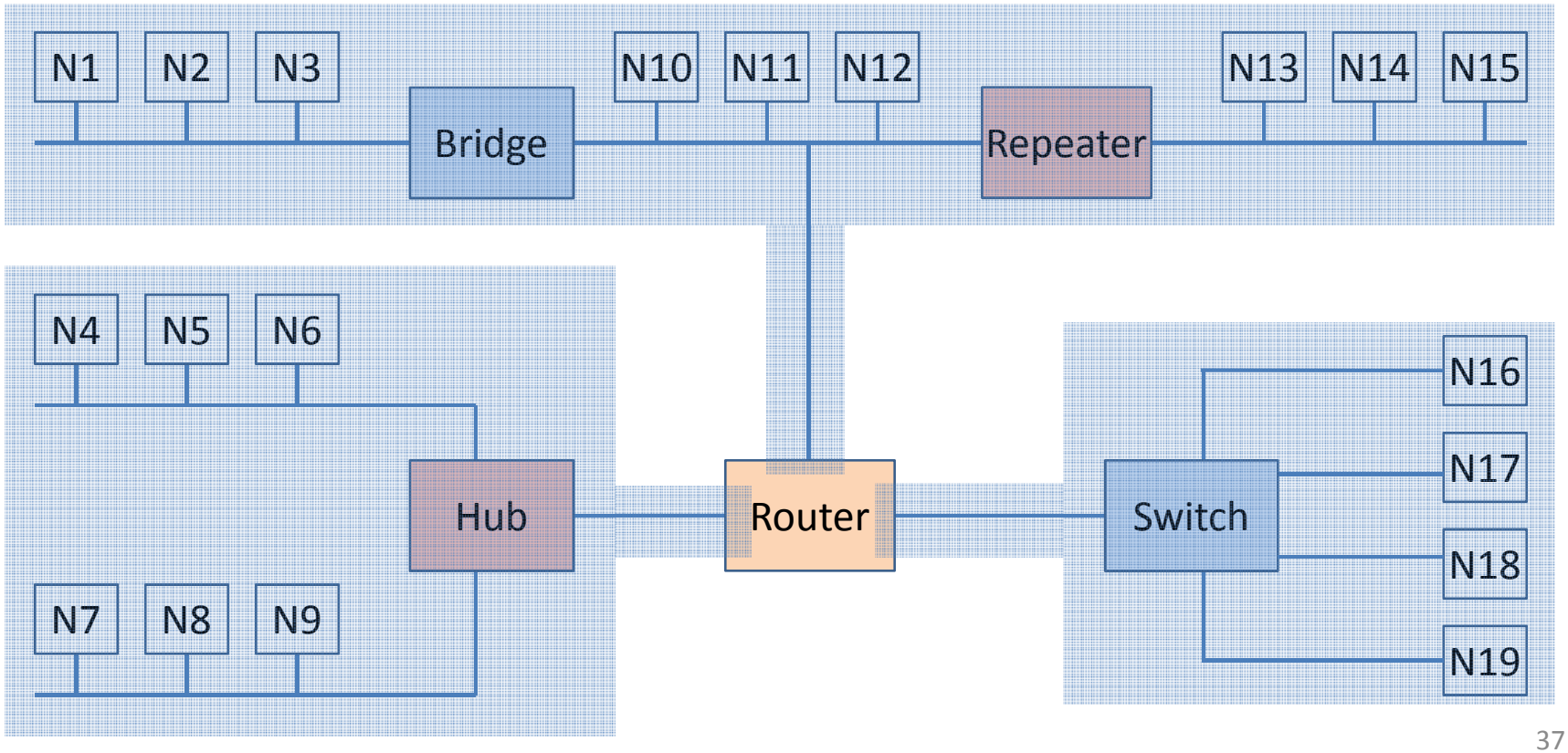
Network Interconnection Devices

- Which node-pairs don't disturb each other?
- Collision domains:



Network Interconnection Devices

- Who is available form where by broadcast?
- Broadcast domains:



Physical layer

Physical layer

First layer of hybrid model (L1)

Specification and properties of different transmission mediums in order to implement signal transmission.

Topics

- Cables and connectors
- Topology
- Modulation and signal coding,
- etc.

Physical transmission and cables

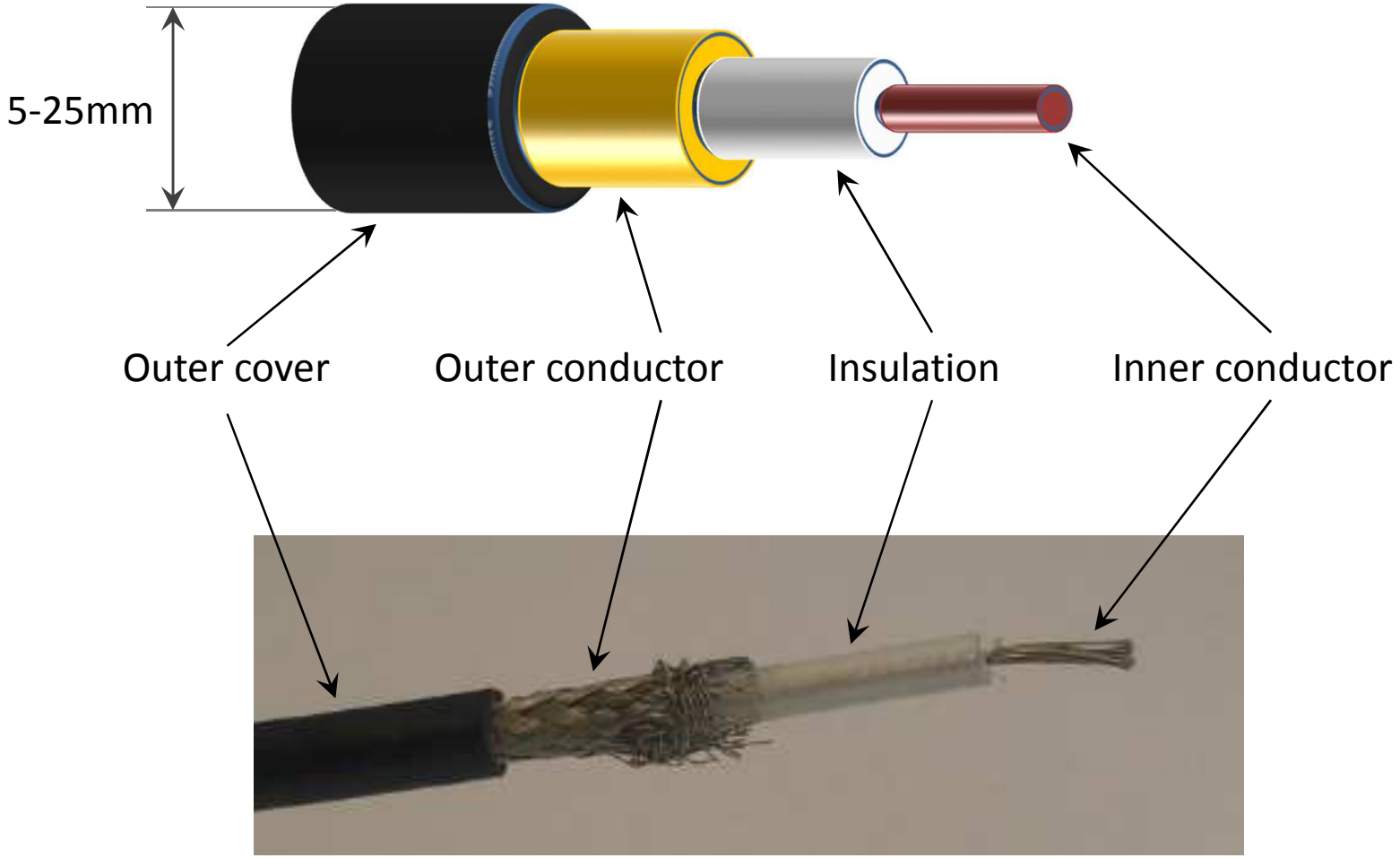
Wired

- Coaxial cable (electric signal)
  - Thin, thick
- Twisted pair (electric signal)
  - UTP, FTP, STP
- Optical fibre (light)
  - Multimode, single mode

Wireless

- Air (electromagnetic waves)
  - Radio wave, microwave, infrared

Coaxial cable



Coaxial cable

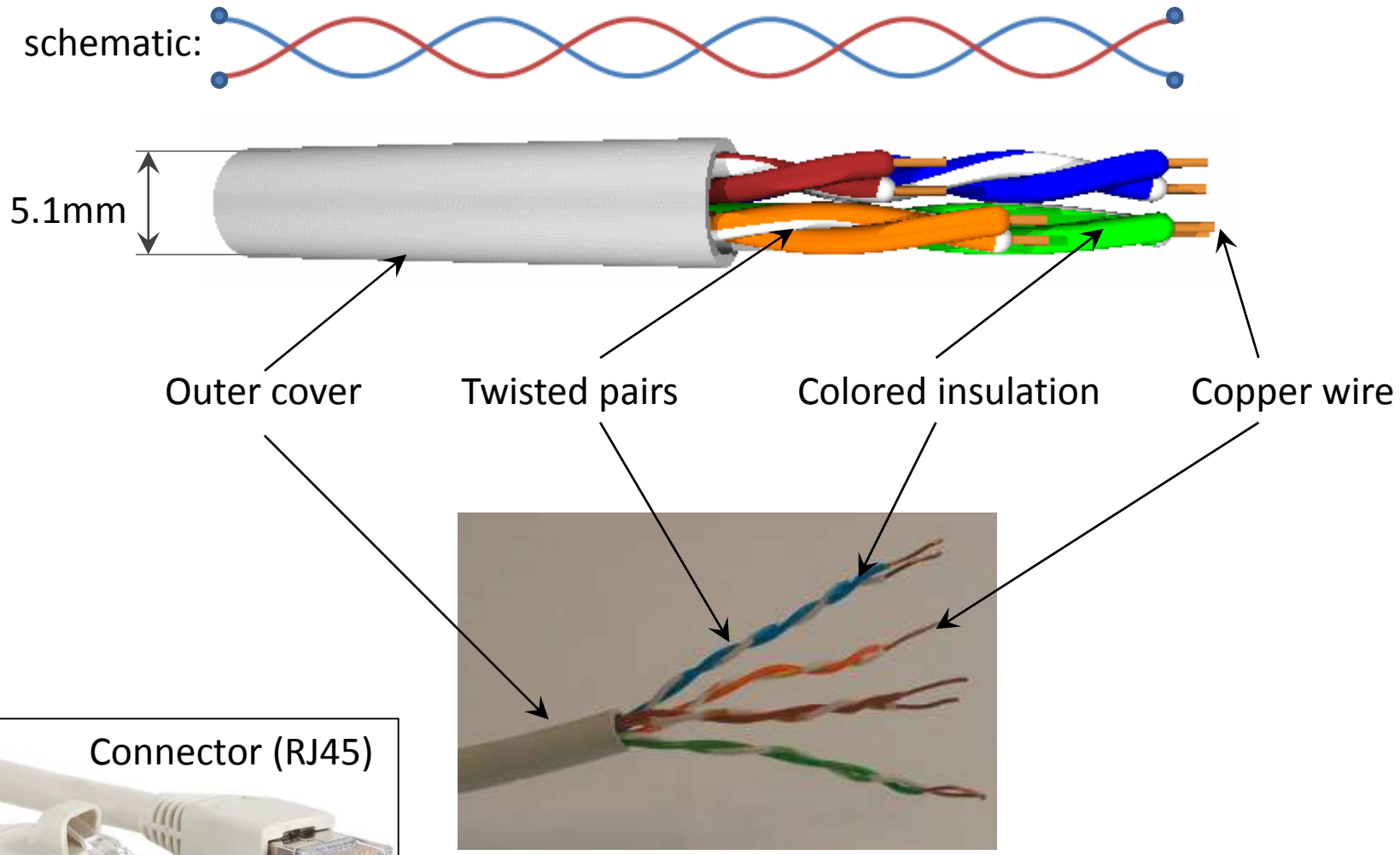
Transmission characteristics:

- Due to the concentric structure of conductors, it is not sensitive for interference and crosstalk
- In case of digital transmission amplifiers are required in every km
- In case of analog transmission, amplifiers are required in every several km

Applications:

- Transmission of television broadcasting
- Large distant telephone transmission
- Connection of computers

Unshielded Twisted Pair

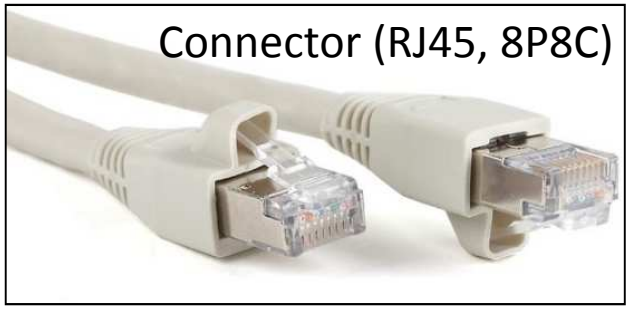


Unshielded Twisted Pair

Characteristics:

- It is the cheapest media
- Data transmission speed (100Mbps) and the distance (100m) to be covered are highly limited
- Two isolated copper conductors are twisted and four such pairs are grouped without shield (UTP)
- Foiled Twisted Pair (FTP): pairs has a common shield cover
- Shielded Twisted Pair (STP): pairs are shielded separately

TIA/EIA T568 standard

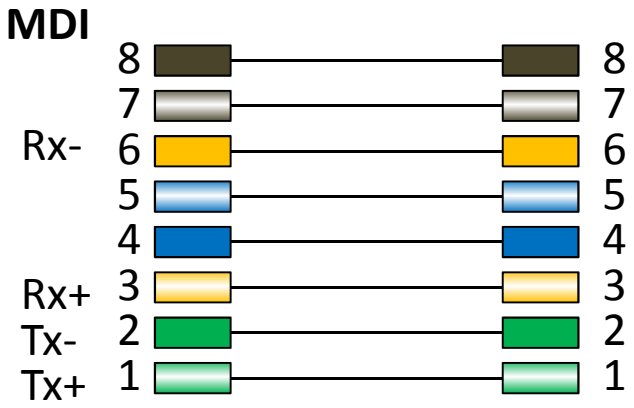


	T568A	T568B
1	white/green	orange/white
2	green	orange
3	orange/white	white/green
4	blue	blue
5	blue/white	blue/white
6	orange	green
7	brown/white	brown/white
8	brown	brown

Cable types

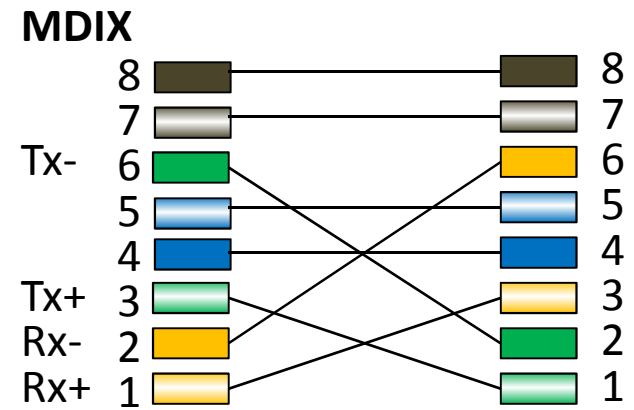
Straight-through

- Ends:
  T568A – T568A or
  T568B – T568B



Crossover (crosslink)

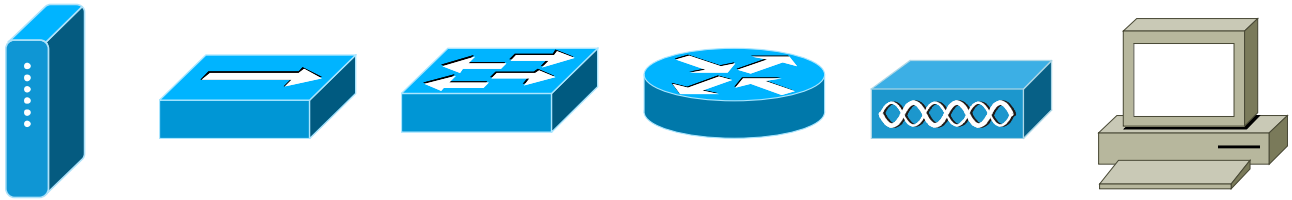
- Ends:
  T568A – T568B or
  T568B – T568A



Auto-MDI/MDIX

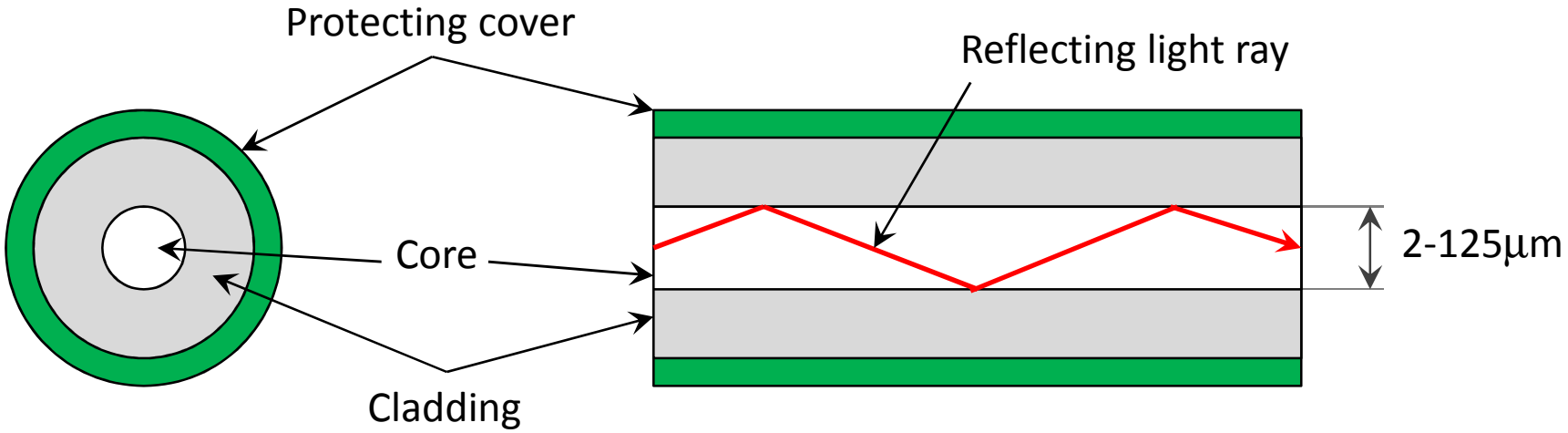
- Automatic detection of cables

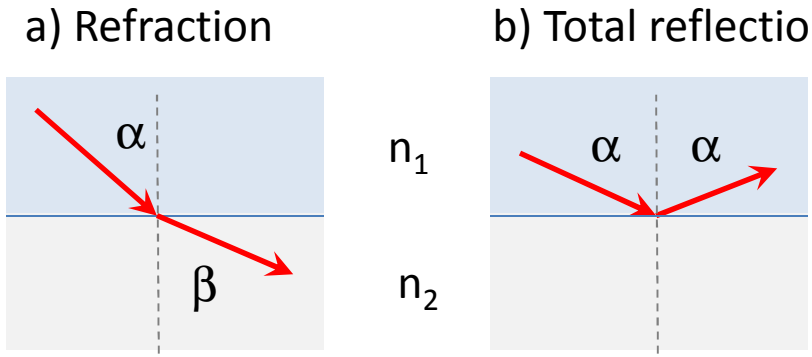
Connection of devices



		MDIX			MDI		
		modem	hub	switch	router	access point	computer
MDIX	modem	crossover	crossover	crossover	straight	straight	straight
	hub	crossover	crossover	crossover	straight	Straight	straight
	switch	crossover	crossover	crossover	straight	straight	straight
MDI	router	straight	straight	straight	crossover	crossover	crossover
	access point	straight	Straight	straight	crossover	crossover	crossover
	computer	straight	straight	straight	crossover	crossover	crossover

Optical fiber





$n_2 < n_1$

Optical fiber

Characteristics:

- Core and cladding: glass or plastic with different reflective index
- Works in 10^{14} - 10^{15} Hz (infrared) domain
- 3 versions are used: multi mode, single mode, multi mode graded index
- Light sources: LED, laser diode

Optical fiber

Advantages:

- **Larger capacity**: High transmission speed can be achieved (2 Gbps in 10x km).
- **Smaller size and weight**
- **Smaller attenuation**: The attenuation is smaller, and it is constant at a wide frequency range.
- **Electromagnetic isolation**: Not sensitive for outer electromagnetic effects, there is no crosstalk.
- **Larger repeating distance**: Smaller the number of repeaters is, smaller the possibilities of errors and the costs are.

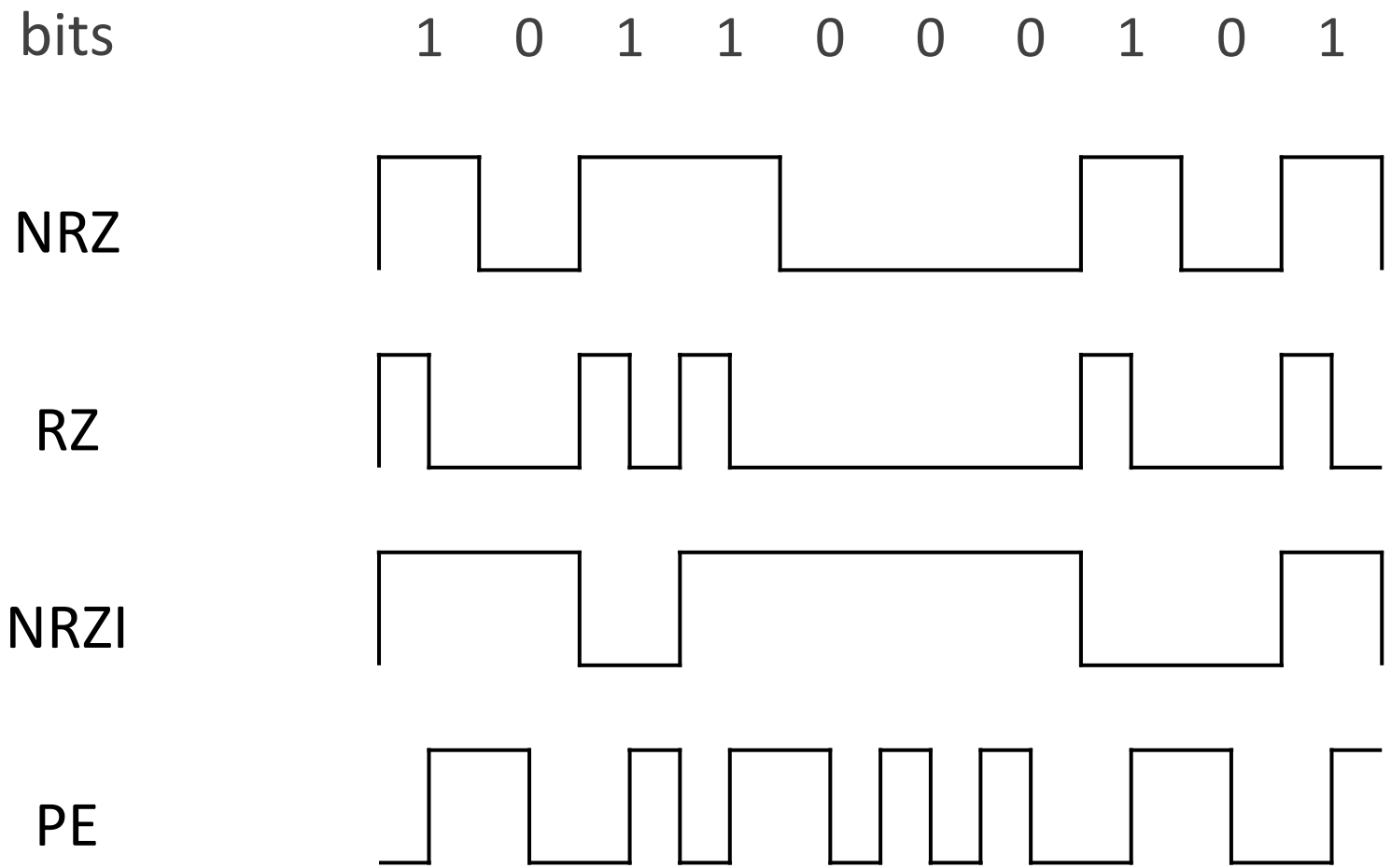
Signal, Signal Coding, Modulation

Signal: Physical quantities, depending on place and time, and carrying information. Information carrier on the communication channel, it could be analog or digital.

Signal Coding: Mapping the (digital) information onto the digital carrier signal (eg. voltage levels, changing of voltage levels).

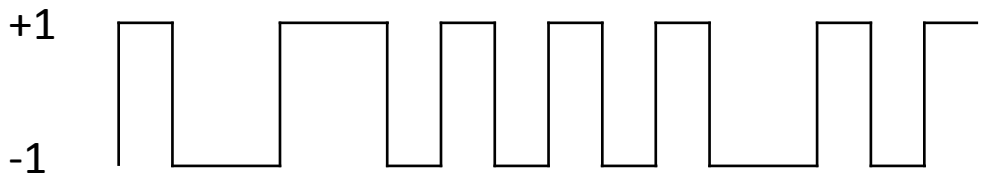
Modulation: Mapping onto analog carrier signal. The process of creating the (modulated) signal to be transmitted through the channel from the modulating signal coming from the source and the analog carrier signal. Inverse process is the demodulation. A modem performs modulation and demodulation, as well.

Signal Coding

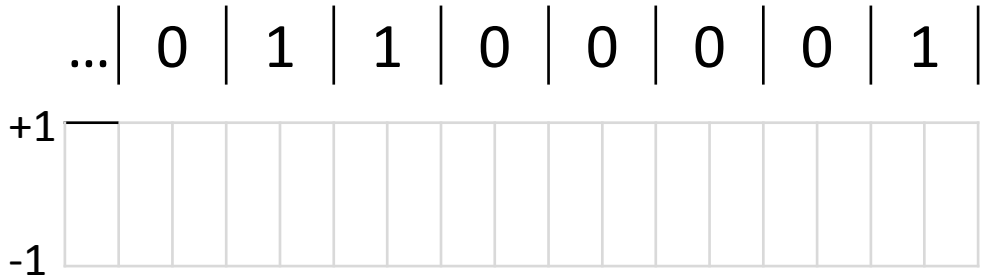


Signal coding exercises

- What is the coded bitseries in case of NRZ, RZ, PE?



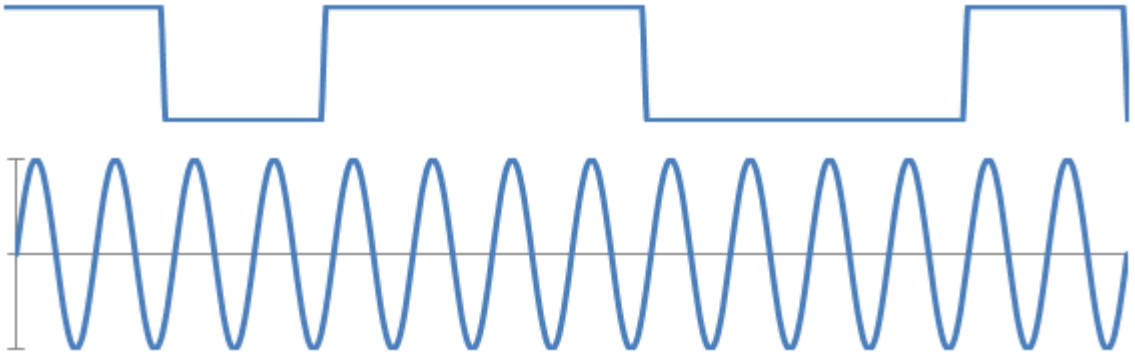
- Continue the encoding of the following bitseries by NRZ, NRZI and PE.



Modulation

Digital signal

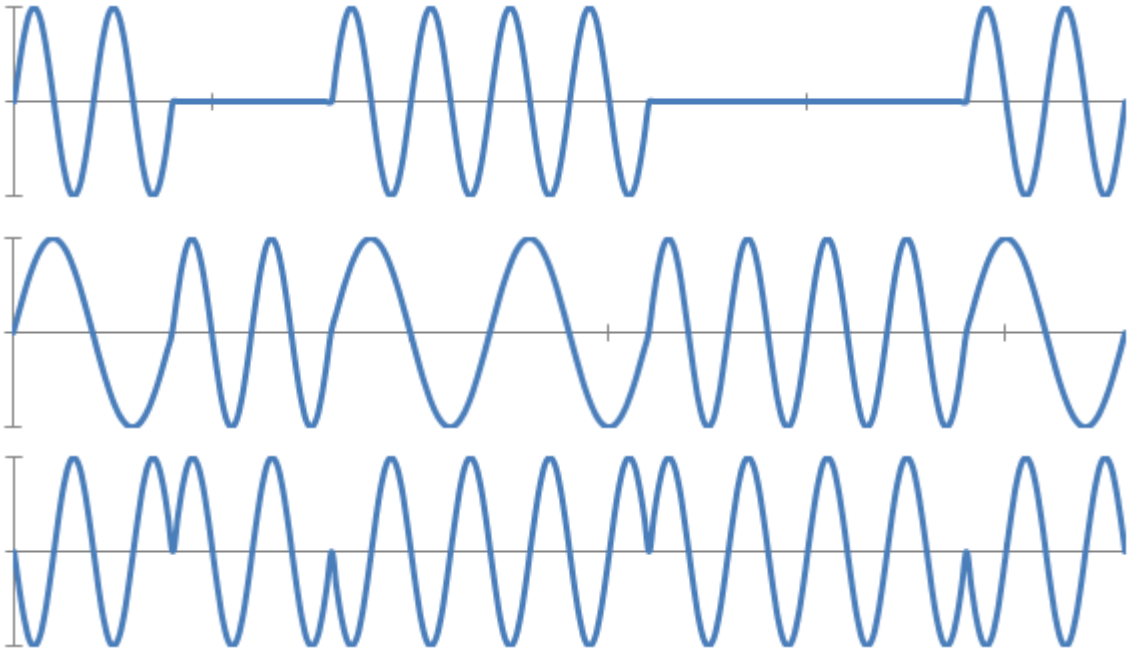
Carrier signal



Amplitude modulation (AM)

Frequency modulation (FM)

Phase modulation (PM)



Data link layer

Data link layer

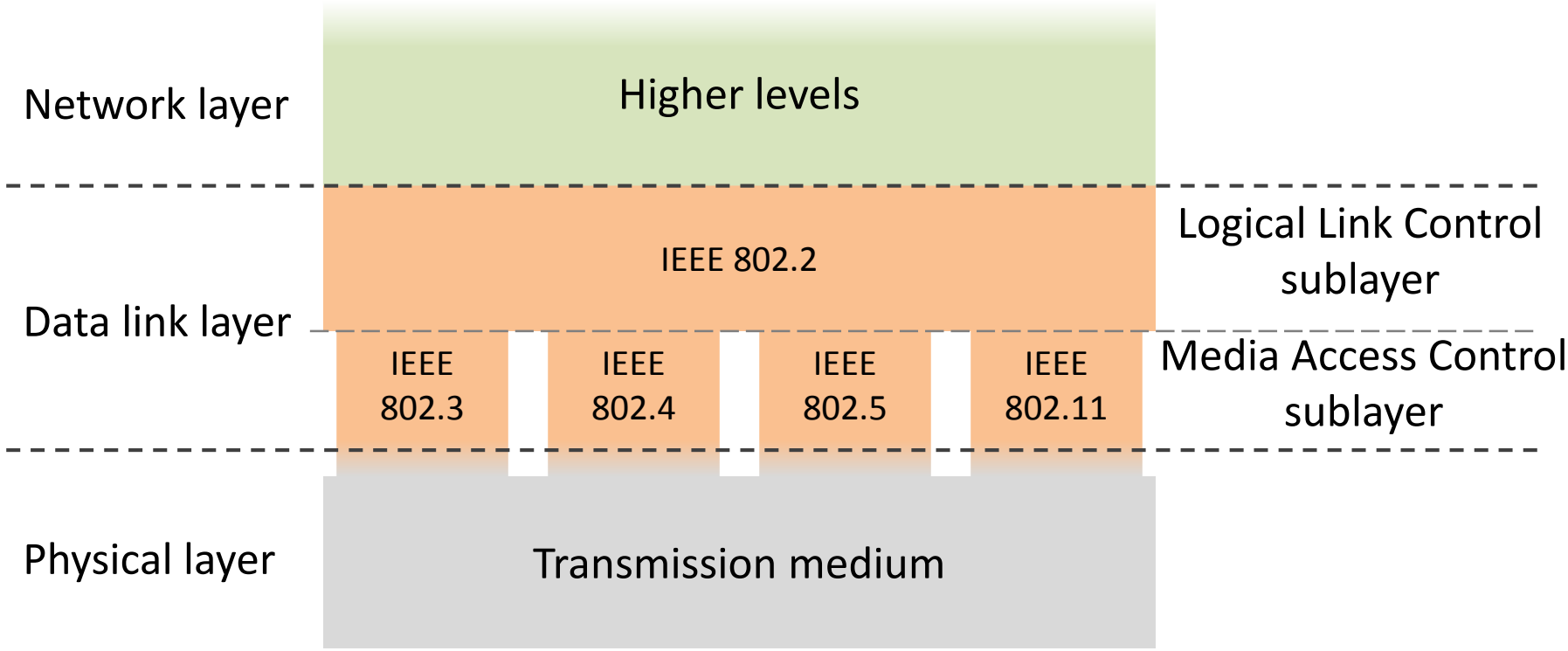
Second layer of hybrid model (L2)

Reliable transmission between two directly connected devices. Two sublayers: LLC, MAC.

Topics

- Physical addressing (identification)
- Media access
- Logical topology
- etc.

Data link Layer



IEEE 802.2 = Logical Link Control (LLC) protocol

IEEE 802.3 = **CSMA/CD**
IEEE 802.4 = Token bus
IEEE 802.5 = Token ring
IEEE 802.11 = Wi-Fi

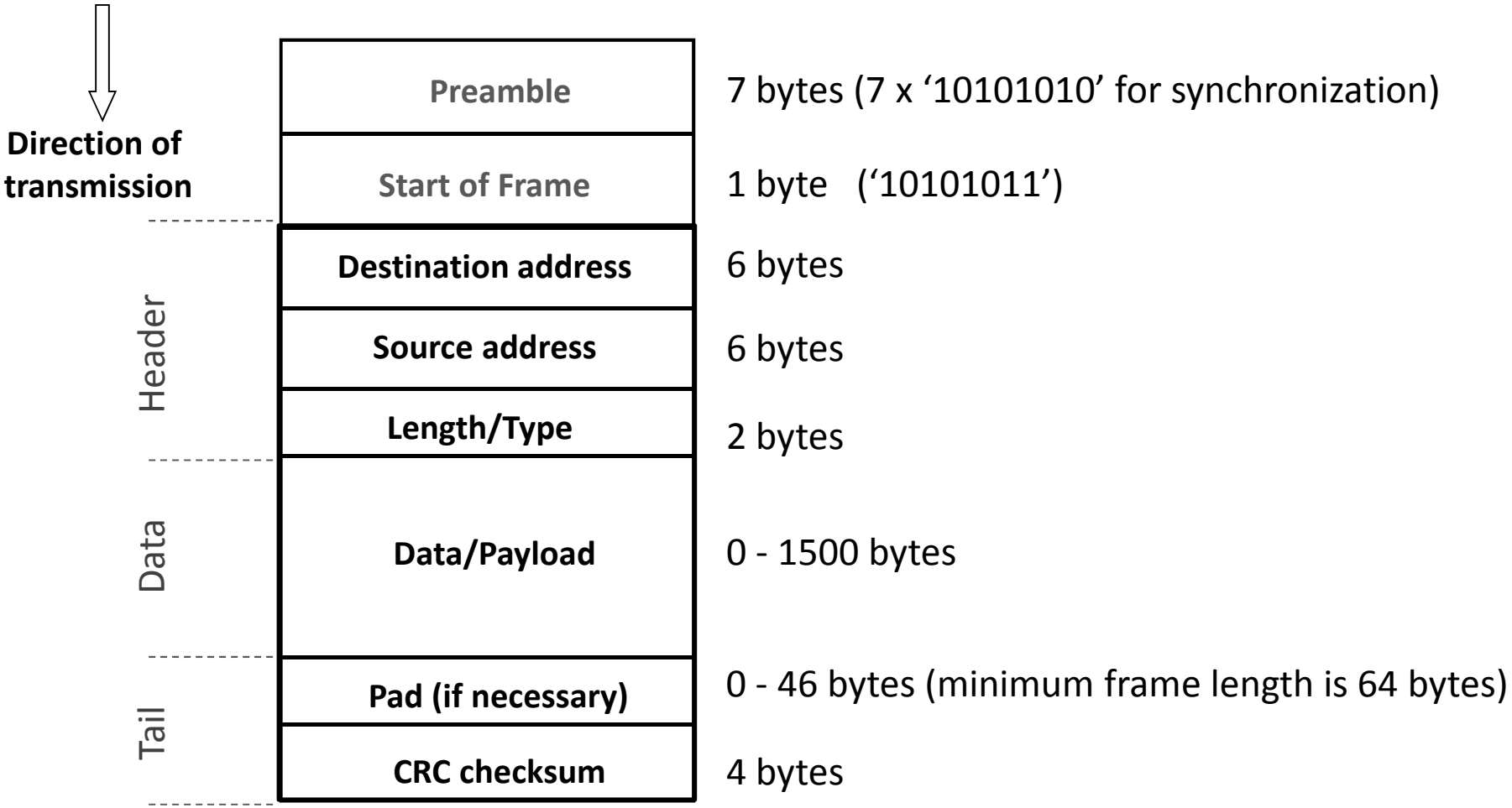
} Media Access Control (MAC) protocols

Ethernet

The most popular technology for wired LANs based on **Carrier Sense Multiple Access with Collision Detection** (CSMA/CD) media access method.

version	standard	year	speed
'Classical' Ethernet	IEEE 802.3	1980	10 Mbps
Fast Ethernet	IEEE 802.3u	1995	100 Mbps
Gigabit Ethernet	IEEE 802.3ab	1999	1.000 Mbps
10Gigabit Ethernet	IEEE 802.3ae	2002	10.000 Mbps
100Gigabit Ethernet	IEEE 802.3ba	2010	100.000 Mbps

Ethernet frame format



Ethernet (MAC) address

6 bytes wide identifier of network cards written in hexadecimal number system separated per bytes.

Example:

00-26-9E-93-75-AA

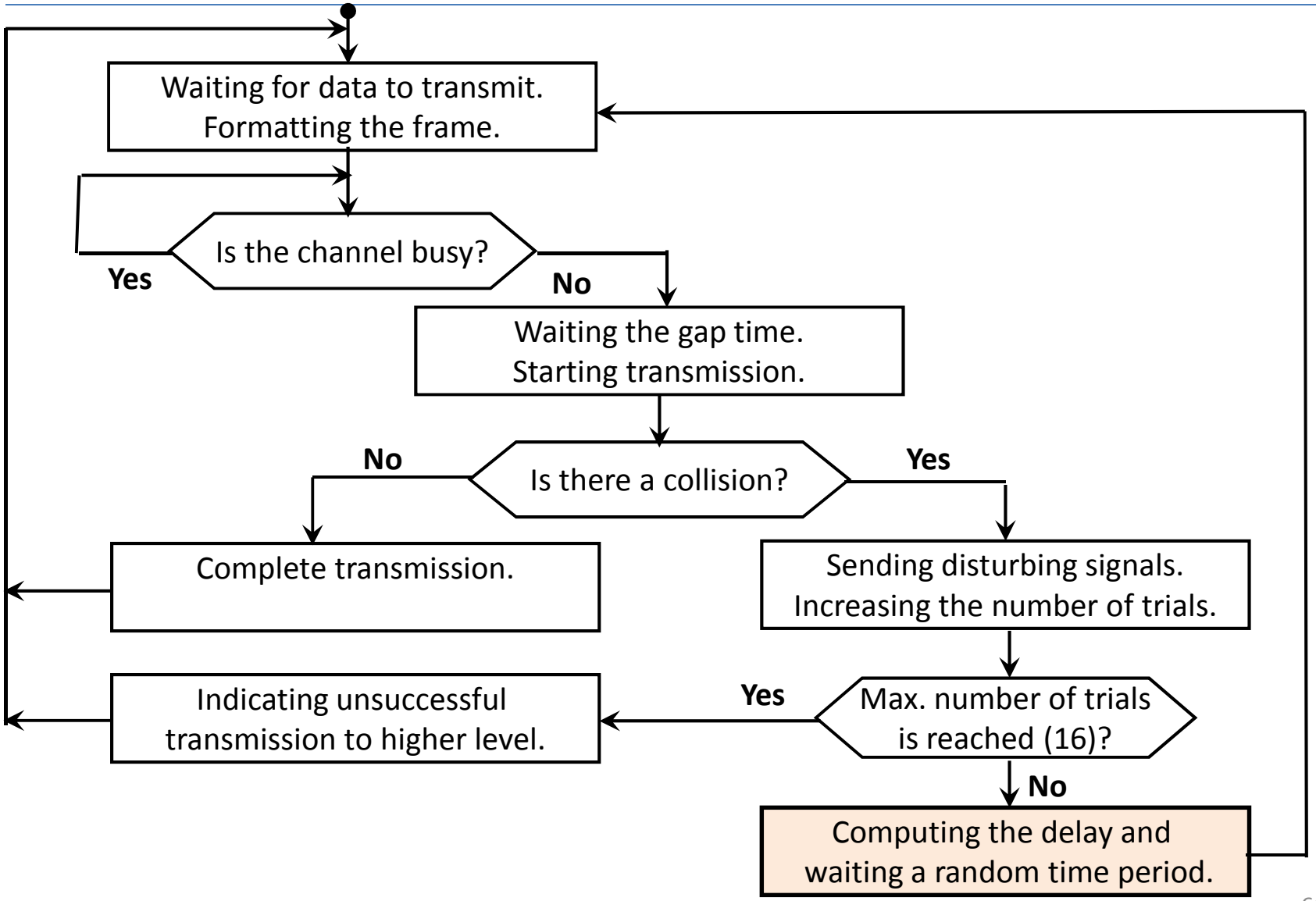
ID of manufacturer (3 bytes)

serial number (3 bytes)

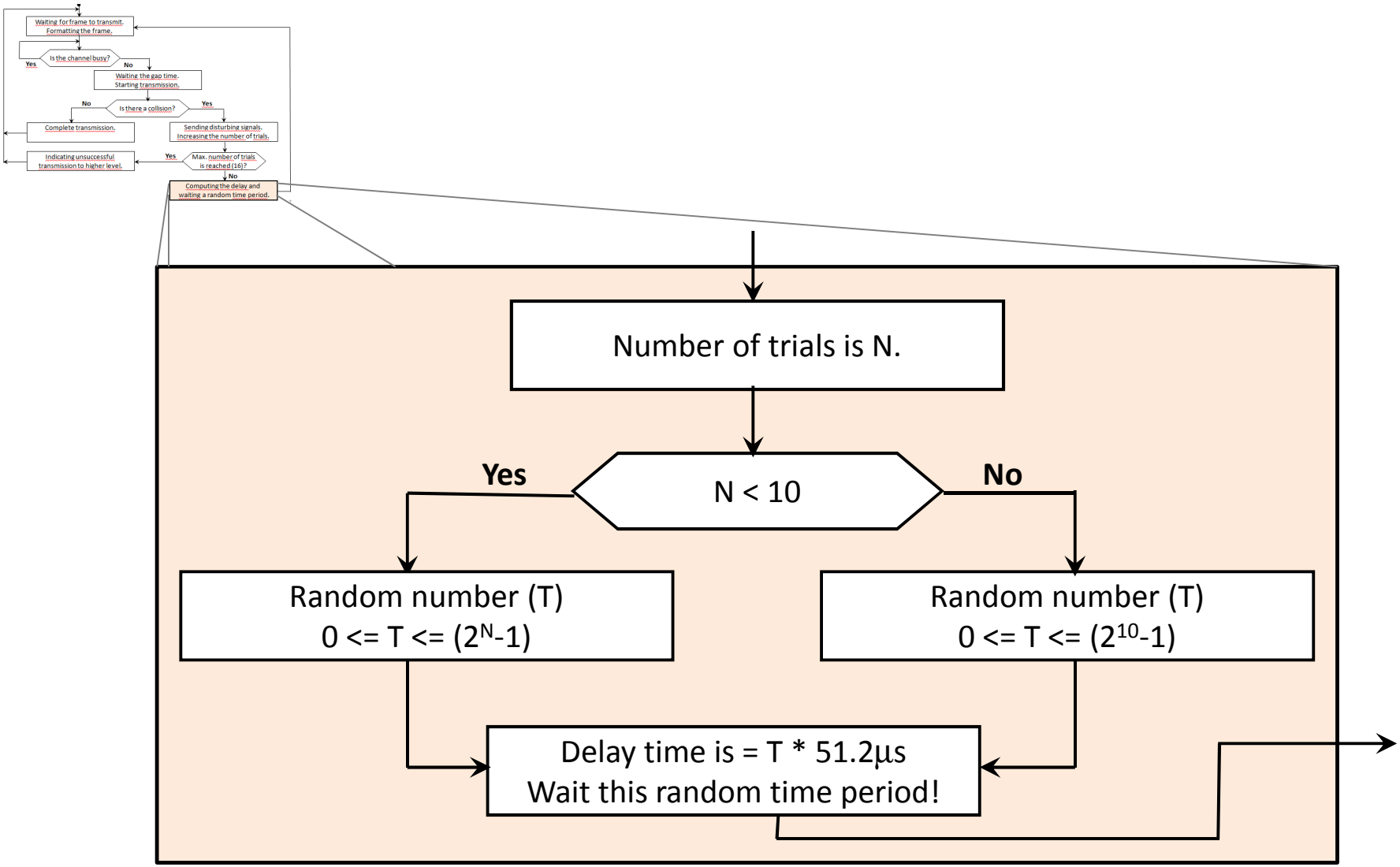
MAC address is ‘burned’ into the network interface.

There are no network cards in the world with same MAC address.

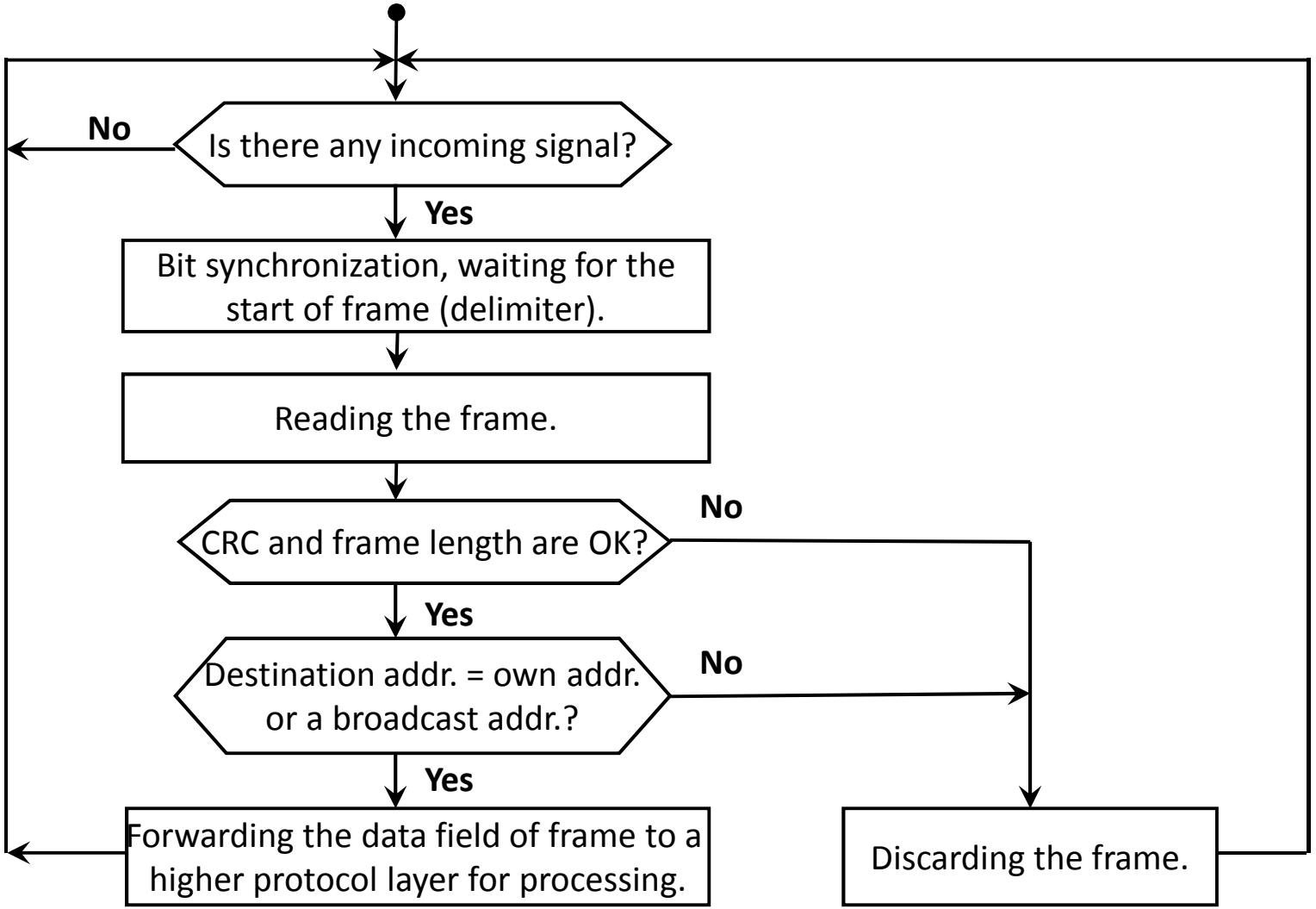
Ethernet frame transmission (CSMA/CD)



Computing the delay and wait



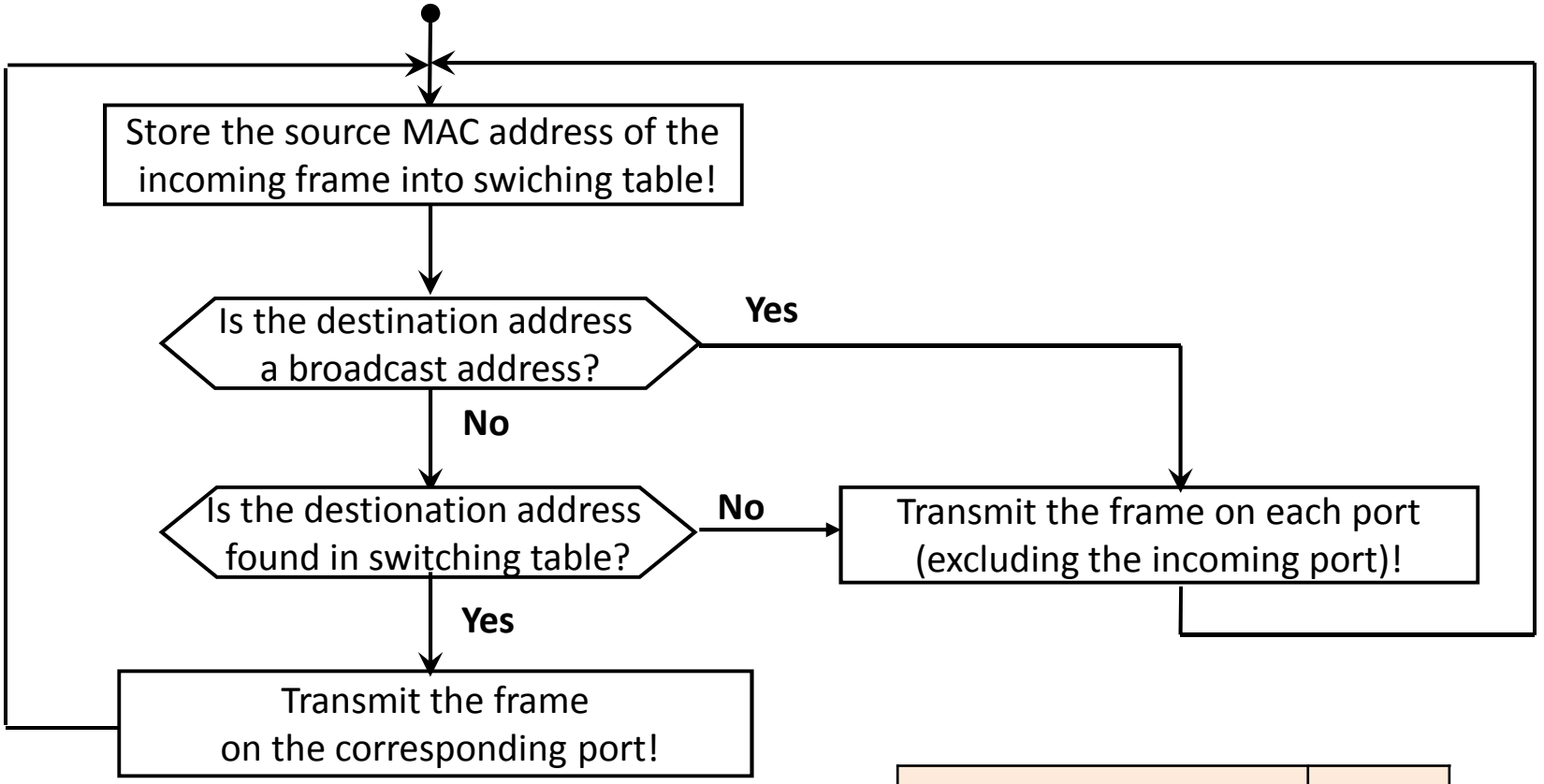
Receiving an Ethernet frame



Ethernet switching

- A collision domain occurs when multiple computers are connected to the single, shared transmisson media (line).
- Devices in second layer (bridge or switch) divide the collision domains.
- Each port of a switch forms a separate collision domain.
- These devices control the transmission of frames by MAC-addresses assigned to the Ethernet devices.
- Switches for each port stores the MAC addresses of the accessible devices from that port in a switching table.
- Switches upload and maintain their switching tables dynamically.

Ethernet switching



MAC address	Port
00-26-9E-93-75-AA	1
00-1E-64-60-0E-B0	2
08-00-27-00-FC-E1	3

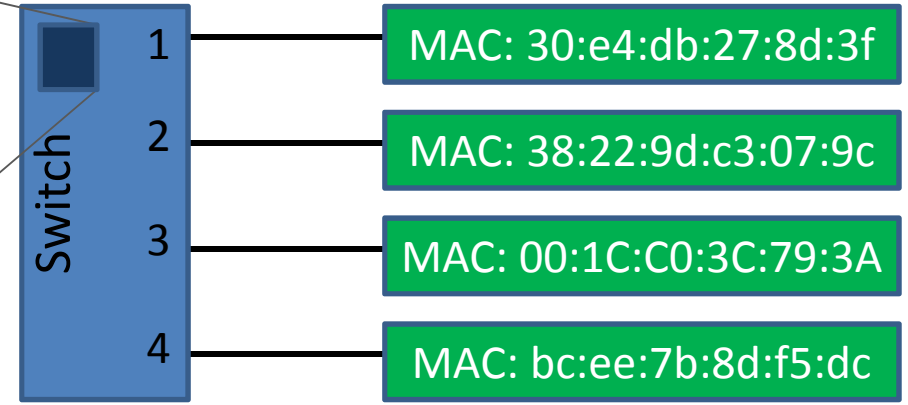
Switching exercises

- What is happening during the following sending?

1. Source: 30:e4:db:27:8d:3f Destination: 38:22:9d:c3:07:9c
2. Source: bc:ee:7b:8d:f5:dc Destination: 00:1C:C0:3C:79:3A
3. Source: 00:1C:C0:3C:79:3A Destination: FF:FF:FF:FF:FF:FF

- What is happening if Step 2 and Step 3 are replaced?

switching table	
MAC address	Port
30:e4:db:27:8d:3f	1
38:22:9d:c3:07:9c	2
bc:ee:7b:8d:f5:dc	4



Data-link layer commands

- `ifconfig | grep HWaddr`
  shows the MAC addresses of interfaces
- `ethtool eth0`
  displays ethernet card settings
- `mii-tool`
  manipulates media-independent interface status

Network layer

Network layer

Third layer of hybrid model (L3)

Connection between any two network nodes (not just dirrectly connected).

Topics

- Network addressing
- Routing
- Subnetting
- etc.

The **IP** network protocol

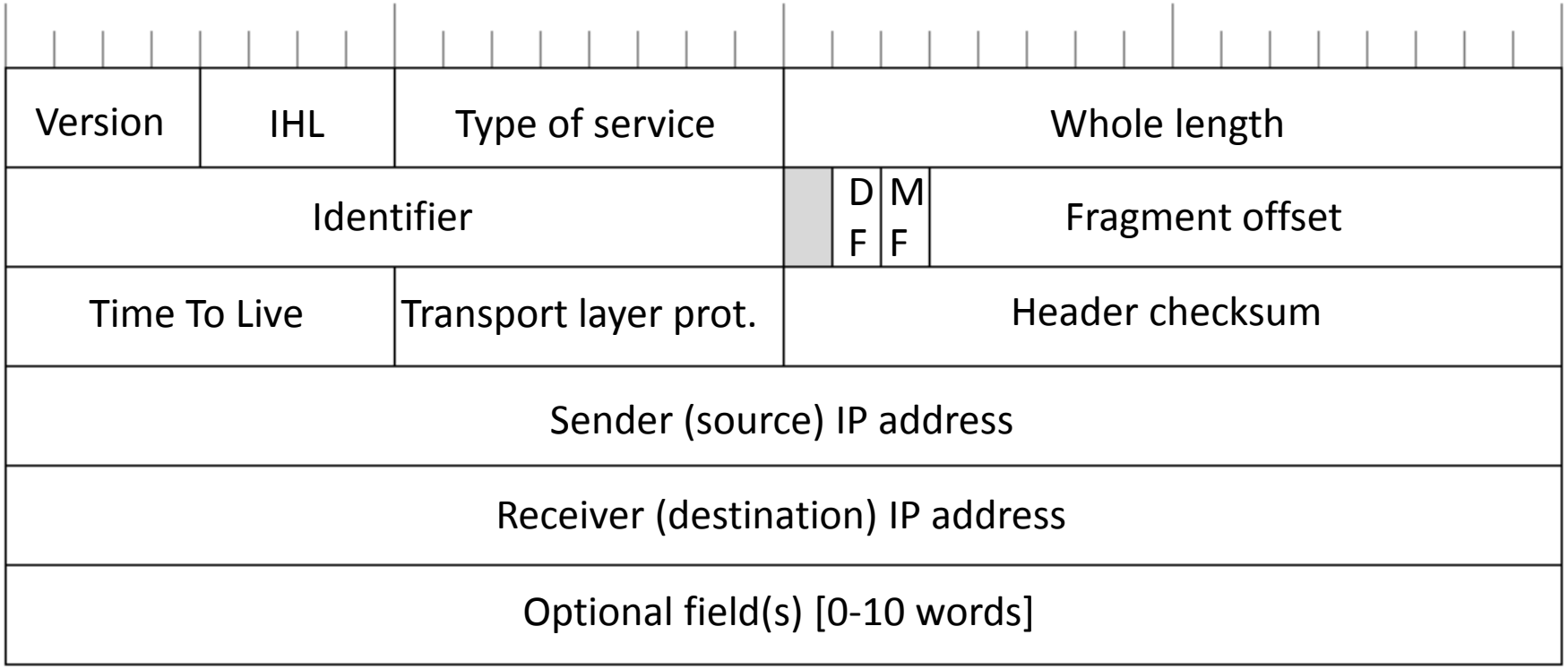
IP (Internet Protocol) (*RFC 791*)

- The network layer protocol of TCP/IP reference model.
- Widely used, it is the basic element of Internet.
- Most important characteristics:
  - Structure of IP header.
  - IP addressing, address classes.
  - Fragment supporting.
  - Datagram services towards Transport Layer.

Structure of IP header

Consists of 32-bit words.

Length: Minimum 5, maximum 15 words.



IP addresses

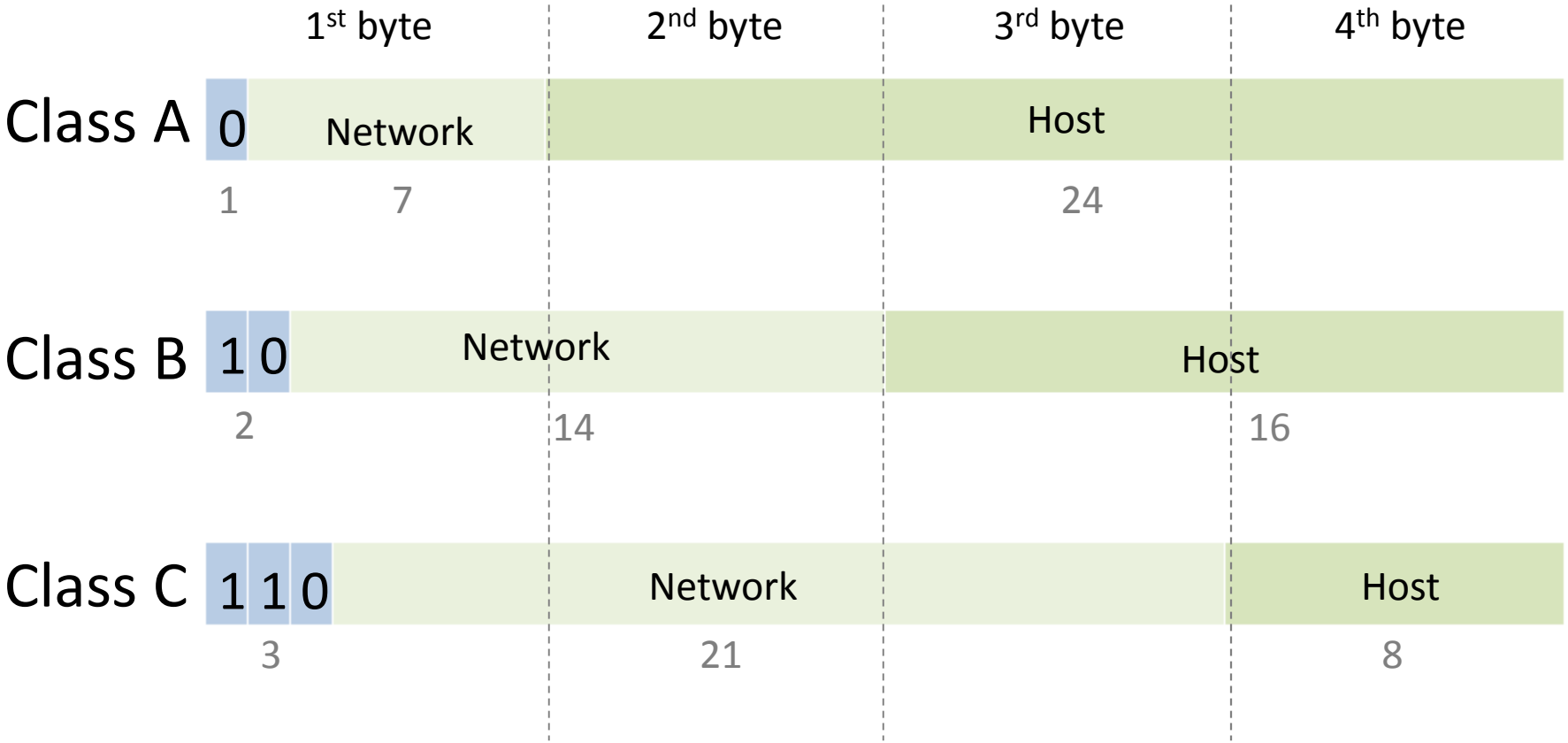
- Identifies the node in Network Layer.
- 32 bit (4 byte) long.
- **Dotted decimal notation**
  - eg. 157.45.190.57
- Managing identifiers
  - InterNIC
  - IANA
- For organisations not unique addresses but address domains (network identifiers) are assigned.

IP addresses

- The first part on an IP address identifies the network, the second part identifies the node (inside the network).

- The IP routing based on the network identifiers.
- How many bits should be in network IDs?
  - If too small, the large domains will be unused.
  - If too large, only small subnetworks can be handled.

Classes of IP addresses



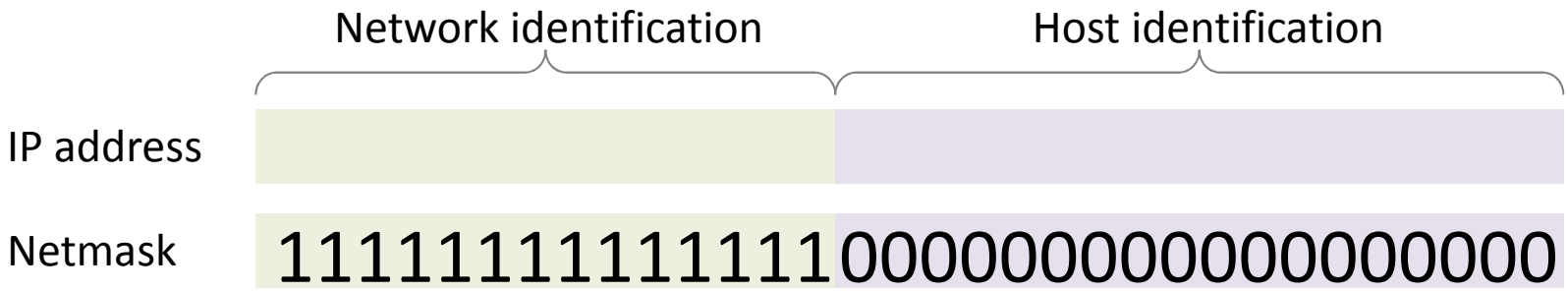
Network mask

Network mask (netmask):

- A 32 bit mask, which contains bits with values of 1 in place of network and subnetwork identifiers, and bits with values of 0 in place of host identifiers.

Prefix length:

- The number of value 1 in netmask (number of binary places in netmask).



Law of First Byte

Class	Leading bit(s)	First byte	Netmask	Prefix
A	0	0-127	255.0.0.0	8
B	10	128-191	255.255.0.0	16
C	110	192-223	255.255.255.0	24

Special IP addresses

- Not specificated host

00000000	00000000000000000000000

- ID of the specific network (network ID)

Network	00000000000000000

- Broadcast on the specific network

Network	11111111111111111

- Loopback address

01111111	Anything

Addressing exercises

What is the Network ID of 172.17.22.45 /12?

- IP address: 172.17.22.45
  10101100.00010001.00010110.00101101
- Netmask: prefix length is 12
  11111111.11110000.00000000.00000000
- Bit-wise logical AND operation (IP & Netmask):
  10101100.00010001.00010110.00101101
  & 11111111.11110000.00000000.00000000
  10101100.00010000.00000000.00000000
- Result (network ID): 172.16.0.0

Addressing exercises

What is the broadcast address of this network?
192.168.64.0 /255.255.224.0

- Network ID in binary:
  11000000.10101000.01000000.00000000
- Netmask in binary:
  11111111.11111111.11100000.00000000
- Broadcast in binary:
  11000000.10101000.01011111.11111111
- Result (broadcast in dotted-decimal):
  192.168.95.255

Addressing exercises

Is the computer with IP 172.20.21.22/255.240.0.0 in the 172.16.0.0 network?

- Binary IP of node:
  10101100.00010100.00010101.00010110
- Binary Netmask:
  11111111.11110000.00000000.00000000
- Network ID of the computer (IP & Netmask):
  10101100.00010000.00000000.00000000
  in dotted decimal: 172.16.0.0
- Ansewer: yes, the computer is inside this network.

Addressing exercises

What is the Network ID of the network of this node in case of default netmask?
Node IP: 193.6.128.5

What is the Network ID of that network which contains IP 172.23.125.22, if netmask is 255.255.192.0?

What is the broadcast address in the network of node 10.0.0.0 /25?

Is the computer with IP 192.168.31.22 /23 in the 192.168.32.0 network?

Problems with classful IP networks

- Class A networks are to large, Class C networks are to small, Class B networks are full.

Solutions:

- Private IP domains (e.g. 192.168.0.0/16) with Network Address Translation (NAT)
- Classless IP addressing: the border between network and host ID is shiftable (e.g. netmask 255.240.0.0)
- IPv6, new version of Internet Protocol (IPv6 address is 128 bit long)

Private IP networks

- Network that uses private IP address space
- Commonly used for home and office LANs, when globally routable addresses are not mandatory
- Must use a network address translator (NAT)
- Private domains:
  - 10.0.0.0/8
  - 172.16.0.0/12
  - 192.168.0.0/16

IP subnets

Why is it necessary to create subnets?

- The logical functionality of the institute can be a reason.
- On an IP network more than one broadcast domains (usually with the same size) have to be created.

How can we create a subnet?

- Some of the higher position bits of host ID of an IP address will be used identifying the subnet.
- The new network-node boundary is denoted with the network mask (longer prefix is used).

IP subnets example

Task:

- Network ID: 192.168.0.0
- Netmask: 255.255.255.0 (prefix: 24)
- We need 5 subnets

How many bits is enough to identify 5 subnets?

- 1 bit: 2 possibilities (0, 1)
- 2 bits: 4 possibilities (00, 01, 10, 11)
- **3 bits: 8 possibilities** (000, 001, 010, 011, 100, 101, 110, 111)
- So 3 bit is enough to identify 5 subnets.

IP subnet example

- Old netmask in dotted-decimal
  255.255.255.0
- Old netmask in binary
  11111111.11111111.11111111.00000000
- New netmask in binary
  11111111.11111111.11111111.**111**00000
- New netmask in dotted-decimal
  255.255.255.224
- The prefix length of new netmask:
  27 (=24+**3**)

IP subnet example

- Network ID in dotted-decimal: 192.168.0.0
- Network ID in binary:

  11000000.10101000.00000000.00000000
- Subnets in binary:

  11000000.10101000.00000000.00000000
  11000000.10101000.00000000.00100000
  11000000.10101000.00000000.01000000
  11000000.10101000.00000000.01100000
  11000000.10101000.00000000.10000000
  11000000.10101000.00000000.10100000
  11000000.10101000.00000000.11000000
  11000000.10101000.00000000.11100000

The required 5 subnets

IP subnets example

- Original network: 192.168.0.0 / 24
- Subnets in dotted-decimal:

192.168.0.0	/ 27	11000000.10101000.00000000.00000000
192.168.0.32	/ 27	11000000.10101000.00000000.00100000
192.168.0.64	/ 27	11000000.10101000.00000000.01000000
192.168.0.96	/ 27	11000000.10101000.00000000.01100000
192.168.0.128	/ 27	11000000.10101000.00000000.10000000

IP subnets example

IPs of (just) the third subnet:

- Subnet ID
  192.168.0.64 / 27 11000000.10101000.00000000.01000000
- IPs of computers
  192.168.0.65 / 27 11000000.10101000.00000000.01000001
  192.168.0.66 / 27 11000000.10101000.00000000.01000010
  192.168.0.67 / 27 11000000.10101000.00000000.01000011
  …
  192.168.0.93 / 27 11000000.10101000.00000000.01011101
  192.168.0.94 / 27 11000000.10101000.00000000.01011110
- Broadcast of subnet
  192.168.0.95 / 27 11000000.10101000.00000000.01011111
  (30 IPs in each subnet)

IP subnets example

Task 2:

- Network ID: 172.16.0.0
- Netmask: 255.255.0.0
- We need 2 subnets

Subnets:

172.16.0.0 / 17	10101100.00010000.00000000.00000000
172.16.128.0 / 17	10101100.00010000.10000000.00000000

(32766 IPs in each subnet)

CIDR

Classless Inter-Domain Routing

Main problem:

We want to divide a network to different sized subnets.
(Previous method results same subnet size.)

Not the number of subnets is important, but the number of nodes in a given subnet.

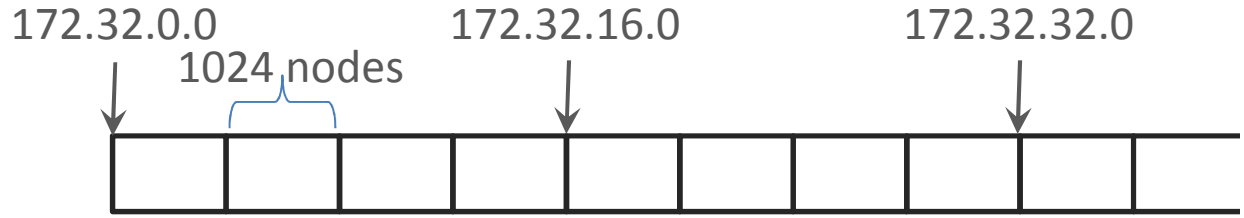
IP classes are not so important.

Network-host border can be shifted.

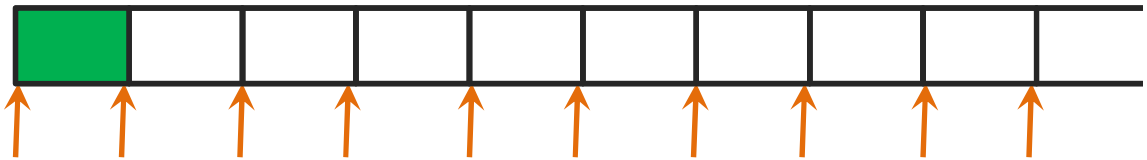
The result depends on the arriving time of demands.

CIDR

Available network
172.32.0.0/16



First demand
1000 nodes

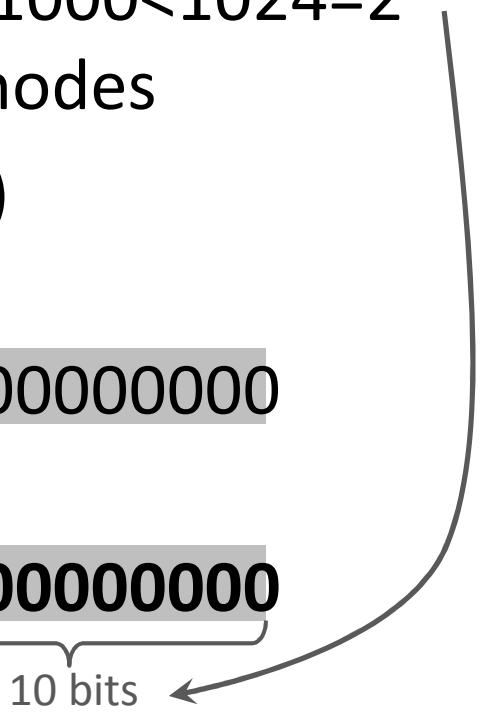


Second demand
4000 nodes

Third demand
2000 nodes

CIDR

- First demand: 1000 nodes → 1000<1024=2^{10}
  10 bits needed to identify 1000 nodes
- Old netmask: /16 (=255.255.0.0)
- Old netmask in binary
  11111111.11111111.00000000.00000000
- New netmask in binary
  11111111.11111111.111111**00.00000000**



- New netmask: /22 (=255.255.252.0)
- Choose the first empty subnet with this netmask!

CIDR

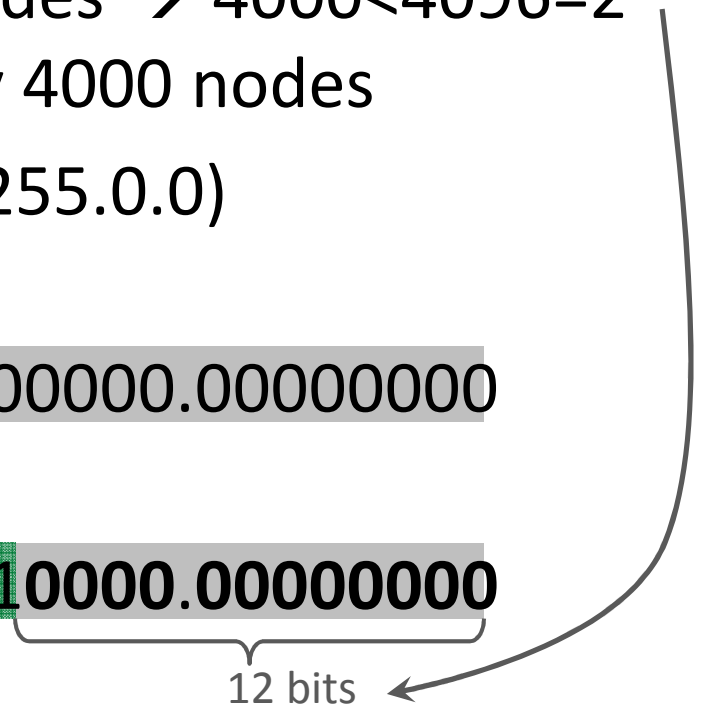
- Network ID in dotted-decimal: 172.32.0.0
- Network ID in binary:

  10101100.00100000.00000000.00000000
- Possible subnets in binary:

  10101100.00100000.00000000.00000000 ← first unused subnets
  10101100.00100000.00000100.00000000
  10101100.00100000.00001000.00000000
  10101100.00100000.00001100.00000000
  10101100.00100000.00010000.00000000
  10101100.00100000.00010100.00000000
  10101100.00100000.00011000.00000000
  10101100.00100000.00011100.00000000

CIDR

- Second demand: 4000 nodes → 4000<4096=2^{12}
  12 bits needed to identify 4000 nodes
- Old netmask: /16 (=255.255.0.0)
- Old netmask in binary
  11111111.11111111.00000000.00000000
- New netmask in binary
  11111111.11111111.1111**0000.00000000**



- New netmask: /20 (=255.255.240.0)
- Choose the first empty subnet with this netmask!

CIDR

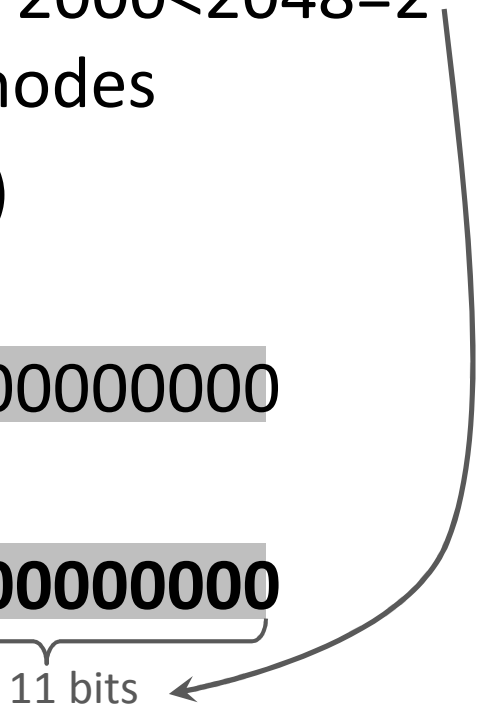
- Network ID in dotted-decimal: 172.32.0.0
- Network ID in binary:

  10101100.00100000.00000000.00000000
- Possible subnets in binary:

  10101100.00100000.00000000.00000000
  10101100.00100000.00010000.00000000 ← first unused subnets
  10101100.00100000.00100000.00000000
  10101100.00100000.00110000.00000000
  10101100.00100000.01000000.00000000
  10101100.00100000.01010000.00000000
  10101100.00100000.01100000.00000000
  10101100.00100000.01110000.00000000

CIDR

- Third demand: 2000 nodes → 2000<2048=2^{11}
  11 bits needed to identify 2000 nodes
- Old netmask: /16 (=255.255.0.0)
- Old netmask in binary
  11111111.11111111.00000000.00000000
- New netmask in binary
  11111111.11111111.11111**000**.**00000000**



- New netmask: /21 (=255.255.248.0)
- Choose the first empty subnet with this netmask!

CIDR

- Network ID in dotted-decimal: 172.32.0.0
- Network ID in binary:

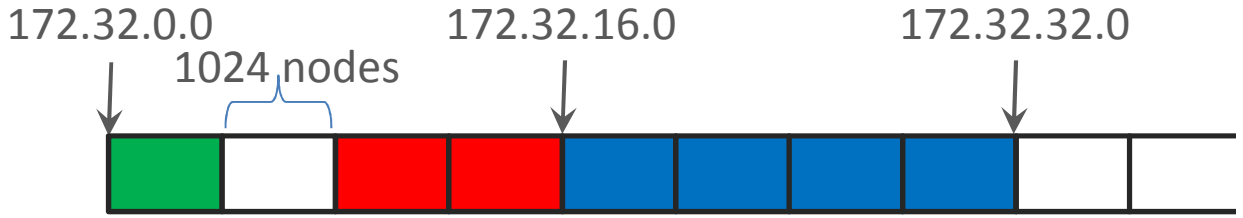
  10101100.00100000.00000000.00000000
- Possible subnets in binary:

  10101100.00100000.00000000.00000000
  10101100.00100000.00001000.00000000 ← first unused subnets
  10101100.00100000.00010000.00000000
  10101100.00100000.00011000.00000000
  10101100.00100000.00100000.00000000
  10101100.00100000.00101000.00000000
  10101100.00100000.00110000.00000000
  10101100.00100000.00111000.00000000

CIDR

Full network

172.32.0.0/16



First subnet (1000 nodes)

172.32.0.0/22 Broadcast: 172.32.3.255

Nodes: 172.32.0.1 – 172.32.3.254

Third demand (2000 nodes)

172.32.8.0/21 Broadcast: 172.32.15.255

Nodes: 172.32.8.1 – 172.32.15.254

Second demand (4000 nodes)

172.32.16.0/20 Broadcast: 172.32.31.255

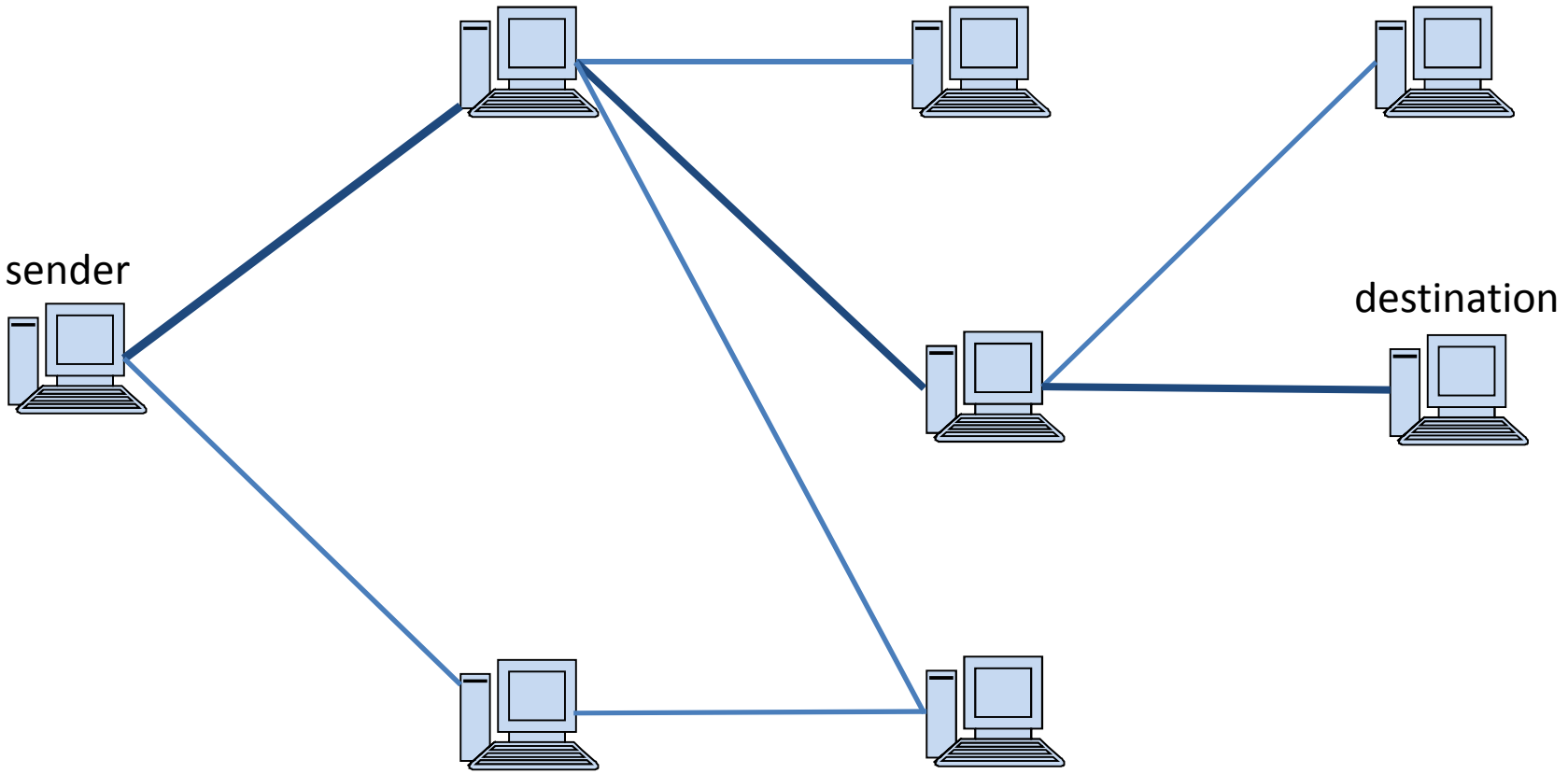
Nodes: 172.32.16.1 – 172.32.31.254

ifconfig command

- `ifconfig`
  shows the settings of all interfaces
- `ifconfig eth0`
  shows the settings of eth0 interface
- `ifconfig eth0 192.168.0.10 netmask 255.255.255.0`
  sets up IP address and netmask to eth0 interface
- `ifconfig eth0 172.16.1.12/16`
  sets up IP address and netmask to eth0 interface
- `ifconfig eth0 mtu 512`
  change the maximum transfer unit of eth0 interface

Routing

- How to find the destination?



Routing table

Each node have a „list” about its (direct) connections and knows who is the „best informed” of them.

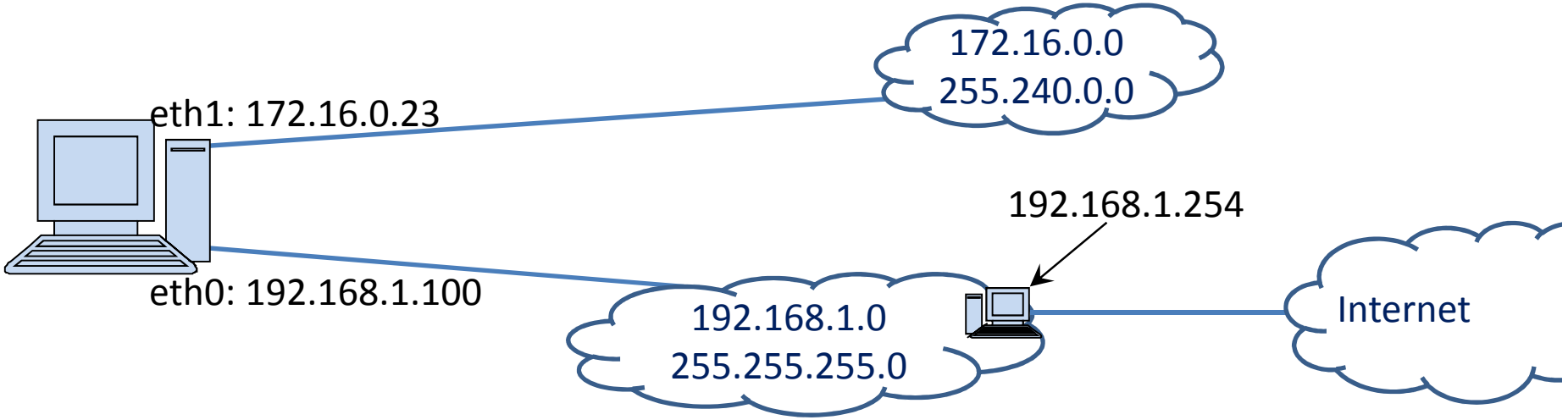
This „list” is called **routing table**.

The „best informed” node in a network called **default gateway**.

If a node wants to send a packet to an other, it searches for the destination in its connection list. If it is in the list, the sender can know how to reach it, else it sends the packet to default gateway maybe it can forward the packet to the addressee.

Routing table example

Computer with 2 network interfaces



Destination Network ID	Gateway	Netmask (genmask)	Interface
192.168.1.0	0.0.0.0	255.255.255.0	eth0
172.16.0.0	0.0.0.0	255.240.0.0	eth1
0.0.0.0	192.168.1.254	0.0.0.0	eth0

Routing process

How the routing works in case of sending to an given IP:

- *Step 1*: See the first row of routing table!
- *Step 2*: Make AND operation between the given destination IP and the netmask in the row!
- *Step 3*: If the result equal to Network ID in the row, send the packet on your interface written at the end of row! (If gateway given send to the gateway, else directly to destination on the link.)
- *Step 4*: Otherwise see the next row (if exists) and go to *Step 2*!

Routing example

Sending a packet to 193.6.128.5. Via which interface?

First row	193. 6.128. 5	
	& 255.255.255. 0	
	193. 6.128. 0	≠ 192.168.1.0
Second row	193. 6.128. 5	
	& 255.240. 0. 0	
	193. 0. 0. 0	≠ 172.16.0.0
Third row	193. 6.128. 5	
	& 0. 0. 0. 0	
	0. 0. 0. 0	= 0.0.0.0

Send the packet to gateway 192.168.1.254
(this is the **next hop**) via the interface eth0 (192.168.1.100).

Maintenance of routing tables

Static routing

- The routing tables are treated by the system administrator (root).

Dynamic routing

- Routers automatically change information between each other to update their routing tables.
- Routing protocols:
  - Distance vector routing: RIP, IGRP, BGP
  - Link-state routing: OSPF, IS-IS, etc.
- (Routed protocols: IP, ICMP, etc.)

Problems of Dual Address systems

In Network and Data Link Layers two independent address systems (IP addresses and Ethernet addresses) are considered.

- For encapsulation of Data Link Layer (forming an Ethernet frame) the physical address (MAC address) belonging to the IP address has to be determined.
- In certain cases it could be necessary to determine the IP address by the help of Ethernet address.

Network Address –> Physical Address

ARP (Address Resolution Protocol):

- Each node records physical addresses belonging to the network addresses in a table (ARP table).
- How get a new data (pair of addresses) into the table?

1. ARP question:
   Who knows the physical address of the network address X?
2. Each node of subnet receives and processes the frame of the question by a broadcast message.
3. If a node ‘identifies itself’ with network address X, sends an answer to the ARP question with own physical address.

Physical Address –> Network Address

DHCP (Dynamic Host Configuration Protocol):

- Allows assignment of IP address domain.
- In case of more DHCP servers, the handled address domains should not overlap (in default).
- Clients get the IP address (and other network setup) for a renewable time period.

Physical Address –> Network Address

DHCP scheme of functioning :

1. DHCP question: Who can give me an IP address?
2. Each node of subnet receives the frame of the question by a broadcast message.
3. A DHCP servers process the question: If there is a free IP address in the handled address domain, then send an answer to DHCP question with that IP address.
4. The client chooses one from the received DHCP answers, and sends a feedback of its choice to the corresponding DHCP server.
5. The DHCP server books the choice of address (the address became occupied), and confirms client on booking.

Network setup

4 necessary properties to use network on a computer:

- IP address
- Netmask
- Gateway
- DNS server

They are given by the Internet Service Provider (ISP).

Either the user do their setup or use dynamic host configuration (if possible).

The user can use ‘command-line’ or GUI (Graphical User Interface) to do setup process.

route command

- `route`
  shows routing table
- `route -n`
  shows routing table in numeric format
- `route add -net 192.168.1.0 netmask 255.255.255.0 dev eth0`
  sets a row into routing table to 192.168.1.0/24 network
- `route add default gw 192.168.1.100`
  sets 192.168.1.100 as default gateway

Other commands

- `ping 193.6.128.5`
  ICMP ‘echo-request’ message to destination
- `ping -c 5 193.6.128.5`
  sends 5 ICMP messages to destination
- `ping -t 4 193.6.128.5`
  sends ICMP message to destination with TTL=4
- `netstat -r`
  shows routing table
- `traceroute 193.6.128.5`
  Shows internal hops to the destination

Other commands

- `arp`
  shows ARP table
- `arp -s <IP address> <MAC address>`
  Sets up a new entry of ARP table
- `/etc/ethers` file
  contains static ARP entries
- `dhclient`
  DHCP client

Transport layer

Transport layer

Fourth layer of hybrid model (L4)

Reliable connection between softwares on two nodes.
Protocols may connectionless or connection-oriented.

Topics

- Error detection/correction
- Order guarantee
- Identifying programs on a node
- etc.

Port

Problem:

- IP address (and DNS name) identifies the node only.
- A node has more different connections, it executes more network applications.
- A program has to know which segment (data unit in L4) belongs to it

Solution: **port**

- It identifies network programs or services on a node.
- It is a 16bits long number in decimal form.
- Range: 0 - 65535

Port

Range: 0 – 65535 (since it is 16bits long)

- **Well-known ports**: 0 – 1023
  Used by system processes that provide widely used types of network services
- Registred ports: 1024 - 49151
- Private ports: 49152 – 65535
  Used freely

Stored in files:

- linux: /etc/services
- windows: C:/WINDOWS/system32/drivers/etc/services

Well-known ports

- 21: **FTP** (File Transfer Protocol)
  used for down/up loading files
- 22: **SSH** (Secure SHell)
  used for secure login to remote computer
- 25: **SMTP** (Simple Mail Transfer Protocol)
  used for e-mail routing to mail servers
- 53: **DNS** (Domain Name System)
  used for eg.: www.unideb.hu → 193.6.128.25
- 80: **HTTP** (HyperText Transfer Protocol)
  used by web browsers

Well-known ports

- 110: **POP3** (Post Office Protocol v3)
  used for downloading e-mails from servers
- 118: **SQL** (Structured Query Language)
  used for distributed database
- 143: **IMAP** (Internet Message Access Protocol)
  used for downloading e-mails from servers (newer)
- 443: **HTTPS** (HyperText Transfer Protocol over SSL)
  used by web browsers for secured sites
- 995: **POP3** (Post Office Protocol v3 over SSL)
  used for secured downloading e-mails from servers

Transport layer protocols

UDP: User Datagram Protocol

- Connection free
- Non-reliable

TCP: Transmisson Control Protocol

- Connection based
- Reliable

UDP

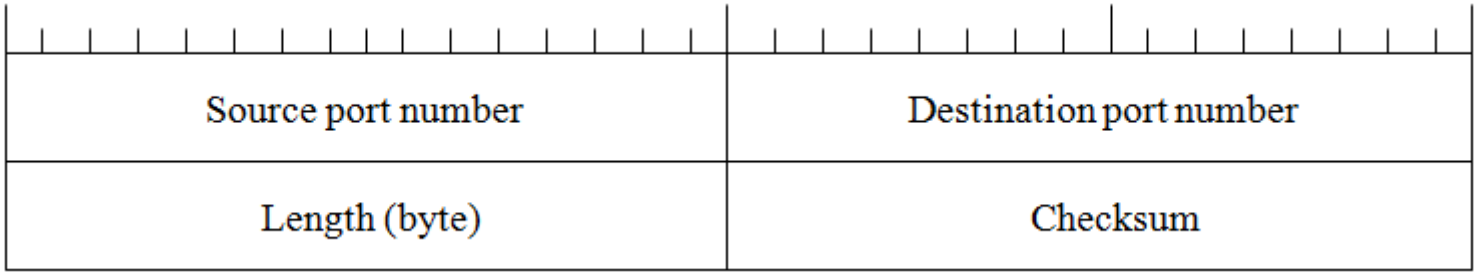
- The UDP (User Datagram Protocol) is the connection free transport protocol of the TCP/IP protocol set.
- Transmission of datagrams without any guarantee (without confirmation).
- Failure management is to higher level (applications) protocols.
- The UDP protocol is suitable applications which do not need to concatenate sequences of segments. Eg. DHCP, DNS .
- Short header, fast transmission.

TCP

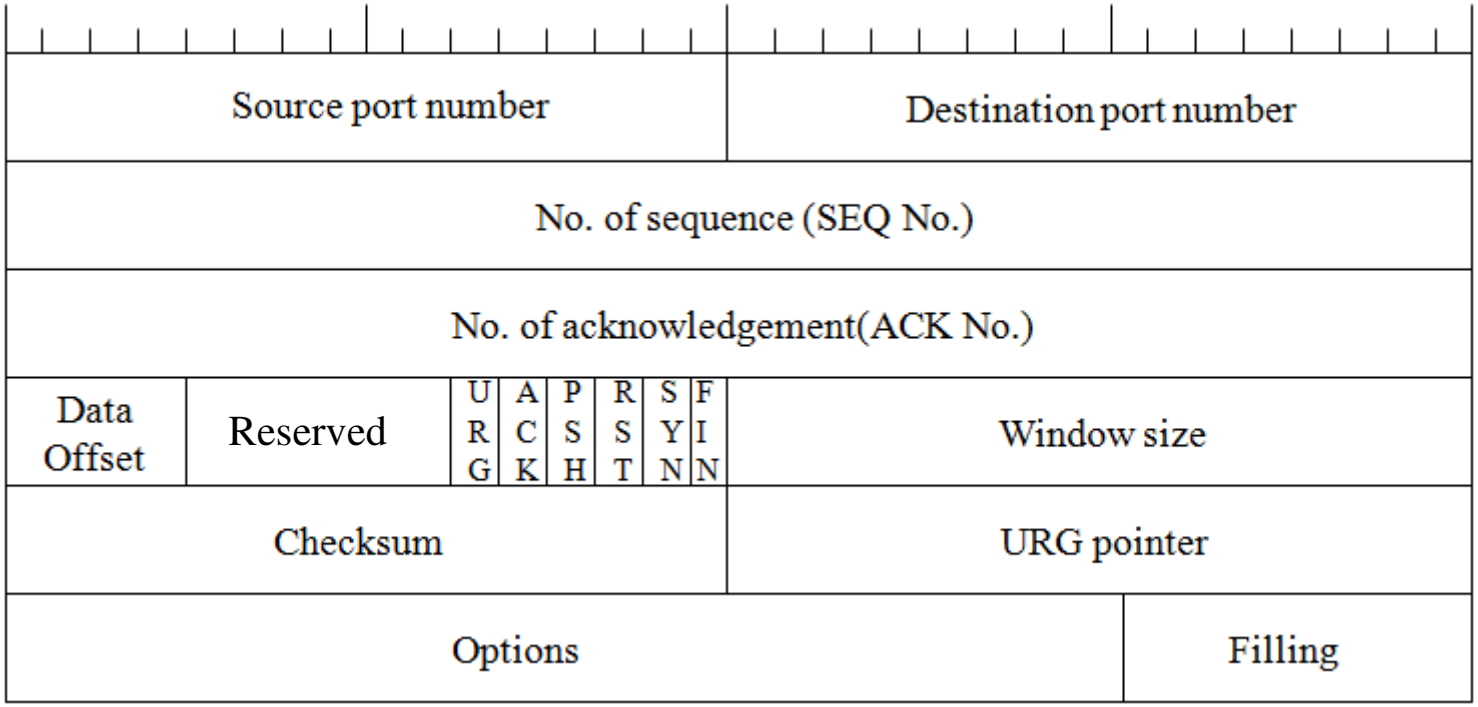
- The TCP (Transmission Control Protocol) is the connection based transfer protocol of the TCP/IP protocol set. It provides a reliable (receipted) bit stream for applications.
- Before starting data transmission, the two nodes build up a TCP connection (Three-way handshake).
- The destination node receipts the segment(s).
- If a segment is missing, the TCP protocol ensures retransmission of the missing segment.
- Long header, slow transmission.

Headers

UDP:



TCP:



Use of TCP and UDP

TCP is used when the reliability is important

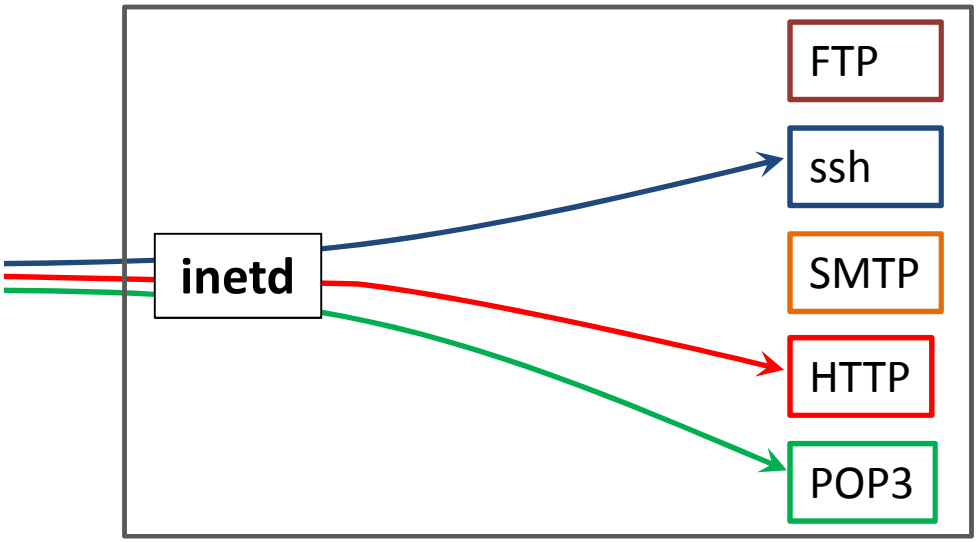
- We nees all bytes precisely even if the speed is slow
- Eg: downloading file, browsing web, reading email

UDP is used when the speed is important

- We need fast, continuous transmission even if some segments are lost.
- Eg: IP phoning (eg: Skype), watching live video

Super-server: inetd

- If all server programs (daemons) always listen to packet, it is not efficient (too much processes).
- Incoming packets first goes to inetd
- inetd decide which server program belongs to this packet (based on port number).
- inetd launches the demon, delivers the packet.



inetd configuration

- /etc/protocols
- /etc/services

Contains services, port numbers, protocols

```
ftp     21/tcp
ssh     22/tcp
ssh     22/udp
telnet  23/tcp
smtp    25/tcp
```

- /etc/inetd.conf

If a service request arrives, how to launch a daemon

```
ftp     stream  tcp6  nowait  root  /usr/sbin/ftpd     ftpd
telnet  stream  tcp6  nowait  root  /usr/sbin/telnetd  telnetd -a
pop3    stream  tcp   nowait  root  /usr/sbin/pop3d    pop3d
```

Access control

tcpd: Access control for internet services

Operation

- Request arrives
- The i*netd* launches *tcpd*, not the service daemon
- The *tcpd* logs the request
- It checks the rights
  - by pattern-based access control config files
- Either starts the requested daemon or don't respond

Access control

- Configuration files

  /etc/hosts.allow

  /etc/hosts.deny
- Control rules
  - Receive a demand
  - Access will be granted when a (daemon, client) pair matches an entry in allow file
  - Otherwise, access will be denied when a (daemon, client) pair matches an entry in deny file
  - Else access will be granted

Access control

- Configuration file structure
  <daemon-list> : <client-list> [: <command>]
- List entries are separated by coma (,)
- Daemon: service daemon name or port number
- Client: IP address or domain name
- We can use *wildcards*
  ALL, LOCAL, UNKNOWN, PARANOID, EXCEPT, *
- Example
  80 : 192.168.1.23 : DENY
  From the IP don’t allow web connection request

Useful commands

- telnet
  Login to a given port of a server
  ```
  telnet 193.6.128.25 80
  ```
- netstat
  Network statistics
  ```
  netstat -i
  netstat -s
  netstat -n
  ```
- nmap
  Port scanning, OS detecting
  ```
  nmap 193.6.128.25
  nmap -v -O 193.6.128.190
  ```

Useful commands

- netcat

  start a server waiting for client to connect on port 4321

  ```
  nc -l -p 4321
  ```

  connect to a given port of a server

  ```
  nc localhost 4321
  ```

  find out a given port is open on a given server

  ```
  nc -vz 193.6.128.25 80
  ```

  opening backdoor

  ```
  nc -l -p 3000 -e /bin/bash
  ```

  …

Application layer

Application layer

Fifth layer of hybrid model (L5)

Interface between applications and users. Ensures the communication required by the users. Displaying data and images to the user in a human-recognizable format.

Topics

- Domain names (DNS)
- World Wide Web (www, HTTP, HTTPS, HTML)
- E-mail (SMPT, POP3, IMAP)
- File transfer (FTP, BitTorrent)
- etc.

Name-IP address assignment

Problem:

- Users likes ‘text-like’ names instead of numbers.
- Computers identify each other by IP addresses (which are numbers).

Solution:

- Mapping IP addresses to names
- **Domain Name System** (DNS)

Components of DNS

Space of domain names and **resource records**

- The computer names and information about them.

Nameservers

- Stores information about names belonging to a zone.

Resolver applications

- Gives IP address to given names.

Domain Namespace

Tree-like graph, where each node is a set of resource (eg. computer).

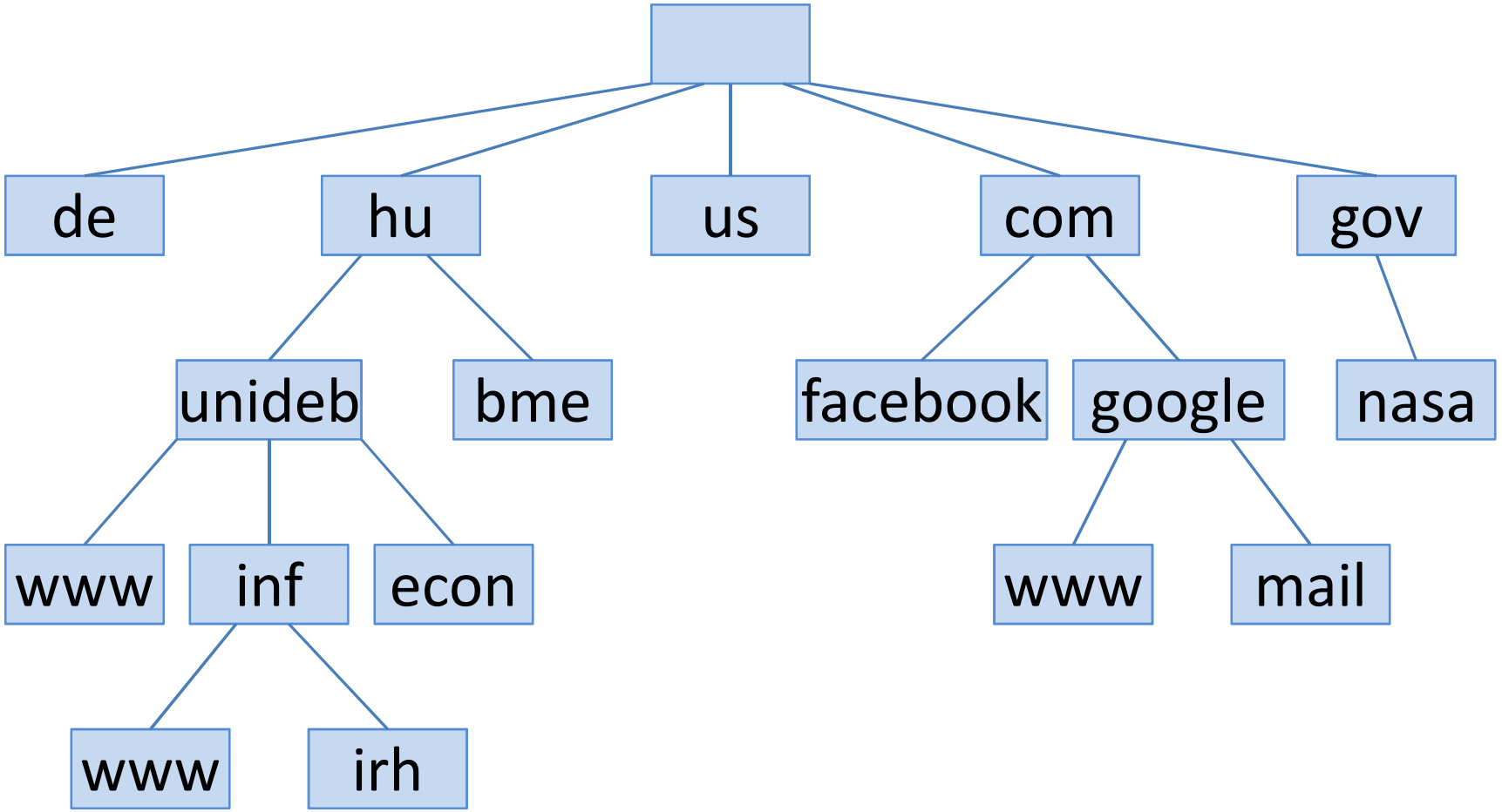
Each node has a label.

- No equal labes with same parent node.
- Max length of labels is 63 characters.
- Lowercase and uppercase letters are the same.

Absolute domain name:

- Nodes can be identifies by the series of labels from the node to the root, separated by dot.
- Eg.: irh.inf.unideb.hu.

Domain Namespace



Resource Record

A Domain Name specify a node of the graph.

A node related to resource set.

Information resources are stored in Resource Records.

Zone file contains RRs.

Examples of Resource Records :

- What is the IP address of a computer?
- Which computer is a name server?
- Which computer is a mail-exchanger?
- etc.

Reource Record

Structure:

```
[domain] [ttl] [class] type data
```

Types:

- SOA: authoritative information about the domain
- NS: authoritative name server of the domain
- A: IPv4 address of the domain
- AAAA : IPv6 address of the domain
- MX: Mail Transfer Agent (MTA) of the domain
- CNAME: alias name of the domain
- PTR: pointer to reverse DNS lookup

Example zone file

```
@  IN     SOA      dns1.example.org.          root.example.org. (
     2009100501   ; serial <2009-Okt-05, update 1>
     86400        ; refresh <1 day>
     3600         ; retry <1 hour>
     1209600      ; expire <2 weeks>
     86400 )      ; negative caching <1 day>
example.org.       86400   IN      NS      dns1.example.org.
example.org.       86400   IN      NS      dns2.example.org.
example.org.       86400   IN      MX      10      mail.example.org.
dns1.example.org.          IN      A       192.168.0.1
dns2.example.org.          IN      A       192.168.0.2
mail.example.org.          IN      AAAA    2001:503:ba3e::2:30
server.example.org.        IN      A       192.168.0.4
host.example.org.          IN      A       192.168.0.101
e2.example.org.            IN      A       192.168.0.102
ftp.example.org.           IN      CNAME   server.example.org.
```

Name server

A server program on a computer.

Relates to zones.

Zone is an administrative unit of namespace, usually belongs to organizations.

Name servers store resource record of the zone (this is the zone file)

Usually each zone has 2 name servers (a primary and a secondary name server).

They give reply to request about IP↔name mapping.

Resolver

A program, which means interface between user applications and name servers.

If a program needs IP address but domain name is given resolver do the address mapping.

It sends a request to name server and gives the reply based on resource records to the user application.

Example of results:

www.unideb.hu ⟶ 193.6.128.25

nslookup

nslookup: command-line tool for querying DNS

- Who is the name server of unideb.hu?

```
nslookup  -type=NS  unideb.hu
```

- What is the canonical name of www.unideb.hu?

```
nslookup  -type=CNAME  www.unideb.hu
```

- What is the IP address of www.unideb.hu?

```
nslookup  -type=A  www.unideb.hu
```

- Who is the mail exchanger of unideb.hu?

```
nslookup  -type=MX  unideb.hu
```

- What is the name of host where IP is 193.6.128.5?

```
nslookup  -type=PTR  5.128.6.193.in-addr.arpa
```

Configuration to DNS

To use name ‘MyPC’ instead of 192.168.0.123:

- Edit: /etc/hosts

```
192.168.0.123   MyPC
```

To use DNS name resolver:

- Edit: /etc/nsswitch.conf

```
hosts: dns files
```

- Edit: /etc/resolv.conf

```
domain  mydomain.com
nameserver  193.6.128.5
```

World Wide Web

The most widely used and most quickly spreading part of Internet.

Concept: Tim Berners-Lee (CERN, 1989)

We can navigate among **website**s by hyperlink.

Based on:

- URL (Uniform Resource Locator)
- HTML (HyperText Markup Language)
- HTTP (HyperText Transfer Protocol)

URL

Known as **web address**.

All webpage can be refered by URL.

Its parts:

- Scheme (protocol)
- Domain name or IP address
- Port number
- Path and name of file on server
- Query string
- Fragment identifier (bookmark)

URL examples

- http://www.example.org:80/index.html?lang=eng#top
- http://www.unideb.hu
- ftp://152.66.115.246/.banner
- http://neptun.unideb.hu/?page=studhun
- https://hu-hu.facebook.com/login.php
- http://en.wikipedia.org/wiki/HTML#History
- mailto:varga.imre@inf.unideb.hu

Legend:

- Scheme
- Domain name
- Port
- Path
- Query
- Fragment ID

HTML

A desription language to create websites.

Standardized by W3C (World Wide Web Consortium).

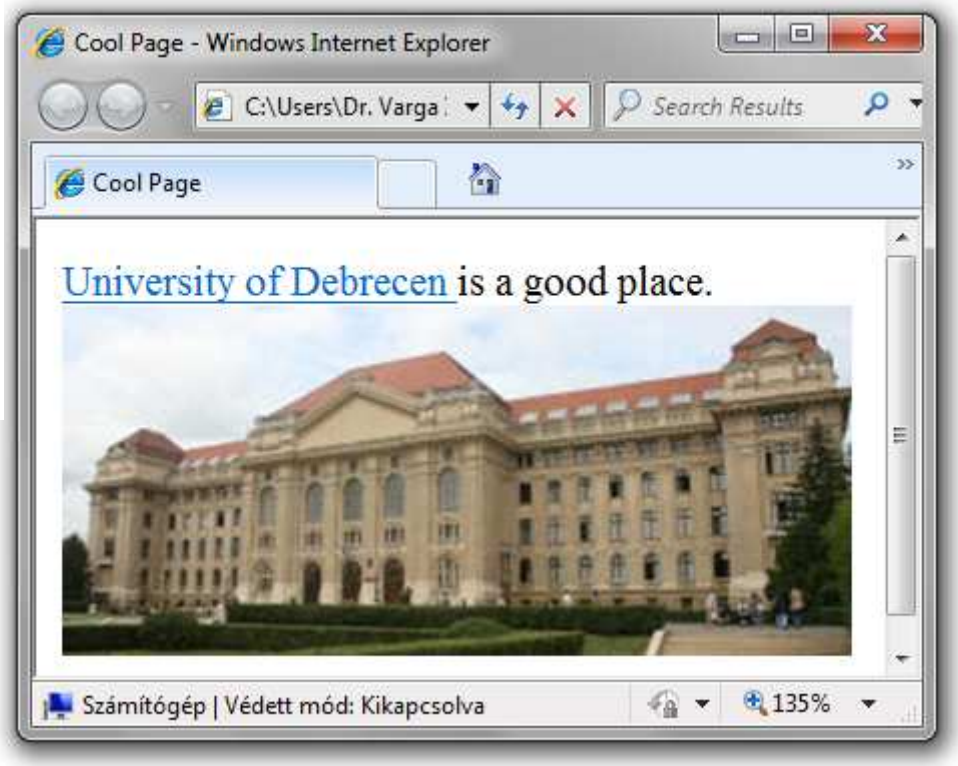
Websites are text-based files (contains only characters) which is represented (in visual form) by **browser**s.

Popular browsers:

- Internet Explorer
- Mozilla Firefox
- Google Chrome
- Netscape Navigator
- Opera
- Safari
- Konqueror
- etc.

Example HTML file

```
<html>
  <head>
    <title>
      Cool Page
    </title>
  </head>
  <body>
    <a href="http://www.unideb.hu">
       University of Debrecen
    </a>
    is a good place. </br>
   <img src="UD.jpg">
  </body>
</html>
```



Hyperlink

A (hyper)link is a reference to data that the reader can directly follow (by a click).

A hyperlink points to

- a whole website or an element within a page,
- different media (picture, audio, video).

Hypermedia is a media with hyperlink.

- Media can be text, picture or video.

Hyperlink based on URL.

Example:

```
<a href="http://www.google.hu"> Google </a>
```

HTTP

HTTP is a request-response (client-server) information transmission protocol of application layer.

Clinet: web browser which visualize web pages for user.

Server: computer (webserver) which stores webpages.

Usually it uses TCP connection (in Transport layer)

Safer solution: HTTPS (HTTP Secure)
HTTP over SSL/TLS protocol

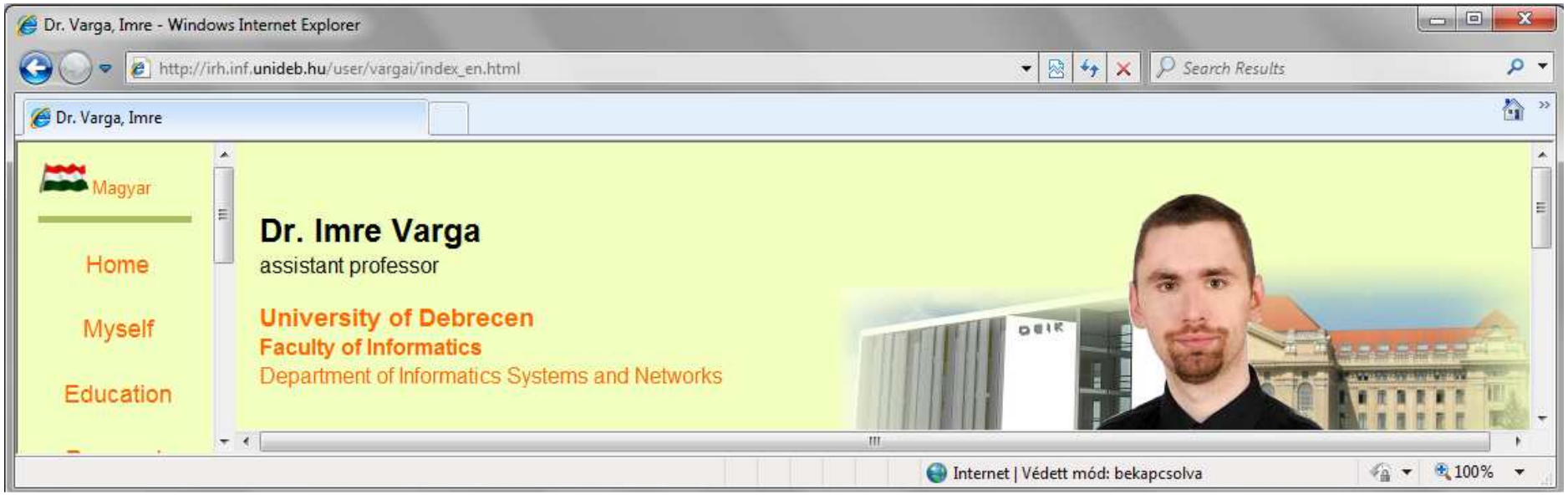
Browsing web

1. The user gives the URL in the address bar of browser.
2. The web browser determines the protocol from URL (eg. http://...).
3. It determines the (IP) address of web server from domain name in URL via DNS (eg. www.unideb.hu).
4. It builds up a session with web server (via TCP usually using port 80).
5. A request sent to HTTP server giving the name of the folder (and the HTML file) containing the web page (eg. /index.html).

Browsing web

6. The server responds the request by sending to client the text or other medias (pictures, sounds, clips, etc.) defined in the HTML page.

7. The browser (client) composes files, displays the web page to user, and closes the session.



HTTP Status Codes

- 1xx: Request received, continuing process.
- 2xx: Indicates the action requested by the client was received, accepted and processed successfully.
- 3xx: The client must take additional action to complete the request.
- 4xx: In cases when the client seems to have erred.
- 5xx: The server failed to fulfill a valid request.

Browsing in terminal

```
linux$> telnet  irh.inf.unideb.hu  80
Trying 193.6.135.80...
Connected to erlang.inf.unideb.hu.
Escape character is '^]'.
GET  /index.htm  HTTP/1.1
Host:  irh.inf.unideb.hu

HTTP/1.1  200  OK
Date: Wed, 12 Feb 2014 11:26:45 GMT
Server: Apache/2.2.17 (Fedora)
Last-Modified: Sun, 20 Jan 2013 11:22:30 GMT
ETag: "1440c6d-135d-4d3b68f634980"
Accept-Ranges: bytes
Content-Length: 4957
Connection: close
Content-Type: text/html; charset=iso-8859-1

<html><head>
  <title>DE IK IRH</title>  …
```

Command

Request

Reply header

Reply: requested page

E-mail

Electronic mail (E-mail, email, eMail)

A method of exchanging digital messages from an author to one or more recipients.

E-mail address:

local_part@domain_part

user@provider

E-mail contains 2 sections

- Header:

  It has several fields (sender, addresse, subject, …)

- Body:

  The ‘message’.

E-mail header fields

- From:
  Sender’s e-mail address
- To:
  The e-mail address(es) of the recipient(s)
- Subject:
  Topic of the message
- Date:
  The local time and date when the message was written
- Message-ID:
  Automatically generated to identify the message

E-mail header fields

- Cc:
  E-mail addresses who will get copies of message.
- Bcc:
  E-mail addresses of recipients who won't see eachother in the header of their message.
- Reply-To:
  Address that should be used to reply to the message.
- Content-Type:
  Information about how the message is to be displayed, usually a MIME type.
- and much more…

Body of e-mail

Originally it contains only characters (text).

Modern graphic email clients allow the use of either plain text or HTML.

Multipurpose Internet Mail Extensions (**MIME**) is an Internet standard that extends the format of email to support:

- Text in character sets other than ASCII (eg.: áíűŁäšş)
- Non-text attachments (jpg, pdf, mp3, avi)
- Message bodies with multiple parts

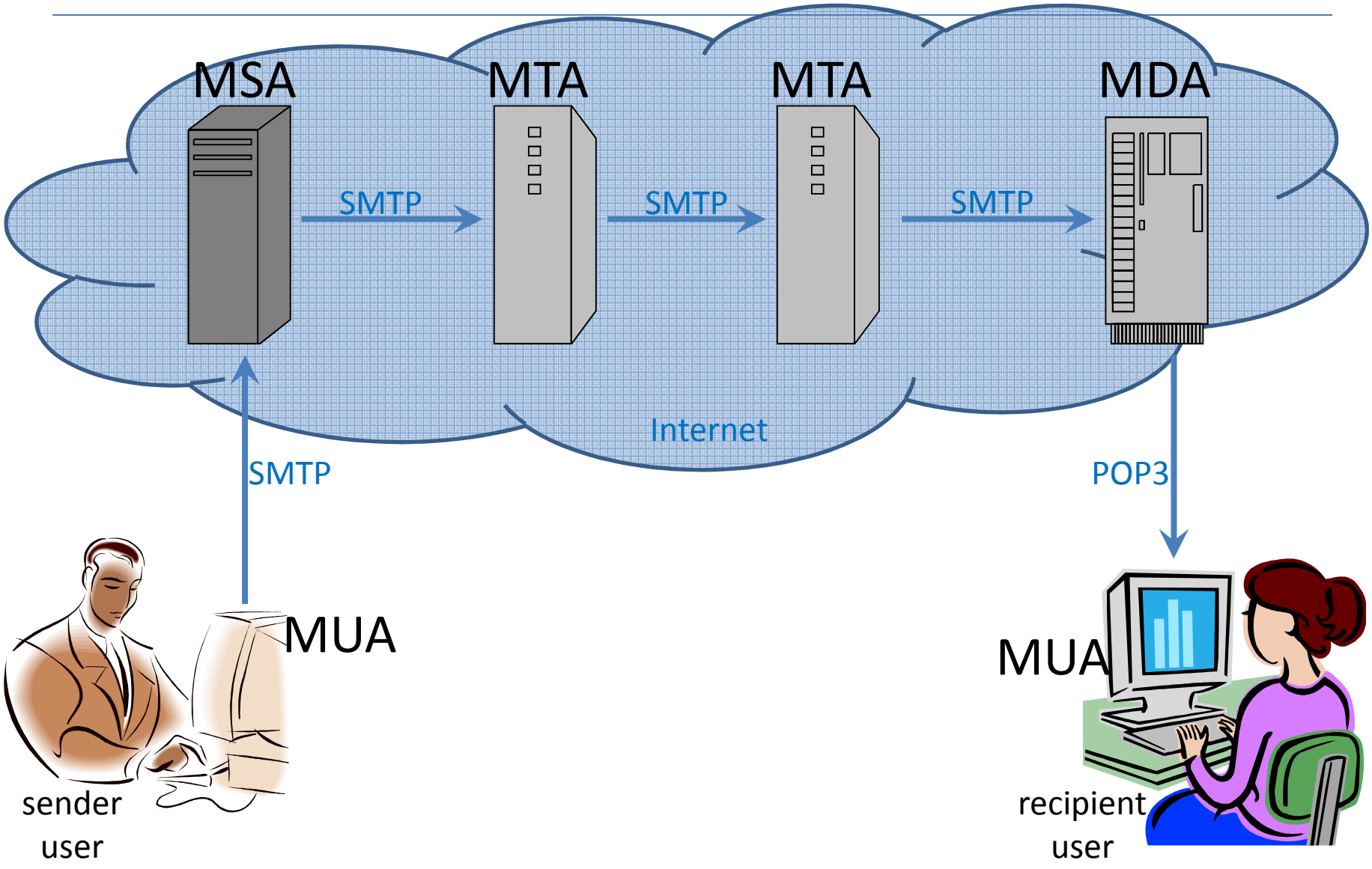
Mail servers and clients

- Programs used by users for managing e-mails are called Mail User Agents (MUA).
- MUA submit the e-mail to Mail Submission Agent (MSA) who will forward it.
- Messages are exchanged between hosts using the Simple Mail Transfer Protocol (SMTP) with software programs called Mail Transfer Agents (MTA).
- Messages are delivered to a mail store by programs called Mail Delivery Agents (MDA). Users can retrieve their messages from servers using standard protocols such as POP3 or IMAP.

Process of e-mailing

1. Sender composes the message and hits „Send” button.
2. Senders MUA formats the e-mail and sends it to MSA by SMTP.
3. MSA forwards the e-mail to recipients MDA (and perhaps to some internal MTA) by SMTP.
4. The MDA delivers e-mail to the recipients mailbox.
5. Recipient presses the "get mail" button in own MUA, which download the e-mail from MDA by POP3 or IMAP.

Process of e-mailing



FTP

- File Transfer Protocol
- Details in RFC 959
- Client-server architecture
- Down/upload files from/to servers
- 2 channels (Control & Data)
- FTP server codes (eg. 220 Service ready for new user.)
- Anonymous FTP
- Browsers support it
- Much popular solution is the peer-to-peer BitTorrent

FTP

Download the `rfc0959.txt` file which is in `documents/rfc` folder of `ftp.bme.hu` server!

- In browser: ftp://ftp.bme.hu/documents/rfc/rfc0959.txt
- In terminal:

```
linux$> ftp ftp.bme.hu
Name (ftp.bme.hu:user): anonymous
Password:
ftp> passive
ftp> cd documents/rfc
ftp> get rfc0959.txt
ftp> quit
```

Other parts of Application layer

- Remote login (telnet, ssh)
- Down/uploading files (scp, FTP, bittorent)
- Voice over IP (VoIP) (Skype, MSN)
- IPTV (UPC)
- Distributed databeses
- Online games
- etc.

Connect to HTTP server

```
linux$> telnet  irh.inf.unideb.hu  80
Trying 193.6.135.80...
Connected to erlang.inf.unideb.hu.
Escape character is '^]'.
GET  /index.htm  HTTP/1.1
Host:  irh.inf.unideb.hu

HTTP/1.1  200  OK
Date: Wed, 12 Feb 2014 11:26:45 GMT
Server: Apache/2.2.17 (Fedora)
Last-Modified: Sun, 20 Jan 2013 11:22:30 GMT
ETag: "1440c6d-135d-4d3b68f634980"
Accept-Ranges: bytes
Content-Length: 4957
Connection: close
Content-Type: text/html; charset=iso-8859-1

<html><head>
  <title>DE IK IRH</title>  …
```

Connect to POP3 server

```
linux$> telnet freemail.hu 110
Trying 195.228.245.1...
Connected to freemail.hu.
Escape character is '^]'.
+OK <6245.1392286988@freemail.hu>
USER proglabor
+OK
PASS proglabor
+OK
LIST
+OK
1 2442
2 12658
.
RETR 1
+OK
Message-ID: <df14a185b13857ef027324fdb8561cd.squirrel@mail.unideb.hu>
Subject: Important mail to you
From: "Dr. Varga Imre" <varga.imre@unideb.hu>
To: proglabor@freemail.hu

Dear Friend, …
```

Connect to SMTP server

```
linux$> telnet mail.server.com 25
Trying 193.6.138.45...
Connected to delfin.unideb.hu.
Escape character is '^]'.
220 delfin.unideb.hu ESMTP Postfix (Ubuntu)
helo mail
250 delfin.unideb.hu
mail from: nobody@nowhere.com
250 2.1.0 Ok
rcpt to: varga.imre@unideb.hu
250 2.1.0 Ok
data
354 Enter mail, end with "." on a line by itself
Subject: test

This is a test e-mail.
.
250 2.0.0 Message accepted for delivery
Connection closed by foreign host.
```

Connect to FTP server

Terminal 1 (Control channel)

```
linux$> telnet ftp.bme.hu 21
Trying 2001:738:2001:2001::c1ca...
Connected to ftp.bme.hu.
Escape character is '^]'.
220--- Welcome to Pure-FTPd ---
USER anonymous
331- Welcome to ftp.bme.hu FTP service.
PASS
230 Any password will work
EPSV
229 Extended Passive mode OK (|||62282|)
RETR ReadMe.txt
150 Accepted data connection
226-File successfully transferred
QUIT
221 Logout.
Connection closed by foreign host.
```

Terminal 2 (Data channel)

```
linux$> telnet ftp.bme.hu 62282
Trying 2001:738:2001:2001::c1ca...
Connected to ftp.bme.hu.
Escape character is '^]'.

This is the content of ReadMe.txt

Connection closed by foreign host
```

Network
setup & commands
on Windows

Network setup

4 necessary properties to use network on a computer:

- IP address
- Netmask
- Gateway
- DNS server

They are given by the Internet Service Provider (ISP).

Either the user do their setup or use DHCP (if possible).

The user can use ‘command-line’ or GUI (Graphical User Interface) to do setup process.

Network setup by Control Panel*

1. Go to Start Menu
2. ‘Control Panel’
3. ‘View network status and tasks’
   in ‘Network and Internet’ block
4. ‘Change adapter settings’
5. Right mouse click on the adapter, choose ‘Properties’
6. Choose ‘Internet Protocol Version 4 (TCP/IPv4)’ and push button ‘Properties’
7. Choose automatic configuration (DHCP) or give the four datas.

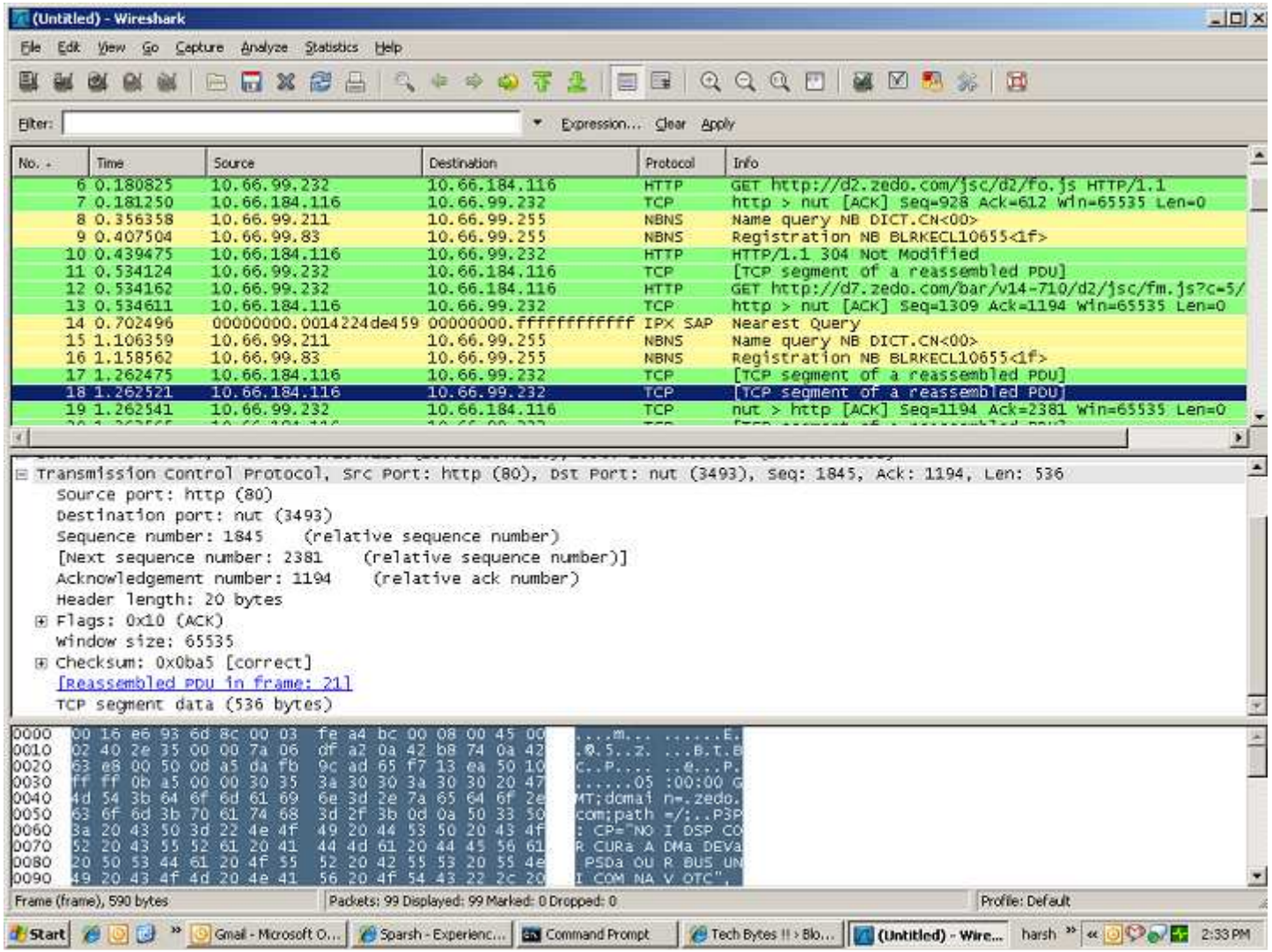
* on Windows 7 operating system

Useful network commands on Windows

- `ipconfig`: Shows the setups of network adapters.
- `ipconfig /all`: Shows the detailed setups of network adapters.
- `route print`: Shows the routing table of the computer.
- `ping <node>`: Check connection to other computers.
- `arp -a`: Shows ARP table.
- `tracert <node>`: Show the hops to a computer.
- `netstat -s`: Shows network statistics (IP, TCP, UDP).

Wireshark

- Free and open-source packet analyzer



References & further readings

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