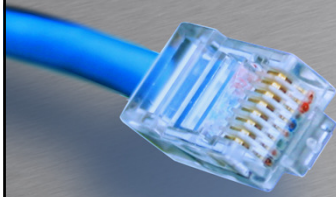# ascom

IP Training Programme

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Module 1: IP Generic
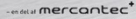## Session 1: Basic networking

---

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Basic Networking

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- Numeric systems and bits and Bytes.
- Ethernet (MAC Address etc.).
- The IP Address/Subnet mask.
- ARP: Binding the MAC and IP address together.
- Switching.
- VLAN.
- Default Gateway and basic Routing.
- Exercises during session:
  - Find your own MAC and IP address.
  - Commands: ipconfig, ping and traceroute.
- Virtual Learning Environment task:
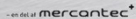 - Configuring static IP addresses, subnet masks and default gateways.

NUMERIC SYSTEMS
BITS AND BYTES

```
A fatal exception 0E has occurred at 0028:C0011E36 in VXD VMM(01)
00010E36. The current application will be terminated.

*  Press any key to terminate the current application.
*  Press CTRL+ALT+DEL again to restart your computer. You will
   lose any unsaved information in all applications.

                    Press any key to continue _
```

Numeric systems

- $B_{16} = 11_{10}$
  - 16 = hexadecimal
  - 10 = decimal
- $B_{16} = 1011_2$
- $A6_{16} = 10100110_2$
- $B6_{16} = 182_{10}$
  - $B_{16} = 11_{10}$
  - $6_{16} = 6_{10}$

$B6_{16} = 11_{10} \times 16_{10} + 6_{10} = 182_{10}$

Binary				decimal	Hexa-decimal
D	C	B	A		
0	0	0	0	0	0
0	0	0	1	1	1
0	0	1	0	2	2
0	0	1	1	3	3
0	1	0	0	4	4
0	1	0	1	5	5
0	1	1	0	6	6
0	1	1	1	7	7
1	0	0	0	8	8
1	0	0	1	9	9
1	0	1	0	10	A
1	0	1	1	11	B
1	1	0	0	12	C
1	1	0	1	13	D
1	1	1	0	14	E
1	1	1	1	15	F

Calculator

- Windows 7 calculator in programmer mode

Translating hex to binary

Binær				decimal	Hexa-decimal
D	C	B	A		
0	0	0	0	0	0
0	0	0	1	1	1
0	0	1	0	2	2
0	0	1	1	3	3
0	1	0	0	4	4
0	1	0	1	5	5
0	1	1	0	6	6
0	1	1	1	7	7
1	0	0	0	8	8
1	0	0	1	9	9
1	0	1	0	10	A
1	0	1	1	11	B
1	1	0	0	12	C
1	1	0	1	13	D
1	1	1	0	14	E
1	1	1	1	15	F

10A7:9CBA76F3

0001 0000 1010 0111 : 1001 1100 1011 1010 0111 0110 1111 0011

Storage capacity

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- One Byte is 8 bits
  - For example 10110111_2

- 1 KiloByte (KB) = 1.024 bytes = 2^{10} bytes
- 1 MegaByte (MB) = 1.048.576 bytes = 2^{20} bytes
- 1 GigaByte (GB) = 1.073.741.824 bytes = 2^{30} bytes
- 1 TeraByte (TB) = 1.099.511.627.776 bytes = 2^{40} bytes
- 1 PetaByte (PB) = 1.125.899.906.842.624 = 2^{50} bytes
- 1 exabyte (EB) = 1.152.921.504.606.846.976 bytes …..
- 1 zetabyte (ZB) = 1.180.591.620.717.411.303.424 bytes …
- 1 yottabyte (YB) = 1.208.925.819.614.629.174.706.176 …
- ….

Serial vs. parallel

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- Serial transmission: (One wire)
  - One bit is transferred at a time
  - Examples:
    - Ethernet
    - SATA (harddisk interface)
    - USB
- Parallel transmission: (Multiple wires)
  - Multiple bits are transferred at a time
  - Examples
    - 32 or 64 bit CPU

Transmission speeds

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- Measured in bits per second (bps)
- Or Bytes per second (Bps)
  - Note B = Byte and b = bit
  - 10 M**b**ps = 10 Mega **bits** per sekund
  - 10 **m**bps = 10 **milli** bits per sekund (slow)
- Ethernet speeds range from
  - 10 Mbps to 100 Gbps

Communications buzzwords

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- UNICAST:
  - Communications from One host to One host.
  - Like a telephone conversation
- MULTICAST:
  - Communications from One host to multiple hosts
  - Like a radiostation. One transmitter
- HALF DUPLEX:
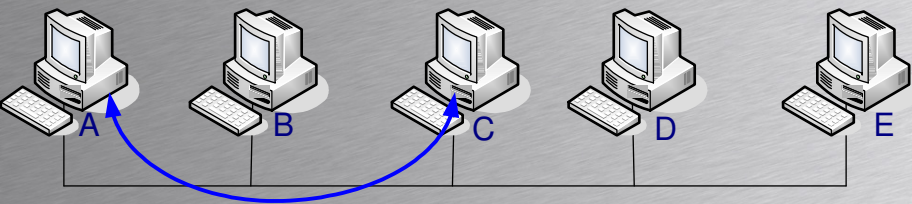 - Communications between two hosts

Communications buzzwords

- Unicast
- Multicast
- Broadcast
- Half and full duplex

Unicast

- **Unicast** transmission is the sending of messages to a single network destination identified by a unique address
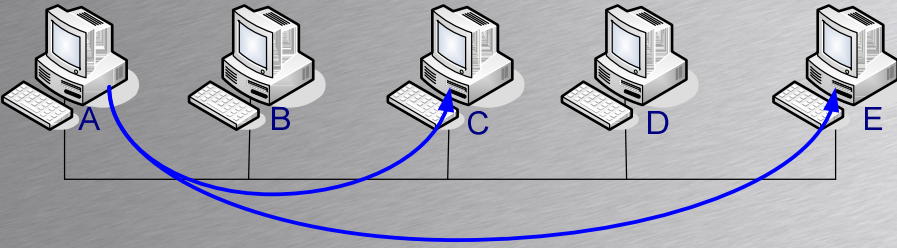
Multicast

- **Multicast** is the sending of a message to a group of destination computers simultaneously in a single transmission from the source
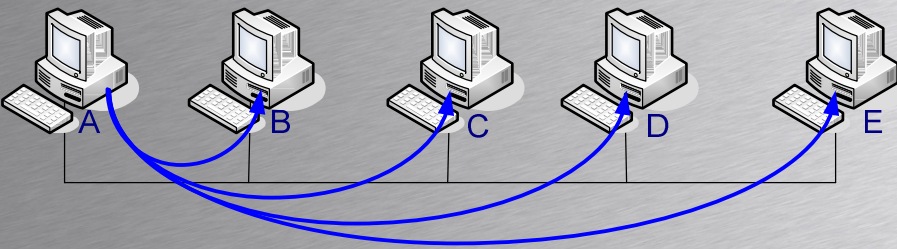

Broadcast

- Broadcast is the sending of a message to a all computers simultaneously in a single transmission from the source

Half duplex
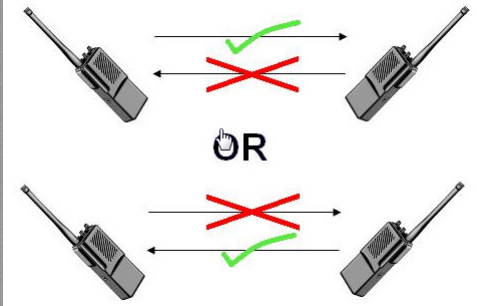
- A *half-duplex* (HDX) system provides communication in both directions but only one direction at a time
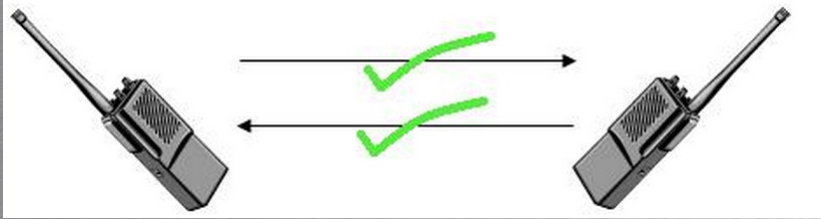 - (not simultaneously).
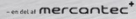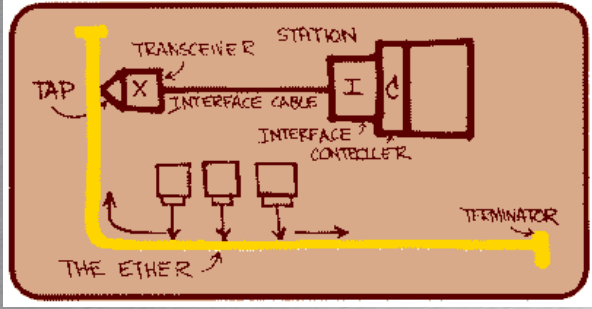

Full duplex

- A *full-duplex* (FDX) allows communication in both directions to happen simultaneously.

ETHERNET

Robert Metcalf's presentation of Ethernet in June 1976.

Ethernet

- Purpose of Ethernet:
  - To exchange digital information between connected stations.
  - Works within limited geographically areas.
    - LAN – Local Area Networks
    - Typically limited to 100 meters in diameter
  - High speed: 10 Mbps to 100 Gbps

Ethernet

- Purpose of Ethernet:
  - To exchange digital information between connected stations.
  - Stations addres each other with unique MAC Addresses (Usually written in hexadecimal)
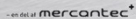   - E.g. 0010E2F11671 or 00-10-E2-F1-16-71

```
Command Prompt
C:\>ipconfig/all
Ethernet adapter Local Area Connection:

    Description . . . . . . . . . . . : Broadcom NetLink (
    Physical Address. . . . . . . . . : 00-21-86-A0-CE-84
    DHCP Enabled. . . . . . . . . . . : Yes
    IPv4 Address. . . . . . . . . . . : 192.168.1.14
```

MAC Address

- MAC addresses are administered by IEEE
- MAC addresses are 48 bits wide
  - Example of presentations of same address
    - Windows presentation: 00-10-F4-A3-10-41
    - UNIX/Linux presentation: 00:10:F4:A3:10:41
    - Cisco presentation: 0010.F4A3.1041
- MAC addresses are unique
  - Burned into hardware electronics

S/N: 3X6T84N9C2856
P/N: 080-396-001-R   REV: A11
MAC: 00-80-A3-8C-1B-90
Made In: China   Date: 0734

MAC Address

offset: 1 2 3 4 5 6

	6th byte	5th byte	4th byte	3rd byte	2nd byte	1st byte	
most significant	1st octet	2nd octet	3rd octet	4th octet	5th octet	6th octet	least significant

6 bytes

or

3 bytes	3 bytes
Organisationally Unique Identifier (OUI)	Network Interface Controller (NIC) Specific

8 bits

b8	b7	b6	b5	b4	b3	b2	b1

0: unicast
1: multicast

0: globally unique (OUI enforced)
1: locally administered

TCP/IP

The IP address (Version 4)

IP Version 4

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- The IPv4 address consists of 4 bytes (32 bit)
- Decimal dotted notation fx. 194.182.53.13
  – Dots between each 8 bit byte
  – Binary 11000010.10110110.00110101.00001101
- Each byte can be in the range from 0 to 255

$$255 = 11111111_2$$

```
Command Prompt
C:\>ipconfig
Ethernet adapter Local Area Connection:
   IPv4 Address. . . . . . . . . . . : 192.168.139.122
   Subnet Mask . . . . . . . . . . . : 255.255.255.0
   Default Gateway . . . . . . . . . : 192.168.139.1
```

The IP address

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- An IP address consists of two parts:
  – A logical network address
  – A host address

- Example: 169.16.32.45

Host address

Network address

The subnet mask

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- The subnet mask is used to split the IP address into a logical network and host part.
  - 255 indicates part of the network address
  - 0 indicates part of the host address

◉ Use the following IP address:

IP address:	172 . 16 . 0 . 100
Subnet mask:	255 . 255 . 0 . 0

- Logical network address: 172.16
- Host address: 0.100

The subnet mask

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◉ Use the following IP address:

IP address:	10 . 78 . 67 . 100
Subnet mask:	255 . 0 . 0 . 0

- Logical network address: 10
- Host address: 78.67.100

  - Or in other words. The host address is 78.67.100 and the host belongs to the logical network address 10

Physical vs. Logical

- A physical network is a number of hosts connected to a shared media where they can communicate with each other based on MAC addresses
  - E.g.
    - Hosts connected via ethernet hubs/switches.
    - Hosts connected to a wireless WiFi network
- A logical network is the network part of an IP address, as specified by the subnet mask.

IP connectivity

- All the hosts below can communicate with each other via IP packets because:
  - All hosts are on the same physical network
  - All hosts belong to the same logical network

| IP: | 194.182.53.10 |
| Subnet: | 255.255.255.0 |

A

| IP: | 194.182.53.11 |
| Subnet: | 255.255.255.0 |

B

| IP: | 194.182.53.12 |
| Subnet: | 255.255.255.0 |

C

| IP: | 194.182.53.13 |
| Subnet: | 255.255.255.0 |

D

IP connectivity

- Host B in the drawing below has no IP connectivity with the other hosts below.
  - All hosts are on the same physical network - but Host B belongs to another logical network.

IP: 194.182.53.10
Subnet: 255.255.255.0   A

IP: 194.182.52.11
Subnet: 255.255.255.0   B
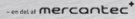
IP: 194.182.53.12
Subnet: 255.255.255.0   C

IP: 194.182.53.13
Subnet: 255.255.255.0   D

No router present to route packets between logical networks

The ping command

- Built in test function in IP
- Send IP test packet(s) to receiver
  - Commonly known as a ping packet
  - In technical terms called a echo request packet
- Receiver responds test packets
  - In daily terms called a pong packet
  - In technical terms called a echo reply packet
- Notice:
  - Firewalls often block ping packets.

The ping command

```
Command Prompt

C:\temp>ping 194.182.53.10

Pinging 194.182.53.10 with 32 bytes of data:
Reply from 194.182.53.10: bytes=32 time<1ms TTL=128
Reply from 194.182.53.10: bytes=32 time<1ms TTL=128
Reply from 194.182.53.10: bytes=32 time<1ms TTL=128
Reply from 194.182.53.10: bytes=32 time<1ms TTL=128

Ping statistics for 194.182.53.10:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 0ms, Average = 0ms
```

Network drawings

- The drawing below has a lot of numbers
- Hosts are on same physical network and must be on same logical network in order to communicate

IP: 194.182.53.10
Subnet: 255.255.255.0   **A**

IP: 194.182.53.11
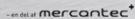Subnet 255.255.255.0   **B**

IP: 194.182.53.12
Subnet: 255.255.255.0   **C**
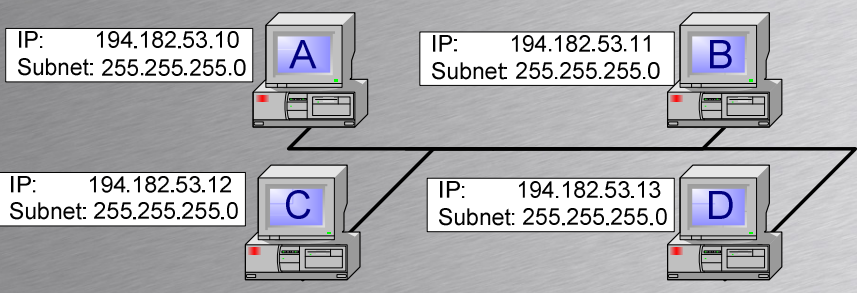
IP: 194.182.53.13
Subnet: 255.255.255.0   **D**

16

Logical network

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- Gathering the information.
- All hosts on the physical network belong to the same logical network.
  - Easier to understand and change

| 10 | A | | Logical network address | | 11 | B |

Network: 194.182.53.0
Subnet: 255.255.255.0

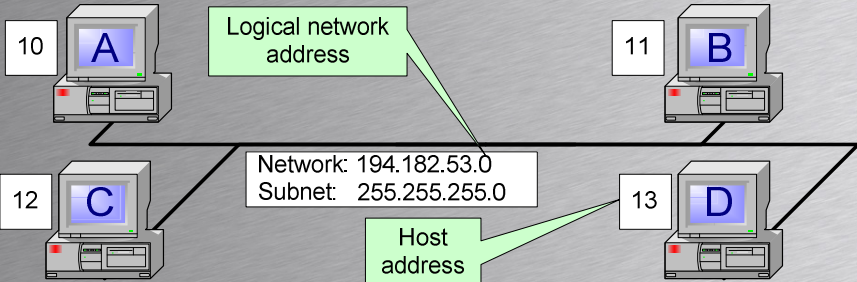| 12 | C | | Host address | | 13 | D |

The "easy" way

ascom

- The subnet mask is four bytes or 32 bits
  - For example 255.255.255.0
    - In binary 11111111.11111111.11111111.00000000
  - The first 24 bits are all ones

Net: 194.182.53.0
Subnet: 255.255.255.0   =   194.182.53/24

- This notation technique is called the prefix method

Prefix notation

- Gathering the information.
- All hosts on the physical network belong to the same logical network.
    - Easier to understand and change

10 A

Logical network including prefix /24 = 255.255.255.0

11 B

12 C

Network: 194.182.53.0/24

13 D

Host address

Prefix notation - examples

0.10 A

Logical network including prefix /16 = 255.255.0.0

18.11 B

8.12 C

Network: 172.16.0.0/16

78.13 D

Host address

0.1.10 A

Logical network including prefix /8 = 255.0.0.0

118.89.11 B

0.1.12 C

Network: 10.0.0.0/8

118.88.13 D

Host address

IP address classes

- Originally the IP address was divided in three unicast areas called Classes.

  - **Class A:** Huge networks
    - 16,7 million IP addresses
  - **Class B:** Big networks
    - 65536 IP addresses
  - **Class C:** Small networks
    - 256 IP addresses

IP address classes

- The value of the first byte indicates which class the IP address belongs to.
  - **Class A:**
    - The first byte is between 0 and 127
    - For example 13.56.89.225
  - **Class B:**
    - The first byte is between 128 and 191
    - For example 182.56.89.225
  - **Class C:**
    - The first byte is between 192 and 223
    - For example 201.56.89.225

Class examples

IP address 13.2.3.4

Class C address
194 is between 192 and 223

og

194.182.53.13

Class A address
13 is between 0 and 127

Subnet masks and classes

- Each class has its own subnet mask
  - **Class A:**
    - Subnet mask 255.0.0.0
  - **Class B:**
    - Subnet mask 255.255.0.0
  - **Class C:**
    - Subnet mask 255.255.255.0

IP Classes

Class	Purpose	First byte between	Subnet mask	Prefix	Max hosts
A	Unicast	0 and 127	255.0.0.0	/8	254
B	Unicast	128 and 191	255.255.0.0	/16	65.534
C	Unicast	192 and 223	255.255.255.0	/24	16.777.214

Additional classes

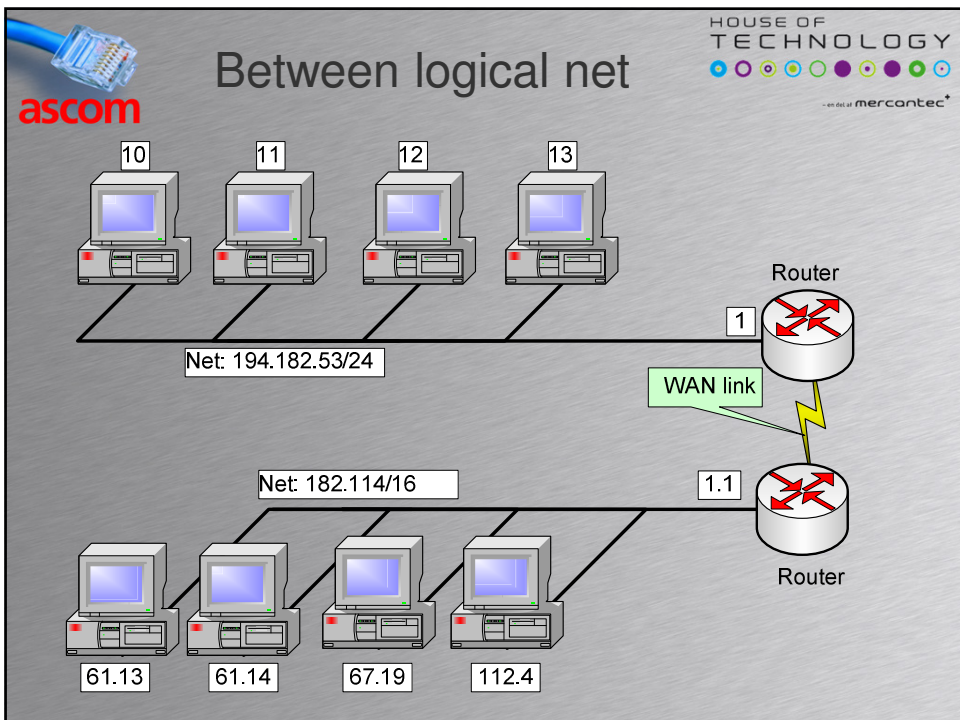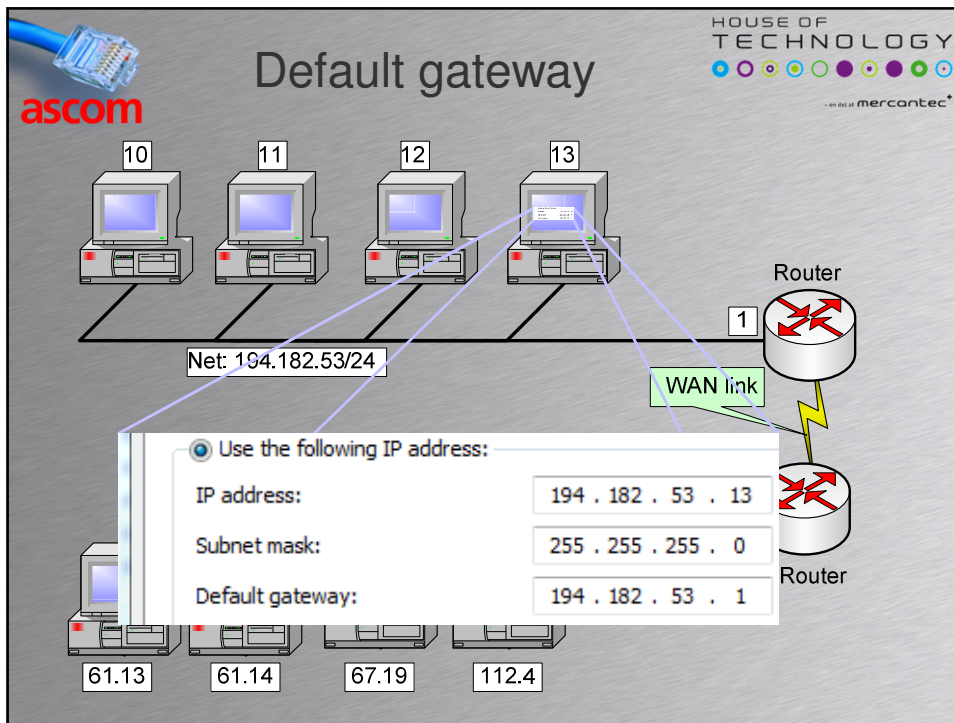| Class	Purpose	First byte between	Subnet mask	Prefix	Max hosts
D	Multicast	224 and 239	None special	None	–
E	Reserved	239 and 255	None	None	–

Unicast classes

- With the growth of the Internet, it was realized that dividing the IP unicast address space in three classes was inefficient.
- Today IP addresses are classless.
- All IP addresses can use all subnet masks
- The class concept however is still used

BASIC ROUTING

Between logical net

| 10 | 11 | 12 | 13 |

Router

1

Net: 194.182.53/24

WAN link

Net: 182.114/16   1.1

Router

| 61.13 | 61.14 | 67.19 | 112.4 |

Default gateway

Net: 194.182.53/24

Use the following IP address:

IP address: 194 . 182 . 53 . 13
Subnet mask: 255 . 255 . 255 . 0
Default gateway: 194 . 182 . 53 . 1

Router
WAN link
Router

10 11 12 13

61.13 61.14 67.19 112.4

The route table

- The route table is a list of all known logical networks the hosts know.
- If the hosts don't know a specific logical network, they will use the default gateway – if present.
  - Logical gateway is known as 0.0.0.0/0
    - 0.0.0.0/0 means all networks with all subnet masks

The route table

Net: 194.182.53/24

Router

WAN link

```
C:\temp>route print

Network Destination          Netmask          Gateway          Interface
        0.0.0.0              0.0.0.0       194.182.53.1      194.182.53.13
      127.0.0.1      255.255.255.255          On-link          127.0.0.1
    194.182.53.0        255.255.255.0          On-link      194.182.53.13
```
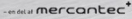

Understanding the route table

- Each line represents a known logical network

List of known logical networks

The subnet mask of each known logical subnet mask

Command to see the route table

Which interface to send the packets out of

```
C:\temp>route print

Network Destination          Netmask          Gateway          Interface
        0.0.0.0              0.0.0.0       194.182.53.1      194.182.53.13
      127.0.0.1      255.255.255.255          On-link          127.0.0.1
    194.182.53.0        255.255.255.0          On-link      194.182.53.13
```

The gateway (router) to send the packet to.
If not on-link (Same physical network)
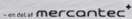
24

Understanding the route table

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```
Command Prompt

C:\temp>route print

Network Destination        Netmask          Gateway        Interface
          0.0.0.0          0.0.0.0      194.182.53.1    194.182.53.13
        127.0.0.1  255.255.255.255          On-link        127.0.0.1
     194.182.53.0    255.255.255.0          On-link    194.182.53.13
```

- If the host have to send a packet to the destination 194.182.53.67 it will search the route table and find two possible ways to the destination
  – 0.0.0.0/0 via 194.182.53.1 out of interface 194.182.53.13
  – 194.182.53.0/24 on-link out of interface 194.182.53.13
- It will choice the most specific route. The one with the best subnet mask. /24 is better than /0

Understanding the route table

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```
Command Prompt

C:\temp>route print

Network Destination        Netmask          Gateway        Interface
          0.0.0.0          0.0.0.0      194.182.53.1    194.182.53.13
        127.0.0.1  255.255.255.255          On-link        127.0.0.1
     194.182.53.0    255.255.255.0          On-link    194.182.53.13
```

- If the host have to send a packet to the destination 8.8.8.8 it will search the route table and find one possible way to the destination
  – 0.0.0.0/0 via 194.182.53.1 out of interface 194.182.53.13
- The packets to 8.8.8.8 will be send to the default gateway as 8.8.8.8 is on another logical network

IP Summary

- A host can send direct to other host on its own logical network
- To send to hosts on other logical network the host need to know a router.
  - A router is an intermediate device which passes packets on towards its destination.
- 172.16.0.0/16 is a class B net
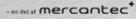 - Network: 172.16.0.0
  - Subnet mask: 255.255.0.0

ARP

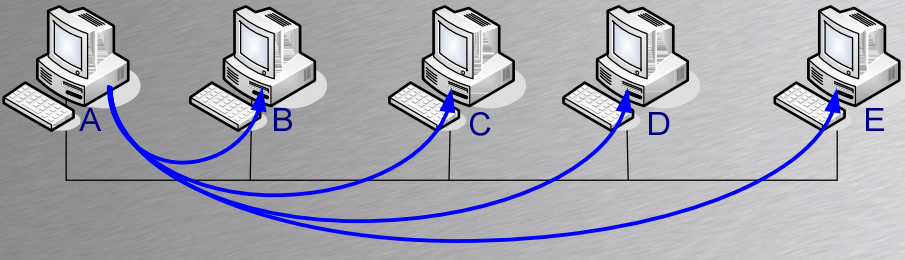Address Resolution Protocol

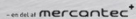Binding the MAC address and the IP address

```
C:\temp>arp -a

Interface: 194.182.53.13
  Internet Address      Physical Address      Type
  194.182.53.1          01-00-5e-7f-ff-fa     dynamic
  194.182.53.12         01-00-5e-7f-ff-fd     dynamic
  194.182.53.11         00-26-82-ed-47-38     dynamic
```
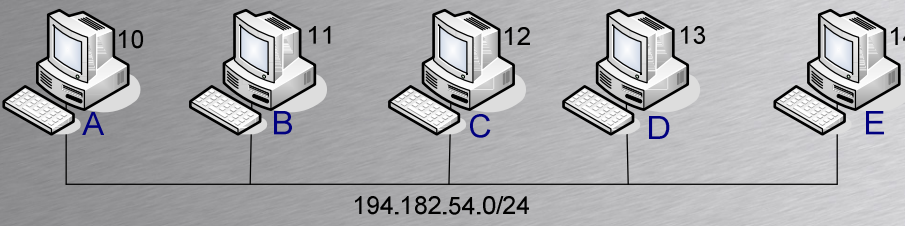
Broadcast

- Ethernet adapters listens for
  - Ethernet frames to its own MAC address
  - Frames to the MAC address FF-FF-FF-FF-FF-FF
- Sending frames to FF-FF-FF-FF-FF will be received by all adapters on the physical network

ARP

- To exchange unicast IP packets between two hosts the transmitting host need to know the MAC address of the receiving host.
- ARP (Address Resolution Protocol) is used to find the MAC address of a given hosts IP address.

194.182.54.0/24

ARP
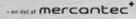
ascom

- If host E – 194.182.54.14 – wants to communicate with host B – 194.168.54.11 – it need to know its MAC address first.
- Host E broadcasts on the physical network
  - Who has the IP address 194.182.54.11 ??
  - Host B responds with its MAC address

10 A   11 B   12 C   13 D   14 E

194.182.54.0/24

Who has 194.18.54.11?

ARP

ascom

- If host E – 194.182.54.14 – wants to communicate with host B – 194.168.54.11 – it need to know its MAC address first.
- Host E broadcasts on the physical network
  - Who has the IP address 194.182.54.11 ??
  - Host B responds with its MAC address

10 A   11 B   12 C   13 D   14 E

194.182.54.0/24

I am 194.182.54.11
My MAC is 00-26-82-ED-47-38
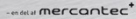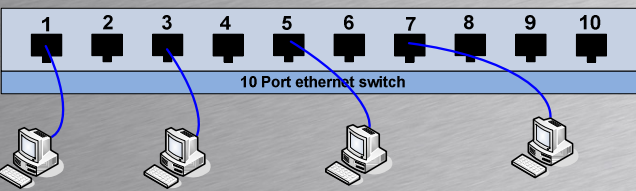
The ARP table

```
C:\temp>arp -a

Interface: 194.182.53.13
  Internet Address      Physical Address      Type
  194.182.53.1          01-00-5e-7f-ff-fa      dynamic
  194.182.53.12         01-00-5e-7f-ff-fd      dynamic
  194.182.53.11         00-26-82-ed-47-38      dynamic
```

194.182.54.0/24

I am 194.182.54.11
My MAC is 00-26-82-ED-47-38

ETHERNET SWITCHES

Ethernet switch

HOUSE OF
TECHNOLOGY

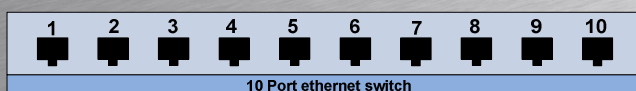**1 2 3 4 5 6 7 8 9 10**

10 Port ethernet switch

- The ethernet switch dynamically learns the connected stations MAC addresses.
  - By looking at the source MAC address in the ethernet frame of transmitted frames

Ethernet II Frame

Destination MAC Adresse	Source MAC Adresse	Type of packet	DATA	FCS Check
6 Bytes	6 Bytes	2 Bytes	46 - 1500 Bytes	4 Bytes

64 to 1518 Bytes

MAC address table

HOUSE OF
TECHNOLOGY

1 2 3 4 5 6 7 8 9 10

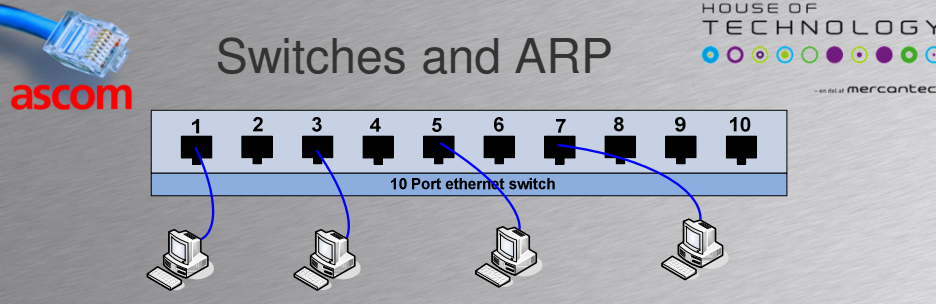10 Port ethernet switch

Assuming 10 connected hosts

```
mars.tekkom.dk - PuTTY

Switch# show mac address-table

      Mac Address        Ports
      -----------------  -------
      00-00-74-c2-56-08  Port 1
      00-0c-29-1c-b1-cd  Port 2
      00-13-e8-3d-32-7f  Port 3
      00-15-c5-45-3c-48  Port 4
      00-16-76-9f-fe-f6  Port 5
      00-18-18-1e-91-14  Port 6
      00-1a-6b-6a-a8-6a  Port 7
      00-1b-21-52-91-7d  Port 8
      00-1b-21-75-57-11  Port 9
      00-1c-bf-0e-79-a9  Port 10
Switch#
```
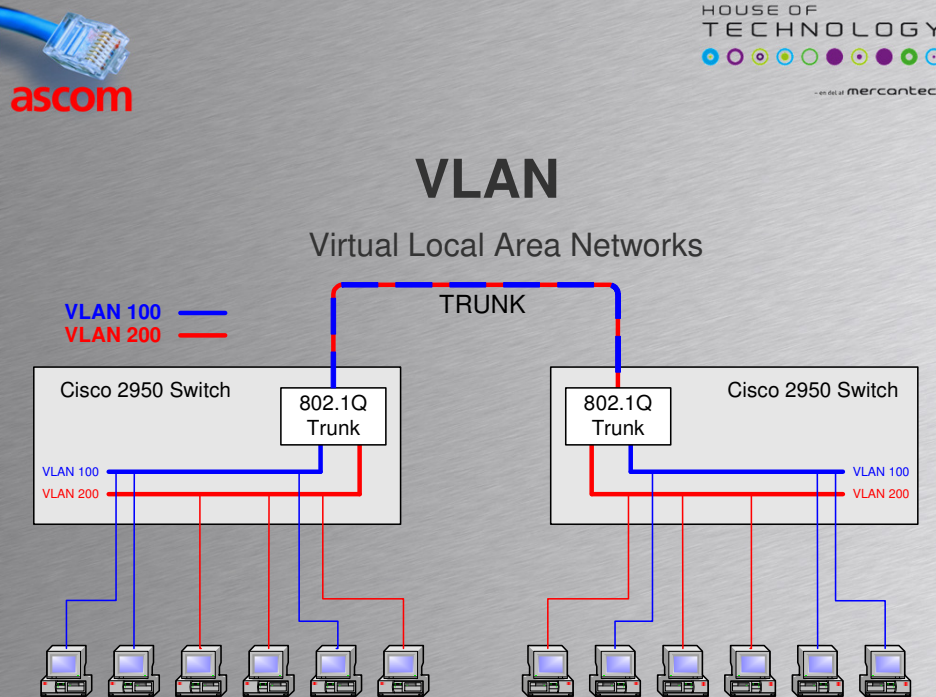
Switches and ARP

- If a switch receives a frame to the broadcast MAC address FF-FF-FF-FF-FF-FF
  - The switch will broadcast the frame to all ports except the one the frame was received on

VLAN

Virtual Local Area Networks
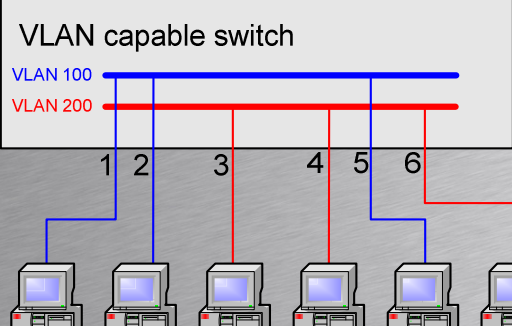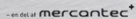
VLAN's

- Virtual Local Area Networks or VLAN's is spliting a switch in two or more seperate sections.
  – One big switch configured as two or more small.

VLAN capable switch
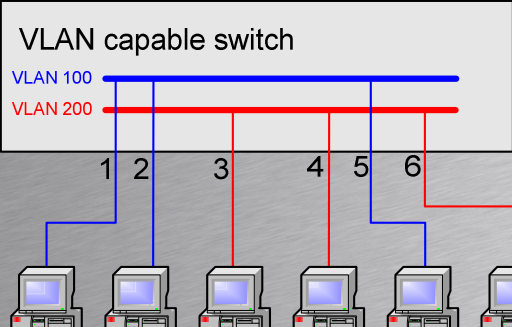
VLAN 100
VLAN 200

1 2   3   4 5 6

VLAN's

- Each port configured to be in a specific VLAN
  – Port 1,2 and 5 are in VLAN 100
  – Port 3,4 and 6 are in VLAN 200

VLAN capable switch

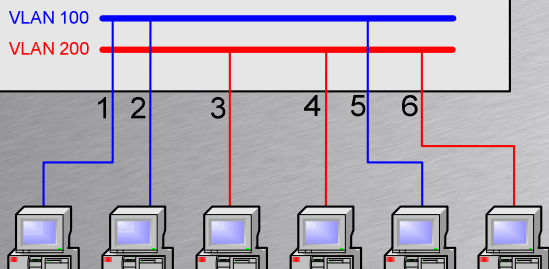VLAN 100
VLAN 200

1 2   3   4 5 6

VLAN's

- All stations in VLAN 100 can communicate.
- All stations in VLAN 200 can communicate.
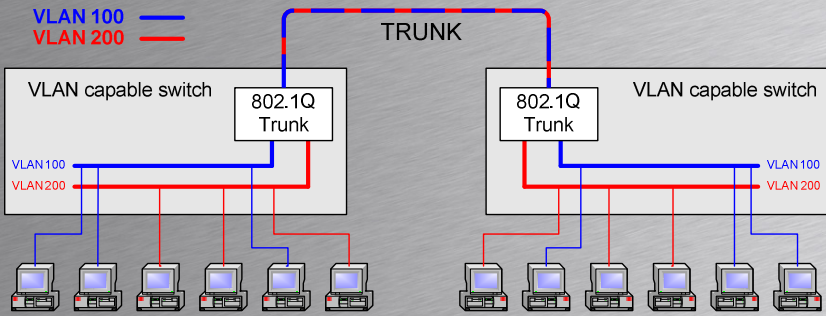- There is no communication between VLAN 100 and VLAN 200

VLAN trunk

- Some switch ports can be configured as trunks
- Trunks cary traffic from one or more VLAN's
  - The two switches in the drawing below are connected with a trunk.

VLAN trunk

HOUSE OF
TECHNOLOGY
– en del af mercantec

- All stations in both VLAN's can communicate
  - The trunk carries VLAN traffic between switches
- There is no communication between VLAN 100 and VLAN 200 in the drawing below.

VLAN 100
VLAN 200

TRUNK

VLAN capable switch

802.1Q
Trunk

802.1Q
Trunk

VLAN capable switch

VLAN100
VLAN200

VLAN100
VLAN 200