Course: Computer Networks
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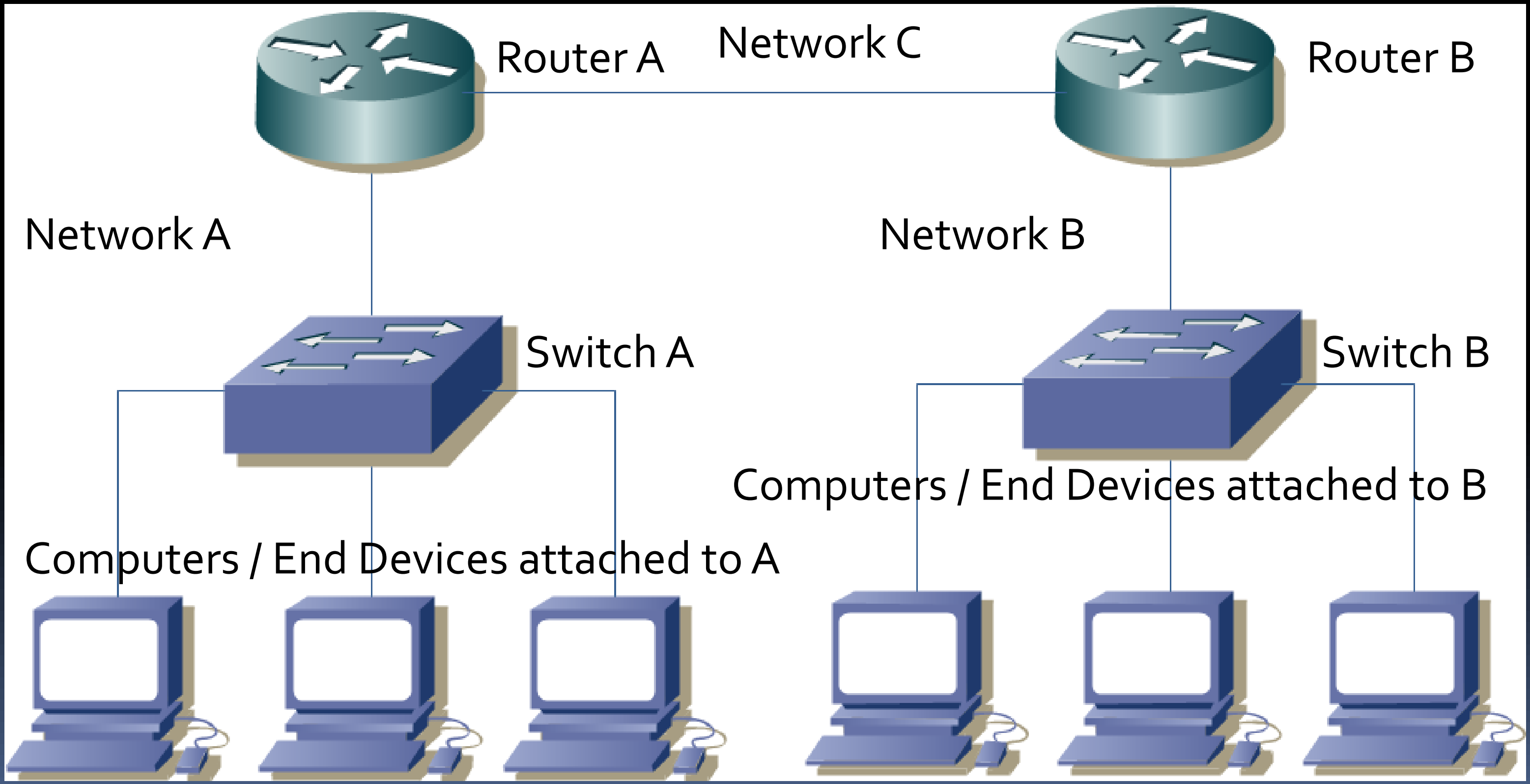
IP ADDRESSING AND NUMERAL SYSTEMS

IP Addressing

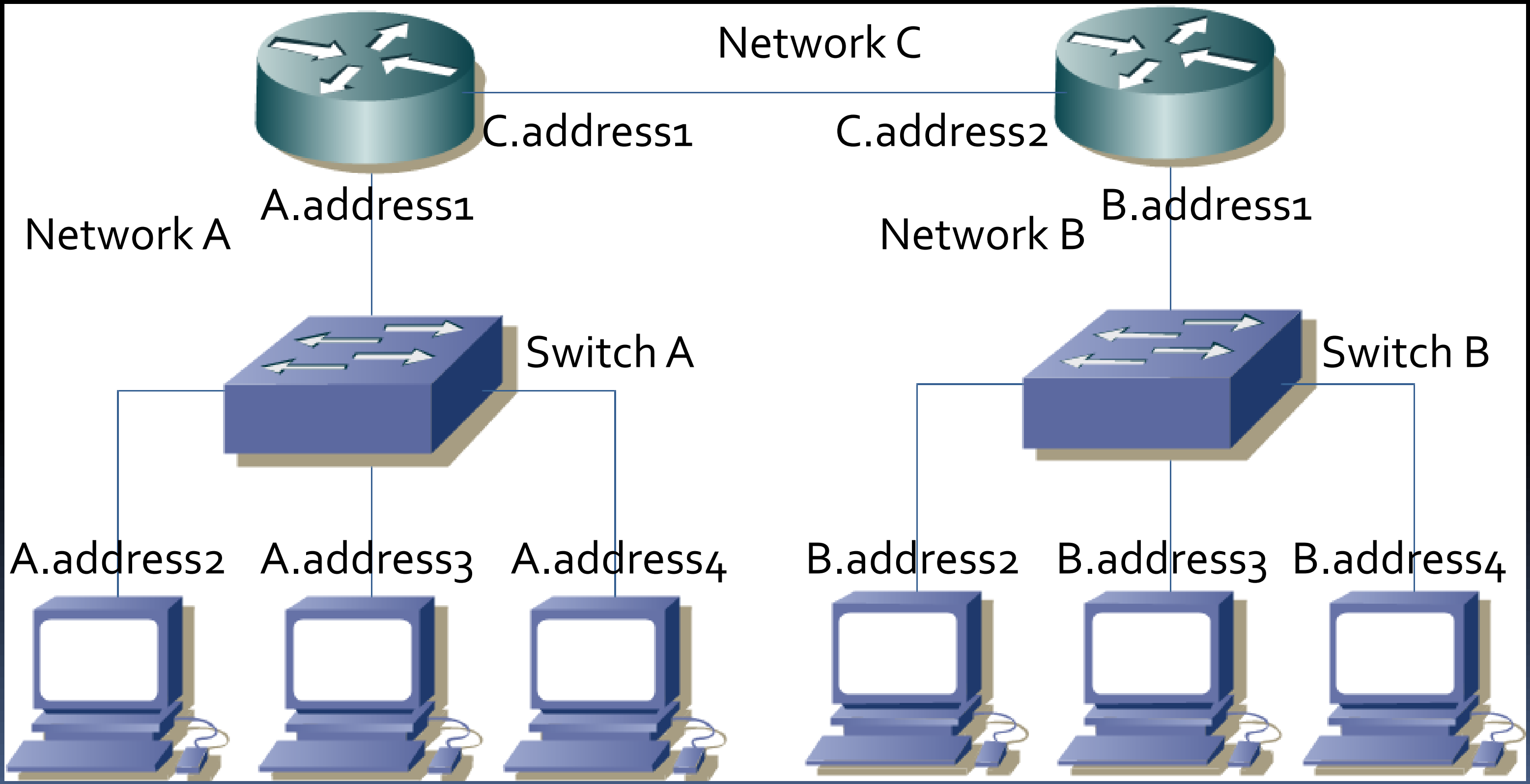
- Layer 2 / MAC address
  - Physically burned into the NIC
  - Doesn’t change
  - The devices ”real identity”
- Layer 3 / Internet Protocol address
  - Also called logical address
  - Set with software
  - Usually changing over time.

IP Addressing



IP Addressing our network

- We must address our devices correctly in order for them to find each other and communicate over the network.
- Addresses on Network A will start with A and addresses on Network B will start with a B. Same goes for Network C.
- Interfaces (ports where you connect the cable) from the devices will be configured accordingly.
- On the computers we'll have to configure the Network Interface Cards (NICs) for Network A or B.
- On the routers, we configure the interfaces connecting to the Networks A and C on Router A - B andC on router B.



Interpreting symbols and characters

- 0
- 10
- 10 bin
- = 2
- 10 dec
- = 10
- 10 hex
- = 16

Numeral systems

- Three numeral systems are of most interest in networking
  - Decimal (base 10)
    - 0,1,2,3,4,5,6,7,8,9
  - Binary (base 2)
    - 0,1
  - Hexadecimal (base 16)
    - 0,1,2,3,4,5,6,7,8,9,A,B,C,D,E,F

Counting with powers of

- What is…
- 3 to the power of 2?
  - 3^2 = 3*3
  - = 9

Counting with powers of

3 to the power of	3	2	1	0
	3^3	3^2	3^1	3^0
Is the same as	3*3*3	3*3	3	1
Equals	27	9	3	1
	---------------→	27/3=9	9/3=3	3/3=1

❖Logical explanation why x^0 equals 1:

In this case:

❖Each step to the left is multiplied by 3.

❖Each step to the right is divided by 3.

Positional Systems - Decimal

- Positions – decimal . Values in each position ranging from 0-9.
- Count with powers of the base. DEC = 10.

Position #	**3**	**2**	**1**	**0**
Value x	6	0	3	0
(10^#)*x	(10*10*10*)*6	(10*10)*0	(10)*3	(10^0)*0
Equals (in dec)	1000*6=6000	100*0=0	10*3=30	1*0=0

Adding	**6000 +**	**0 +**	**30 +**	**0 =**
			Sum	6030

Positional Systems - Binary

- Positions – binary. Values in each position ranging from 0-1.
- Count with powers of the base. BIN = 2.

Position #	**3**	**2**	**1**	**0**
Value x	1	0	1	0
(2^#)*x	(2*2*2)*1	(2*2)*0	(2)*1	(2^0)*0
Equals (in dec)	8*1=8	4*0=0	2*1=2	1*0=0

Adding	**8 +**	**0 +**	**2 +**	**0 =**
			Sum	10

Positional Systems - Hexadecimal

- Positions – hexadecimal. Values in each position ranging from 0-F.
- Count with powers of the base. HEX = 16.

Position #	3	2	1	0
Value x	0	A	3	C
(16^#)*x	(16*16*16*)*0	(16*16)*A	(16)*3	(16^0)*C
Equals (in dec)	4096*0=0	256*10=2560	16*3=48	1*12=12

Adding	0 +	2560 +	48 +	12 =
			Sum	2620

Comparison: DEC – BIN - HEX

#	3	2	1	0		Equals (in dec)
dec (10^#)*	0	1	0	0	=10*10*1	100
bin (2^#) *	0	1	0	0	=2*2*1	4
hex (16^#) *	0	1	0	0	=16*16*1	256

Binary

Position #	7	6	5	4	3	2	1	0
Value	1	1	1	1	1	1	1	1
(2^#) * 0 or 1	(2^7)*1	(2^6)*1	(2^5)*1	(2^4)*1	(2^3)*1	(2^2)*1	(2^1)*1	(2^0)*1
Equals (in dec)	128	64	32	16	8	4	2	1

Working with binary. We will always get either zero or a fix value depending on whitch position is occupied by a 1.
Example: If we have a 1 in position 7, that will always mean we have a value of 128 represented (in decimal notation).

Try to memorize 128 – 64 – 32 – 16 – 8 – 4 – 2 – 1.
It will be helpfull and speed up various situations working with computer networks.

Binary - memorize

7	6	5	4	3	2	1	0
1	1	1	1	1	1	1	1
128	64	32	16	8	4	2	1

BIN – 8 bits, one byte of information.

Position #	7	6	5	4	3	2	1	0
Value	1	1	1	1	1	1	1	1
(2^#) * 0 or 1	(2^7)*1	(2^6)*1	(2^5)*1	(2^4)*1	(2^3)*1	(2^2)*1	(2^1)*1	(2^0)*1
Equals (in dec)	128	64	32	16	8	4	2	1

Having all positions occupied by 1-bits would give us:

128	64	32	16	8	4	2	1	=255

You can use 2 ^ N to calculate the maximum amount of values for N amount of bits.
2^N (N=8)
=2^8=256
Values are (0-255)

Working with Binary

128	64	32	16	8	4	2	1

bin

1	1	0	0	0	0	0	0

Converted to dec

128	64	0	0	0	0	0	0

=192

Working with Binary

128	64	32	16	8	4	2	1

bin

0	0	1	0	1	0	1	1

Converted to dec

0	0	32	0	8	0	2	1

=43

Hexadecimal - Repetition

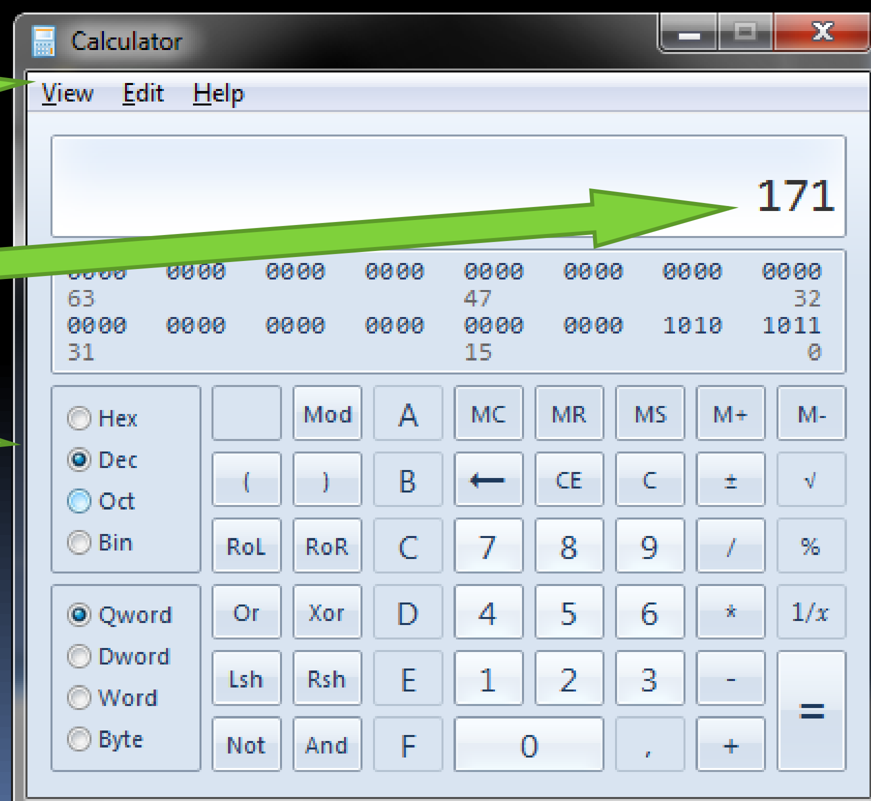
- What values in hex?
- 0-9 and A-F representing 10-15.
- Base of 16.
  - – Check back on slide *"Positional Systems – Hexadecimal"* if needed.

HEX (which position…?)	DEC
12	?
A2	?
11C	?

HEX	DEC
12	(16*1)+(1*2)= 18
A2	(16*10)+(1*2) = 162
11C	(16*16*1)+(16*1)+(1*12)= 284

Practice conversion – check result with calculator

- View Scientific/ Programmer
- Type in a value
- Shift between HEX DEC BIN
- Heads up though…
  - You will need to be able to calculate basic operations without the calculator.



IP-addressing

- Now that you are familiar with the numeral systems, let us look at how we use binary numbers in the IPv4 protocol.

BIN	11000000	10101000	00000001	00000001
DEC	192	168	1	1

Address Example

- IPv4 is using 32 bits for addresses.
- The 32 bits are divided into four parts concisting of 8 bits each.
  - Each part called an ”octet”.
    - (Equals one byte of information)

IP-addressing
Network – Host portion

- IP-addresses are divided into two portions.
- One network number portion – starting from the left.
- One host number portion – starting from the right.

	NET	NET	NET	HOST
BIN	11000000	10101000	00000001	00000001
DEC	192	168	1	1

Address Example

Comparable to:

Address	Halmstad University | Box 823 | S-301 18 Halmstad, Sweden	Philip Heimer

How many different host addresses from one octet?

- Do you remember:
  - *"You can use 2 ^ N to calculate the maximum amount of values for N amount of bits"* – in this case values=host addresses.

	NET	NET	NET	HOST
BIN	11000000	10101000	00000001	00000001
DEC	192	168	1	1

Address Example

2^8 (bits)=256
Addresses ranging from: 0 – 255
254 of those can be used for addressing hosts (devices) because:

The first address is reserved as "Network-ID". In this case: 192.168.1.0
Last address reserved as "Broadcast address". In this case: 192.168.1.255
The addresses 1-254 may be used by hosts on this network.

How many different host addresses from two octets?

- Do you remember:
  - *"You can use 2 ^ N to calculate the maximum amount of values for N amount of bits"* – in this case values=host addresses.

	NET	NET	HOST	HOST
BIN	11000000	10101000	00000000	00000000
DEC	172	16	0	0

Address Example

2^16 (bits)=65536 addresses total
65536-2 = 65534 addresses can be used for hosts.

First address reserved as "Network-ID". In this case: 172.16.0.0
Last address reserved as "Broadcast address". In this case: 172.16.255.255
The addresses 172.16.0.1 - 172.16.255.254 may be used by hosts on this network.

Network ID

- All zeros in the host portion of the address

	NET	NET	HOST	HOST
BIN	11000000	10101000	00000000	00000000
DEC	172	16	0	0

Address Example: *Network-ID*

- Network IDs cannot be used as an address for any device that is attached to the network
- Host on a network can only communicate directly with devices if they have the same network ID
- Routers use the network ID when it forwards data on the Internet

Broadcast Address

- All ones in the host portion of the address

	NET	NET	HOST	HOST
BIN	11000000	10101000	11111111	11111111
DEC	172	16	255	255

Address Example: *Broadcast Address*

- Broadcast addresses cannot be used as an address for any device that is attached to the network
- Used to send data to all devices on the network
- All devices pay attention to a broadcast

IP Address Classes Once upon a time...

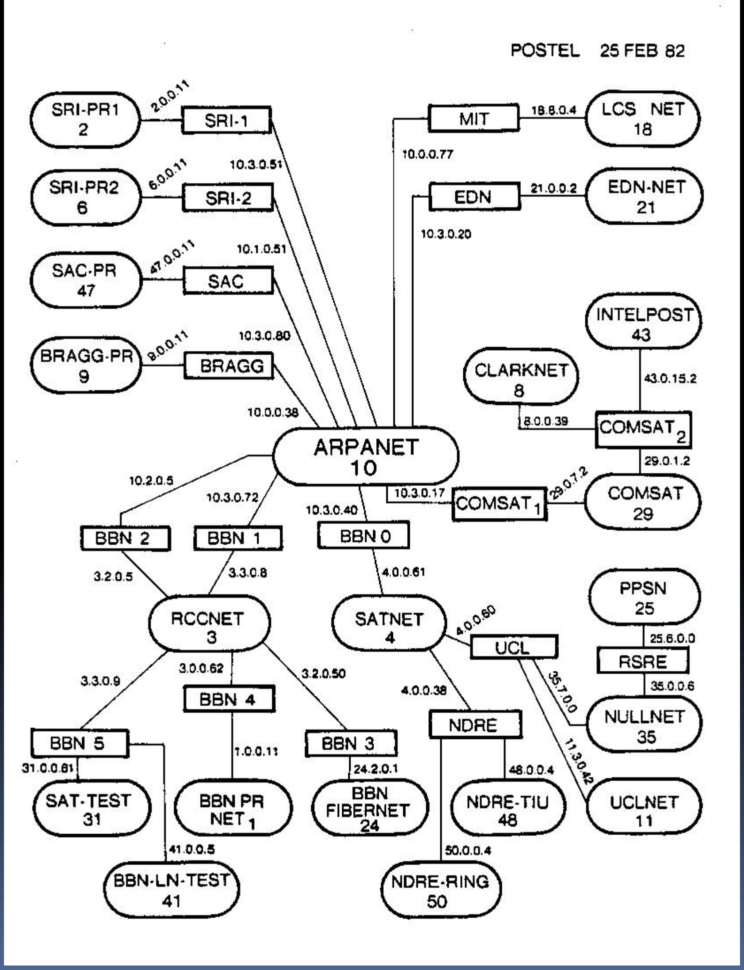
- ... we only used the first octet for network addressing.

- This format was sufficient at a time when only a few large networks existed, such as the ARPANET which was assigned the network number 10, and before the wide proliferation of local area networks (LANs). As a consequence of this architecture, the address space supported only a low number (254) of independent networks, and it became clear very early on that this would not be enough.

  - Description: Map of the prototype Internet in 1982, showing 8-bit-numbered networks (ovals) only, interconnected by routers (rectangles).

ARPANET

(**Advanced Research Projects Agency Network**)



IP Address Classes

- "A **classful network** is a network architecture used in the Internet until around 1993. It divides the address space for Internet Protocol Version 4 (IPv4) into five address classes."
- A B C D E
  - A B C are used for addressing devices
  - D for multicasting
  - E for experimenting
- Class A using one octet for network addressing
- Class B using two octets for network addressing
- Class C using three octets for network addressing

IP Address Classes

CLASS	RANGE (Network-IDs)	MAX NETWORKS	MAX HOSTS
A	0.0.0.0 – 127.0.0.0	128 or 2^7	16M or 2^24
B	128.0.0.0 – 191.255.0.0	16,3k or 2^14	64k or 2^16
C	192.0.0.0 – 223.255.255.0	2M or 2^21	256 or 2^8
D	224.0.0.0 – 239.255.255.255	N/A	N/A
E	250.0.0.0 – 255.255.255.255	N/A	N/A

Example:
Class A Address
10.0.0.0

	NET	HOST	HOST	HOST
BIN	00001010	00000000	00000000	00000000
DEC	10	0	0	0

Example:
Class B Address
172.16.0.0

	NET	NET	HOST	HOST
BIN	10101100	00010000	00000000	00000000
DEC	172	16	0	0

Example Class C

Example:
Class C Address
192.168.1.0

	NET	NET	NET	HOST
BIN	11000000	10101000	00000001	00000000
DEC	192	168	1	0

Which part of this address is the network?

- Ok, lets say we have a device, a host, with IP-address: 125.1.3.6
- Which part of this address is the network?
  - 125.1.3.6
- We can determine that this address is within the class A –range.
  - Class A – using first octet for network addressing

CLASS	OCTETS USED	RANGE (Network-IDs)
A	1	0.0.0.0 – 127.0.0.0
B	2	128.0.0.0 – 191.255.0.0
C	3	192.0.0.0 – 223.255.255.0
D	-	224.0.0.0 – 239.255.255.255
E	-	250.0.0.0 – 255.255.255.255

Subnet Mask

- Now, with all network-addresses being used, a subnet mask is sent along to let devices understand which part is the network.
- A subnet mask represents the network part by ones, and the host part by zeros.

	NET	NET	NET	HOST
ADD BIN	11000000	10101000	00000001	00000000
ADD DEC	192	168	1	0
SUB MASK BIN	11111111	11111111	11111111	00000000
SUB MASK DEC	255	255	255	0

A class C address using 3 octets or 24 bits to address the network

Subnet Mask

- The Network part is 192.168.1
- The Subnet mask is 255.255.255.0
- The Network-ID using this mask would be?
- 192.168.1.0

	NET	NET	NET	HOST
ADD BIN	11000000	10101000	00000001	00000000
ADD DEC	192	168	1	0
SUB MASK BIN	11111111	11111111	11111111	00000000
SUB MASK DEC	255	255	255	0

A class C address using 3 octets or 24 bits to address the network

You will see prefix notation used to define a Subnet Mask

Prefix: /8 (8 bits used) - Default Subnet Mask Class A

NET	HOST	HOST	HOST
255	0	0	0

Example address 10.0.0.1 /8

Prefix: /16 (16 bits used) - Default Subnet Mask Class B

NET	NET	HOST	HOST
255	255	0	0

Example address 172.16.13.5 /16

Prefix: /24 (24 bits used) - Default Subnet Mask Class C

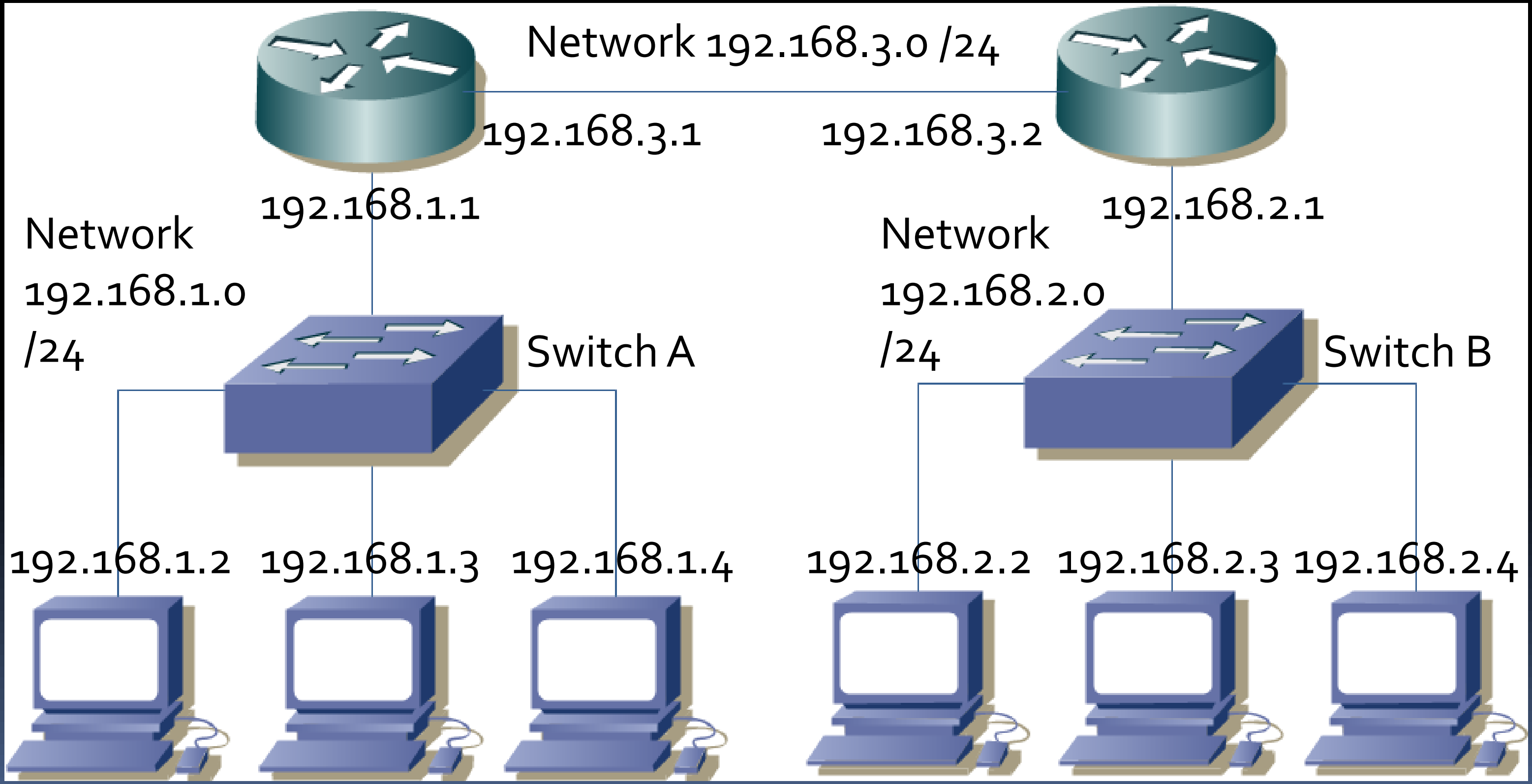
NET	NET	NET	HOST
255	255	255	0

Example address 192.168.1.3 /24

**Prefix notation, alternately referred to as CIDR notation or Slash notation*

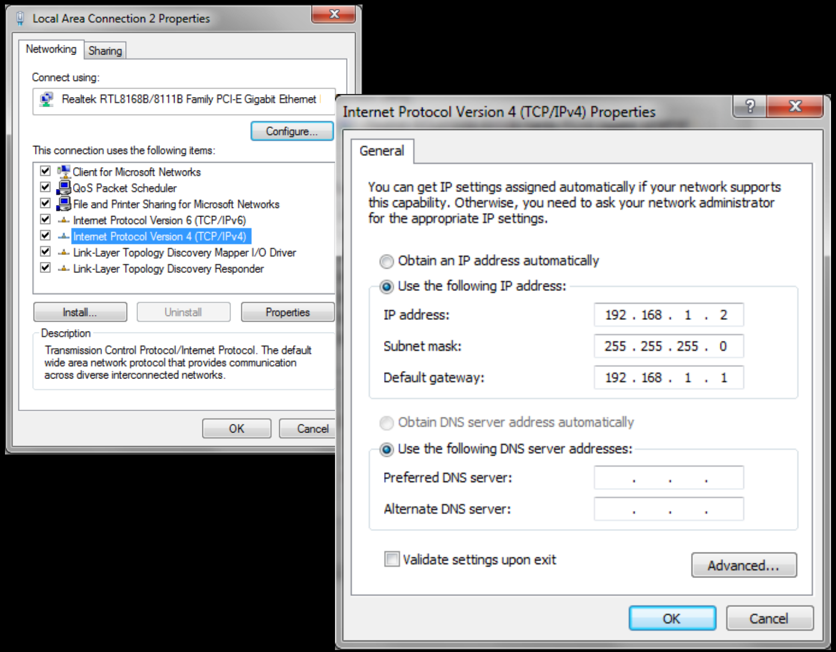
IP Addressing

- This time with real IP addresses.
- We assign free host-addresses to the interfaces.
- Start by assigning the first free addresses of the network to the interfaces of the routers in order to ”create” the networks. Then continue with the other devices.
- Make sure you get this, or repeat all the previous slides in vain.



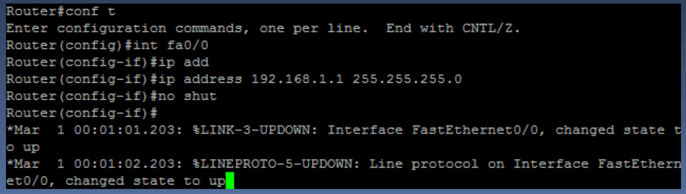
Configuring Interfaces

- Computer
  - Windows 7 –
    - Control Panel
      - Network and Internet
        - Network Connections



- Router
  - Configure ip address settings on an interface using the Command Line Interface (CLI).
    - Use Hyper Terminal or Terra Term

The CLI



To save IPv4 Addresses, we have...

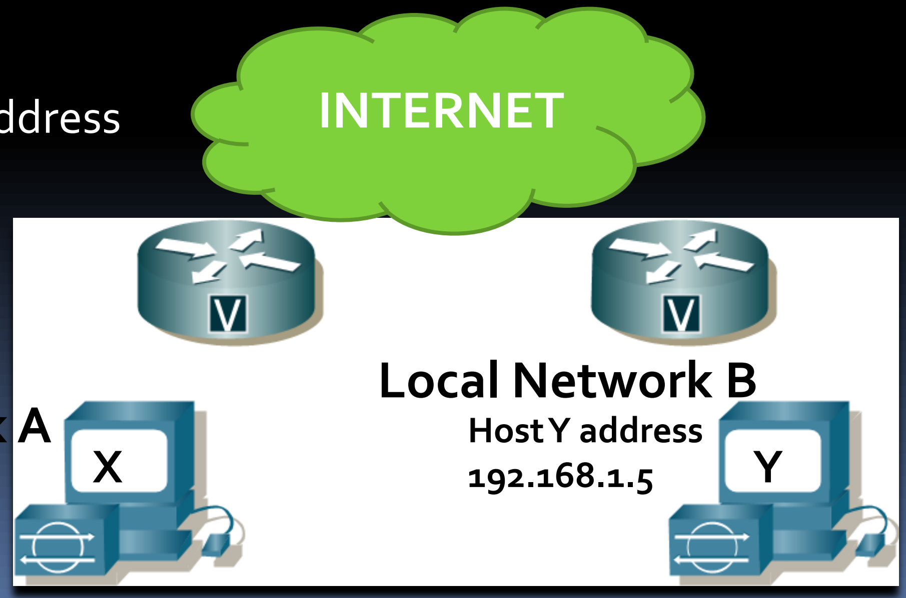
- Been using private addresses that may not be used on the Internet.
  - Private addresses are used for devices inside networks and translated to a public address once a device must communicate over the Internet.
  - This means that devices only communicating inside a network does not have to use up the public address space (and we can still use the IP protocol).

Private Addresses

Class	Private Addresses
A	10.0.0.0 – 10.255.255.255
B	172.16.0.0 – 172.31.255.255
C	192.168.0.0 – 192.168.255.255

Example:

Host X and Y may use the same private IP address as long as they dont communicate over the Internet or belong to the same Local Area Network.



Explain

- Subnet mask
- Network-ID
- Broadcast address
- The Prefix notation
- Private addresses
- How many octets used by IPv4?
- How many bits is that total?