

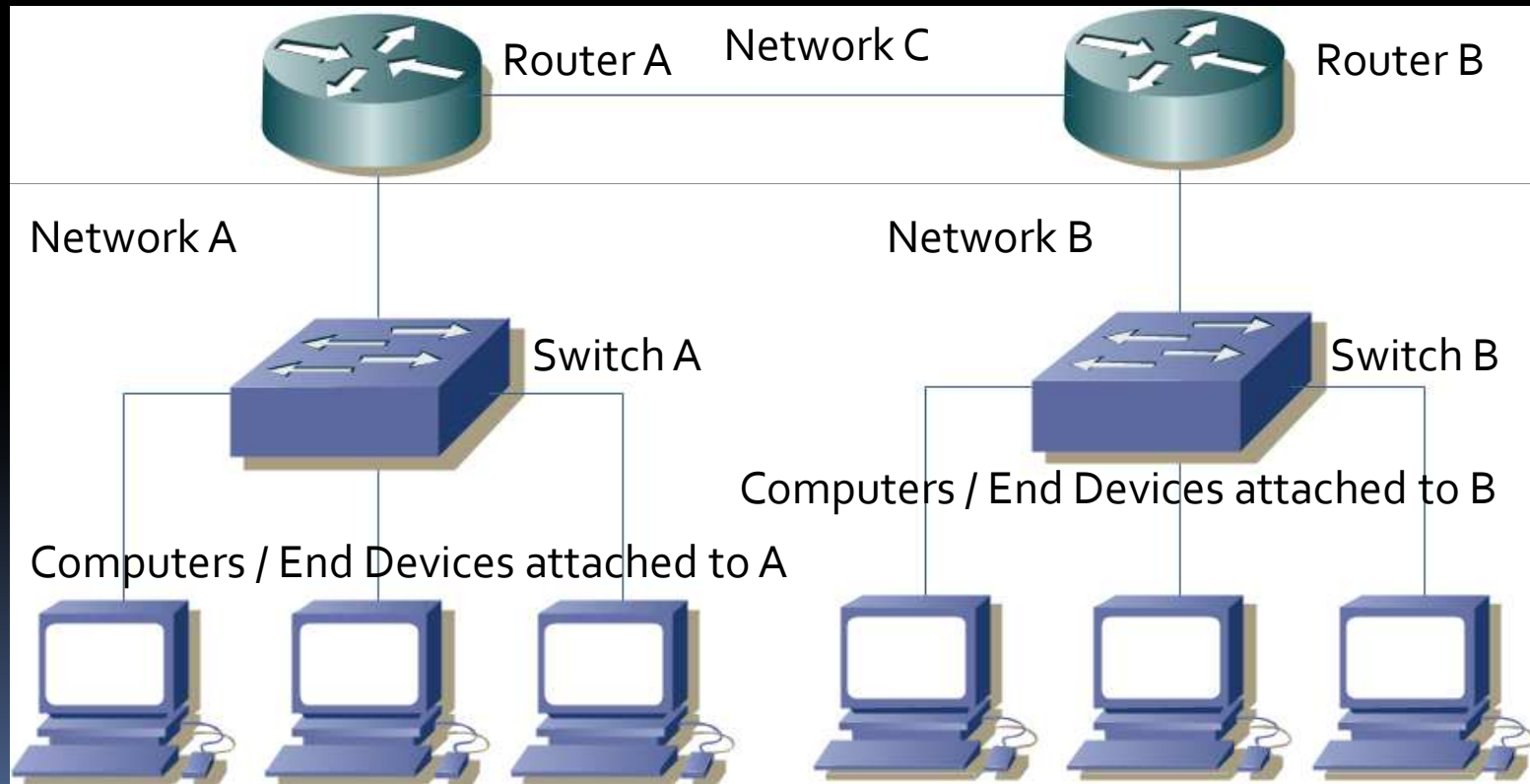
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IP ADDRESSING AND NUMERAL SYSTEMS

IP Addressing

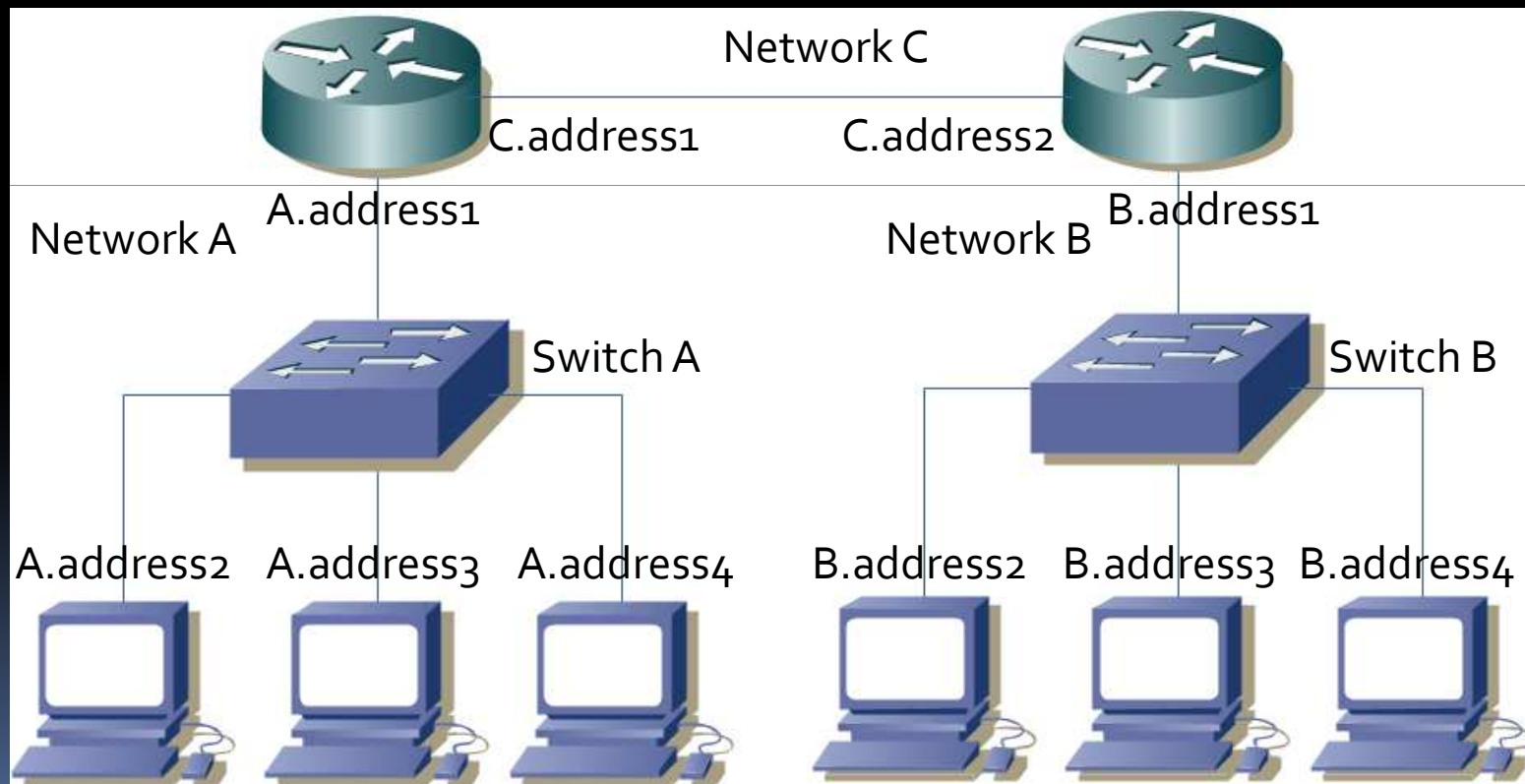
- Layer 2 / MAC address
 - Physically burned into the NIC
 - Doesn't change
 - The devices "real identity"
- Layer 3 / Internet Protocol address
 - Also called logical address
 - Set with software
 - Usually changing over time.

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 and C 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
$(2^{\#}) * 0 \text{ or } 1$	$(2^7)*1$	$(2^6)*1$	$(2^5)*1$	$(2^4)*1$	$(2^3)*1$	$(2^2)*1$	$(2^1)*1$	$(2^0)*1$
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 which 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
$(2^{\#}) * 0 \text{ or } 1$	$(2^7)*1$	$(2^6)*1$	$(2^5)*1$	$(2^4)*1$	$(2^3)*1$	$(2^2)*1$	$(2^1)*1$	$(2^0)*1$
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.

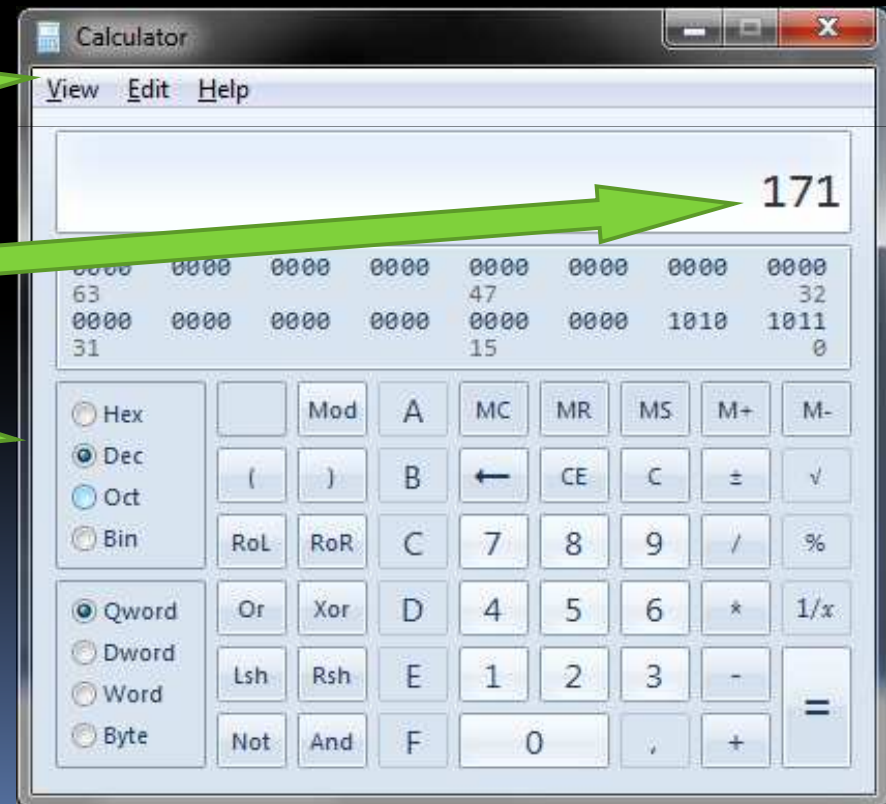
HEX (which position...?)	DEC
12	?
A2	?
11C	?

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 consisting 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
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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

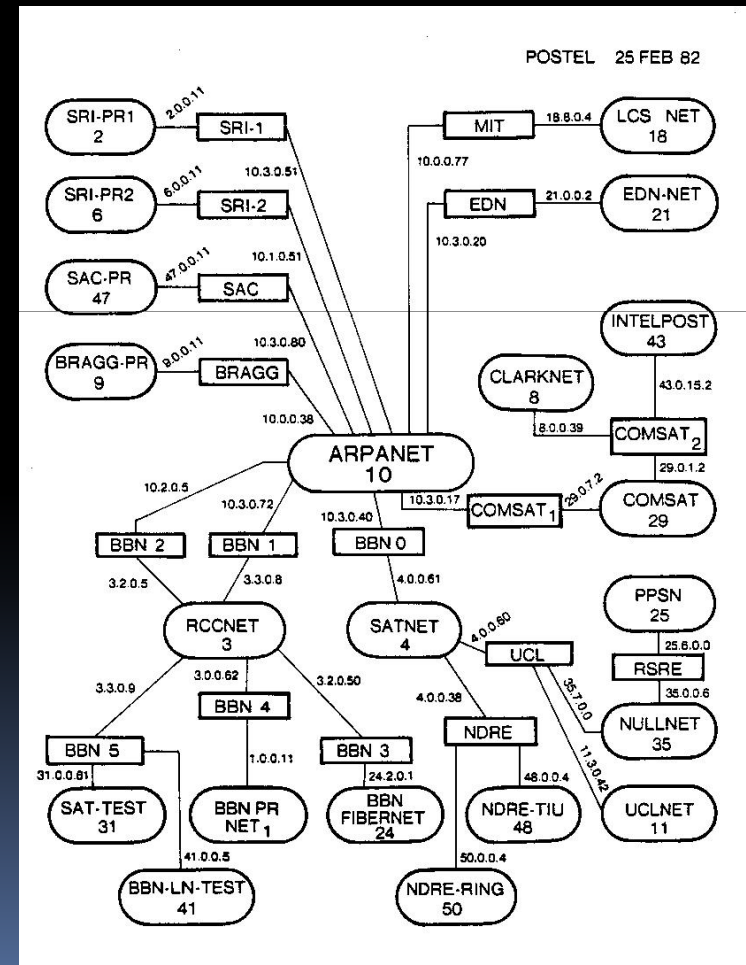
IP Address Classes

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**

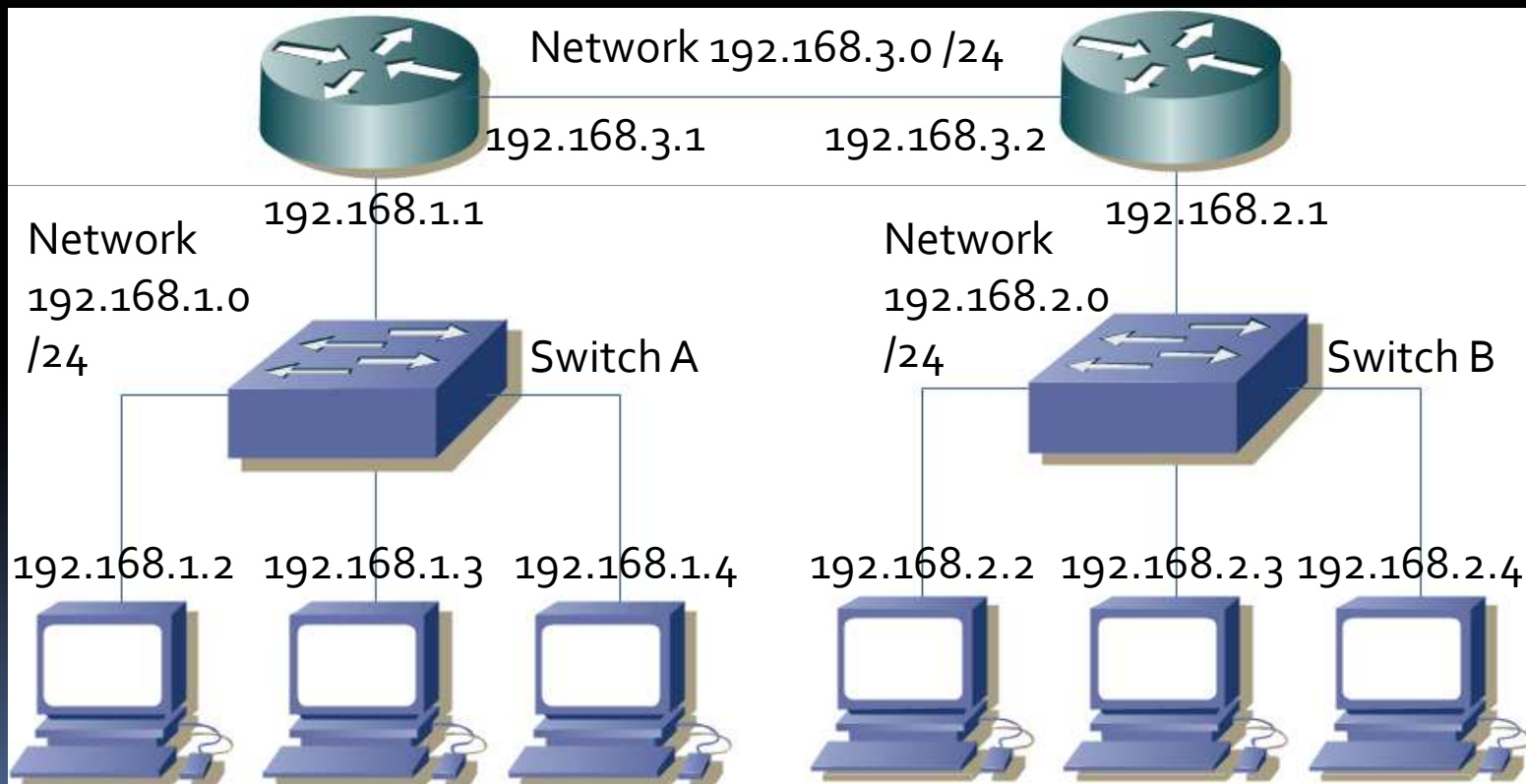
NET	NET	NET	HOST
255	255	255	0

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.

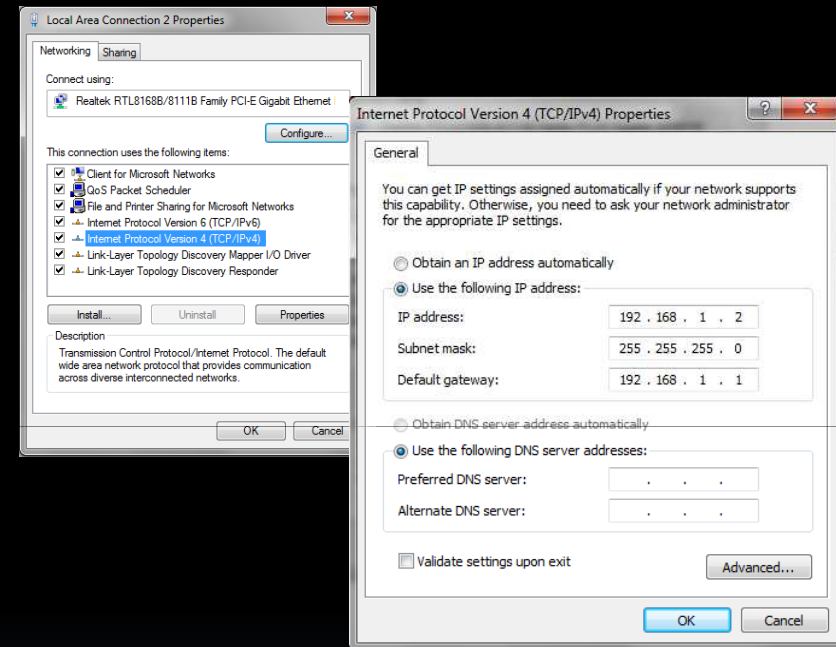


Configuring Interfaces

- 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

```
Router#conf t
Enter configuration commands, one per line. End with CNTL/Z.
Router(config)#int fa0/0
Router(config-if)#ip add
Router(config-if)#ip address 192.168.1.1 255.255.255.0
Router(config-if)#no shut
Router(config-if)#
*Mar 1 00:01:01.203: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Mar 1 00:01:02.203: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
```

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

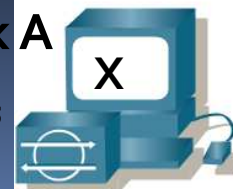
Class	Private Addresses
A	10.0.0.0 – 10.255.255.255
B	172.16.0.0 – 172.31.255.255
C	192.168.0.0 – 192.168.255.255

Example:

Host X and Y may use the same private IP address as long as they don't communicate over the Internet or belong to the same Local Area Network.

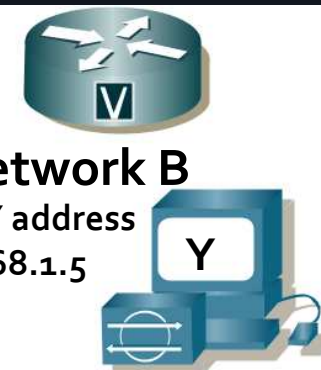
Local Network A

Host X address
192.168.1.5



Local Network B

Host Y address
192.168.1.5



Explain

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