Internet
IP Addressing

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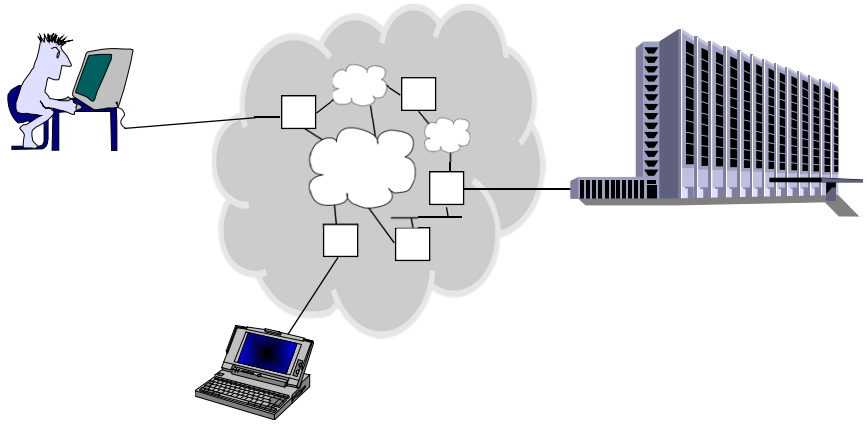
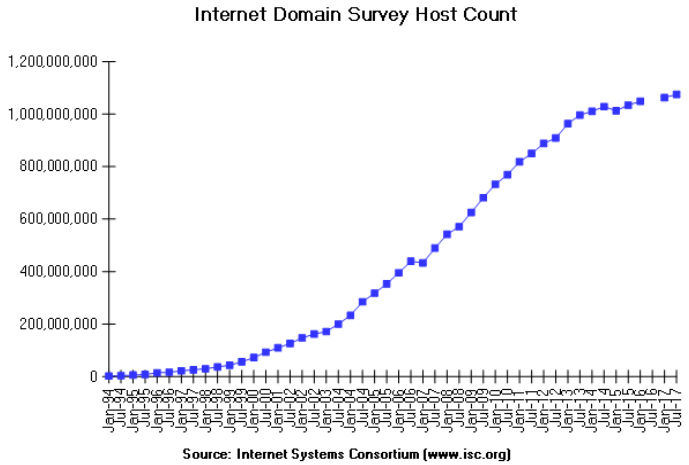
Cloud Abstraction



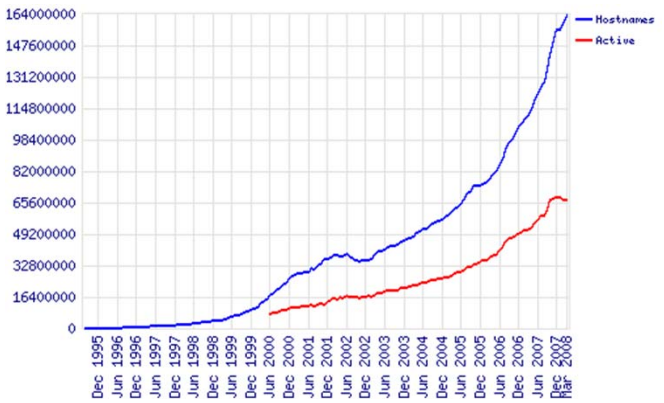
Internet Evolution



Source: Internet Systems Consortium (www.isc.org)

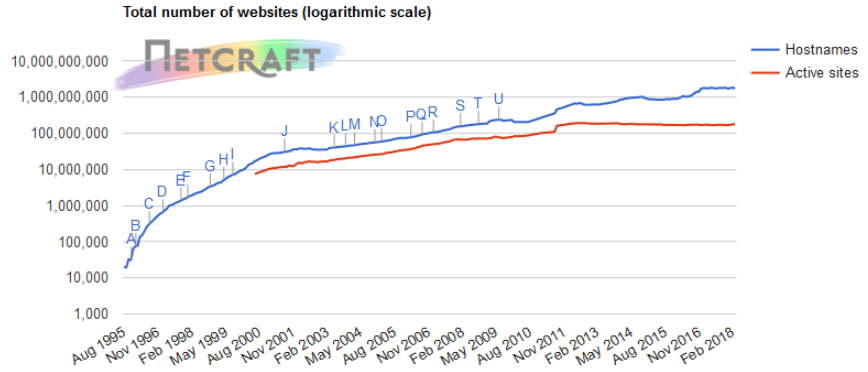
Year	Hosts
1983	562
1984	1.024
1985	1.961
1986	2.308
1987	5.089
1988	28.174
1989	80.000
1990	290.000
1991	500.000
1992	727.000
1993	1.200.000
1994	2.217.000
1995	4.852.000

Total Sites Across All Domains August 1995 - March 2008



http://news.netcraft.com/archives/web_server_survey.html

Total Sites Across All Domains August 1995 - Feb 2018



Source: https://news.netcraft.com/archives/category/web-server-survey/

Internet Evolution…

IP Addresses Assignment History

1º *Stanford Research Institute - Network Information Center (SRI–NIC)*

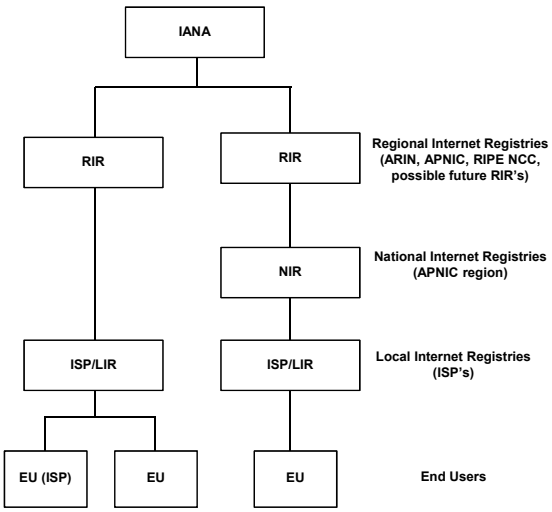
2º *SRI International Inc,* Menlo Park, CA

3º InterNIC, *Internet Network Information Center*

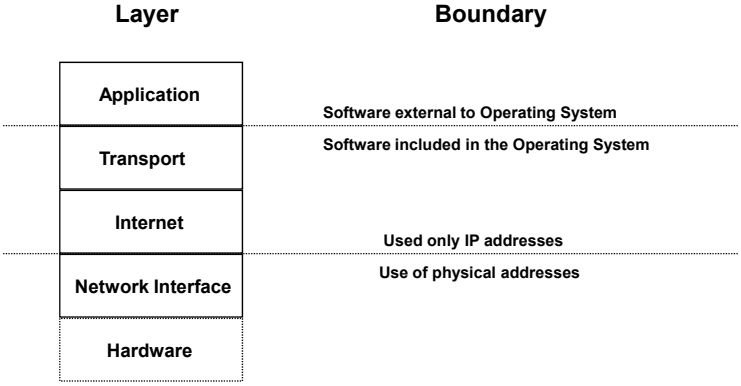
4º Delegation by region/continent

- *Regional Internet Registries (RIR)*:
  - *1992 - Réseaux IP Européens (RIPE-NCC);*
  - *1996 - Asia Pacific Network Information Centre (APNIC);*
  - *1997 - American Registry for Internet Numbers (ARIN);*
  - *2002 - Latin-American and Caribbean Network Information Centre (LACNIC);*
  - *2005 - African Network Information Center (AfriNIC)*
- *Internet Service Providers ⇔ Local Internet Registries (LIR)*

Management of IPv6 address spaces

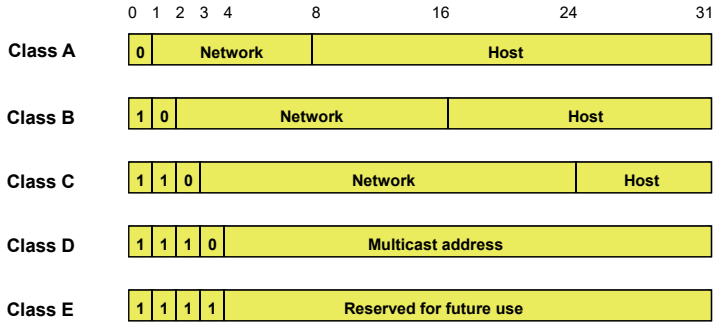


TCP/IP - Boundaries



Internet IPv4 Addressing

RFC1166 - INTERNET NUMBERS



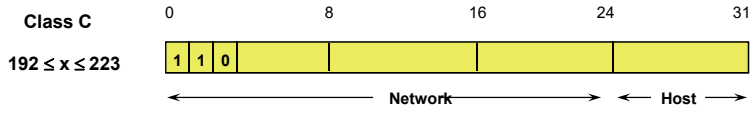
Internet IPv4 Addressing

Class	Addresses	Status
A	0.0.0.0	Reserved
	1.0.0.0 to 126.0.0.0	Available
	127.0.0.0	Reserved, loopback network *
B	128.0.0.0	Reserved
	128.1.0.0 to 191.254.0.0	Available
	191.255.0.0	Reserved
C	192.0.0.0	Reserved
	192.0.1.0 to 223.255.254.0	Available
	223.255.255.0	Reserved
D	224.0.0.0 to 239.255.255.255	Multicast
E	240.0.0.0 to 255.255.255.255	Reserved

* 127.0.0.1 loopback, localhost

Internet IPv4 Addressing

Example: let's consider the IP address **`192.168.246.10`**



"hosts" field

All bits = 0 -> Network address
`192.168.246.0`

All bits = 1 -> Broadcast address
`192.168.246.255`

- When we want to send a packet to all the stations of a network we use the broadcast address; the broadcast address allows you to simultaneously address all the stations in a network.

IP Addresses Format

- IPv4 address 32-bit

  Decimal, 1 octet fields, period separation

  `192.168.246.10`

- IPv6 address 128-bit

  Hexadecimal, 2 octet fields, colon separation

  `2001:0DB8:0000:0001:02A0:C9FF:FE61:1216`

IPv6 Addresses

- IPv6 addresses are 128-bit identifiers for interfaces and sets of interfaces [RFC4291]
- Types of addresses *(There are no broadcast addresses in IPv6, their function being superseded by multicast addresses)*
  - **Unicast**: An identifier for a single interface; a packet sent to a unicast address is delivered to the interface identified by that address.
  - **Anycast**: An identifier for a set of interfaces (typically belonging to different nodes); a packet sent to an anycast address is delivered to one of the interfaces identified by that address (the "nearest" one, according to the routing protocols' measure of distance).
  - **Multicast**: An identifier for a set of interfaces; a packet sent to a multicast address is delivered to all interfaces identified by that address.

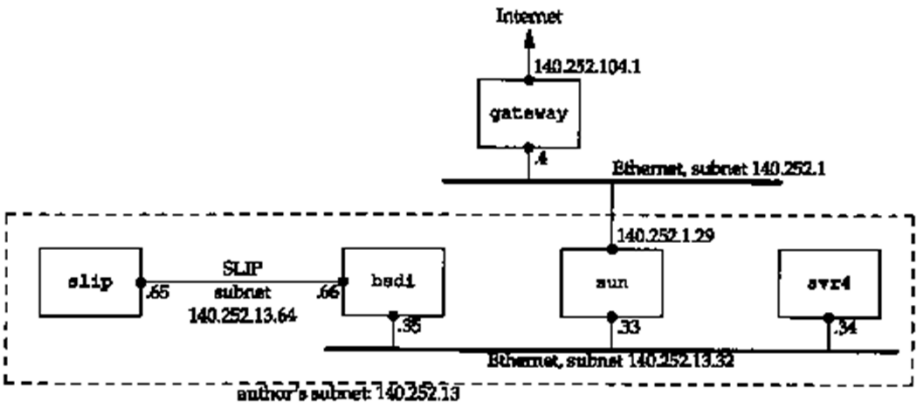
ifconfig

```
root@homer# /sbin/ifconfig -a
lo0: flags=1000849<UP,LOOPBACK,RUNNING,MULTICAST,IPv4> mtu 8232 index 1
        inet 127.0.0.1 netmask ff000000
ge0: flags=1000843<UP,BROADCAST,RUNNING,MULTICAST,IPv4> mtu 1500 index 2
        inet 194.117.24.1 netmask ffffff00 broadcast 194.117.24.255
        ether 8:0:20:d1:d4:97
hme0: flags=1000843<UP,BROADCAST,RUNNING,MULTICAST,IPv4> mtu 1500 index 3
        inet 192.35.246.1 netmask ffffff00 broadcast 192.35.246.255
        ether 8:0:20:d1:d4:97
lo0: flags=2000849<UP,LOOPBACK,RUNNING,MULTICAST,IPv6> mtu 8252 index 1
        inet6 ::1/128
hme0: flags=2000841<UP,RUNNING,MULTICAST,IPv6> mtu 1500 index 3
        ether 8:0:20:d1:d4:97
        inet6 fe80::a00:20ff:fed1:d497/10
```


netstat

```
root@animal# /usr/bin/netstat -in
Name  Mtu  Net/Dest      Address        Ipkts  Ierrs    Opkts  Oerrs Collis Queue
lo0   8232 127.0.0.0     127.0.0.1      8286631   0    8286631   0     0      0
ge0   1500 194.117.24.0  194.117.24.1   6487926 178   21581387   0     0      0
hme0  1500 192.35.246.0  192.35.246.1  91261455   0   91172209   0     0      0
[...]
root@homer# /usr/bin/netstat -rn
Routing Table: IPv4
  Destination           Gateway           Flags  Ref   Use   Interface
-------------------- -------------------- ----- ----- ------ ---------
194.117.24.0         194.117.24.1          U        1 424815  ge0
192.35.246.0         192.35.246.1          U        1   7051  hme0
224.0.0.0            192.35.246.1          U        1      0  hme0
default              192.35.246.254        UG       1 450384
127.0.0.1            127.0.0.1             UH       5  16148  lo0
[...]
```

Subnet Concept

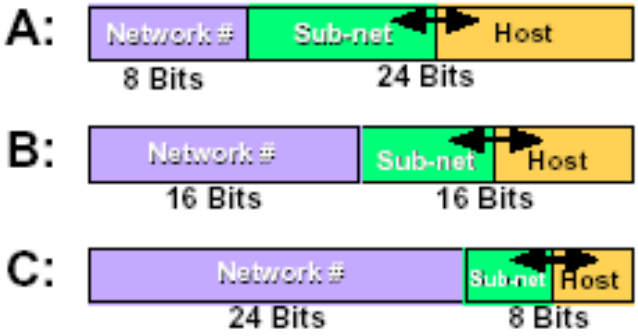


Subnetting

Masks for the subnetting of a class C network

Bits of the subnet	Bits for hosts	Hex Mask	Decimal Mask
0	8	0	0
1	7	0x80	128
2	6	0xC0	192
3	5	0xE0	224
4	4	0xF0	240
5	3	0xF8	248
6	2	0xFC	252
7	1	0xFE	254
8	0	0xFF	255

Variable Mask



Sub Addressing

Example of sub addressing of a class C network

```
Net:    192.168.246.0       192 . 168 . 246 . 128 -> 1000 0000
Mask: 255.255.255.192       255 . 255 . 255 . 192 -> 1100 0000
```

Example of sub addressing of a class B network

```
Net:    172.20.26.0         172 . 20  .    26    . 0
Mask: 255.255.240.0         255 . 255 .   240    . 0
                                       1111 0000 . 0000 0000
```

Sub Addressing...

How to split a Class C Network to address Point-to-Point links?

```
192 . 168 . 246 .   0
255 . 255 . 255 . 252 -> 1111 1100
```

Net: 192.168.246.0
Mask: 255.255.255.252

252 = 256 – **4**
4 is the block size!

Sub Addressing...

How to split a Class C Network to address Point-to-Point links?

```
192 . 168 . 246 .   0
255 . 255 . 255 . 252 -> 1111 1100
```

Net: 192.168.246.0
Mask: 255.255.255.252

And a subnet with 64 addresses?

```
192 . 168 . 246 .   0
255 . 255 . 255 . 192 -> 1100 0000
```

Net: 192.168.246.0
Mask: 255.255.255.192

1st block	0000 0000 -> 0011 1111
2nd block	0100 0000 -> 0111 1111
3rd block	1000 0000 -> 1011 1111
4th block	1100 0000 -> 1111 1111

Problem

Split the network 200.17.30.0 into subnets with 32 addresses.

1. Which mask to apply?
2. How many subnets?
3. Which are they?
4. Which is the broadcast address?

Problem

Split the network 200.17.30.0 into subnets with 32 addresses.

1. Which mask to apply? 1110 0000 -> 255.255.255.224
2. How many subnets? 8
3. Which are they?
4. Which is the broadcast address?

Problem

Split the network 200.17.30.0 into subnets with 32 addresses.

1. Which mask to apply? 1110 0000 -> 255.255.255.224
2. How many subnets? 8
3. Which are they?
4. Which is the broadcast address?

200.17.30.0	-	200.17.30.31
200.17.30.32	-	200.17.30.63
200.17.30.64	-	200.17.30.95
200.17.30.96	-	200.17.30.127
200.17.30.128	-	200.17.30.159
200.17.30.160	-	200.17.30.191
200.17.30.192	-	200.17.30.223
200.17.30.224	-	200.17.30.255

Problem

Split the network 200.17.30.0 into subnets with 32 addresses.

1. Which mask to apply? 1110 0000 -> 255.255.255.224
2. How many subnets? 8
3. Which are they?
4. Which is the broadcast address?

200.17.30.0	-	200.17.30.31
200.17.30.32	-	200.17.30.63
200.17.30.64	-	200.17.30.95
200.17.30.96	-	200.17.30.127
200.17.30.128	-	200.17.30.159
200.17.30.160	-	200.17.30.191
200.17.30.192	-	200.17.30.223
200.17.30.224	-	200.17.30.255

What if I want to create 2 subnets with 64 addresses?

Problem

Split the network 200.17.30.0 into subnets with 32 addresses.

1. Which mask to apply? 1110 0000 -> 255.255.255.224
2. How many subnets? 8
3. Which are they?
4. Which is the broadcast address?

200.17.30.0 - 200.17.30.31
200.17.30.32 - 200.17.30.63
200.17.30.64 - 200.17.30.95
200.17.30.96 - 200.17.30.127
200.17.30.128 - 200.17.30.159
200.17.30.160 - 200.17.30.191
200.17.30.192 - 200.17.30.223
200.17.30.224 - 200.17.30.255

What if I want to create 2 subnets with 64 addresses?

Is easy! Just group 4 of 32 ....
(it will be???)

Problem

Split the network 200.17.30.0 into subnets with 32 addresses.

1. Which mask to apply? 1110 0000 -> 255.255.255.224
2. How many subnets? 8
3. Which are they?
4. Which is the broadcast address?

200.17.30.0 - 200.17.30.31
200.17.30.32 - 200.17.30.63
200.17.30.64 - 200.17.30.95
200.17.30.96 - 200.17.30.127
200.17.30.128 - 200.17.30.159
200.17.30.160 - 200.17.30.191
200.17.30.192 - 200.17.30.223
200.17.30.224 - 200.17.30.255

```
200.17.30.64  -> 200.17.30.95    0100 0000
                                 0101 1111
200.17.30.96  -> 200.17.30.127   0110 0000
                                 0111 1111
200.17.30.160 -> 200.17.30.191   1010 0000
                                 1011 1111
200.17.30.192 -> 200.17.30.223   1100 0000
                                 1101 1111
```

Problem

Split the network 200.17.30.0 into subnets with 32 addresses.

1. Which mask to apply? 1110 0000 -> 255.255.255.224
2. How many subnets? 8
3. Which are they?
4. Which is the broadcast address?

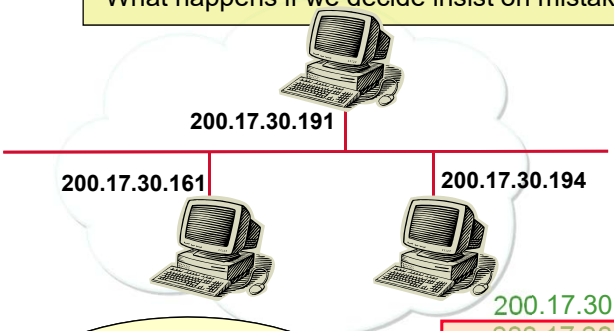
```
200.17.30.64  -> 200.17.30.95    0100 0000
                                 0101 1111
200.17.30.96  -> 200.17.30.127   0110 0000
                                 0111 1111
200.17.30.128 -> 200.17.30.159   1000 0000
                                 1011 1111
200.17.30.160 -> 200.17.30.191   1010 0000
                                 1011 1111
```

200.17.30.0 - 200.17.30.31
200.17.30.32 - 200.17.30.63
200.17.30.64 - 200.17.30.95
200.17.30.96 - 200.17.30.127
200.17.30.128 - 200.17.30.159
200.17.30.160 - 200.17.30.191
200.17.30.192 - 200.17.30.223

ALWAYS RESERVE THE LARGEST BLOCKS AT THE BEGINNING TO AVOID OVERLAPPING!

Problem

What happens if we decide insist on mistake?..

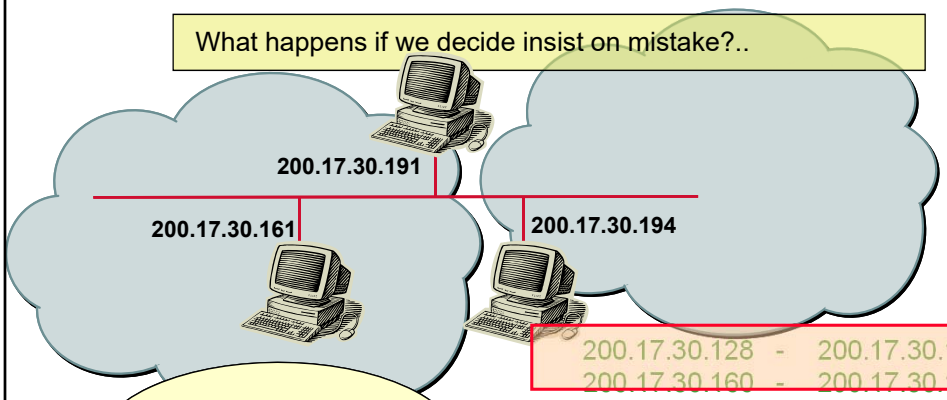


Consider the hosts 200.17.30.161, 200.17.30.191 and 200.17.30.194....

200.17.30.128 - 200.17.30.159
200.17.30.160 - 200.17.30.191
200.17.30.192 - 200.17.30.223
200.17.30.224 - 200.17.30.255

Problem

What happens if we decide insist on mistake?..

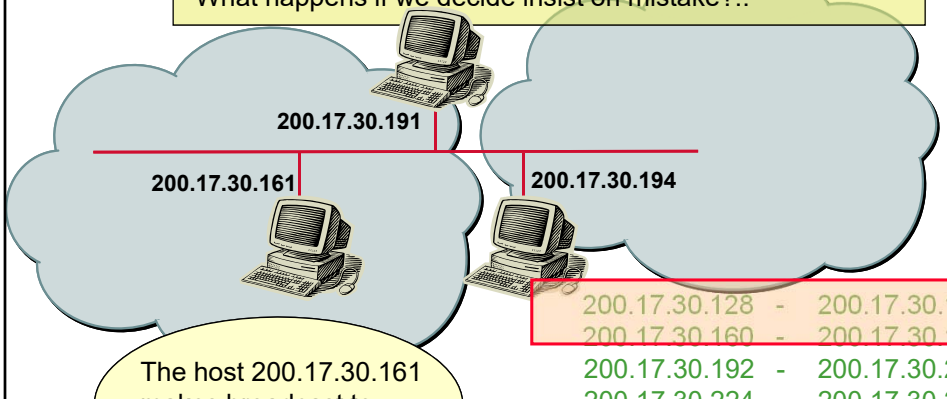


200.17.30.128 - 200.17.30.159
200.17.30.160 - 200.17.30.191
200.17.30.192 - 200.17.30.223
200.17.30.224 - 200.17.30.255

Each host “see” the local network defined by the mask 255.255.255.192

Problem

What happens if we decide insist on mistake?..



200.17.30.128 - 200.17.30.159
200.17.30.160 - 200.17.30.191
200.17.30.192 - 200.17.30.223
200.17.30.224 - 200.17.30.255

The host 200.17.30.161 makes broadcast to 200.17.30.191 !!!....

Supernetting, why?

RFC1519 - *Classless Inter-Domain Routing (CIDR): an Address Assignment and Aggregation Strategy*

- Exhaustion of the address space of class B networks
- Route Aggregation
  - Two Class C Networks Instead One Class B ...
  - Reduction of Routing Tables of Backbone Routers
- There are not enough IPv4 addresses

Increase of the Advertisements....

MM/YY	ROUTES ADVERTISED*	MM/YY	ROUTES ADVERTISED*
Dec-92	8561	Sep-90	1988
Nov-92	7854	Aug-90	1894
Oct-92	7354	Jul-90	1727
Sep-92	6640	Jun-90	1639
Aug-92	6385	May-90	1580
Jul-92	6031	Apr-90	1525
Jun-92	5739	Mar-90	1038
May-92	5515	Feb-90	997
Apr-92	5291	Jan-90	927
Mar-92	4976	Dec-89	897
Feb-92	4740	Nov-89	837
Jan-92	4526	Oct-89	809
Dec-91	4305	Sep-89	745
Nov-91	3751	Aug-89	650
Oct-91	3556	Jul-89	603
Sep-91	3389	Jun-89	564
Aug-91	3258	May-89	516
Jul-91	3086	Apr-89	467
Jun-91	2982	Mar-89	410
May-91	2763	Feb-89	384
Apr-91	2622	Jan-89	346
Mar-91	2501	Dec-88	334
Feb-91	2417	Nov-88	313
Jan-91	2338	Oct-88	291
Dec-90	2190	Sep-88	244
Nov-90	2125	Aug-88	217
Oct-90	2063	Jul-88	173

*** Source for the routing table size data is MERIT**

CIDR Notation

- A route is an address plus the mask (number of consecutive '1's)
- Netid / Mask
- Used in BGP

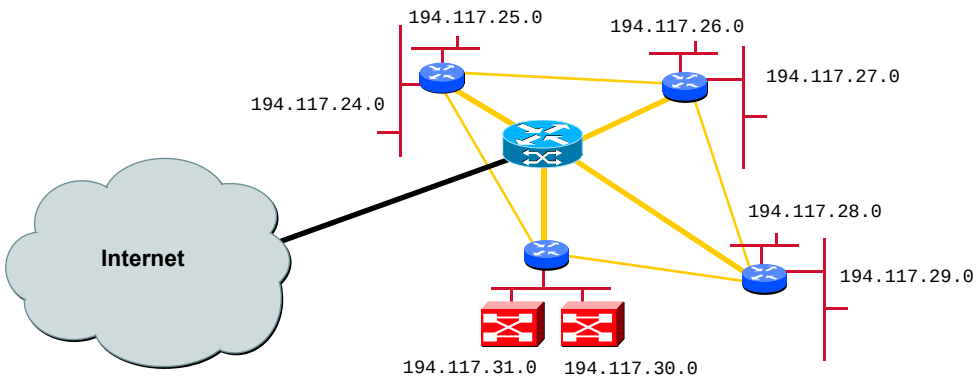
	CLASS 'A' NETWORKS
BINARY	11111111.00000000.00000000.00000000
DECIMAL	255.0.0.0
CIDR	/8

	CLASS 'B' NETWORKS
BINARY	11111111.11111111.00000000.00000000
DECIMAL	255.255.0.0
CIDR	/16

	CLASS 'C' NETWORKS
BINARY	11111111.11111111.11111111.00000000
DECIMAL	255.255.255.0
CIDR	/24

	1/2 CLASS 'C' NETWORK
BINARY	11111111.11111111.11111111.10000000
DECIMAL	255.255.255.128
CIDR	/25

Example of Supernetting



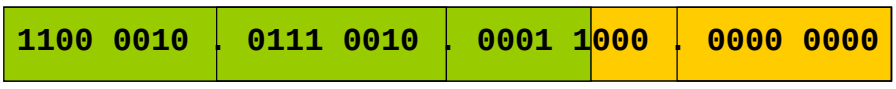
Example of Supernetting

Because class C addresses are consecutive we can aggregate them!

```
194.117.24.0 -> 1100 0010 . 0111 0010 . 0001 1000 . 0000 0000
194.117.25.0 -> 1100 0010 . 0111 0010 . 0001 1001 . 0000 0000
194.117.26.0 -> 1100 0010 . 0111 0010 . 0001 1010 . 0000 0000
194.117.27.0 -> 1100 0010 . 0111 0010 . 0001 1011 . 0000 0000
194.117.28.0 -> 1100 0010 . 0111 0010 . 0001 1100 . 0000 0000
194.117.29.0 -> 1100 0010 . 0111 0010 . 0001 1101 . 0000 0000
194.117.30.0 -> 1100 0010 . 0111 0010 . 0001 1110 . 0000 0000
194.117.31.0 -> 1100 0010 . 0111 0010 . 0001 1111 . 0000 0000
```


CIDR Notation

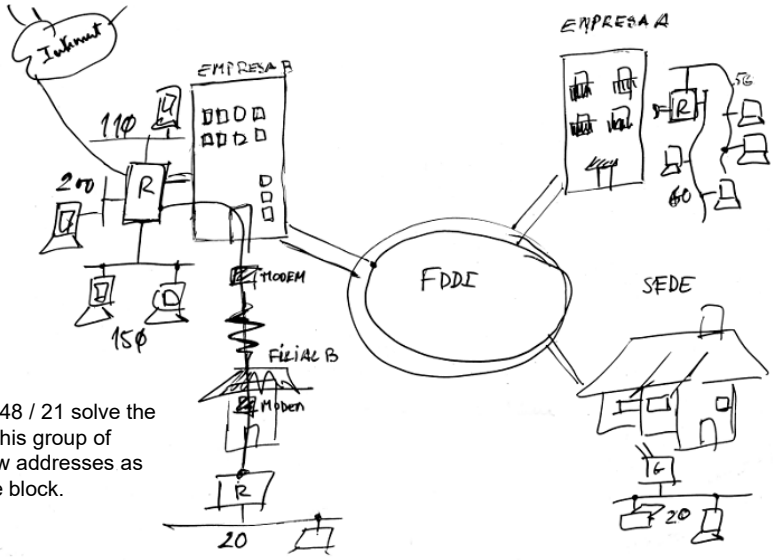
194 . 117 . 24 . 0 / 21



Network address (netid)

With the CIDR notation, the 194.117.24 / 21 network has 21 bits and 2048 addresses.

Problem



Problem:

Using the block 200.23.48 / 21 solve the addressing problem of this group of companies, using as few addresses as possible in the available block.

A good solution:

No. of Addresses	Block	No. bits	Network Address	Broadcast Address	Bits of Mask
200+Ro+N+B	256	8	200.23.48.0	200.23.48.255	24
150+Ro+N+B	256	8	200.23.49.0	200.23.49.255	24
110+Ro+N+B	128	7	200.23.50.0	200.23.50.127	25
60+Ro+N+B	64	6	200.23.50.128	200.23.50.191	26
56+Ro+N+B	64	6	200.23.50.192	200.23.50.255	26
20+Ro+N+B	32	5	200.23.51.0	200.23.51.31	27
20+Ro+N+B	32	5	200.23.51.32	200.23.51.63	27
3+N+B	8	3	200.23.51.64	200.23.51.71	29
2+N+B	4	2	200.23.51.72	200.23.51.75	30

Private Address Space

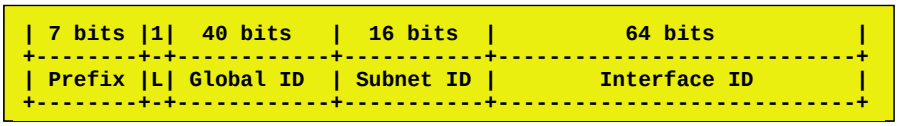
RFC1918, BCP0005 - *Address Allocation for Private Internets*

```
10.0.0.0      10.255.255.255   (10/8)
172.16.0.0    172.31.255.255   (172.16/12)
192.168.0.0   192.168.255.255  (192.168/16)
```

- Block of addresses reserved for internal use of a network without direct connectivity to the Internet.
- Different Private Networks can have the same network address.
- Addresses filtered on the external access router (either on the in or output traffic!).
- They are not expected to be routable on the global Internet.

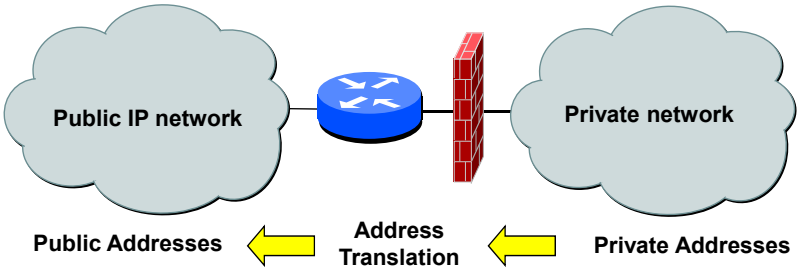
Unique Local Addresses

RFC4193 - *Unique Local IPv6 Unicast Addresses*



Prefix	**FC00::/7** prefix to identify Local IPv6 unicast addresses ▪ The block **FC00::/8** has not been defined yet; ▪ The block **FD00::/8** is defined for /48 prefixes.
L	Set to 1 if the prefix is locally assigned. Set to 0 may be defined in the future.
Global ID	40-bit global identifier used to create a globally unique prefix.
Subnet ID	16-bit identifier of a subnet within the site.
Interface ID	64-bit Interface ID

Private Addressing



- Private addresses can not be used for direct connections to the Internet but can access through indirect access via proxy servers, with or without NAT (*Network Address Translation*) and PAT (*Port Address Translation*) .

Other addresses to refuse...

RFC3330 – *Special-Use IPv4 Addresses*

```
0.0.0.0      0.0.0.0
0.0.0.0      255.0.0.0
127.0.0.0    255.0.0.0
192.0.2.0    255.255.255.0
224.0.0.0    255.240.0.0
```

- Addresses filtered at the border router with the outside (either at the exit or at the entrance!).

IPv4 Special Addresses

Address Block	Present Use	Reference
0.0.0.0/8	"This" Network	[RFC1700]
10.0.0.0/8	Private-Use Networks	[RFC1918]
14.0.0.0/8	Public-Data Networks	[RFC1700]
24.0.0.0/8	Cable Television Networks	--
39.0.0.0/8	Reserved but subject to allocation	[RFC1797]
127.0.0.0/8	Loopback	[RFC1700]
128.0.0.0/16	Reserved but subject to allocation	--
169.254.0.0/16	Link Local	--
172.16.0.0/12	Private-Use Networks	[RFC1918]
191.255.0.0/16	Reserved but subject to allocation	--
192.0.0.0/24	Reserved but subject to allocation	--
192.0.2.0/24	Documentation, Test-Net	[RFC5737]
192.88.99.0/24	6to4 Relay Anycast	[RFC3068]
192.168.0.0/16	Private-Use Networks	[RFC1918]
198.18.0.0/15	Network Interconnect Device Benchmark Testing	[RFC2544]
198.51.100.0/24	Documentation, Test-Net	[RFC5737]
203.0.113.0/24	Documentation, Test-Net	[RFC5737]
223.255.255.0/24	Reserved but subject to allocation	--
224.0.0.0/4	Multicast	[RFC3171]
240.0.0.0/4	Reserved for Future Use	[RFC1700]

Special-Use IPv6 Addresses

RFC6890 – *Special-Purpose Address Registries*

Address Block	Present Use	Reference
::1/128	Loopback Address	[RFC4291]
::/128	Unspecified Address	[RFC4291]
64:ff9b::/96	IPv4-IPv6 Translation	[RFC6052]
::ffff:0:0/96	IPv4-mapped Address	[RFC4291]
100::/64	Discard-Only Address Block	[RFC6666]
2001::/23	IETF Protocol Assignments	[RFC2928]
2001::/32	TEREDO	[RFC4380]
2001:2::/48	Benchmarking	[RFC5180]
2001:10::/28	ORCHID	[RFC4843]
2001:db8::/32	Documentation	[RFC3849]
2002::/16	6to4	[RFC3056]
fc00::/7	Unique-Local	[RFC4193]
fe80::/10	Linked-Scoped Unicast	[RFC4291]

Special Addresses IPv4 vs. IPv6

- Multicast
  IPv4: **224/8 - 239.255.255.255/8** [RFC2365]
  IPv6: **FFxx:x:x:x:x:x:x:x**
- Anycast [RFC1546]
  Unicast, but with multiple advertisers
- Site-local
  IPv4: **10/8, 172.16/12, 192.168/16** [RFC1918]
  IPv6: **FEC0:0:0:<Subnet ID>:<Interface ID>**
- Link-local
  IPv4: **169.254/16** [RFC3927]
  IPv6: **FE80:0:0:0:<Interface ID>**
- Loopback
  IPv4: **127.0.0.1/8**
  IPv6: **0:0:0:0:0:0:0:1/128** (**::1/128**)

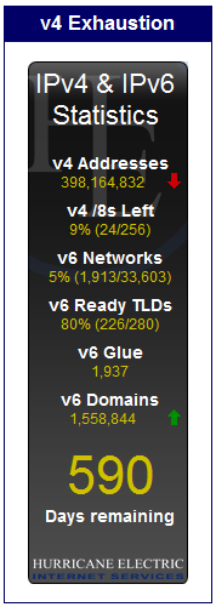
IPv6 Multicast Addresses

- **FF02::1** : “All nodes” on link, scope is link-local
- **FF02::2** : “All routers” on link
- **FF02::9** : “All RIP routers” on link
- **FF02::1:FFXX:XXXX** : Solicited-node multicast on link (**XX:XXXX** are lower 24 bits of target IPv6 address)
- **FF05::101** : “All NTP servers” in the site, scope is site-local

IPv4 Exhaustion

- In 2010 this was estimated exhaustion time and rate of IPv4, and the growing adoption of IPv6…

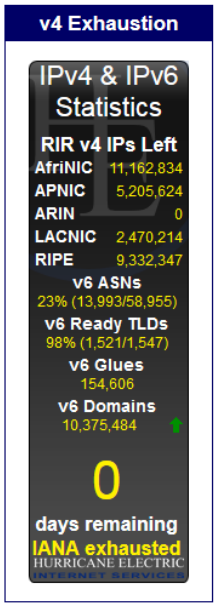
http://ipv6.he.net/statistics/



IPv4 Exhaustion

- Today, in 2018, the estimate is…

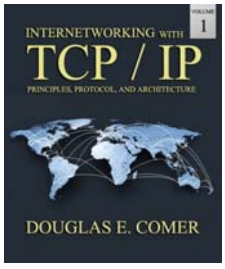
http://ipv6.he.net/statistics/



Names and addresses...

Any two stations on a network must have addresses on that network in order to communicate

Additional Reading



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