Campus Network Design Workshop

IP Addressing

IP Addresses

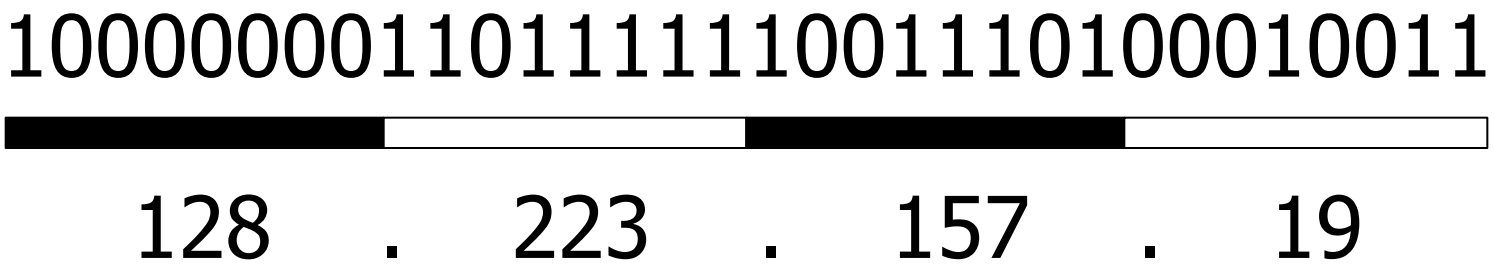
- Internet connected networks use two types of IP Addressing
  - IPv4 – legacy Internet protocol
  - IPv6 – new Internet protocol
- Presentation describes IPv4 addresses and IPv6 addresses & addressing
- The Campus Network Design Workshop labs use both IPv4 and IPv6 for all exercises
  - Dual stack network (both protocols running in parallel)

IPv4 addresses

- 32-bit binary number
  - How many unique addresses in total?

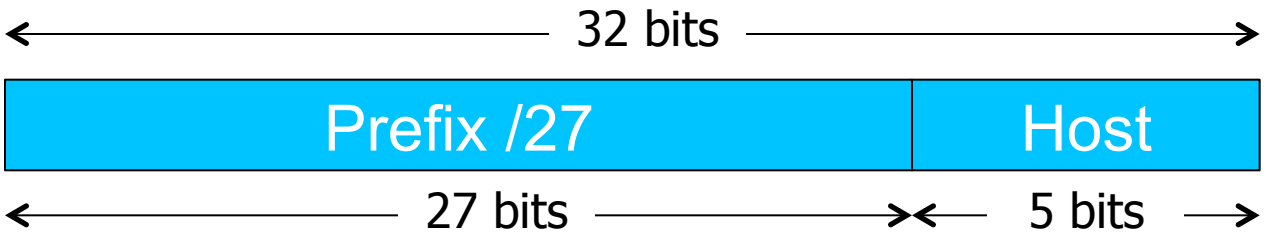
IPv4 addresses

- 32-bit binary number
  - How many unique addresses in total?
  - 2^{32} which is 4,294,967,296 addresses
- Conventionally represented as four dotted decimal octets



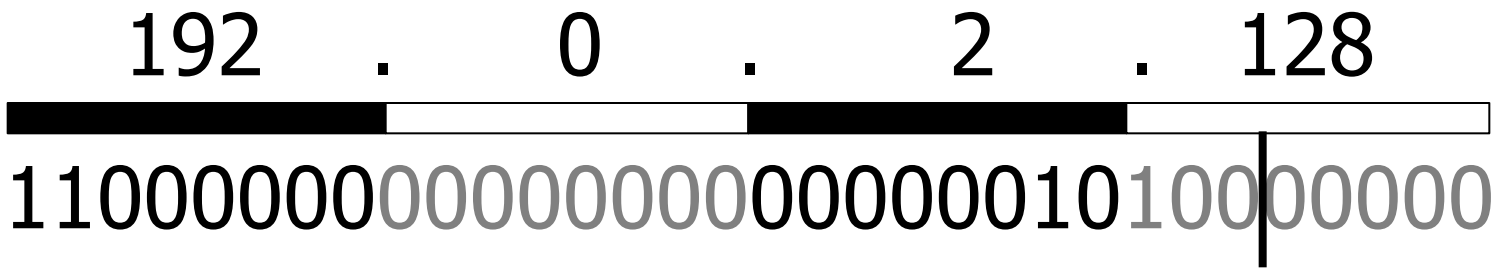
Can you explain why 00010011 = 19 in decimal?

Prefixes



- A range of IP addresses is given as a prefix, e.g. 192.0.2.128/27
- In this example:
  - How many addresses are available?
  - What are the lowest and highest addresses?

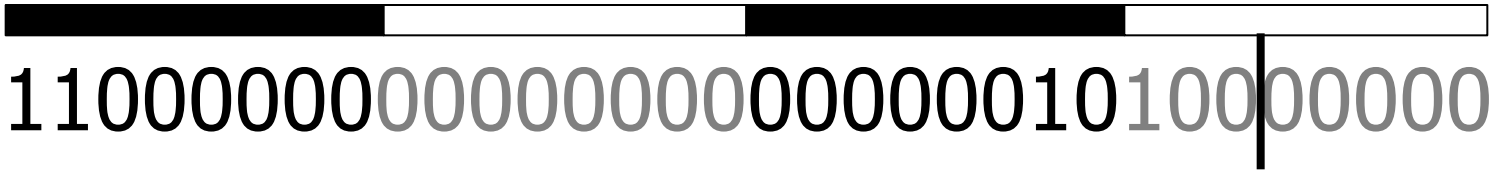
Prefix calculation



Prefix length /27 ➔ First 27 bits are fixed

Prefix calculation

192 . 0 . 2 . 128



11000000000000000000001010000000

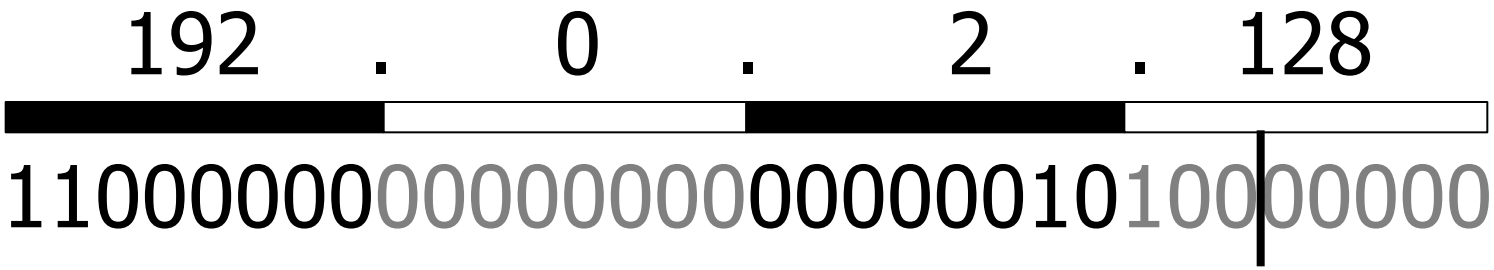
Prefix length /27 ➔ First 27 bits are fixed

Lowest address:

11000000000000000000001010000000

192 . 0 . 2 . 128

Prefix calculation



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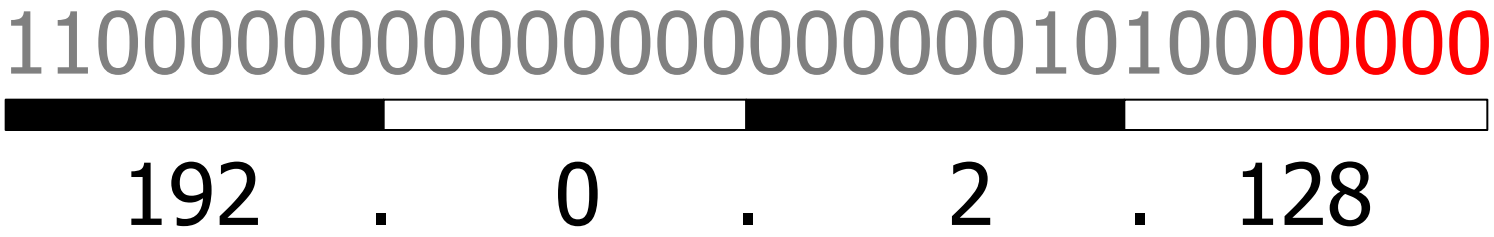
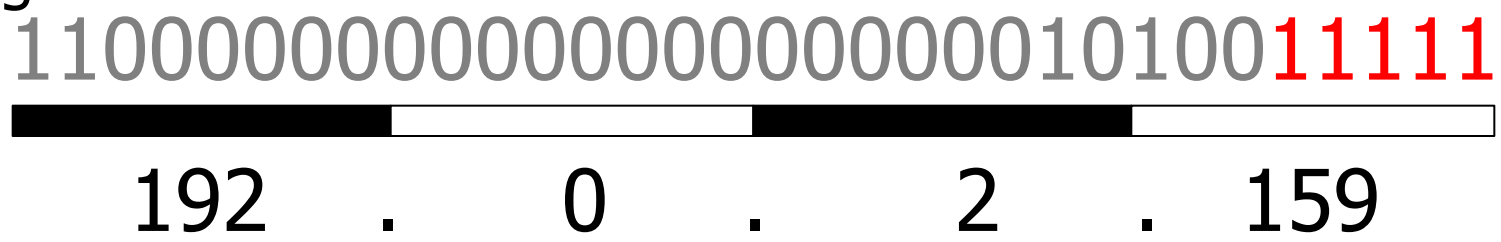
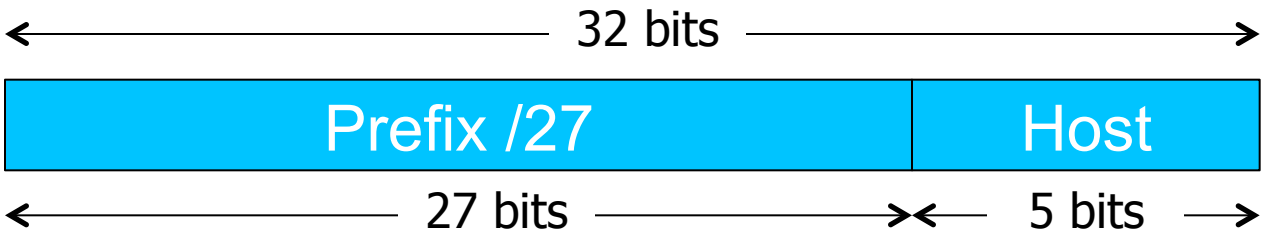
Lowest address:



Highest address:



IPv4 “Golden Rules”



1. All hosts on the same L2 network must share the same prefix
2. All hosts with the same prefix have different host part
3. Host part of all-zeros and all-ones are reserved

Golden Rules for 192.0.2.128/27

- Lowest 192.0.2.128 = network address
- Highest 192.0.2.159 = broadcast address
- Usable: 192.0.2.129 to 192.0.2.158
- Number of usable addresses: 32 - 2 = 30

Exercises

- Network 10.10.10.0/25
  - How many addresses in total?
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- Network 10.10.20.0/22
  - How many addresses in total?
  - How many usable addresses?
  - What the the lowest and highest usable addresses?

An edge case

- How many usable addresses in a /30 prefix?
- What is this used for?
  - (Note: modern routers support /31 for this purpose to reduce IPv4 address wastage)

Netmask

- Netmask is just an alternative (old) way of writing the prefix length
- A '1' for a prefix bit and '0' for a host bit
- Hence N x 1's followed by (32-N) x 0's

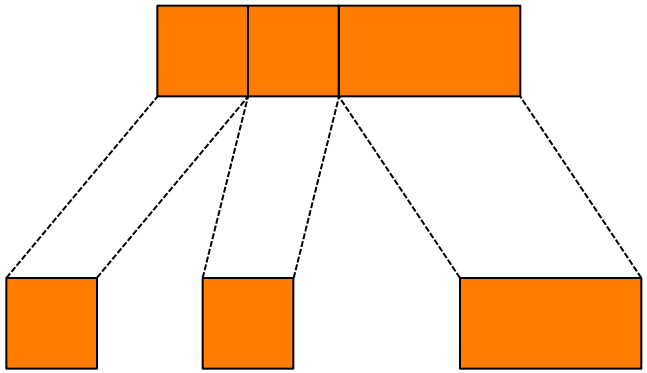
/27 =

11111111111111111111111111100000

255 . 255 . 255 . 224

Subnetting

- Since each L2 network needs its own prefix, then if you route more than one network you need to divide your allocation
- Ensure each prefix has enough IPs for the number of hosts on that network



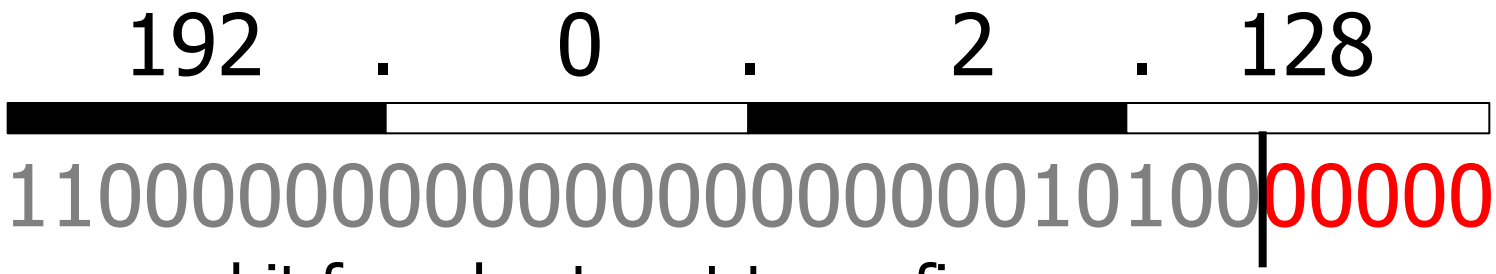
End User Allocation

Subnets

Subnetting Example

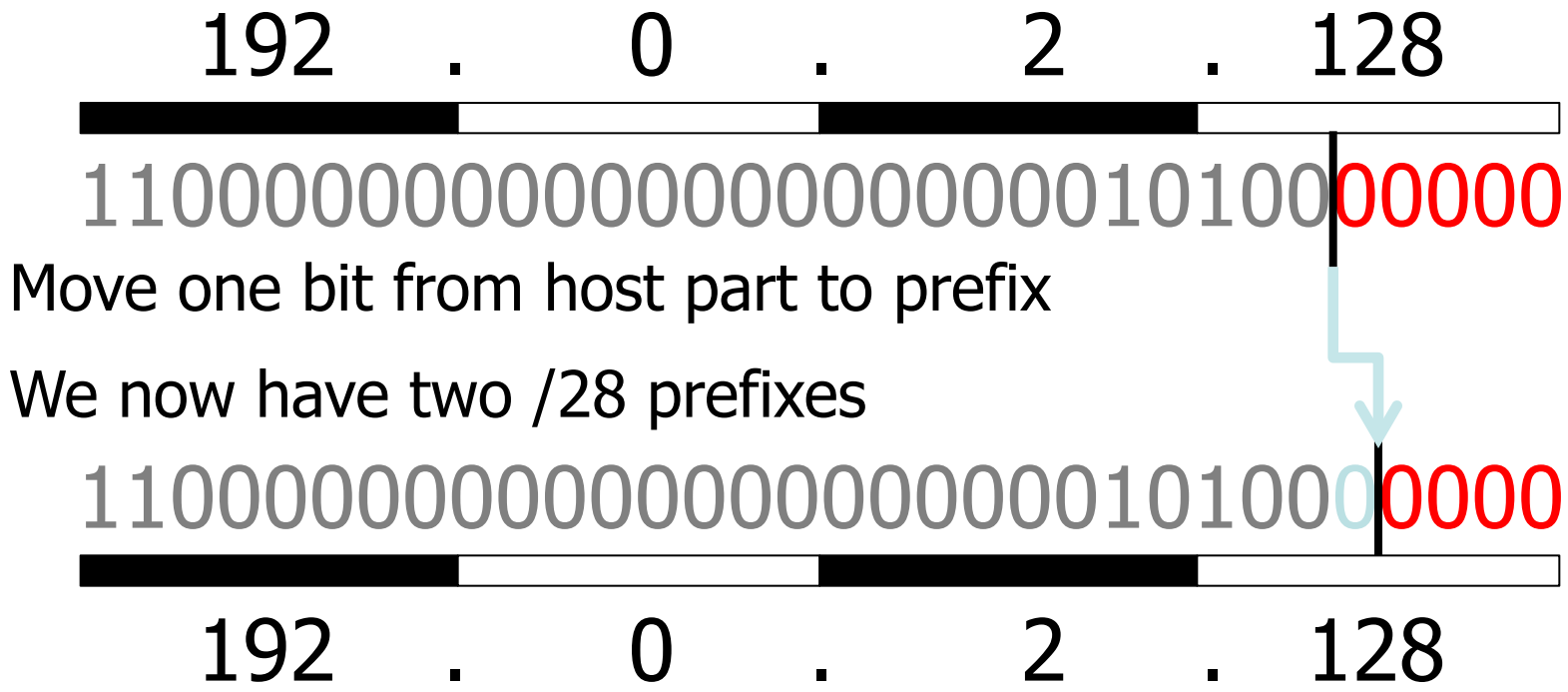
- You have been given 192.0.2.128/27
- However you want to build two Layer 2 networks and route between them
- The Golden Rules demand a different prefix for each network
- Let's split this address space into two equal-sized pieces

Subnetting /27

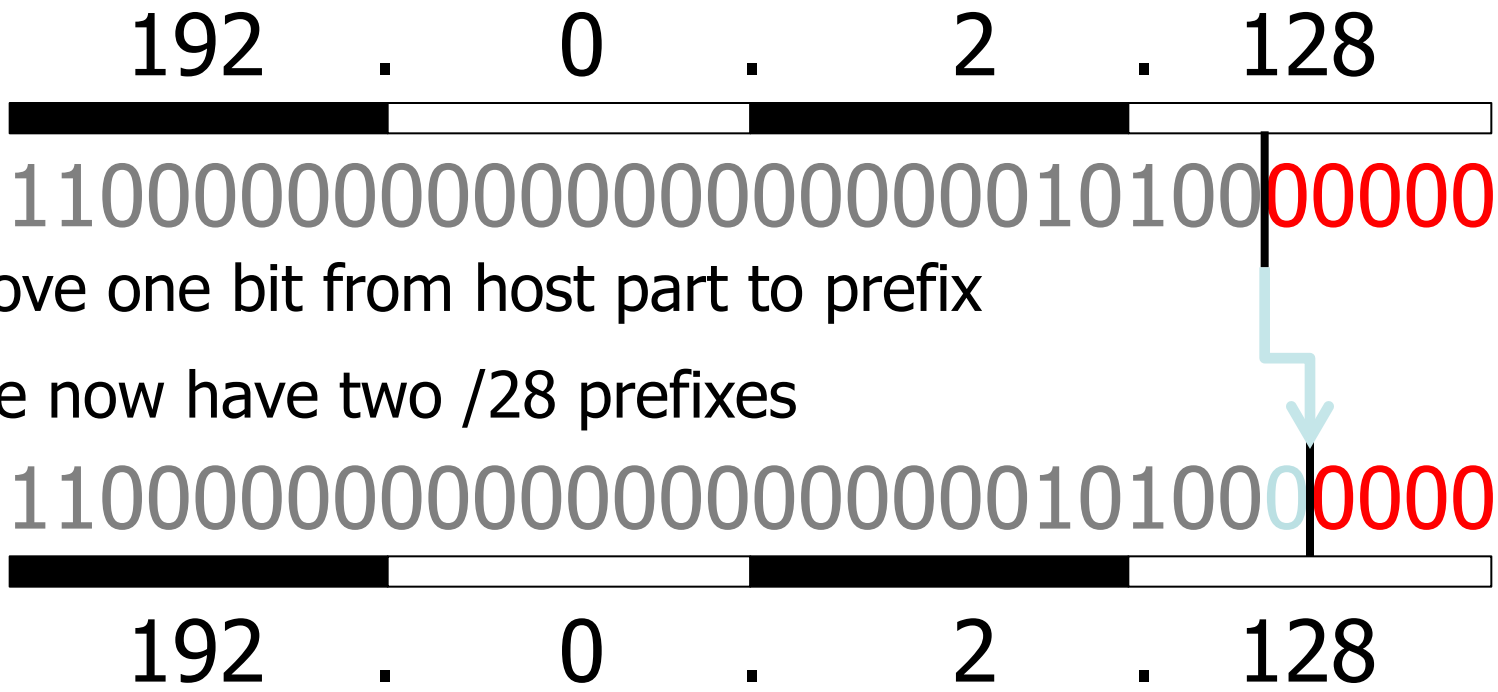


Move one bit from host part to prefix

Subnetting /27



Subnetting /27

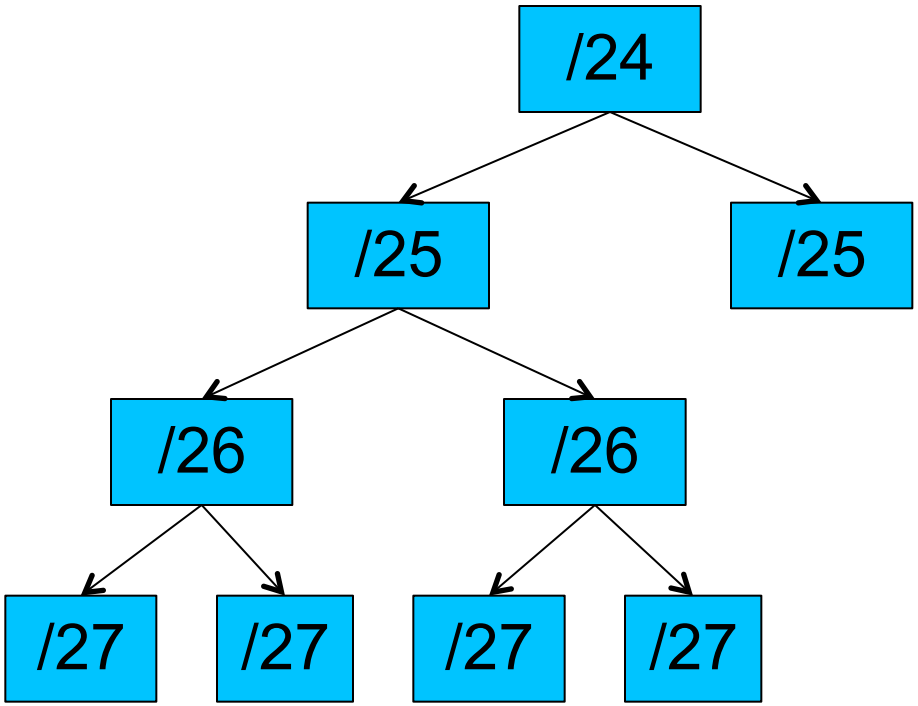


Check correctness

- Expand each new prefix into lowest and highest
- Ranges should not overlap
  - 192.0.2.128/28
    - Lowest (network) = 192.0.2.128
    - Highest (broadcast) = 192.0.2.143
  - 192.0.2.144/28
    - Lowest (network) = 192.0.2.144
    - Highest (broadcast) = 192.0.2.159
  - How many usable addresses now?

Aggregation tree

- Continue to divide prefixes as required
- Can visualise this as a tree



Questions about IPv4?

IPv6 addresses

- 128-bit binary number
  - How many unique addresses in total?

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  - $3.402823669209 \times 10^{38}$
- Conventionally represented in hexadecimal – 8 words of 16 bits, separated by colons

  2607:8400:2880:0004:0000:0000:80DF:9D13

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  2607:8400:2880:0004:0000:0000:80DF:9D13
- Leading zeros can be dropped
- The right-most contiguous run of all-zero words can be replaced by "::"

  2607:8400:2880:4::80DF:9D13

Hexadecimal

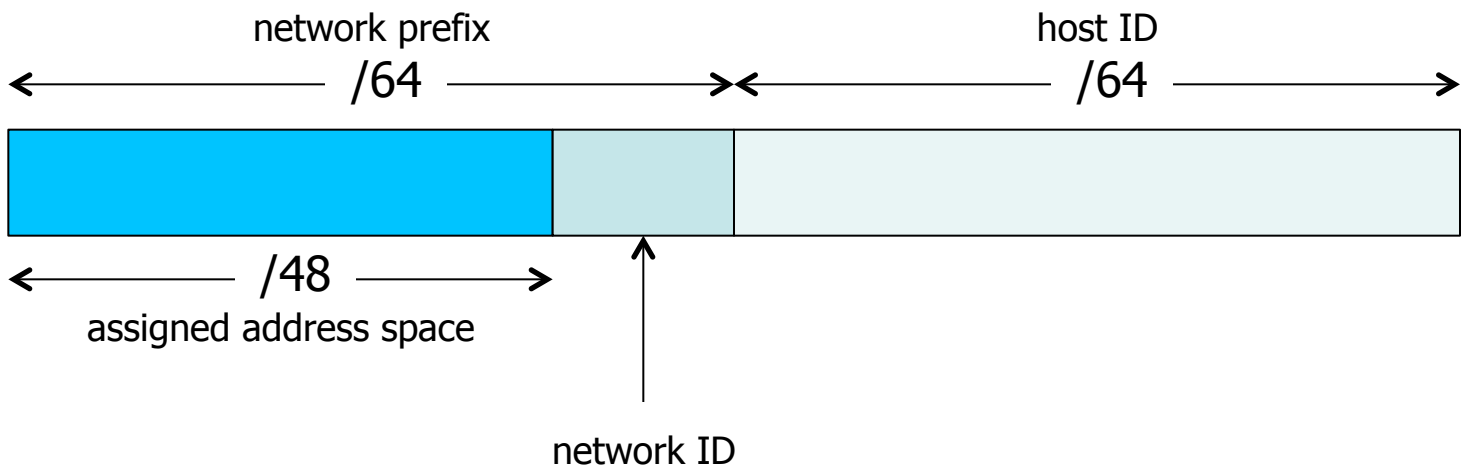
0000	**0**	1000	**8**
0001	**1**	1001	**9**
0010	**2**	1010	**a**
0011	**3**	1011	**b**
0100	**4**	1100	**c**
0101	**5**	1101	**d**
0110	**6**	1110	**e**
0111	**7**	1111	**f**

```
0000 = 0000000000000000
FFFF = 1111111111111111
```

IPv6 rules

- With IPv6, every network prefix is /64
  - (/127 is recommended for P2P links)
- The remaining 64 bits can be assigned by hand, or picked automatically
  - e.g. derived from NIC MAC address
- There are special prefixes
  - e.g. link-local addresses start fe80::
- Total available IPv6 space is ≈ 2^{61} subnets
- Typical end-user allocation is /48

IPv6 addressing



- How many /64 networks can you build from a /48 allocation?

IPv6 addressing

- You are assigned 2001:DB8:123::/48
  - 2001:0DB8:0123:0000:0000:0000:0000:0000
- Lowest /64 network?

IPv6 addressing

- You are assigned 2001:DB8:123::/48
  - 2001:0DB8:0123:0000:0000:0000:0000:0000
- Lowest /64 network?
  - 2001:DB8:123:0000::/64
  - written simply 2001:DB8:123::/64

IPv6 addressing

- You are assigned 2001:DB8:123::/48
  - 2001:0DB8:0123:0000:0000:0000:0000:0000
- Lowest /64 network?
  - 2001:DB8:123:0000::/64
  - written simply 2001:DB8:123::/64
- Highest /64 network?
  - 2001:DB8:123:FFFF::/64

Ways to allocate the host part

- Do it automatically from MAC address – "stateless autoconfiguration"
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Ways to allocate the host part

- Do it automatically from MAC address – "stateless autoconfiguration"
  - Not recommended for servers: if you change the NIC then the IPv6 address changes!
- Can number sequentially from 1, or use the last octet of the IPv4 address
- Or embed the whole IPv4 address
  - e.g. 2607:8400:2880:4::80DF:9D13
  - 80DF9D13 hex = 128.223.157.19 in decimal
  - Can write 2607:8400:2880:4::128.223.157.19

Notes on IPv6

- Broadly similar to IPv4
- "ARP" is replaced by "NDP"
- IPv6 client configuration options
  - Stateless autoconf (router advertisements)
  - Stateless autoconf + stateless DHCPv6
  - Stateful DHCPv6
- Interfaces typically get both a link-local address and one or more routable prefixes
- "Dual stack" = v4 and v6 side-by-side

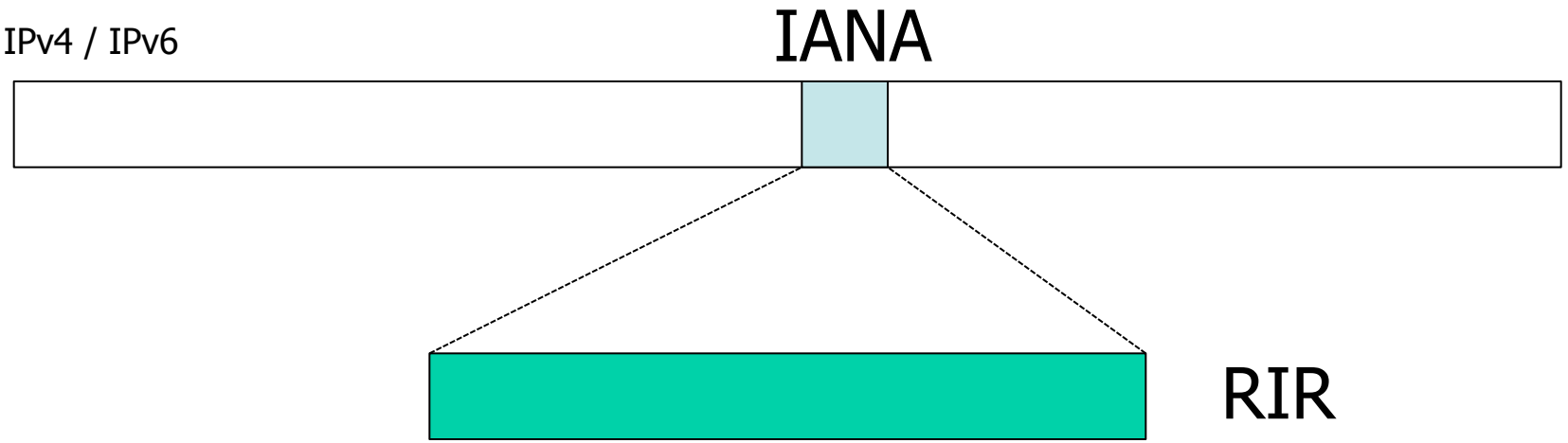
Questions about IPv6?

Hierarchical address allocation

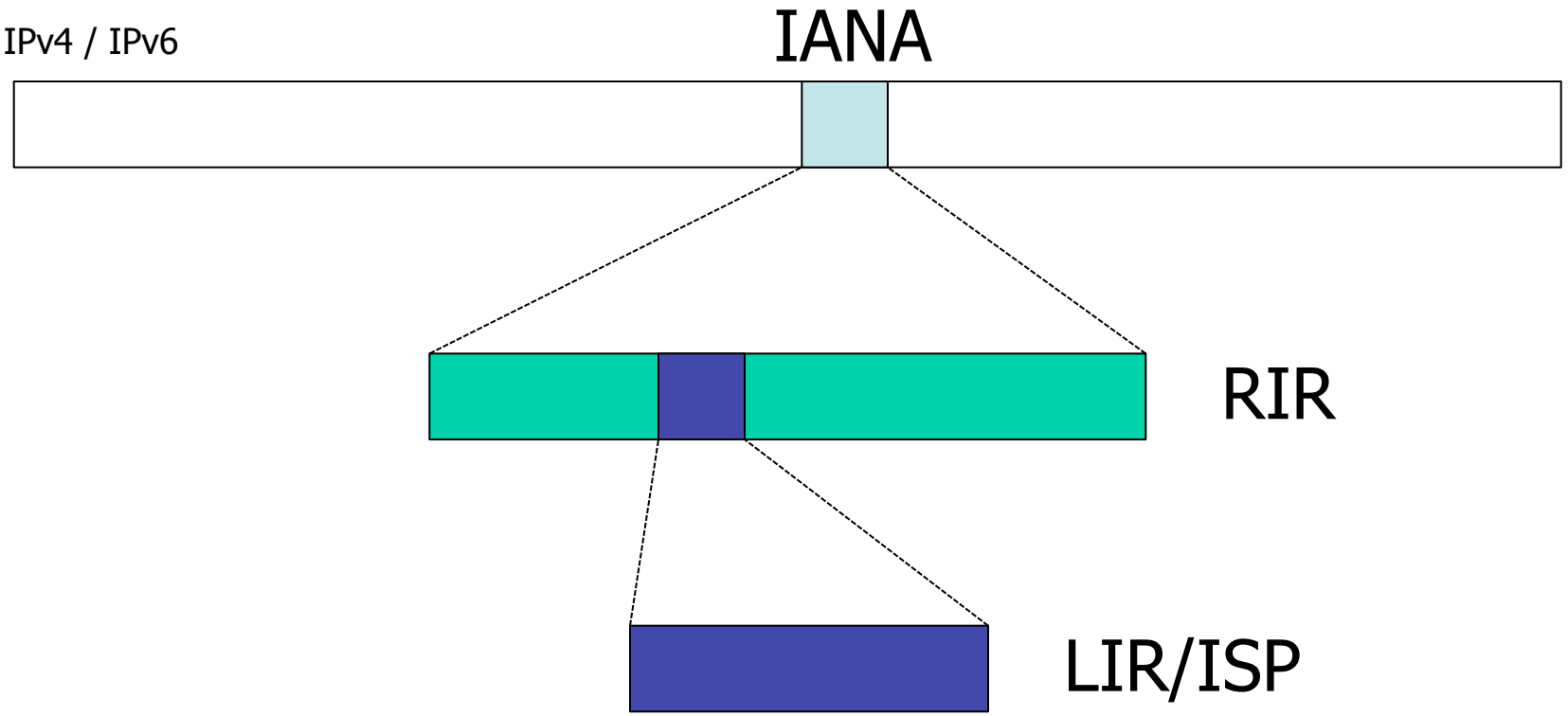
IPv4 / IPv6

IANA

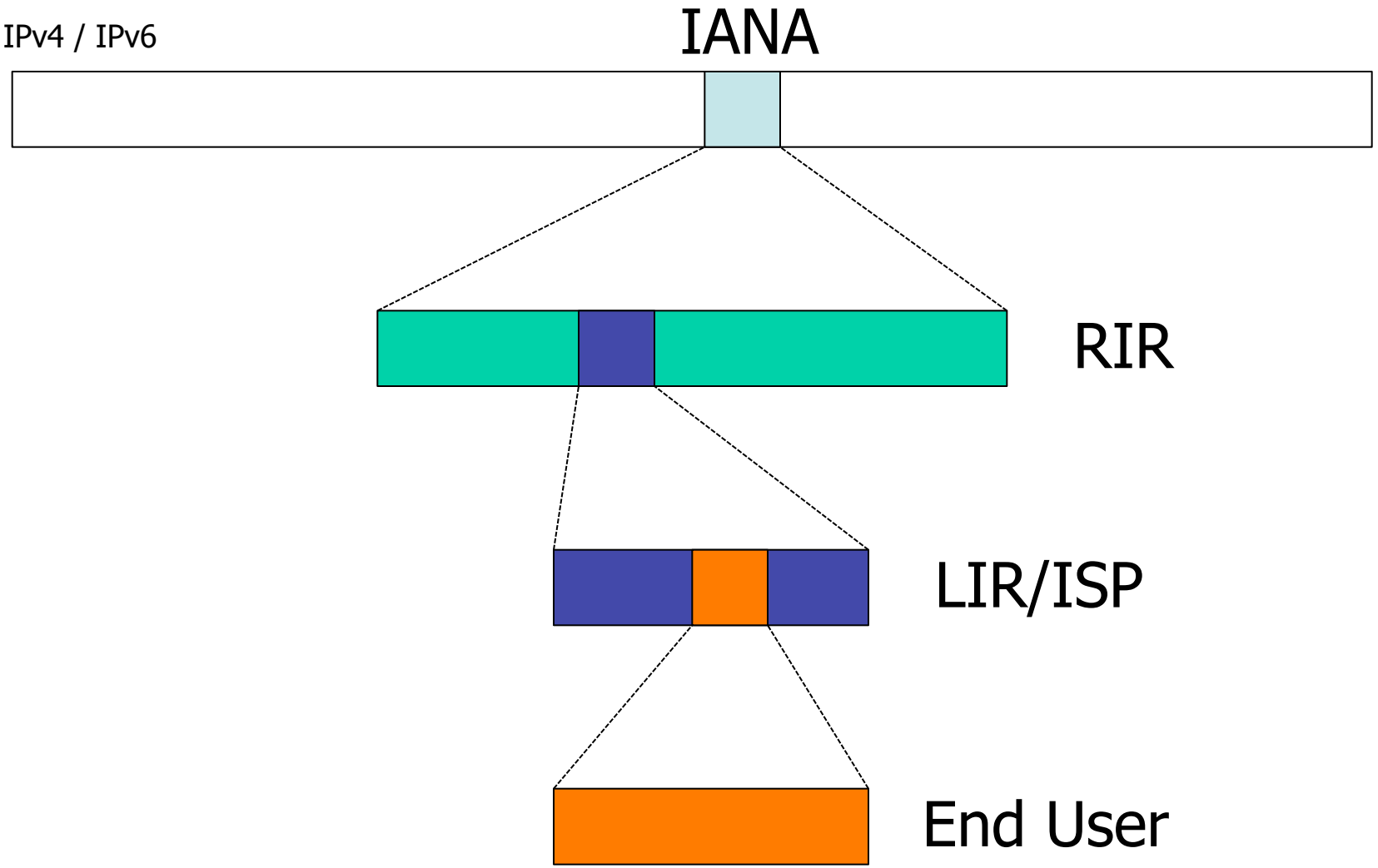
Hierarchical address allocation



Hierarchical address allocation



Hierarchical address allocation



IPv4 Address Distribution

- IPv4 addresses
  - Distributed by RIRs according to demonstrated need
  - Have almost all run out
  - RIRs have IPv4 run out policies
    - E.g. one off assignment from a limited pool
- Typical Campus:
  - Small public address block
    - For public servers, NAT pools
    - Anything from /28 to /21 depending on RIR region/upstream
  - Private address block
    - For internal end users, network management, etc

IPv6 Address Distribution

- IPv6 addresses
  - Network operators receive minimum of /32
    - Includes RENs, University Campuses, etc
  - End-sites receive /48
  - Smallest subnet size is /64
- Typical Single Campus:
  - /48 divided out amongst buildings
- Typical Multi-Campus or Multi-Faculty:
  - /32 divided out amongst Campuses
    - /48 per campus

Questions about IP Address Distribution?

Questions?