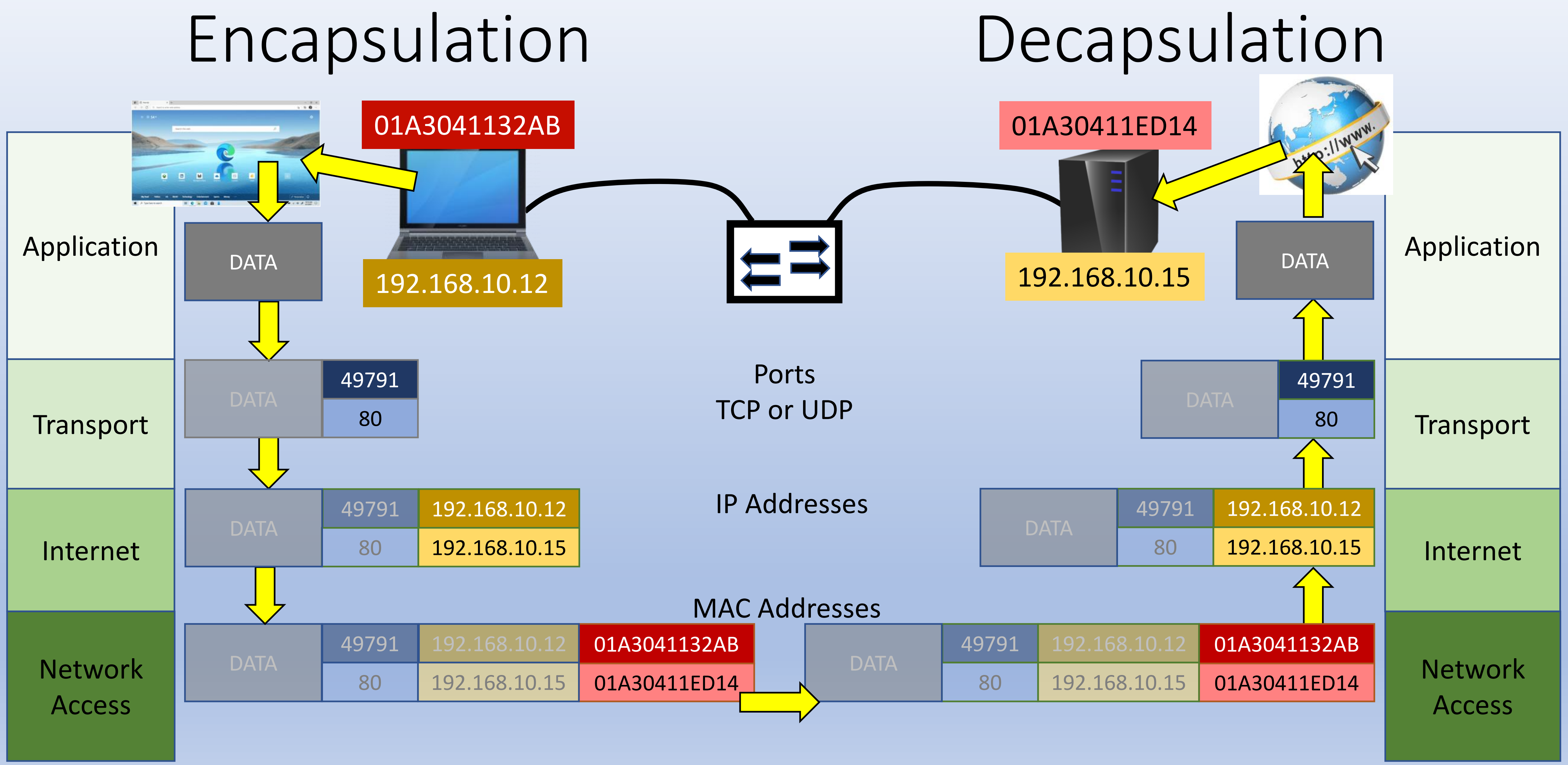
Networking Introduction

OSI vs TCP/IP

OSI		TCP/IP
Application	Application Protocols	Application
Presentation		
Session		
Transport	Ports UDP TCP	Transport
Network	IP	Internet
Data Link	MAC	Network Access
Physical		



Encapsulation
Decapsulation
01A3041132AB
192.168.10.12
01A30411ED14
192.168.10.15
Application
Transport
Internet
Network Access
DATA
49791
80
192.168.10.12
192.168.10.15
01A3041132AB
01A30411ED14
Ports
TCP or UDP
IP Addresses
MAC Addresses
http://www.

Addressing

- Physical – Media Access Control (MAC Address) of NIC
- Logical – IP Address of NIC
- Network Services – Port numbers

Physical Address (MAC Address)

- MAC Address - basically made up of two parts
  - Vendor Address
  - Random Address
- 013E1FBB23A1
  - 013E1FBB23A1 – First part is the Vendor Address
  - 013E1FBB23A1 – Last part is the Random Address
- FFFFFFFFFFFF
  - Special MAC address for Broadcasts
- This is how computers communicate with each other NIC to NIC

Logical Addresses (IP)

- IP addresses can be used to:
  - Provide a unique address for a host
  - Provide a way to group hosts on a subnet
  - Facilitate the transmission of network packets (data) between
    - Local hosts (on the same subnet)
    - Remote hosts (on different subnets separated by routers)
  - Provide private addresses
  - Provide public addresses
  - Allow private addresses to be translated to public and back again

IP Addresses and Binary

- 131.107.1.4
  - Dotted decimal notation
  - Each decimal number represents an octet (8 binary digits)
  - 0 = 00000000 (Minimum value)
  - 255 = 11111111 (Maximum value)
- 131 = 10000011
- 107 = 01101011
- 1 = 00000001
- 4 = 00000100
- 131.107.1.4 = 10000011 01101011 00000001 00000100

Binary

- Consists of 0 or 1 *(off / on)*
- Counting in binary:
  - 00000000 bin = 0 dec
  - 00000001 bin = 1 dec
  - 00000010 bin = 2 dec
  - 00000011 bin = 3 dec
  - 00000100 bin = 4 dec
  - 00000101 bin = 5 Dec
  - ….
  - 11111111 bin = 255 dec

For each 1 in binary add the corresponding decimal values:

Binary to Decimal conversion							
1	1	1	1	1	1	1	1
128	64	32	16	8	4	2	1
11111111 bin => 128+64+32+16+8+4+2+1 = 255 dec							

Binary to Decimal conversion							
1	0	1	0	1	0	1	1
128	64	32	16	8	4	2	1
10101011 bin => 128+32+8+2+1 = 171 dec							

Binary to Decimal conversion							
0	0	0	1	0	0	1	0
128	64	32	16	8	4	2	1
10010 bin => 16+2 = 18 dec							

IP Address (Network vs Host)

- IP Addresses describe two things - Network section & Host section
  - Network section: is like the name of a street
  - Host section is like the house number
- Examples:
  - 192.168.0.1
    - 192.168.0.1 – Network section, 192.168.0.1 – Host section
  - 131.107.1.4
    - 131.107.1.4 – Network section, 131.107.1.4 – Host section
  - 10.34.2.1
    - 10.34.2.1 – Network section, 10.34.2.1 – Host section
- Subnet Mask
  - Shows which section is the network and which is the host

Subnet Mask

- Determines which part of the IP address is the:
  - Network section
  - Host section
- Helps to determine if a destination host is on:
  - Local subnet
  - Remote subnet
- Traditional Class Subnet masks

	Dotted Decimal	Binary	CIDR
Class A =	255.0.0.0	= 11111111 00000000 00000000 00000000 =	/8
Class B =	255.255.0.0	= 11111111 11111111 00000000 00000000 =	/16
Class C =	255.255.255.0	= 11111111 11111111 11111111 00000000 =	/24

  - Class D = no subnet mask specified (Used for multicast)
- Traditional masks wasted a lot of address
  - Solution = Classless inter-domain routing (CIDR)
  - CIDR allows for bitwise manipulation of the subnet mask

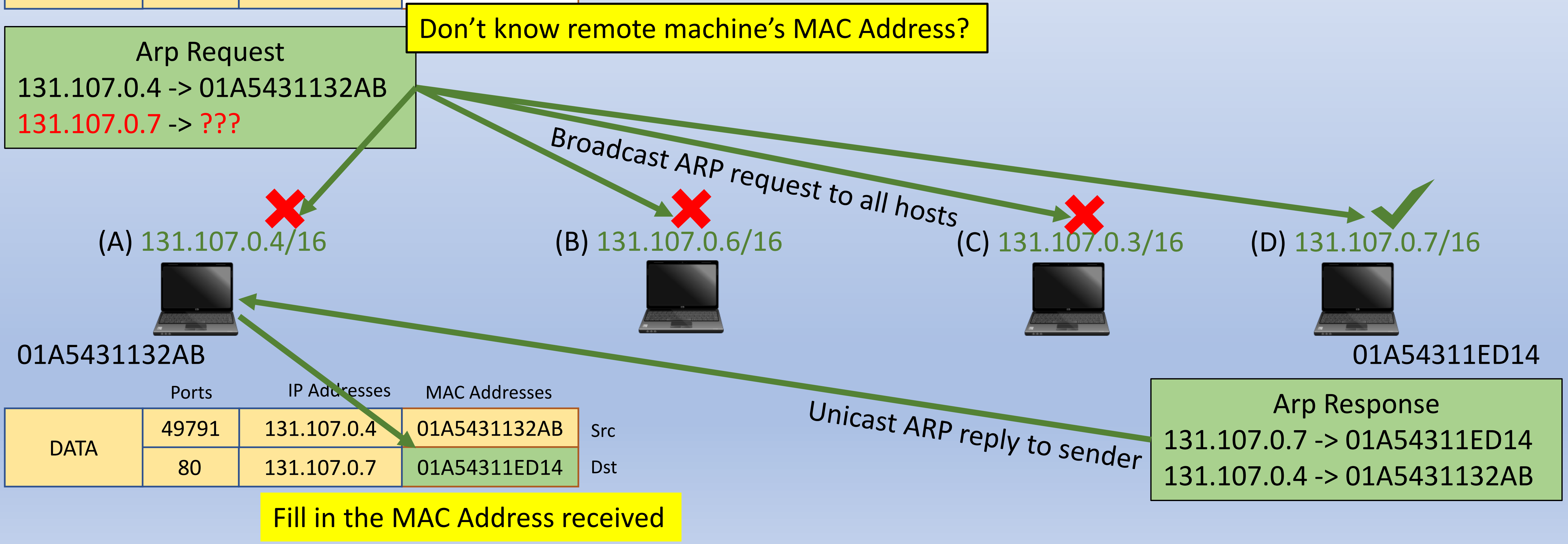
Original IP Classes (assignable addresses)

- Class A
  - First octet 1-126 (Binary 00000000 – 01111111) *[0 & 127 by convention are not used)*
  - First octet is the network section
  - Last three octets are the Host section
- Class B
  - First octet 128-191 (Binary 10000000 – 10111111)
  - First two octets are the network section
  - Last two octets are the Host section
- Class C
  - First octet 192-223 (Binary 11000000 – 11011111)
  - First three octets are the network section
  - Last octet is the Host section

ARP – Address Resolution Protocol

- ARP resolves an IP address into its corresponding MAC address
- ARP request is sent as a broadcast packet
- Asks who owns an IP address
  - IP owner answers with its MAC address with a unicast packet
  - ARP resolution information is cached in memory (for both the sender and receiver)
  - ARP cache entries last about 10 minutes in memory
- Routers do not pass broadcasts
  - Cannot ARP for an IP on a remote subnet
  - To communicate with a remote host, route packet through a router
  - Set Default Gateway IP so hosts can be used to find the default router
- Use arp -a to show the contents of the ARP cache
- Use arp -d to delete the contents of the ARP Cache

ARP in action (Host A to Host D)



	Ports	IP Addresses	MAC Addresses	
DATA	49791	131.107.0.4	01A5431132AB	Src
	80	131.107.0.7	???	Dst

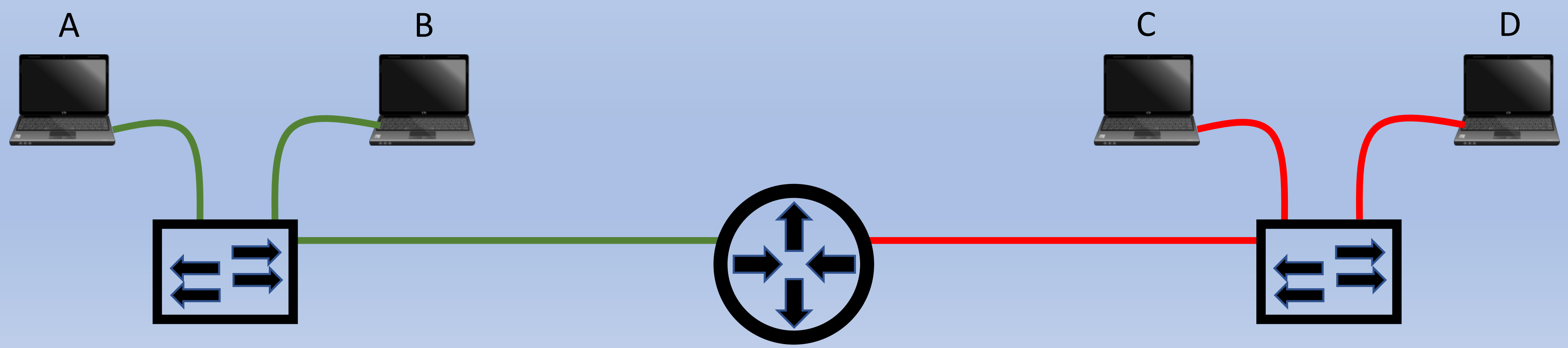
	Ports	IP Addresses	MAC Addresses	
DATA	49791	131.107.0.4	01A5431132AB	Src
	80	131.107.0.7	01A54311ED14	Dst

Default Gateway

- Typically set on each host
  - Allows the host to route traffic out of the local subnet
  - Points to the default router
  - Is used when the host needs to:
    - Send traffic to a remote network
    - There is no specific route for the intended destination
- Only used for remote destinations
- Sender sends an ARP request for the Default Gateway’s IP address
- Sender receives the MAC address of the router’s NIC

Determine if destination is local or remote

- Sending host
  - ANDs its IP address with the senders Subnet Mask
  - ANDs the destination IP address with the senders Subnet Mask
- Compare the results of the previous ANDing calculations
  - if the results are the same then the destination IP is local (Computers A & B)
  - if the results are different then destination IP is remote (Computers B & C)



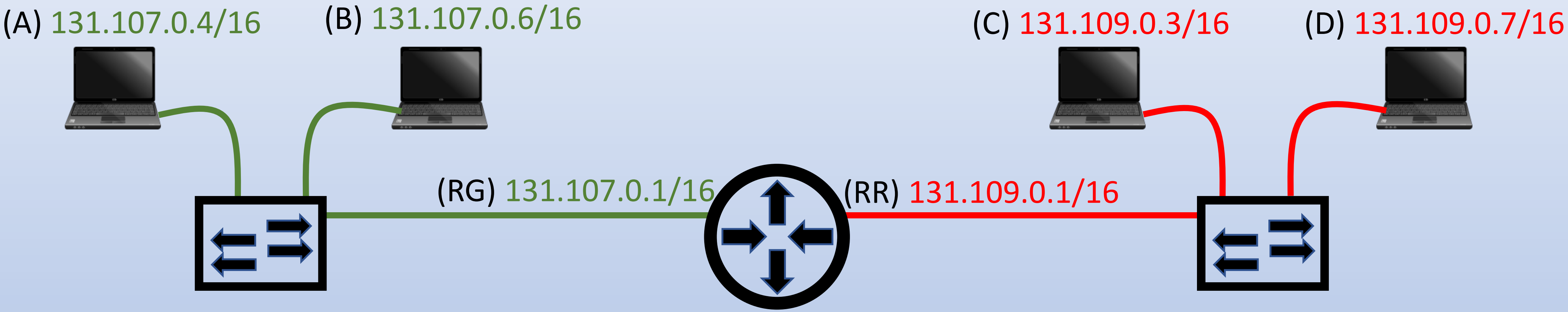
Determine how to route traffic

- Each time a network transmission happens
  - Sender need to determine if destination is on the local or remote network
- If the destination IP address is on the local network
  - ARP for the destination IP address
  - This informs the sender of the remote host’s MAC address
  - Send the network packet to the MAC address of the destination host
- If the destination IP address is on a remote network
  - ARP for the IP address of the Default Gateway
  - This informs the sender of the default gateway’s MAC address
  - Send the network packet to the MAC address of the default router

Boolean AND calculation

BOOLEAN AND				
0	AND	0	=	0
0	AND	1	=	0
1	AND	0	=	0
1	AND	1	=	1

Determining if hosts are local or remote



- A -> B (Local)
  - 131.107.0.4 AND 255.255.0.0 = 131.107.0.0
  - 131.107.0.6 AND 255.255.0.0 = 131.107.0.0
- B -> C (Remote)
  - 131.107.0.6 AND 255.255.0.0 = 131.107.0.0
  - 131.109.0.3 AND 255.255.0.0 = 131.109.0.0

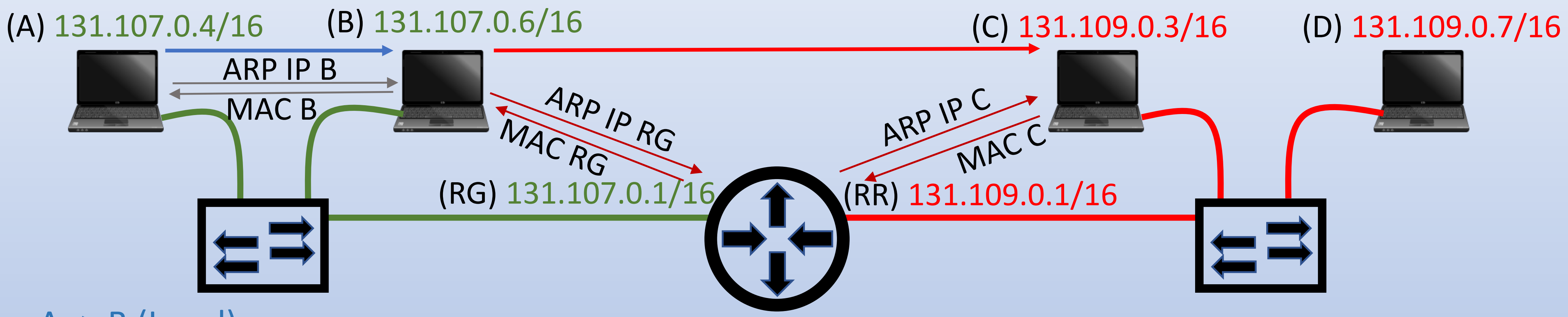
AND calculation (A -> B)

- 131.107.0.4 AND 255.255.0.0
  - 10000011 01101011 00000000 00000100 (131.107.0.4)
  - 11111111 11111111 00000000 00000000 (255.255.0.0)
  - 10000011 01101011 00000000 00000000 (131.107.0.0 - AND Result)
- 131.107.0.6 AND 255.255.0.0
  - 10000011 01101011 00000000 00000110 (131.107.0.6)
  - 11111111 11111111 00000000 00000000 (255.255.0.0)
  - 10000011 01101011 00000000 00000000 (131.107.0.0 - AND Result)
- Results are the same – this means the two addresses are local

AND calculation (B -> C)

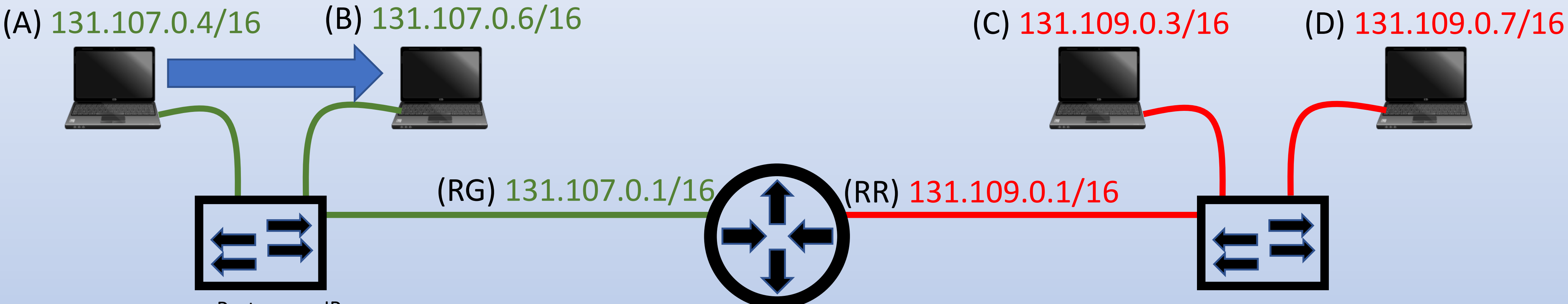
- 131.107.0.6 AND 255.255.0.0
  - 10000011 01101011 00000000 00000110 (131.107.0.6)
  - 11111111 11111111 00000000 00000000 (255.255.0.0)
  - 10000011 01101011 00000000 00000000 (131.107.0.0 - AND Result)
- 131.109.0.3 AND 255.255.0.0
  - 10000011 01101101 00000000 00000011 (131.109.0.3)
  - 11111111 11111111 00000000 00000000 (255.255.0.0)
  - 10000011 01101101 00000000 00000000 (131.109.0.0 - AND Result)
- Results are different – this means the two addresses are remote

ARP Requests



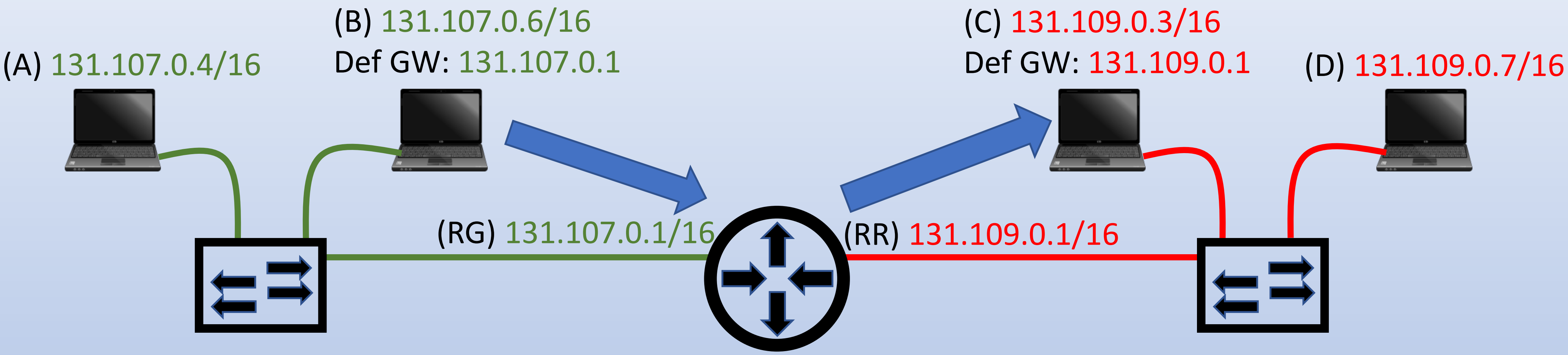
- A -> B (Local)
  - From A, ARP for destination IP B
  - Reply with MAC address from B
- B -> C (Remote)
  - From B, ARP for the router RG IP address
  - Reply with MAC address from RG
  - Send the network packet to the routers MAC address
  - From Router, ARP for destination C IP address
  - Reply with MAC address from C

Routing local (A -> B [Webserver])



	Port	IP	MAC	
	50331	A	A	SRC
	80	B	B	DST

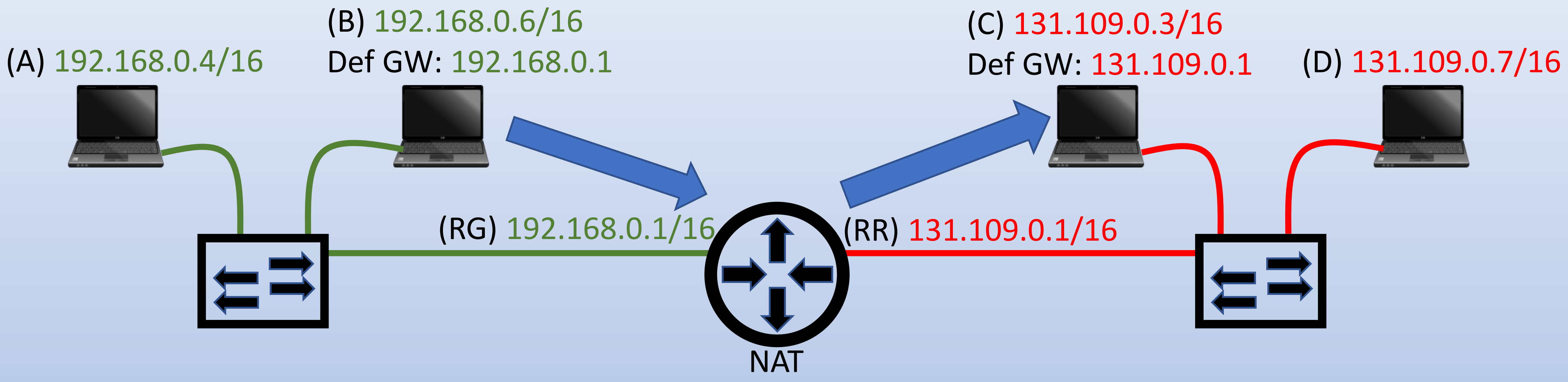
Routing remote (B -> C [Webserver])



	Port	IP	MAC	
	49791	B	B	SRC
	80	C	RG	DST

	Port	IP	MAC	
	49791	B	RR	SRC
	80	C	C	DST

Routing and NAT (B -> C [Webserver])



	Port	IP	MAC	
	49961	B	B	SRC
	80	C	RG	DST

	Port	IP	MAC	
	10001	RR	RR	SRC
	80	C	C	DST

NAT TABLE
192.168.0.6:49961 ---> 131.109.0.1:10001

Subnetting Introduction

Why do we subnet

- To convert a single network into smaller networks
- To reduce wasting of IP addresses
- To control network traffic congestion
- To manage the growth of a network
- To make network security more granular

How do we subnet

- You need to answer several questions before you are ready to subnet
  - What network address are we starting with
  - How many smaller networks do we need (Subnets)
  - How many IP addresses do we need on each subnet (minimum: 1 per NIC)
  - What growth do we expect to happen within the subnets
  - Is it possible to achieve the result with the given conditions

What network are we starting with

- Class A, B, C each have default subnet masks /8, /16, /24
- Some IP addresses on each network have special purposes
- We will use 131.12.0.0/16 as an example:
  - Network ID: 131.12.0.0/16
  - Broadcast ID: 131.12.255.255/16
  - The first address in each subnet is its Network ID
  - The last address in each subnet is its Broadcast ID
  - The Network ID and Broadcast ID are not used for addressing hosts
  - So, the usable (valid) addresses are: 131.12.0.1 -> 131.12.255.254 / 16

Subnetting example - 131.12.0.0/16

- *Responses from an organisation to our questions*:
- How many subnets are required
  - 28
- How many IP addresses are required per subnet
  - 1300
- What growth do we expect on these subnets
  - 5% growth in the number of subnets
  - 10% growth in IP addresses
- Therefore, max subnets: 28 + 5% = 28 + 1.4 (~ 2) = 30
- Therefore, max IP addresses: 1300 + 10% = 1300 + 130 = 1430

Example continued - Calculate subnets

- Subnets Required: 30
- IP addresses / subnet required : 1430
- Starting Network ID: 131.12.0.0/16
- /16 means
  - That the first 16 bits are network
  - This leaves the last 16 bits for us to slice up into smaller subnets
- How many bits are required to make at least 30 subnets
- 5 Bits
  - 00000 -> 11111 = is 32 possible numbers (we need 30)
- That leaves eleven bits for hosts (16 – 5)
  - 00000000000 -> 11111111111 = 2048 possible numbers – 2 (one for Net ID and one for BC ID)
  - 2046 IP addresses on each of the 32 subnets
- The subnetting is possible!

How is the subnetting performed

- The new subnet mask is the old mask + the network bits required
  - Old mask = 16 bits
  - Subnet bits required for subnetting = 5 bits
  - New subnetting mask = 21 bits
- Old 131.12.0.0/16 in binary looks like this:
  - 10000011 00001100 00000000 00000000
  - 11111111 11111111 00000000 00000000 (16 bits)
- New 131.12.0.0/21 in binary looks like this:
  - 10000011 00001100 00000000 00000000 (Subnet portion Host portion)
  - 11111111 11111111 11111000 00000000 (21 bits)

How to create the first subnet

- 10000011 00001100 00000000 00000000
- The first subnet would look like this in binary:
  - 10000011 00001100 00000000 00000000 - Subnet ID
  - 10000011 00001100 00000000 00000001 - First valid address
  - 10000011 00001100 00000111 11111110 - Last valid address
  - 10000011 00001100 00000111 11111111 - Broadcast ID
- In Decimal
  - 131.12.0.0 - Subnet ID
  - 131.12.0.1 - First valid address
  - 131.12.7.254 - Last valid address
  - 131.12.7.255 - Broadcast ID

How to create the second subnet

- 10000011 00001100 00001000 00000000
- The second subnet would look like this in binary:
  - 10000011 00001100 00001000 00000000 - Subnet ID
  - 10000011 00001100 00001000 00000001 - First valid address
  - 10000011 00001100 00001111 11111110 - Last valid address
  - 10000011 00001100 00001111 11111111 - Broadcast ID
- In Decimal
  - 131.12.8.0 - Subnet ID
  - 131.12.8.1 - First valid address
  - 131.12.15.254 - Last valid address
  - 131.12.15.255 - Broadcast ID

How to create the third subnet

- 10000011 00001100 00010000 00000000
- The third subnet would look like this in binary:
  - 10000011 00001100 00010000 00000000 - Subnet ID
  - 10000011 00001100 00010000 00000001 - First valid address
  - 10000011 00001100 00010111 11111110 - Last valid address
  - 10000011 00001100 00010111 11111111 - Broadcast ID
- In Decimal
  - 131.12.16.0 - Subnet ID
  - 131.12.16.1 - First valid address
  - 131.12.23.254 - Last valid address
  - 131.12.23.255 - Broadcast ID

How to create the fourth subnet

- 10000011 00001100 00011000 00000000
- The fourth subnet would look like this in binary:
  - 10000011 00001100 00011000 00000000 - Subnet ID
  - 10000011 00001100 00011000 00000001 - First valid address
  - 10000011 00001100 00011111 11111110 - Last valid address
  - 10000011 00001100 00011111 11111111 - Broadcast ID
- In Decimal
  - 131.12.24.0 - Subnet ID
  - 131.12.24.1 - First valid address
  - 131.12.31.254 - Last valid address
  - 131.12.31.255 - Broadcast ID

Supernetting Introduction

Why Supernetting

- Optimising Route tables
- Creating larger networks by combining networks
- It is the opposite to subnetting

How to Supernet

- Combined networks are only in sets of 2,4,8,16,32 …
- Supernetting only can combine subsequent networks together
- The host section of the supernet must:
  - Start with all binary 0’s
  - End with all binary 1’s

Supernet Example

- Situation:
  - Need 1000 hosts on a single network
  - Class C networks are all we have to work with
  - Each class C network only gives us 256 - 2 = 254 host addresses
- What is required
  - Determine the number of bits to accommodate 1000 hosts?
    - Ten bits minimum are required to provide 1000 hosts
    - Using groups of class C we would need 4 subnets (1024 - 2 = 1022 hosts)

Supernet Solution

- Using these 4 networks
  - 191.9.8.0/24, 191.9.9.0/24, 191.9.10.0/24, 191.9.11.0/24
- 10111111 00001001 00001000 00000000 /24
- 10111111 00001001 00001001 00000000 /24
- 10111111 00001001 00001010 00000000 /24
- 10111111 00001001 00001011 00000000 /24
- --
- 10111111 00001001 00001000 00000000 /22
- 191.9.8.0/22 [1 subnet, 1022 hosts (1024 - 2)]

Bits 23 and 24 start at 00 and end with 11 this is a requirement

By removing bits 23 and 24 from the subnet mask we create 1 subnet from 4 subnets

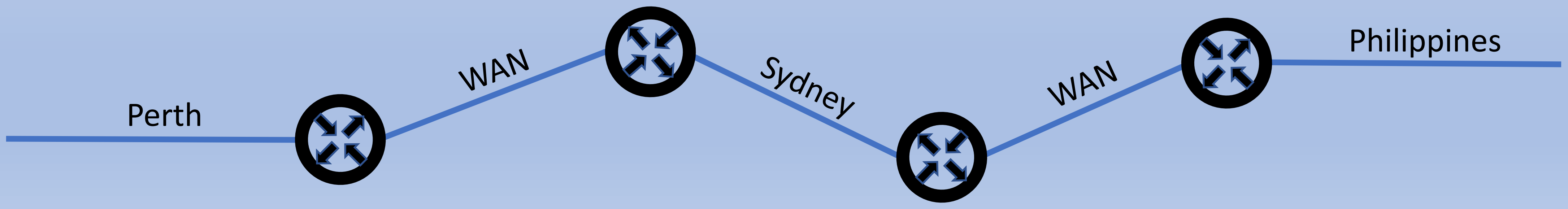
Variable Length Subnet Masks (VLSM)

Why VLSM

- The subnets we need are rarely the same size
- We need some subnets that only require two host addresses (WANs)
- VLSM is a more efficient use of network address space
- It is much more practical to use VLSM

VLSM Example

- 1st network requires 100 hosts (Sydney)
- 2nd network requires 20 hosts (Philippines)
- 3rd network requires 15 hosts (Perth)
- 4th network is a WAN links that require 2 hosts (Per -> Syd)
- 5th network is a WAN links that require 2 hosts (Syd -> Php)
- Network to subnet is 189.10.10.0/24



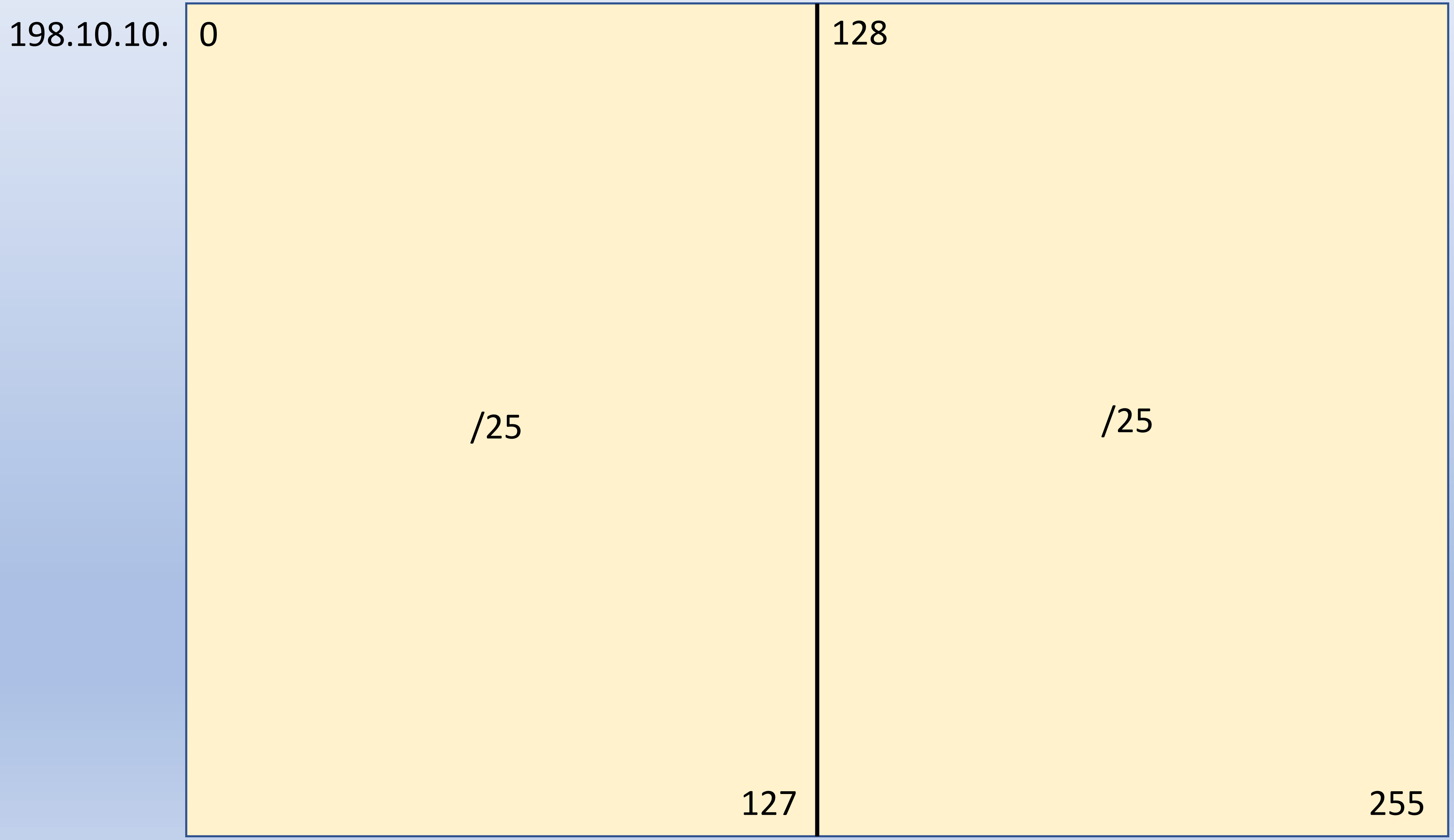
VLSM Box method

198.10.10. 0

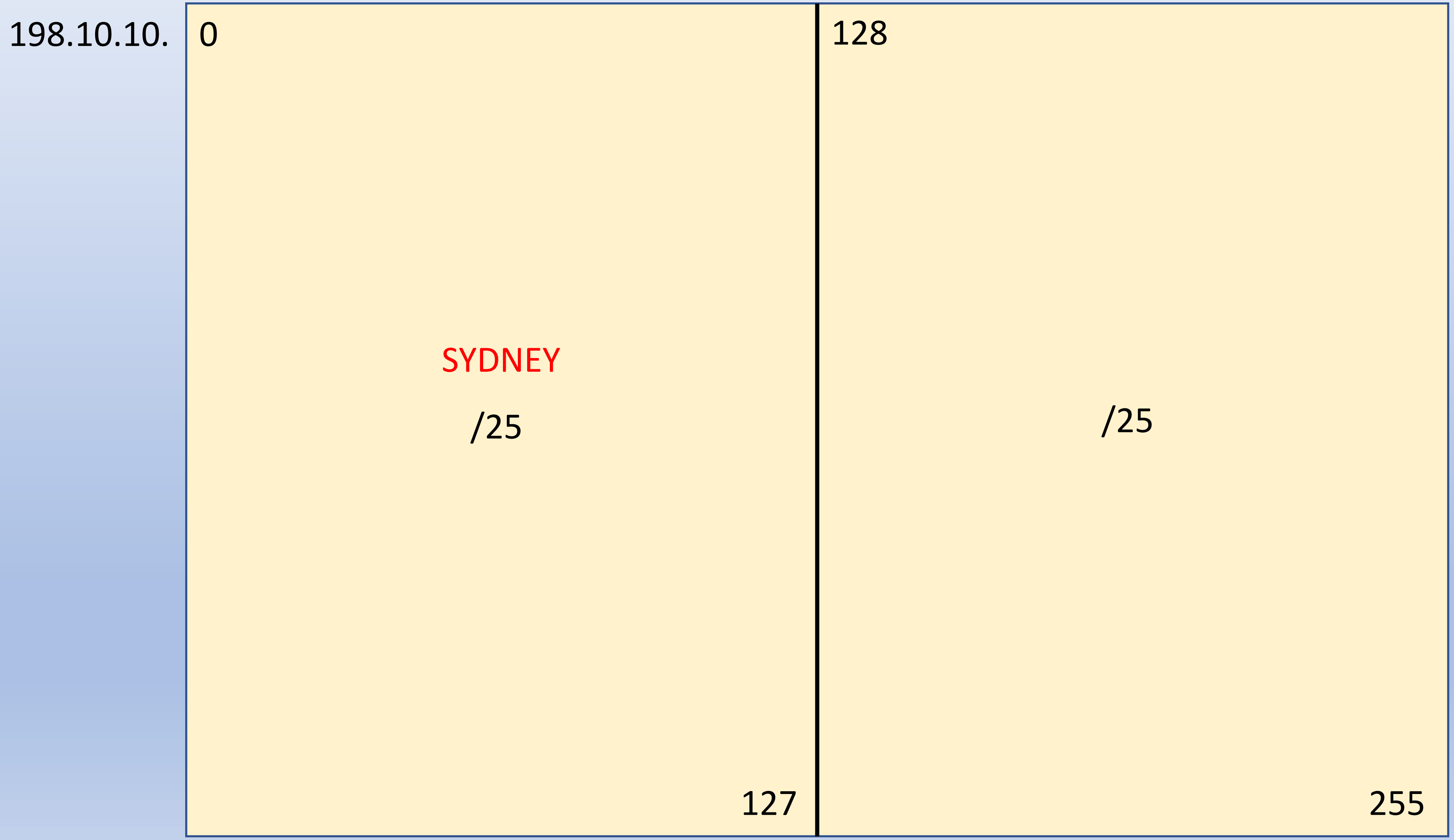
/24

255

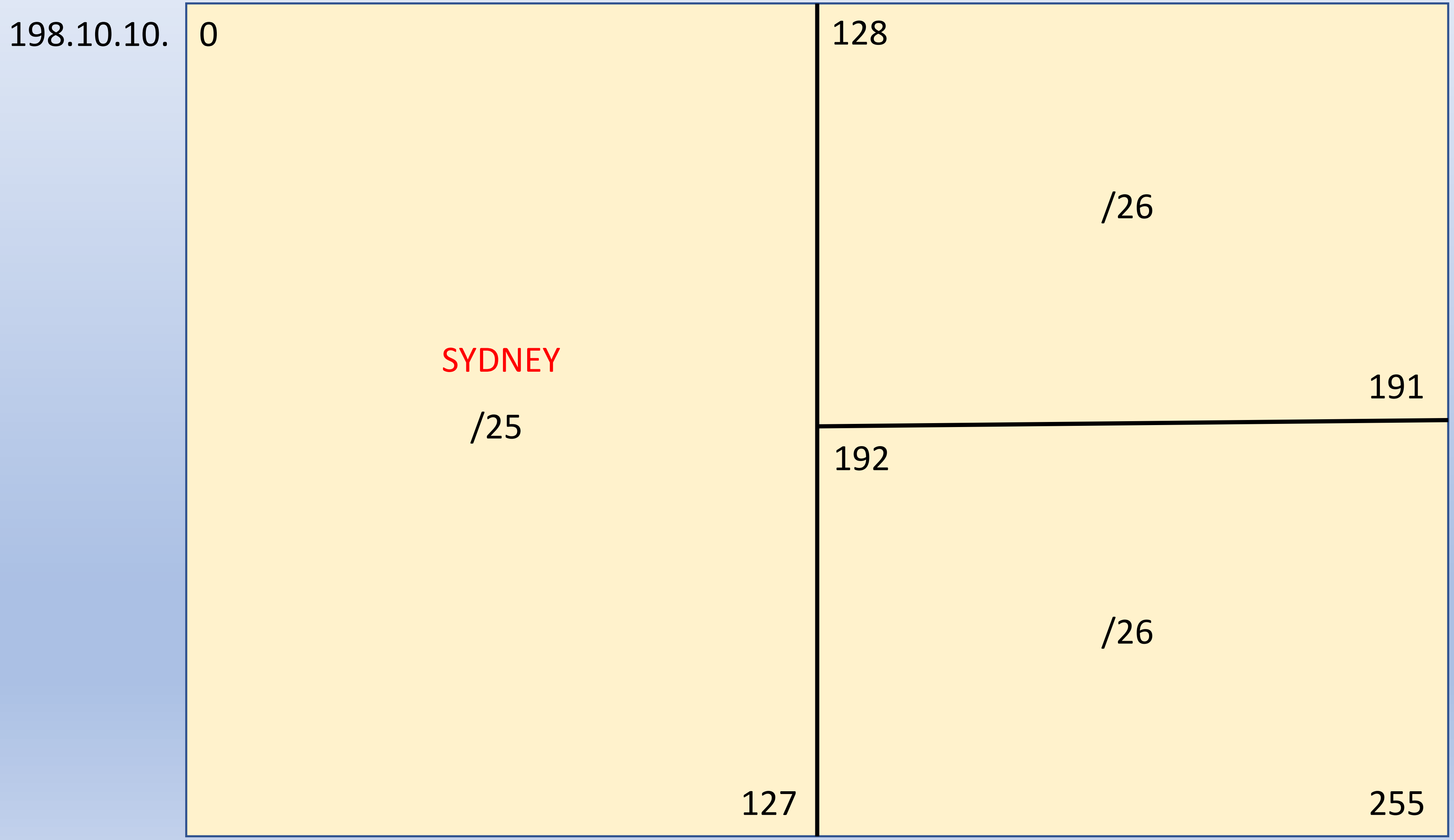
VLSM Box method



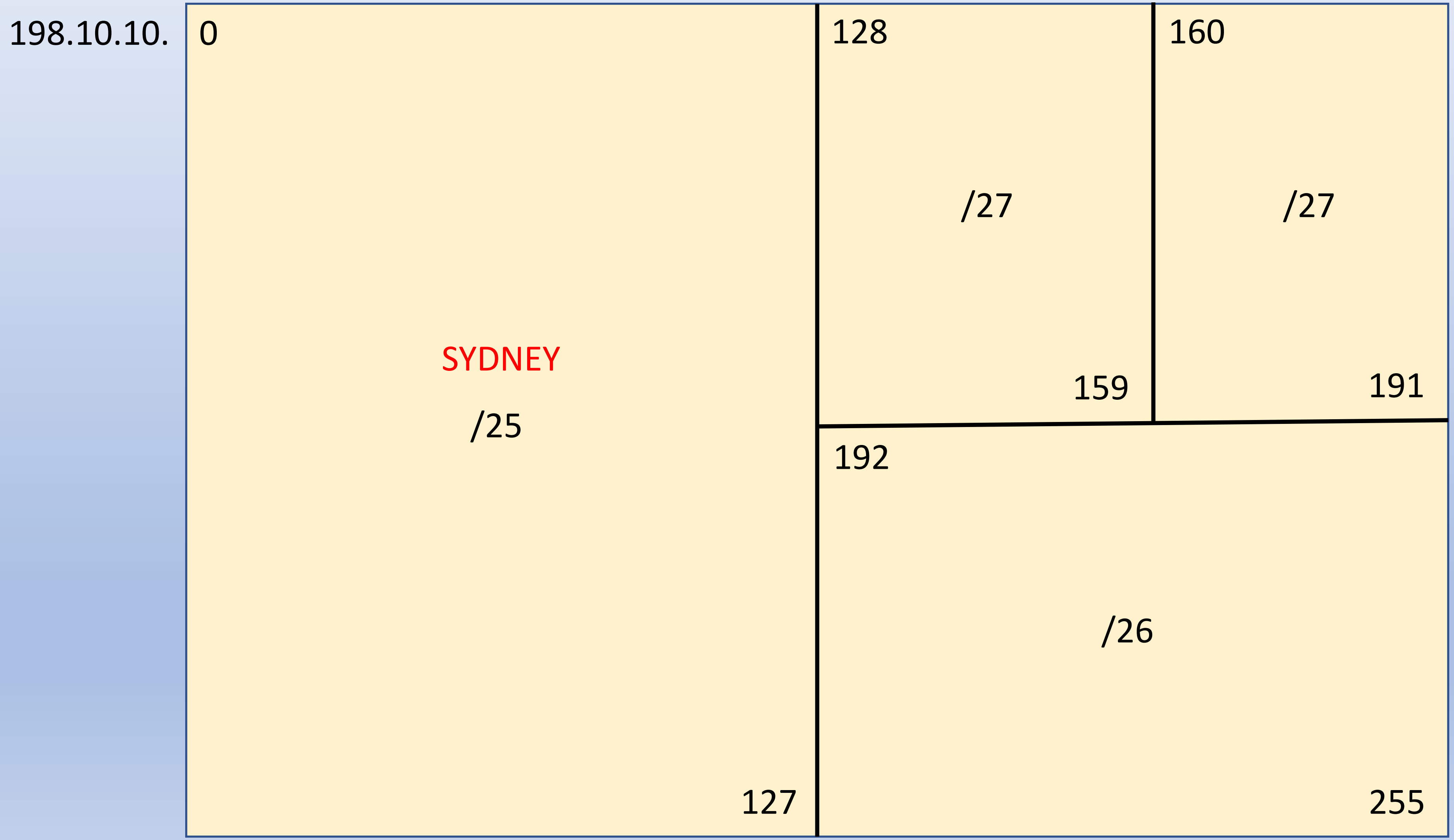
VLSM Box method



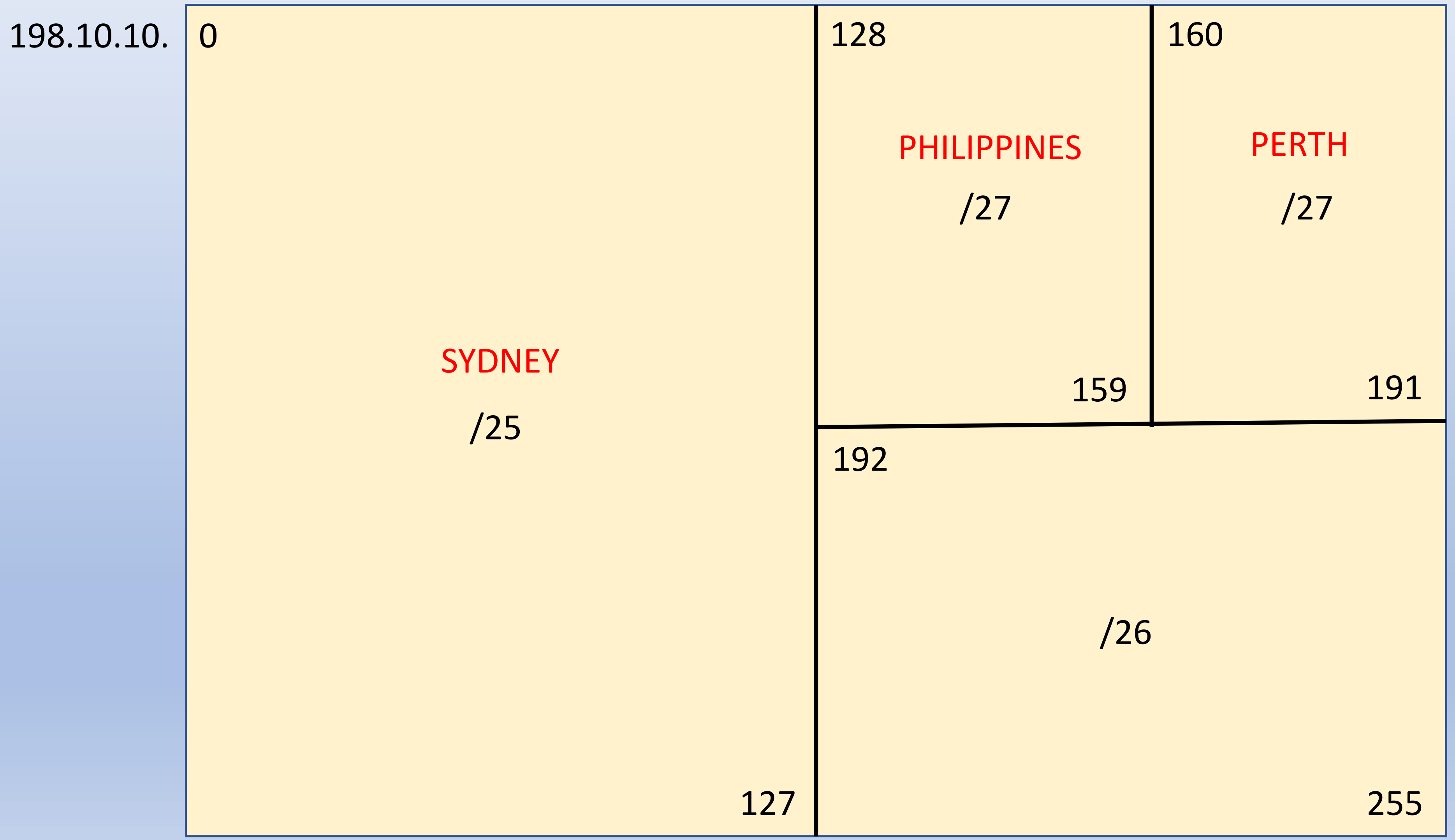
VLSM Box method



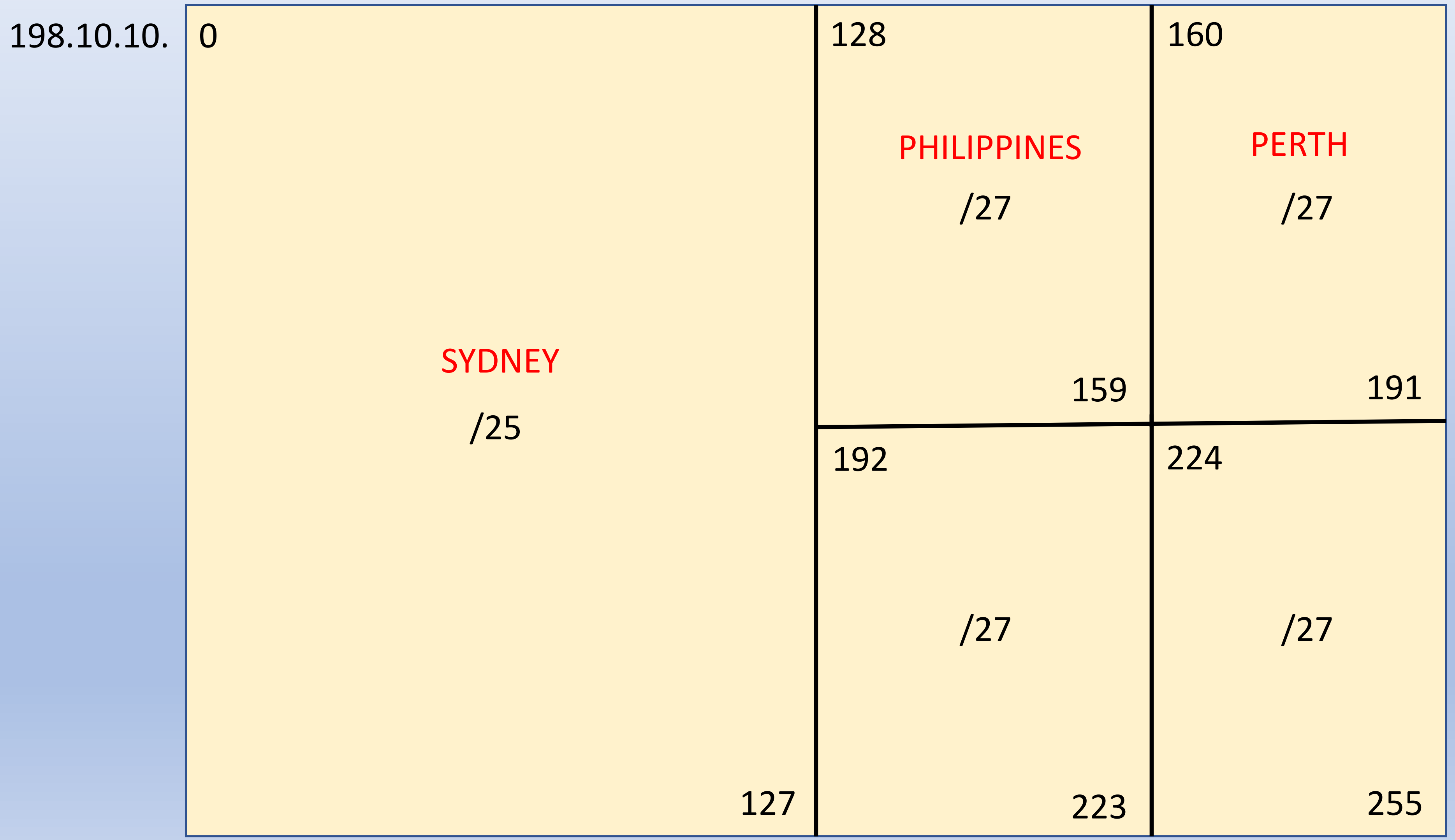
VLSM Box method



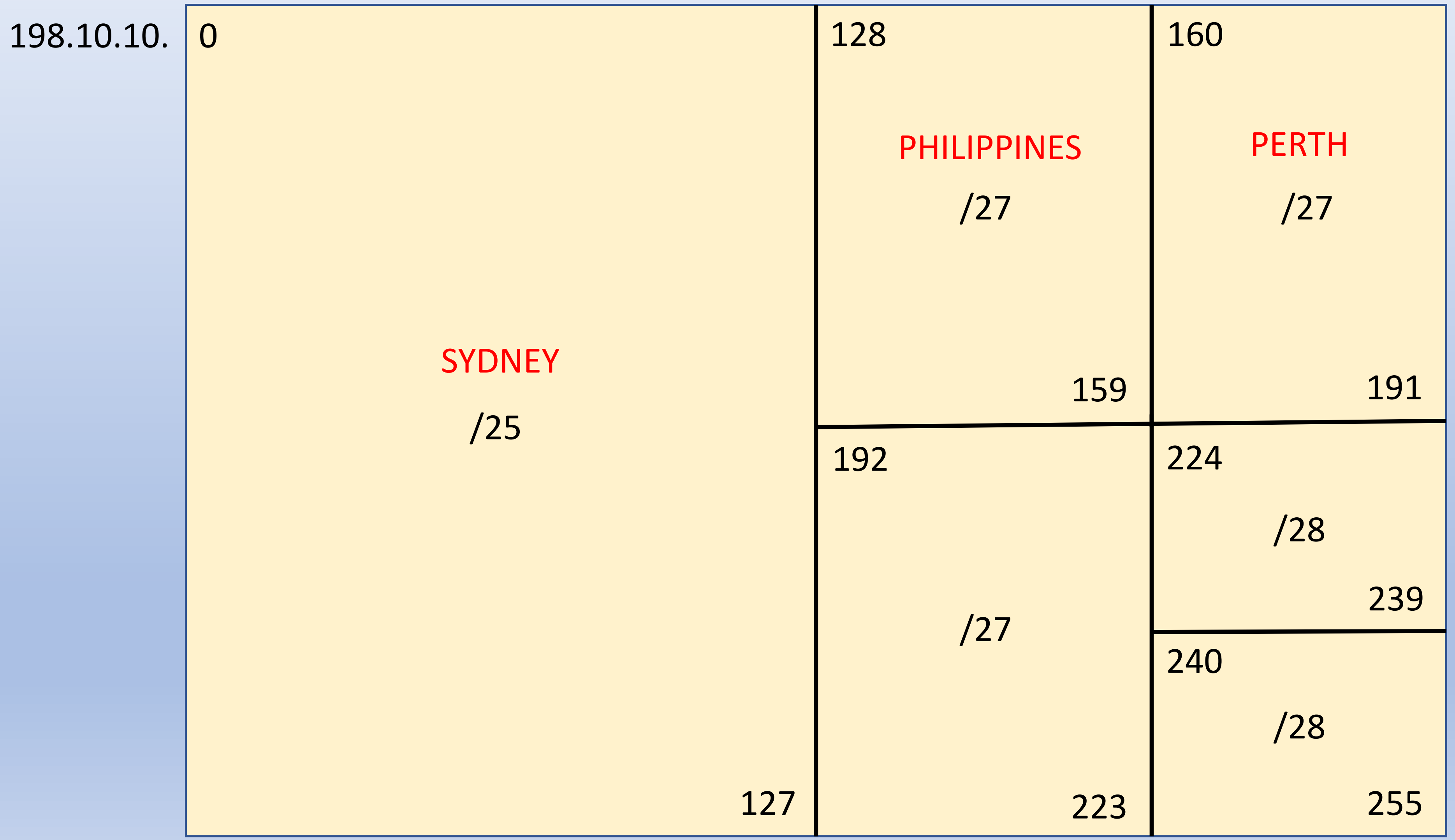
VLSM Box method



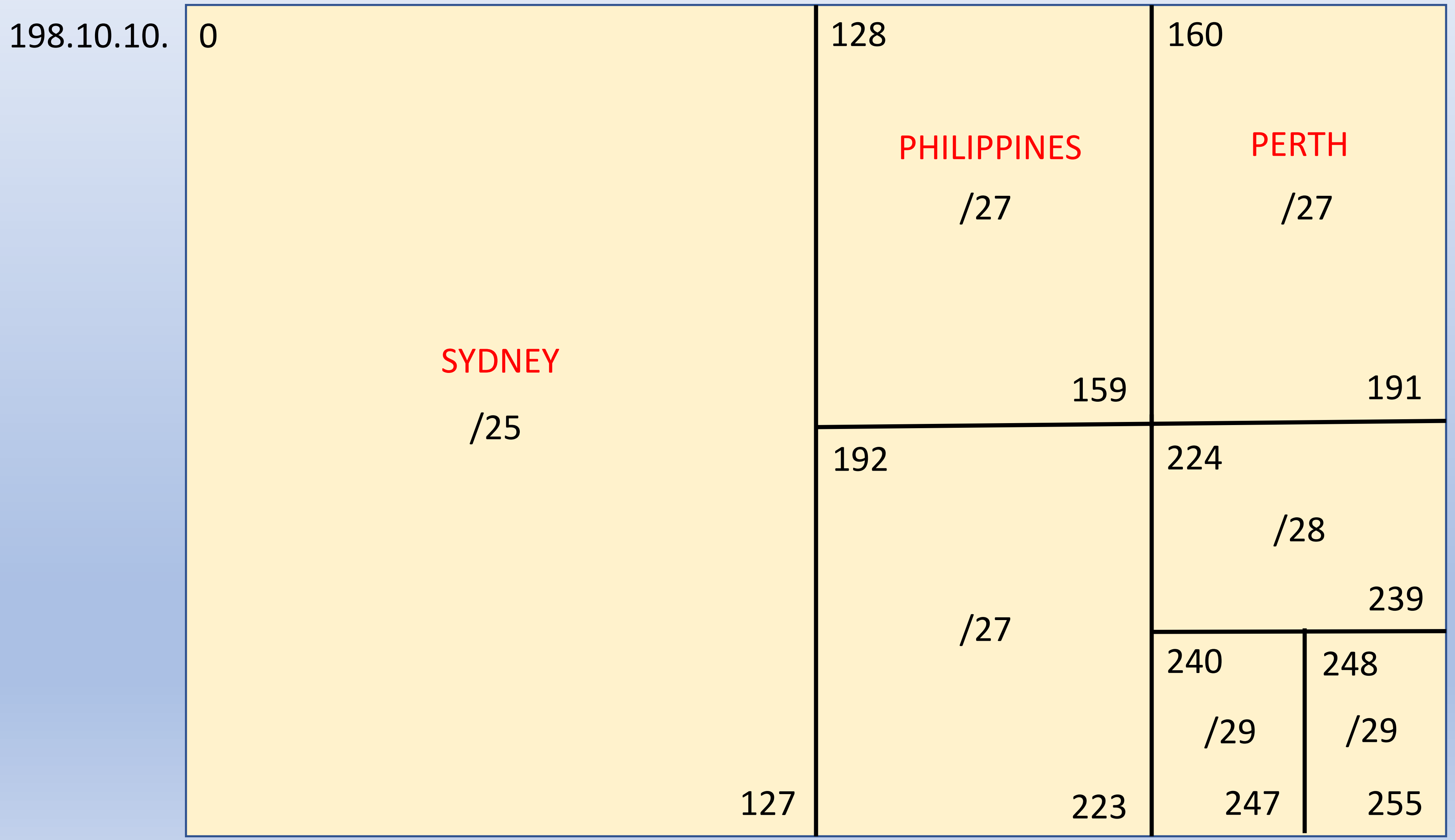
VLSM Box method



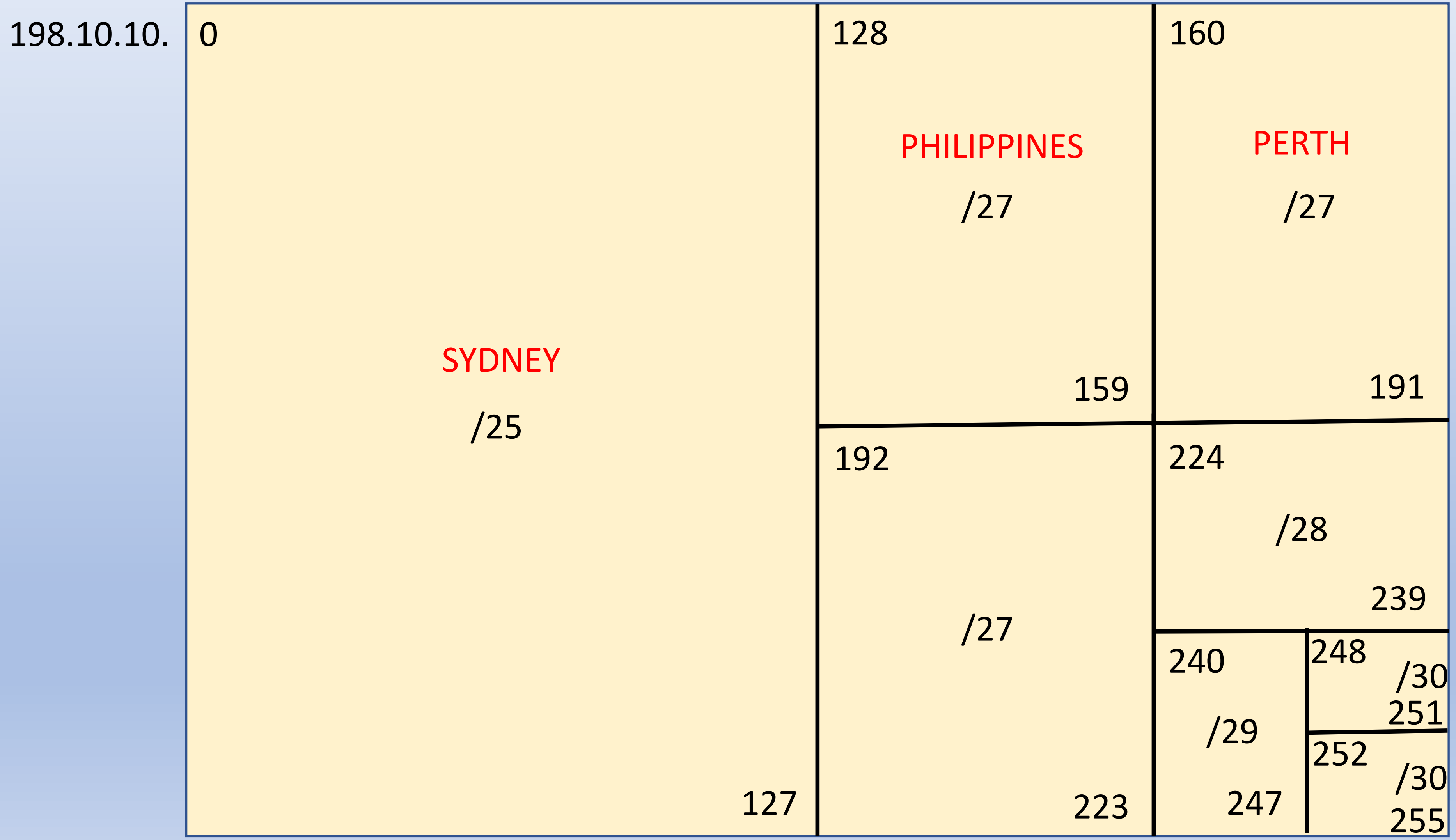
VLSM Box method



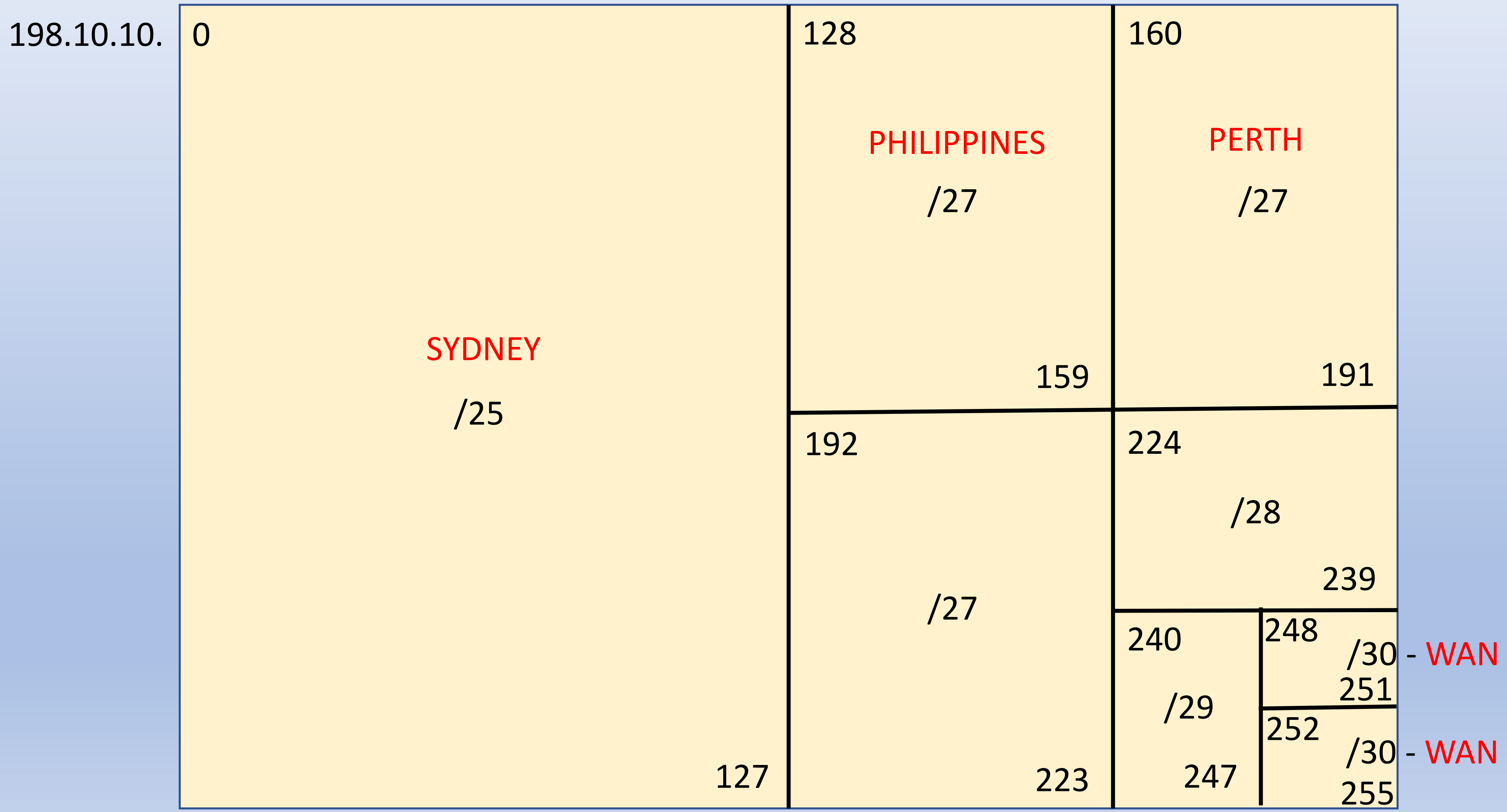
VLSM Box method



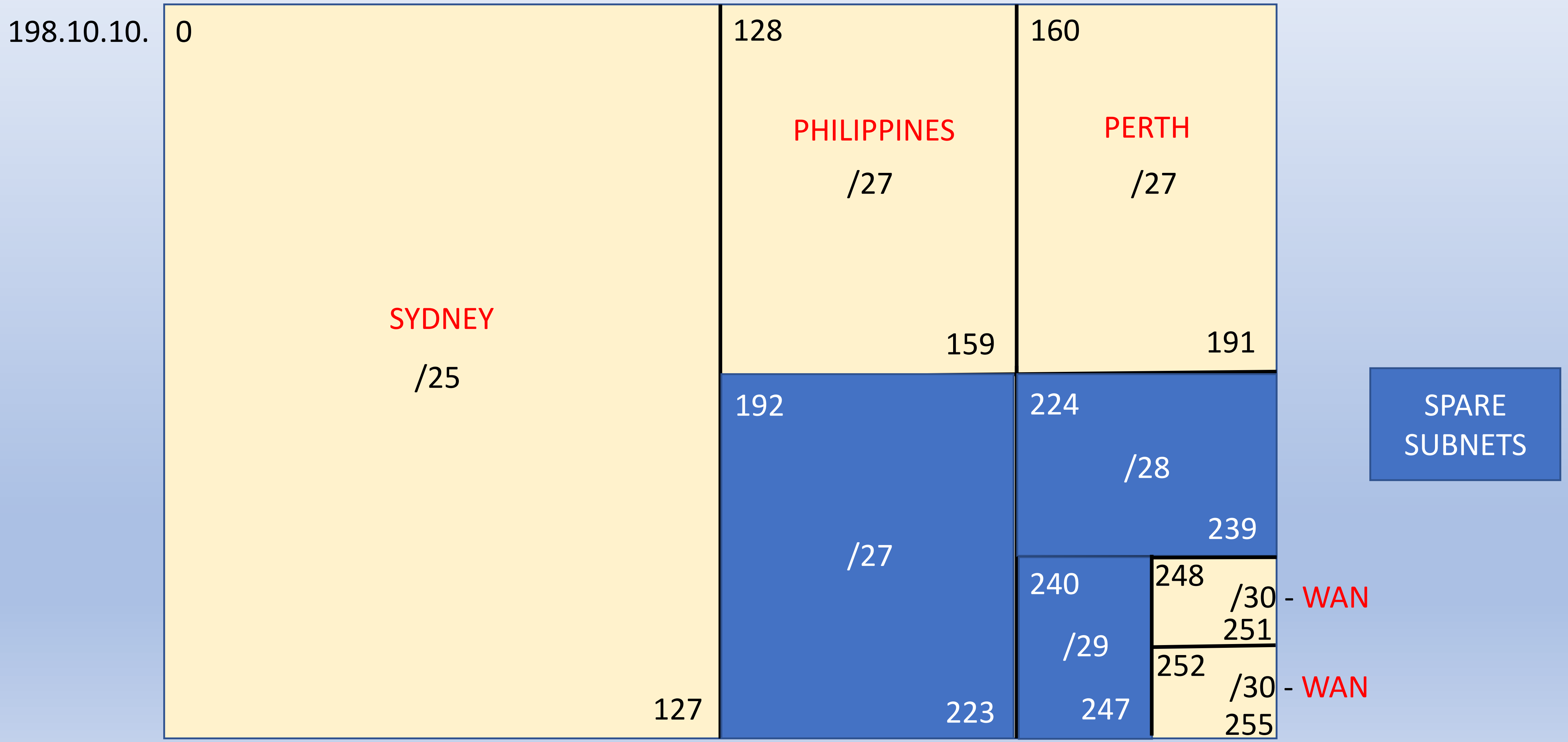
VLSM Box method



VLSM Box method



VLSM Box method



VLSM Solution

- Sydney
  - 198.10.10.0/25 (198.10.10.1 - 198.10.10.126) [100/126 hosts]
- Philippines
  - 198.10.10.128/27 (198.10.10.129 - 198.10.10.158) [20/30 hosts]
- Perth
  - 198.10.10.160/27 (198.10.10.161 - 198.10.10.190) [15/30 hosts]
- WAN
  - 198.10.10.248/30 (198.10.10.249 - 198.10.10.250) [2/2 hosts]
- WAN
  - 198.10.10.252/30 (198.10.10.253 - 198.10.10.254) [2/2 hosts]
- Spare
  - Three subnets spare for future network growth