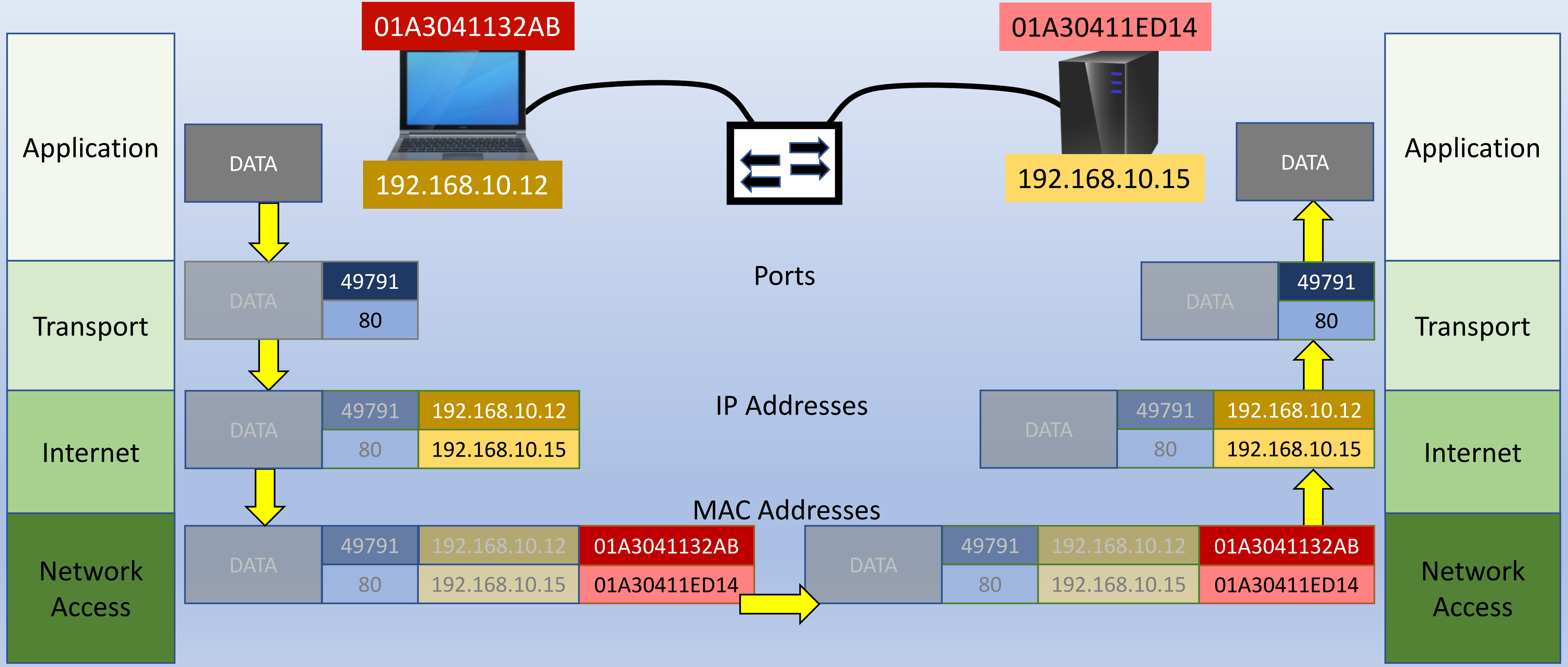
Networking Introduction

OSI vs TCP/IP

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

Encapsulation

Decapsulation



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
- How computers communicate with each other

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

- Determines which part of the IP address is the:
  - Network section
  - Host section
- Determines whether a destination host is on:
  - Local subnet
  - Remote subnet
- Traditional Class Subnet masks
  - 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
- 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 191-223 (Binary 11000000 – 11011111)
  - First three octets are the network section
  - Last octet is the Host section

Subnet Mask

- Directs the host to the default router
  - When hosts needs to communicate outside its network
  - When a specific route for that destination is not found on the host
- Assists in determining if a host is
  - On the local subnet (local)
  - On a separate subnet (remote)

ARP – Address Resolution Protocol

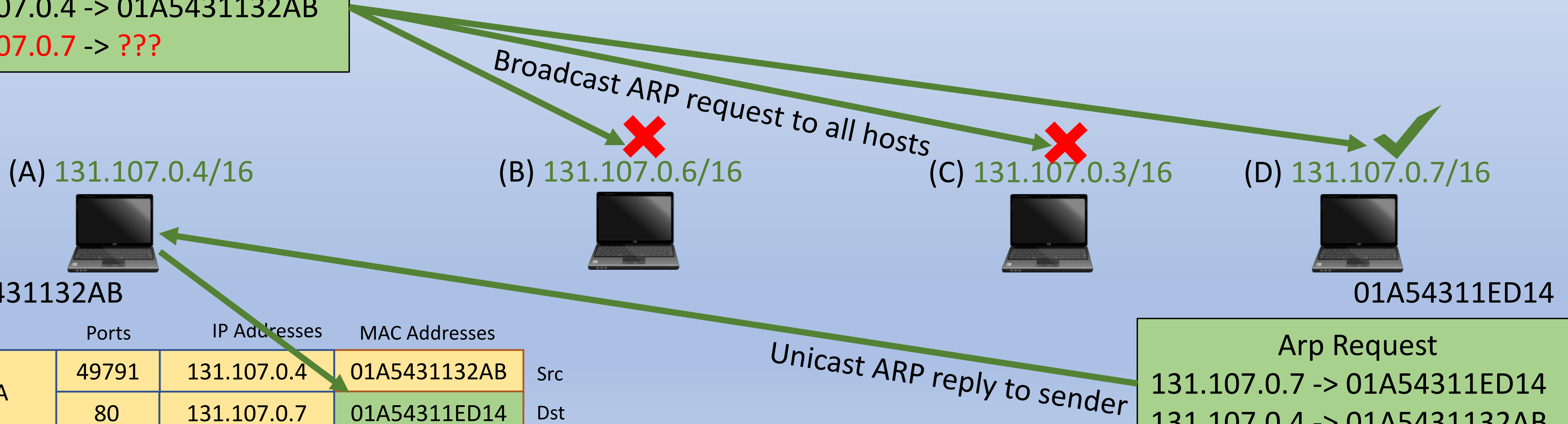
- ARP resolves an IP address into its corresponding MAC address
- ARP request is sent as a broadcast packet
- Asks who owns an IP address
  - IP owner answers with its MAC address with a unicast packet
  - ARP resolution information is cached in memory (for both the sender and receiver)
  - ARP cache 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 (A -> D)

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

Don’t know remote machine’s MAC Address?

Arp Request
131.107.0.4 -> 01A5431132AB
131.107.0.7 -> ???



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

Arp Request
131.107.0.7 -> 01A54311ED14
131.107.0.4 -> 01A5431132AB

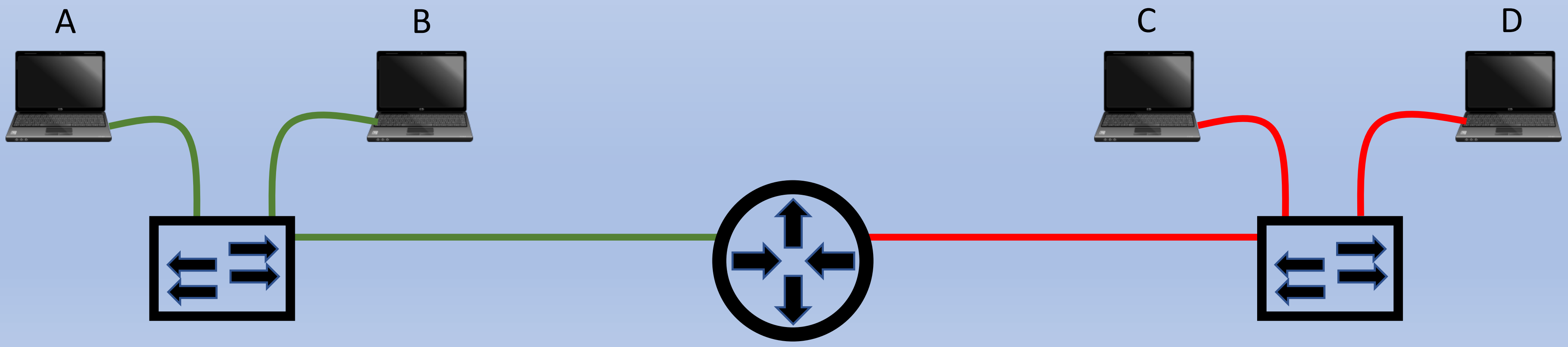
Fill in the MAC Address received

Determine how to route traffic

- Each time a network transmission happens
  - Sender need to determine if destination is local or remote
- If the destination IP address is on the local network
  - ARP for the destination IP address
- If the destination IP address is on a remote network
  - ARP for the IP address of the Default Gateway

Determine if destination is local or remote

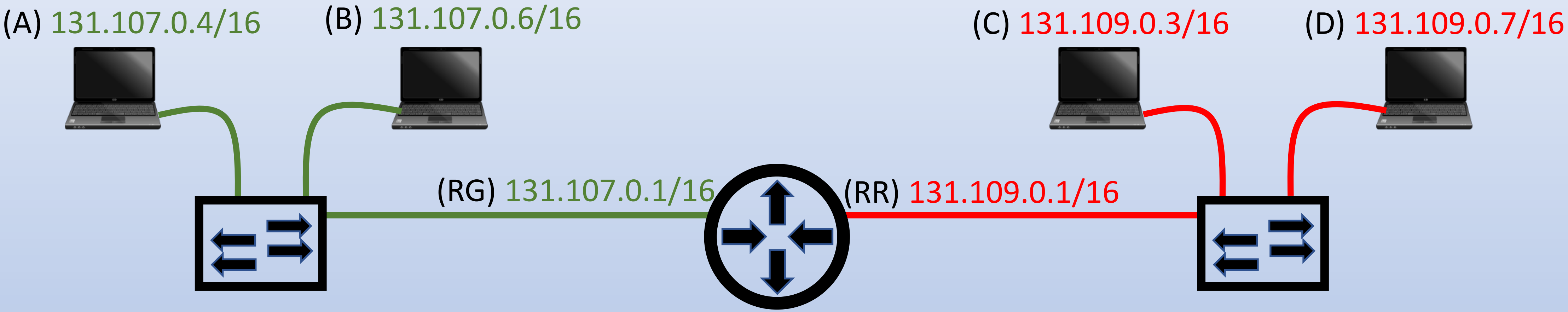
- AND source IP address with subnet mask
- AND destination IP address with subnet mask
- Compare both results
  - if same then local (Computers A & B)
  - if different then remote (Computers B & C)



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

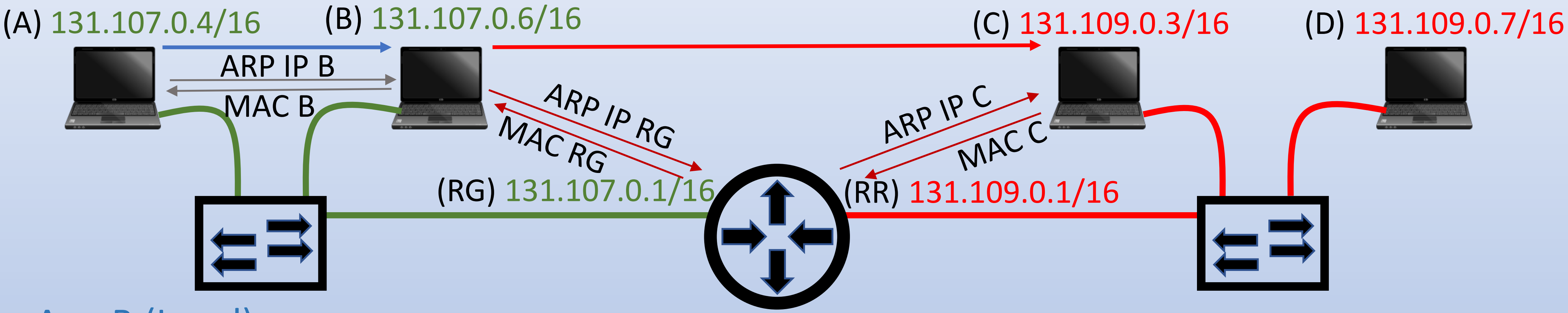
AND calculation (A -> B)

- 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)

AND calculation (B -> C)

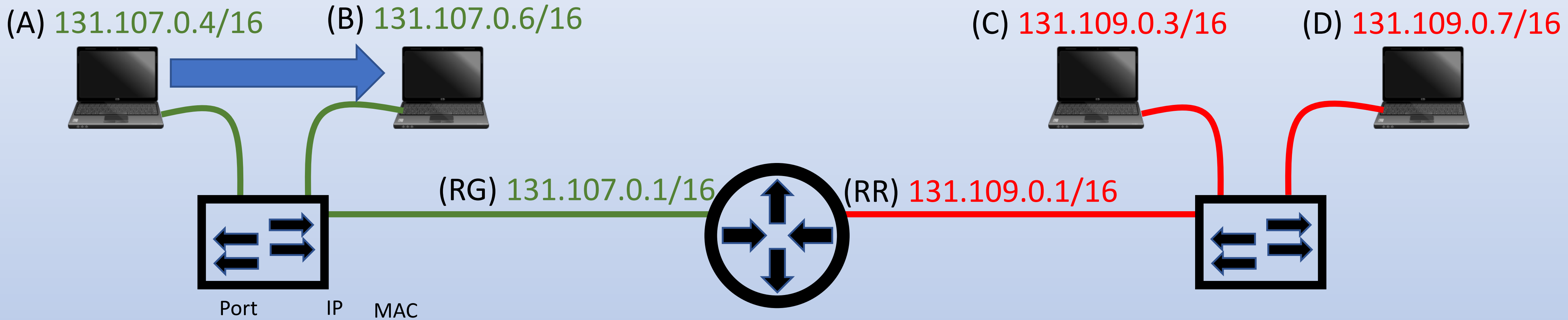
- 131.107.0.6 AND 255.255.0.0
  - 10000011 01101011 00000000 00000110 (131.107.0.6)
  - 11111111 11111111 00000000 00000000 (255.255.0.0)
  - 10000011 01101011 00000000 00000000 (131.107.0.0 - AND Result)
- 131.109.0.3 AND 255.255.0.0
  - 10000011 01101101 00000000 00000011 (131.109.0.3)
  - 11111111 11111111 00000000 00000000 (255.255.0.0)
  - 10000011 01101101 00000000 00000000 (131.109.0.0 - AND Result)

ARP Requests



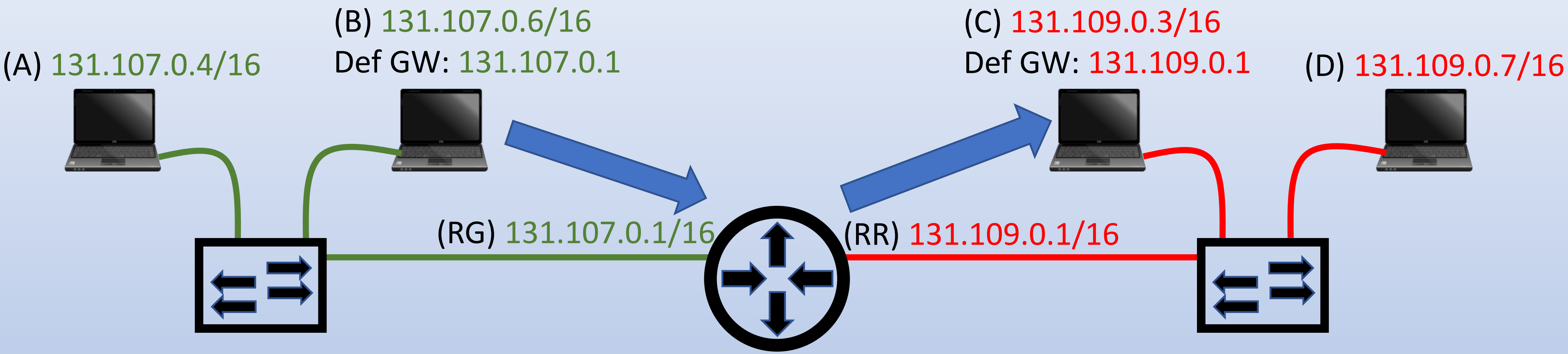
- A -> B (Local)
  - From A, ARP for destination IP B
  - Reply with MAC address from B
- B -> C (Remote)
  - From B, ARP for the router RG IP address
  - Reply with MAC address from RG
  - From Router, ARP for destination C IP address
  - Reply with MAC address from C

Routing local (A -> B [Webserver])



	Port	IP	MAC	
	50331	A	A	SRC
	80	B	B	DST

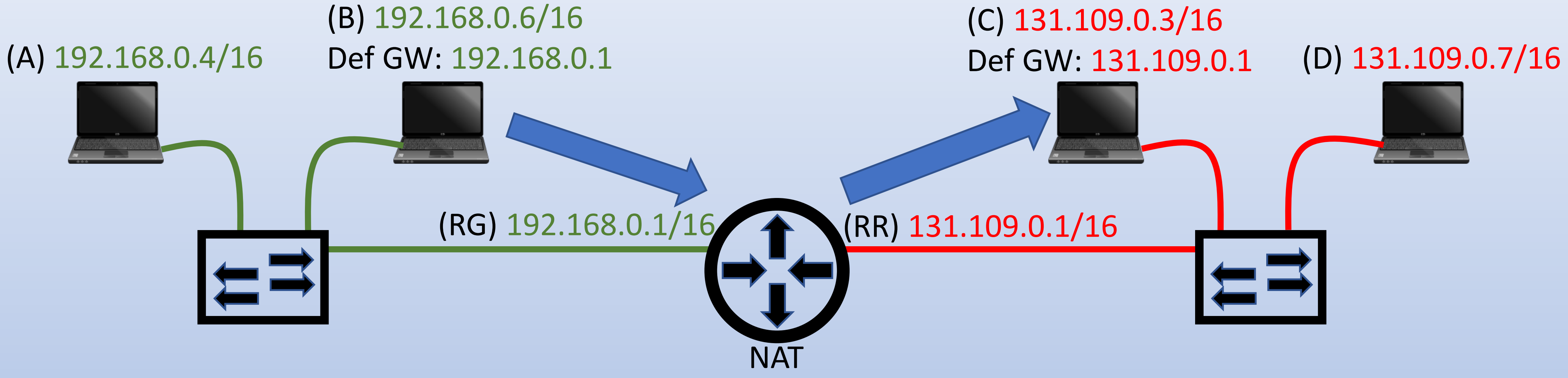
Routing remote (B -> C [Webserver])



	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
SRC	49961	B	B
DST	80	C	RG

	Port	IP	MAC
SRC	10001	RR	RR
DST	80	C	C

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
  - These two addresses are not used for addressing hosts
  - So, the usable 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 second 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

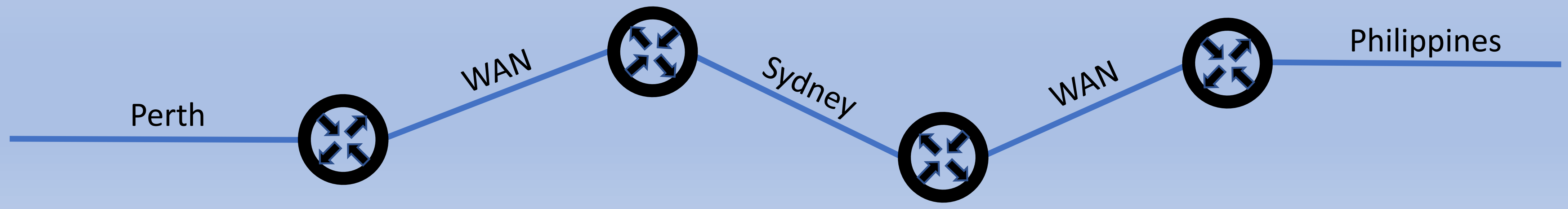
Variable Length Subnet Masks (VLSM)

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

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



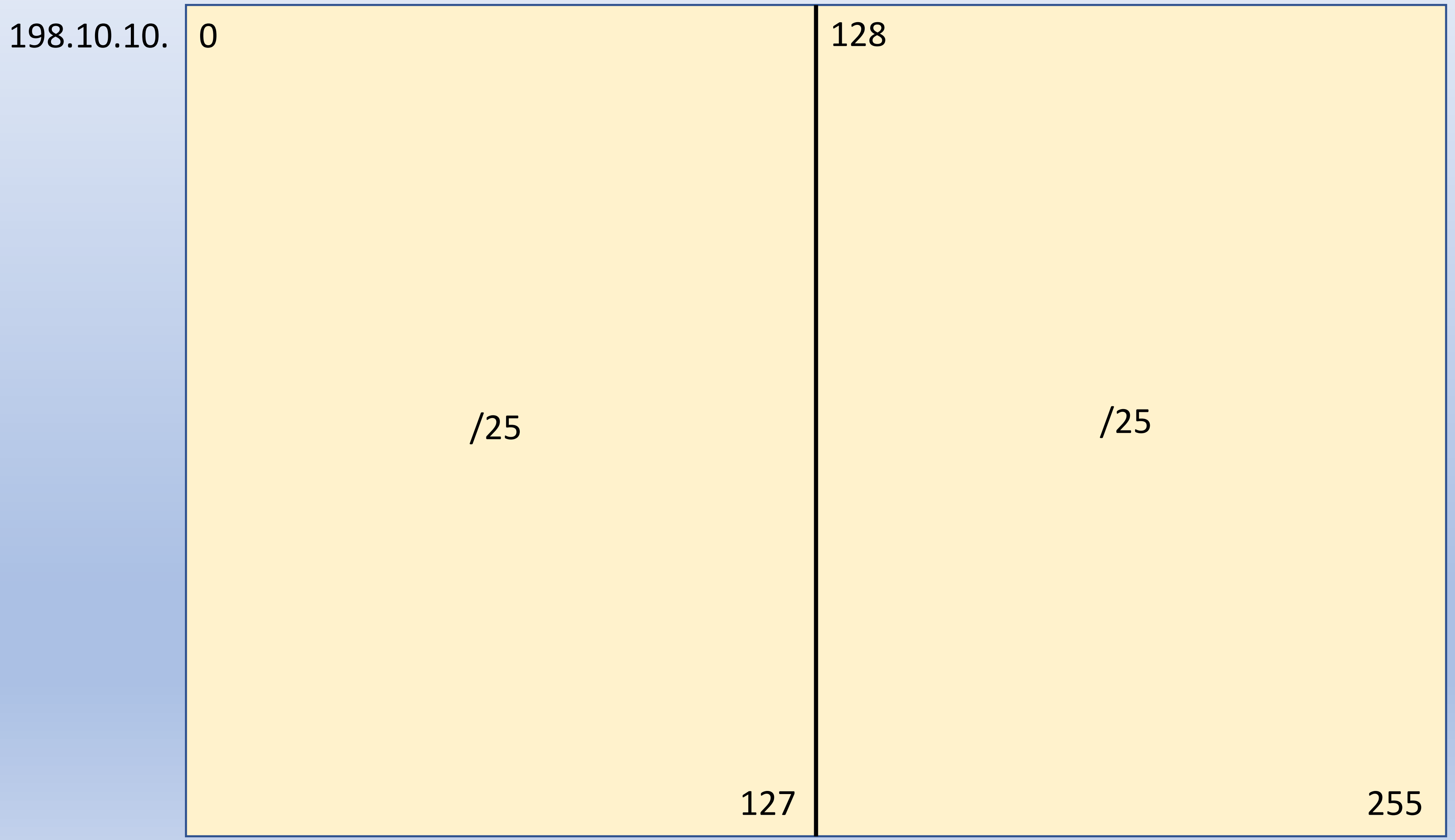
VLSM Box method

198.10.10. 0

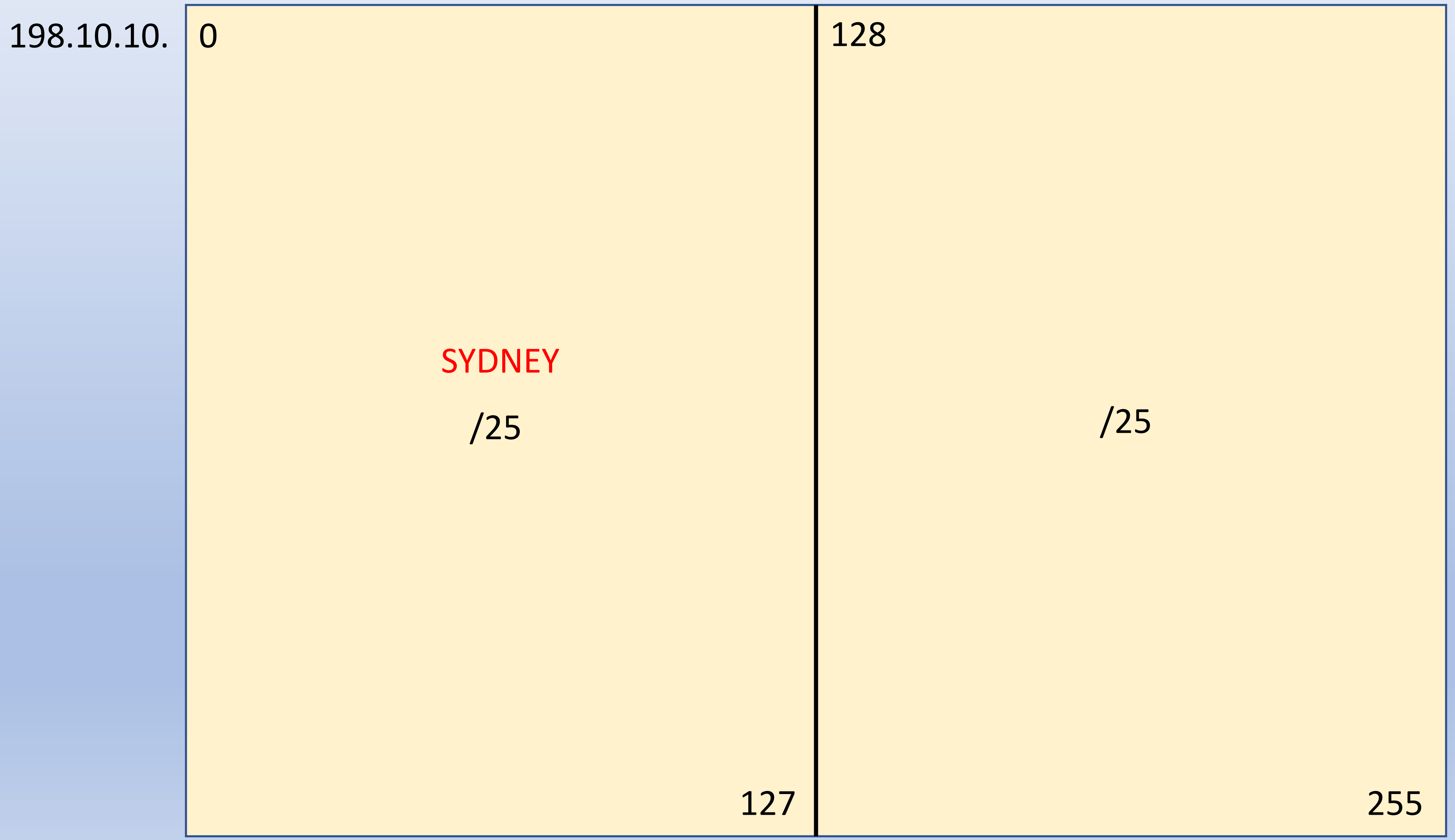
/24

255

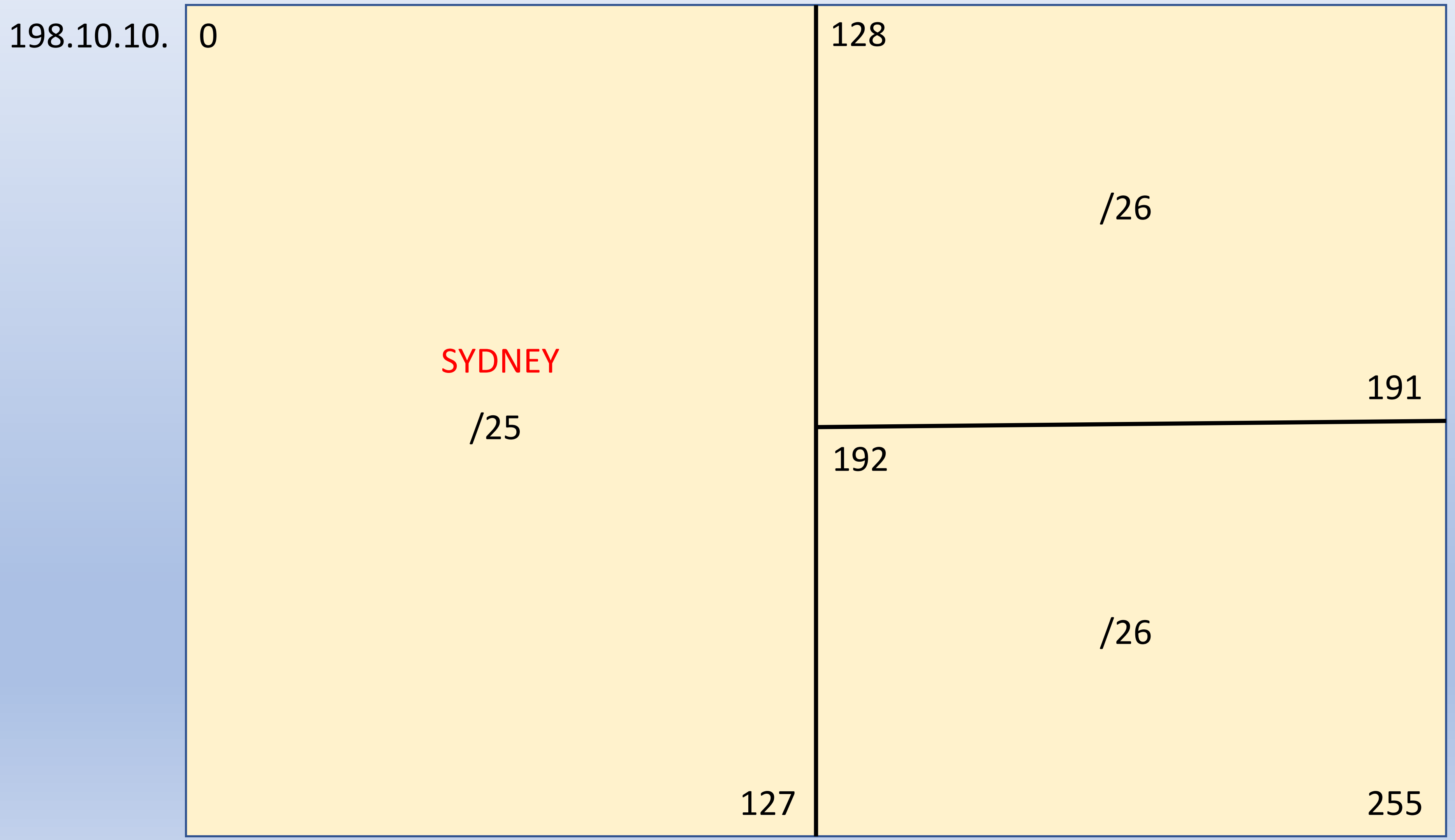
VLSM Box method



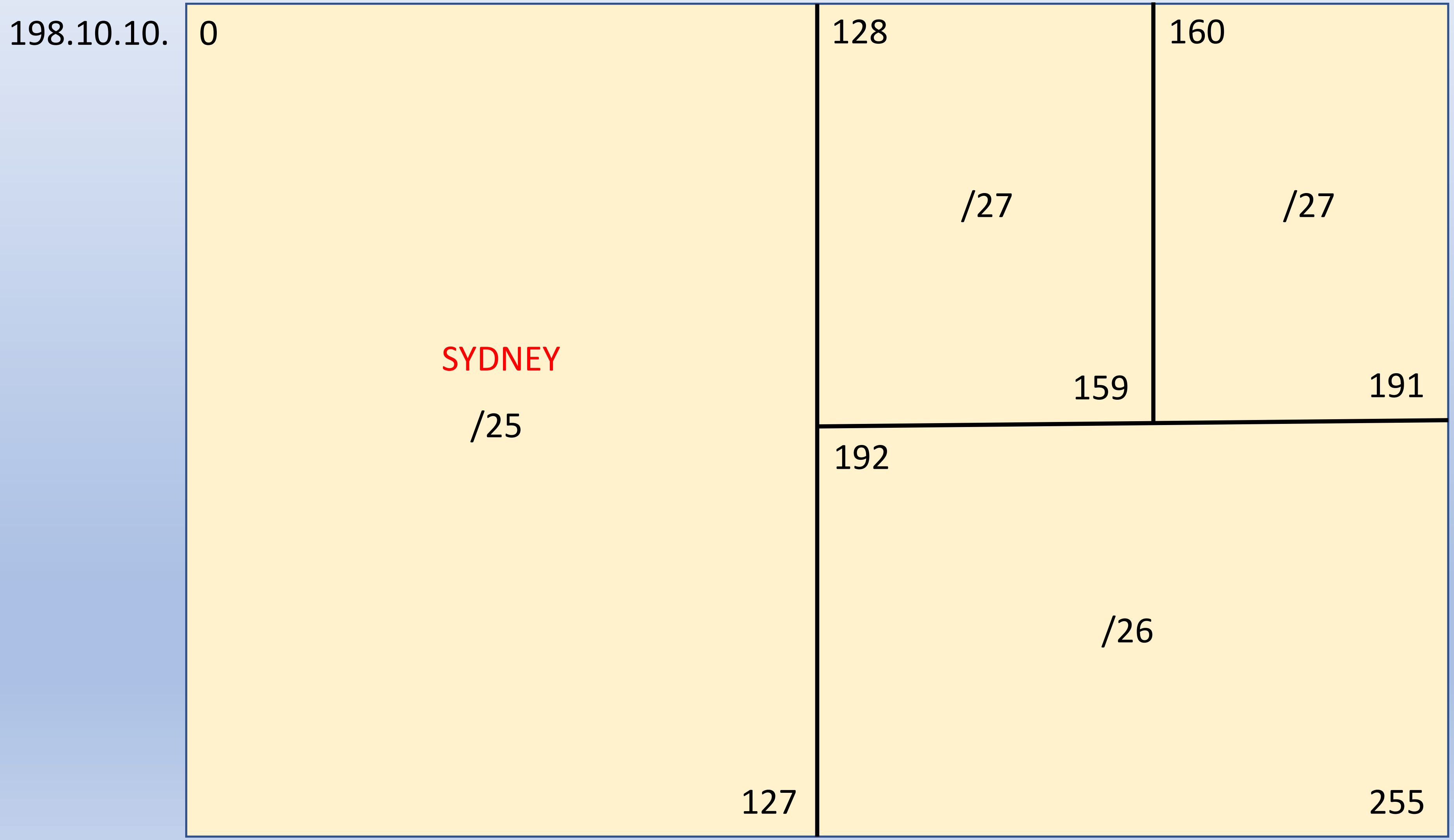
VLSM Box method



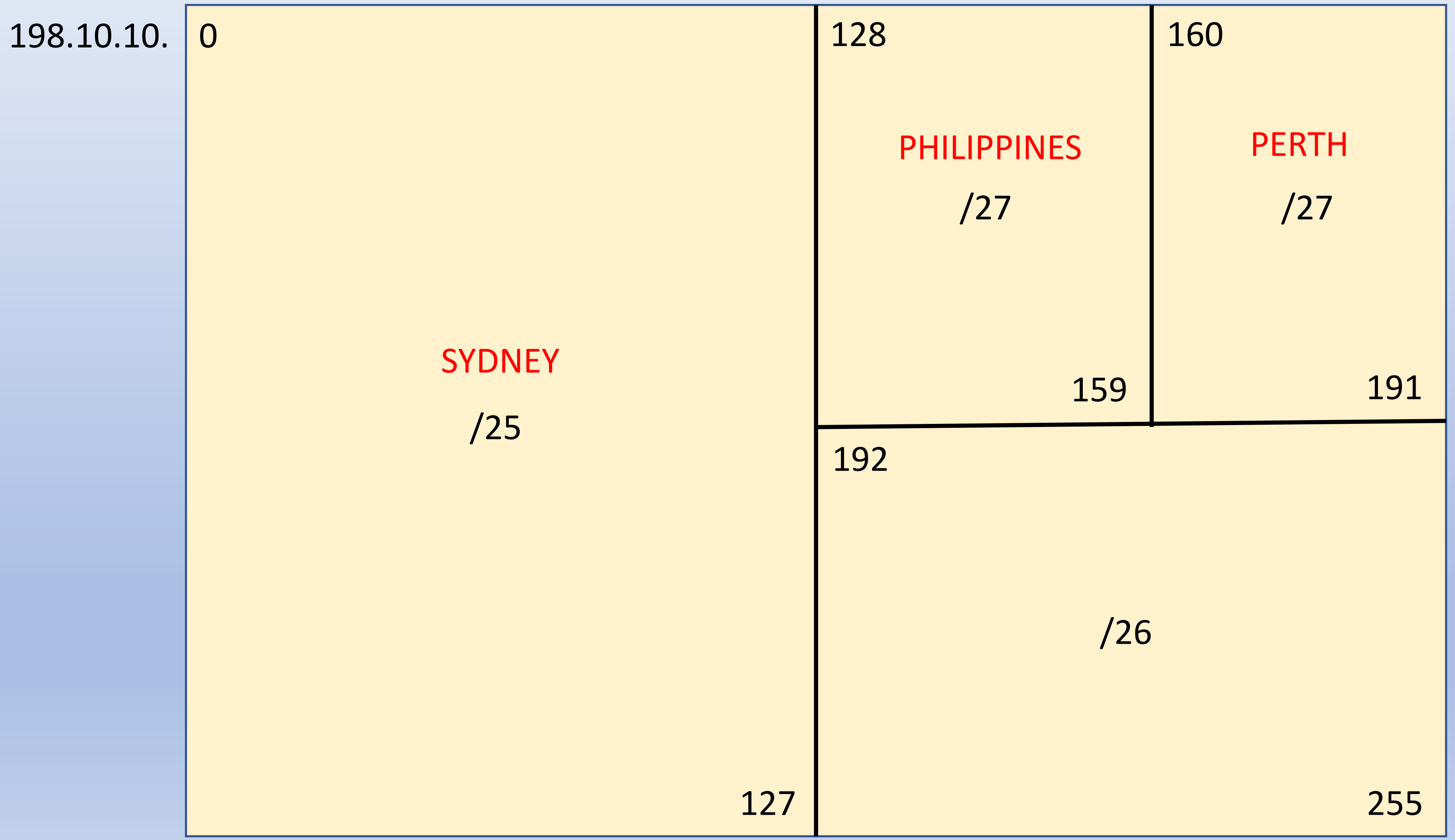
VLSM Box method



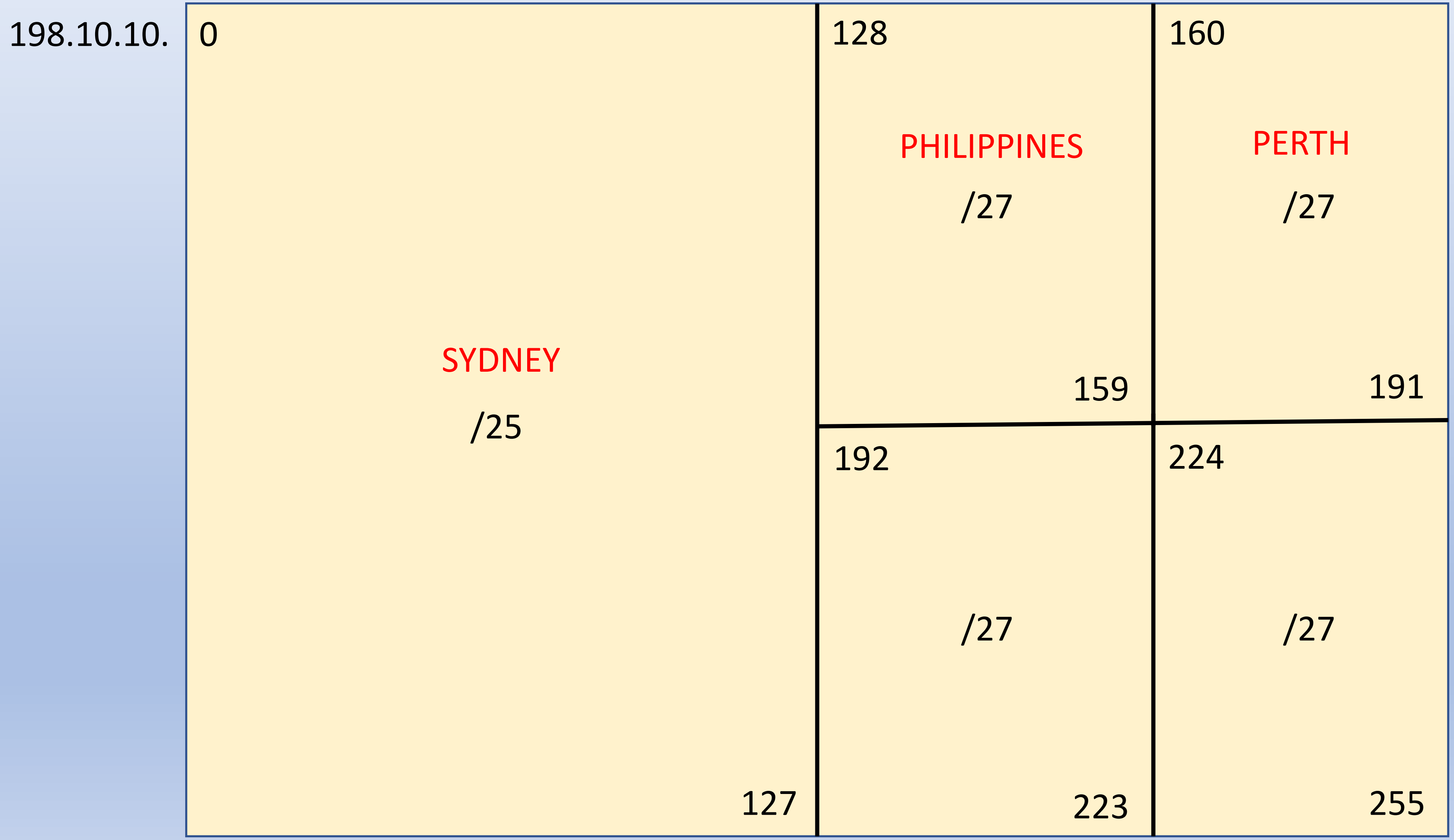
VLSM Box method



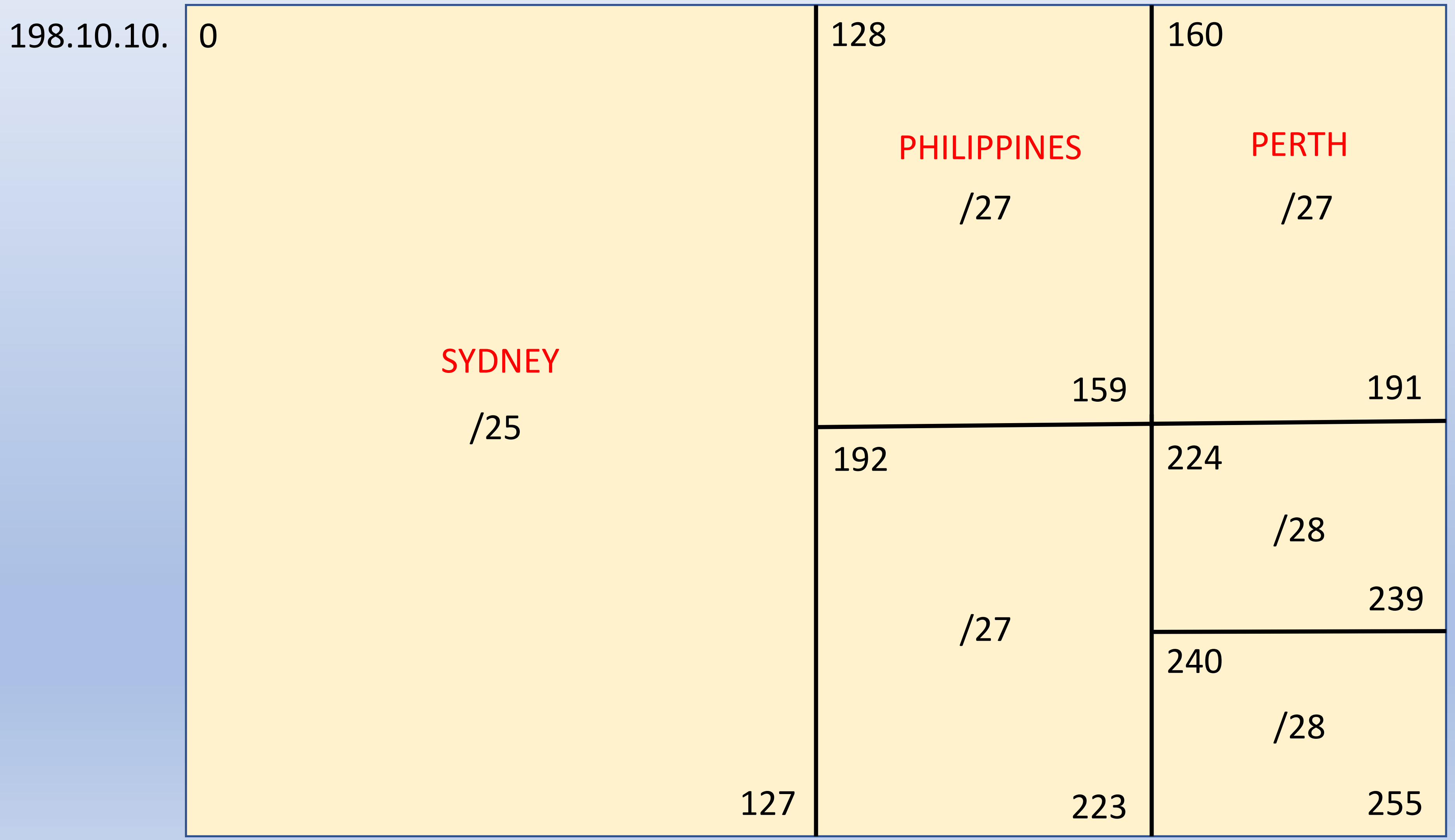
VLSM Box method



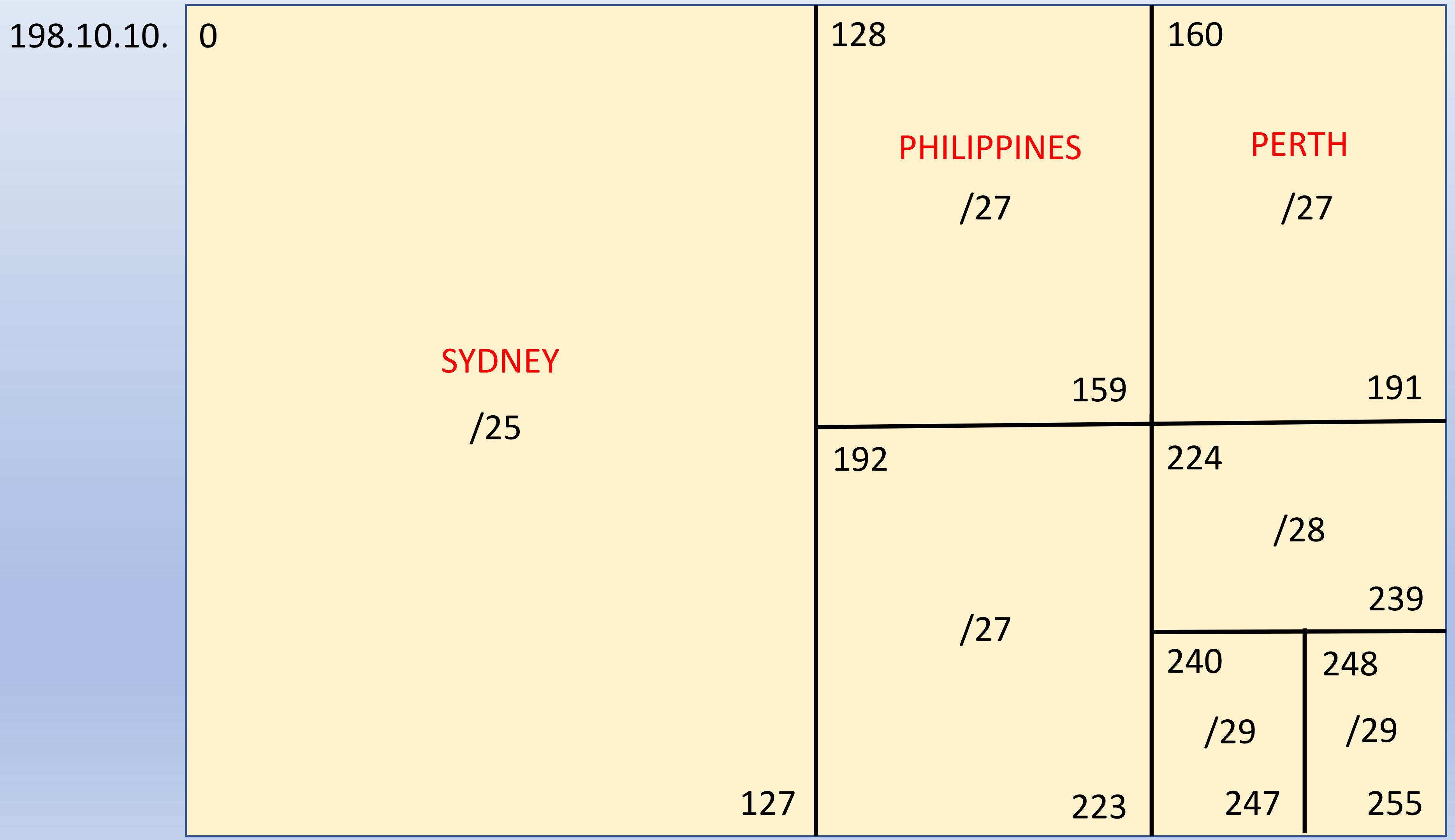
VLSM Box method



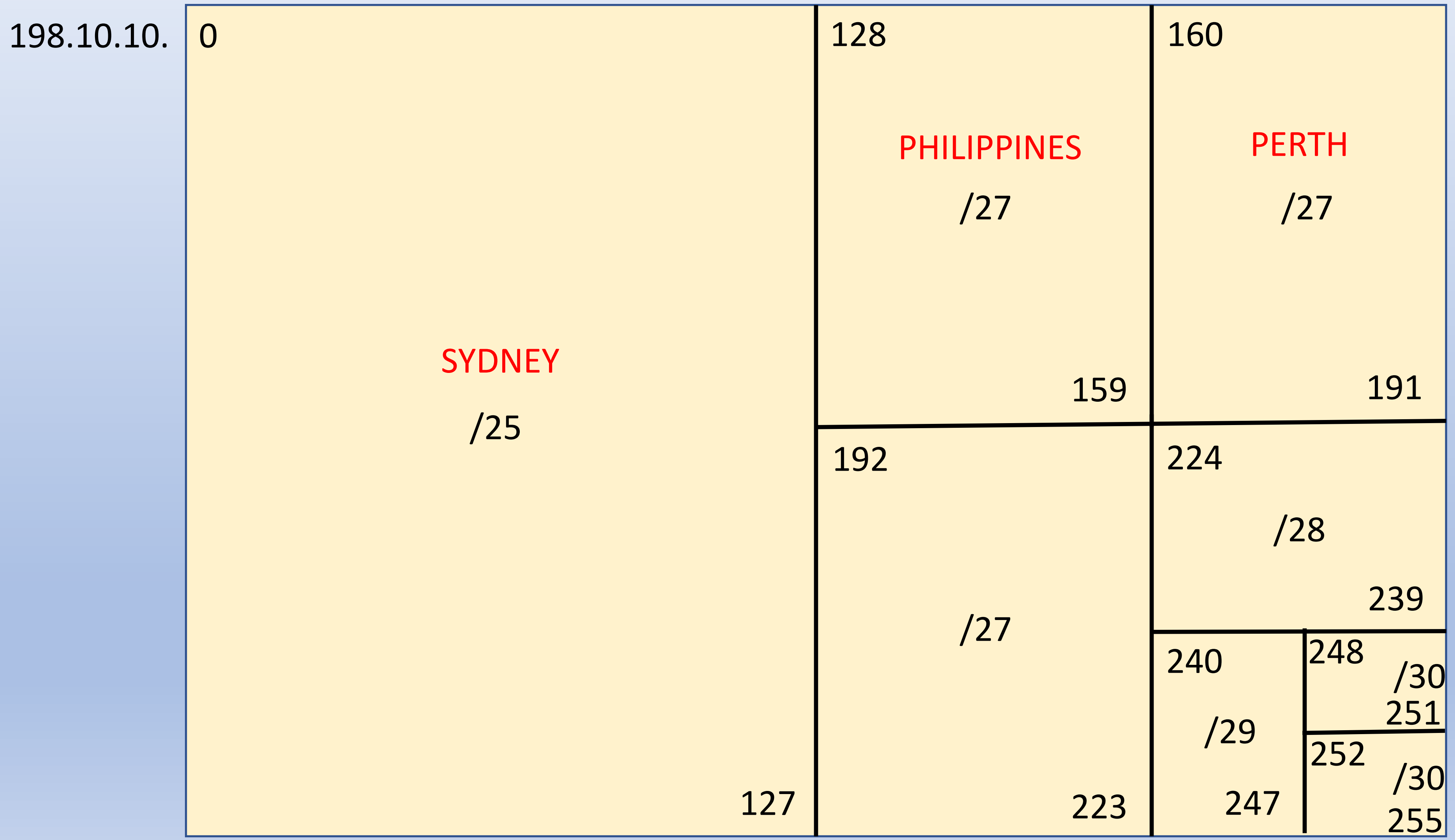
VLSM Box method



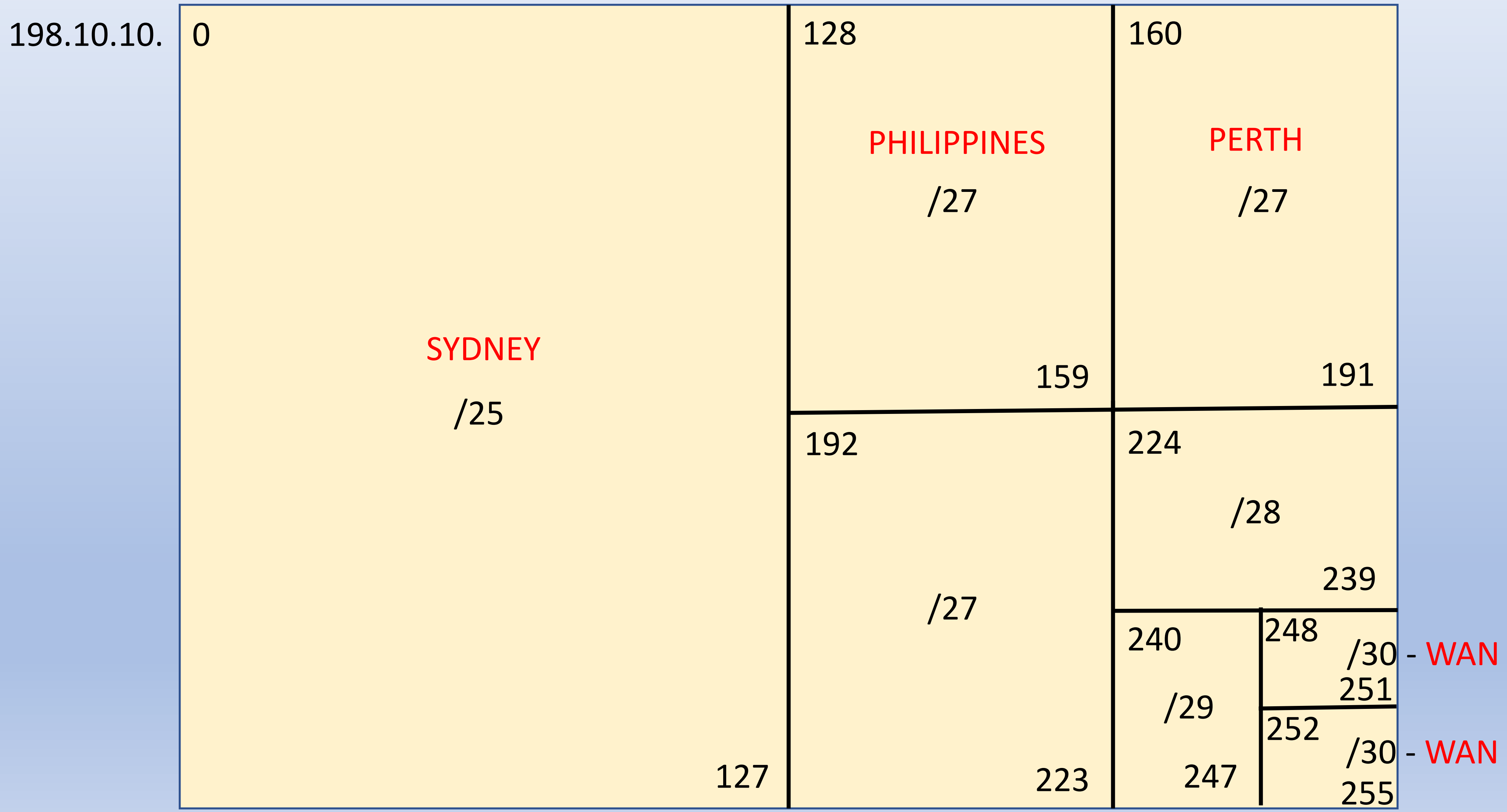
VLSM Box method



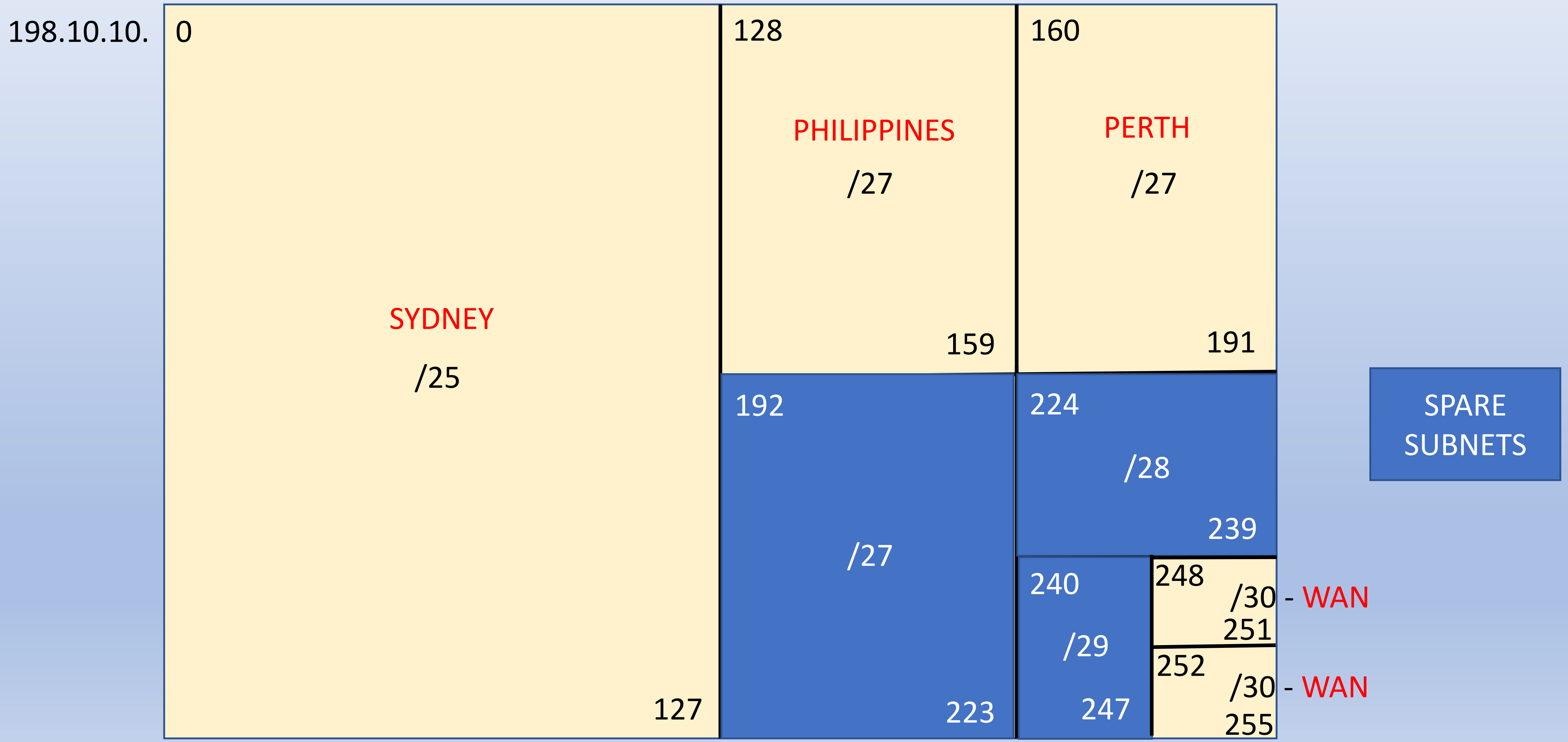
VLSM Box method



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