

CPSC 317 COMPUTER NETWORKING

Module 5: Network Layer – Day 3 – IP Address Ranges

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ADMINISTRATION

- Programming assignment 4 has been released
 - Due March 24
 - PL deadline will be set to Mar 28
 - Keep track of your own extension hour use
- Clicker questions coming up ...

LEARNING GOALS

IP addresses and forwarding

- Describe the relationship between IP addresses and forwarding in routers
- Perform longest prefix matching
- Define what is meant by a non-routable IP address and give an example
- Explain how an organization gets IP addresses for its use
- Understand the concepts of sub-dividing and aggregation of IP address ranges
- Given a router, its forwarding tables and an incoming packet, determine the link the packet will go out on
- Given a collection of routers, their forwarding tables, and a packet, trace the packet through the network

READING

- Reading: 4.3 (up to 4.3.2)

WHAT OPERATIONS DO WE NEED ON IPS?

- Is an IP address in my network?
 - If so, I can send a message to it directly without going through a router
 - If not, I must send the message to the router
- Which of many networks is an IP address in?
 - Forwarding function of a router

IS AN IP IN MY NETWORK?

- Assume:
 - Host has IP 192.168.45.24/255.255.240.0 (or /20)
 - Destination IP is 192.168.49.104
- Is destination in the same network as host?
- If so, we can send a message to it directly (no router)
- Write the addresses in binary
- **Host:** 11000000 10101000 00101101 00011000
- **Dst :** 11000000 10101000 00110001 01101000

Network part

WHICH NETWORKS MATCH AN ADDRESS

Consider the IP address

198.162.54.12

Which of these networks contain this address?

0.0.0.0/0

198.0.0.0/8

198.162.0.0/16

198.162.54.0/24

198.162.54.0/28

198.162.54.16/28

WHICH NETWORKS MATCH AN ADDRESS

Consider the IP address

11000110 10100010 00110110 00001100 198.162.54.12

Which of these networks contain this address?

XXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXX
11000110	XXXXXXXX	XXXXXXXX	XXXXXXXX
11000110	10100010	XXXXXXXX	XXXXXXXX
11000110	10100010	00110110	XXXXXXXX
11000110	10100010	00110110	0000XXXX
11000110	10100010	00110110	0001XXXX

0.0.0.0/0
198.0.0.0/8
198.162.0.0/16
198.162.54.0/24
198.162.54.0/28
198.162.54.16/28

FORWARDING TABLE

- Each router keeps a forwarding table indicating, for each destination IP range, the link to be used
- Formally, the Forwarding Information Base (FIB)
- Built from aggregating information retrieved from other routers (routing table, or RIB)

LONGEST PREFIX MATCHING

- If more than one range in the table matches an IP address, the most specific entry is used
- Since ranges are prefixes, the longest prefix is the most specific
- Hence, longest prefix match
- Example: 192.168.35.0/24 is more specific than 192.168.0.0/16 and both match 192.168.35.101

CLICKER QUESTION

A router has the following prefixes in its forwarding table. Which entry is used to route to address 198.162.51.175?

(Hint: when /8, /16, or /24 you can do the matching in hex)

- A. 0.0.0.0/0
- B. 198.0.0.0/8
- C. 198.162.0.0/16
- D. 198.162.54.0/24
- E. More than one of the ranges above

CLICKER QUESTION

A router has the following prefixes in its forwarding table. Which entry is used to route to address 205.96.3.1?

- A. 0.0.0.0/0
- B. 198.0.0.0/8
- C. 198.162.0.0/16
- D. More than one of the ranges above
- E. None of the above

NON-ROUTABLE IP ADDRESSES

- Some addresses are defined to be non-routable
- If a router sees a datagram with a non-routable destination address, it just throws it away
- RFC 1918 defines these three CIDR networks as non-routable:
 - 10.0.0.0/8
 - 172.16.0.0/12
 - 192.168.0.0/16

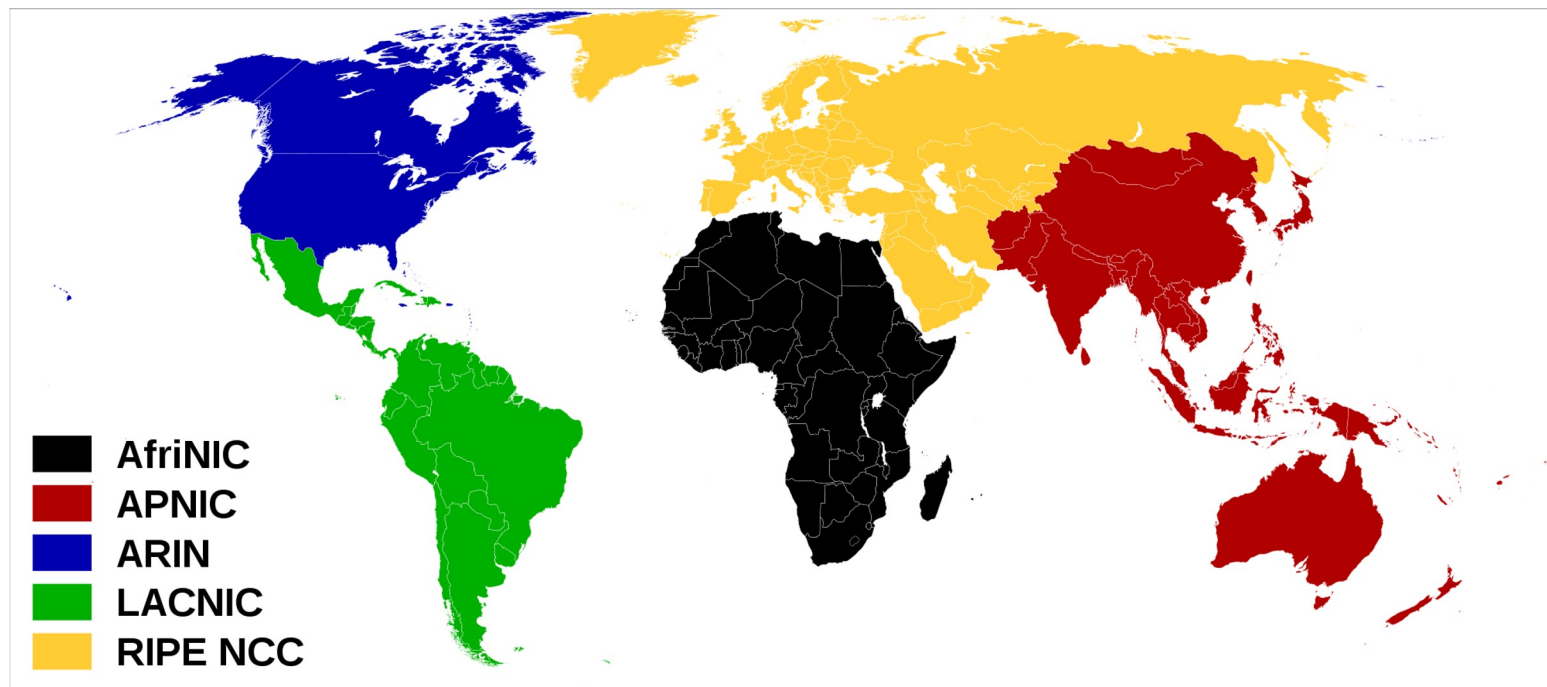
IP ADDRESS ASSIGNMENT

IP address ranges are assigned to ISPs through a complicated process

- Through the Regional Internet Registries
- Then to various ISPs
- Who assign sub-portions to their customer ISPs
- And so forth

REGIONAL INTERNET REGISTRIES

From http://commons.wikimedia.org/wiki/File:Regional_Internet_Registries_world_map.svg



https://en.wikipedia.org/wiki/List_of_assigned_/8_IPv4_address_blocks

List of assigned /8 blocks to the [regional Internet registries](#) [edit]

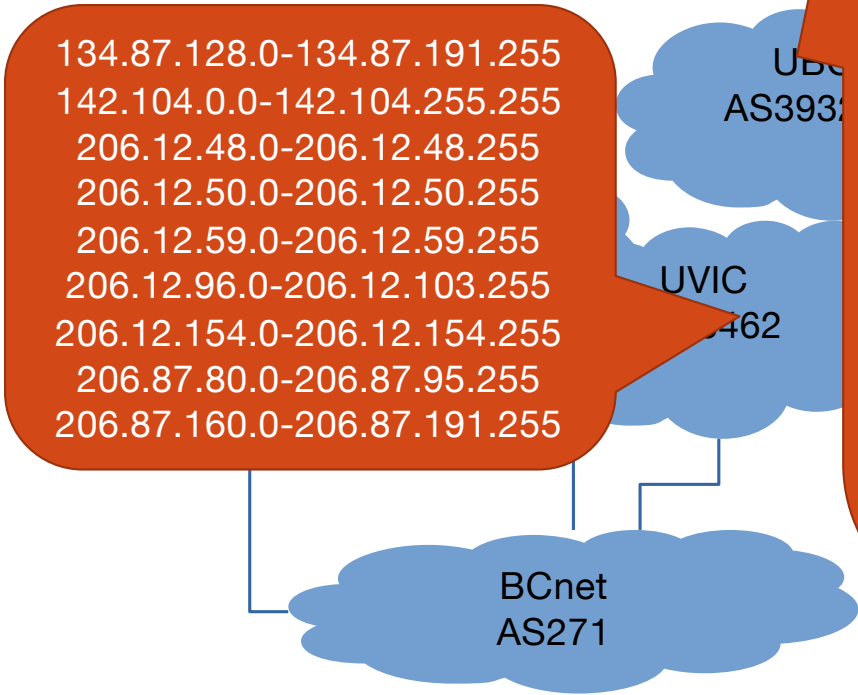
The **regional Internet registries** (**RIR**) allocate **IPs** within a particular region of the world.

Block	Organization	IANA date	RIR date	Notes
1.0.0.0/8	APNIC	2010-01		Formerly IANA - reserved 1981-09.
2.0.0.0/8	RIPE NCC	2009-10		Formerly IANA - reserved 1981-09.
3.0.0.0/8	ARIN	1994-05		Amazon.com . ^[3] Formerly General Electric Company .
4.0.0.0/8	ARIN	1992-12		Various registries (maintained by ARIN). Formerly Bolt Beranek and Newman Inc. , then GTE , then Genuity , then Level 3 Communications, Inc.
5.0.0.0/8	RIPE NCC	2010-11		Formerly IANA - reserved 1995-07.
8.0.0.0/8	ARIN	1992-12	1992-12-01	Various registries (maintained by ARIN). Formerly Bolt Beranek and Newman Inc. , then GTE , then Genuity , then Level 3 Communications, Inc.
9.0.0.0/8	ARIN	1992-08		IBM except for 9.9.9.0/24, which is Quad9 .
13.0.0.0/8	ARIN	1991-09		Various registries (maintained by ARIN). Formerly Xerox .
14.0.0.0/8	APNIC	2010-04		Starting 1991-06-01, was used to map Public Data Network (X.121) addresses to IP addresses. Returned to IANA 2008-01-22. This network was reclaimed by IANA in 2007 and was subsequently re-allocated in 2010. See RFC 877 and RFC 1356 for historical information. ^[4]
15.0.0.0/8	ARIN	1991-09		Various registries (maintained by ARIN). Formerly Hewlett-Packard Company .
16.0.0.0/8	ARIN	1994-11	1989-05-18	Various registries (maintained by ARIN). Formerly Digital Equipment Corporation , then Compaq , then Hewlett-Packard.

SO, WHY DO WE CARE ABOUT ALL THIS?

- Real-life IP address assignments are “messy”
- Regions / ISPs / Customers need more IP addresses over time as they grow

AUTONOMOUS SYSTEMS



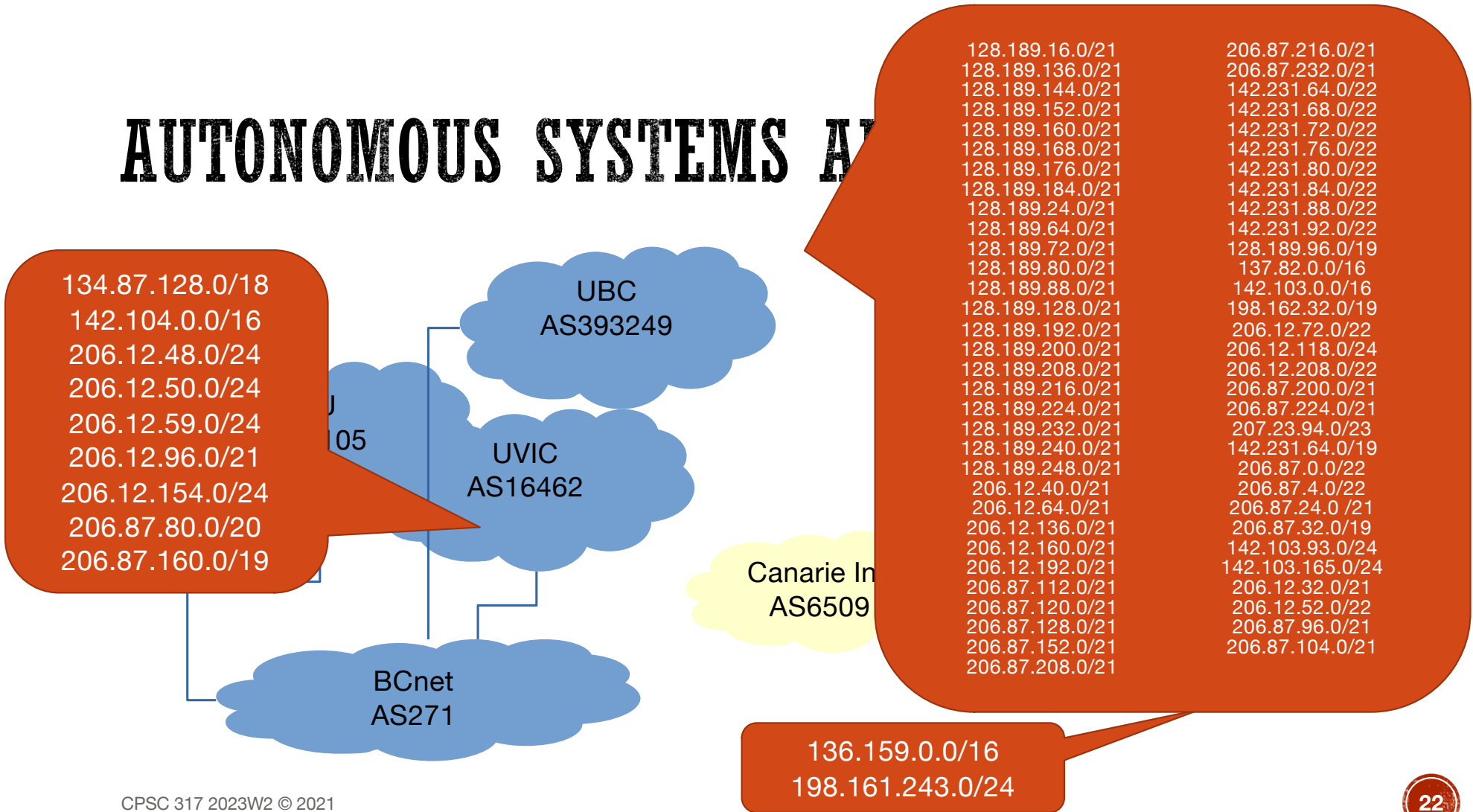
134.87.128.0-134.87.191.255
 142.104.0.0-142.104.255.255
 206.12.48.0-206.12.48.255
 206.12.50.0-206.12.50.255
 206.12.59.0-206.12.59.255
 206.12.96.0-206.12.103.255
 206.12.154.0-206.12.154.255
 206.87.80.0-206.87.95.255
 206.87.160.0-206.87.191.255

128.189.16.0 - 128.189.23.255
 128.189.136.0 - 128.189.143.255
 128.189.144.0 - 128.189.151.255
 128.189.152.0 - 128.189.159.255
 128.189.160.0 - 128.189.167.255
 128.189.168.0 - 128.189.175.255
 128.189.176.0 - 128.189.183.255
 128.189.184.0 - 128.189.191.255
 128.189.24.0 - 128.189.31.255
 128.189.64.0 - 128.189.71.255
 128.189.72.0 - 128.189.79.255
 128.189.80.0 - 128.189.87.255
 128.189.88.0 - 128.189.95.255
 128.189.128.0 - 128.189.135.255
 128.189.192.0 - 128.189.199.255
 128.189.200.0 - 128.189.207.255
 128.189.208.0 - 128.189.215.255
 128.189.216.0 - 128.189.223.255
 128.189.224.0 - 128.189.231.255
 128.189.232.0 - 128.189.239.255
 128.189.240.0 - 128.189.247.255
 128.189.248.0 - 128.189.255.255
 206.12.40.0 - 206.12.47.255
 206.12.64.0 - 206.12.71.255
 206.12.136.0 - 206.12.143.255
 206.12.160.0 - 206.12.167.255
 206.12.192.0 - 206.12.199.255
 206.87.112.0 - 206.87.119.255
 206.87.120.0 - 206.87.127.255
 206.87.128.0 - 206.87.135.255
 206.87.152.0 - 206.87.159.255
 206.87.208.0 - 206.87.215.255

206.87.216.0 - 206.87.223.255
 206.87.232.0 - 206.87.239.255
 142.231.64.0 - 142.231.67.255
 142.231.68.0 - 142.231.71.255
 142.231.72.0 - 142.231.75.255
 142.231.76.0 - 142.231.79.255
 142.231.80.0 - 142.231.83.255
 142.231.84.0 - 142.231.87.255
 142.231.88.0 - 142.231.91.255
 142.231.92.0 - 142.231.95.255
 128.189.96.0 - 128.189.127.252
 137.82.0.0 - 137.82.255.255
 142.103.0.0 - 142.103.255.255
 198.162.32.0 - 198.162.63.255
 206.12.72.0 - 206.12.75.255
 206.12.118.0 - 206.12.118.255
 206.12.208.0 - 206.12.211.255
 206.87.200.0 - 206.87.207.255
 206.87.224.0 - 206.87.231.255
 207.23.94.0 - 207.23.95.255
 142.231.64.0 - 142.231.95.255
 206.87.0.1 - 206.87.3.255
 206.87.4.0 - 206.87.7.255
 206.87.24.0 - 206.87.31.255
 206.87.32.0 - 206.87.63.255
 142.103.93.1 - 142.103.93.252
 142.103.165.1 - 142.103.165.251
 206.12.32.0 - 206.12.39.255
 206.12.52.0 - 206.12.55.255
 206.87.96.0 - 206.87.103.255
 206.87.104.0 - 206.87.111.255

136.159.0.0-136.159.255.255
 198.161.243.0-198.161.243.255

AUTONOMOUS SYSTEMS AND IP ADDRESSING



ADDRESS RANGE AGGREGATION

- Ranges can be aggregated if, when combined:
 - All ranges being aggregated are covered
 - New range does not include groups not being aggregated
- Useful for collapsing range information
 - Example: when advertising network ranges

ADDRESS RANGE AGGREGATION EXAMPLE

- Example: 192.205.0.0/22 and 192.205.4.0/22

10100000 11001101 000000xx xxxxxxxx

10100000 11001101 000001xx xxxxxxxx

- Aggregated range: 192.205.0.0/21

10100000 11001101 00000xxx xxxxxxxx

CLICKER QUESTION

Consider these two CIDR networks: 192.205.4.0/22 and 192.205.8.0/22

- A) These can be aggregated to 192.205.0.0/20
- B) These can be aggregated to 192.205.4.0/21
- C) These can be aggregated to 192.205.8.0/21
- D) These can not be aggregated

ADDRESS RANGE AGGREGATION EXAMPLE

- Example: 192.205.0.0/22 and 192.205.2.0/23

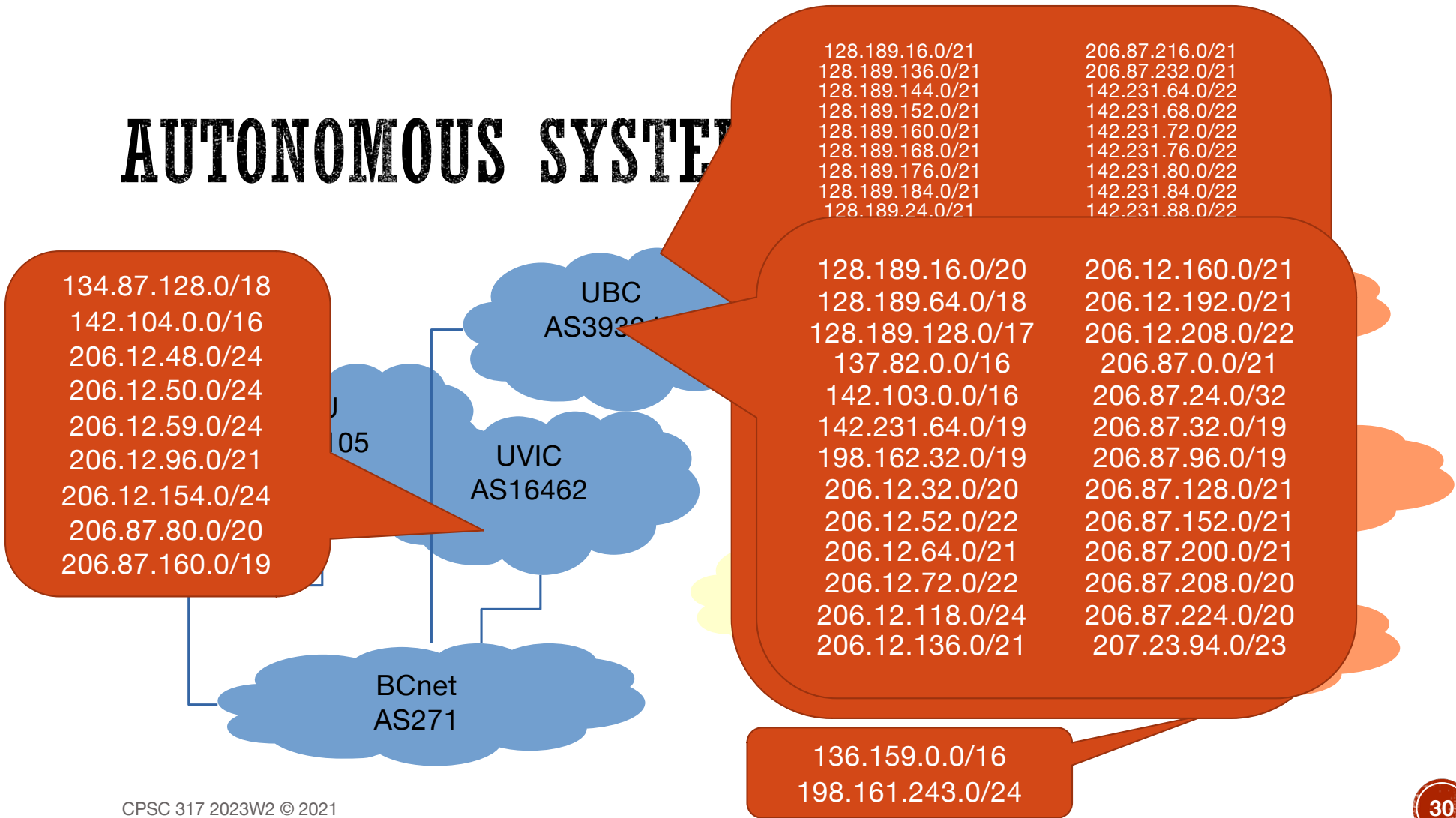
10100000 11001101 000000xx xxxxxxxx

10100000 11001101 0000001x xxxxxxxx

- First range includes all addresses in the second
- Aggregated range: 192.205.0.0/22 (same as first)

10100000 11001101 000000xx xxxxxxxx

AUTONOMOUS SYSTEMS



WHAT HAPPENED HERE?

142.231.64.0/22	142.231.01000000.0/22
142.231.68.0/22	142.231.01000100.0/22
142.231.72.0/22	142.231.01001000.0/22
142.231.76.0/22	142.231.01001100.0/22
142.231.80.0/22	142.231.01010000.0/22
142.231.84.0/22	142.231.01010100.0/22
142.231.88.0/22	142.231.01011000.0/22
142.231.92.0/22	142.231.01011100.0/22

142.231.64.0/19

ADDRESS RANGE DIVISION

- How to divide an address range into two (or more) smaller ranges?
- Why would we ever need to do this?
- First consider dividing into 2 sub-ranges
 - Set the first unfixed bit as a fixed bit in the two sub-ranges
 - One range has that bit as 0, the other has that bit as 1
- Repeat if multiple ranges required

ADDRESS RANGE DIVISION EXAMPLE

- Example: divide 198.162.0.0/16 into two ranges
 - Full range: 198.162.0.0 to 198.162.255.255

11000000 10101000 xxxxxxxx xxxxxxxx

- 1st range: 198.162.0.0 to 198.162.127.255 → 198.162.0.0/17

11000000 10101000 0xxxxxxx xxxxxxxx

- 2nd range: 198.162.128.0 to 198.162.255.255 → 198.162.128.0/17

11000000 10101000 1xxxxxxx xxxxxxxx

IN-CLASS ACTIVITY

- ICA53
- Address aggregation
- Address splitting
- Forwarding