CPSC 317 COMPUTER NETWORKING

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

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	0.0.0.0/0
11000110 xxxxxxxx xxxxxxxx xxxxxxxx	198.0.0.0/8
11000110 10100010 xxxxxxxx xxxxxxxx	198.162.0.0/16
11000110 10100010 00110110 xxxxxxxx	198.162.54.0/24
11000110 10100010 00110110 0000xxxx	198.162.54.0/28
11000110 10100010 00110110 0001xxxx	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

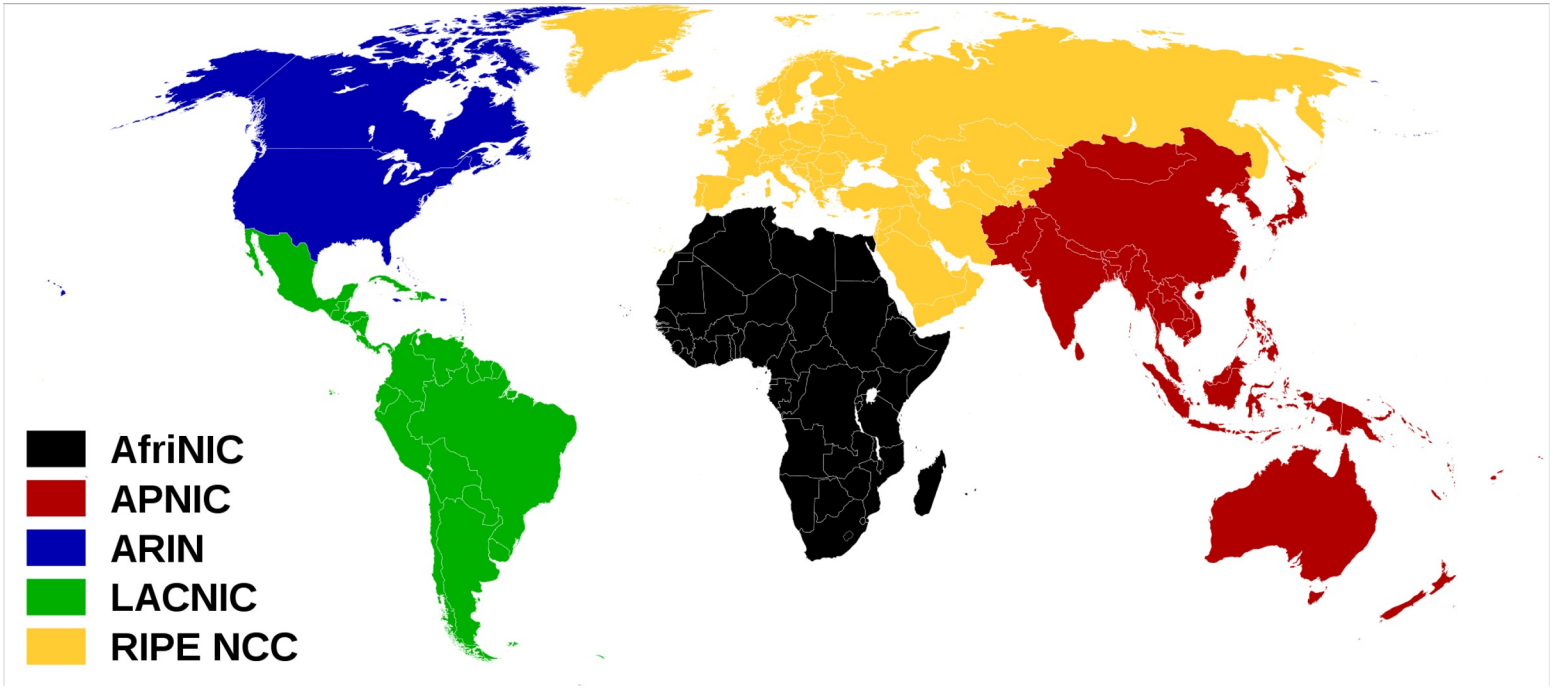
IP ADDRESS ASSIGNMENT

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]

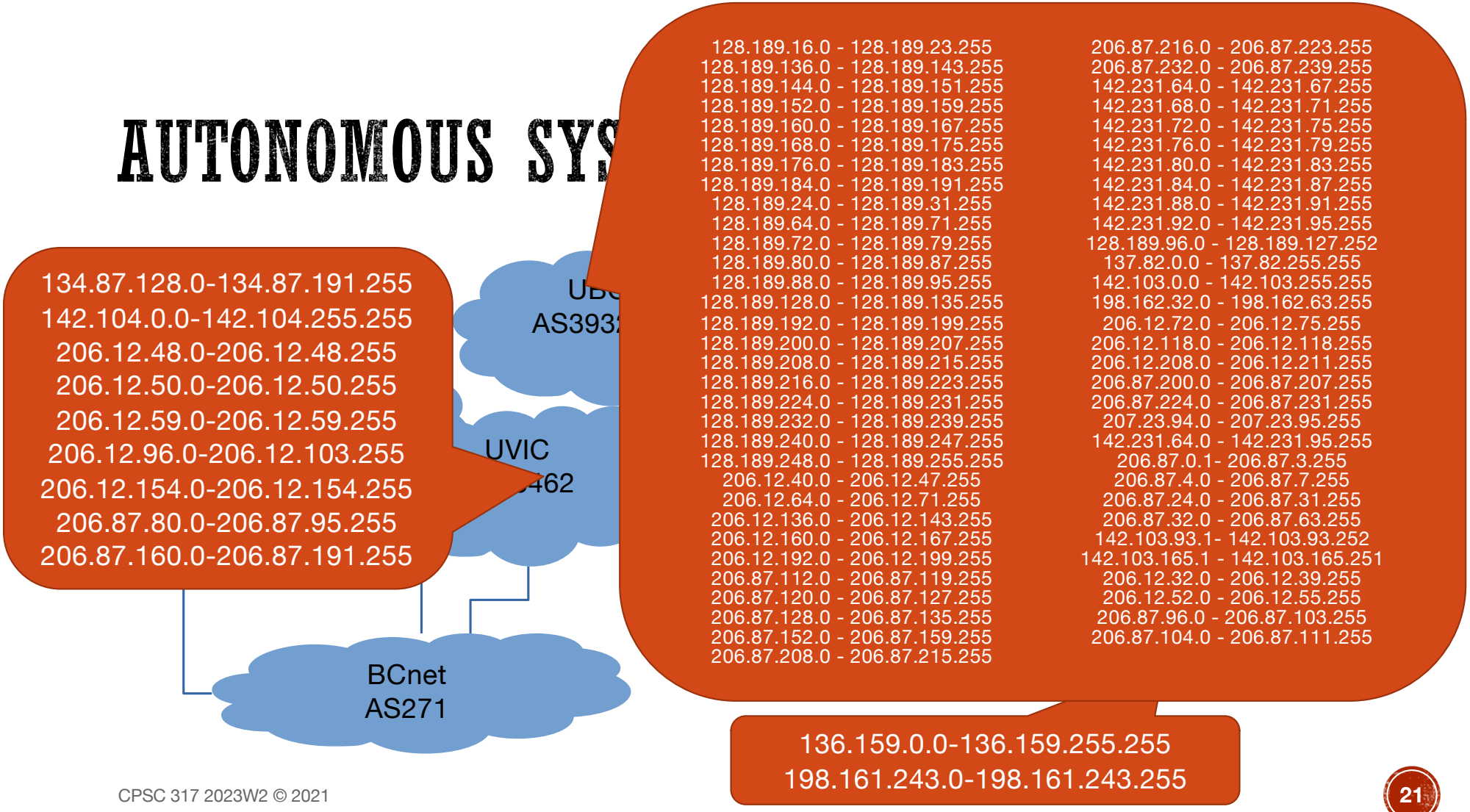
The **regional Internet registries** (**RIR**) allocate IPs within a particular region of the world.

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.

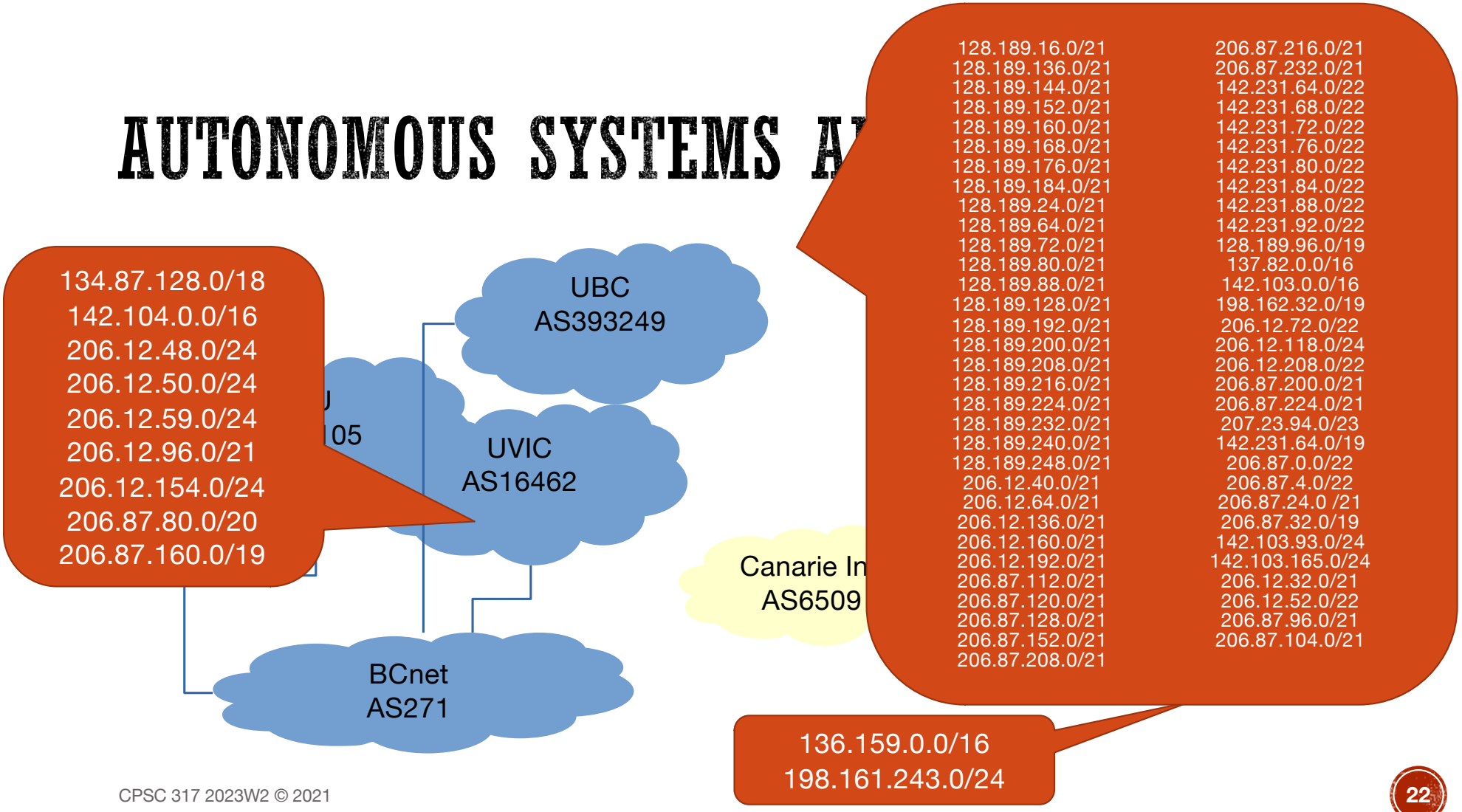
SO, WHY DO WE CARE ABOUT ALL THIS?

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

AUTONOMOUS SYS



AUTONOMOUS SYSTEMS A



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

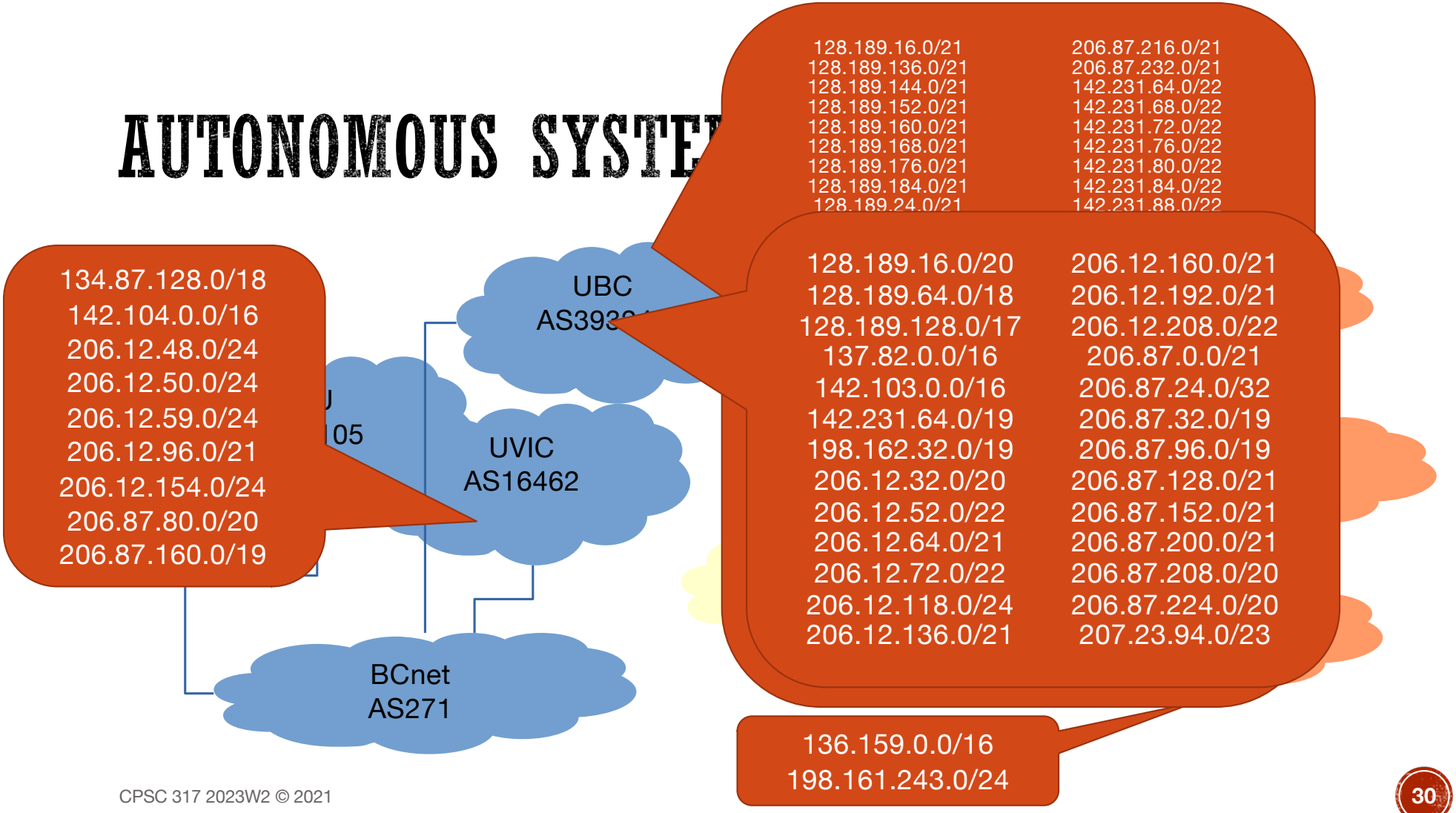
- Example: 192.205.0.0/22 and 192.205.2.0/23

```
10100000 11001101 000000xx xxxxxxxx
10100000 11001101 0000001x xxxxxxxx
```

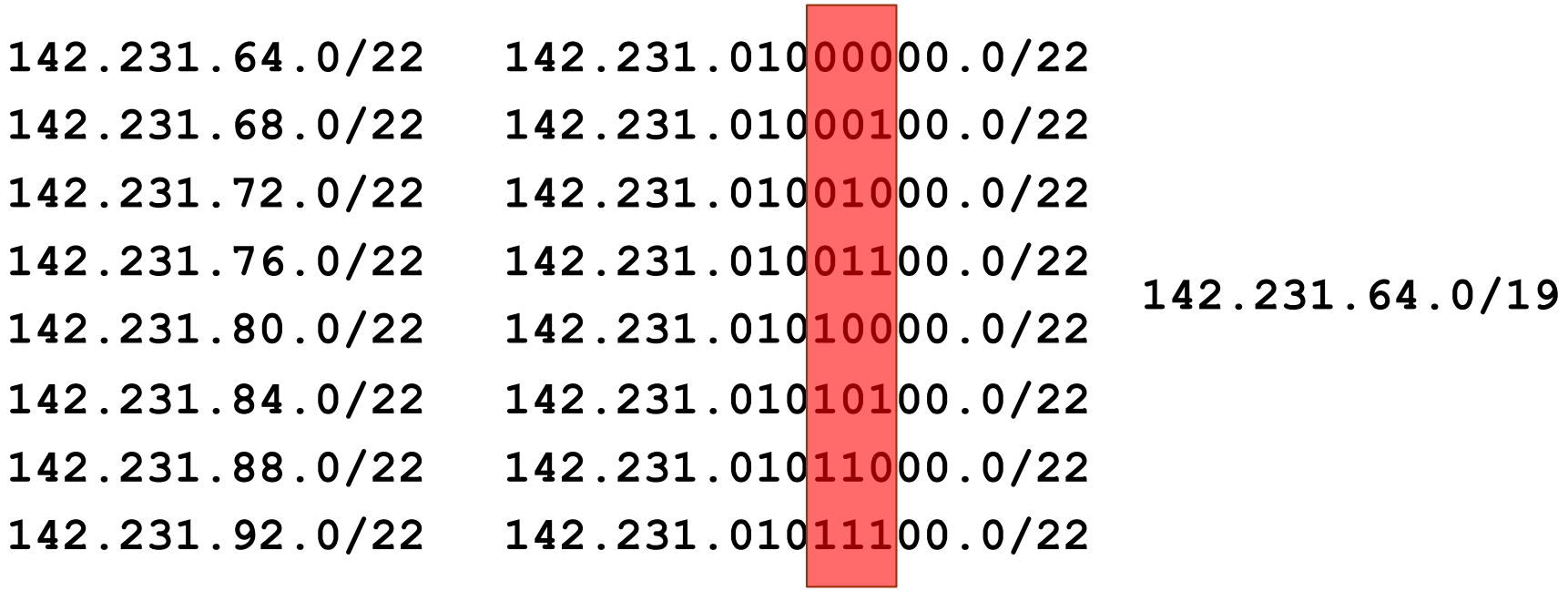
- First range includes all addresses in the second
- Aggregated range: 192.205.0.0/22 (same as first)

```
10100000 11001101 000000xx xxxxxxxx
```

AUTONOMOUS SYSTE



WHAT HAPPENED HERE?



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