Internet Addressing

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Internet address

- To send a message, we need a destination address
- Every host connecting to the Internet needs to have a unique address

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163.239.27.151

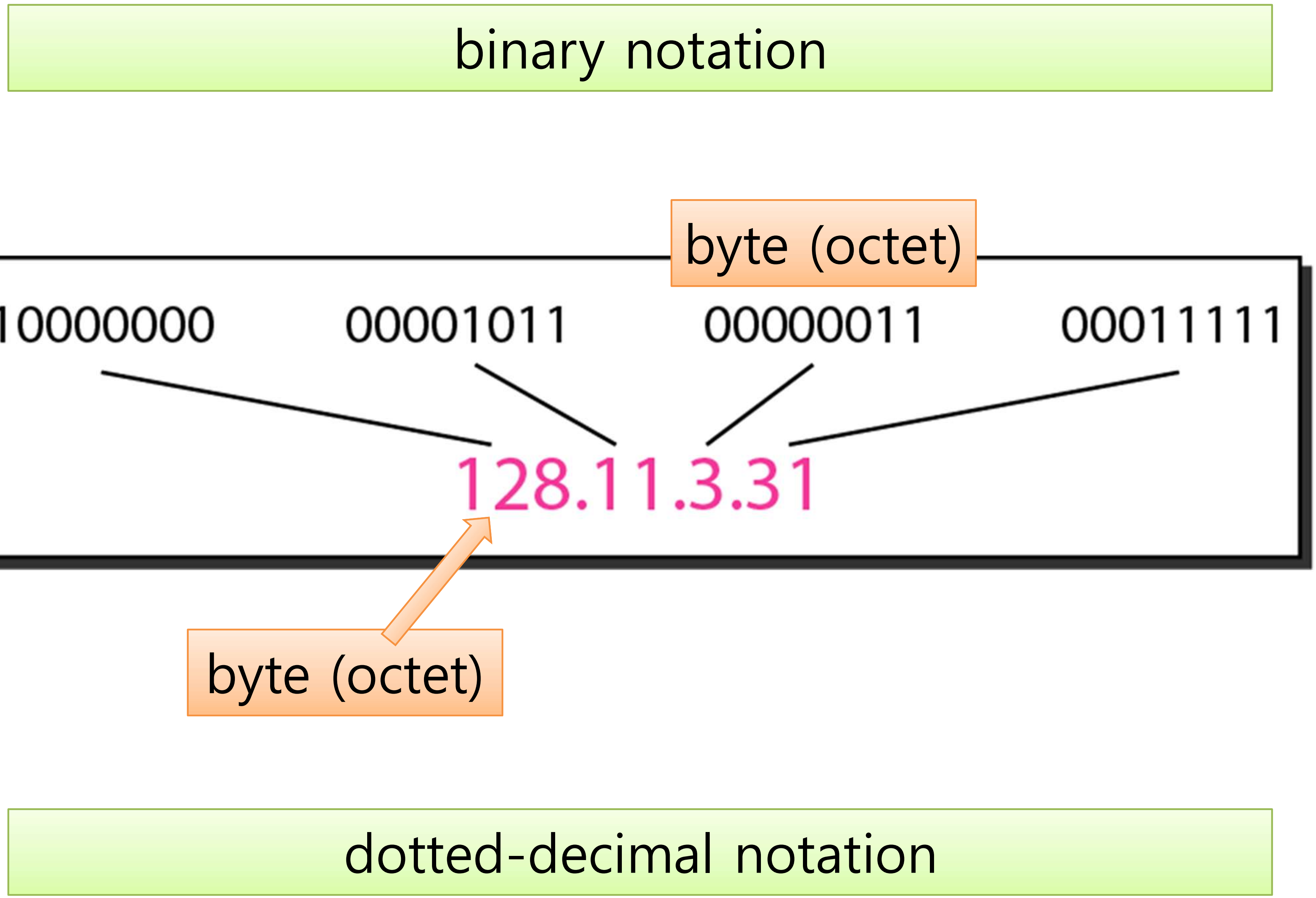
Internet address

- IPv4
  - the address system used today
  - 32 bits
  - possible number of hosts: 4,294,967,296

private ip address 192.168.0.2
집마다 ip address를 kt가 주는데, 공유기가 하나의 ip address로 내부망을 구축
원래는 기계마다 ip address를 주어야함

- IPv6
  - a new address system designed to replace IPv4
    - IPv4 address exhaustion
  - Still not used widely, but eventually will
  - Routers need to be upgraded in order to support IPv6
    - takes time
  - 128 bits

IP address: notations



IP address: exercise

- Convert the following IPv4 addresses into dotted-decimal representation
  - 10000001 00001011 00001011 11100111
  - 11000001 10000011 00011011 11111111

IP address: exercise

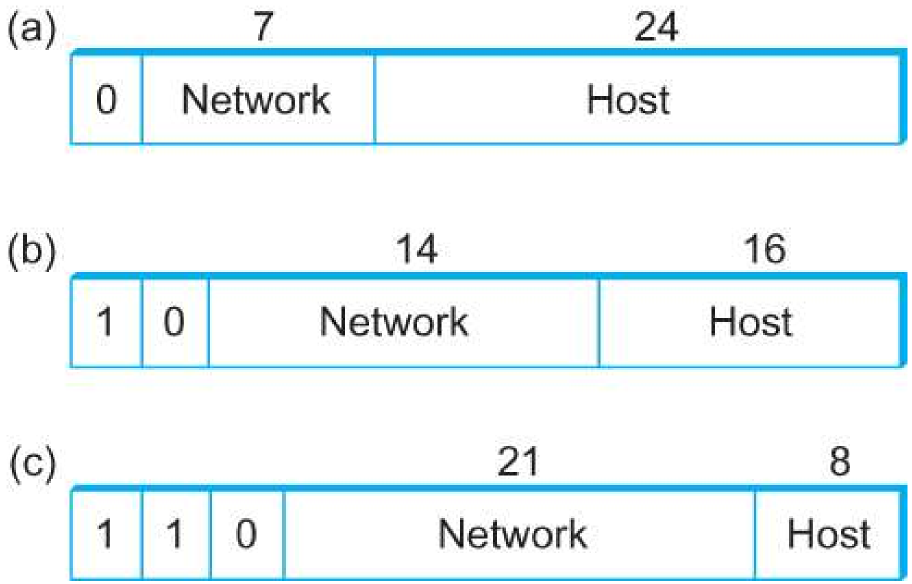
- Dotted-decimal notation: wrong use case
  - 111.56.045.78
  - 221.34.7.8.20
  - 75.45.301.14
  - 11100010.23.14.67

IP address: hierarchical structure

- Network address + Host address
- Nodes in the same network has the same network address

host에 할당된 비트가 많을 수록 기관에서 할당할 수 있는 ip가 많음

type a
맨 앞이 0



- Ethernet address: flat (no structure)

IP address: allocation

- IP address allocation system
  - Administrator: IANA (Internet Assigned Numbers Authority)
    - allocates address space to continents
    - Asia: APNIC (Asia-Pacific Network Information Center)
  - APNIC allocates IP addresses to countries in Asia
    - Republic of Korea: KRNIC (Korea Network Information Center)
  - KRNIC allocates address space to ISPs (Internet Service Providers) and organizations in Korea

Classful addressing

- system used to allocate address space based on network size

	First byte	Second byte	Third byte	Fourth byte
Class A	0			
Class B	10			
Class C	110			
Class D	1110			
Class E	1111			

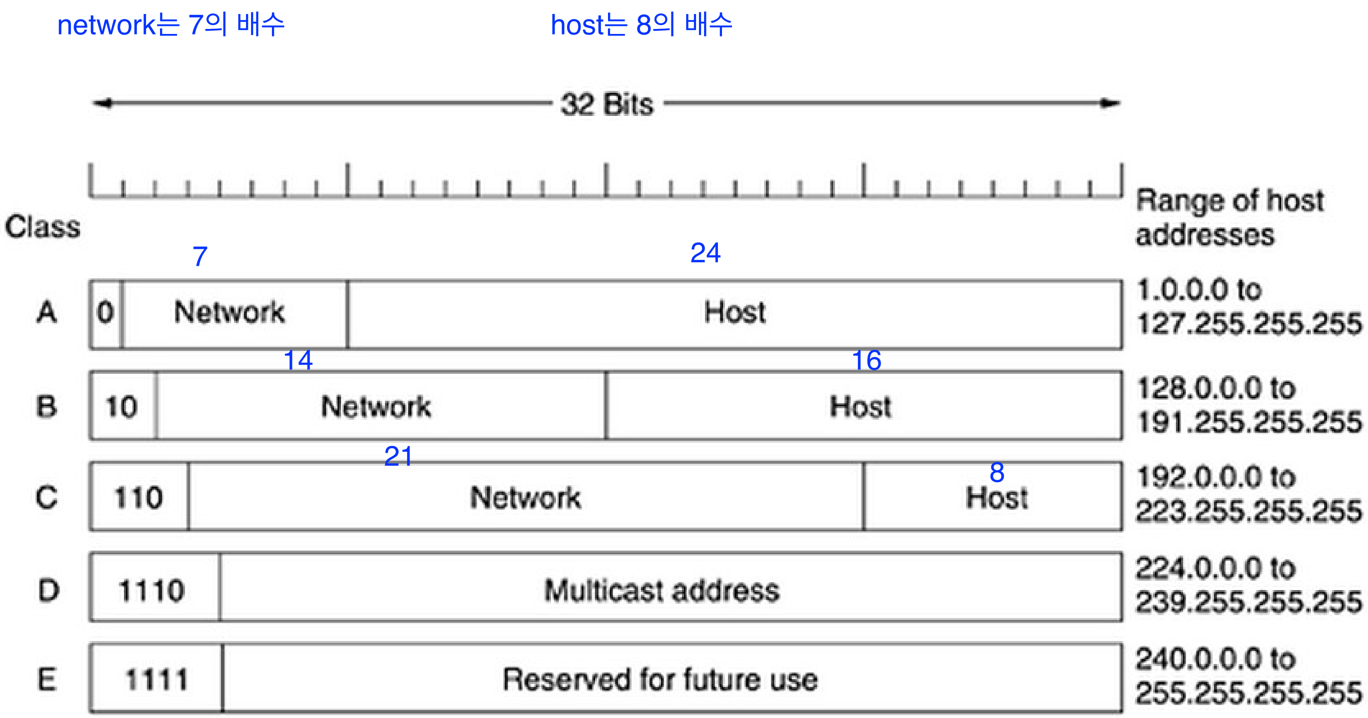
a. Binary notation

	First byte	Second byte	Third byte	Fourth byte
Class A	0–127			
Class B	128–191			
Class C	192–223			
Class D	224–239			
Class E	240–255			

b. Dotted-decimal notation

Classful addressing

- class A: IP address (binary notation) starts with ‘0’
- class B: starts with ‘10’
- class C: starts with ‘110’



Classful addressing: exercise

- What are the classes of the following addresses?
  - 00000001 00001011 00001011 11101111
  - 11000001 10000011 00011011 11111111
  - 14.23.120.8
  - 210.115.229.74

Classful addressing

- Network address: indicates a network as a “group of hosts”
  - Class A: 7 bits
  - Class B: 14 bits
  - Class C: 21 bits

- Host address: indicates a host inside a network
  - Class A: 24 bits
  - Class B: 16 bits
  - Class C: 8 bits

Classful addressing

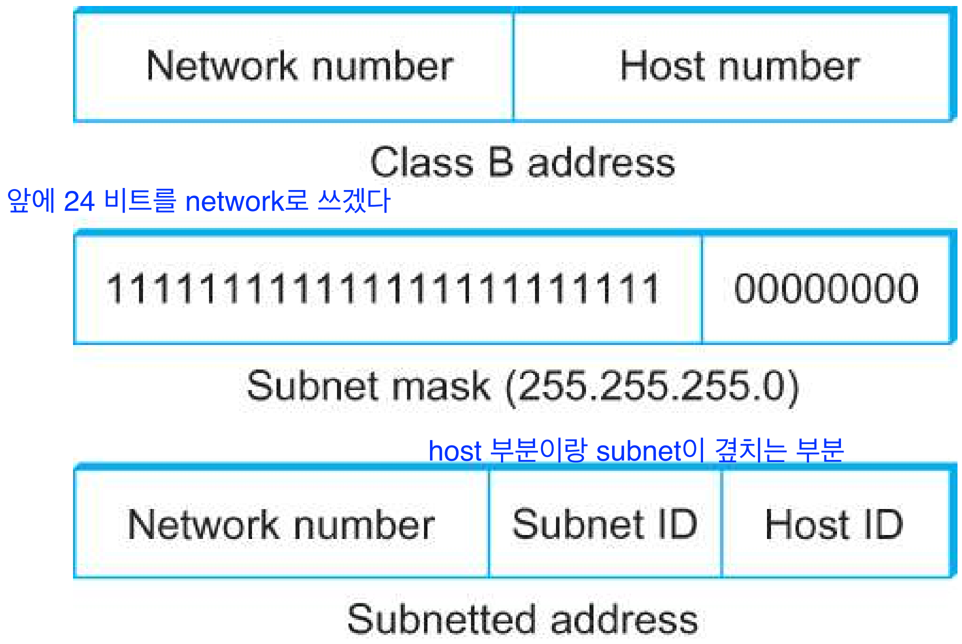
- For large ISPs or organizations, a class A address space is allocated
- For smaller ISPs or organizations, a class B or class C address space is allocated

Class	*Number of Blocks*	*Block Size*	*Application*
A	128	16,777,216	Unicast
B	16,384	65,536	Unicast
C	2,097,152	256	Unicast
D	1	268,435,456	Multicast
E	1	268,435,456	Reserved

Subnetting

하나의 기관에서 망을 나누고 싶을 때

- An organization can re-allocate its address space to organize multiple subnets
- Subnet masks define partition of host part to subnet ID and host ID



Classless Addressing

- "Supernetting"   여러 c type을 받아서 subnet을 더 큰걸로 해서 합침
  - Similar to subnetting, it is also possible to use subnet mask to combine multiple network addresses

- Using subnet mask, we can define a network of any size → Classless addressing

모두가 subnet mask를 쓰니까 이젠 subnet으로 네트워크를 구분

- Classless addressing is also called "CIDR"
  - Classless Interdomain Routing
  - Widely used in today's routers

Classless Addressing

- Problem with classful addressing
  - class A and B: too large
  - class C: too small
  - For a network of 1000-2000 hosts, a class C address space is not enough, but a class B address space is too wasteful
- As the number of networks increase, address space should be efficiently allocated
- Classful addressing is inefficient

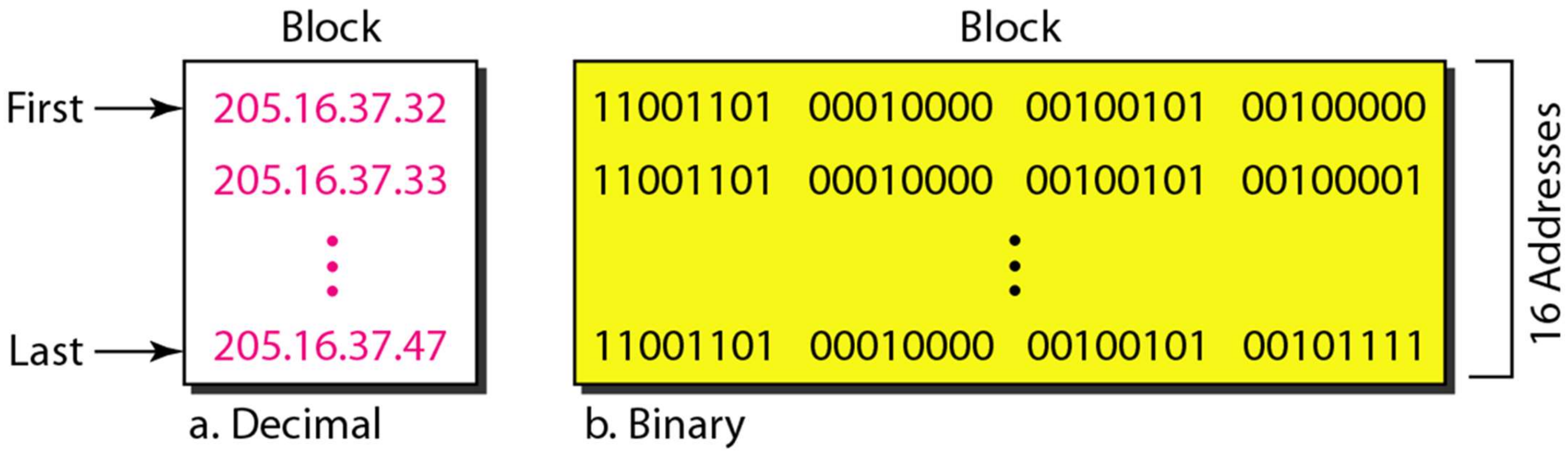
Classless addressing

- A newer approach of address allocation
- No class: addresses allocated as an address block
- Three rules of address allocation
  - address space should be continuous
    - should not be partitioned
  - Number of addresses should be a power of 2
  - The first address in the block should be divided by number of addresses in the block

Classless addressing

- Example: an organization needs 16 addresses
  - allocated: 205.16.37.32 ~ 205.16.37.47

16개의 주소가 있는데
first address in the block (205.16.37.32) 가 16으로 나누어짐



Classless addressing

- network mask
  - IP address prefix that indicates the same network
  - IP address: 210.115.227.98
  - subnet mask: 255.255.255.0

11010010 01110011 11100011 01100010

network block address

11111111 11111111 11111111 00000000

Classless addressing

- network mask
  - representation: x.y.z.t/n
  - n: subnet mask (prefix length)

  - 205.16.37.39/28 앞 28비트가 subnet mask

11001101 00010000 00100101 00100111

28 binary numbers from the front

Classless addressing: exercise

- An ISP was allocated an IP address block
- One of the address was 205.16.37.39/28

- What is the first address in this block?

205.16.37.39/28 → 11001101 00010000 00100101 00100111

The first address is 11001101 00010000 00100101 00100000

Thus, the first address is 205.16.37.32

- Usually, the first address in a block also indicates the address block itself
  - 205.16.37.32/28 can mean the address block 205.16.37.32 – 205.16.37.47

Classless addressing: exercise

- One of the addresses allocated to an ISP is 205.16.37.39/28.

- What is the last address in this block?

0010 0000 - 0010 1111

205.16.37.47

- What is the number of addresses in the block?

16

Forwarding with CIDR

- Routing table must store entries
  - Entry: (Destination, Next Hop)
- Routing table size affects performance
  - Large size slows down processing
  - Too much space needed
- Solution: prefix routing

Prefix routing

- Suppose 194.24.x.x indicates a host in Cambridge university, UK.

- From a router in Sogang University,
  - It is probable that destination address 194.24.1,1, 194.24.83.72, and 194.24.235.55 will have the same next hop router.
  - Thus, for these destinations, only one route entry is maintained as the following.

  - <u>destination: 194.24.0.0/16</u>
  - <u>If the first 16 bits of the destination matches 194.24.0.0, then this entry should be used.</u>

Prefix routing

- Suppose addresses of hosts in universities are as follows.

University	First address	Last address	How many	Written as
Cambridge	194.24.0.0	194.24.7.255	2048	194.24.0.0/21
Edinburgh	194.24.8.0	194.24.11.255	1024	194.24.8.0/22
(Available)	194.24.12.0	194.24.15.255	1024	194.24.12/22
Oxford	194.24.16.0	194.24.31.255	4096	194.24.16.0/20

- The routing table is maintained as follows.
  - Cambridge: 194.24.0.0/21
  - Edinburgh: 194.24.8.0/22
  - Oxford: 194.24.16.0/20

```
   Address                             Mask
C: 11000010 00011000 00000000 00000000 11111111 11111111 11111000 00000000
E: 11000010 00011000 00001000 00000000 11111111 11111111 11111100 00000000
O: 11000010 00011000 00010000 00000000 11111111 11111111 11110000 00000000
```

Prefix routing

- For a packet destined for 194.24.17.4
  - compare the first 21 bits with 194.24.0.0 → no match
  - compare the first 22 bits with 194.24.8.0 → no match
  - compare the first 20 bits with 194.24.16.0 → match
  - Thus the route for Oxford is used.

- If there are multiple matching entries
  - <u>The one with the longest prefix is used</u>

Prefix routing

- Destination IP address: 194.24.17.25
  - 11000010 00011000 00010001 00011001
  - Cambridge: 194.24.0.0/21
    - 11000010 00011000 00000000 00000000
  - Edinburgh: 194.24.8.0/22
    - 11000010 00011000 00001000 00000000
  - Oxford: 194.24.16.0/20
    - 11000010 00011000 00010000 00000000
    - Prefix match!

Longest matching prefix

- If destination IP address is 194.24.14.72, which next hop should be used?

Destination	Next Hop
194.24.0.0/19	London
194.24.12.0/22	San Francisco

- Since both routes match, San Francisco is selected as the next hop
  - Longer prefix: a more specific path

Route aggregation

- For routers in Sogang university, routes to Cambridge, Edinburgh, and Oxford all have the same next hop.
- In this case, the three route entries can be aggregated. (route aggregation)

- Cambridge: 194.24.0.0/21 0000 0\000
- Edinburgh: 194.24.8.0/22 0000 10\00
- Oxford: 194.24.16.0/20 0001\ 0000

세 라우터의 공통 부분

- aggregated: 194.24.0.0/19 000\0 0000

Route aggregation

- Used to reduce routing table size

Destination	Next Hop
194.24.12.1	210.115.227.1
194.24.12.2	210.115.227.1
194.24.12.3	210.115.227.1
194.24.12.4	210.115.227.1
194.24.12.5	210.115.227.1
194.24.12.6	210.115.227.1
194.24.12.7	210.115.227.1

Destination	Next Hop
194.24.12.0/29 19	210.115.227.1