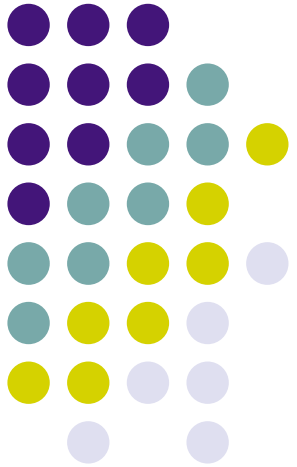
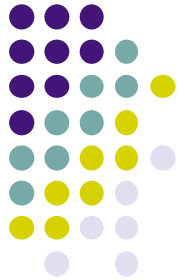
Lecture 6: Internet Layer

Reading 5.1. and 5.6 in Computer Networks, Tanenbaum



Bài giảng có sử dụng nguồn tài liệu cung cấp bởi trường Đại học Keio, Nhật Bản

Contents



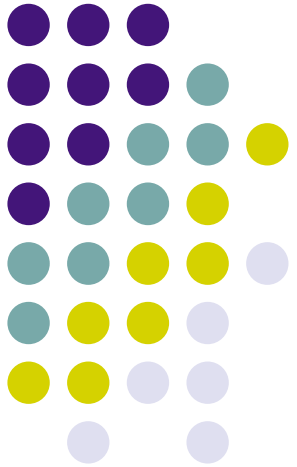
- Internet Protocol
- IP address and IP packet format
- ICMP- Protocol for control message

Introduction about IP

Concepts

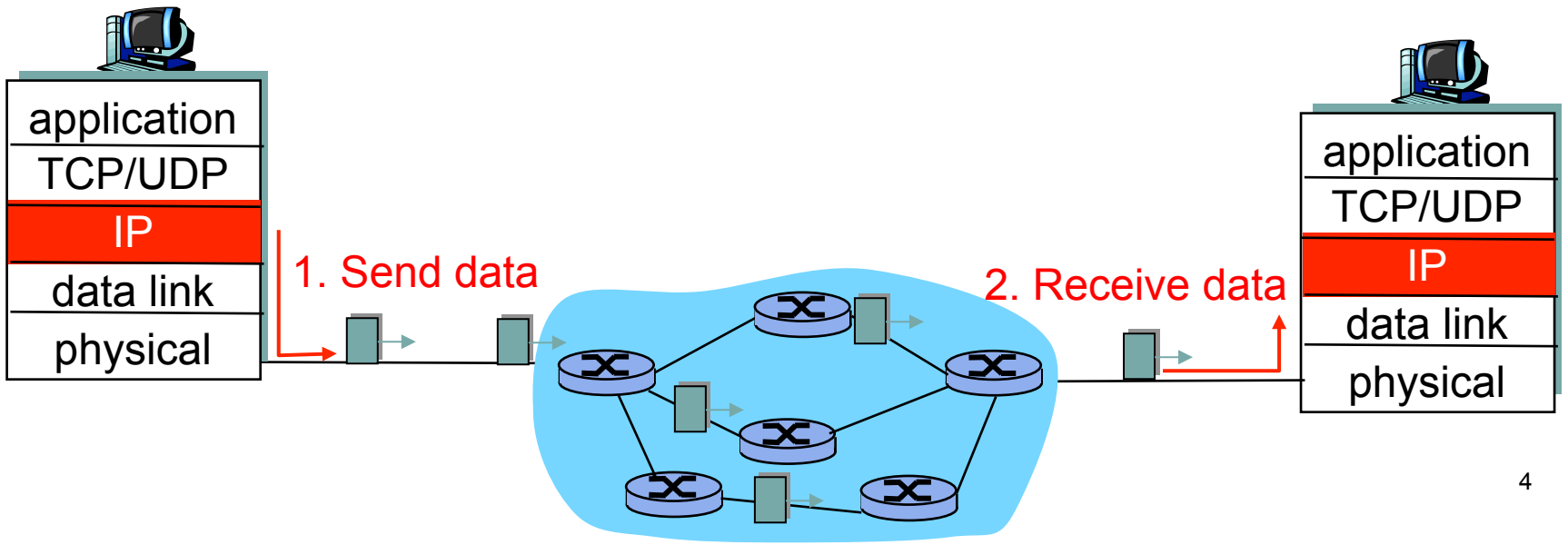
Store and forward principles

Characteristic of IP

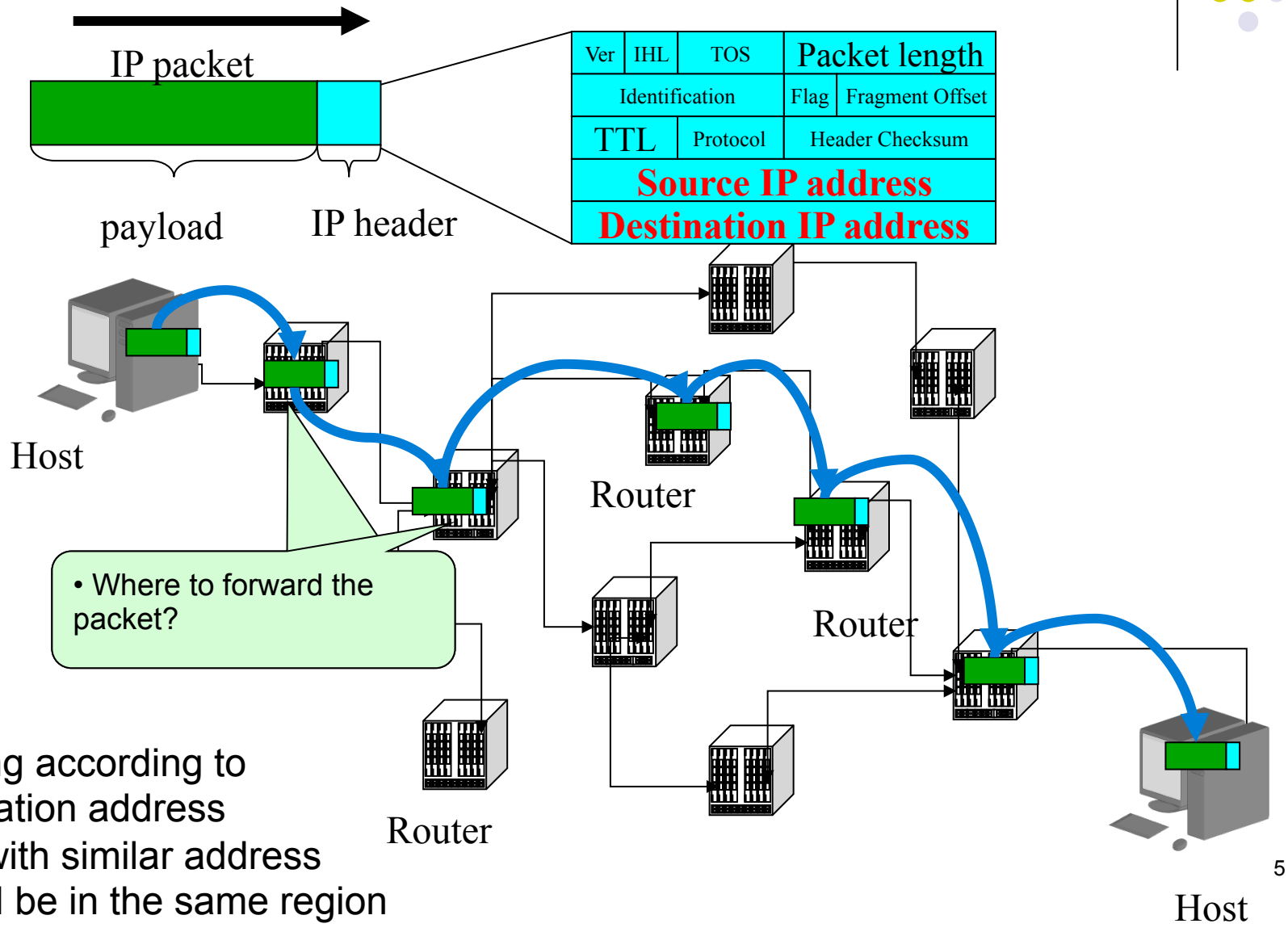


Network layer and Internet protocol

- Role of network layer: Transferring data between distant nodes
- Two main functionalities of Network layer
  - *Routing*: Determine the path for transferring data from the source to the destination nodes → Role of routing protocol.
  - *Forwarding*: Transferring data from the an incoming port to an outgoing port of a node (router) according to the path defined above ➔ Role of routed protocol: Internet Protocol (IP

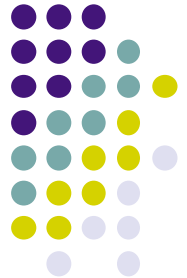


Routing and forwarding



- Routing according to destination address
- Host with similar address should be in the same region

IP characteristics



- Not reliable / fast
  - Sending data in "*best effort*" manner
  - No mechanism to recover error data at the receiver
  - When necessary, leave the upper layer (TCP) to ensure the data reliability.
- Packets are processed independently one of the other.

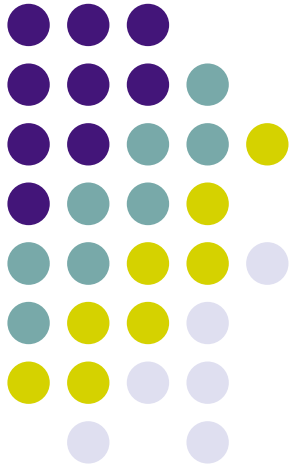
IP address

IP address classes

CIDR – Classless Inter-Domain routing

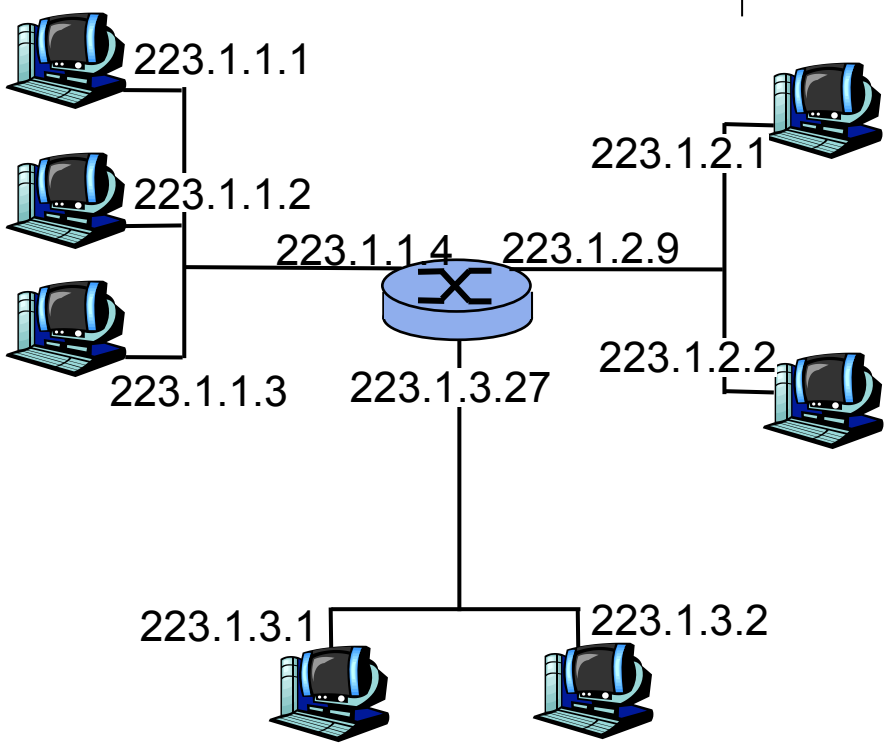
Subnet and netmask

Special IP addresses



IP address (IPv4)

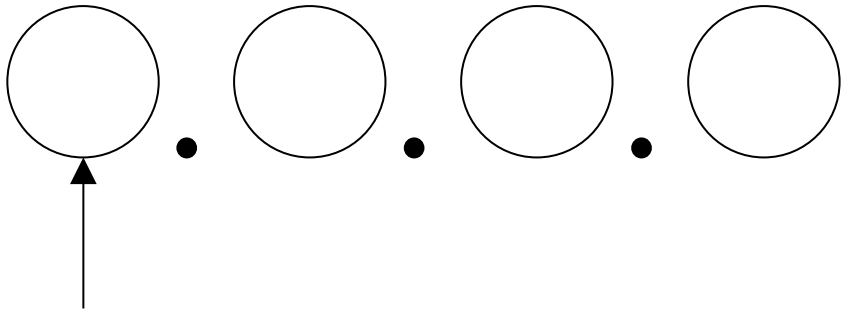
- IP address: A 32-bit number identifying a network interface of a host or a router.
- Each IP address is assigned to one network interface.
- An IP address is unique



223.1.1.1 = 11011111 00000001 00000001 00000001

223 1 1 1

Dot notation

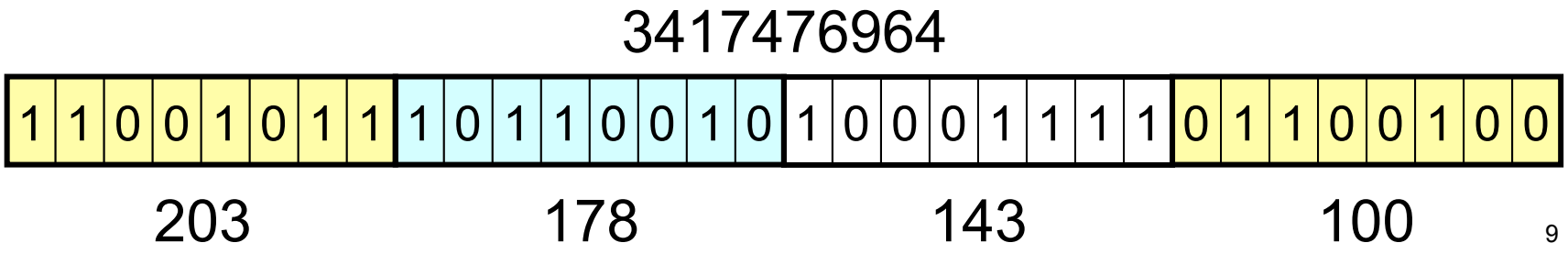


8 bits
0 – 255 integer

Example:

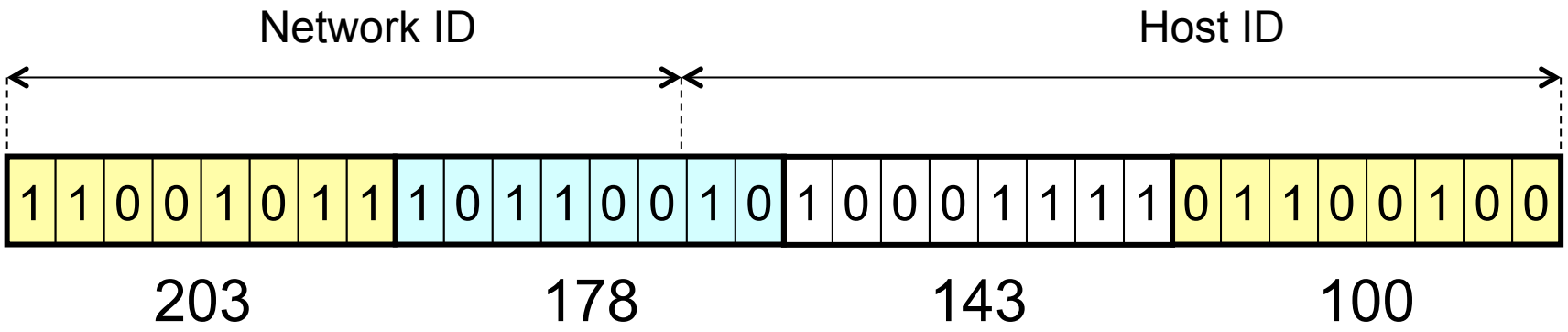
203.178.136.63	o
259.12.49.192	x
133.27.4.27	o

Use 4 x 8 bits describing a 32 bits address



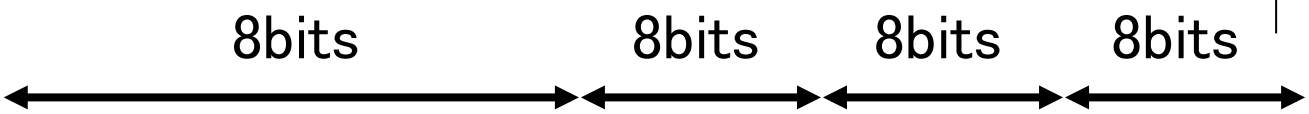
Host address, network address

- IP address contains two parts
  - Host ID – identify a host in a network
  - Network ID – identify a network



- How to know which bits belong to network ID or host ID parts?
  - Use classful IP address
  - Use classless IP address– CIDR

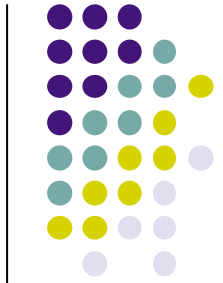
Classify IP addresses



Class A	0	7 bit	H	H	H
Class B	1 0	6bit	N	H	H
Class C	1 1 0	5 bit	N	N	H
Class D	1 1 1 0	Multicast			
Class E	1 1 1 1	Reserve for future use			

	# of network	# of hosts
Class A	128	2^24
Class B	16384	65536
Class C	2^21	256

Limitation of classful IP address

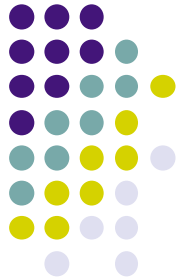


- Inefficient use of addressing space
  - Hard classification of addressing space into classes (A, B, C, D, E) makes it is difficult to use all the address space

Solution…

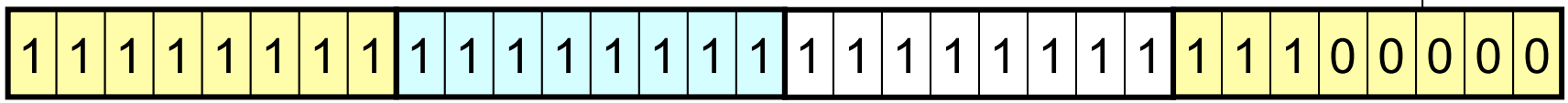
- CIDR: Classless Inter Domain Routing
  - Network ID part will have variable length.
  - Address notation: a.b.c.d/x, where x (mask) the number of bit of Network ID part.

Network mask



- Network mask divides the IP address into two parts
  - Part corresponding to Host ID
  - Part corresponding to Network ID
- IP addresses are assigned to hosts so that all hosts in the same network have the same Network ID part.
- Based on Network mask, it is possible to
  - Identify the network where an IP address belongs to
  - Calculate how many IP addresses available in the network associate with the mask.

Presentation of network mask



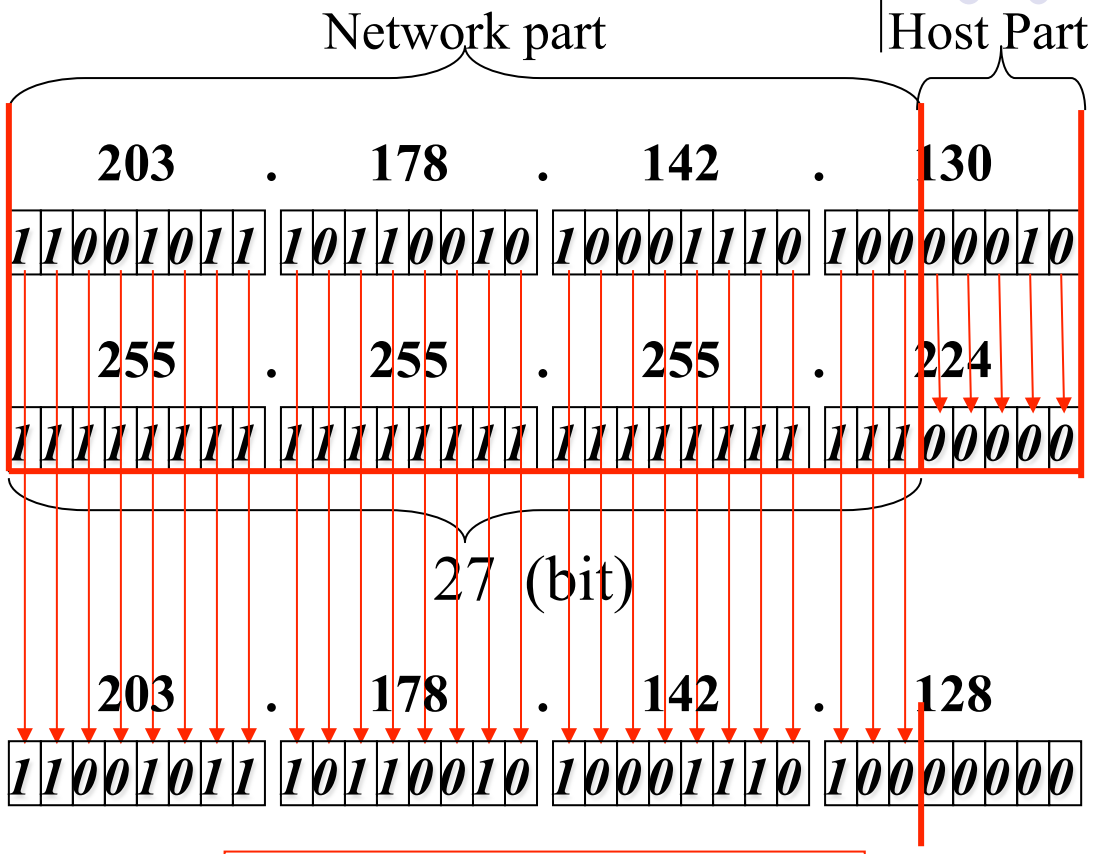
255 255 255 224

- 255.255.255.224
- /27
- 0xFFFFFFe0

- Last byte may be:

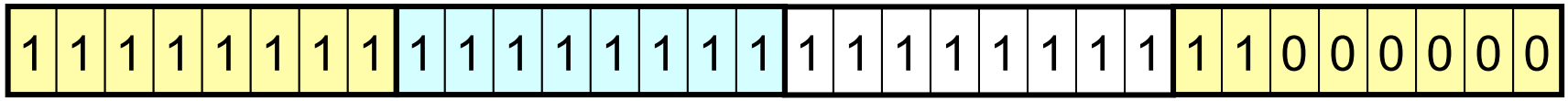
0 248
128 252
192 254
224 255
240

Calculation of network address



Network address **203.178.142.128/27**

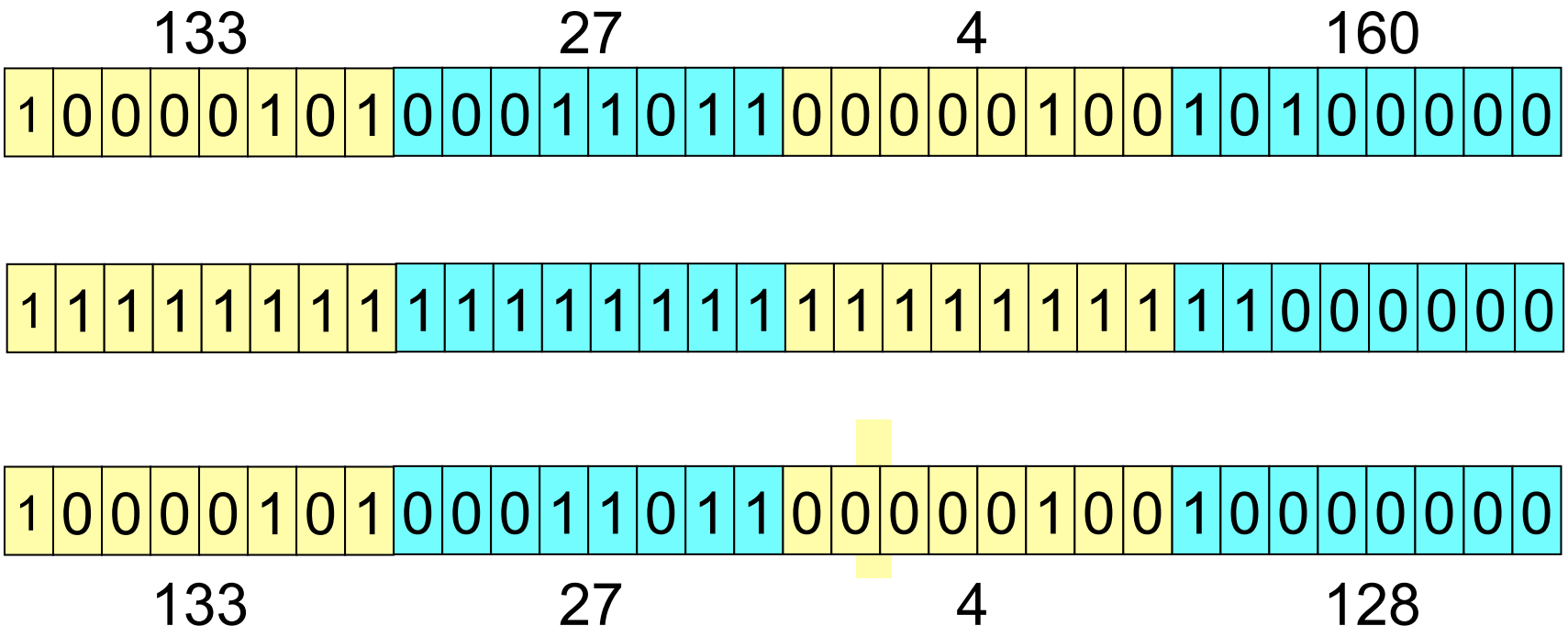
Calculation of network size



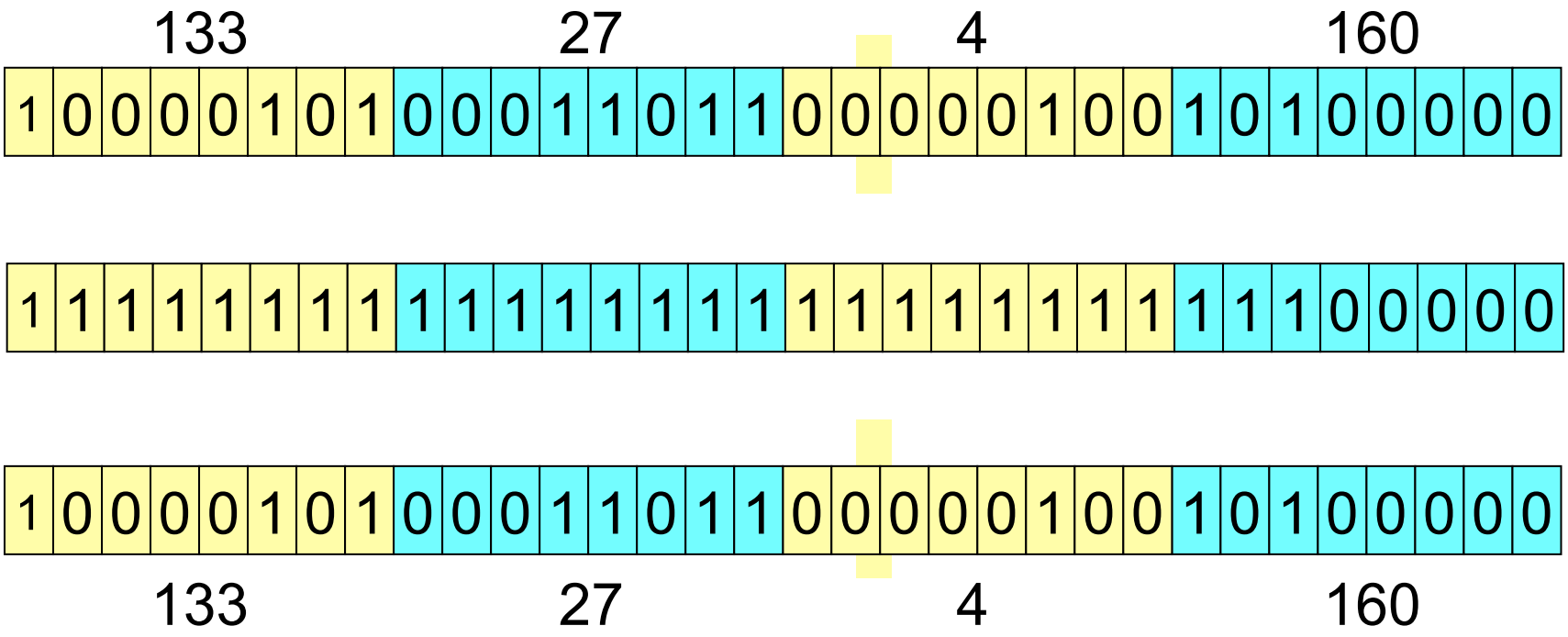
- Network size
  - Power of 2
- RFC1878

- In case of mask /26
  - Bits for Host ID = 6 bits
  - 2^6=64 possible address:
    - 0 - 63
    - 64 - 127
    - 128 - 191
    - 192 – 255
  - Including network address and broadcast address

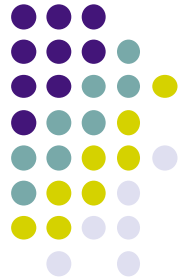
Network address or host address (1)



Network address or host address (2)



Different significations of IP address



- Network address
  - IP address assigned to a network
  - hostID contains all 0
- Host address
  - IP address assigned to a network card
- Broadcast address
  - Address used for sending data to all hosts in a network
  - All bit 1 in HostID part.

Exercice: IP address and network mask

- Which of the following IP addresses are host address, network address, broadcast address?

(1) 203.178.142.128 /25

(2) 203.178.142.128 /24

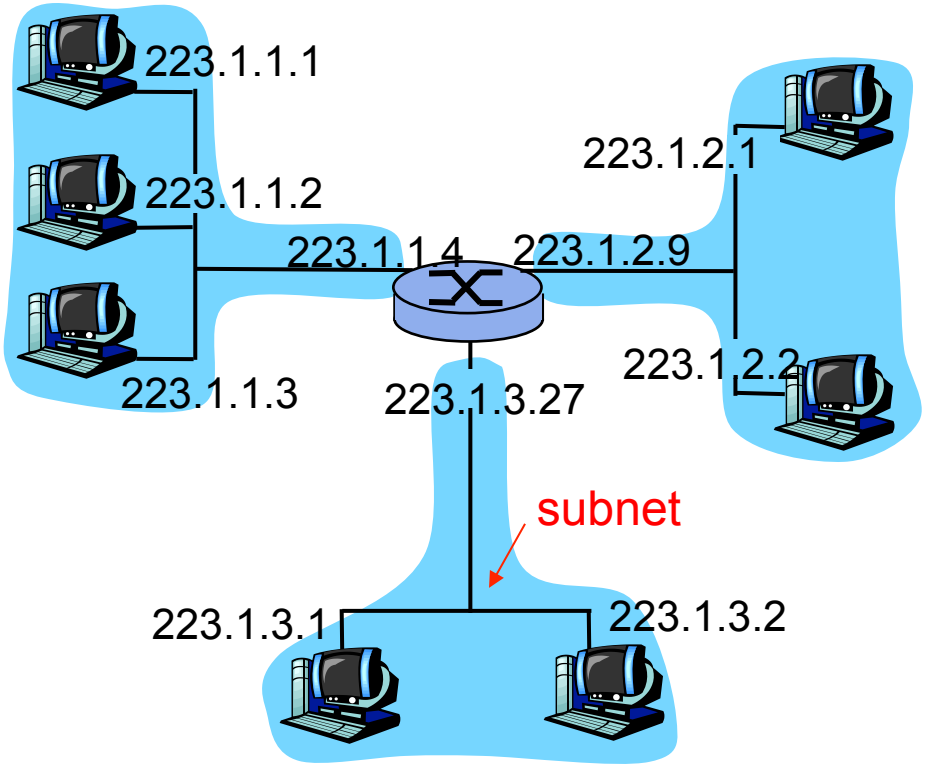
(3) 203.178.142.127 /25

(4) 203.178.142.127 /24

- Attn: With CIDR addressing, IP address should always coming with a network mask

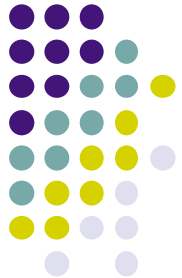
Subnet

- Subnet is a part of a network
  - An ISP/organization is usually assigned a block of address IP
  - Organization may be grown with more departments
  - Divide the networks into smaller ones→ subnet
- How to divide network to subnets
  - Use a longer netmask

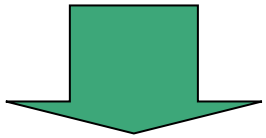


Mạng với 3 mạng con

Example: Divide into 2 subnets



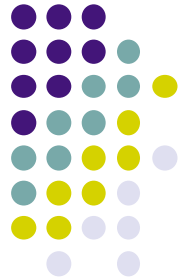
11001000 00010111 00010000 00000000
200. 23. 16. 0 /24



11001000 00010111 00010000 00000000
200. 23. 16. 0 /25

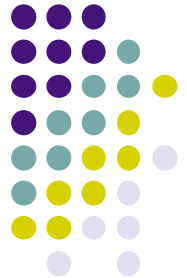
11001000 00010111 00010000 10000000
200. 23. 16. 128 /25

Exercise: Dividing into subnets



- Given IP addresses in the range 200.23.16.0/24
- Need to organize into 4 subnets
  - Address of each subnetwork? Mask? Number of hosts/network
- General question: Need to create N subnets. Network address? Mask?
  - Each network contains 14 hosts → /28
  - Each network contains 30 hosts → /27
  - Each network contains 31 hosts → /26
  - Each network contains 70 hosts → /25

Addressing space of IPv4

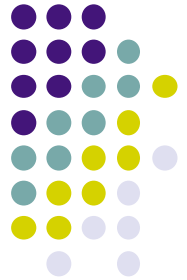


- In theory
  - All between 0.0.0.0 ～ 255.255.255.255
  - Some special IP address (RFC1918)

Private address	10.0.0.0/8 172.16.0.0/12 192.168.0.0/16
Loopback address	127.0.0.0
Multicast address	224.0.0.0 ～239.255.255.255

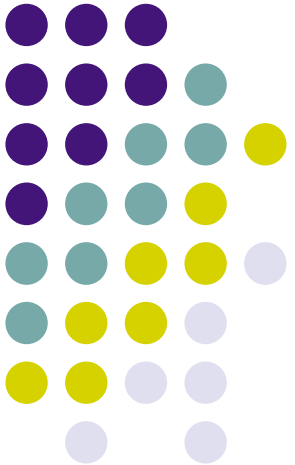
- Self assigned IP address: 169.254.0.0/16

Attention about IP

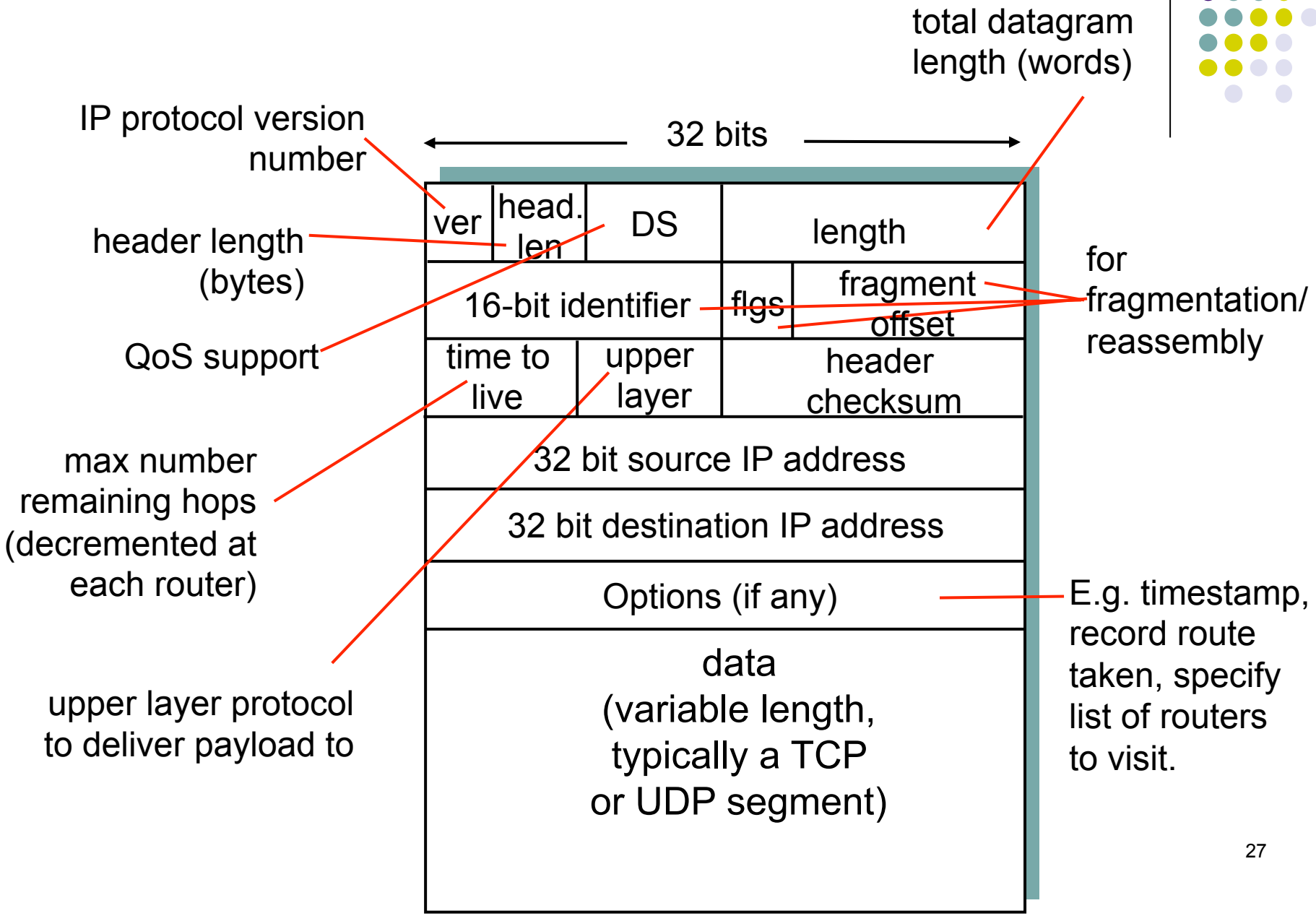


- Currently IPv4: 32 bits
  - 133.113.215.10 (IPv4)
- IPv6 is also widely used: 128bits
  - 2001:200:0:8803::53 (IPv6)
  - Fix 64 first bit for subnet ID, 64 last bit belongs to interface ID.
  - Security feature is integrated

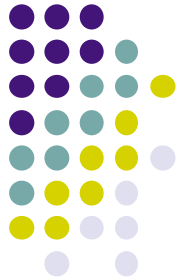
IP package



Header of IP

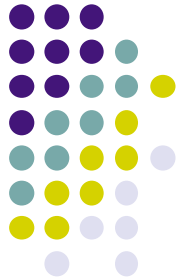

total datagram length (words)
IP protocol version number
32 bits
header length (bytes)
QoS support
ver
head. len
DS
length
16-bit identifier
flgs
fragment offset
for fragmentation/ reassembly
time to live
upper layer
header checksum
max number remaining hops (decremented at each router)
32 bit source IP address
32 bit destination IP address
Options (if any)
E.g. timestamp, record route taken, specify list of routers to visit.
upper layer protocol to deliver payload to
data (variable length, typically a TCP or UDP segment)

IP header (1)



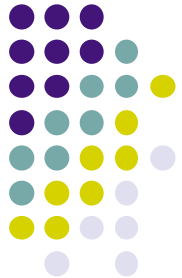
- Version (4 bits)
  - IPv4
  - IPv6
- Header length: 4bits
  - In word unit (4 bytes)
  - Min: 5
  - Max: 60

IP header (2)



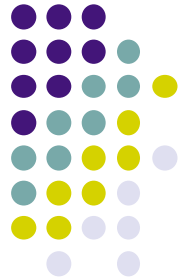
- DS (Differentiated Service : 8bits)
  - Old name: Type of Service
  - Used for QoS management by some router
  - Diffserv

IP header (3)



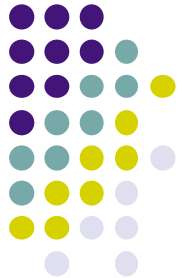
- Length: total length including header (16 bits)
  - In bytes unit
  - Max: 65536
- 16 bits Identifier– ID of the packet
  - Used for identifying all fragments of the same packet when it is fragmented
  - Flag
  - Fragmentation offset – offset of the first byte of the fragment in its original packet

IP header (4)



- TTL, 8 bits – Time to live
  - Maximum number of hops (router) the packet is allowed to travel
  - Max: 255
  - Router decreases TTL 1 unit when processing a packet
  - The packet will be destroyed when TTL reaches to 0
- Protocol – upper layer protocol
  - Transport protocol (TCP, UDP,…)
  - Other network layer protocols that are encapsulated in IP packet (ICMP, IGMP, OSPF)

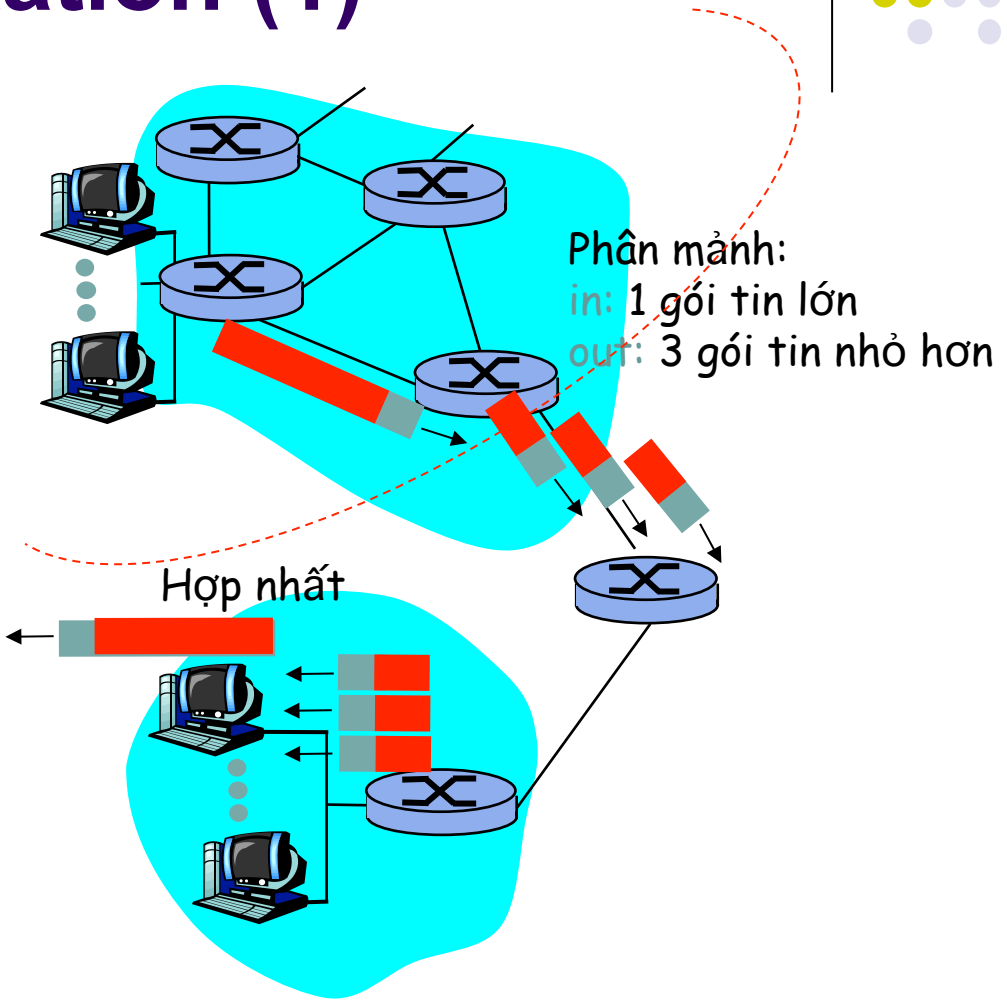
IP header (4)



- Checksum: to detect corruption in the header of IPv4 data packets
- Source IP address
  - 32 bit, address of the sender
- Destination IP address
  - 32 bit, address of the receiver.

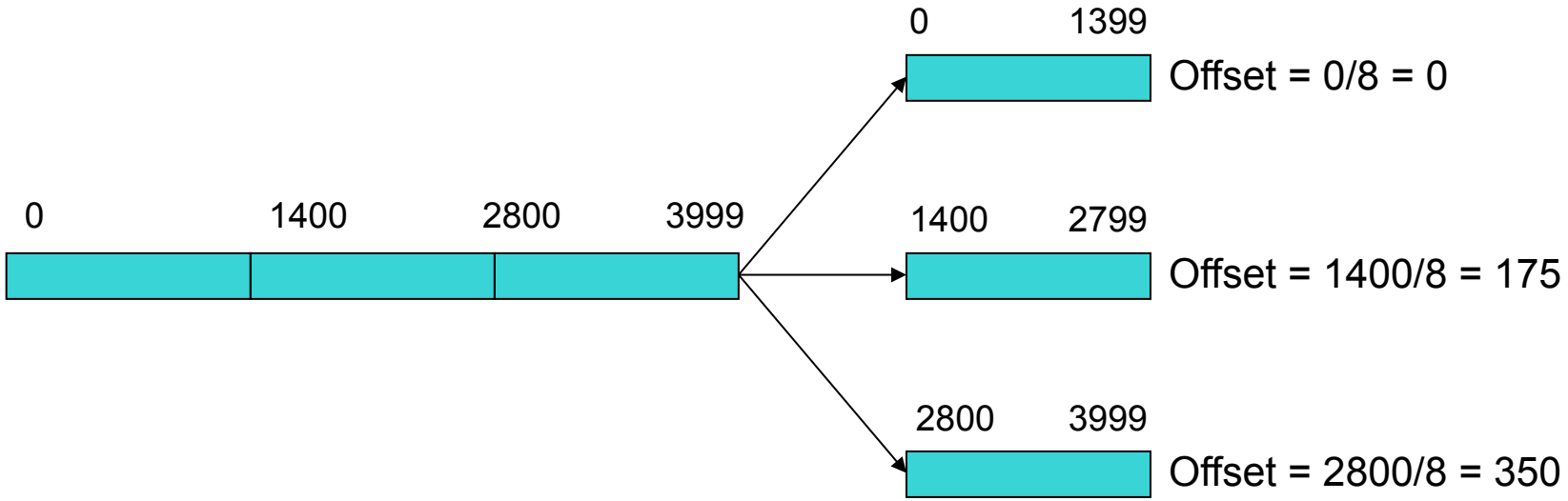
Packet fragmentation (1)

- Each link has a fixed MTU (Maximum transfering unit)
- Different media have different MTU
- If IP packet > MTU, it should be
  - Divided into small fragments
  - Gathered at the destination



Packet fragmentation (2)

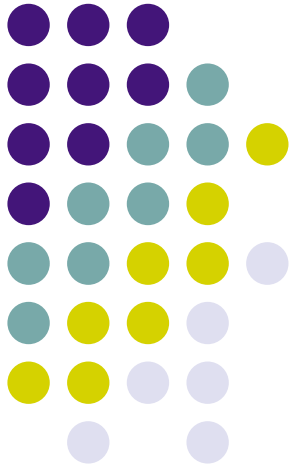
- Offset
  - Position of the fragment in the original packet
  - In 8 bytes units



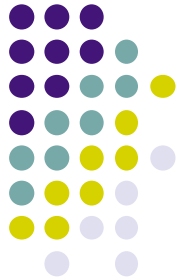
Internet Control Message Protocol

Packet format

Ping and Traceroute

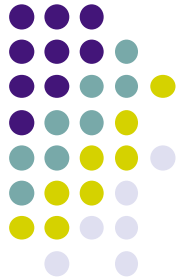


Idea of ICMP (1)

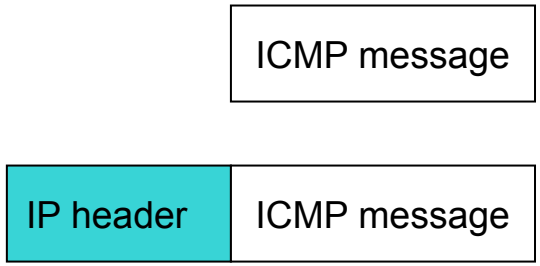


- IP is unreliable, connectionless
  - Lack of supporting and error control mechanism
- ICMP is used in network layer for providing information exchange between sender and receivers
  - Error information: inform that a packet cannot reach a host, a network or a port.

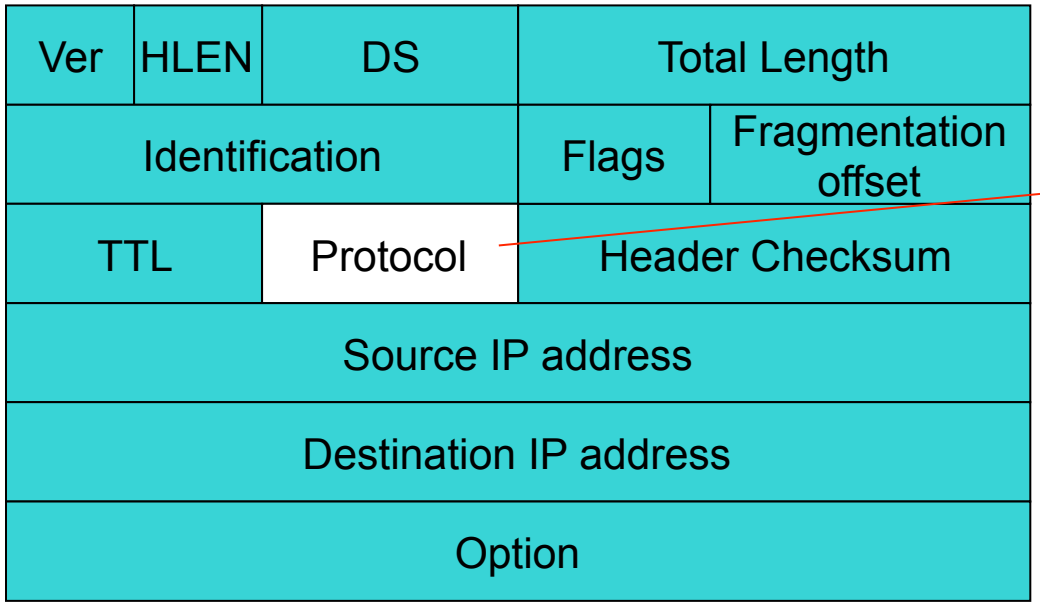
Idea of ICMP (2)



- Also in network layer but is “above” IP
  - ICMP message is encapsulated in IP
- ICMP message: Type, Code, with 8 first bytes of the error IP message

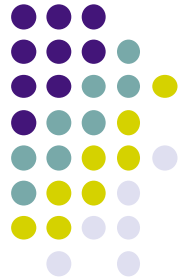


IP header and Protocol field

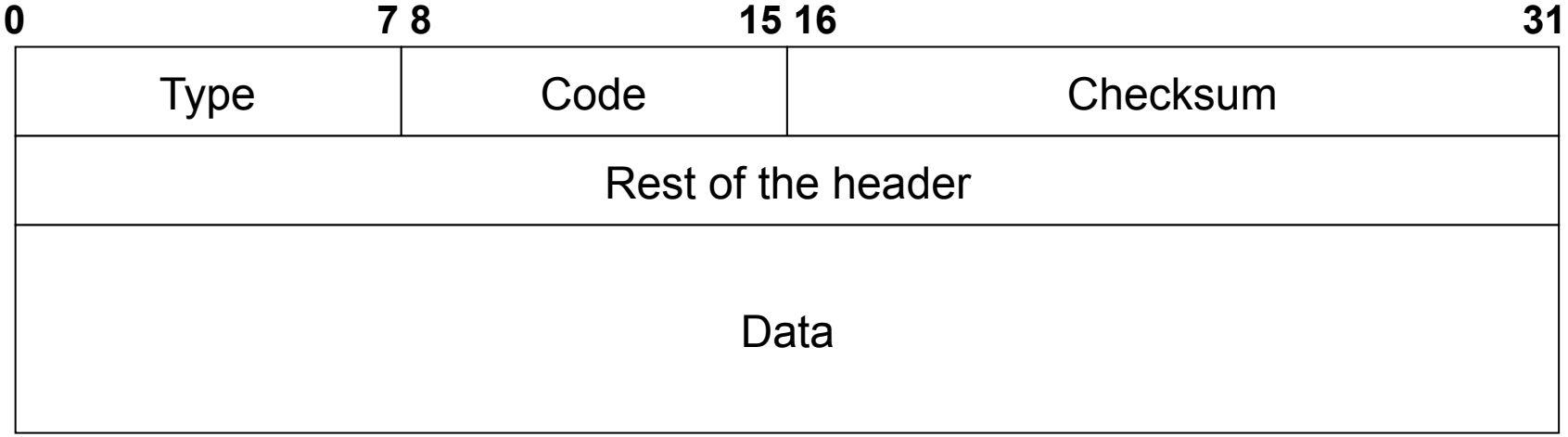


Protocol:
- 1: ICMP
- 2: IGMP
- 6: TCP
- 17: UDP
- 89: OSPF

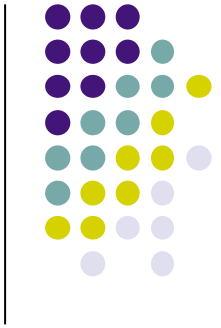
ICMP message format



- Type: type of ICMP message
- Code: cause of error
- Checksum
- Rest of header varies according on type

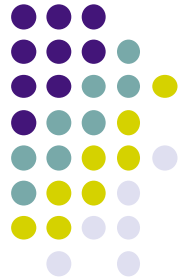


Some ICMP message types



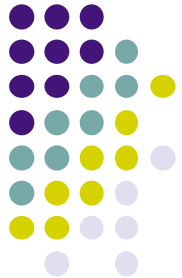
ICMP Message Type			
	Error-reporting messages	3	Destination Unreachable
		4	Source quench (nguồn giảm tốc độ)
		5	Redirection
		11	Time exceeded
		12	Parameter problem
	Query messages	8 or 0	Echo reply or request
		13 or 14	Time stamp request or reply
		17 or 18	Address mask request or reply
		9 or 10	Router advertisement or solicitation

ICMP and debuging tools



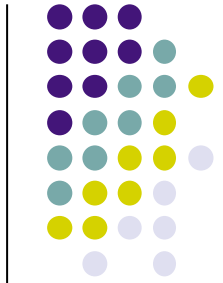
- ICMP always works transparently for users
- Users can use ICMP by using some debuging tools
  - ping
  - traceroute

Ping and ICMP



- ping
  - Test a connection
  - Sender sends packet “ICMP echo request”
  - Receiver responses with “ICMP echo reply”
- Data field contains the time stamp when the packet is sent
  - For calculating RTT (round-trip time)

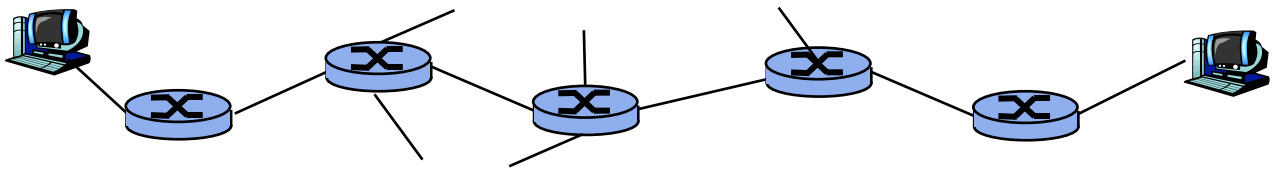
Ping: Example



```
C:\Documents and Settings\hongson>ping www.yahoo.co.uk

Pinging www.euro.yahoo-eu1.akadns.net [217.12.3.11] with 32 bytes of data:

Reply from 217.12.3.11: bytes=32 time=600ms TTL=237
Reply from 217.12.3.11: bytes=32 time=564ms TTL=237
Reply from 217.12.3.11: bytes=32 time=529ms TTL=237
Reply from 217.12.3.11: bytes=32 time=534ms TTL=237

Ping statistics for 217.12.3.11:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 529ms, Maximum = 600ms, Average = 556ms
```

Traceroute and ICMP

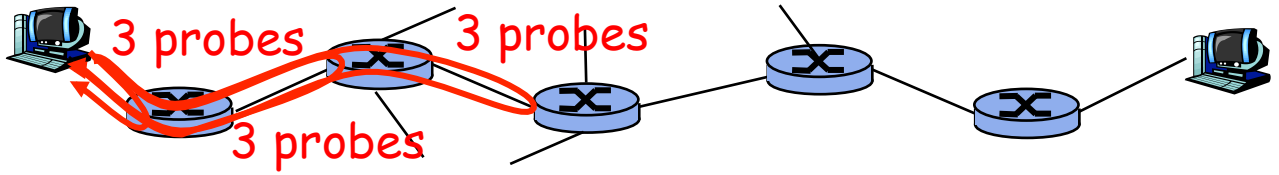
- Sender send many packets to receiver
  - First packet has TTL =1
  - Second packet has TTL=2, …
- When packet number n arrives to n^{th} router:
  - Router destroys the packer
  - Router send back an ICMP packet (type 11, code 0) containing IP address of the router
- Based on the reply message, the sender can calculate RTT



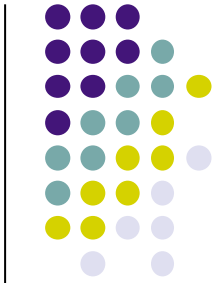
Traceroute and ICMP

Termination condition

- When ICMP echo packet arrive to the destination
- When source receives ICMP “host unreachable” (type 3, code 3)



Traceroute: Example



```
C:\Documents and Settings\hongson>tracert www.jaist.ac.jp

Tracing route to www.jaist.ac.jp [150.65.5.208]
over a maximum of 30 hops:

  1    1 ms    <1 ms    <1 ms  192.168.1.1
  2   15 ms    14 ms    13 ms  210.245.0.42
  3   13 ms    13 ms    13 ms  210.245.0.97
  4   14 ms    13 ms    14 ms  210.245.1.1
  5  207 ms   230 ms    94 ms  pos8-2.br01.hkg04.pccwbtn.net [63.218.115.45]
  6    *      403 ms   393 ms  0.so-0-1-0.XT1.SCL2.ALTER.NET [152.63.57.50]
  7  338 ms   393 ms   370 ms  0.so-7-0-0.XL1.SJC1.ALTER.NET [152.63.55.106]
  8  402 ms   404 ms   329 ms  POS1-0.XR1.SJC1.ALTER.NET [152.63.55.113]
  9  272 ms   288 ms   310 ms  193.ATM7-0.GW3.SJC1.ALTER.NET [152.63.49.29]
 10   205 ms   206 ms   204 ms  wide-mae-gw.customer.alter.net [157.130.206.42]
 11   427 ms   403 ms   370 ms  ve-13.foundry2.otemachi.wide.ad.jp [192.50.36.62]
 12   395 ms   399 ms   417 ms  ve-4.foundry3.nezu.wide.ad.jp [203.178.138.244]
 13   355 ms   356 ms   378 ms  ve-3705.cisco2.komatsu.wide.ad.jp [203.178.136.193]
 14   388 ms   398 ms   414 ms  c76.jaist.ac.jp [203.178.138.174]
 15   438 ms   377 ms   435 ms  www.jaist.ac.jp [150.65.5.208]

Trace complete.
```