Network Layer (1): Network Layer and IPv4 Protocol

Required reading:
Kurose 4.3

EECS 3214, Winter 2020
Instructor: N. Vlajic

1. **Introduction**
2. Network Layer Protocols in the Internet
   - 2.1 IPv4
   - 2.2 IPv4 Addressing and Subnetting
   - 2.3 IPv6
   - 2.4 ARP
   - 2.5 ICMP
3. Routing Algorithms
4. Routing in the Internet

Introduction

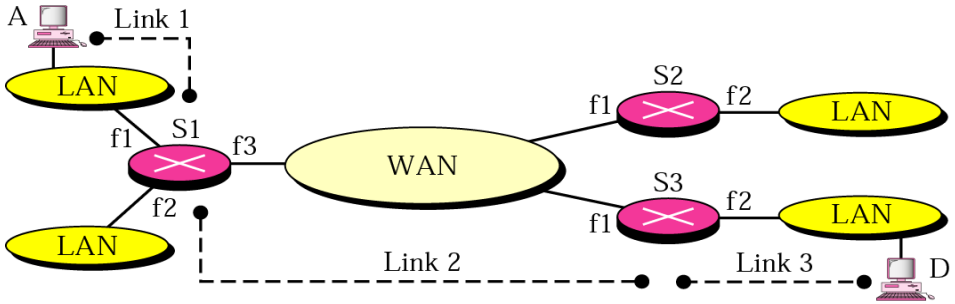
Network Layer – supervises host-to-host packet delivery – hosts could be separated by several physical networks

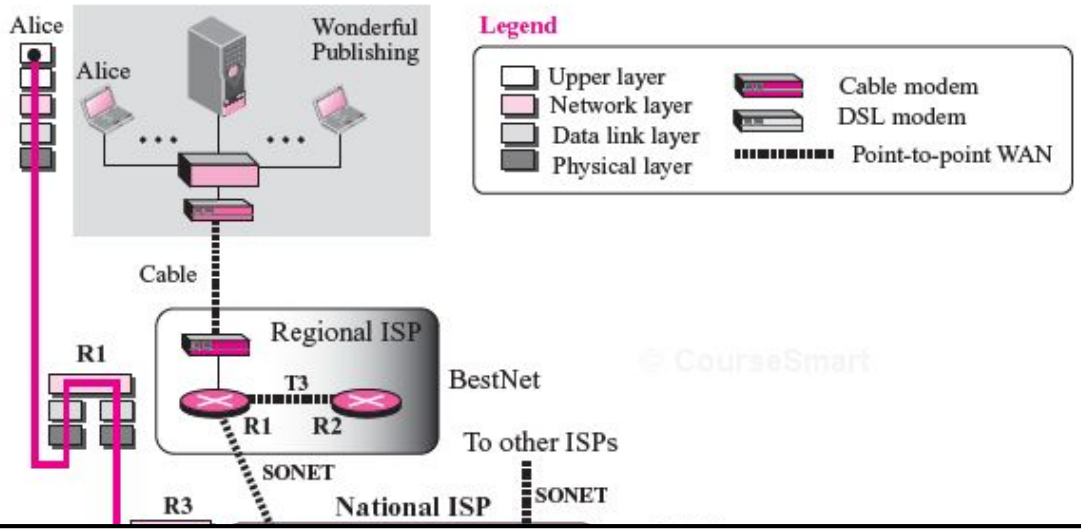
- data-link layer provides node-to-node delivery, transport layer provides process-to-process delivery

Major (Specific) Network Layer Duties

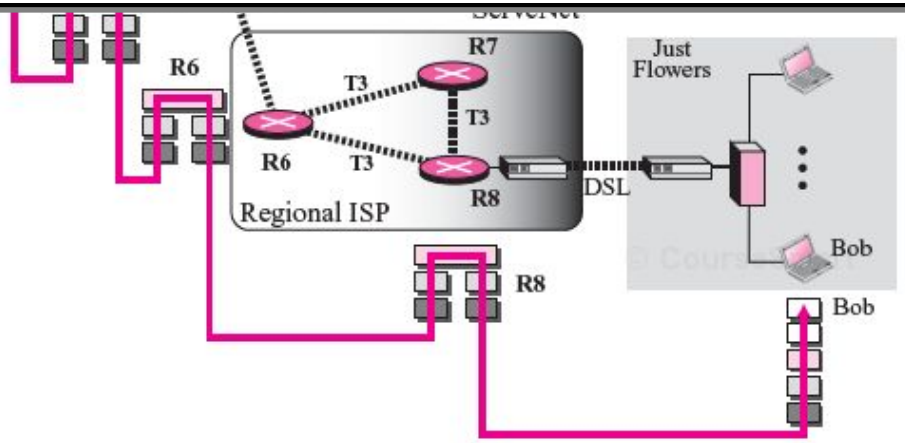
- **addressing**: identify each device uniquely to allow global communication
- **packetizing**: encapsulate packets received from upper-layer protocols
- **routing**: determine the optimal route for sending a packet from one host to another
- **fragmenting**: decapsulate packets from one and encapsulate them for another network

performed on packet-to-packet basis





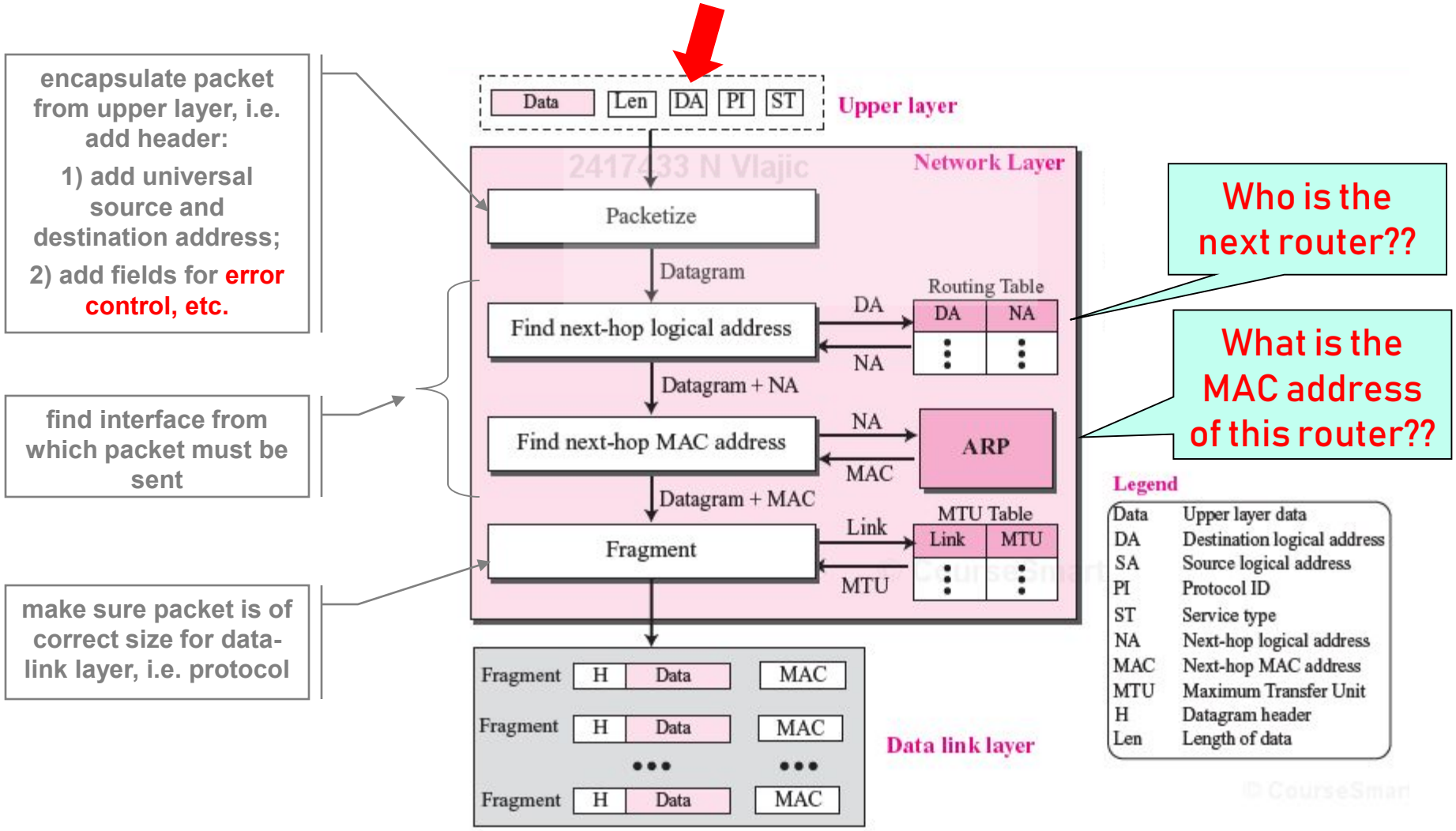
Do all network-layer modules perform exactly the same set of functions at all involved machines?!



From "TCP/IP Protocol Suite" by B. Forouzan, 4/e, pp. 104

Introduction (cont.)

Example [network layer duties in the Internet, at the **SOURCE**]



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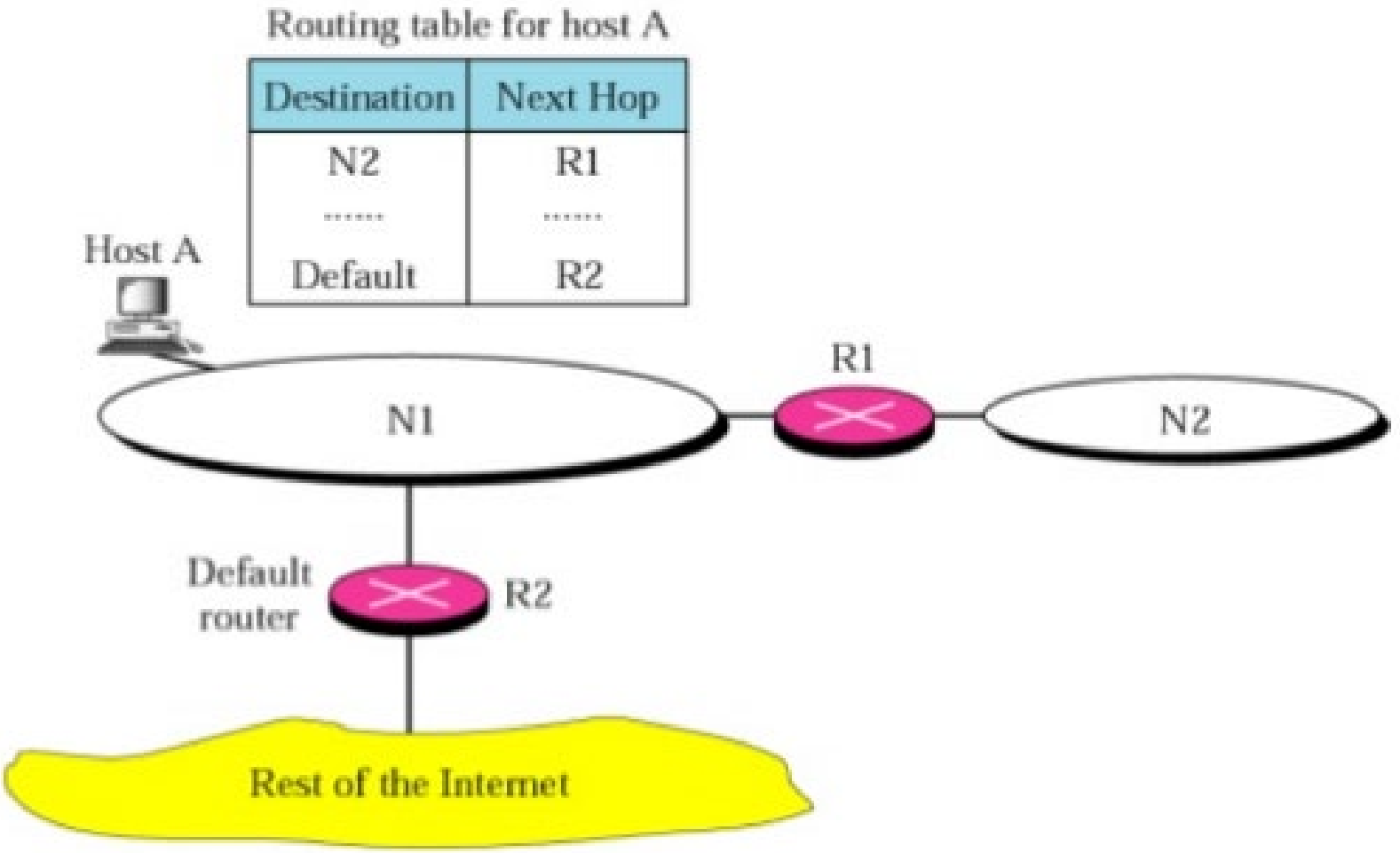
Introduction (cont.)

Example [network layer duties in the Internet, at the SOURCE cont.]



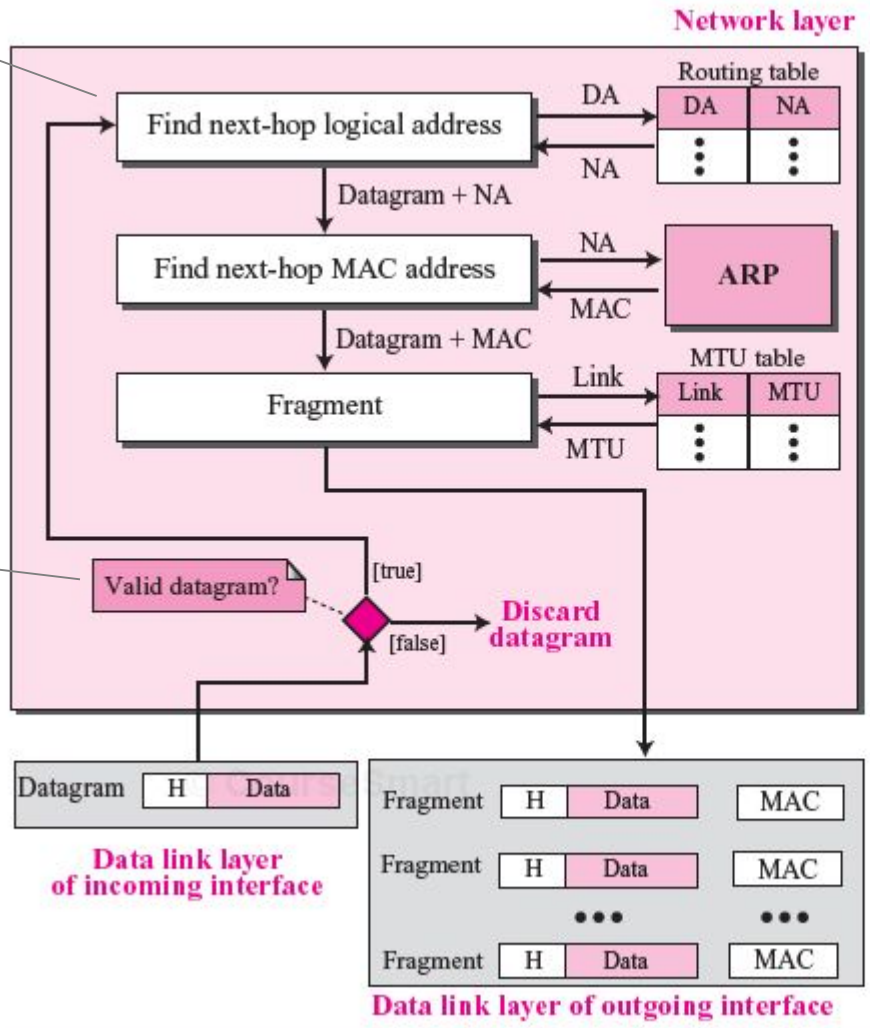
Introduction (cont.)

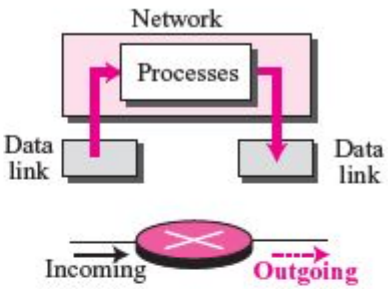
Example cont. [network layer duties in the Internet, at a ROUTER]

find interface from which packet must be sent

1) check if packet has reached its final destination or needs to be forwarded (TTL!)

2) header error checking !!!





Legend

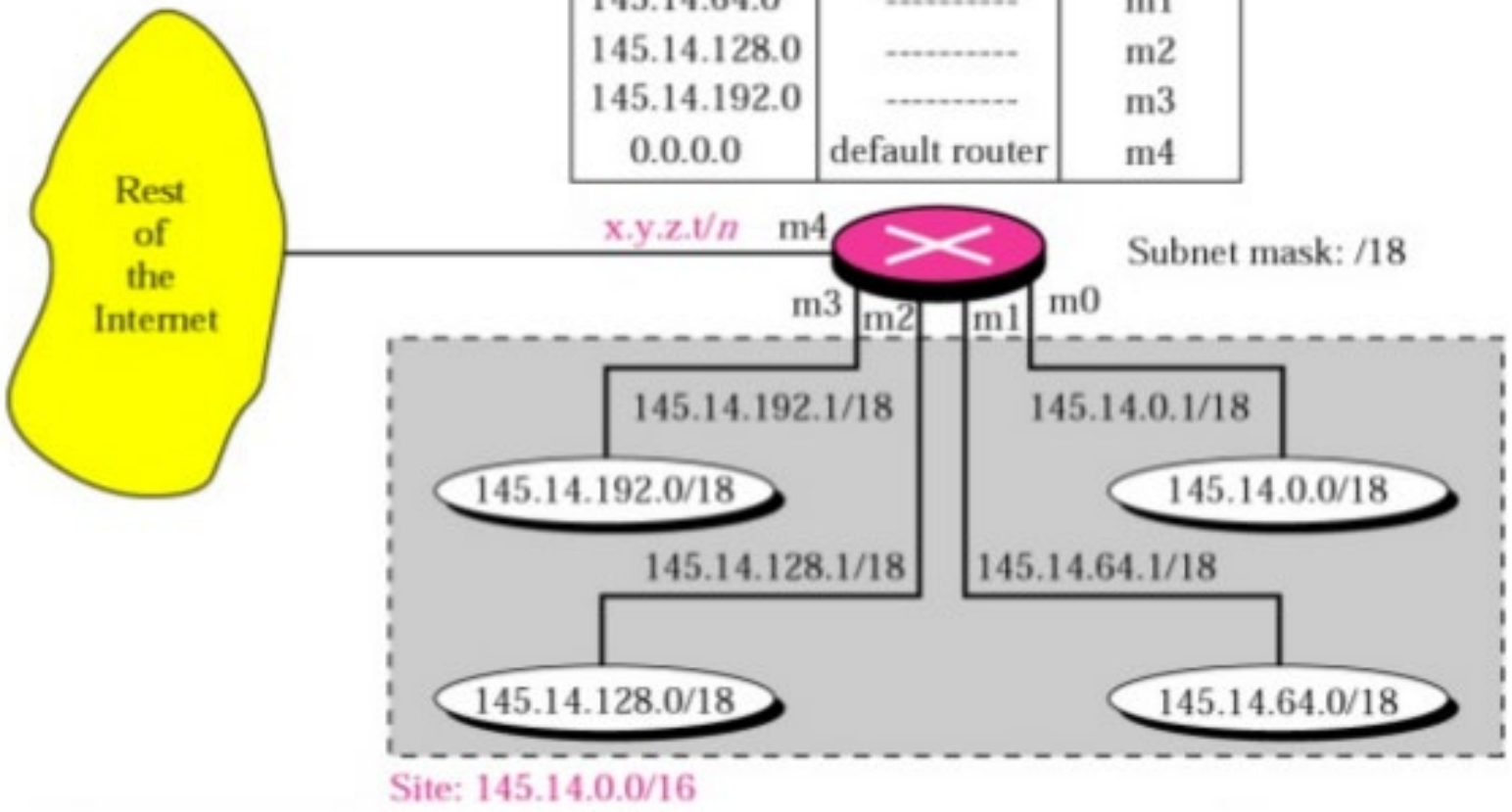
Data	Upper layer data
DA	Destination logical address
NA	Next-hop logical address
MAC	Next-hop MAC address
MTU	Maximum Transfer Unit
H	Datagram header

From "TCP/IP Protocol Suite" by B. Forouzan, 4/e, pp. 107

Introduction (cont.)

Example cont. [network layer duties in the Internet, at a ROUTER cont.]

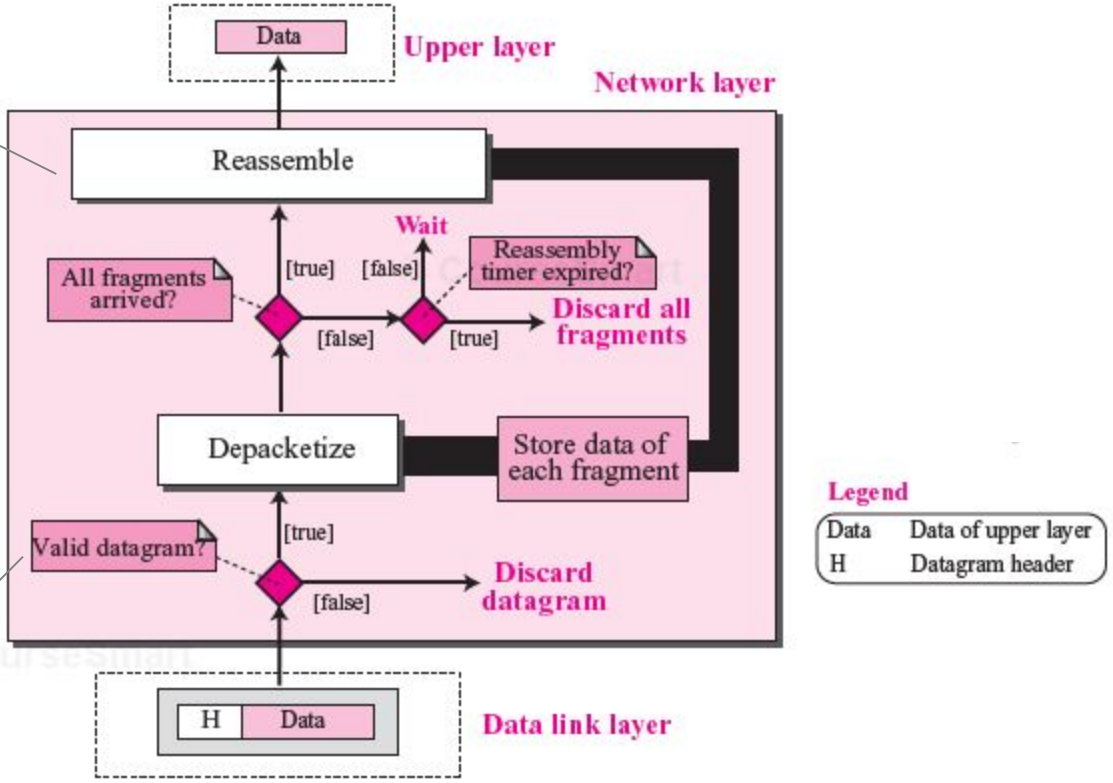
Subnet address	Next-hop address	Interface number
145.14.0.0	----------	m0
145.14.64.0	----------	m1
145.14.128.0	----------	m2
145.14.192.0	----------	m3
0.0.0.0	default router	m4



Introduction (cont.)

Example cont. **[network layer duties in the Internet, at the DESTINATION]**

if packet has been fragmented, wait until all fragments have arrived, reassemble them, and then deliver the reassembled packet to transport layer



1) verify whether destination address is host address

2) check if packet has been corrupted during transmission

From "TCP/IP Protocol Suite" by B. Forouzan, 4/e, pp. 108

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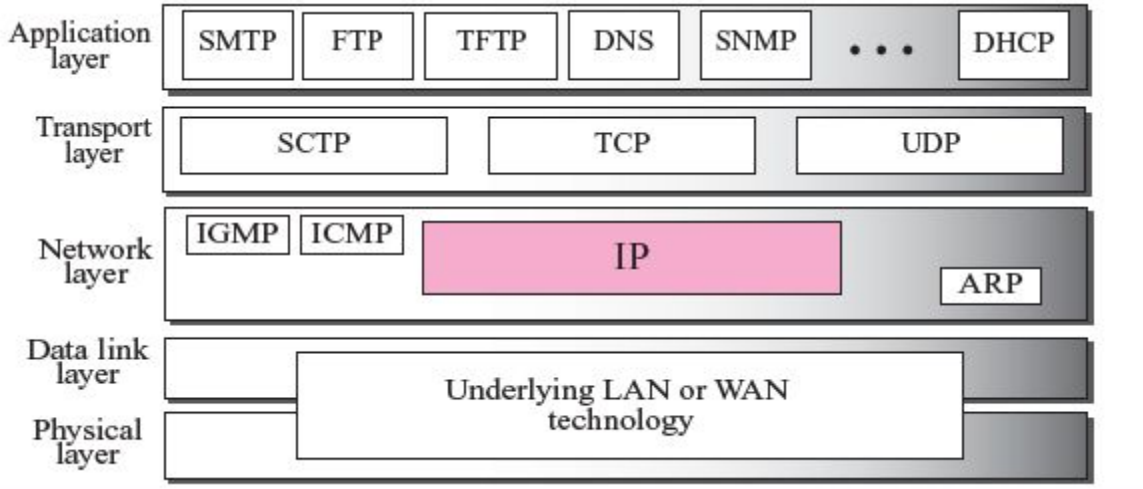
Internet Network Layer Protocols

Network Layer Protocols in the Internet

- **IP** – main protocol, responsible for 'best effort' host-to-host delivery
- **ARP** – maps IP address of next hop to its MAC/physical address (used when passing packets to lower data-link layer)
- **ICMP** – used by hosts and routers to handle unusual situations such as IP packet-header errors, unreachable hosts and networks, etc.
- **IGMP** – used by host and routers to achieve efficient network-layer multicasting
- **Routing Protocols** – responsible for routing table maintenance



From "TCP/IP Protocol Suite" by B. Forouzan, 4/e, pp. 187

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IP Protocol

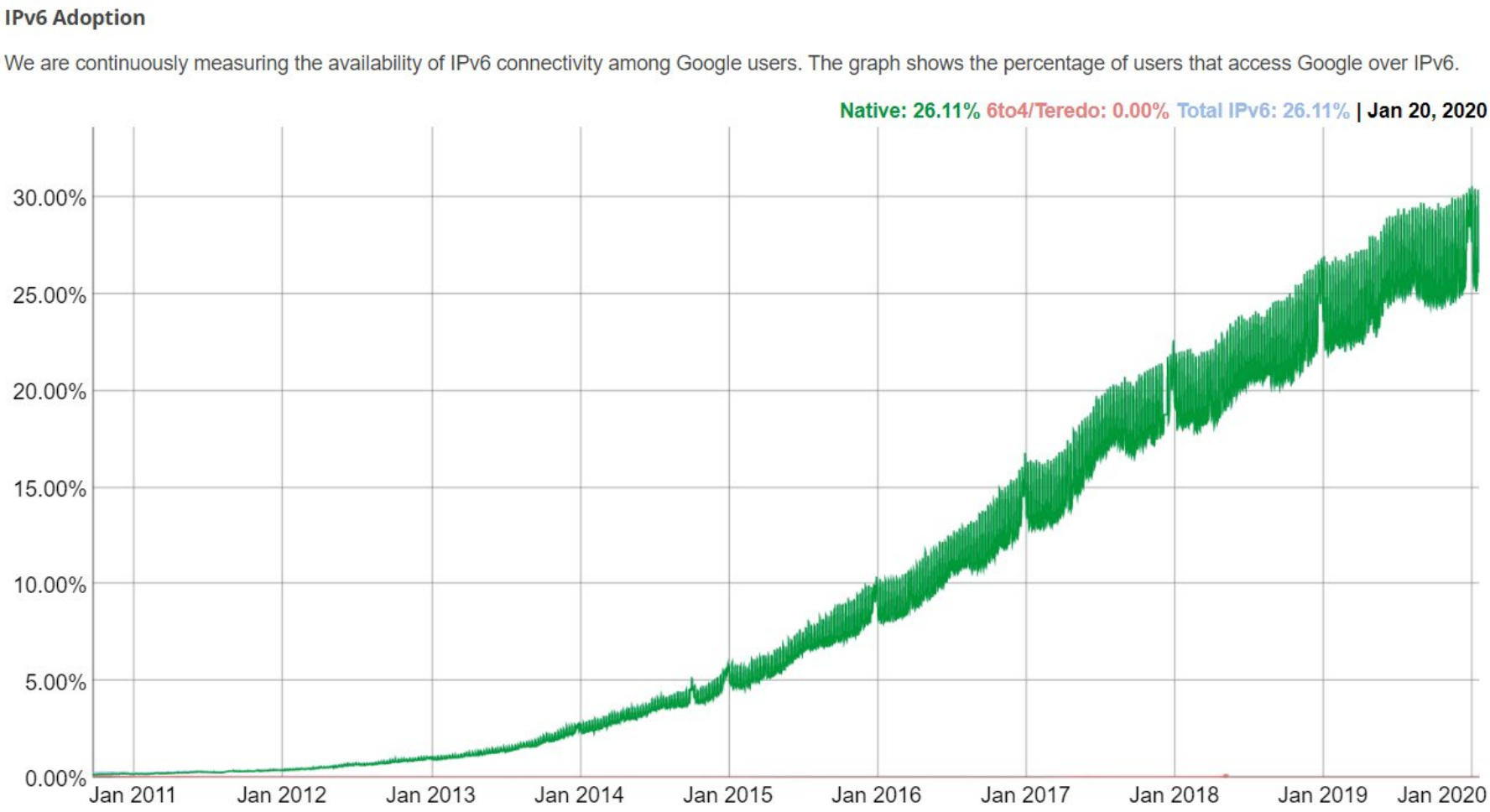
Internet Protocol (IP) – host-to-host network-layer delivery protocol for the Internet with following properties

- **connectionless service**
  each packet is handled independently
- **best-effort delivery service**
  1) does its best to deliver packet to its destination, but with no guarantees
  2) limited error control – only error detection, corrupted packets are discarded
  3) no flow control
- **must be paired with a reliable transport- (TCP) and/or application- layer protocol to ensure reliability**

IP Protocol Versions

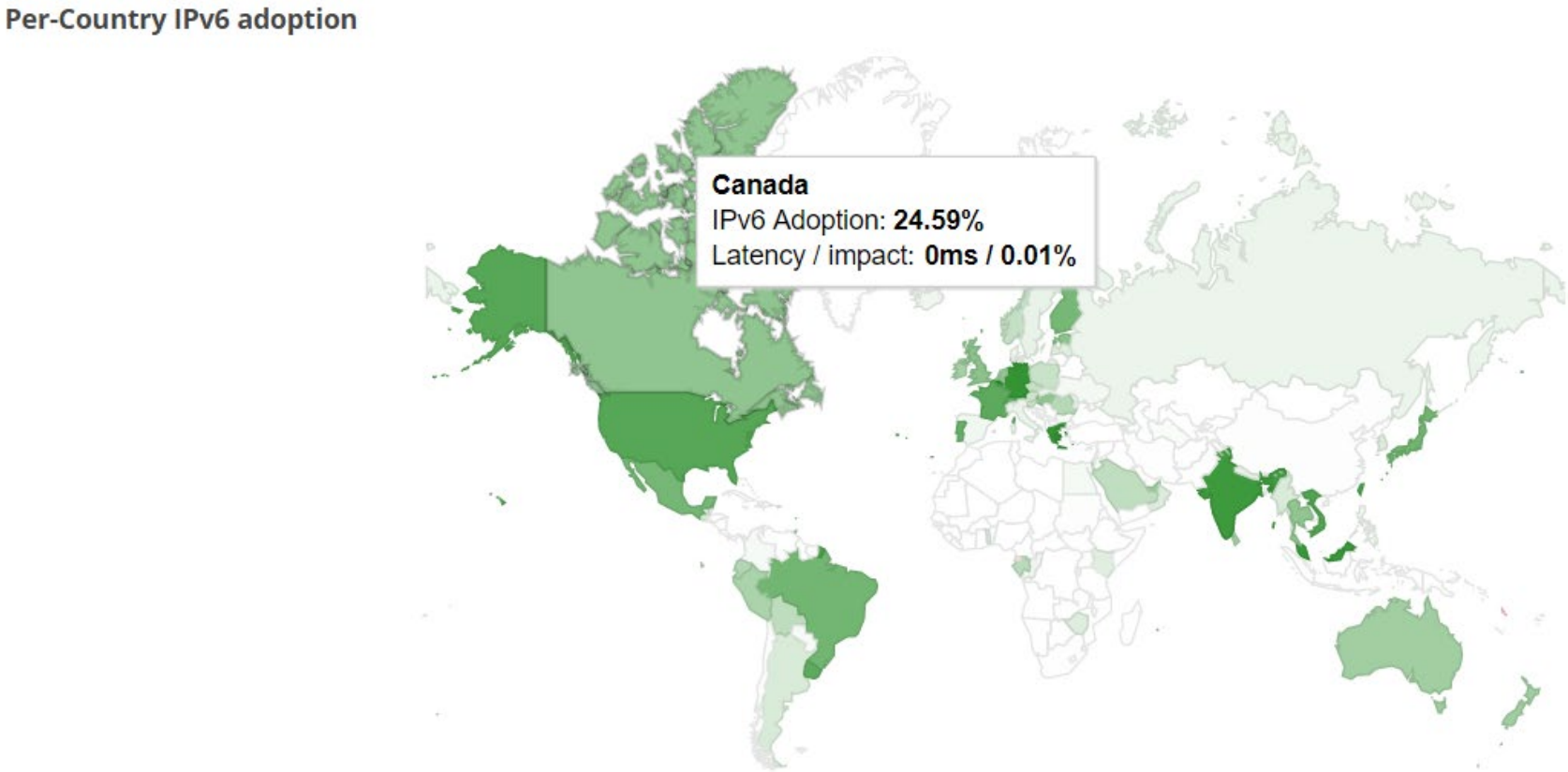
- **IPv4** – version currently in wide use (formalized in 1981)
- **IPv6** – latest version of IP protocol created to correct some of significant problems of IPv4 such as exhaustion of address space (formalized in 1996)

IPv6 Adoption (cont.)



https://www.google.ca/intl/en/ipv6/statistics.html#tab=ipv6-adoption&tab=ipv6-adoption

IPv6 Adoption

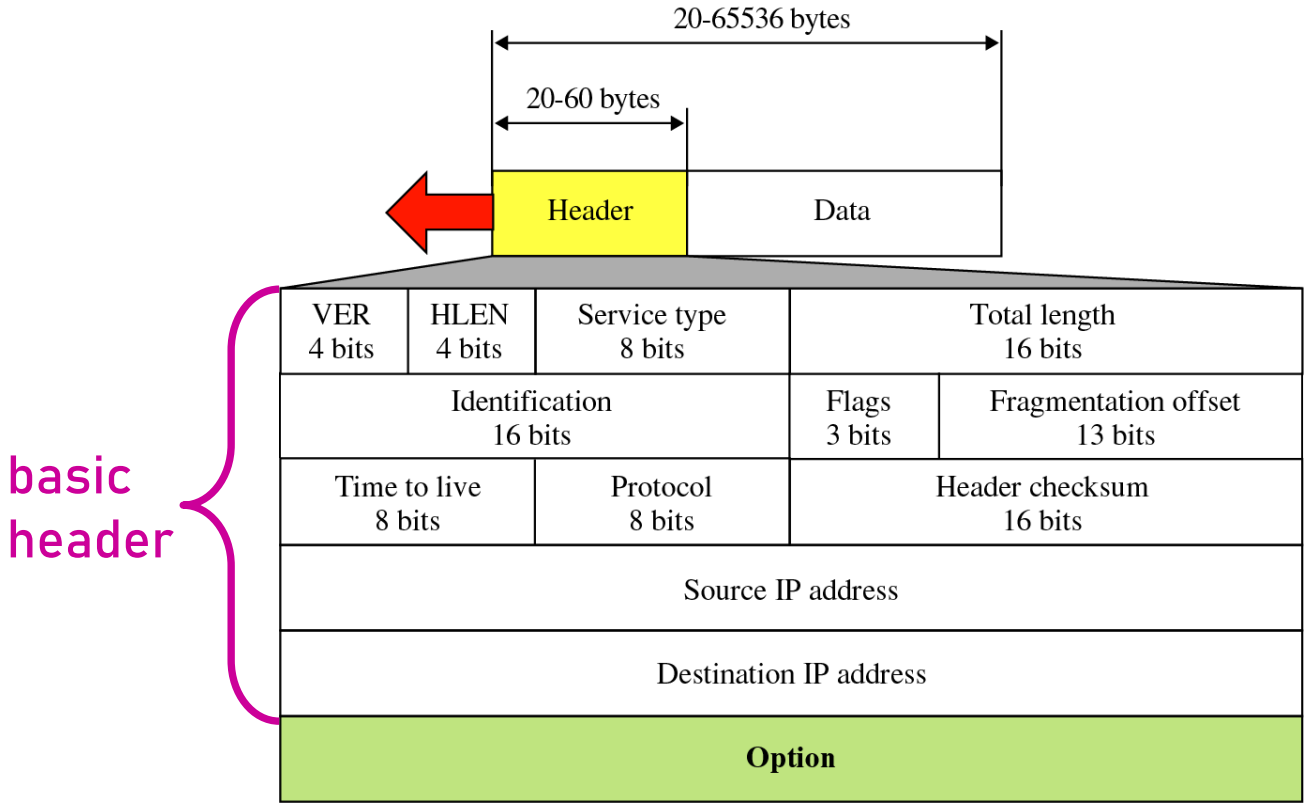


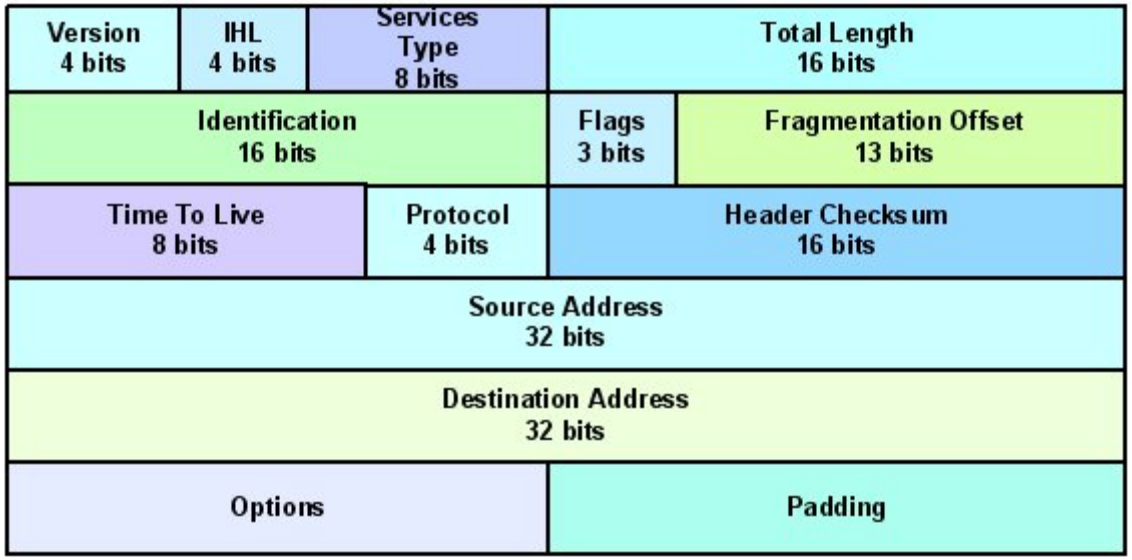
https://www.google.ca/intl/en/ipv6/statistics.html#tab=ipv6-adoption&tab=ipv6-adoption

IP Datagram Fields

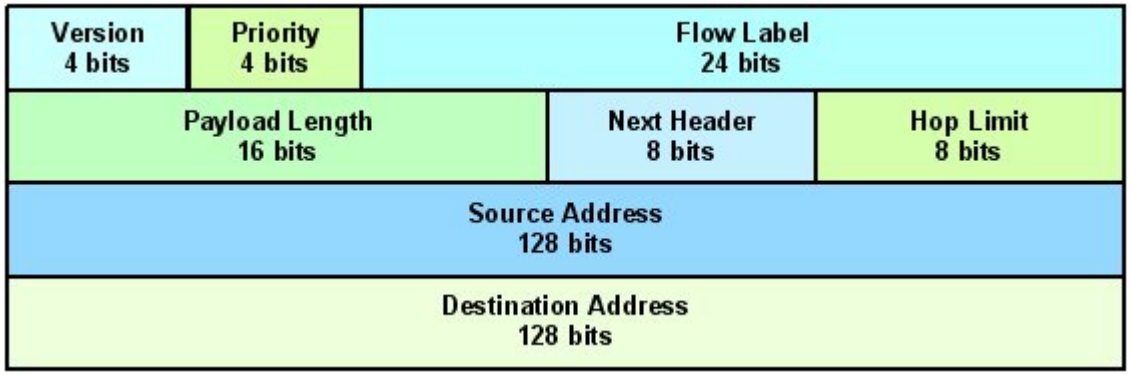
Datagram – **IP packet** = **variable length** packet consisting of **header** and **data**

- **header – 20 to 60 bytes in length, contains information essential to routing and delivery**
- **data – length determined by Maximum Transmission Unit (MTU) of link layer protocol** (theoretically between 0 to (65536-20) bytes)





IPv4 packet



IPv6 packet

IP Datagram Fields (cont.)

Version Number – 4-bit field – specifies IP protocol version of the datagram (IPv4 or IPv6)

- different version of IP use different datagram formats
- by looking at version number router can determine how to interpret remainder of datagram

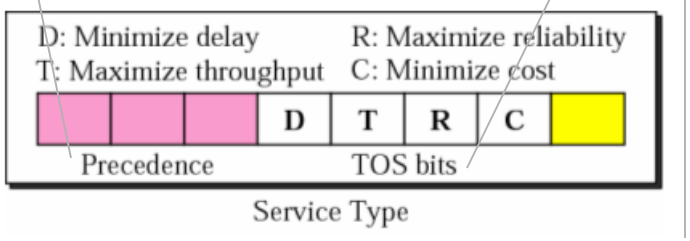
Header Length – 4-bit field – defines total length of datagram header in 4-byte words

- when there are no options header length is 20 ⇒ HLEN = 5

Differentiated Service (formerly Service Type) – 8-bit field – allows different types of datagrams to be distinguished from each other based on their associated / requested QoS

- e.g. datagrams particularly requiring low delay, high throughput, or reliability

Precedence defines the priority of datagram in case of congestion. If a router is congested and needs to discard some datagrams, those datagrams with lowest precedence are discarded first. **Network management datagrams have the highest precedence!**

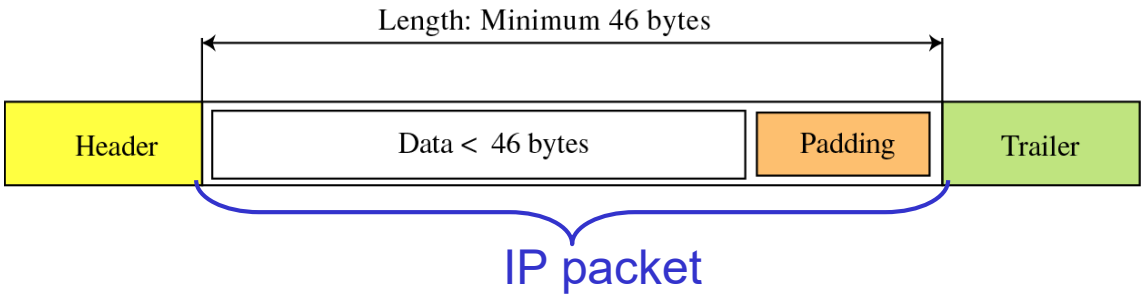


Although each TOS bit has a special meaning, only one bit can be set to 1 in each datagram.
0000 – normal type of service
0001 – minimize cost
0010 – maximize reliability
0100 – maximize throughput
1000 – minimize delay

IP Datagram Fields (cont.)

Total Length – 16-bit field – defines total datagram length in bytes, including header

- 16 bits ⇒ maximum size = 65,535 bytes
- some physical networks are not able to encapsulate a datagram of 65,535 bytes, so datagram must be fragmented to be able to pass through those networks
- some physical networks have restriction on minimum size of data that can be encapsulated in a frame, so datagram must be padded (e.g. Ethernet min size of data – 46 bytes)



Identifier, Flags, Fragmentation Offset – 3 fields used in fragmentation

- IPv6 does not allow fragmentation at routers since it is time consuming operation – if an IPv6 packet is too big, it is simply dropped and an ICMP message is sent back to the source