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Network Layer 4

ELEC3227/ELEC6255

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Source: ThinkStock

Overview

- Packet Fragmentation
- Networking and IP addresses in the internet
- IPv4/IPv6
- Internet Control Protocols

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How Networks Differ

- The network layer (IP) handles potentially substantial differences between underlying data links. These differences are not apparent to higher layers – this is part of the network layer's service to the transport layer.
- Differences can be large; complicates internetworking

Item	Some Possibilities
Service offered	Connectionless versus connection oriented
Addressing	Different sizes, flat or hierarchical
Broadcasting	Present or absent (also multicast)
Packet size	Every network has its own maximum
Ordering	Ordered and unordered delivery
Quality of service	Present or absent; many different kinds
Reliability	Different levels of loss
Security	Privacy rules, encryption, etc.
Parameters	Different timeouts, flow specifications, etc.
Accounting	By connect time, packet, byte, or not at all

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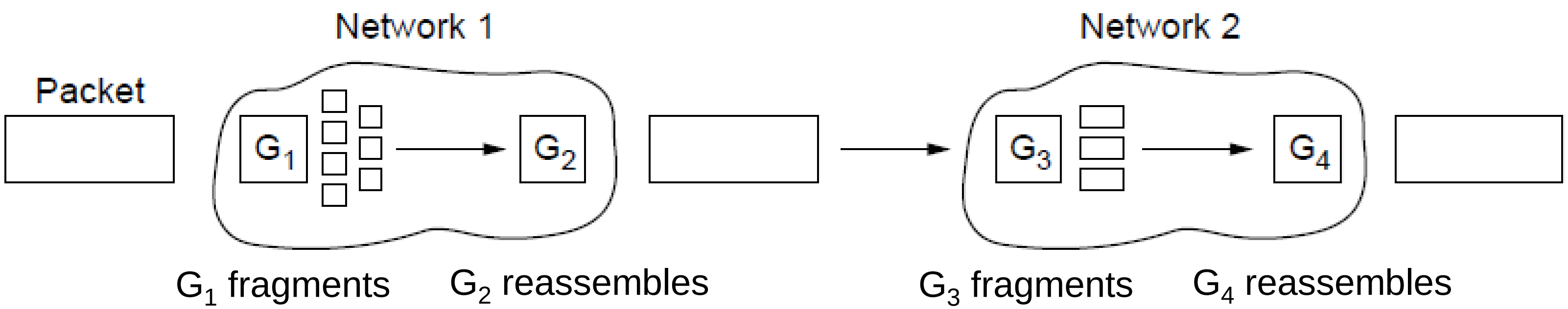
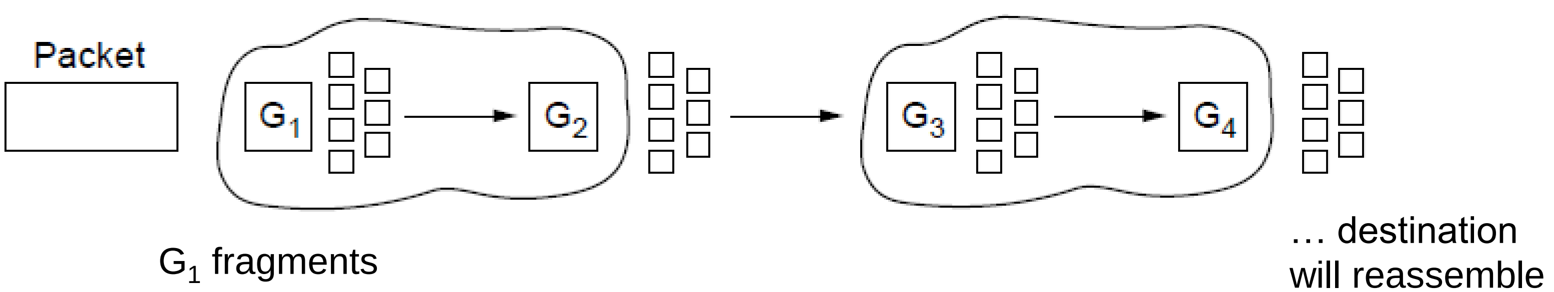
Packet Fragmentation

- Links have different packet size limits for many reasons
  - Large packets sent with fragmentation & reassembly



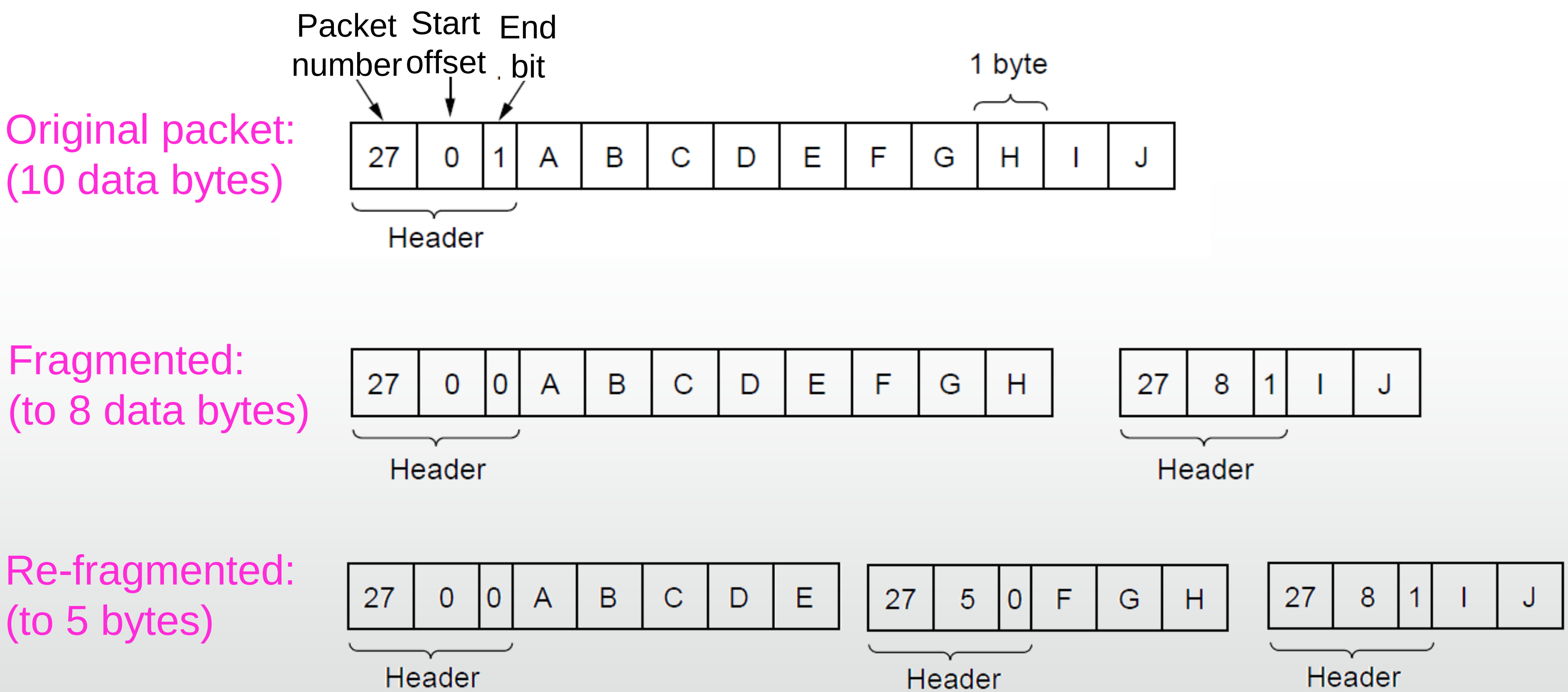
Transparent – packets fragmented / reassembled in each network



Non-transparent – fragments are reassembled at destination

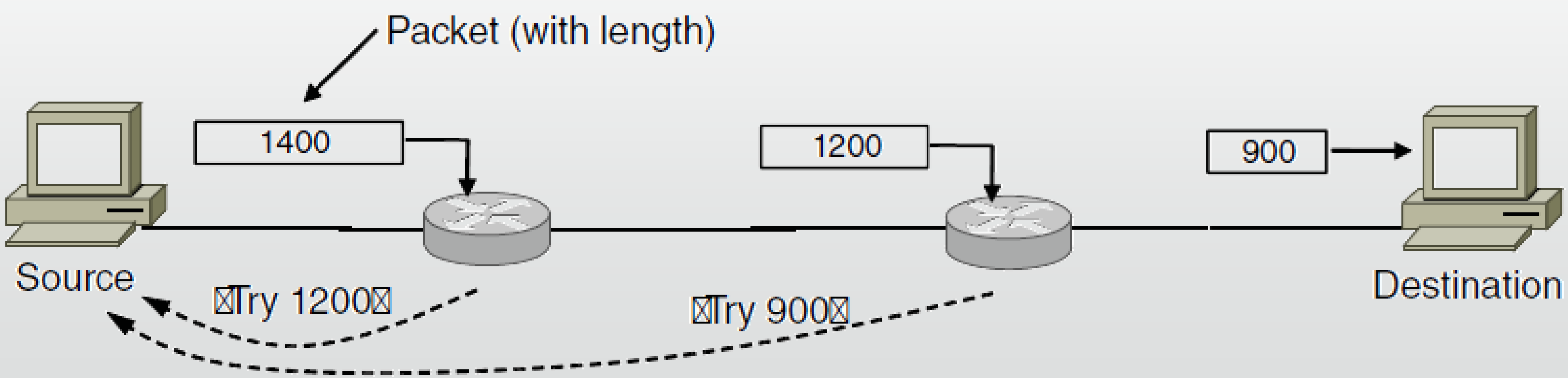
Packet Fragmentation

- Example of IP-style fragmentation (non-transparent):



Packet Fragmentation

- Fragmentation can affect performance: header overheads for fragmented packets, and whole packet lost if any fragments lost
- Packets not fragmented in IPv6 (but can be in IPv4)
- In IPv6, packets dropped if larger than MTU (Maximum Transmission Unit), which is a function of the underlying links (routing path).
- Path MTU discovery is used to learn MTU for that path:
    1. Each packet sent with header bits set to "no fragmentation"
    2. If a router receives a packet that is too large for the link, it generates an error packet, sends it to the source, and drops the packet.

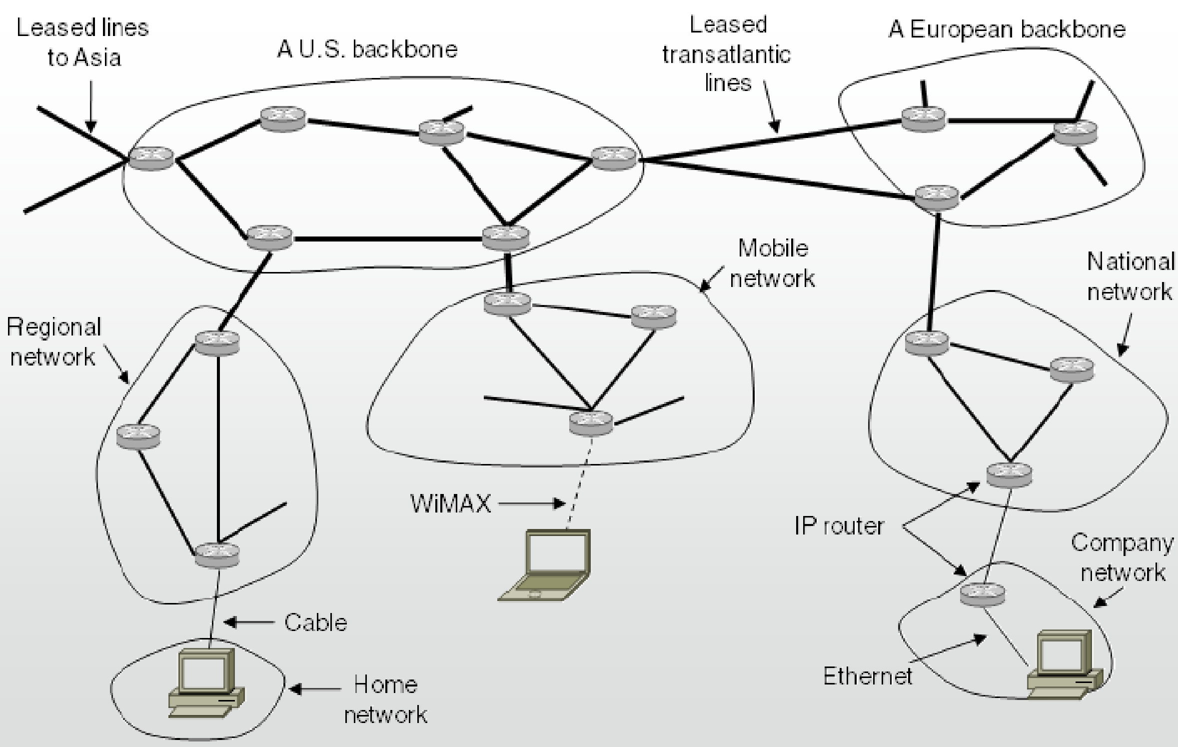


Network Layer in the Internet

- IP has been shaped by guiding principles:
  - Make sure it works
  - Keep it simple
  - Make clear choices
  - Exploit modularity
  - Expect heterogeneity
  - Avoid static options and parameters
  - Look for good design (not perfect)
  - Strict sending, tolerant receiving
  - Think about scalability
  - Consider performance and cost

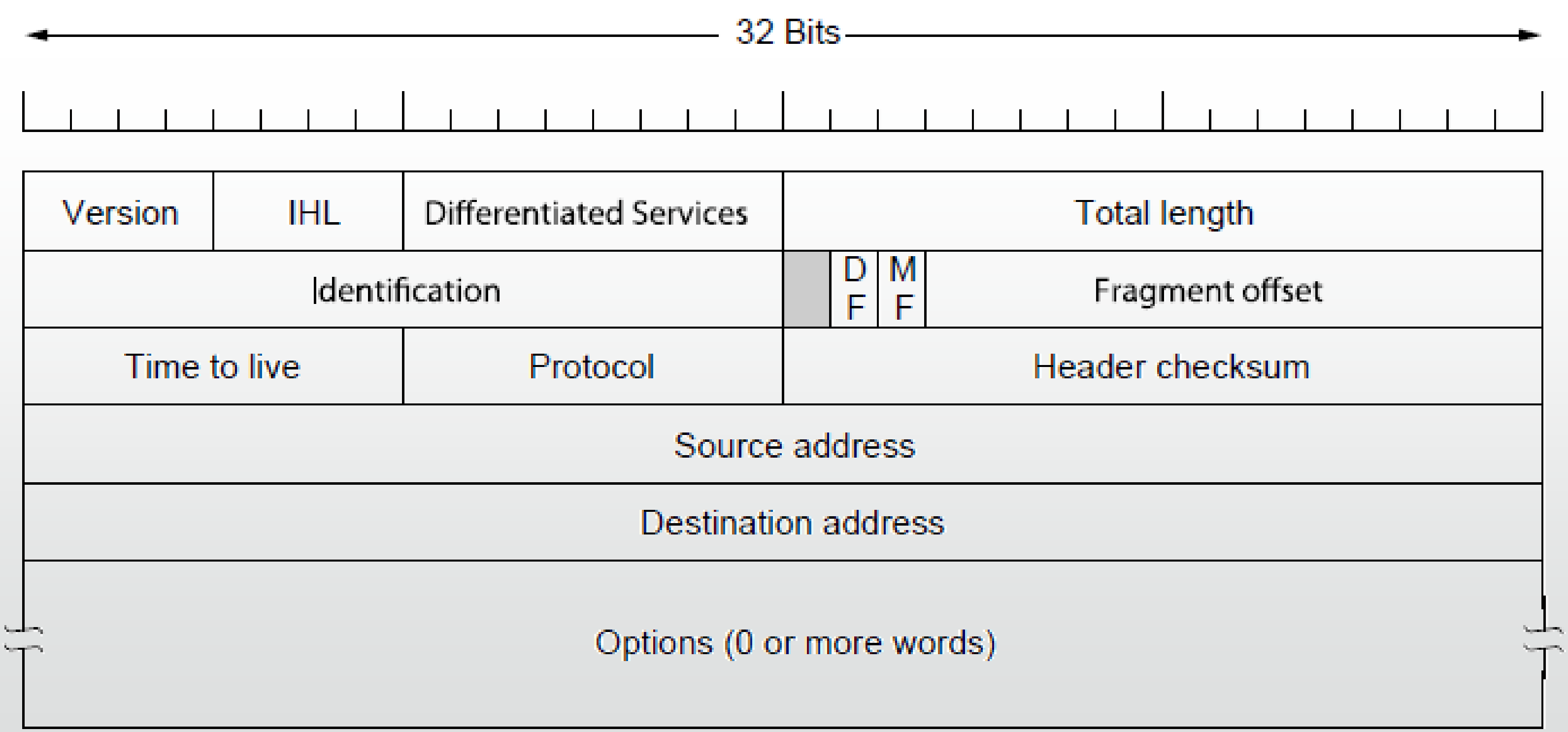
Network Layer in the Internet

- Internet is an interconnected collection of many networks that is held together by the IP protocol
- In the IETF participants often distinguish between 3 distinct ISP roles
  - Tier 1, Tier 2, Tier 3



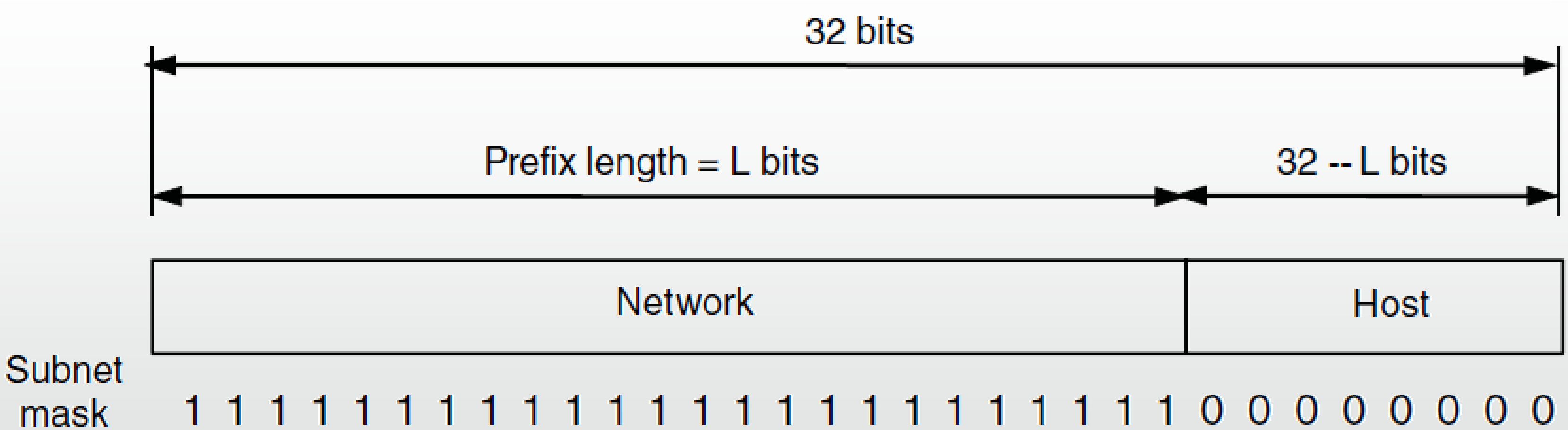
IPv4 Protocol

- IPv4 (Internet Protocol) header is carried on all packets and has fields for the key parts of the protocol:
- Transmission must be big endian (left to right, high order bit first)



IP Addresses - Prefixes

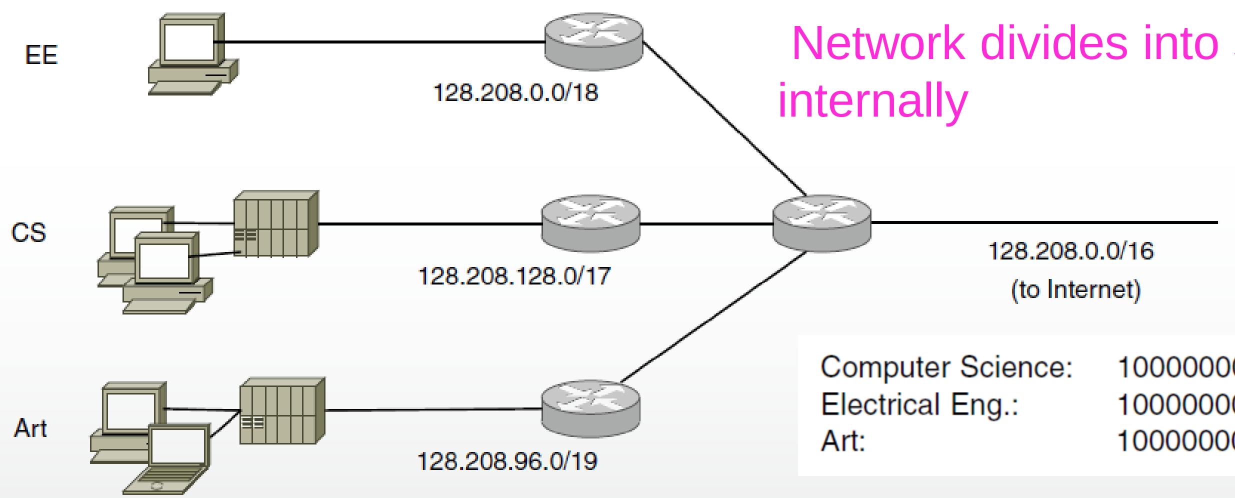
- Addresses are allocated in blocks called <u>prefixes</u>
  - Prefix is the network portion (routing topology locator)
  - Host – identifies a specific network interface within that subnetwork
  - Written: address/length (of prefix), e.g., 18.0.31.0/24



Subnetwork mask for this example is 255.255.255.0

IP Addresses - Subnets

- Subnetting splits up IP prefix to help with management
  - Looks like a single prefix outside the network



Network divides into subnets internally

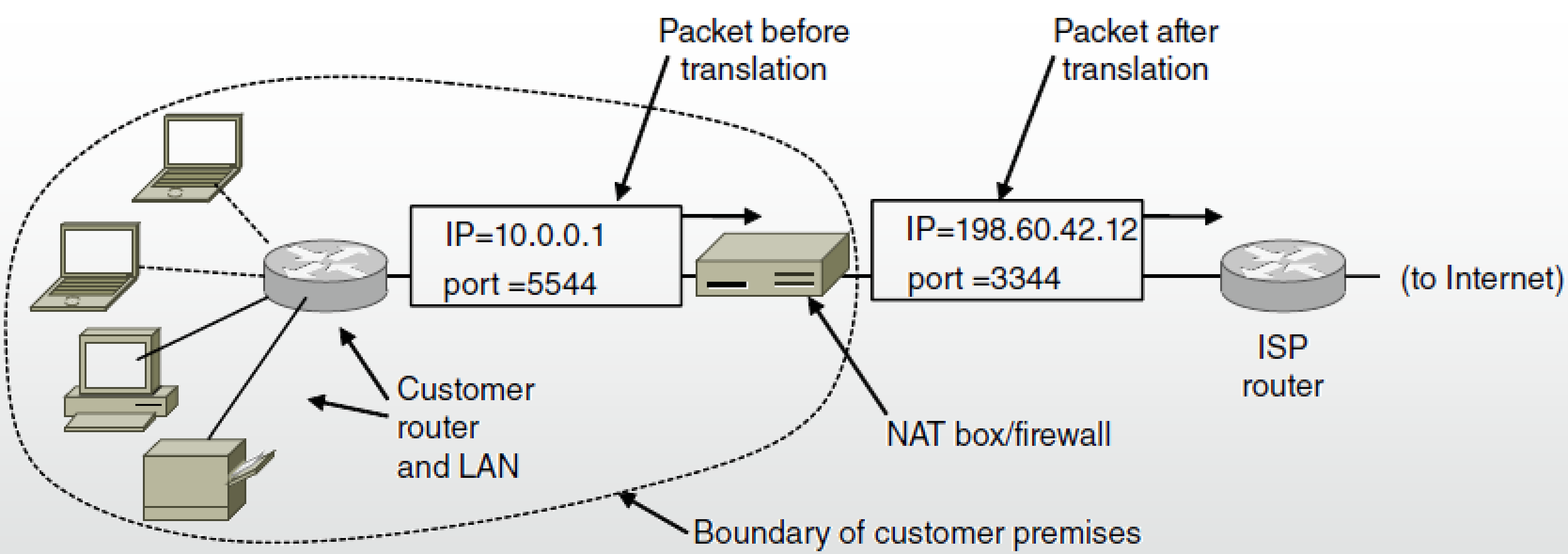
Computer Science:	10000000	11010000	1|xxxxxxx	xxxxxxxx
Electrical Eng.:	10000000	11010000	00|xxxxxx	xxxxxxxx
Art:	10000000	11010000	011|xxxxx	xxxxxxxx

- Small entities get their IP addresses from their ISP
  - Change ISP, then IP addresses also change
- Larger entities get their IP addresses from a registrar
  - Larger entities own their IP addresses

ISP gives network a single prefix

IP Addresses – NAT

- NAT (Network Address Translation) box maps one external IP address to many internal IP addresses
  - Uses TCP/UDP port to tell connections apart
  - Violates layering; very common in homes, etc.



IP version 6

- Major upgrade in the 1990s due to impending address exhaustion, with various other goals:
    - Support billions of hosts
    - Reduce routing table size
    - Simplify protocol
    - Better security
    - Attention to type of service
    - Aid multicasting
    - Roaming host without changing address
    - Allow future protocol evolution
    - Permit coexistence of old, new protocols, …
- Deployment was slow & painful, but picked up recently as address space became exhausted…

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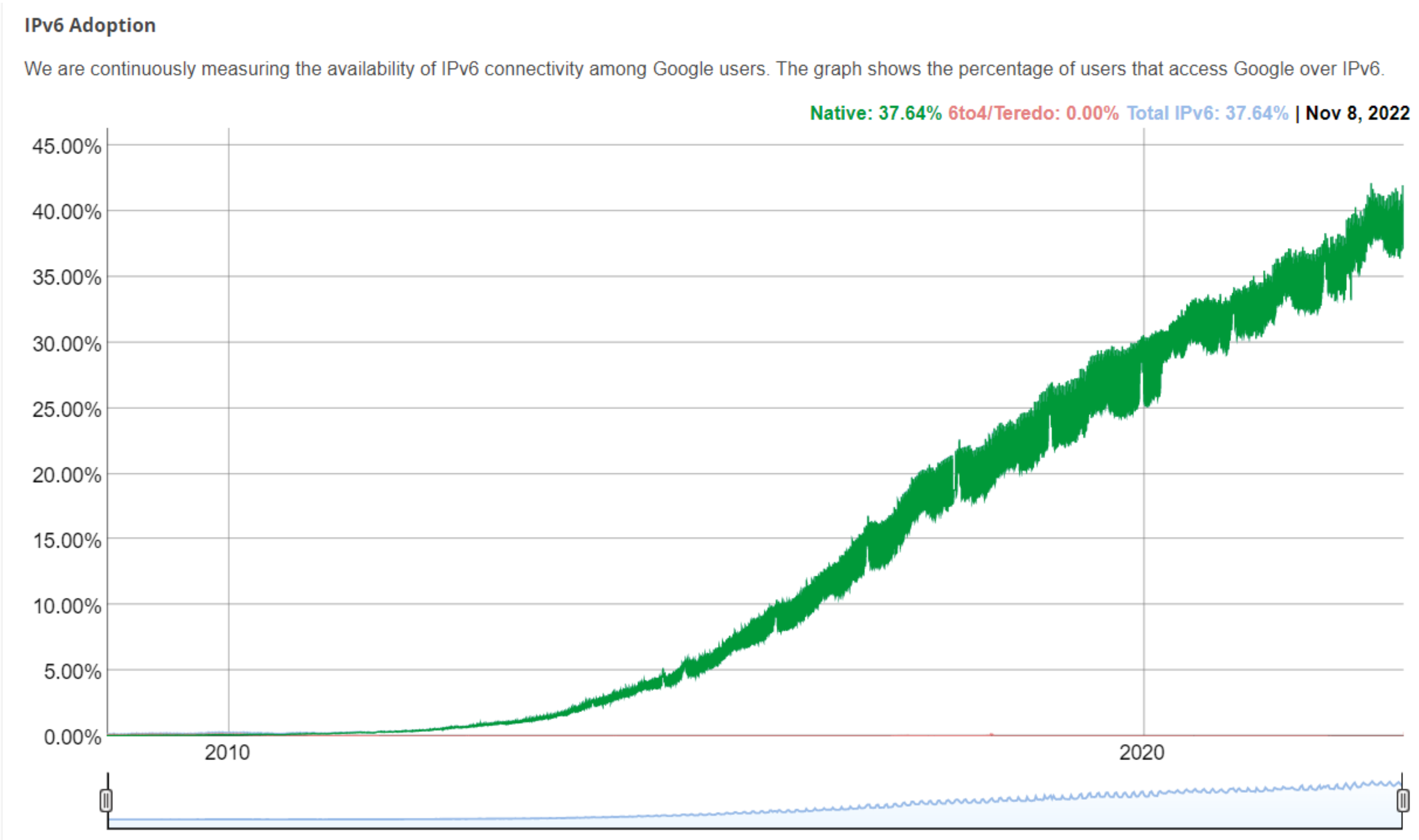
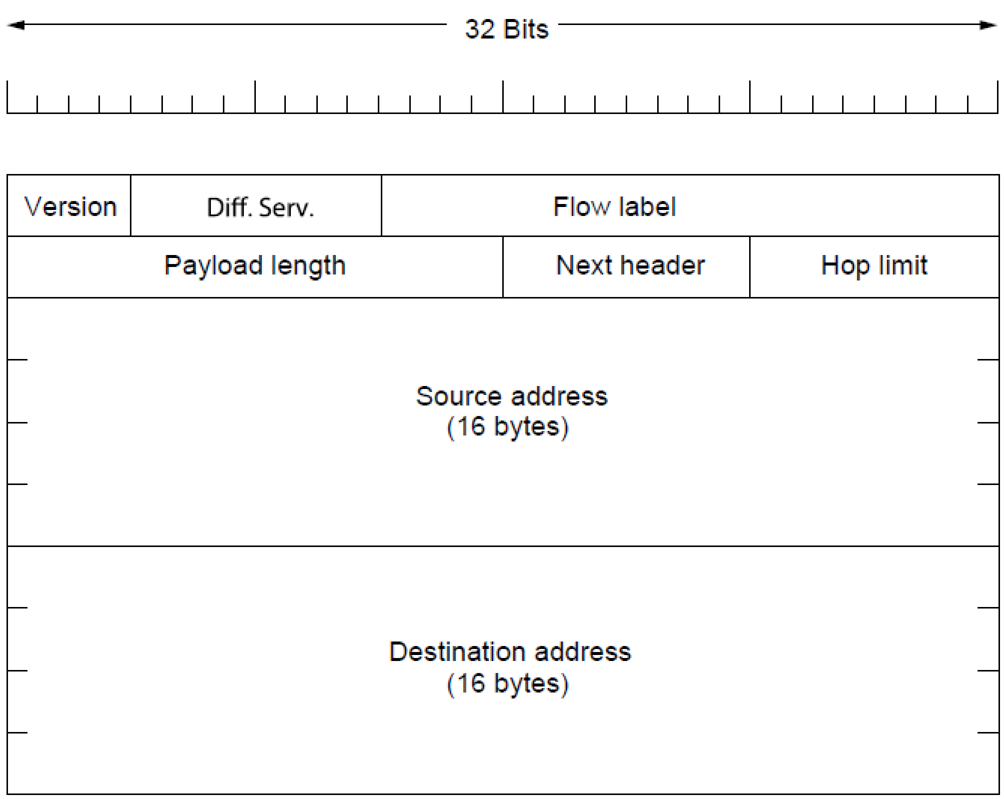
IPv6 Adoption



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

IPv6 Header

- IPv6 protocol header has much longer addresses (128 vs. 32 bits) and is simpler (by using extension headers)



IPv6 Header

- IPv6 Extension Headers can deliver other functionality

Extension header	Description
Hop-by-hop options	Miscellaneous information for routers
Destination options	Additional information for the destination
Routing	Loose list of routers to visit
Fragmentation	Management of datagram fragments
Authentication	Verification of the sender's identity
Encrypted security payload	Information about the encrypted contents

Internet Control Protocols

- IP works with the help of several control protocols:
  - **ICMP** is a companion to IP that returns error info
    - **Internet Control Message Protocol**
    - Required, and used in many ways, e.g., for traceroute, ping
  - **ARP** finds Ethernet address of a local IP address
    - **Address Resolution Protocol**
    - "Glue" that is needed to send any IP packets
    - Host queries an address and the owner replies
  - **DHCP** assigns a local IP address to a host
    - **Dynamic Host Configuration Protocol**
    - Gets host started by automatically configuring it
    - Host sends request to server, which grants a lease

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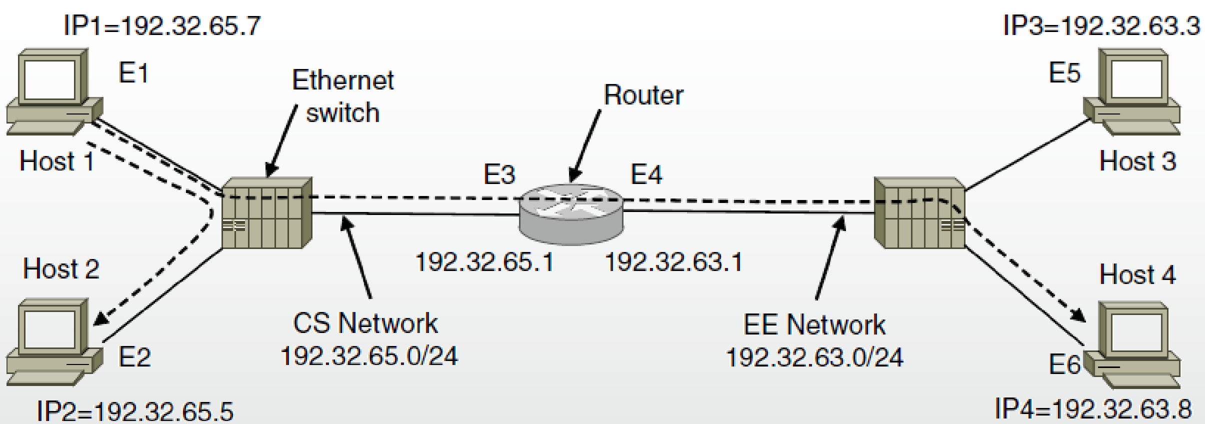
Internet Control Protocols

- ARP (Address Resolution Protocol) lets nodes find target Ethernet addresses [pink] from their IP addresses
    - Protocol to establish mapping between DL and Network addresses
    - MAC broadcast asking “who owns the destination IP address?”
    - Off-LAN traffic sent to the local router (i.e., default gateway) for forwarding



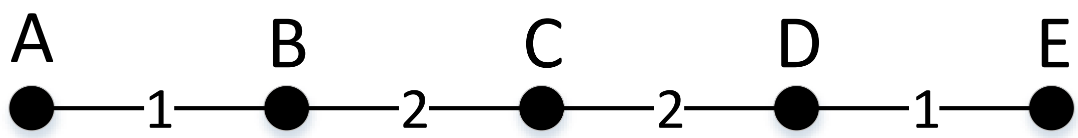
Frame	Source IP	Source Eth.	Destination IP	Destination Eth.
Host 1 to 2, on CS net	IP1	E1	IP2	E2
Host 1 to 4, on CS net	IP1	E1	IP4	E3
Host 1 to 4, on EE net	IP1	E4	IP4	E6

Summary

- Tunneling
- Packet Fragmentation
- Networking and IP addresses in the internet
- IPv4/IPv6
- Internet Control Protocols

Question 1

Distance Vector Routing



Question 2

In IP, the checksum covers only the header and not the data.

Why do you suppose this design was chosen?

Question 3

Your system is running fair queuing to control the transmission of packets from several queues. Assume that all queues have an equal weight. The data arrives with the parameters shown in Table 1. Calculate the finish virtual time of each packet, and state the order in which the packets will be outputted.

Queue	Packet	Arrival Time	Length		
A	A1	0	9		
A	A2	10	6		
A	A3	15	8		
B	B1	5	6		
B	B2	9	12		
B	B3	13	4		
C	C1	5	9		
C	C2	20	5		

Question 4

- You now switch to a weighted fair queuing system, with queue B given a weighting of 2. Calculate the new virtual finish time of each packet, and state the new order of packet output.

Queue	Packet	Arrival Time	Length	Finish Virtual T.	Order
A	A1	0	9	9	
A	A2	10	6	16	
A	A3	15	8	24	
B	B1	5	6		
B	B2	9	12		
B	B3	13	4		
C	C1	5	9	14	
C	C2	20	5	25	

Question 5

A token bucket scheme is used for traffic shaping. A new token is put into the bucket every 5 µsec.

Each token is good for one short packet, which contains 48 bytes of data.

What is the maximum sustainable data rate?

Question 6

A computer on a 6-Mbps network is regulated by a token bucket. The token bucket is filled at a rate of 1 Mbps. It is initially filled to capacity with 8 megabits.

How long can the computer transmit at the full 6 Mbps?

Question 7

Consider the user of differentiated services with expedited forwarding. Is there a guarantee that expedited packets experience a shorter delay than regular packets?

Why or why not?

Question 8

While IP addresses are tied to specific networks, Ethernet addresses are not.

Can you think of a good reason why they are not?

Question 9

Most IP datagram reassembly algorithms have a timer to avoid having a lost fragment tie up reassembly buffers forever.

Suppose that a datagram is fragmented into four fragments. The first three fragments arrive, but the last one is delayed.

Eventually, the timer goes off and the three fragments in the receiver's memory are discarded. A little later, the last fragment stumbles in. What should be done with it?

Question 10

A large number of consecutive IP addresses are available starting at 198.16.0.0.

Suppose that four organizations, A, B, C, and D, request 4000, 2000, 4000, and 8000 addresses, respectively, and in that order.

For each of these, give the first IP address assigned, the last IP address assigned, and the mask in the w.x.y.z/s notation.