CSC358H5: Principles of Computer Networking — Winter 2025

Worksheet 6: Internet Protocol (IP) Address, Prefix, and Forwarding

Q0 Knowledge Check (from Week 06 Lecture)

0.a (True/False) The IP protocol guarantees reliable data delivery.

Answer. False

0.b What happens when a router receives an IP packet with a destination IP address that is NOT in any of the IP prefixes in its routing table?

Answer. It drops the packet

0.c In the context of routers, compare the two concepts **"Routing"** and **"Forwarding"**. Explain the key differences – the context/layer(s) they are defined at, protocol(s) they are related to, when/where they are used, etc.

- **Routing:**
  - The context/layer(s) it is defined at: **Network layer**
  - The protocol(s) it is related to: **OSPF, RIP, BGP, EIGRP, IS-IS** (we will discuss these protocols later in the course)
  - When/where it is used/implemented: **Control plane of routers**
  - Is it implemented locally or distributedly? **Distributedly**
  - In at most 2-3 sentences, explain its purpose: **It is concerned about how to populate Forwarding Tables so that packet from any source could be successfully delivered to any destination. Routing happens before packets are forwarded and occurs periodically to keep routing tables updated.**
- **Forwarding:**
  - The context/layer(s) it is defined at: **Network layer**
  - The protocol(s) it is related to: **Not protocol-specific**
  - When/where it is used/implemented: **Data plane of routers**
  - Is it implemented locally or distributedly? **Locally**
  - In at most 2-3 sentences, explain its purpose: **Each router has a forwarding table. It is used for mapping destination addresses to an outgoing interfaces. Packet forwarding is concerned about how to use Forwarding Tables. Forwarding happens per-packet as packets arrive at the router.**

0.d (IP Prefix) The following is the list of IP prefix of Networks 1, 2, and 3.

Network 1: 131.21.0.0/16 **Network 2:** 131.22.0.0/16 **Network 3:** 133.22.12.0/24

Consider the following hosts with IP addresses:

Host A: 131.21.12.19 **Host B:** 133.21.12.19 **Host C:** 133.22.11.19 **Host D:** 131.21.21.21

To which network do the different hosts belong? Are there any hosts that do not belong to any of the above networks?

- **Host A:** ☑ Network 1 ☐ Network 2 ☐ Network 3 ☐ None
- **Host B:** ☐ Network 1 ☐ Network 2 ☐ Network 3 ☑ None
- **Host C:** ☐ Network 1 ☐ Network 2 ☐ Network 3 ☑ None
- **Host D:** ☑ Network 1 ☐ Network 2 ☐ Network 3 ☐ None

0.e (Routing Table and Maximum Prefix Matching) Consider the routing table given in Table 1. Where does it send packets destined to 128.96.39.10, 128.96.40.12, 128.96.40.151, 192.4.153.17, and 192.4.153.90?

- Packet with destination 128.96.39.10: **Interface 0**

Table 1: Routing Table

SubnetNumber	SubnetMask	NextHop
128.96.39.0	255.255.255.128	Interface 0
128.96.39.128	255.255.255.128	Interface 1
128.96.40.0	255.255.255.128	R2
192.4.153.0	255.255.255.192	R3
0.0.0.0 <default>	0.0.0.0	R4

- Packet with destination 128.96.40.12: **R2**
- Packet with destination 128.96.40.151: **R4**
- Packet with destination 192.4.153.17: **R3**
- Packet with destination 192.4.153.90: **R4**

0.f (IP Header) In lecture, we reviewed the list of tasks that packet headers are needed for:

A. Read packet correctly
B. Get the packet to the destination
C. Get responses to the packet back to source
D. Carry data
E. Tell host what to do with the packet once arrived
F. Specify any special network handling of the packet
G. Dealing with Header Corruption
H. Dealing with Loops
I. Dealing with Packets that are too large
J. Dealing with Payload Corruption

Consider the IPv4 headers shown in Figure 1. Each of these fields is devoted to a task. In Table 2, map between tasks listed above and the header fields. For your reference, we filled out the mapping for the first row in the table.

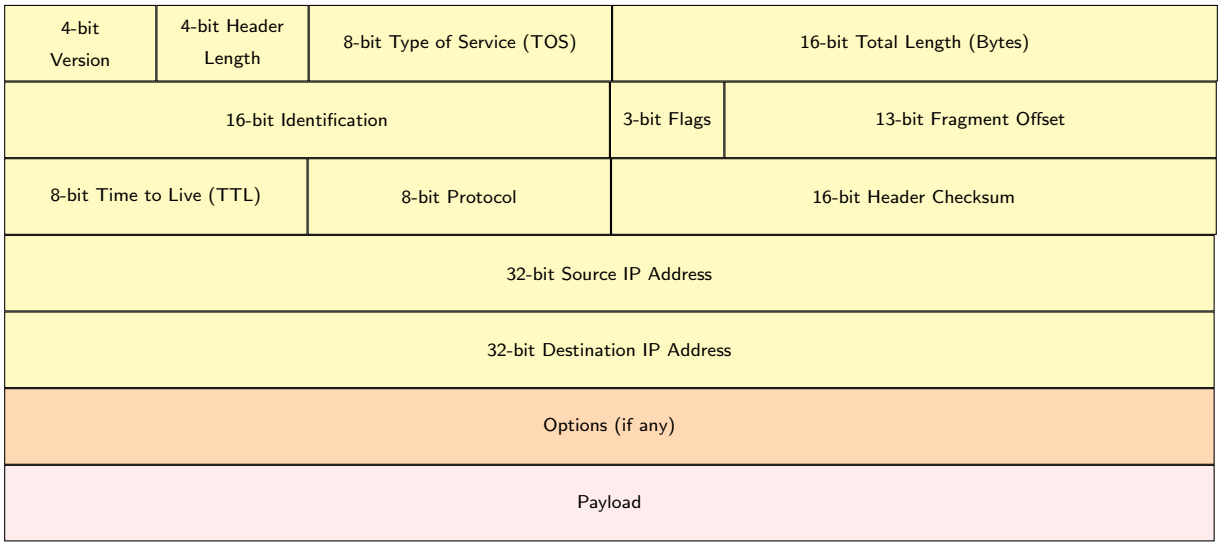


Figure 1: IPv4 headers.

Table 2: Map between tasks listed above and the header fields.

Field(s)	Task
Payload	D
TTL	**H**
Version number, Header length, and Total length	**A**
Destination IP address	**B**
Identification, Flags, Fragment Offset	**I**
Type-of-Service, Options	**F**
Source IP address	**C**
Protocol	**E**
Checksum	**G**

Q1 **(IP Fragmentation – Loss Probability)** Suppose an IP packet is fragmented into 10 fragments. Suppose that each fragments has (independent) loss probability of 1%.

1.a Find the probability of losing the whole packet. The whole packet is lost even if a single fragment is lost.

Answer. The whole packet is not lost only if all fragments are transmitted without loss. Thus,

$$\mathbb{P}[\text{successful transmission of a fragment}] = 1 - 0.01 = 0.99$$
$$\mathbb{P}[\text{successful transmission of all fragments}] = 0.99^{10} \approx 0.90$$
$$\mathbb{P}[\text{losing the whole packet}] = 1 - 0.99^{10} \approx 0.1$$

1.b Find the probability of net loss of the whole packet if the packet is transmitted twice,

1.b.i Assuming all fragments received must have been part of the same transmission?

Answer. From **1.a**, each transmission of the packet is lost with probability 0.1. The whole packet after two transmissions is lost only if both transmissions are failed. Therefore,

$$\mathbb{P}[\text{whole packet being lost after 2 transmission}] \approx 0.1 \times 0.1 = 0.01$$

1.b.ii Assuming any given fragment may have been part of either transmission?

Answer. The success probability is the probability of successfully transmitting at least one of the copies of each fragment. Probability of loss in transmission of one copy of a fragment is 0.01. Probability of losing both copies of a fragment is $0.01 \times 0.01 = 10^{-4}$. Probability of successfully transmitting at least one of the copies of each fragment is $(1 - 10^{-4})^{10} \approx 0.9990$. Probability of loss is approximately 0.001.

Q2 **(IP Fragmentation – MTU)** Suppose the following IP datagrams all pass through another router onto a link with a Maximum Transmission Unit (MTU) of 370 bytes.

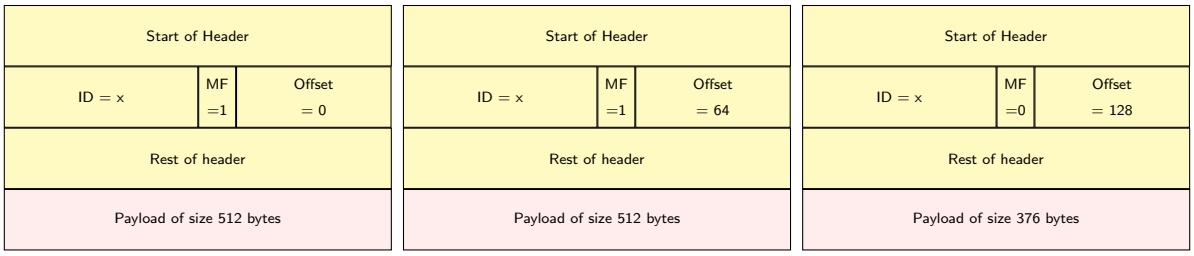
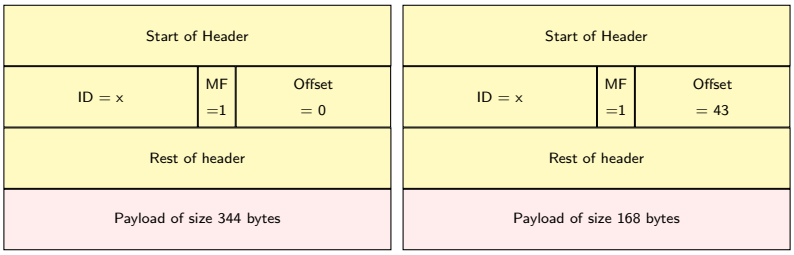


Figure 2: Three IPv4 packets and their header fields value.

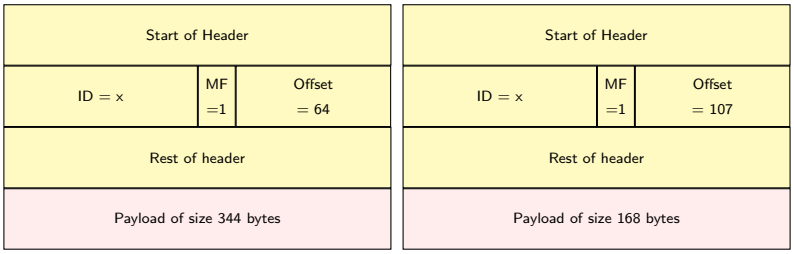
2.a Considering the typical IP header size of 20 Bytes, show the IP fragments produced.

Answer.

- Consider the packet with ID x, MF bit 1, and Offset 0. Considering the typical IP header size of 20 Bytes, Since MTU of this link is 370, the payload of the IP packets on this link must be no larger than 350 bytes. Note that we have to ensure that payload size of the fragments is multiple of 8 since offset is designed to count in 8-bytes. Thus, The payload of 512 bytes must be fragmented into two fragments with payloads of $\lfloor \frac{350}{8} \rfloor \times 8 = 344$ and $512 - 344 = 168$ bytes. The offset of the first fragment is $0 + 0 = 0$, and the offset of the second fragment is $0 + \lfloor \frac{350}{8} \rfloor = 43$. The MF bit of both fragments will be set to 1 since MF bit of the original packet was set to 1 originally. The ID of both fragments should be the same as the ID of the original packet.



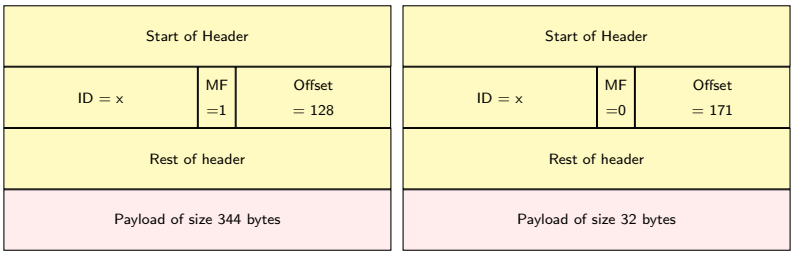
- Consider the packet with ID x, MF bit 1, and Offset 64. Thus, The payload of 512 bytes must be fragmented into two fragments with payloads of $\lfloor \frac{350}{8} \rfloor \times 8 = 344$ and $512 - 344 = 168$ bytes. The offset of the first fragment is $64+0 = 0$, and the offset of the second fragment is $64+\lfloor \frac{350}{8} \rfloor = 107$.[1] The MF bit of both fragments will be set to 1 since MF bit of the original packet was set to 1 originally. The ID of both fragments should be the same as the ID of the original packet.



- Consider the packet with ID x, MF bit 0, and Offset 128. Thus, The payload of 376 bytes must be fragmented into two fragments with payloads of $\lfloor \frac{350}{8} \rfloor \times 8 = 344$ and $376 - 344 = 32$ bytes. The

[1] The offset of each fragment is equal to the value in the Offset field of the original packet plus the offset required for that fragment.

offset of the first fragment is $128+0 = 0$, and the offset of the second fragment is $128+\lfloor\frac{350}{8}\rfloor = 171$. Since the MF bit of the original packet was set to 0, the MF bit of the last fragment will be set to 0 and the MF bit of the remaining fragments will be 1. The ID of both fragments should be the same as the ID of the original packet.



2.b If we had found the path MTU to be 370 and fragmented the data with respect to that, how many datagrams (*i.e.*, IP packets) would be produced by the sender?

Answer. There would be five datagrams. The first four would have 344 bytes of data each. The last would have 26 bytes.