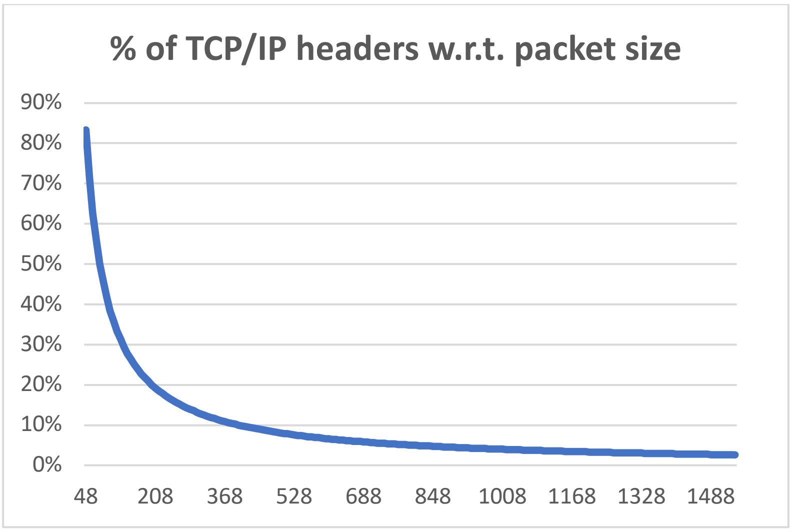
Homework #2 Student ID: **2018280070,** Name: **Peter Garamvoelgyi**

1. Calculate/estimate the header overhead of the TCP/IP communication.

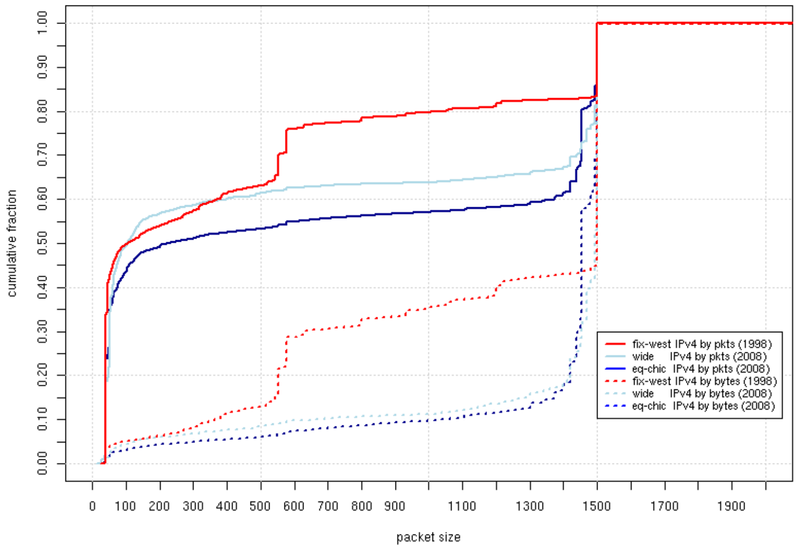
A minimal TCP and IP header is 20 bytes each, i.e. 40B in total. The payload of an IP packet can range from 8B to 64 KB, but a more common practical upper bound is 1500B, due to Ethernet MTU. Using these, we can arrive at the following plot:



We can see that

a) for small packets, the 40B header can be a serious overhead, constituting up to 80%+ of the whole packet,
b) for large packets, the header constitutes about 3% or less of the overall packet.

For getting a more definite understanding of packet size distribution, we can take a look at Caida's plots of IPv4 packet distribution in 1998 and 2008[1] (measured in California and Chicago):



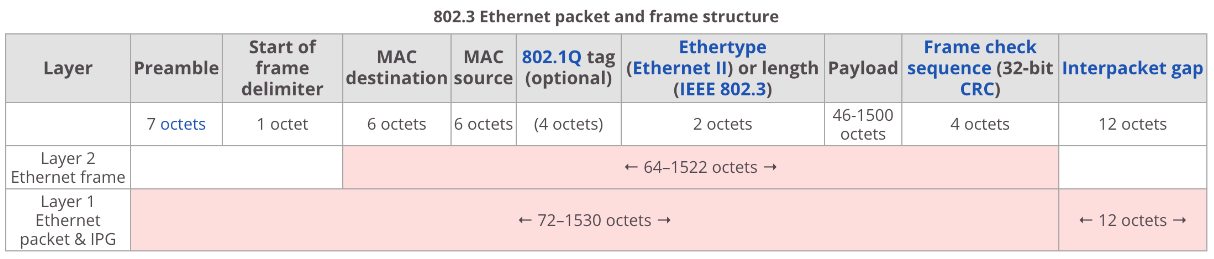
This plot suggests that 50% of the packets are smaller than 100B, while 20-40% are nearing 1500B.

The header overhead for a 100B packet is around 40%. If these stats can be generalized, that means that IP header overhead takes up a significant portion of network bandwidth.

[1] source: https://www.caida.org/research/traffic-analysis/pkt_size_distribution/graphs.xml

2. **Some say the maximum packet size is 1518 bytes, others use other numbers, such as 1500 or even 1540, why?**

Let us take a look at the Ethernet packet/frame structure[2]:



802.3 Ethernet packet and frame structure

Layer	Preamble	Start of frame delimiter	MAC destination	MAC source	802.1Q tag (optional)	Ethertype (Ethernet II) or length (IEEE 802.3)	Payload	Frame check sequence (32-bit CRC)	Interpacket gap
	7 octets	1 octet	6 octets	6 octets	(4 octets)	2 octets	46-1500 octets	4 octets	12 octets
Layer 2 Ethernet frame			← 64–1522 octets →						
Layer 1 Ethernet packet & IPG	← 72–1530 octets →								← 12 octets →

This shows that:

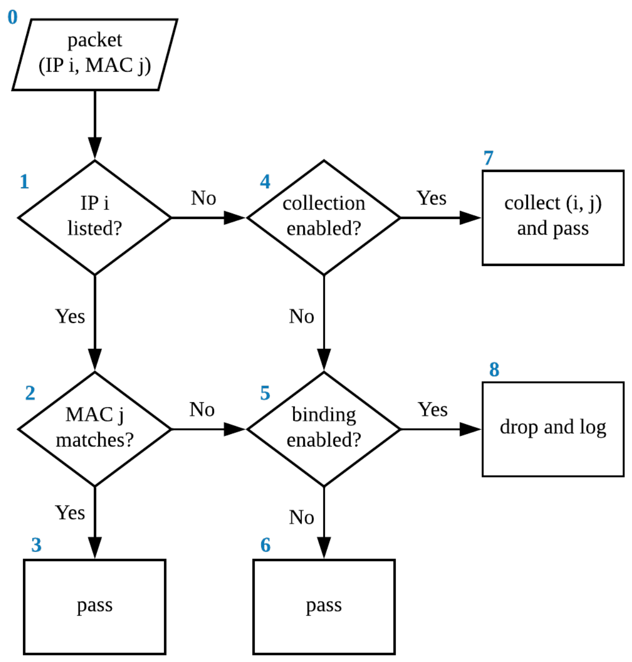
- The Ethernet **payload MTU is 1500 bytes**.
- Ethernet packets have a 14B header (destination MAC, source MAC, type/length) and a 4B CRC, **adding up to 1518B per packet**. (This becomes 1522B if we include the optional 802.1Q tag.)
- If we count the preamble, delimiter, and interpacket gap necessary for physical transmission, this adds an additional 20B, **adding up to 1538/1542B**.

To summarize: The reason for the inconsistencies in discussions of Ethernet maximum packet size is that different people mean different things when they talk about a packet. Some only consider the actual payload, some consider the headers and CRC, while others include the whole L1 frame.

[2] source: https://en.wikipedia.org/wiki/Ethernet_frame#Structure

3. **Design a firewall MAC-IP binding implementation with optional automatic MAC-IP pair collection and binding. A high level programming flowchart and description of the implementation will be fine. No actual coding is needed.**

High level programming flowchart:



Discussion:

In my design, a packet can pass in three different scenarios:

a) The IP is listed and the MAC matches the corresponding one in our database. (**0-1-2-3**)

b) The IP is not listed but we enabled collection. In this case, we simply store the new IP-MAC pair and pass. (**0-1-4-7**)

c) The IP is not listed but MAC-IP binding is not enabled. (**0-1-4-5-6**)

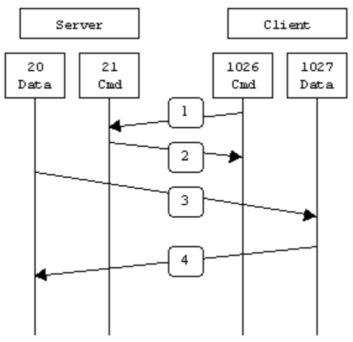
The two drop scenarios are as follows:

a) We enabled MAC-IP binding and we encountered a packet with listed IP but non-matching MAC. (**0-1-2-5-8**)

b) We enabled IP-MAC binding and we encountered a packet with an unlisted IP, and we also disabled collection. (**0-1-4-5-8**)

The implementation basically relies on two boolean switches/flags which can preferably set through a UI. Moreover, we need a way of storage and efficient lookup of IP-MAC pairs. (As such lookups are costly, our design could be improved by bypassing this when both collection and binding are disabled.) A typical use for this system would be to enable collection at the initialization phase, and then disable it and enable binding afterwards.

4. **(Bonus) When there is client side NAT and NPAT, how do you suggest we handle "dynamic protocols" such as Active FTP? Describe your method in details but no coding necessary.**



During active FTP, the client first connects to the server's FTP command port (21) from any port `N`. Then, the client sends a command to the server specifying it's data port (`M`). After this, the server proceeds to send the data from its FTP data port (20) to `M`.[3]

Let us assume that the client is behind a NAT-enabled gateway. This way, the client's command packet is translated this way:

```
[client IP] : N  -->  [gateway IP] : [random port K]
```

When the server sends replies to the client, it sends these to `[gateway IP]:K` and the gateway forwards these to `[client IP]:N`. However, when the server tries to send to `[gateway IP]:M` (`M` being specified in the command packet), the gateway does not know where to forward this packet, as there have been no corresponding outbound packets.

Solutions:

- The most robust solution is deep packet inspection. An FTP-aware NAT gateway, upon receiving an outbound packet to port 21, could inspect the payload and rewrite the proposed port to `L`, then add 2 PAT entries:

```
[client IP] : N      -->  [gateway IP] : K
[client IP] : M      -->  [gateway IP] : L
```

- While in theory `M` could be any port, typically `M = N + 1`. An FTP-aware NAT gateway can use this information. When the gateway receives an outbound packet to port 21, it saves two entries:

```
[client IP] : N      -->  [gateway IP] : K
[client IP] : (N+1)  -->  [gateway IP] : (N+1)
```

  Of course, this requires that port `N+1` on the gateway is not assigned yet.

- Alternatively, we can use the above solution with FTP-aware forwarding. If we receive an inbound packet from port 20 to port `L`, we check the entry for `K=(L-1)` and forward the packet to the corresponding host (port `N+1`). We only need one entry:

```
[client IP] : N      -->  [gateway IP] : K
```

[3] image source: lecture slides