10. The IPv4 Header Breakdown

The IPv4 header is a critical component of Layer 3 (Network Layer), enabling communication between devices across different networks via routing. It encapsulates Layer 4 PDUs (TCP/UDP segments) and consists of several fields, each with specific roles. Here's a structured overview:

Fields of the IPv4 Header

Field	# of Bits	Description
Version	4	Identifies the IP version: IPv4 (binary `0100`) or IPv6 (binary `0110`).
IHL	4	Internet Header Length in **4-byte increments**; Min = 5 (20 bytes), Max = 15 (60 bytes).
DSCP	6	Differentiated Services Code Point for QoS (e.g., prioritizing voice/video traffic).
ECN	2	Explicit Congestion Notification, for notifying congestion without dropping packets.
Total Length	16	Total packet size (IPv4 header (L3) + L4 segment) in bytes. Min = 20 bytes, Max = 65,535 bytes.
Identification	16	Identifies fragments belonging to the same packet for reassembly. Packets are fragmented if larger than MTU (Maximum Transmission Unit, usually 1500 bytes). Fragments are reassembled by the receiving host
Flags	3	Fragmentation control: Bit 0: Reserved and always set to 9, Bit 1:Don't Fragment (DF), used to indicate a packet that should not be fragmented, Bit 2:More Fragments (MF). set to 1 if there are more fragments in the packet, set to 0 for the last segment
Fragment Offset	13	Indicates a fragment's position within the original packet.
TTL	8	Time to Live, decremented at each router; prevents infinite loops. Default: 64 hops.
Protocol	8	Specifies the encapsulated protocol (e.g., TCP = 6, UDP = 17, ICMP = 1).

Header Checksum	16	Error-checking for the IPv4 header only; packets with mismatched checksums are dropped.
Source Address	32	IPv4 address of the packet's sender.
Destination Address	32	IPv4 address of the intended recipient.
Options	Up to 320	Optional field for rare use cases (e.g., security, routing, debugging); increases header size.

Detailed Field Descriptions

1. Version

- Identifies the IP version (IPv4 = 4, IPv6 = 6).

2. Internet Header Length (IHL)

- Specifies the size of the IPv4 header in 4-byte increments.
- Min: 20 bytes (5 * 4 bytes, with no options).
- Max: 60 bytes (15 * 4 bytes, with options).

3. DSCP (Differentiated Services Code Point)

- Enhances Quality of Service (QoS).
- Used for prioritizing time-sensitive traffic (e.g., streaming media).

4. ECN (Explicit Congestion Notification)

- Indicates network congestion without dropping packets.
- Requires end-to-end and network infrastructure support.

5. Total Length

- Includes both the IPv4 header and encapsulated data.
- Min: 20 bytes (header only).
- Max: 65,535 bytes (due to 16-bit limit).

6. Identification

- A unique value for each packet, used for fragment reassembly.
- All fragments of a single packet share the same ID.

7. Flags

- 3-bit field for fragmentation control:
    - **Bit 0 (Reserved):** Always set to 0.
    - **Bit 1 (DF):** Don't Fragment.

    - **Bit 2 (MF):** More Fragments (1 = more fragments, 0 = last/no fragments).

8. Fragment Offset

- Indicates the fragment's position within the original packet.
- Helps in reassembling fragments at the destination.

9. Time to Live (TTL)

- Prevents infinite loops by decrementing at each router hop.
- Default: 64 hops.
- When TTL reaches 0, the router drops the packet.

10. Protocol

- Identifies the encapsulated Layer 4 protocol:
    - **1:** ICMP
    - **6:** TCP
    - **17:** UDP
    - **89:** OSPF (Dynamic Routing).

11. Header Checksum

- Ensures the integrity of the IPv4 header (not the data).
- Routers recalculate it and drop packets with mismatched checksums.

12. Source and Destination Addresses

- 32-bit addresses for the sender and recipient.

13. Options

- Rarely used; provides additional functionality like security or debugging.
- Only present if IHL > 5.

Key Takeaways

- **IPv4 Header Min/Max Sizes:** 20–60 bytes.
- **Core Functions:** Routing, fragmentation, and error-checking.
- **Critical Fields:** TTL (prevents loops), Protocol (identifies encapsulated data), and Checksum (error detection).
- **Fragmentation:** Managed using Identification, Flags, and Fragment Offset fields.