### **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.