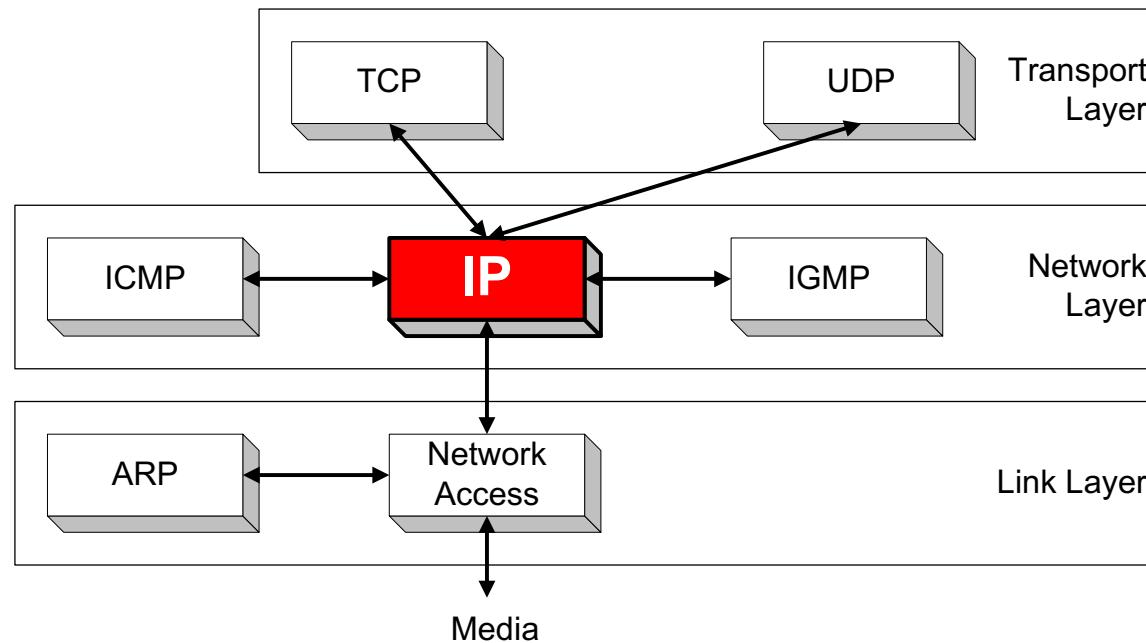


IP - The Internet Protocol

- Introduction
- IP Addressing
- Subnetting
- Variable Length Subnet Mask (VLSM)

Orientation

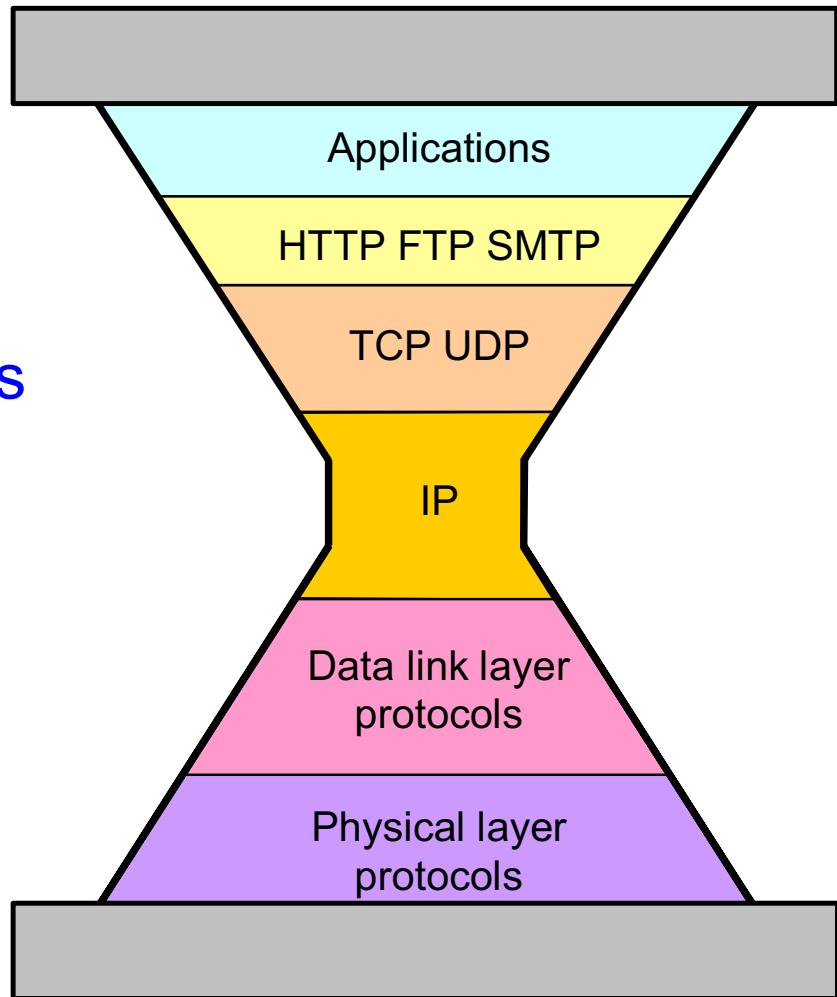
- IP (Internet Protocol) is a Network Layer Protocol.



- IP's current version is Version 6 (IPv6).

IP: The waist of the hourglass

- IP is the waist of the hourglass of the Internet protocol architecture
- Multiple higher-layer protocols
- Multiple lower-layer protocols
- Only one protocol at the network layer.



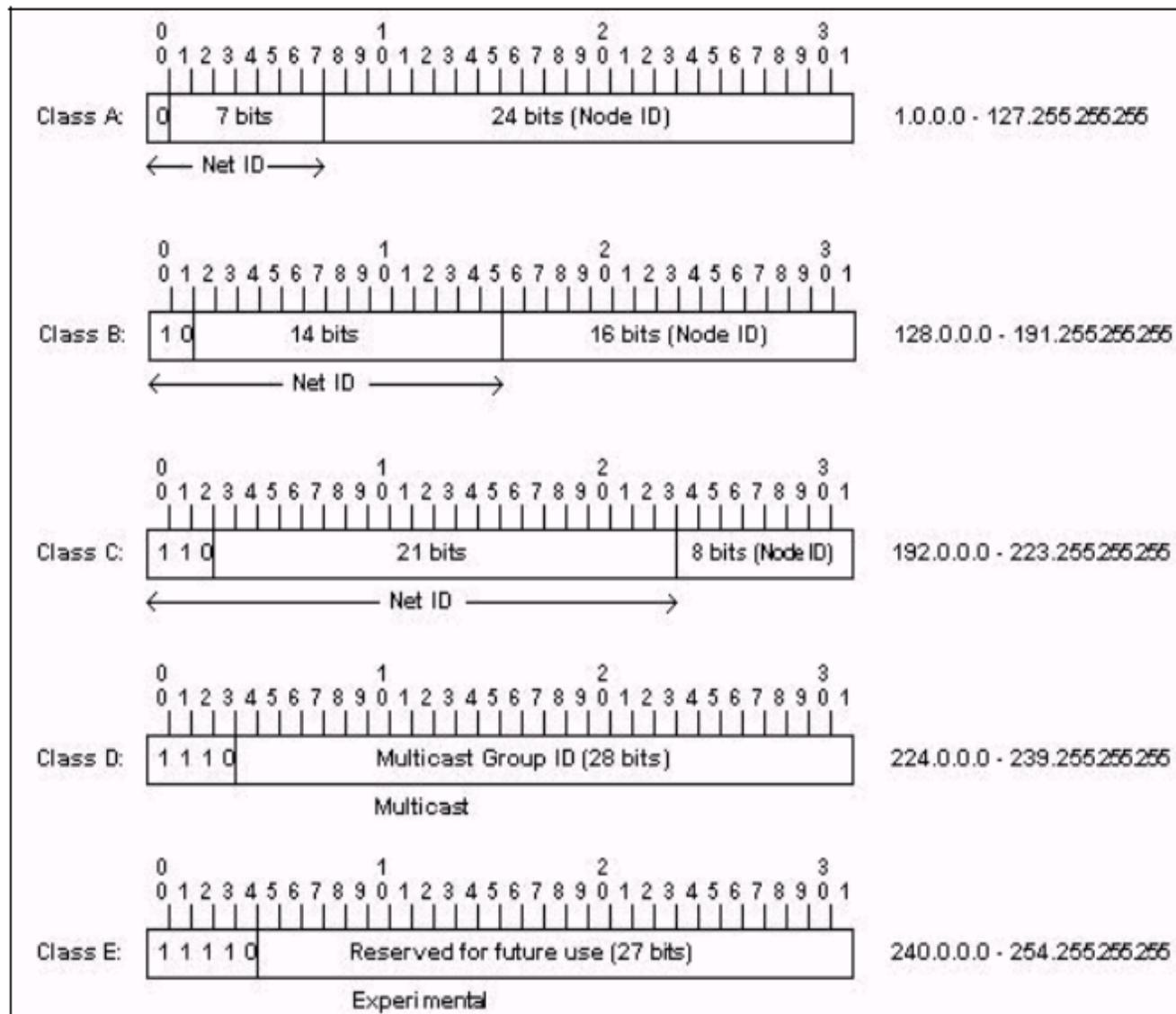
IP Service

- Delivery service of IP is minimal
- IP provides an **unreliable connectionless** best effort service (also called: “datagram service”).
 - **Unreliable:** IP does not make an attempt to recover lost packets
 - **Connectionless:** Each packet (“datagram”) is handled independently. IP is not aware that packets between hosts may be sent in a logical sequence
 - **Best effort:** IP does not make guarantees on the service (no throughput guarantee, no delay guarantee,...)
- Consequences:
 - Higher layer protocols have to deal with losses or with duplicate packets
 - Packets may be delivered out-of-sequence

IP Addresses

- An IP address is an address used to uniquely identify a device on an IP network.
- The address is made up of 32 binary bits which can be divisible into a network portion and host portion with the help of a subnet mask.
- 32 binary bits are broken into four octets (1 octet = 8 bits)
- Dotted decimal format (for example, 172.16.81.100)

IP Address Classes



IP Address Classes

- Class A: The first octet is the network portion. Octets 2, 3, and 4 are for subnets/hosts
- Class B: The first two octets are the network portion. Octets 3 and 4 are for subnets/hosts
- Class C: The first three octets are the network portion. Octet 4 is for subnets/hosts

Private Address Range

Address Class	Reserved Address Space
Class A	10.0.0.0 - 10.255.255.255
Class B	172.16.0.0 - 172.31.255.255
Class C	192.168.0.0 - 192.168.255.255

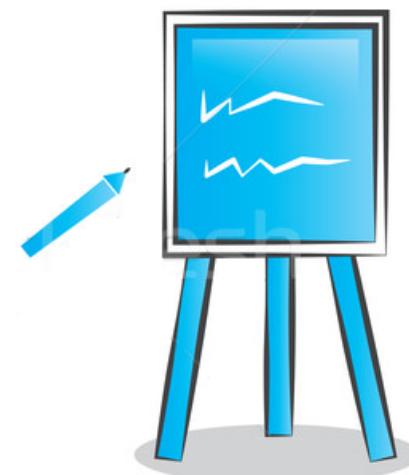
Network/Subnet Masks

- Distinguishes which portion of the address identifies the network and which portion of the address identifies the node.
- Default masks:
 - Class A: 255.0.0.0/8
 - Class B: 255.255.0.0/16
 - Class C: 255.255.255.0/24

Subnetting

- Creates multiple logical networks that exist within a single Class A, B, or C network.
- If you do not subnet, you will only be able to use one network from your Class A, B, or C network, which is unrealistic
- Each data link on a network must have a unique network ID, with every node on that link being a member of the same network

Example

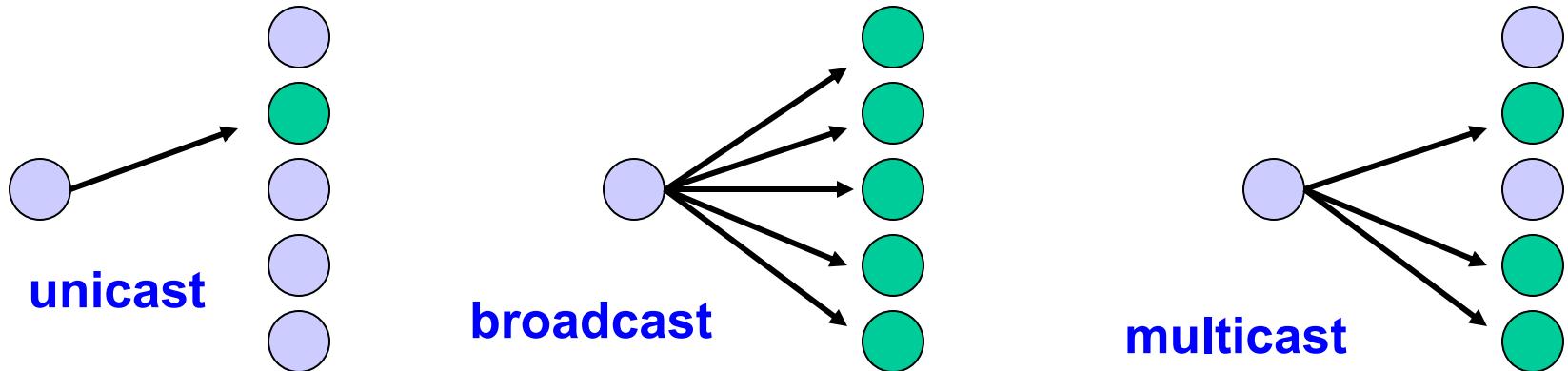


Benefits of Subnetting

- 1) Reduced network traffic
- 2) Optimized network performance
- 3) Simplified management
- 4) Facilitated spanning of large geographical distances

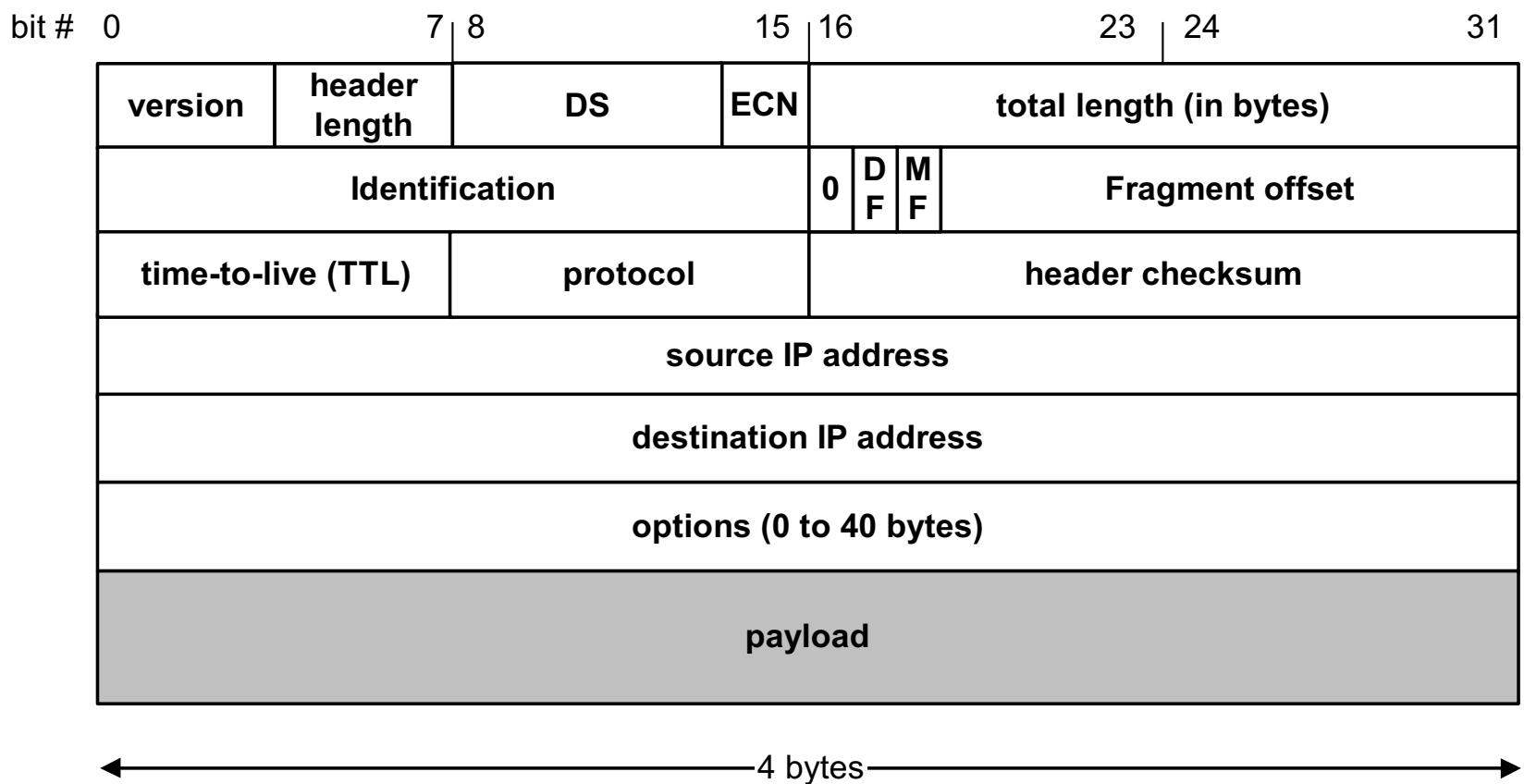
IP Service

- IP supports the following services:
 - one-to-one (unicast)
 - one-to-all (broadcast)
 - one-to-several (multicast)



- IP multicast also supports a many-to-many service.
- IP multicast requires support of other protocols (IGMP, multicast routing)

IP Datagram Format



- $20 \text{ bytes} \leq \text{Header Size} < 2^4 \times 4 \text{ bytes} = 60 \text{ bytes}$
- $20 \text{ bytes} \leq \text{Total Length} < 2^{16} \text{ bytes} = 65536 \text{ bytes}$

Fields of the IP Header

- **Version (4 bits)**: current version is 4, next version will be 6.
- **Header length (4 bits)**: length of IP header, in multiples of 4 bytes
- **DS/ECN field (1 byte)**
 - This field was previously called as Type-of-Service (TOS) field. The role of this field has been re-defined, but is “backwards compatible” to TOS interpretation
 - **Differentiated Service (DS) (6 bits)**:
 - Used to specify service level (currently not supported in the Internet)
 - **Explicit Congestion Notification (ECN) (2 bits)**:
 - New feedback mechanism used by TCP

Fields of the IP Header

- **Identification (16 bits):** Unique identification of a datagram from a host. Incremented whenever a datagram is transmitted
- **Flags (3 bits):**
 - First bit always set to 0
 - DF bit (Do not fragment)
 - MF bit (More fragments)

Will be explained later → Fragmentation

Fields of the IP Header

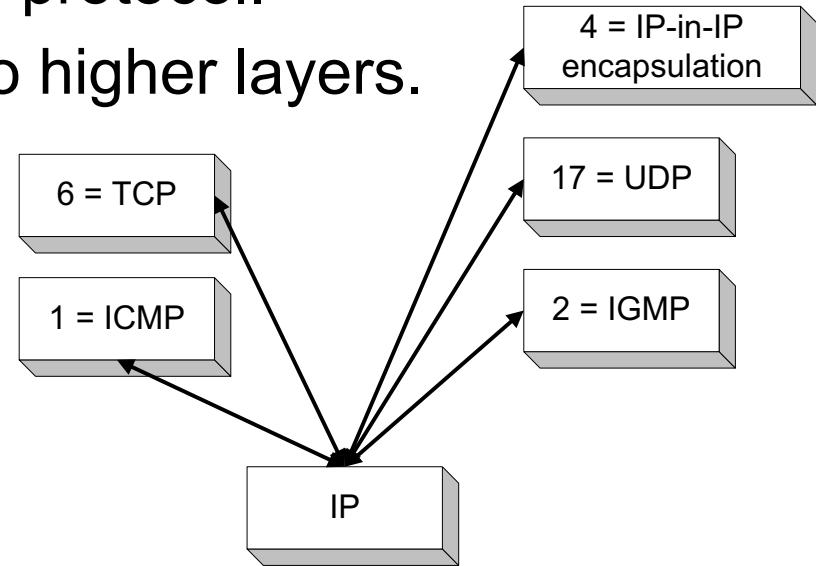
- **Time To Live (TTL) (1 byte):**
 - Specifies longest paths before datagram is dropped
 - Role of TTL field: Ensure that packet is eventually dropped when a routing loop occurs

Used as follows:

- Sender sets the value (e.g., 64)
- Each router decrements the value by 1
- When the value reaches 0, the datagram is dropped

Fields of the IP Header

- **Protocol (1 byte):**
 - Specifies the higher-layer protocol.
 - Used for demultiplexing to higher layers.



- **Header checksum (2 bytes):** A simple 16-bit long checksum which is computed for the header of the datagram.

Fields of the IP Header

- **Options:**
 - Security restrictions
 - Record Route: each router that processes the packet adds its IP address to the header.
 - Timestamp: each router that processes the packet adds its IP address and time to the header.
 - (loose) Source Routing: specifies a list of routers that must be traversed.
 - (strict) Source Routing: specifies a list of the only routers that can be traversed.
- **Padding:** Padding bytes are added to ensure that header ends on a 4-byte boundary

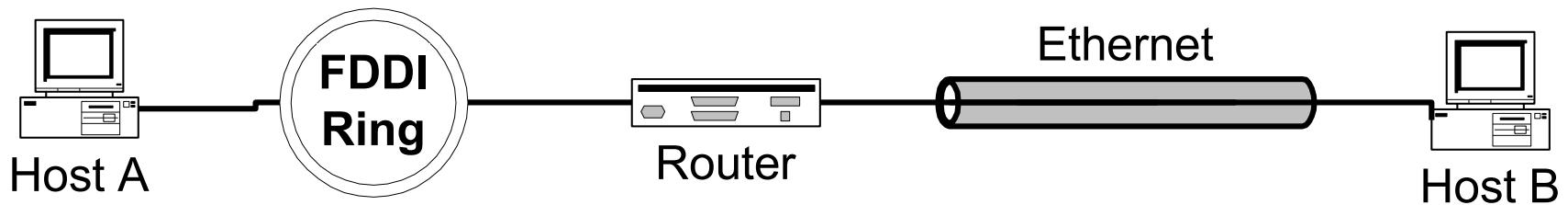
Maximum Transmission Unit

- Maximum size of IP datagram is 65535, but the data link layer protocol generally imposes a limit that is much smaller
- Example:
 - Ethernet frames have a maximum payload of 1500 bytes
→ IP datagrams encapsulated in Ethernet frame cannot be longer than 1500 bytes
- The limit on the maximum IP datagram size, imposed by the data link protocol is called **maximum transmission unit (MTU)**
- MTUs for various data link protocols:

Ethernet:	1500	FDDI:	4352
802.3:	1492	ATM AAL5:	9180
802.5:	4464	PPP:	negotiated

IP Fragmentation

- What if the size of an IP datagram exceeds the MTU?
IP datagram is fragmented into smaller units.
- What if the route contains networks with different MTUs?



MTUs:

FDDI: 4352

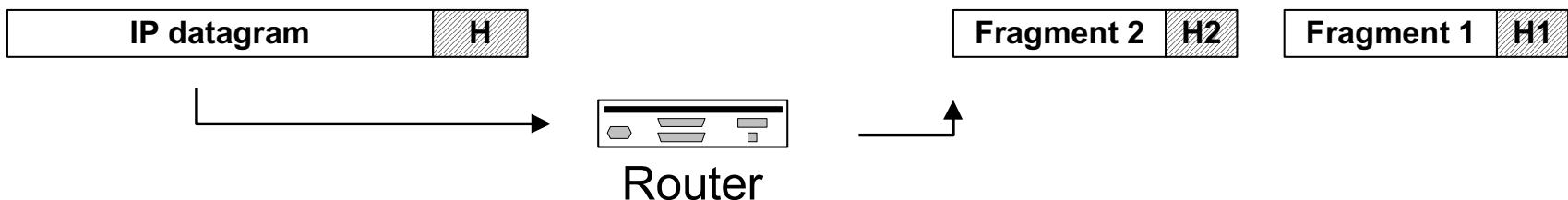
Ethernet: 1500

- **Fragmentation:**

- IP router splits the datagram into several datagram
- Fragments are reassembled at receiver

Where is Fragmentation done?

- Fragmentation can be done at the sender or at intermediate routers
- The same datagram can be fragmented several times.
- Reassembly of original datagram is only done at destination hosts !!



What's involved in Fragmentation?

- The following fields in the IP header are involved:

version	header length	DS	ECN	total length (in bytes)			
Identification				0	D	M	Fragment offset
time-to-live (TTL)		protocol		header checksum			

Identification

When a datagram is fragmented, the identification is the same in all fragments

Flags

DF bit is set: Datagram cannot be fragmented and must be discarded if MTU is too small

MF bit set: This datagram is part of a fragment and an additional fragment follows this one

What's involved in Fragmentation?

- The following fields in the IP header are involved:

version	header length	DS	ECN	total length (in bytes)			
Identification				0	D	M	
				F	F		Fragment offset
time-to-live (TTL)	protocol		header checksum				

Fragment offset

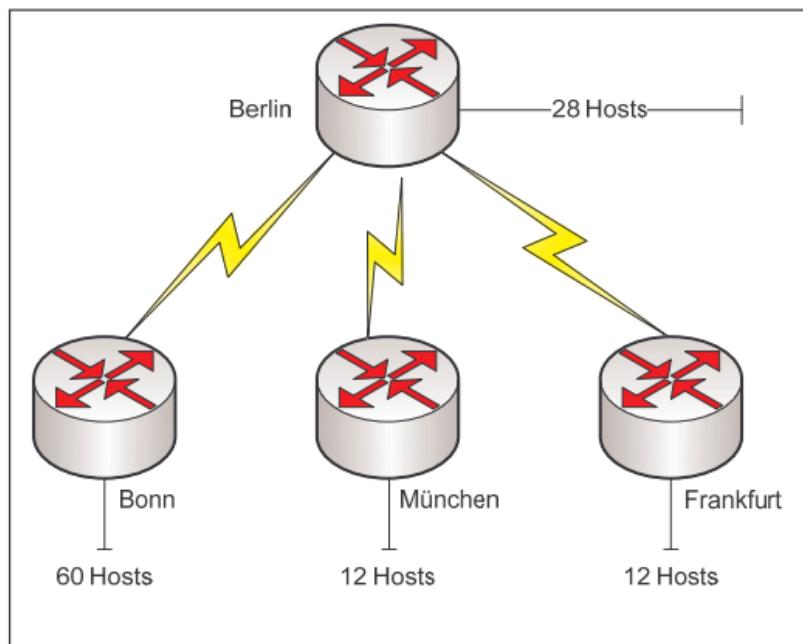
Offset of the payload of the current fragment in the original datagram

Total length

Total length of the current fragment

Next Week: VLSM Subnetting

- Using classful subnetting wastes IP addresses
- The number of hosts involved in each subnet must of same size
- Create a number of subnet masks that suit our needs more efficiently than a classful subnetting scheme could



Example

