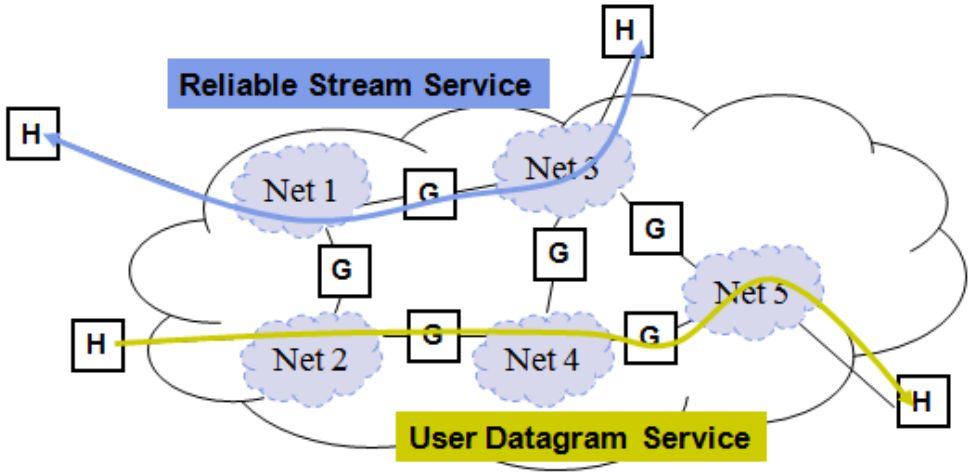
Why Internetworking?

- To build a “network of networks” or internet
    - operating over multiple, coexisting, different network technologies
    - providing ubiquitous connectivity through IP packet transfer
    - achieving huge economies of scale
    - To provide *universal communication services*
    - independent of underlying network technologies
    - providing common interface to user applications



Internet Names & Addresses

Internet Names

- Each host has a unique name
    - Independent of physical location
    - Facilitate memorization by humans
    - Domain Name
    - Organization under single administrative unit
- Host Name
    - Name given to host computer

- User Name
    - Name assigned to user

leongarcia@comm.utoronto.ca

Internet Addresses

- Each host has globally unique *logical* 32 bit IP address
- Separate address for each physical connection to a network
- Routing decision is done based on destination IP address
- IP address has two parts:
    - *netid* and *hostid*
    - *netid* unique
    - *netid* facilitates routing
- Dotted Decimal Notation:

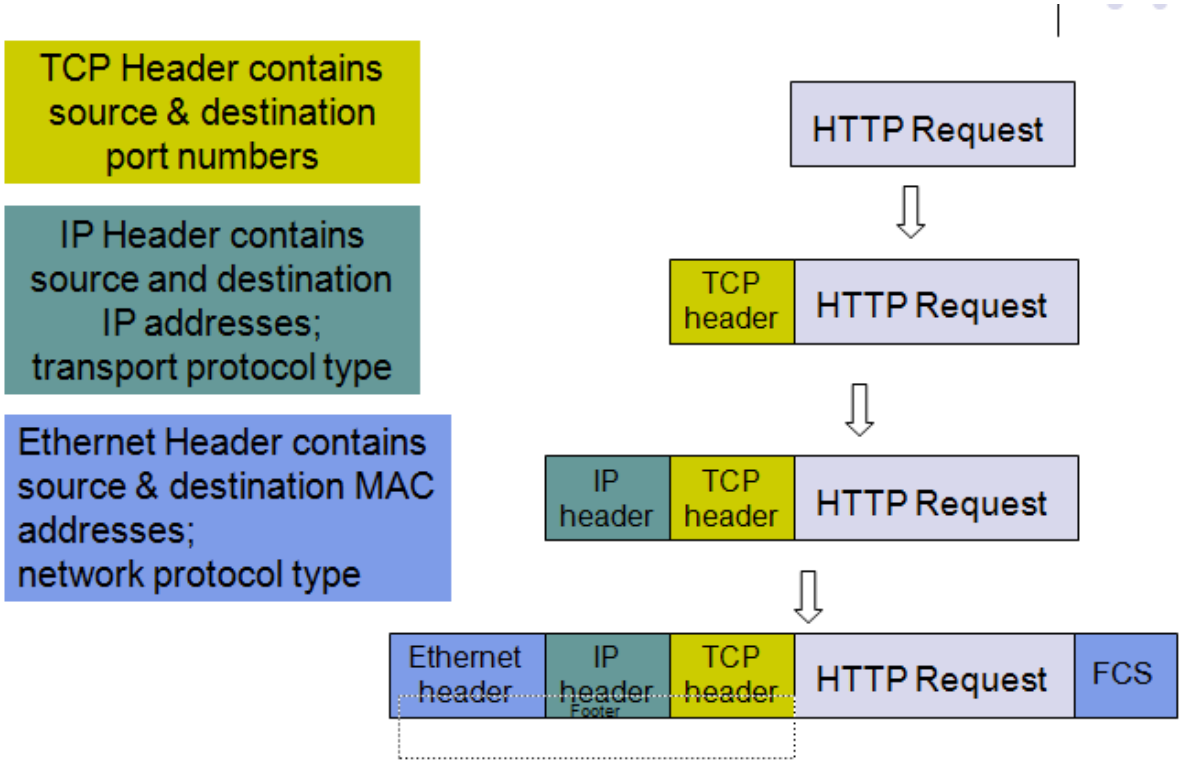
  int1.int2.int3.int4

  (intj = jth octet)

  128.100.10.13

DNS resolves IP name to IP address

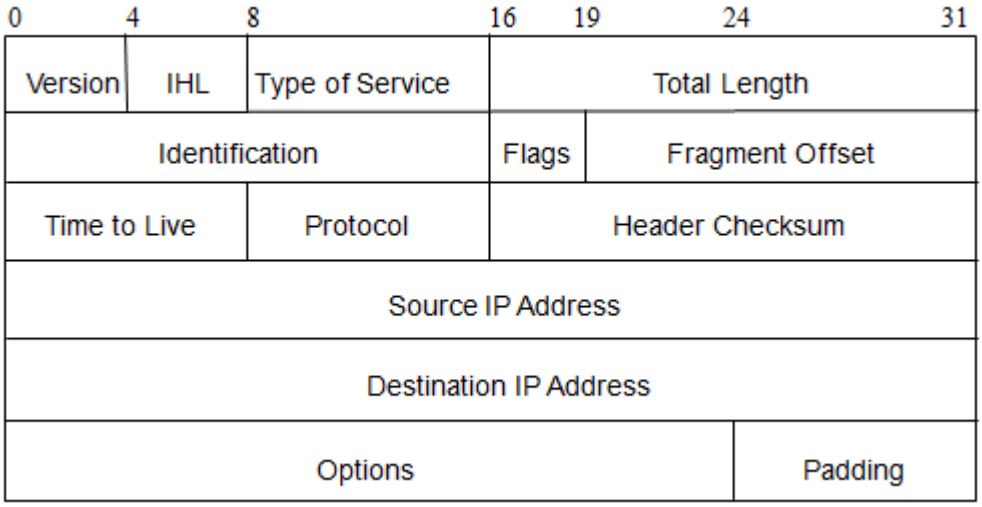
Encapsulation



The Internet Protocol

- Provides best effort, connectionless packet delivery
    - motivated by need to keep routers simple and by adaptibility to failure of network elements
    - packets may be lost, out of order, or even duplicated
    - higher layer protocols must deal with these, if necessary
- RFCs 791, 950, 919, 922, and 2474.
- IP is part of Internet STD includes
    - Internet Control Message Protocol (ICMP), RFC 792
    - Internet Group Management Protocol (IGMP), RFC 1112

IP V4 Packet Header



- Minimum 20 bytes
- options that can be up to 40 bytes.
- **Version:** current IP version is 4.
- **Internet header length (IHL):** length of the header in 32-bit words.
- **Type of service (TOS):** traditionally priority of packet at each router. delay, throughput, reliability, and cost requirements
- **Total length:** number of bytes of the IP packet including header and data, maximum length is 65535 bytes.
- **Identification, Flags, and Fragment Offset:** used for fragmentation and reassembly (More on this shortly).
- **Time to live (TTL):** number of hops packet is allowed to traverse in the network.

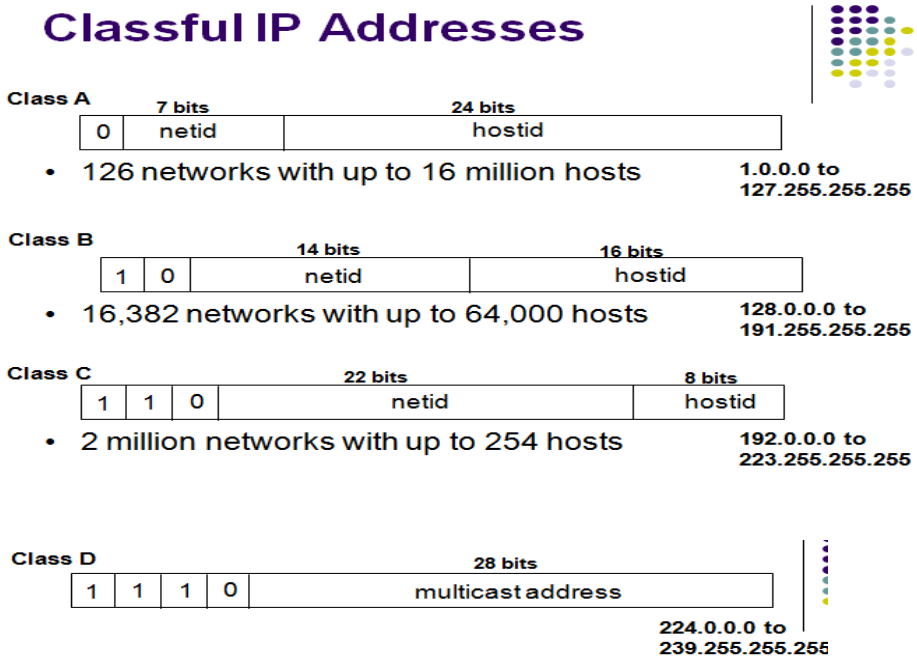
  ->Each router along the path to the destination decrements this value by one.

  -> If the value reaches zero before the packet reaches the destination, the router discards the packet and sends an error message back to the source.
- **Protocol:** specifies upper-layer protocol that is to receive IP data at the destination. Examples include TCP (protocol = 6), UDP (protocol = 17), and ICMP (protocol = 1).

- **Header checksum:** verifies the integrity of the IP header.
- **Source IP address** and **destination IP address:** contain the addresses of the source and destination hosts.
- **Options:** Variable length field, allows packet to request special features such as security level, route to be taken by the packet, and timestamp at each router.
- **Padding:** This field is used to make the header a multiple of 32-bit words.

IP Addressing

- RFC 1166
- Each host on Internet has unique 32 bit IP address
- Each address has two parts: Each address consists of two parts
    1. The network address
    2. The host address
- Network ID identifies the network the host is connected to.
- all hosts connected to the same network have the same network ID.
- The IP address structure is divided into five address classes,, Class A, Class B, Class C, Class D, and Class E.
- Valid addresses can range from 0.0.0.0 to 255.255.255.255.
- Theoretically, a total of » 4.3 billion addresses are available.
- An ID that contains all 1s or all 0s has a special purpose.



Class E will be from 240.0.0.0 to 254.255.255.255

- Up to 250 million multicast groups at the same time
- Permanent group addresses
    - All systems in LAN; All routers in LAN;
- Temporary groups addresses created as needed
- Special multicast routers

The loopback address can be used for interprocess communication on a local host

- A host ID that contains all 1s is meant to broadcast the packet to all hosts on the network specified by the network ID.
- A host ID that contains all 0s refers to the network specified by the network ID, rather than to a host.
- IP addresses are usually written in dotted-decimal notation.
- IP address of

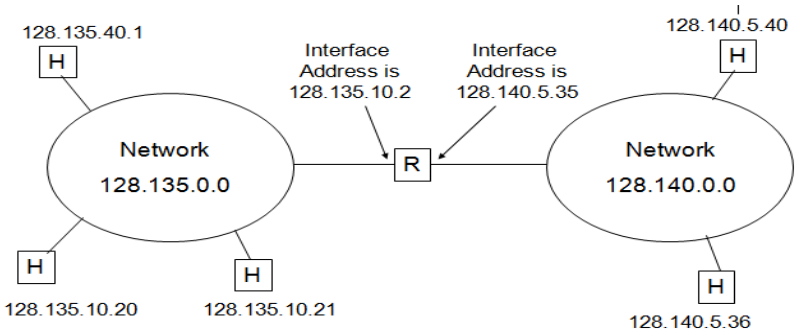
10000000 10000111 01000100 00000101

128.135.68.5 -Class B Address

Private IP Addresses

- Specific ranges of IP addresses set aside for use in private networks (RFC 1918)-Home Networks.
- Use restricted to private internets; routers in public Internet discard packets with these addresses
- Range 1: 10.0.0.0 to 10.255.255.255
- Range 2: 172.16.0.0 to 172.31.255.255
- Range 3: 192.168.0.0 to 192.168.255.255
- Network Address Translation (NAT) used to convert between private & global IP addresses

Example of IP Addressing



Subnet Addressing

- The original IP addressing scheme described above has some drawbacks
- Subnet addressing introduces another hierarchical level.
- Inside the organization the local network administrator is free to choose any combination of lengths for the subnet and host ID fields.
- Transparent to remote networks
- Simplifies management of multiplicity of LANs
- Masking used to find subnet number

An example of subnet

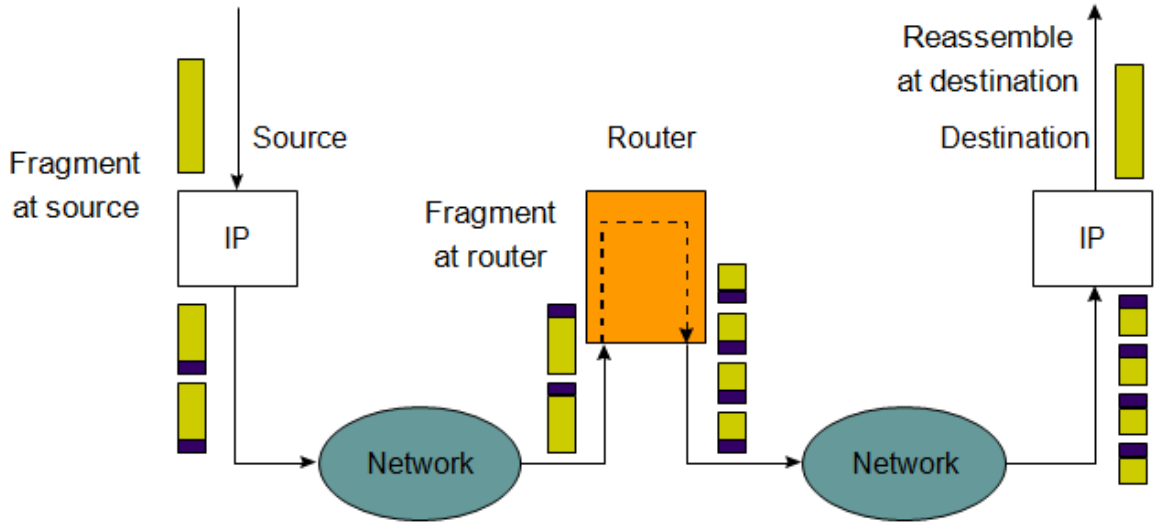
Original address	1 0	Net ID	Host ID	
Subnetted address	1 0	Net ID	Subnet ID	Host ID

- consider an organization that has been assigned a Class B IP address with a network ID of 150.100.
- Suppose the organization has many LANs, each consisting of no more than 100 hosts.
- Then seven bits are sufficient to uniquely identify each host in a subnetwork.
- The other nine bits can be used to identify the subnetworks within the organization.
- If a packet with a destination IP address of **150.100.12.176** arrives at the site from the outside network, which subnet should a router forward this packet to?
- To find the subnet number, the router uses a subnet mask that consists of binary 1's for every bit position of the address except in the host ID field where binary 0s are used.
- Organization has Class B address (16 host ID bits) with network ID: 150.100.0.0
- Create subnets with up to 100 hosts each
- 7 bits sufficient for each subnet
- 16-7=9 bits for subnet ID
- Apply subnet mask to IP addresses to find corresponding subnet
- Example: Find subnet for **150.100.12.176**
- IP add = 10010110 01100100 00001100 10110000
- Mask = 11111111 11111111 11111111 10000000
- AND = 10010110 01100100 00001100 10000000
- Subnet = 150.100.12.128 this address is used to forward packets to the correct subnetwork inside the organization.
- Subnet address used by routers within organization

- IP address 150.100.12.255 is used to broadcast packets inside the subnetwork.
- A host connected to this subnetwork must have an IP address between 150.100.12.129 and 150.100.12.254.

Fragmentation and Reassembly

- Identification identifies a particular packet
- Flags = (unused, don't fragment/DF, more fragment/MF)
- Fragment offset identifies the location of a fragment within a packet



Fragmentation Bits

1. Three fields in the IP header (identification, flags, and fragment offset) have been assigned to manage fragmentation and reassembly.
2. At the destination IP has to collect fragments for reassembling into packets.
3. The flags field has **three** bits,, **one unused** bit, one ‘‘**don’t fragment**’’ (DF) bit, and one **‘‘more fragment**’’ (MF) bit.

4. If the DF bit is set to 1, it forces the router not to fragment the packet. If the packet length is greater than the MTU, the router will have to discard the packet and send an error message to the source.
5. The MF bit tells the destination host whether or not more fragments follow. If there are more, the MF bit is set to 1; otherwise, it is set to 0.
6. The **fragment offset** field identifies **the location** of a fragment in a packet.
7. The data length of each fragment, except the last one, must be a multiple of eight bytes .

Example: Fragmenting a Packet

A packet is to be forwarded to a network with MTU of 576 bytes. The packet has an IP header of 20 bytes and a data part of 1484 bytes. and of each fragment.

Maximum data length per fragment = 576 - 20 = 556 bytes.

556 is not a multiple of 8,set maximum data length to 552 bytes to get multiple of 8..

Break it as 552+552+380

X=unique identification value

	Total Length	Id	MF	Fragment Offset
Original packet	1504	x	0	0
Fragment 1	572	x	1	0
Fragment 2	572	x	1	69
Fragment 3	400	x	0	138

IPv6

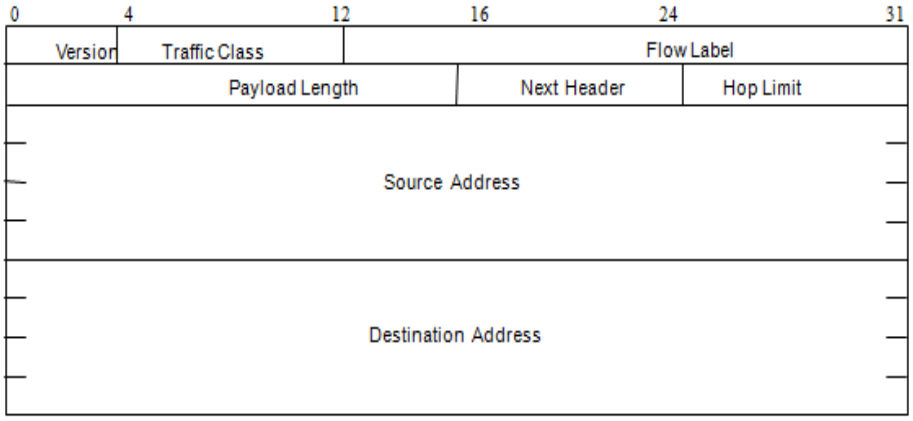
- **Longer address field:**
  - Extended from 32 bits to 128 bits can support up to 3.4 x 10^{38} hosts
- **Simplified header format:**
  - Simpler format to speed up processing of each header
  - All fields are of fixed size
  - IPv4 vs IPv6 fields:
    - Same: Version
    - Dropped: Header length, ID/flags/frag offset, header checksum
    - Replaced:
      - Datagram length by Payload length
      - Protocol type by Next header
      - TTL by Hop limit
      - TOS by traffic class
    - New: Flow label

Other IPv6 Features

- **Flexible support for options:** more efficient and flexible***extension headers*** options encoded in optional
- **Flow label capability:** "flow label" to identify a packet flow that requires a certain QoS
- **Security:** built-in authentication and confidentiality
- **Large packets:** supports payloads that are longer than 64 K bytes, called *jumbo* payloads.
- **Fragmentation at source only:** Routers do not perform fragmentation source should check the minimum MTU along the path

- **No checksum field:** removed to reduce packet processing time in a router

IPv6 Header Format



- Version field same size, same location
- Traffic class to priority of the packet. Support Differentiated Services
- Flow: sequence of packets from particular source to particular destination for which source requires special handling(Host that do not support this option is set to 0)
- Payload length: length of data excluding header, up to 65535 B
- Next header: type of extension header that follows basic header
- Hop limit: # hops packet can travel before being dropped by a router

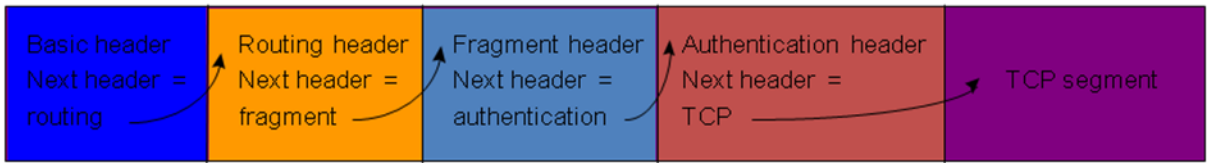
IPv6 Addressing

- Address Categories
    - Unicast:
    - Multicast: .
    - Anycast:
- Hexadecimal notation
    - Groups of 16 bits represented by 4 hex digits

- Separated by colons
  - **4BF5:AA12:0216:FEBC:BA5F:039A:BE9A:2176**
- Shortened forms:
  - **4BF5:0000:0000:0000:BA5F:039A:000A:2176**
  - **To 4BF5:0:0:0:BA5F:39A:A:2176**
  - **To 4BF5::BA5F:39A:A:2176**
- Mixed notation:
  - ::FFFF:128.155.12.198

Extension Headers

Daisy chains of extension headers



- Extension headers processed in order of appearance