IP Datagrams and Datagram Forwarding

Dr. Pipat

Introduction

- Fundamental Internet communication service
- Format of packets
- Processing of packets by routers
- Forwarding
- Delivery

Connectionless service

- End-to-end delivery service is connectionless
- Extension of LAN abstraction
  - Universal addressing
  - Data delivered in packets (frames), each with a header
- Combines collection of physical networks into single, virtual network
- Transport protocols use this connectionless service to provide connectionless data delivery (UDP) and connection-oriented data delivery (TCP)

IP datagram format

- Formally, the unit of IP data delivery is called a datagram
- Includes header area and data area

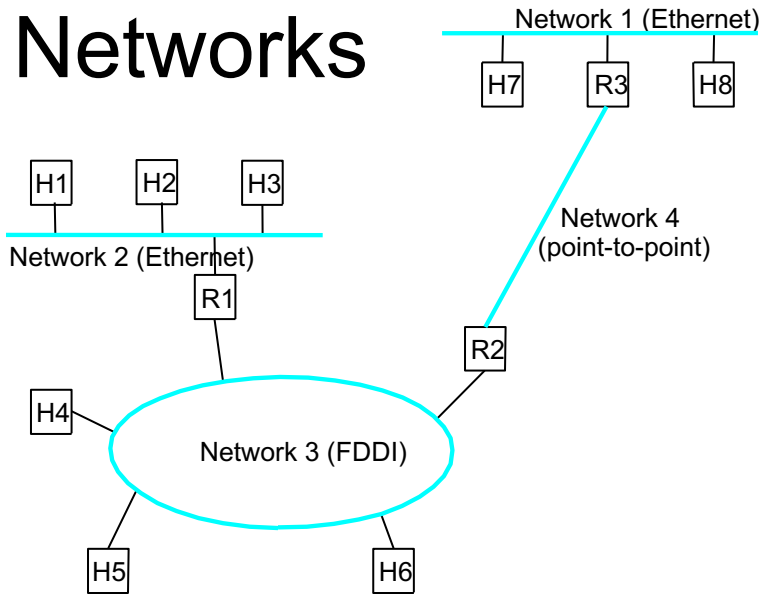
- Datagrams can have different sizes
- Header area usually fixed (20 octets) but can have options

Forwarding datagrams

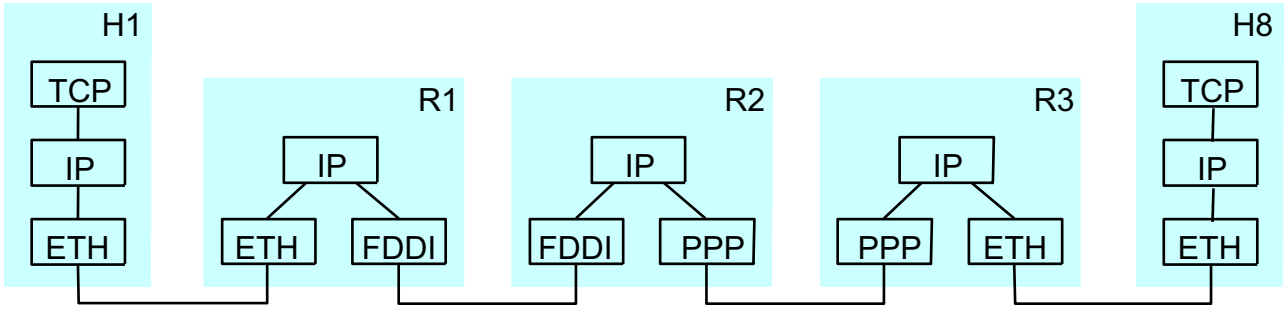
- Header contains all information needed to deliver datagram to destination computer
  - Destination address
  - Source address
  - Identifier
  - Other delivery information
- Router examines header of each datagram and forwards datagram along path to destination

IP Internet

- Concatenation of Networks

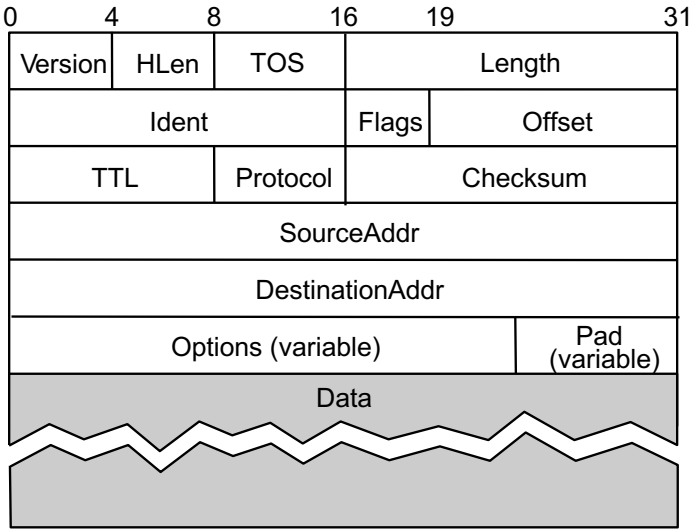


- Protocol Stack



Service Model

- Connectionless (datagram-based)
- Best-effort delivery (unreliable service)
  - packets are lost
  - packets are delivered out of order
  - duplicate copies of a packet are delivered
  - packets can be delayed for a long time
- Datagram format



IP datagram header fields

- `VERS` - version of IP (currently 4)
- `H. LEN` - header length (in units of 32 bits)
- `SERVICE TYPE` - sender's preference for low latency, high reliability (rarely used)
- `TOTAL LENGTH` - total octets in datagram
- `IDENT, FLAGS, FRAGMENT OFFSET` - used with fragmentation
- `TTL` - time to live; decremented in each router; datagram discarded when `TTL` = 0
- `TYPE` - type of protocol carried in datagram; e.g., `TCP, UDP`
- `HEADER CHECKSUM` - 1s complement of 1s complement sum
- `SOURCE, DEST IP ADDRESS` - IP addresses of original source and ultimate destination

Fragmentation and Reassembly

- Each network has a *Maximum Transmission Unit* (MTU)
- IP datagrams can be larger than most hardware MTUs
  - IP: $2^{16} - 1$
  - Ethernet: 1500
  - Token ring: 2048 or 4096
- Strategy
  - fragment when necessary (MTU < Datagram)
  - try to avoid fragmentation at source host
  - re-fragmentation is possible
  - fragments are self-contained datagrams
  - delay reassembly until destination host
  - do not recover from lost fragments

MTU and heterogeneous networks

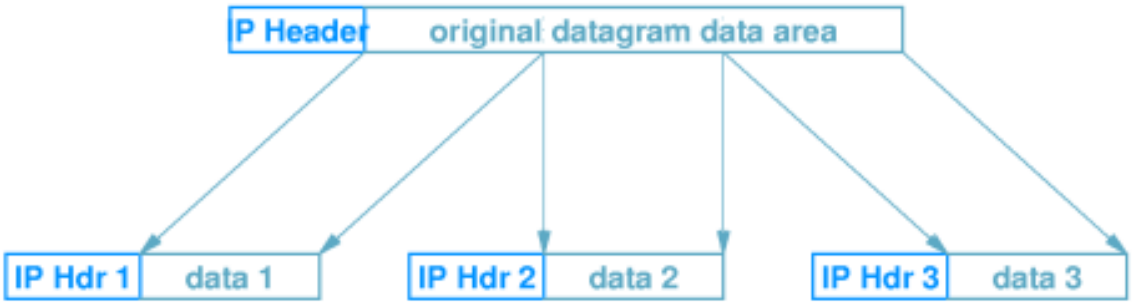
- An internet may have networks with different MTUs
- Suppose downstream network has smaller MTU than local network?

Fragmentation

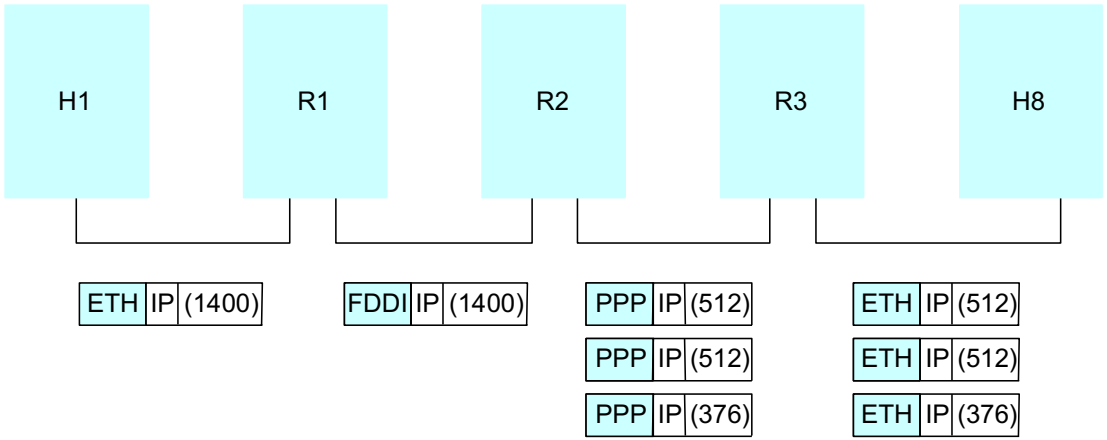
- One technique - limit datagram size to smallest MTU of any network
- IP uses *fragmentation* - datagrams can be split into pieces to fit in network with small MTU
- Router detects datagram larger than network MTU
  - Splits into pieces
  - Each piece smaller than outbound network MTU

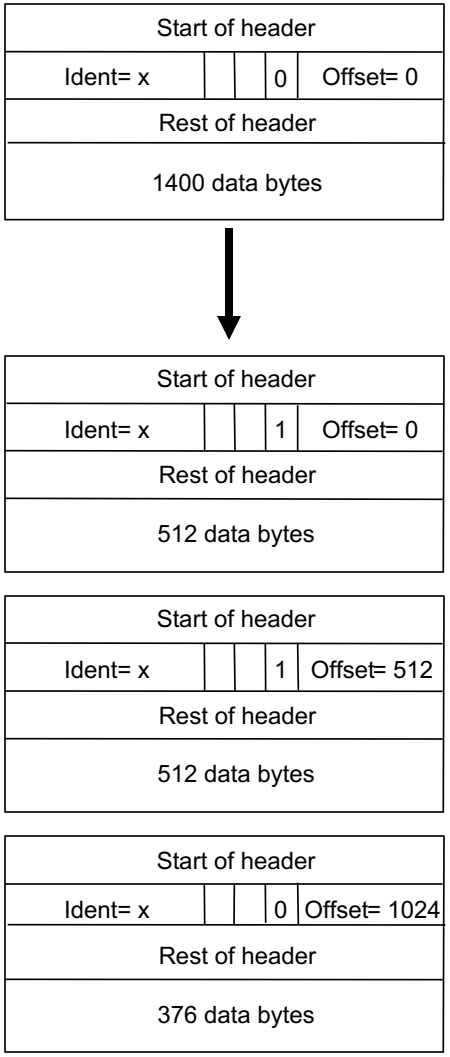
Fragmentation (details)

- Each fragment is an independent datagram
  - Includes all header fields
  - Bit in header indicates datagram is a fragment
  - Other fields have information for reconstructing original datagram
  - FRAGMENT OFFSET gives original location of fragment
- Router uses local MTU to compute size of each fragment
- Puts part of data from original datagram in each fragment
- Puts other information into header



Example


H1
R1
R2
R3
H8
ETH IP (1400)
FDDI IP (1400)
PPP IP (512)
PPP IP (512)
PPP IP (376)
ETH IP (512)
ETH IP (512)
ETH IP (376)


Start of header
Ident= x
0
Offset= 0
Rest of header
1400 data bytes
Start of header
Ident= x
1
Offset= 0
Rest of header
512 data bytes
Start of header
Ident= x
1
Offset= 512
Rest of header
512 data bytes
Start of header
Ident= x
0
Offset= 1024
Rest of header
376 data bytes

Fragment loss

- IP may drop fragment
- What happens to original datagram?
  - Destination drops entire original datagram
- How does destination identify lost fragment?
  - Sets timer with each fragment
  - If timer expires before all fragments arrive, fragment assumed lost
  - Datagram dropped
- Source (application layer protocol) assumed to retransmit

Summary

- Basic unit of delivery in TCP/IP is IP datagram
- Routers use destination address in IP datagram header to determine next-hop
- Forwarding information stored in routing table
- IP datagram header has 20 bytes of fixed field information and (possibly) options
- During transmission a IP datagram may be fragmented and reassembled