PART VI

INTERNET PROTOCOL: CONNECTIONLESS DATAGRAM DELIVERY

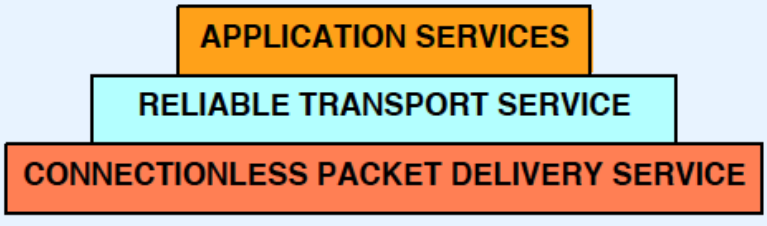
Internet Protocol

- One of two major protocols in TCP/IP suite
- Major goals
  - Hide heterogeneity
  - Provide the illusion of a single large network
  - Virtualize access

The Concept

IP allows a user to think of an internet as a single virtual network that interconnects all hosts, and through which communication is possible; its underlying architecture is both hidden and irrelevant.

Internet Services And Architecture Of Protocol Software



- Design has proved especially robust

IP Characteristics

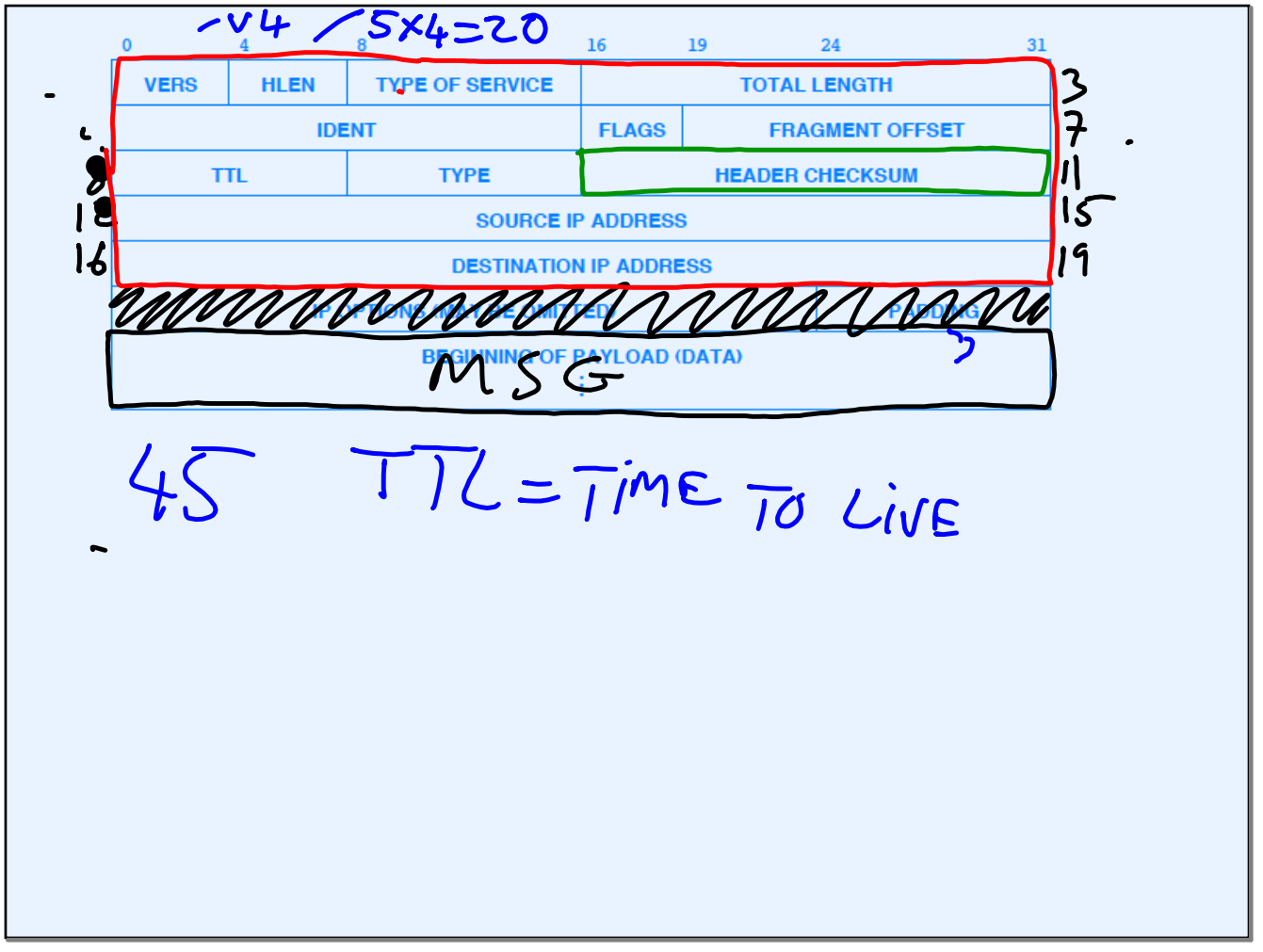
- Provides connectionless packet delivery service
- Defines three important items
  - Internet addressing scheme
  - Format of packets for the (virtual) Internet
  - Packet forwarding

Internet Packet

- Analogous to physical network packet
- Known as *IP datagram*

IP Datagram Layout

- Header contains
  - Source Internet address
  - Destination Internet address
  - Datagram type field
- Payload contains data being carried


-v4 /5x4=20
0
4
8
16
19
24
31
VERS
HLEN
TYPE OF SERVICE
TOTAL LENGTH
IDENT
FLAGS
FRAGMENT OFFSET
TTL
TYPE
HEADER CHECKSUM
SOURCE IP ADDRESS
DESTINATION IP ADDRESS
BEGINNING OF PAYLOAD (DATA)
MSG
3
7
11
15
19
45
TTL=TIME TO LIVE

Addresses In The Header

- SOURCE is the address of original source
- DESTINATION is the address of ultimate destination

IP Versions

- Version field in header defines version of datagram
- Internet currently uses version 4 of IP, IPv4
- Preceding figure is the IPv4 datagram format
- IPv6 discussed later in the course

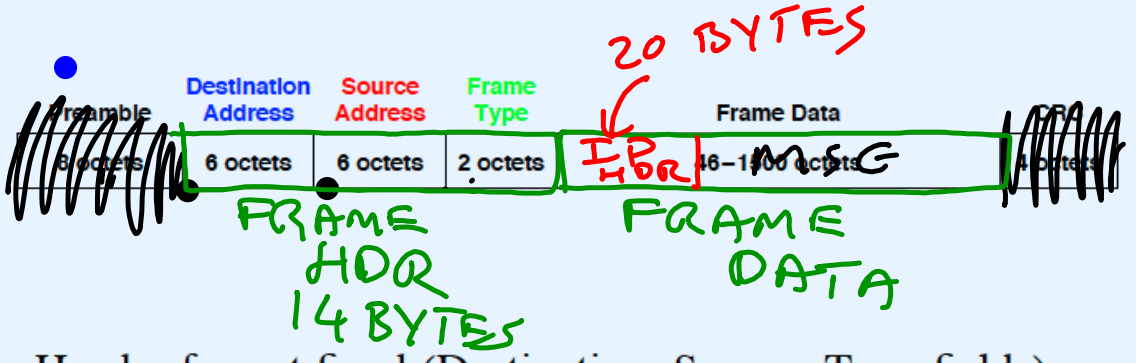
Datagram Encapsulation

- Datagram *encapsulated* in network frame
- Network hardware treats datagram as data
- Frame type field identifies contents as datagram
  - Set by sending computer
  - Tested by receiving computer

Datagram Encapsulation For Ethernet

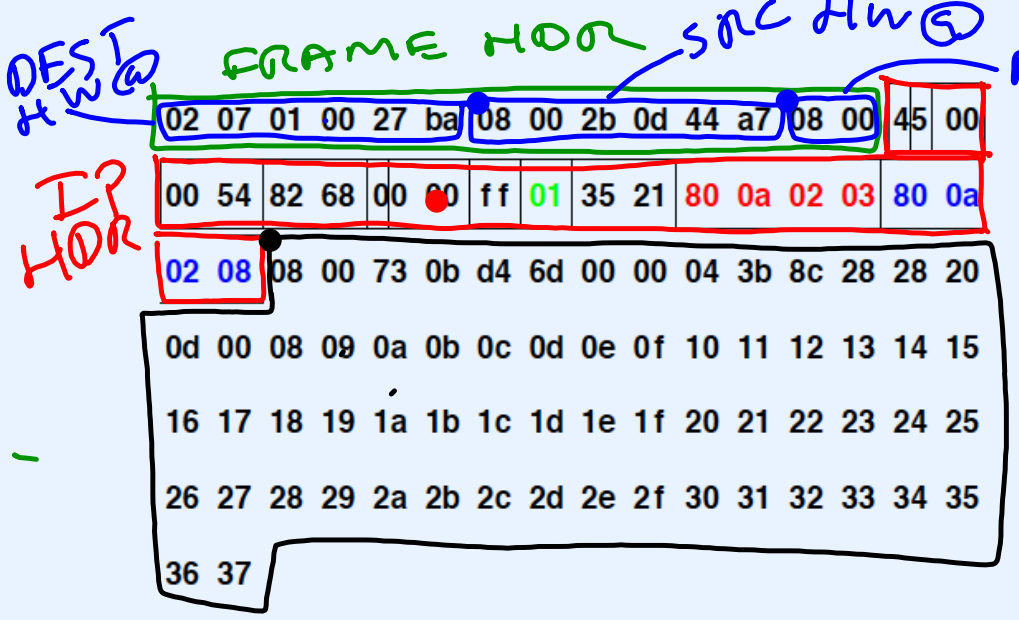
- Ethernet header contains Ethernet hardware addresses
- Ethernet type field set to 0x0800

Ethernet Frame Format



- Header format fixed (Destination, Source, Type fields)
- Frame data size can vary from packet to packet
  - Maximum 1500 octets
  - Minimum 46 octets
- Preamble and CRC removed by framer hardware before frame stored in computer's memory

Datagram Encapsulated In Ethernet Frame



- 20-octet IP header follows Ethernet header
- IP source: 128.10.2.3 (800a0203)
- IP destination: 128.10.2.8 (800a0208)
- IP type: 01 (ICMP)

Standards For Encapsulation

- TCP/IP protocols define encapsulation for each possible type of network hardware
  - Ethernet
  - Frame Relay
  - Others

Encapsulation Over Serial Networks

- Serial hardware transfers stream of octets
  - Leased serial data line
  - Dialup telephone connection
- Encapsulation of IP on serial network
  - Implemented by software
  - Both ends must agree
- Most common standards: Point to Point Protocol (PPP)

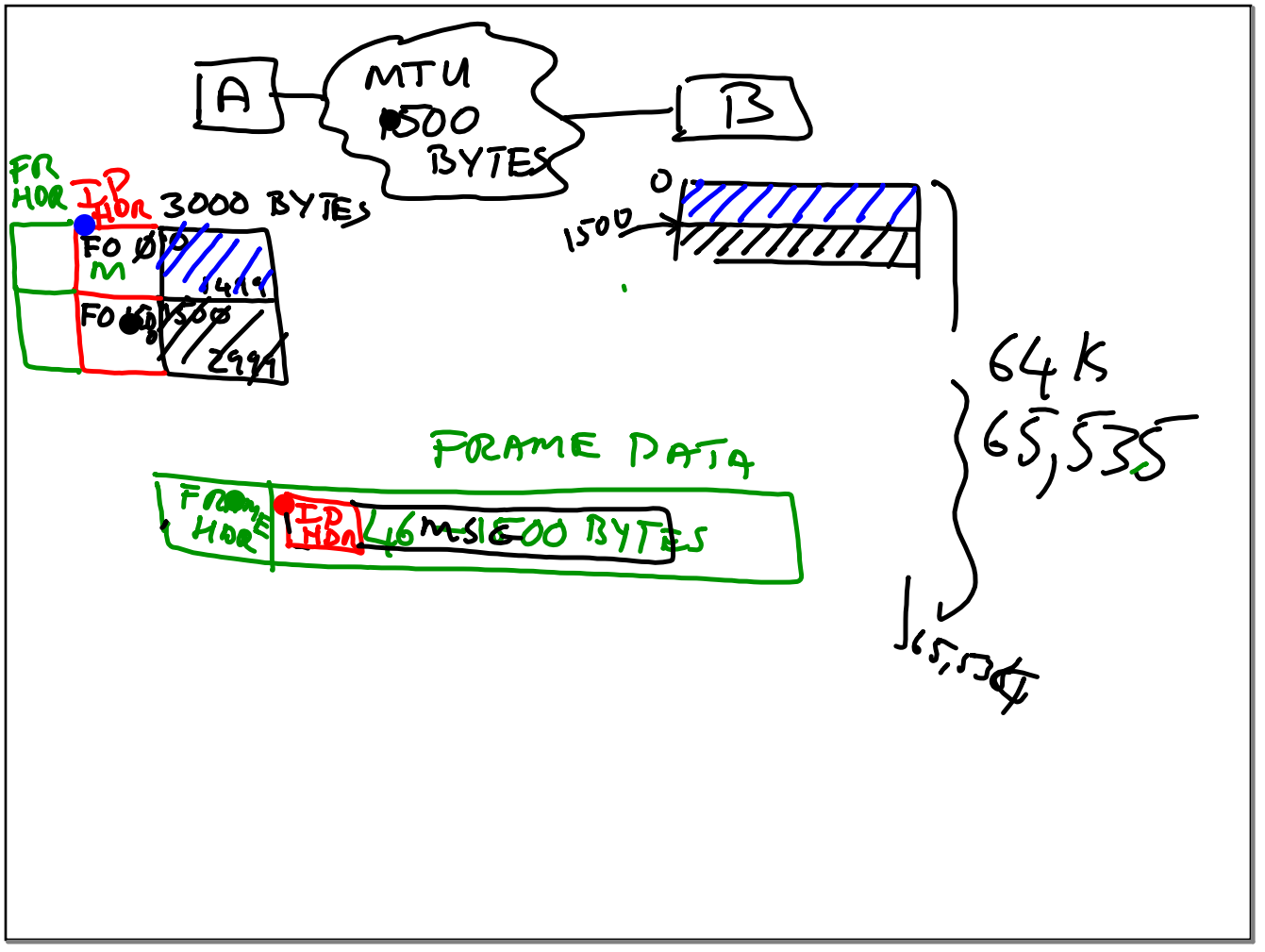
Encapsulation For Avian Carriers (RFC 1149)

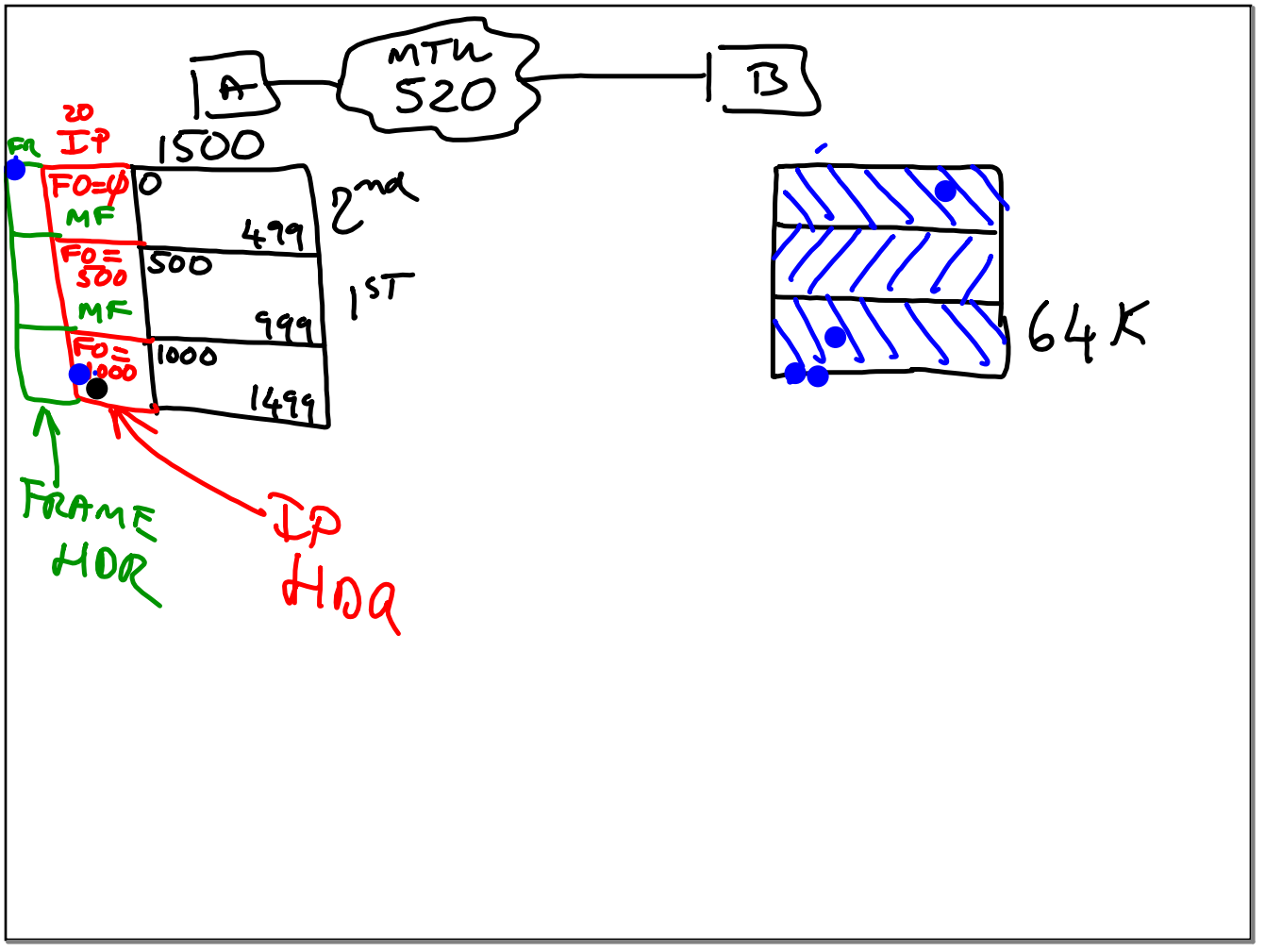
- Characteristics of avian carrier
  - Low throughput
  - High delay
  - Low altitude
  - Point-to-point communication
  - Intrinsic collision avoidance
- Encapsulation
  - Write in hexadecimal on scroll of paper
  - Attach to bird's leg with duct tape
- For an implementation see

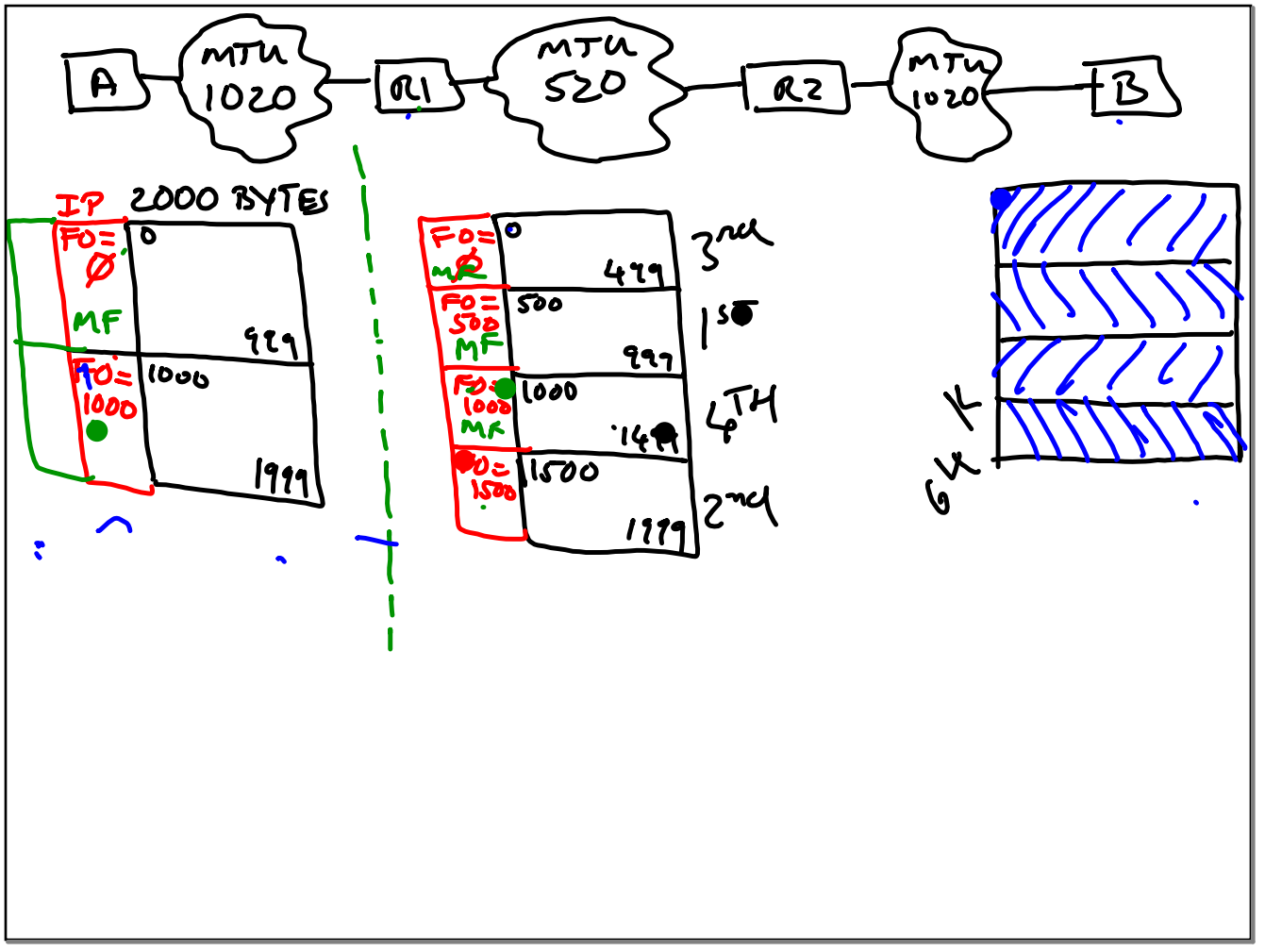
http://www.blug.linux.no/rfc1149

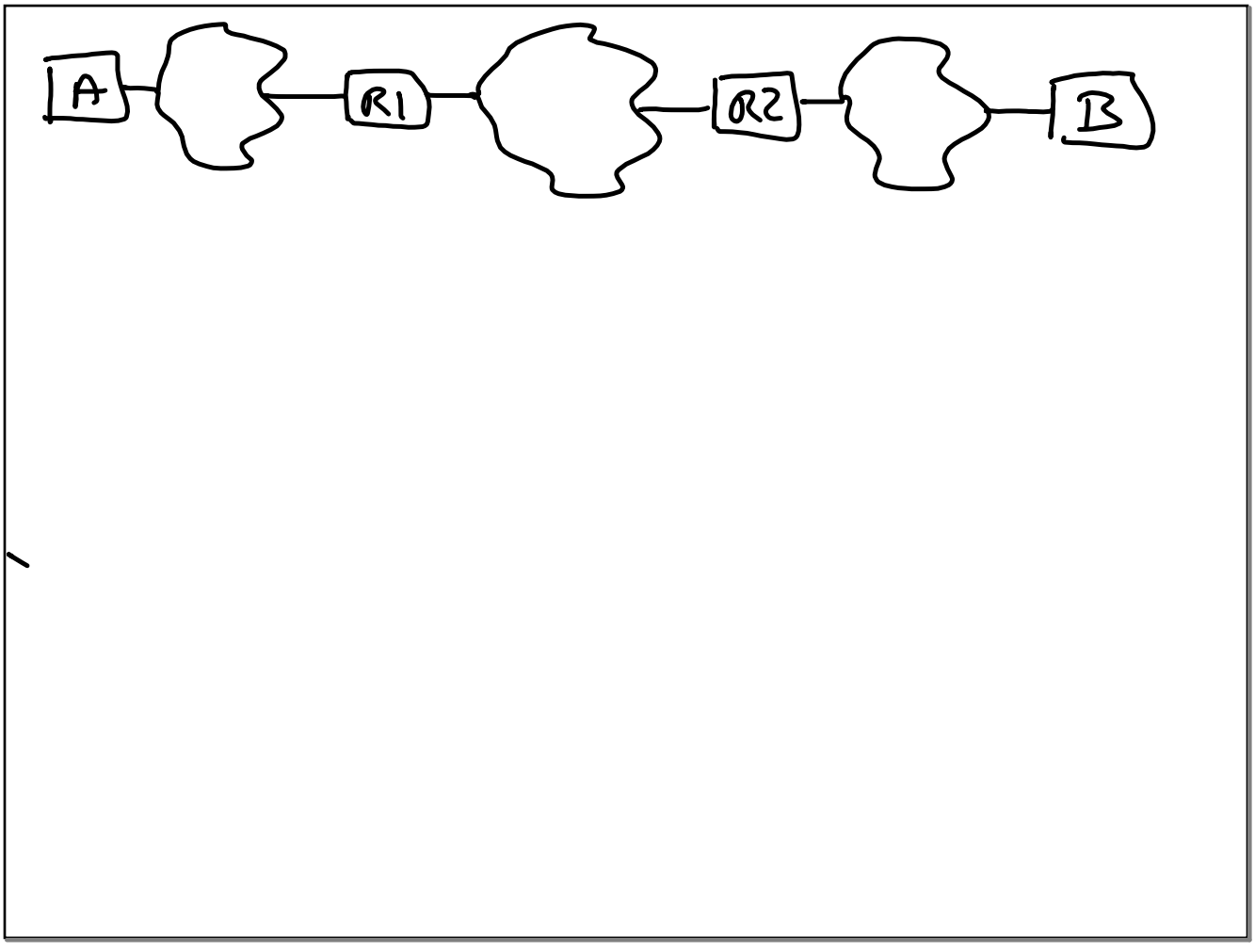
A Potential Problem

- A datagram can contain up to 65535 total octets (including header)
- Network hardware limits maximum size of frame (e.g., Ethernet limited to 1500 octets)
  - Known as the network *Maximum Transmission Unit* (*MTU*)
- Question: how is encapsulation handled if datagram exceeds network MTU?


A
MTU
1500
BYTES
B
FR HDR
IP HDR
3000 BYTES
FO Ø
M
1419
FO
1500
2991
1500
0
64 K
65,535
FRAME DATA
FRAME HDR
IP HDR
1480 BYTES
65,536


A
MTU
520
B
20
IP
1500
FR
FO=0
MF
0
499
2nd
FO=
500
MF
500
999
1ST
FO=
1000
1000
1499
64K
FRAME
HDR
IP
HDR


A
MTU 1020
R1
MTU 520
R2
MTU 1020
B
IP 2000 BYTES
FO= 0
MF
0
999
FO= 1000
1000
1999
FO= 0
MF
0
499
3RD
FO= 500
MF
500
999
1ST
FO= 1000
MF
1000
1499
4TH
FO= 1500
1500
1999
2ND
64K


A
R1
R2
B

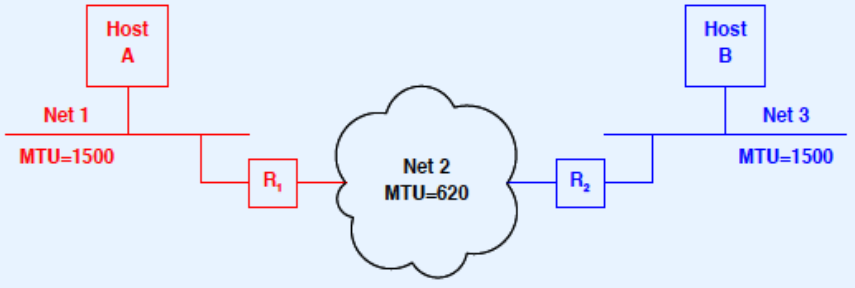
Possible Ways To Accommodate Networks With Differing MTUs

- Force datagram to be less than smallest possible MTU
  - Inefficient
  - Cannot know minimum MTU
- Hide the network MTU and accommodate arbitrary datagram size

Accommodating Large Datagrams

- Cannot send large datagram in single frame
- Solution
  - Divide datagram into pieces
  - Send each piece in a frame
  - Called *datagram fragmentation*

Illustration Of When Fragmentation Needed

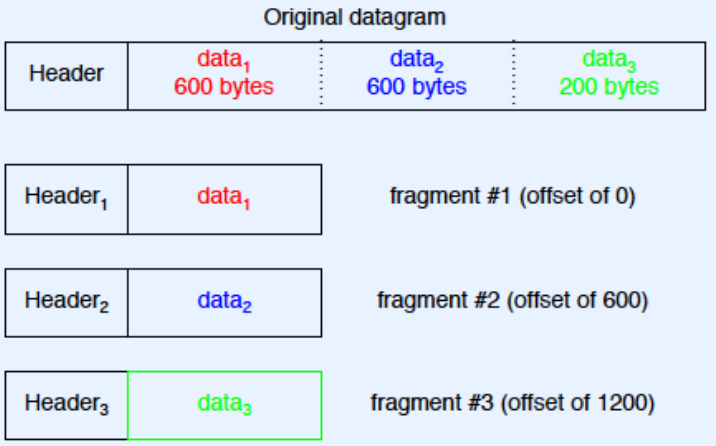


- Hosts A and B send datagrams of up to 1500 octets
- Router R_1 fragments large datagrams from Host A before sending over Net 2
- Router R_2 fragments large datagrams from Host B before sending over Net 2

Datagram Fragmentation

- Performed by routers
- Divides datagram into several, smaller datagrams called fragments
- Fragment uses same header format as datagram
- Each fragment forwarded independently

Illustration Of Fragmentation



- Offset specifies where data belongs in original datagram
- Offset actually stored as multiples of 8 octets
- MORE FRAGMENTS bit turned off in header of fragment #3

Fragmenting A Fragment

- Fragment can be further fragmented
- Occurs when fragment reaches an even-smaller MTU
- Discussion: which fields of the datagram header are used, and what is the algorithm?

- Key concept!
- Needed in a connectionless Internet

- Known as *reassembly*
- No need to reassemble subfragments first
- Timer used to ensure all fragments arrive
  - Timer started when first fragment arrives
  - If timer expires, entire datagram discarded

Time To Live

- TTL field of datagram header decremented at each hop (i.e., each router)
- If TTL reaches zero, datagram discarded
- Prevents datagrams from looping indefinitely (in case forwarding error introduces loop)
- IETF recommends initial value of 255 (max)

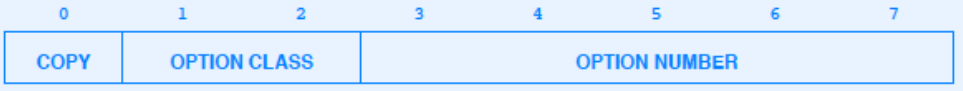
Checksum Field In Datagram Header

- 16-bit 1's complement checksum
- Over IP header only!
- Recomputed at each hop

IP Options

- Seldom used
- Primarily for debugging
- Only *some* options copied into fragments
- Are variable length
- Note: padding needed because header length measured in 32-bit multiples
- Option starts with option code octet

Option Code Octet



Option Class	Meaning
0	Datagram or network control
1	Reserved for future use
2	Debugging and measurement
3	Reserved for future use

IP Semantics

- IP uses best-effort delivery
  - Makes an attempt to deliver
  - Does not guarantee delivery
- In the Internet, routers become overrun or change routes, meaning that:
  - Datagrams can be lost
  - Datagrams can be duplicated
  - Datagrams can arrive out of order or scrambled
- Motivation: allow IP to operate over the widest possible variety of physical networks

Output From PING Program

```
PING venera.isi.edu (128.9.0.32): 64 data bytes
      at 1.0000 second intervals

72 bytes from 128.9.0.32: icmp_seq=0. time=170. ms
72 bytes from 128.9.0.32: icmp_seq=1. time=150. ms
72 bytes from 128.9.0.32: icmp_seq=1. time=160. ms
72 bytes from 128.9.0.32: icmp_seq=2. time=160. ms
72 bytes from 128.9.0.32: icmp_seq=3. time=160. ms

----venera.isi.edu PING Statistics----
4 packets transmitted, 5 packets received,
             -25% packet loss
round-trip (ms)  min/avg/max = 150/160/170
```

- Shows actual case of duplication

Summary

- Internet Protocol provides basic connectionless delivery service for the Internet
- IP defines *IP datagram* to be the format of packets on the Internet
- Datagram header
  - Has fixed fields
  - Specifies source, destination, and type
  - Allows options
- Datagram encapsulated in network frame for transmission

Summary
(continued)

- Fragmentation
  - Needed when datagram larger than MTU
  - Usually performed by routers
  - Divides datagram into fragments
- Reassembly
  - Performed by ultimate destination
  - If some fragment(s) do not arrive, datagram discarded
- To accommodate all possible network hardware, IP does not require reliability (best-effort semantics)