Network Layer

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Fragmentation

- All networks have a maximum size for packets (Maximum Transmission Unit, MTU)
  - Hardware and operating system
  - Protocols and
  - Efficiency of t
- Solution: fragmentation
  - divides packets into fragments w ckets need to be routed through a network whose maximum packet size is too small.

Types of Fragmentation (1)

- **Solution: Fragmentation and Reassembly**.
- **Transparent:** packets fragmented & reassembled in each network. Route constrained, more work.

G_1 fragments G_2 reassembles G_3 fragments G_4 reassembles

Types of Fragmentation (2)

- **Solution: Fragmentation and Reassembly**.
- **Non-transparent:** fragments are reassembled at destination. Router has less work. IP works this way. Each packet requires packet number, byte offset, end of packet flag

G_1 fragments

reassemble at destination

IP-Style Fragmentation

Byte offset

Original packet:
(10 data bytes)

Fragmented:
(to 8 data bytes)

Re-fragmented:
(to 5 bytes)

Path MTU Discovery

- Alternative to Fragmentation
- Advantage: the source knows what length packet to send
- If the routes and path MTU change, new error packets will be triggered and the source will adapt to the new path

Try 1200
(error packet)

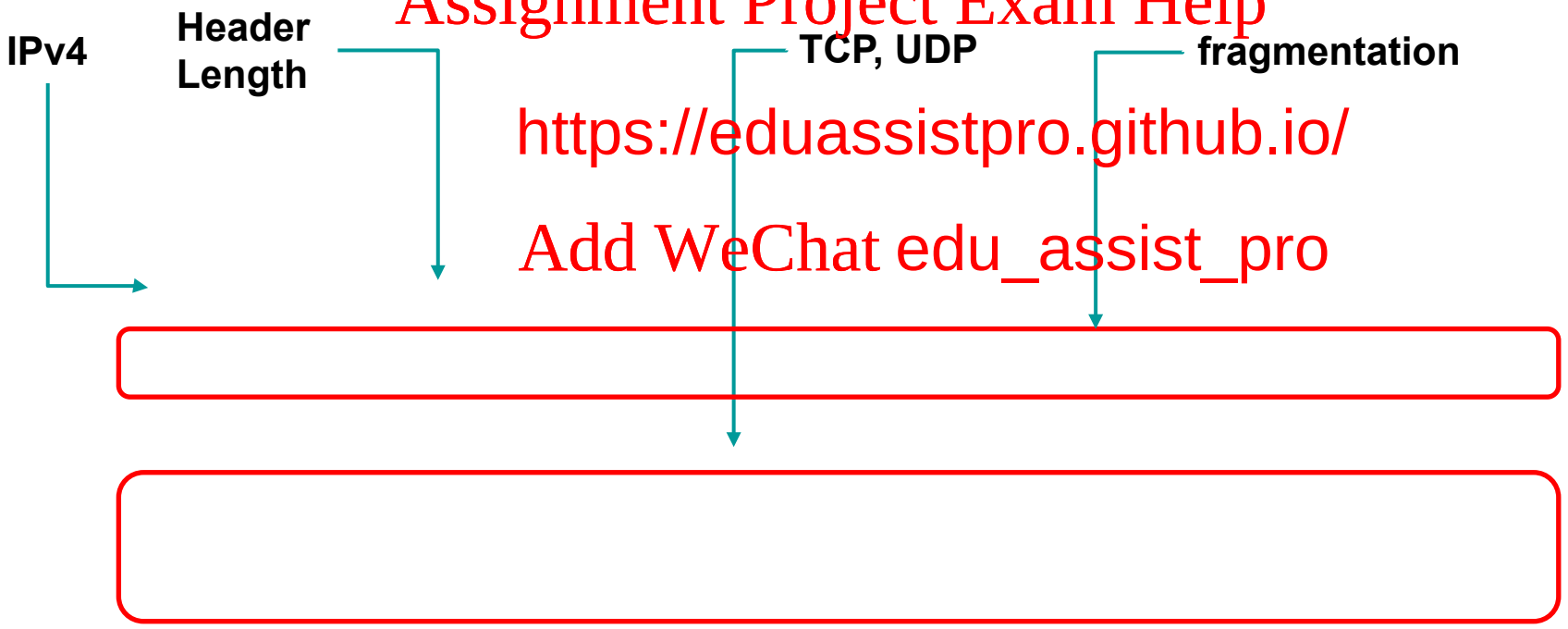
Try 900
(error packet)

Outline

- Network layer in the Internet
- Types of services
- Internetworking
  - Tunneling
  - Fragmentation
  - Path MTU discovery
- Internet Protocol
  - Addressing
  - Subnetting
- Routing algorithms

IPv4 Datagram Structure (1)

- **IPv4 (Internet Protocol) datagram** consists of a header and payload
- **IPv4 header** has fields for the key parts of the protocol
- **Header format**: 20-byte fixed part + variable-length optional part



IPv4 Datagram Structure (2)

- **IHL**: Internet Header Length, in 32-bit units, min is 5 and max is 15
- **Differentiated services**: different classes of service
- **Total Length**: header and payload, max length 65535 bytes

- **Identification**:
  - Allows host to dete ment belongs to.
  - All fragments of same datagram have sa
- **DF**: Don't Fragment
  - is used as part of the process to discover the path MTU
- **MF**: More Fragment, is this the last one?
- **Fragment offset**: where in the datagram the current fragment belongs

IPv4 Datagram Structure (3)

- **TTL**: Time to live, limits packet lifetimes in hops or seconds
- **Protocol**: TCP, UDP
- **Header Checksum**: verifies the header only

- **Source Address**:

- **Destination Add** ver

- **Options**: e.g. security, strict vs. loose source routing, record route, timestamp

IP Addresses (1)

- IP address (IPv4) is 32-bit long, written in dotted decimal notation

128.18.3.11

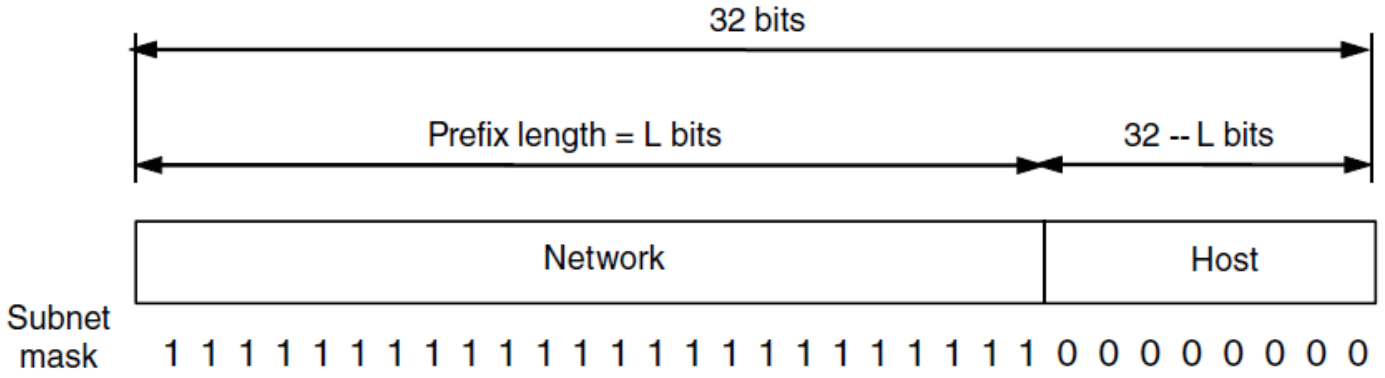
- Addresses are **hierarchical** and c d in **blocks**

  e.g. 256 addresses in the block 128.18.3.0 – 128.18.3.255
- Overall, IP allocation is managed by Internet Corporation for Assigned Names and Numbers (ICANN)

IP Addresses (2)

- network portion + host portion
- **Prefix:** determined by the network portion, all hosts on a single network has the same network portion.
  prefix is written as: lowest address/bit-length

- **Subnet mask**:
- **Extract** prefix: AND the IP address and the subnet mask



IP Addressing and Routing Tables

- Routing tables are typically built on a triplet:
  - Prefix Address
  - Subnet Mask
  - Outgoing Line
- Example: a ro

Prefix	Subnet M	nterface
128.18.3.0/24	255.255.255.0	Eth 0