Simple Internetworking: Overview and IP Packet Format

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Outline

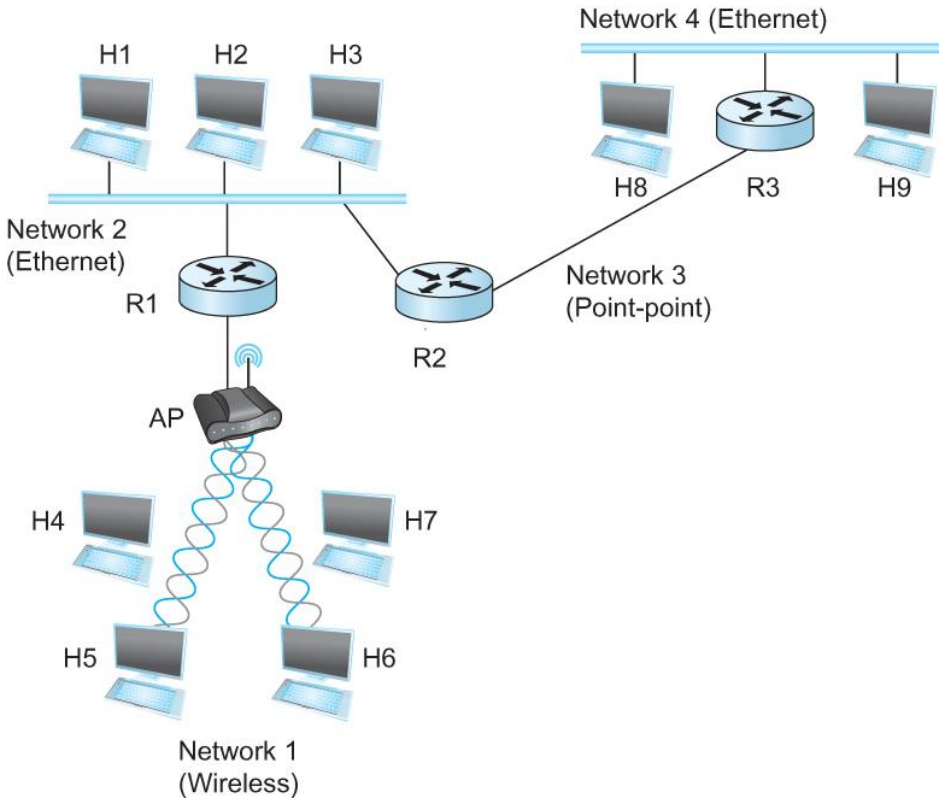
- Topic: internetworking
  - Case study: Internet Protocol (IP) Suite
- Simple interworking
  - **Overview of internet and the Internet**
  - **IP packet format**
  - Global addressing scheme
  - Best effort service model and datagram forwarding
  - Packet fragmentation and assembly
  - Address translation
  - Host configuration
  - Error reporting

Heterogeneity and Scalability

- LAN: small in size
- How to extend LAN?
  - Bridges and switches
  - Good for global networks?
    - Spanning tree algorithms → very long path and huge forwarding tables
    - Bridges and switches: link level/layer 2 devices → networks must be using the same type of links
- Problems to deal with
  - Scalability: global networks are huge in size
  - Heterogeneity: networks of different types of links are in use

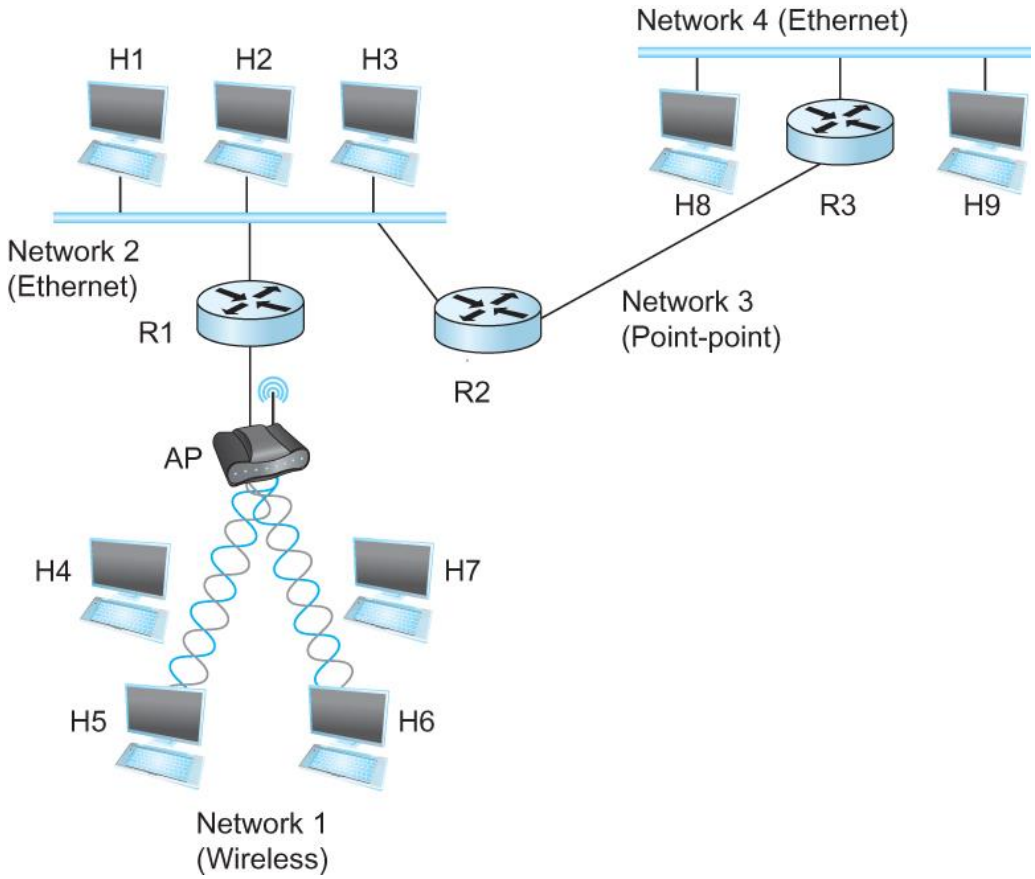
Network of Networks: internetworking

- An arbitrary collection of networks interconnected to provide some sort of host-host to packet delivery service



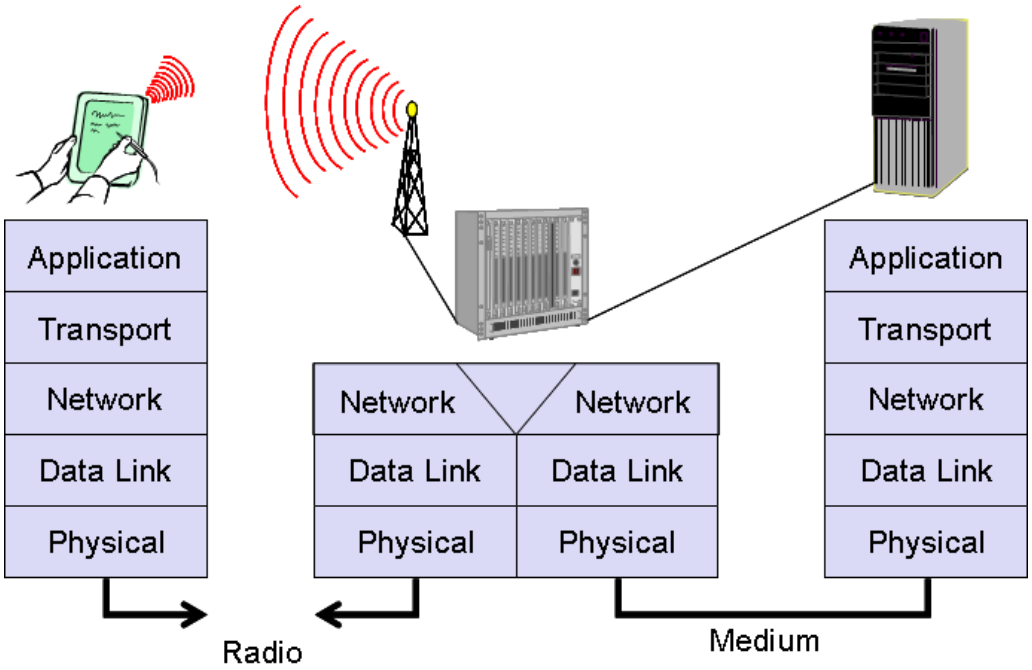
Solution to Scalability: Network of Networks

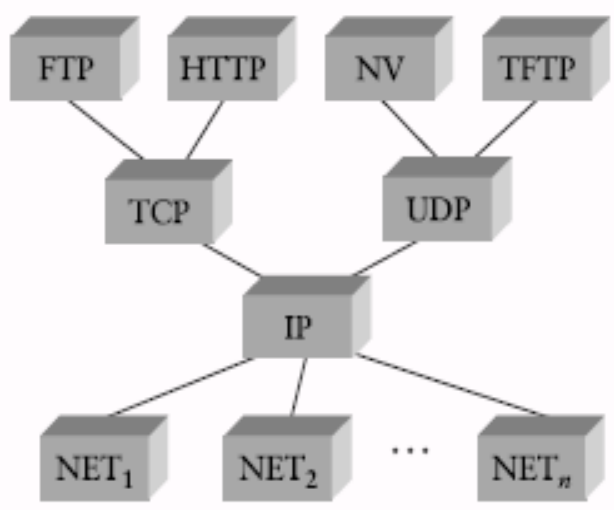
- Forwarding packets to networks from networks: smaller forwarding tables



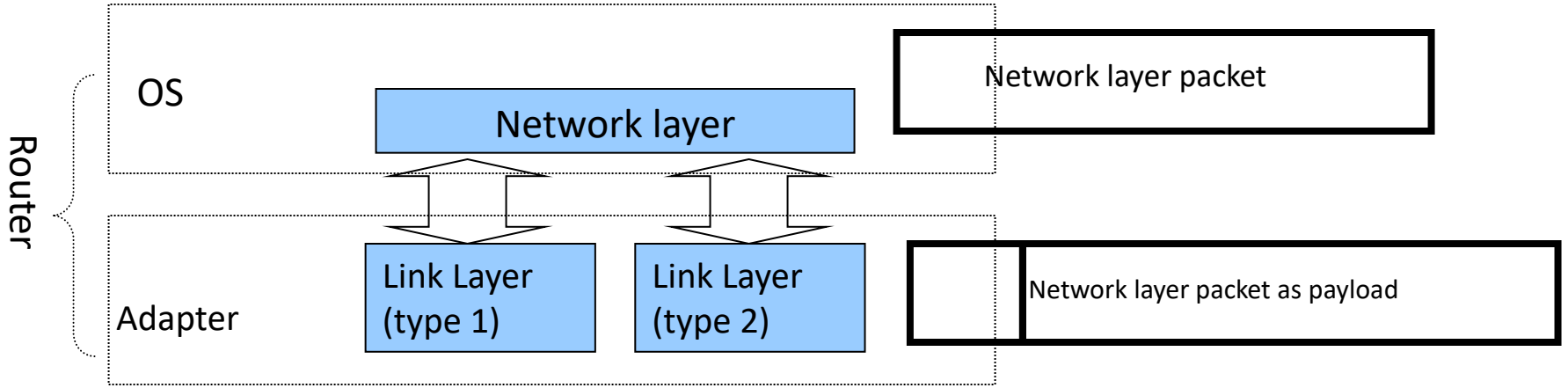
Solution to Heterogeneity: layered architecture and hourglass design

- Network layer encapsulates the heterogeneity and the complexity of data link and physical layers (or the host-to-network layer)



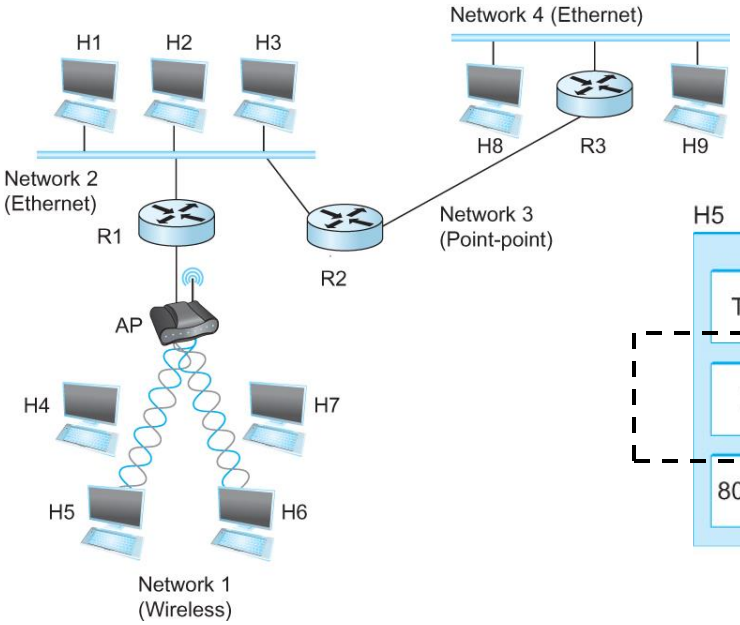


Network Layer and Lower Layers

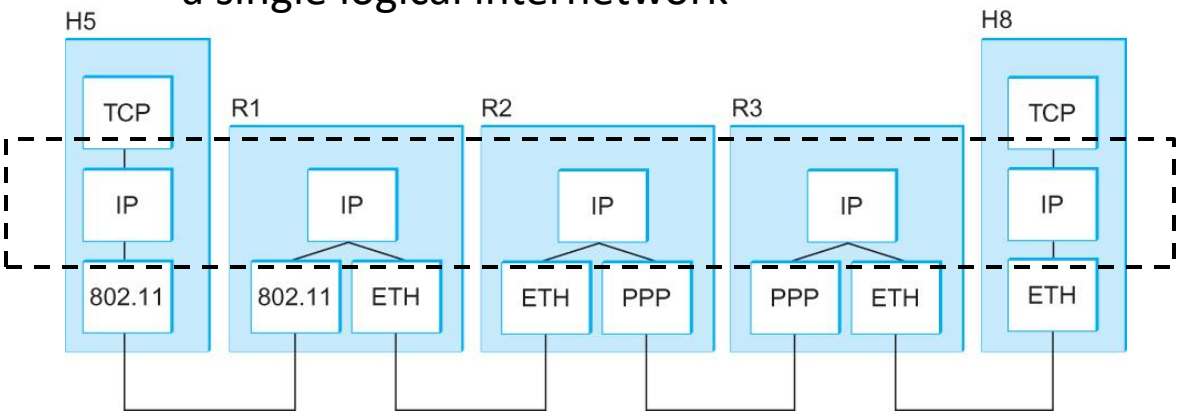


Internet Protocol

- IP = Internet Protocol
- Key tool used today to build scalable, heterogeneous internetworks
  - Routers forward packets to "**networks**": forwarding tables can be smaller
  - Above link layer: can cope with different link layer technology



- Runs on all the nodes in a collection of networks
- Defines the infrastructure
- Allows these nodes and networks to function as a single logical internetwork



IP Service Model: Application of Datagram Switching

- Packet Delivery Model
  - Connectionless model for data delivery
  - Best-effort delivery (unreliable service)
    - packets may be lost
    - packets may be delivered out of order
    - duplicate copies of a packet may be delivered
    - packets may be delayed for a long time
- Global Addressing Scheme
  - Provides a way to identify all hosts in the network
- Datagram switching
  - Forward packets to networks

IP: Application of Datagram Switching

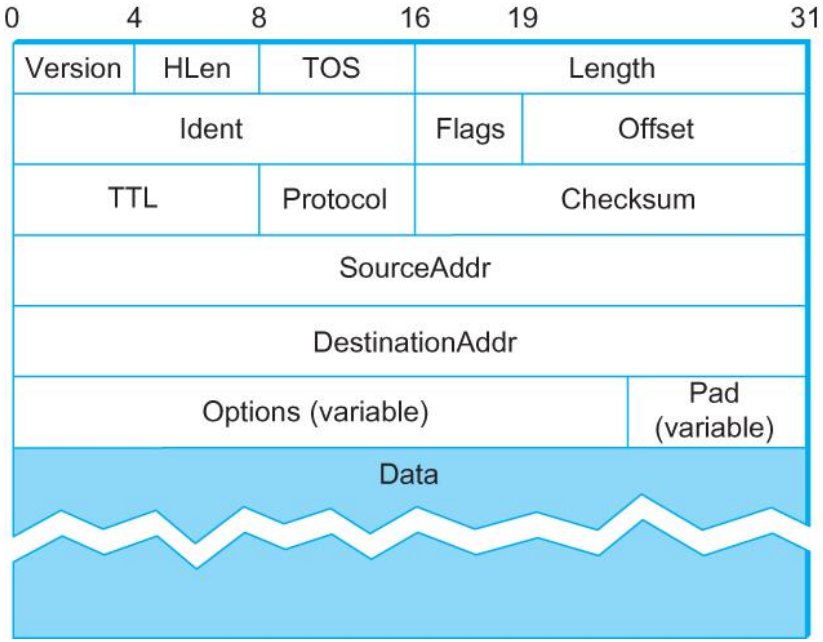
- Forward packets to networks
  - How do we define networks?
- Essential data structure: IP packet format
- Global addressing schemes
- Datagram forwarding

Basic Data Structure: IP Packet

- Design Goals
  - Attributes and purposes
    - Support error detection and handling
    - Support networks as a forwarding source and destinations
    - Support different networking technologies
    - Support multiplexing
    - Support extensibility

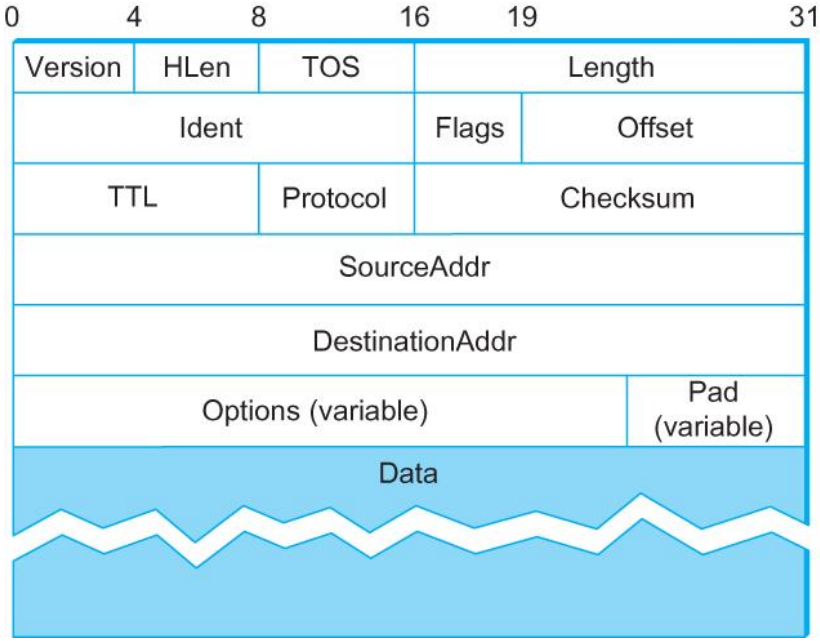
IP Packet Format

- Discussing IP version 4 (IPv4). Discussing IP version 6 (IPv6) in later lessons
  - Convention used to illustrate IP packet
    - 32 bit words
    - Top word transmit first
    - Left-most byte transmit first



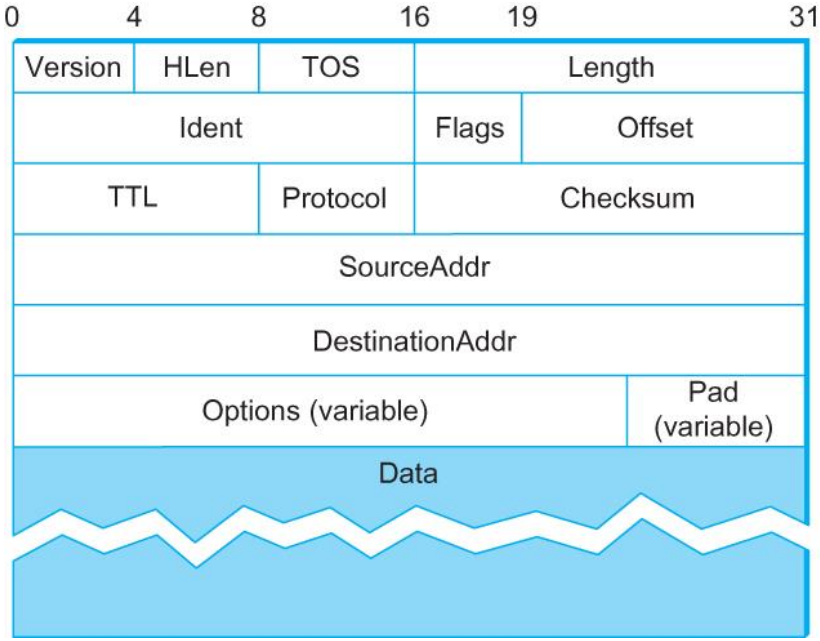
IPv4 Packet Format

- Version (4): 4 or 6. The rest is for version 4. Discussing 6 in later lessons
- Hlen (4): number of 32-bit words in header
- TOS (8): type of service (not widely used)
- Length (16): number of bytes in this datagram
- Ident (16): used by fragmentation
- Flags/Offset (16): used by fragmentation
- TTL (8): number of hops this datagram has traveled
- Protocol (8): demux key (TCP=6, UDP=17)
- Checksum (16): of the header only
- DestAddr & SrcAddr (32)



IPv4 Packet Format: Essential Problems and Solutions

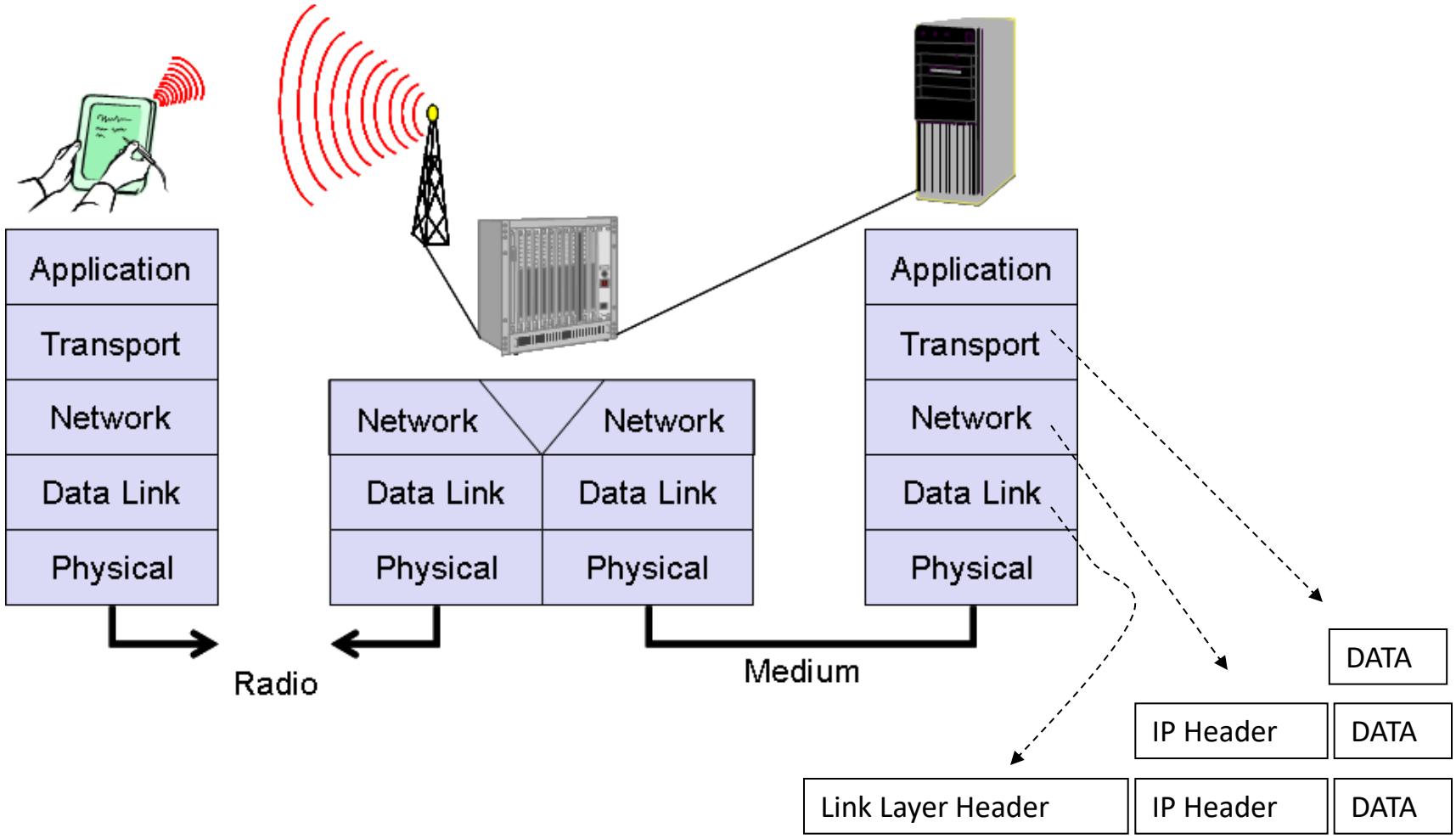
- The packet is designed to address a few essential problems:
- Scalability and Heterogeneity problems:
  - IP datagram forward: application of datagram switching
  - Fields: SourceAddr, DestinationAddr, Length
- Heterogeneity problem
  - Packet fragmentation
  - Fields: Ident, Flags, Offset, Length
- Quality of service and serving upper layers
  - TOS, Protocol
- Error detection
  - Checksum
- Extensibility
  - Version, HLen, Optional Fields



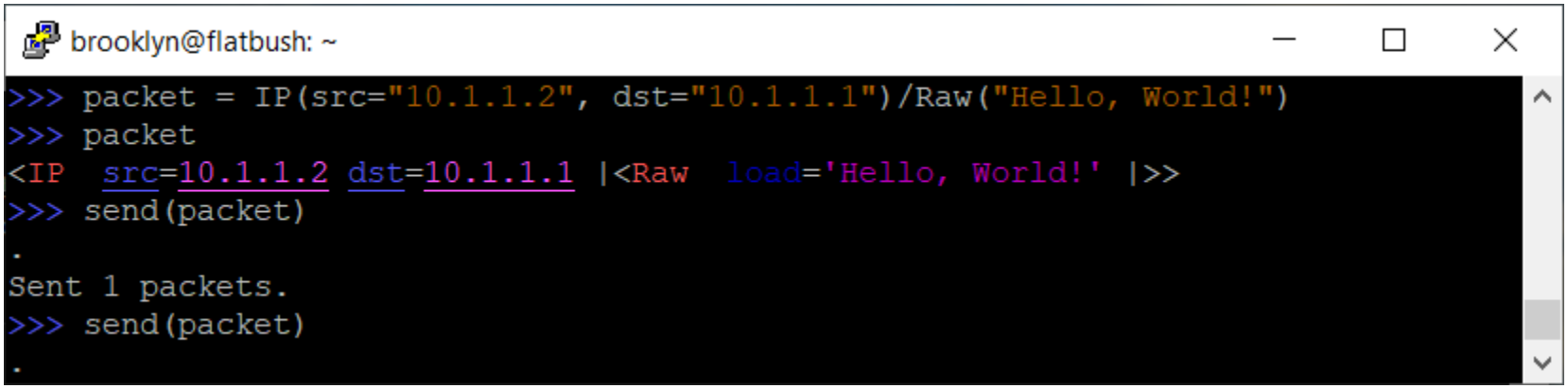
Capturing an IP Packet

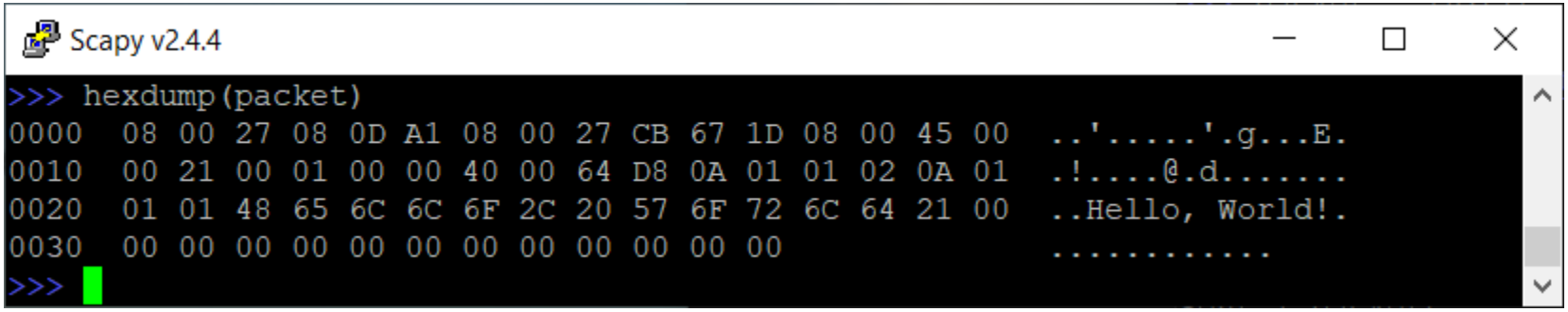
- And examining it …

IP Packet


Application
Transport
Network
Data Link
Physical
Network
Network
Data Link
Data Link
Physical
Physical
Application
Transport
Network
Data Link
Physical
Radio
Medium
DATA
IP Header
DATA
Link Layer Header
IP Header
DATA

A Captured IP Packet





Ethernet Protocol Numbers

VIM - /usr/include/net/ethernet.h

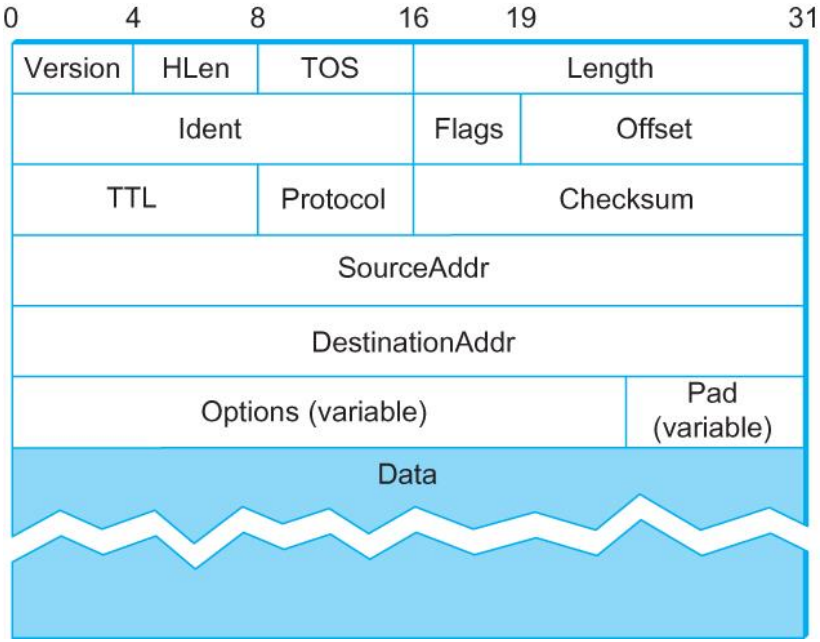
```
/* 10Mb/s ethernet header */
struct ether_header
{
  u_int8_t  ether_dhost[ETH_ALEN];  /* destination eth addr */
  u_int8_t  ether_shost[ETH_ALEN];  /* source ether addr    */
  u_int16_t ether_type;             /* packet type ID field */
} __attribute__ ((__packed__));

/* Ethernet protocol ID's */
#define ETHERTYPE_PUP         0x0200          /* Xerox PUP */
#define ETHERTYPE_SPRITE      0x0500      /* Sprite */
#define ETHERTYPE_IP          0x0800      /* IP */
#define ETHERTYPE_ARP         0x0806      /* Address resolution */
#define ETHERTYPE_REVARP      0x8035      /* Reverse ARP */
#define ETHERTYPE_AT          0x809B      /* AppleTalk protocol */
#define ETHERTYPE_AARP        0x80F3      /* AppleTalk ARP */
#define ETHERTYPE_VLAN        0x8100      /* IEEE 802.1Q VLAN tagging */
#define ETHERTYPE_IPX         0x8137      /* IPX */
#define ETHERTYPE_IPV6        0x86dd      /* IP protocol version 6 */
#define ETHERTYPE_LOOPBACK    0x9000      /* used to test interfaces */


#define ETHER_ADDR_LEN  ETH_ALEN                /* size of ethernet addr */
"/usr/include/net/ethernet.h" [readonly] 84L, 3221C           49,1          60%
```

Exercise 1

- Below shows a captured Ethernet frame
  - Q1: what is the length in bytes of the largest IP packet?
  - Q2: what is the length in bytes of the smallest IP packet?
  - Q3: what are the values (bits) of each field in the IP packet below (underlined). Which byte is the last byte of this IP packet?




```
0000   00 23 ae 7b 49 11 00 13 72 8f ba 11 08 00 45 00
0010   00 28 78 41 40 00 80 06 fe d4 c0 a8 01 34 c0 a8
0020   01 35 07 e3 00 16 b6 c0 0a da b6 1e 1a b7 50 10
0030   f1 80 a0 30 00 00 00 00 00 00 00 00
```

Summary

- Overview of Internetworks and simple Internet
- IP packet format
  - Packet format
  - Overview of problems and solutions

Summary: Essential Problems and Solutions

- Global internetworks built on IP → The Internet ≠ internet
- Using Internet Protocol (IP) as a case study
  - IP packet format
  - Global IP addressing scheme
  - Datagram forwarding and service model
  - Deal with Link layer and network layer interfacing
    - Packet fragmentation and assembly
    - Address translation
  - Other important issues
    - Host configuration
    - Error reporting