MODULE 11: The Internet Protocol Suite

Lecture 11.3
Internet Protocol (IP)

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Lecture 11.3 Objectives

- Enumerate the services provided by IP
- Describe the format of IP datagrams and the IP header fields
- Discuss IP fragmentation
- Describe addressing in IPv4, including Classless Interdomain Routing (CIDR)
- Given a network address and subnet mask, identify what host addresses can be assigned in that network

TCP/IP Network Layer Components

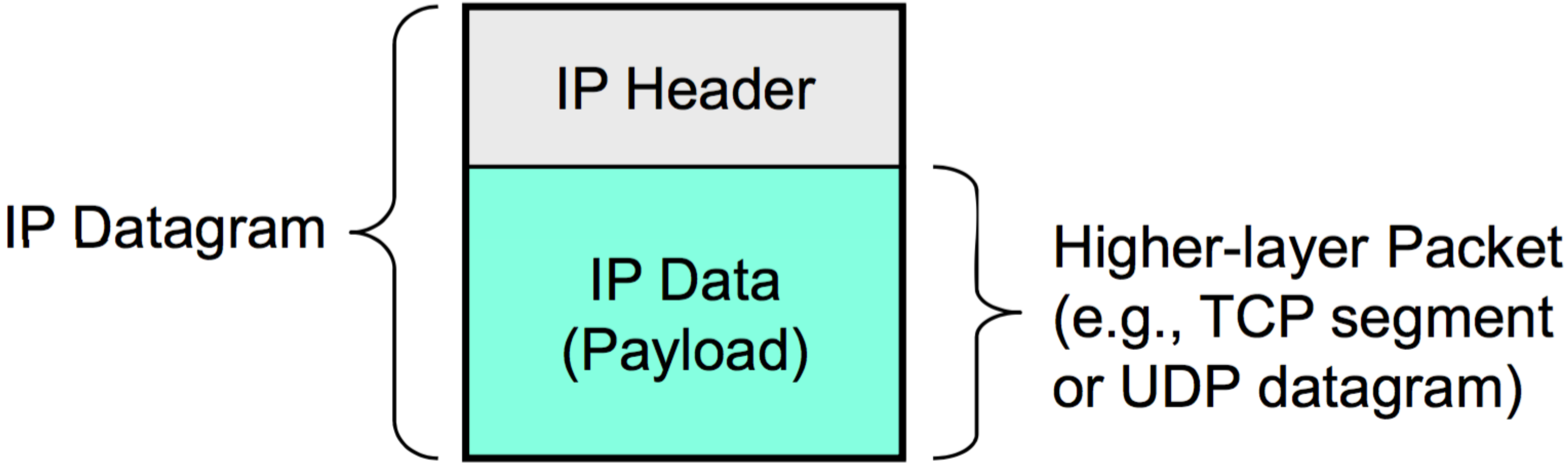
- Internet Protocol (IP)
  - Addressing conventions
  - Datagram format
  - Packet handling conventions, including fragmentation
- Routing protocols (e.g., OSPF and BGP)
  - Path selection by building the forwarding table
- Internet Control Message Protocol (ICMP)
  - Error messages
  - Status messages
  - Router signaling messages

Internet Protocol Service Model

- The Internet Protocol (IP) provides service to deliver datagrams across networks through routers
- IP provides unreliable datagram service
  - Datagrams (packets) may or may not be delivered
  - Datagrams may arrive at destination out of order
  - Datagrams may be arbitrarily delayed

IP Datagrams

- IP datagrams include
  - Header with minimum size of 20 bytes (five 32-bit words)
  - Data



IP Datagram Format

<table>
<tr><th>0</th><th>4</th><th>8</th><th></th><th>16</th><th></th><th>24</th><th>31</th></tr>
<tr><td>Vers</td><td>HLen</td><td colspan="2">ToS</td><td colspan="4">Total Length</td></tr>
<tr><td colspan="4">Identification</td><td>Flags</td><td colspan="3">Fragment Offset</td></tr>
<tr><td colspan="2">Time To Live</td><td colspan="2">Protocol</td><td colspan="4">Header Checksum</td></tr>
<tr><td colspan="8">Source IP Address</td></tr>
<tr><td colspan="8">Destination IP Address</td></tr>
<tr><td colspan="6">IP Options (if any)</td><td colspan="2">Padding</td></tr>
<tr><td colspan="8">Data</td></tr>
</table>

IP: Header Fields

- Identification: unique datagram identifier
- Total Length: length of this datagram, with header, in bytes
  - Hosts required to accept datagrams up to 576 bytes
  - Many applications (e.g., NFS) accept up to 8,192 bytes
  - Datagram may be fragmented
- Internet Header Length: length of header in 32-bit words
- Fragment Offset: offset of fragment in this datagram in 8-byte units
- Flags: indicate if this is last fragment and if datagram should not be fragmented

IP: Header Fields (2)

- Time to live: maximum number of routers through which the datagram may pass
  - Decremented at each router
  - Used to prevent looping in the network
- Protocol: identifies higher level protocol that provided data
- Version: IP version identifier (most common is 4, though 6 is increasingly common)
- Type of Service: used when service differentiation is implemented (rarely used)
- Header Checksum: checksum over header (protects addresses, lengths, etc.) – 16-bit one's complement sum

IP: Header Fields (3)

- Source IP Address: full address of source node
- Destination IP Address: full address of destination node
- Options (may not be supported by all routers):
  - Examples: security and handling restrictions, source routing

CHECK POINT

As a checkpoint of your understanding, please pause the video and make sure you can do the following:

- Enumerate the services provided by IP
- Describe the format of IP datagrams and the IP header fields

If you have any difficulties, please review the lecture video before continuing.

IP Fragmentation

- When required, packets are fragmented on 8-byte boundaries
- Fragmentation may occur at any IP entity that sends a datagram
  - Original host
  - Intermediate router
- Receiver reconstructs fragments using fragment length, fragment offset, datagram ID, and last fragment flag

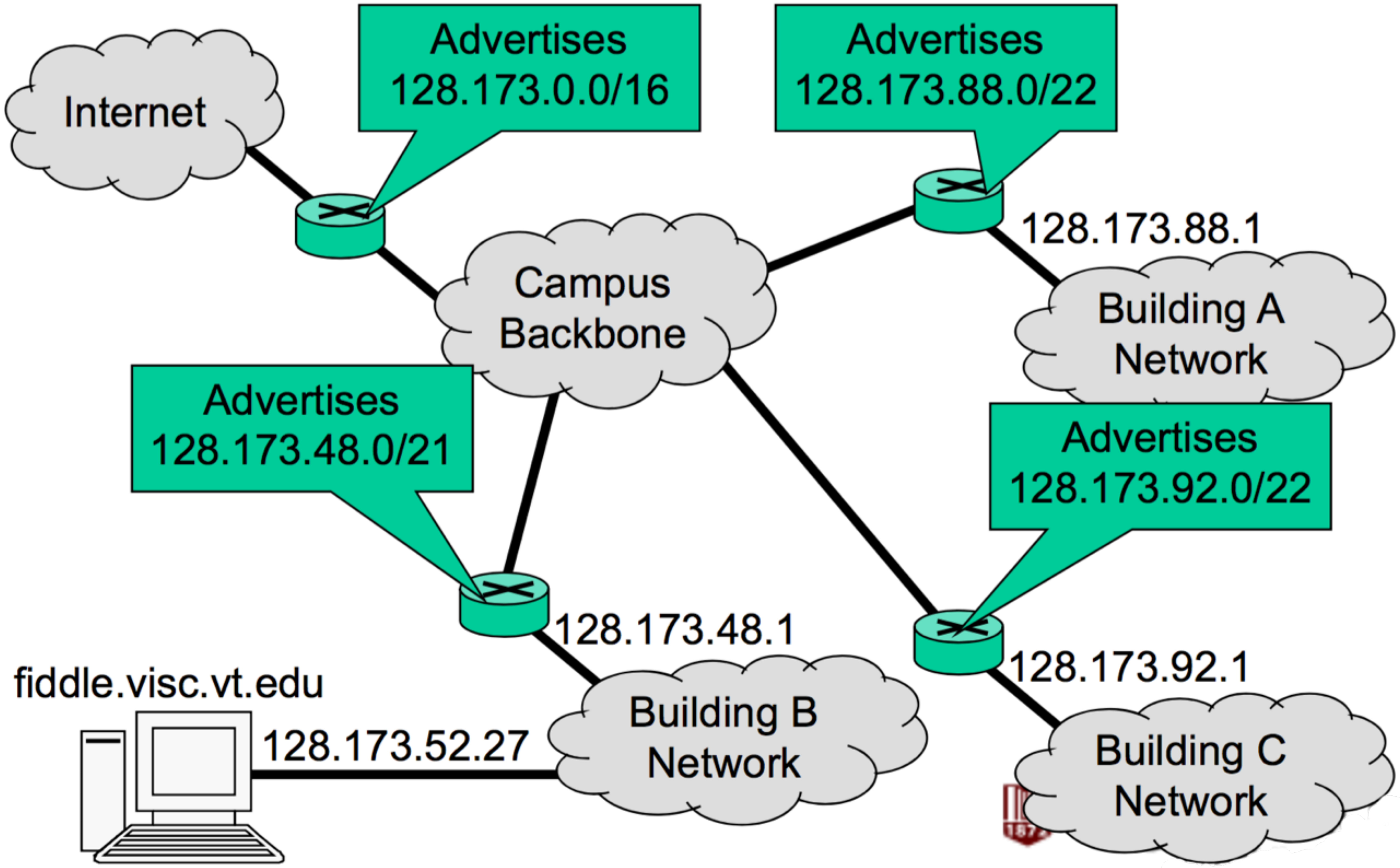
IPv4 Addressing

- Hierarchical 32-bit addresses identify a connection to a network, i.e., an interface, rather than a specific machine
  - Network (site) – smaller number of networks
  - Host – huge number of hosts
- Need a way to determine the network identifier and the host identifier
  - IP addressing initially based on five “classes” of IP addresses
  - Since the early 1990’s, the more flexible Classless Interdomain Routing (CIDR) scheme has been in use

Classless Interdomain Routing

- CIDR requires that two pieces of information be available to determine the network identifier and host identifier
  - IP address, which contains the actual identifiers
  - A network mask or network field size that indicates the number of bits used for the network identifier
- Example: Network = 128.173.0.0, Host = 52.27
  - CIDR specification: 128.173.52.27/16
    - a.b.c.d/16 indicates that the leading 16 bits are the network identifier
  - Network mask: 255.255.0.0
    - 1 in mask indicates that this is part of the network id

CIDR Addressing Example



CIDR Addressing Example (cont'd)

- Example subnet sizes
  - Building A and Building C networks
    - 22-bit network id ⇒ 10-bit host id ⇒ ~1,000 hosts
  - Building B network
    - 21-bit network id ⇒ 11-bit host id ⇒ ~2,000 hosts
    - IP addresses 128.173.48.0–128.173.55.255
- Suppose a packet is addressed to fiddle in the Internet
  - Internet backbone routes to 128.173.0.0/16 (VTnetwork)
  - Campus backbone routes to 128.173.48.0/21 (Bldg.B)
  - Packet is delivered to 128.173.52.27 (fiddle.visc.vt.edu)

CHECK POINT

As a checkpoint of your understanding, please pause the video and make sure you can do the following:

- Discuss IP fragmentation
- Describe addressing in IPv4, including Classless Interdomain Routing (CIDR)
- Given a network address and subnet mask, identify what host addresses can be assigned in that network

If you have any difficulties, please review the lecture video before continuing.

Summary

- IP provides unreliable datagram service
- Header identifies source and destination IP addresses, the protocol that the payload encapsulates, and information required for fragmentation and reassembly
- In IPv4, hierarchical 32-bit IP addresses identify a connection to a network
- In CIDR, a network mask distinguishes between the host and the network identifiers that are part of an IP address

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