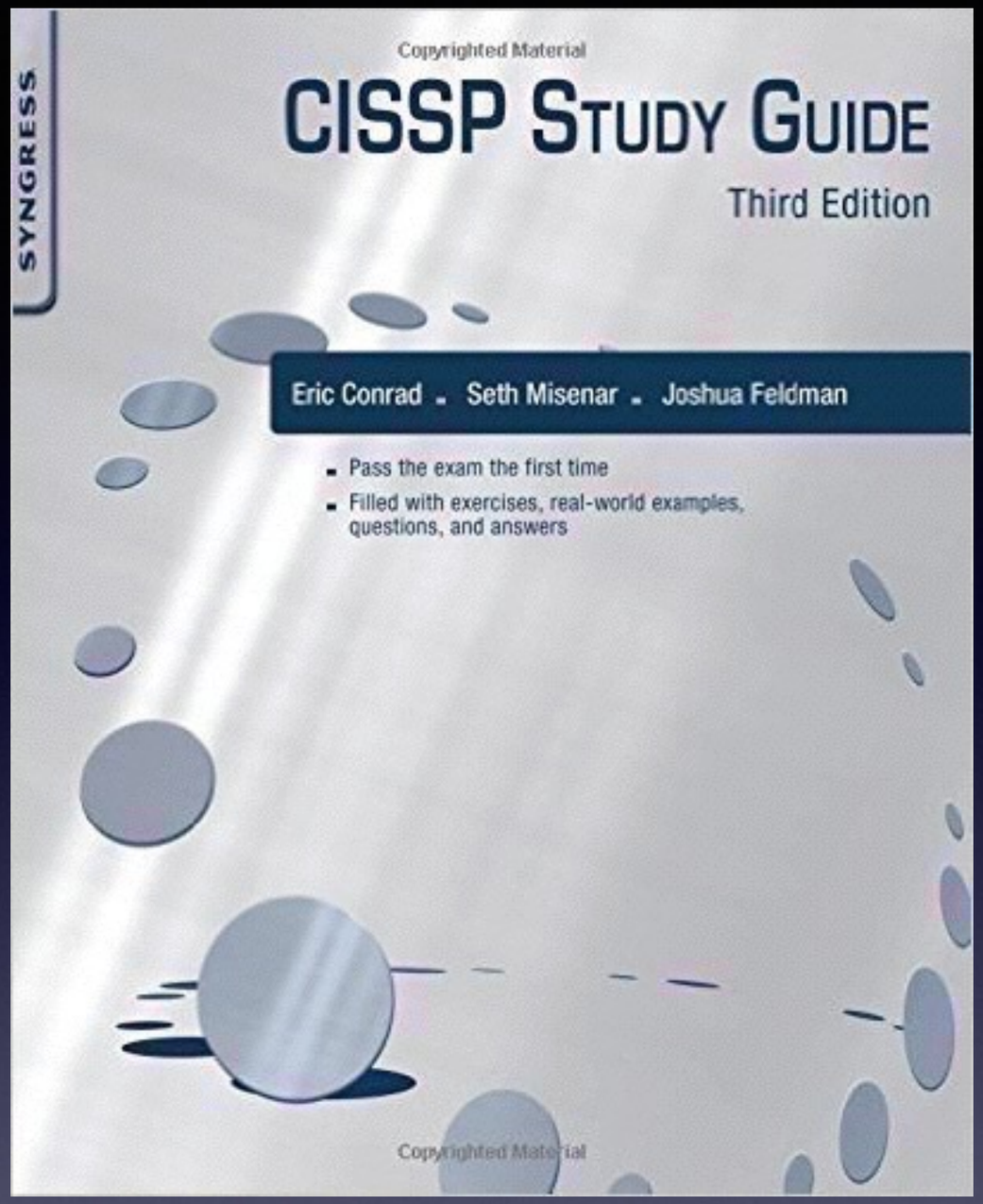
CNIT 125: Information Security Professional (CISSP Preparation)



Ch 5. Communication and Network Security (Part 1)

Network Architecture and Design

Fundamental Network Concepts

- **Simplex**
  - **One-way communication, like an FM radio**
- **Half Duplex**
  - **Sends or receives, but not both at once, like a walkie-talkie**
- **Full Duplex**
  - **Sends & receives simultaneously, like a telephone**

Fundamental Network Concepts

- **Baseband**
  - **Whole frequency range dedicated to one signal, like Ethernet**
- **Broadband**
  - **Multiple channels, each gets only a portion of the bandwidth**
  - **Like broadcast FM radio**

Fundamental Network Concepts

- **Analog**
  - **Continuous variations of signal**
  - **Signal degrades over distance and when repeated**
  - **Like a vinyl record**
- **Digital**
  - **Signal is a series of zeroes and ones**
  - **Can be transmitted and repeated with no loss of accuracy**
  - **Like a CD**

Fundamental Network Concepts

- **LAN (Local Area Network)**
  - **Within a building**
- **MAN (Metropolitan Area Network)**
  - **Within a city**
- **WAN (Wide Area Network)**
  - **Covering cities, states, or countries**
- **GAN (Global Area Network)**
  - **A global collection of WANs**
- **PAN (Personal Area Network)**
  - **Devices you carry, often using Bluetooth**

Fundamental Network Concepts

- **Internet**
  - **Global collection of networks running TCP/IP**
- **Intranet**
  - **Privately owned network using TCP/IP**
- **Extranet**
  - **Connects private Intranets**
  - **Such as connections to business partners**

Fundamental Network Concepts

- **Circuit-Switched Network**
  - **Dedicated circuit or channel for one connection**
  - **Ex: a T1 line between businesses**
- **Packet-Switched Network**
  - **Multiple signals share the same lines**
  - **Data is broken into packets**
  - **Less wasteful and therefore cheaper than circuit switching**

Fundamental Network Concepts

- **Quality of Service**
  - **Can give specific traffic precedence over other traffic**
  - **On a packet-switched network**
    - **Ex: VoIP packets get precedence over email packets**

Fundamental Network Concepts

- **Layered Design**
  - **OSI and TCP/IP models use layers**
  - **Each layer performs a specific function**
  - **Changes in one layer do not directly affect another layer**

Fundamental Network Concepts

- **Network Model**
  - **A description of how a network protocol suite operates**
  - **Ex: OSI model, TCP/IP model**
- **Network Stack**
  - **A network protocol suite programmed in software or hardware**
  - **Ex: TCP/IP**

OSI Model

- **Mnemonics**
  - **Please Do Not Throw Sausage Pizza Away**
  - **All People Seem To Need Data Processing**

7	Application
6	Presentation
5	Session
4	Transport
3	Network
2	Data Link
1	Physical

Layer 1: Physical

- **Protocol Data Unit: *bit***
- **Physical media that carry signals**
  - **Ethernet cables**
  - **Radio waves**
  - **Fiber optic cables**
- **Devices**
  - **Hubs**
  - **Repeaters**
  - **Cables**

Layer 2: Data Link

- **Protocol Data Unit: *frame***
- **Uses MAC addresses (for Ethernet)**
- **Devices**
  - **Ethernet card**
  - **Switch**
  - **Bridge**

Layer 2: Data Link

- **Two sub-layers**
  - **Media Access Control**
    - **Connects to layer 1**
  - **Logical Link Control**
    - **Connects to layer 3**

Layer 3: Network

- **Protocol Data Unit: *packet***
- **Performs routing, using IP addresses**
- **Uses IPv4 and/or IPv6**
- **Device: Router**

Layer 4: Transport

- **Protocol Data Unit: *Segment***
- **Protocols include UDP and TCP**
- **Uses Port Numbers**
- **TCP is reliable, orders segments, and re-sends undelivered segments**

Layer 5: Session

- **Network file shares are mounted at the session layer**
  - **For example, you must log in first**
- **Connections between applications**

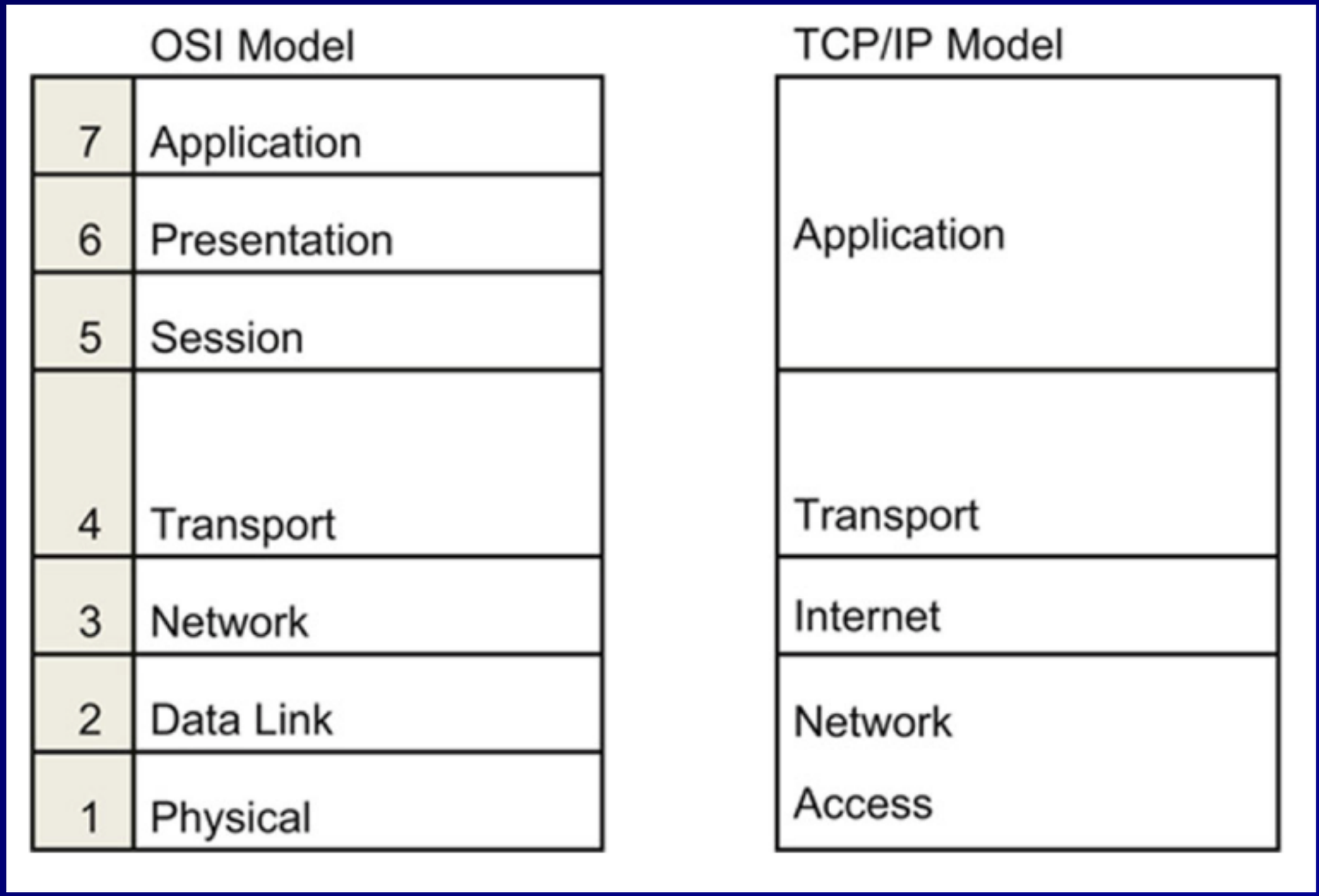
Layer 6: Presentation

- **Presents data to the application layer in a comprehensible way**
- **Data conversion**
- **Character encoding such as ASCII**
- **Image formats like GIF and JPEG**
- **Encryption**
- **Compression**

Layer 7: Application

- **Numen-Readable data**
- **Web browser, word processor, IM client**
- **Protocols:**
  - **Telnet**
  - **FTP**
  - **HTTP**

TCP/IP Model


OSI Model
7
Application
6
Presentation
5
Session
4
Transport
3
Network
2
Data Link
1
Physical
TCP/IP Model
Application
Transport
Internet
Network
Access

Network Access Layer

- **Combines OSI layers 1 and 2**
- **Includes cable and NIC**
- **Uses MAC addresses**

Internet Layer

- **OSI Layer 3**
- **IP addresses and routing**
- **Uses IPv4 or IPv6**

Transport Layer

- **Matches OSI layer 4**
- **Contains TCP and UDP**

Application Layer

- **Combines OSI layers 5-7**
- **Presents network data to the human user**
- **Like a Web browser**

Encapsulation

- **Takes information from a higher layer, and adds a header to it**
  - **Like putting a letter in an envelope and addressing it**
- **Layer 4 TCP *SEGMENT***
- **Is encapsulated in a Layer 3 IP *PACKET***
- **That's encapsulated in a Layer 2 *FRAME***
- **Sent over the wire at layer 1 as *BITS***

SPF10

- **Segment**
- **Packet**
- **Frame**
- **One and Zero (Bits)**

Decapsulation

- **Also called de-multiplexing**
- **Happens at receiving end**
- **The addresses are stripped off the data packets, and the data is delivered to higher levels**
- **BITS are converted to FRAMES**
- **FRAMES are converted to PACKETS**
- **PACKETS are converted to SEGMENTS**
- **SEGMENTS are converted to application data**

Network Access, Internet and Transport Layer Protocols and Concepts

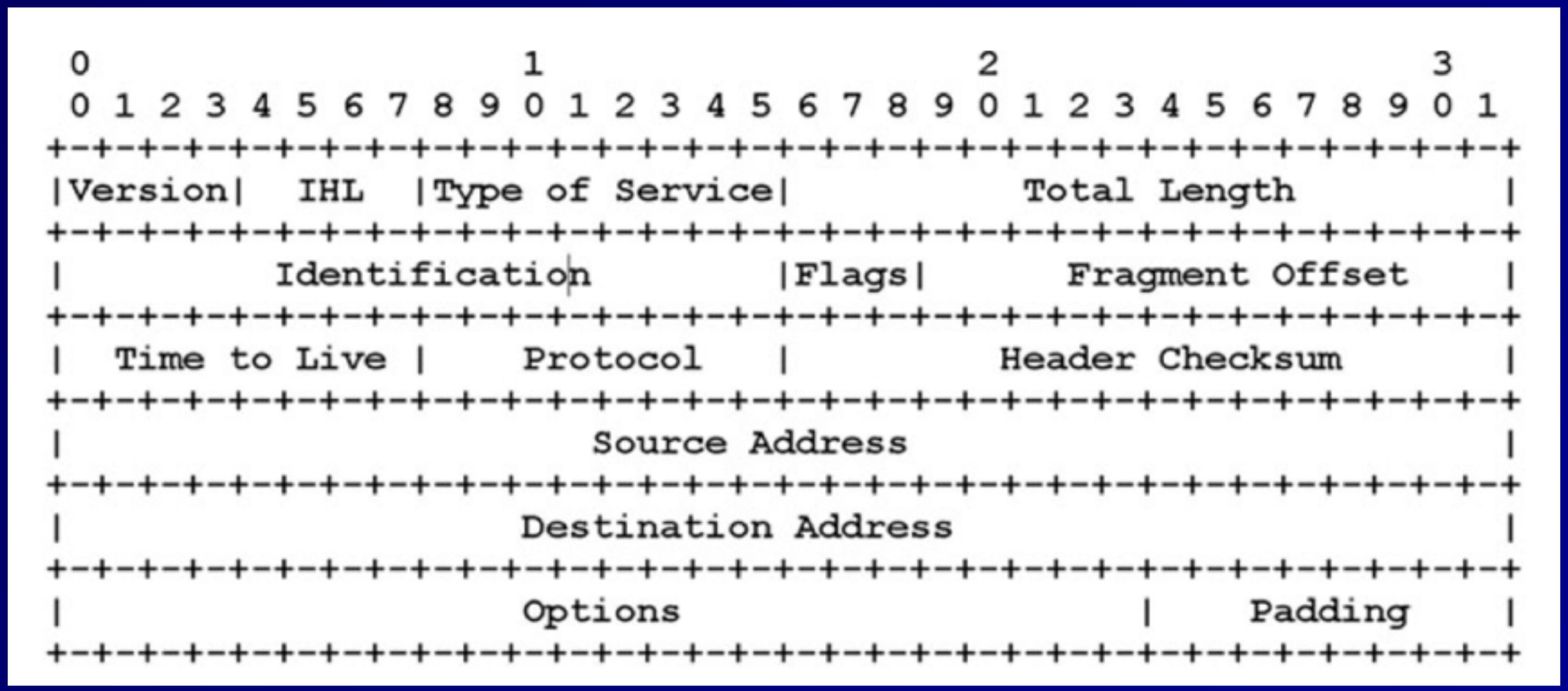
MAC Addresses

- **Media Access Control address**
- **Unique hardware address of an Ethernet NIC**
- **Burned in at the factory**
- **48 bits long**
  - **First 24 bits form Organizationally Unique Identifier**
- **EUI-64 addresses are 64 bits long**
  - **Used in IPv6**

IPv4

- **Internet Protocol version 4**
- **32-bit addresses**
- **Written as four bytes in decimal**
  - **192.168.0.1**

IPv4 Header


0 1 2 3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
Version
IHL
Type of Service
Total Length
Identification
Flags
Fragment Offset
Time to Live
Protocol
Header Checksum
Source Address
Destination Address
Options
Padding

IPv4 Fragmentation

- **An intermediate router can *fragment* a packet into smaller packets**
  - **To move it onto a network with a smaller *maximum transmission unit***
- **"Path MTU Discovery"**
  - **Send a large packet with the DF (Don't Fragment) bit set**
  - **If it's dropped, try a lower packet size**

IPv6 Header

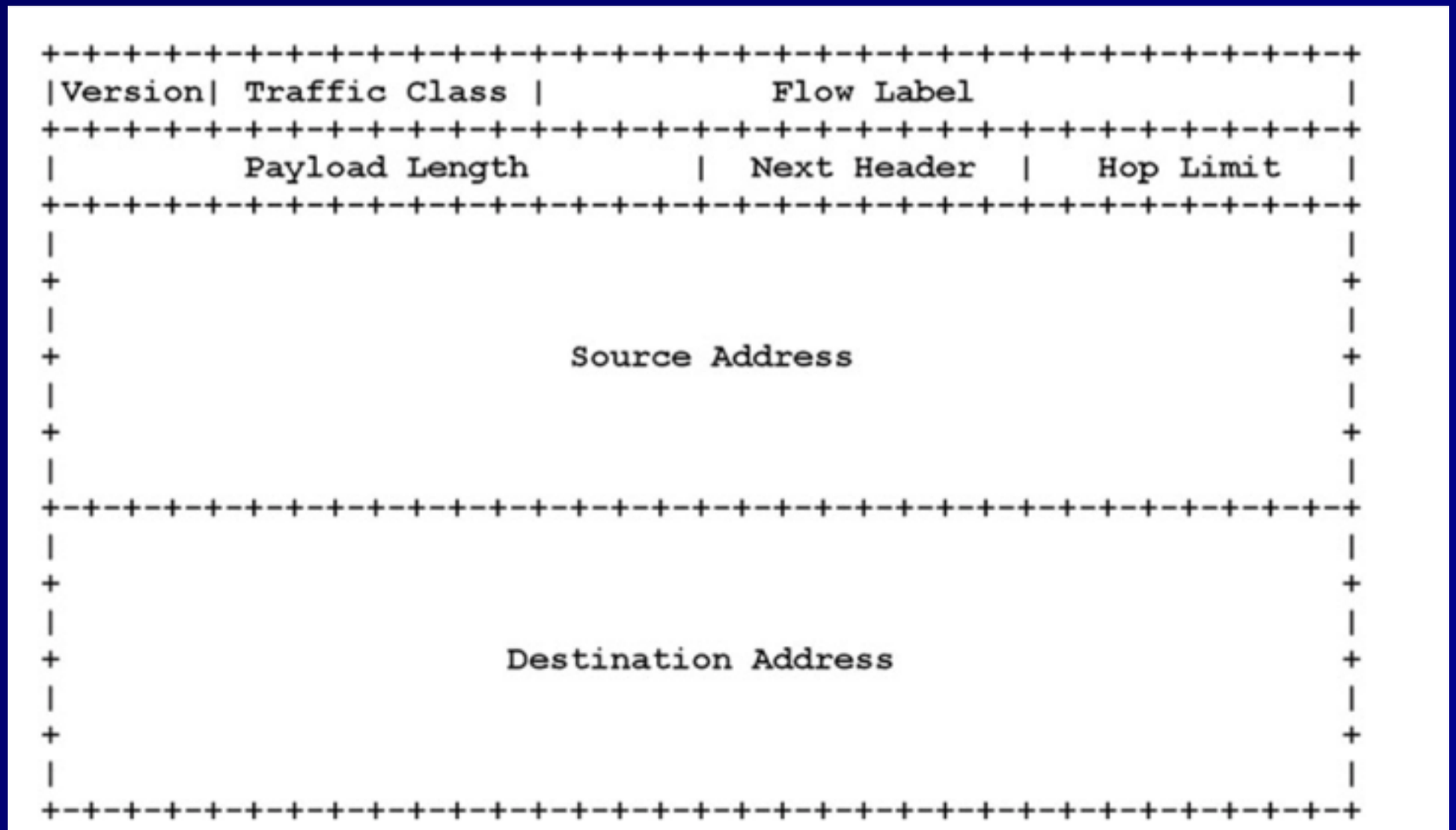


FIGURE 5.2 IPv6 Header [4]

IPv6 Addresses and Autoconfiguration

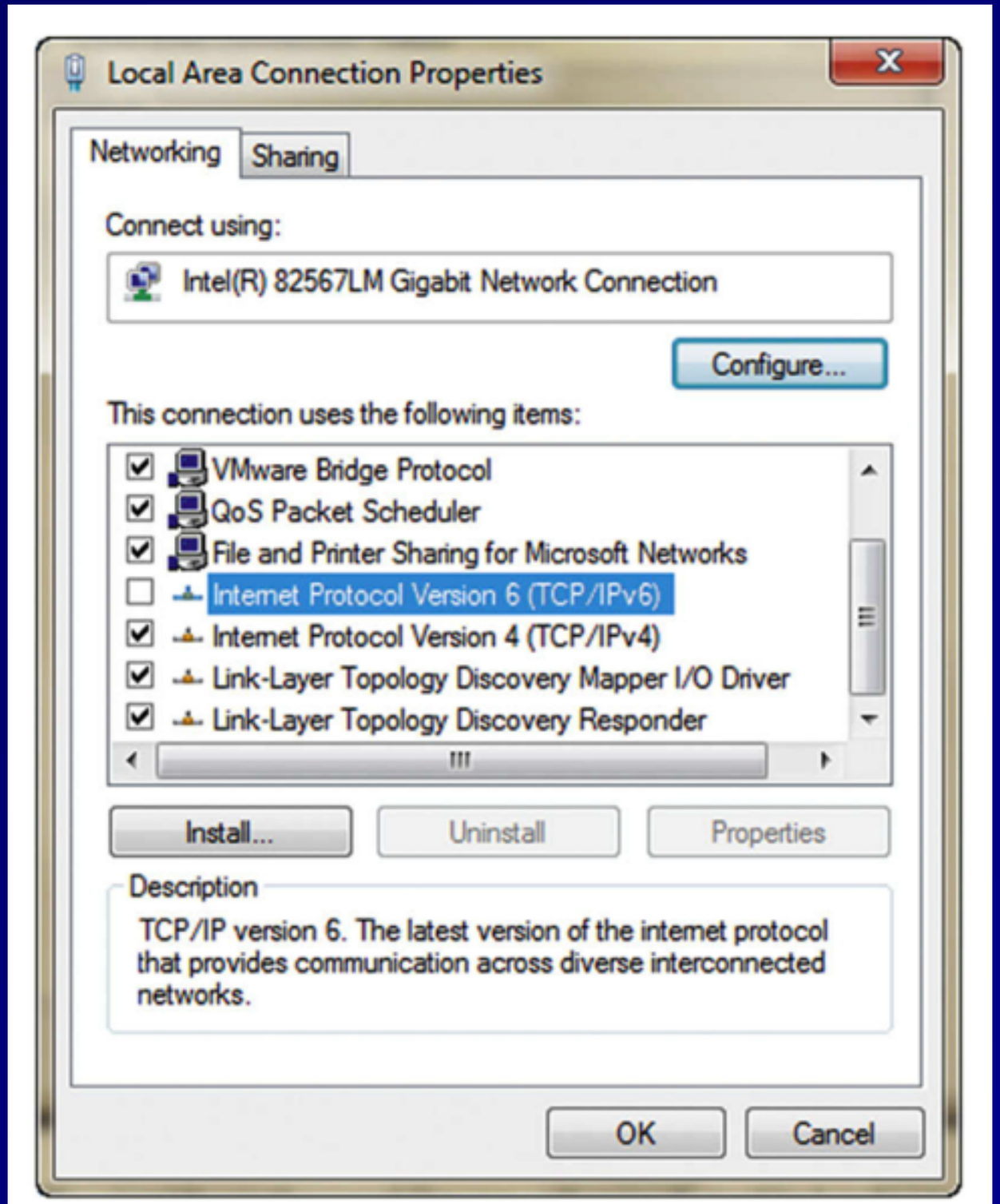
```
Sams-MacBook-Pro:~ sambowne$ ifconfig en0
en0: flags=8863<UP,BROADCAST,SMART,RUNNING,SIMPLEX,MULTICAST> mtu 1500
        ether ac:bc:32:c3:9e:b3
        inet6 fe80::aebc:32ff:fec3:9eb3%en0 prefixlen 64 scopeid 0x4
        inet 172.31.98.174 netmask 0xfffffe00 broadcast 172.31.99.255
        nd6 options=1<PERFORMNUD>
        media: autoselect
        status: active
```

- **MAC address used to construct host portion of IPv6 Address**
  - **Right 64 bits**
- **fe80:: is the *link-local* prefix**
- **Public addresses start with 2 or 3**

IPv6 Security Challenges

- **Many networks have IPv6 enabled, but the administrators don't understand how to manage it**
- **It can be used for forbidden activity, such as BitTorrent over IPv6**

Disabling IPv6



Classful Networks

- **Used until 1993**

Class	IP Range
Class A	0.0.0.0 – 127.255.255.255
Class B	128.0.0.0 – 191.255.255.255
Class C	192.0.0.0 – 223.255.255.255
Class D (multicast)	224.0.0.0 – 239.255.255.255
Class E (reserved)	240.0.0.0 – 255.255.255.255

Classless Inter-Domain Routing (CIDR)

- **Allows network sizes between the classes**
- **Class A is /8 16 million hosts**
- **Class B is /16 65,536 - 2 hosts**
- **Class C is /24 256 - 2 hosts**
- **147.144.96.0/20**
  - **16 class Cs 2048 - 2 hosts**

Private IPv4 Addresses

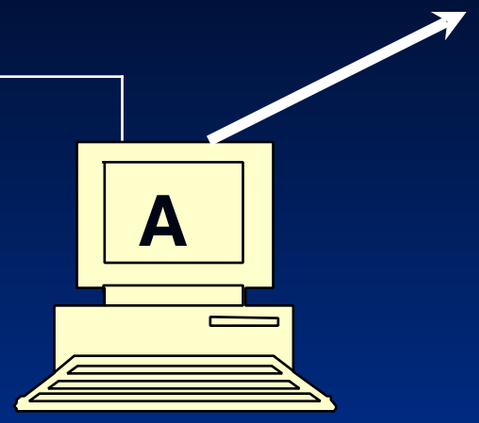
- **Defined in RFC 1918**
- **10.0.0.0 - 10.255.255.255 (10.0.0.0/8)**
- **172.16.0.0 - 172.31.255.255 (172.16.0.0/12)**
- **192.168.0.0 - 192.168.255.255 (192.168.0.0/16)**

Network Address Translation (NAT)

- **Usually used with Port Address Translation (PAT)**
- **So many clients can share a single public address**
- **Other techniques (rarely used)**
  - **Static NAT**
    - **One private address to one public address**
  - **Pool NAT**
    - **A group of public addresses translated one-by-one to the same number of local addresses**

NAT

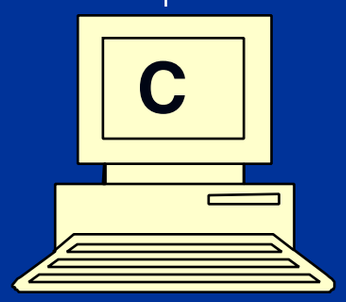
To the Internet



IP Address
Subnet Mask
Default Gateway

192.168.1.1
255.255.255.0
147.144.51.1

Hub



192.168.1.101
255.255.255.0
192.168.1.1

192.168.1.102
255.255.255.0
192.168.1.1

192.168.1.103
255.255.255.0
192.168.1.1

ARP (Address Resolution Protocol)

arp who-has 192.168.2.140 tell 192.168.2.4

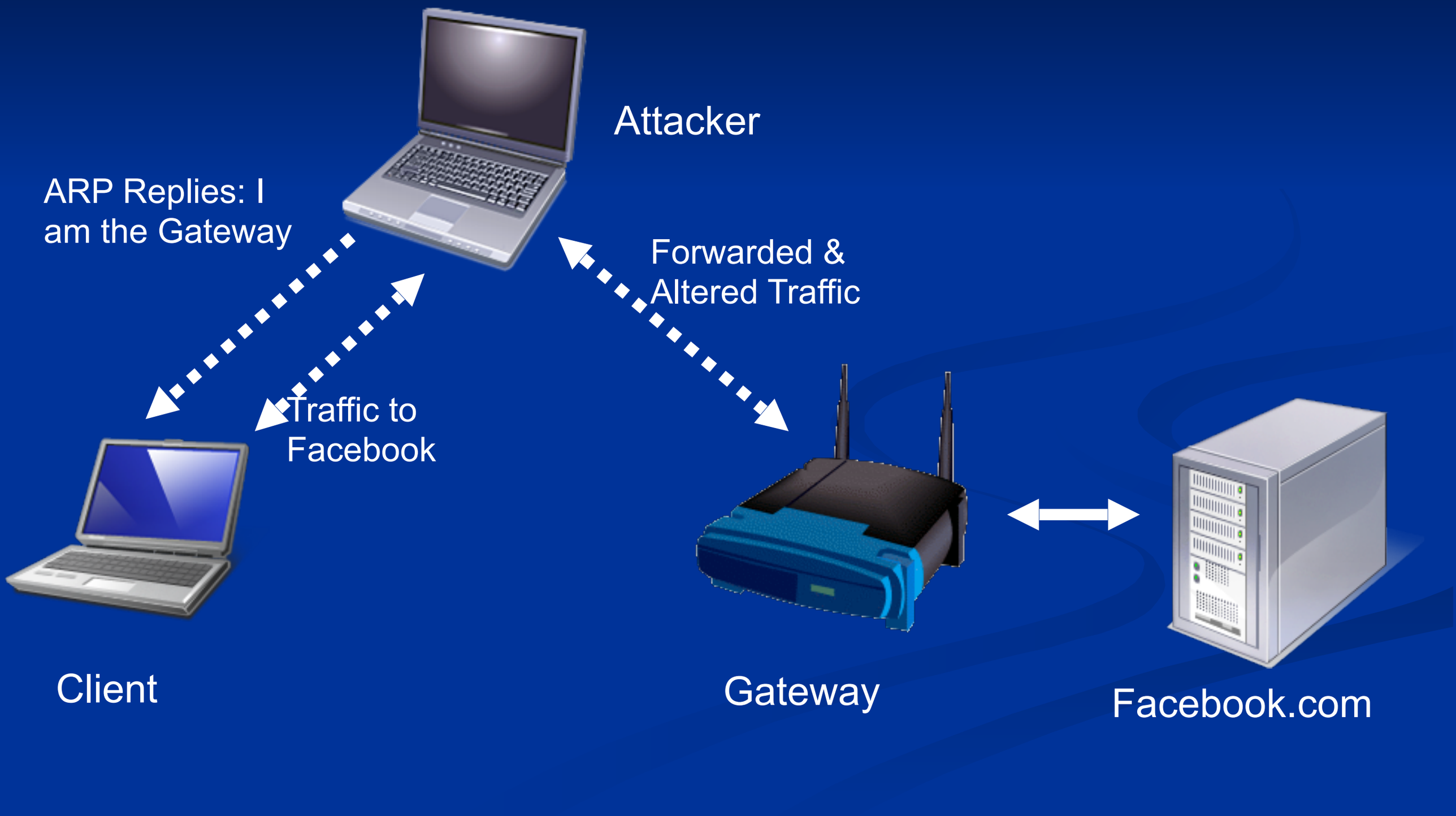
arp reply 192.168.2.140 is-at 00:0c:29:69:19:66

- Used to find MAC addresses on a LAN
- RARP (Reverse Address Resolution Protocol)
  - An early competitor to DHCP to deliver IP addresses, not common anymore

ARP Request and Reply

- Client wants to find Gateway
- ARP Request: Who has 192.168.2.1?
- ARP Reply:
  - MAC: 00-30-bd-02-ed-7b has 192.168.2.1

ARP Poisoning



Unicast and Multicast Traffic

- **Unicast: One sender to one receiver**
  - **Most common**
- **Multicast: One sender to several receivers**
  - **Rare, used by routing protocols**

Broadcast Traffic

- One sender to every device on the LAN
- Limited broadcast: 255.255.255.255
  - Actually sends layer 2 broadcast, to MAC address FF:FF:FF:FF:FF:FF
- Directed broadcast: 147.144.255.255
  - Was once sent over the Internet
  - Blocked now to stop smurf attacks

Promiscuous Network Access

- **A NIC in promiscuous mode passes all frames upward for use**
  - **Even if they are for a different MAC**
- **Required for Network Intrusion Detection Systems (NIDS)**
- **Entering promiscuous mode requires root privileges**
- **Switches isolate traffic segments**
  - **So traffic won't be sent to the wrong MAC address**

TCP

- **Transmission Control Protocol**
- **OSI Layer 4**

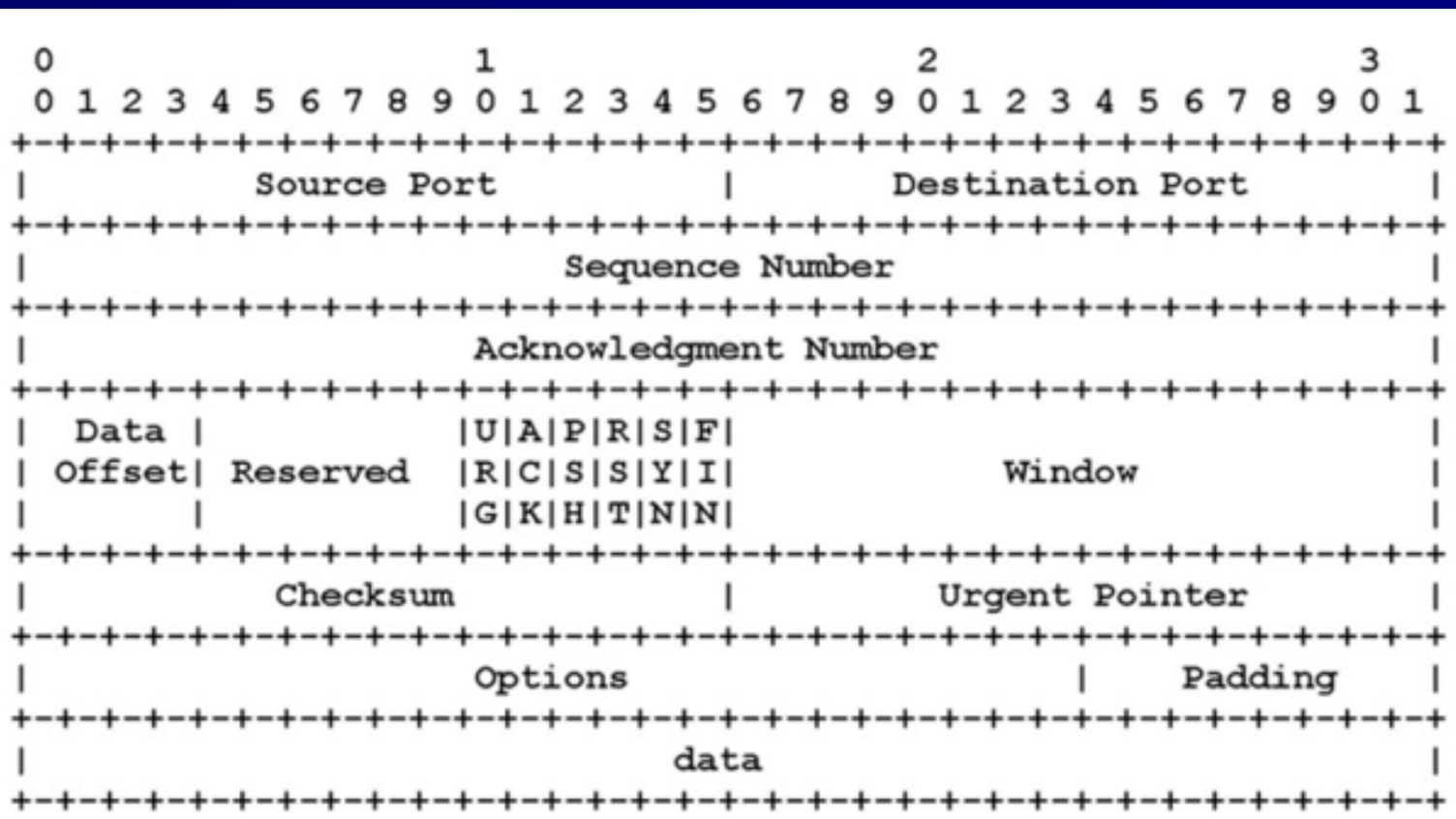


FIGURE 5.5 TCP Packet [5]

TCP Ports

- **0-1023: Well-known ports**
  - **Require root privileges to listen on**
  - **Also called "reserved ports"**
- **1024 - 65535**
  - **Ephemeral ports**
  - **Any user can listen on them**

Socket

- **A socket is a combination of four numbers**
  - **Source IP and Source Port**
  - **Destination IP and Destination Port**
- **Acts like a cable for two-way transmission**

```
root@ubuntu:~# netstat -nat
Active Internet connections (servers and established)
Proto Recv-Q Send-Q Local Address           Foreign Address         State
tcp        0      0 127.0.0.1:631           0.0.0.0:*               LISTEN
tcp        0      0 192.168.80.144:51178    192.168.2.4:22          ESTABLISHED
```

FIGURE 5.6 **TCP Socket Pair**

State

- **LISTEN**
  - **Waiting for a SYN**
- **ESTABLISHED**
  - **Handshake complete**

TCP Flags

- **URG: Urgent**
- **ACK: Acknowledge**
- **PSH: Push**
- **RST: Reset &**
- **SYN: Synchronize**
- **FIN: Finish**
- **Three new flags added in 2001 & 2003**
  - **CWR: Congestion Window Reduced**
  - **ECE: Explicit Congestion Notification Echo**
  - **NS: Nonce Sum**

TCP Handshake

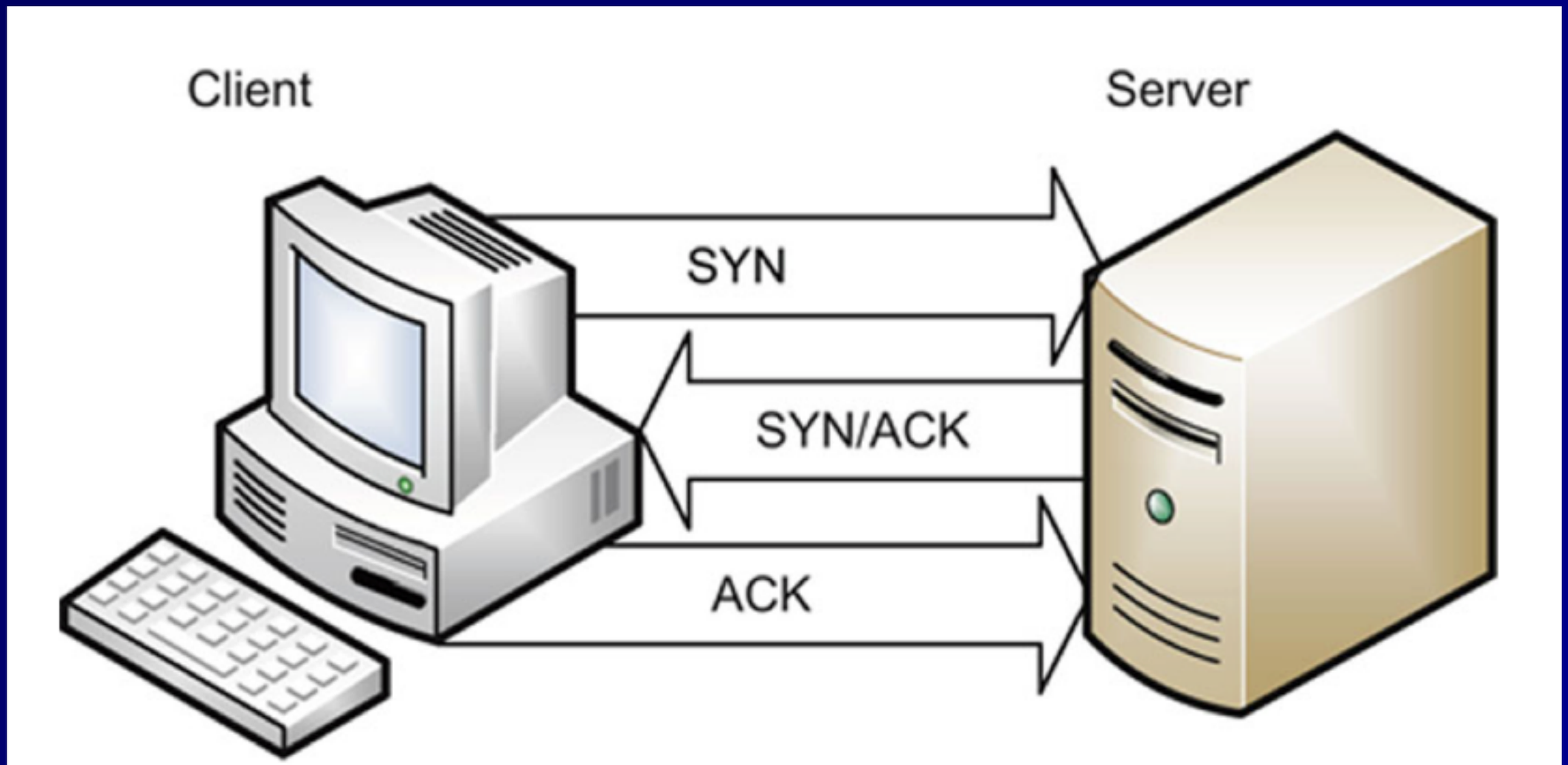


FIGURE 5.8 TCP Three-Way Handshake

UDP

- **User Datagram Protocol**
- **No handshake**
- **No acknowledgements**

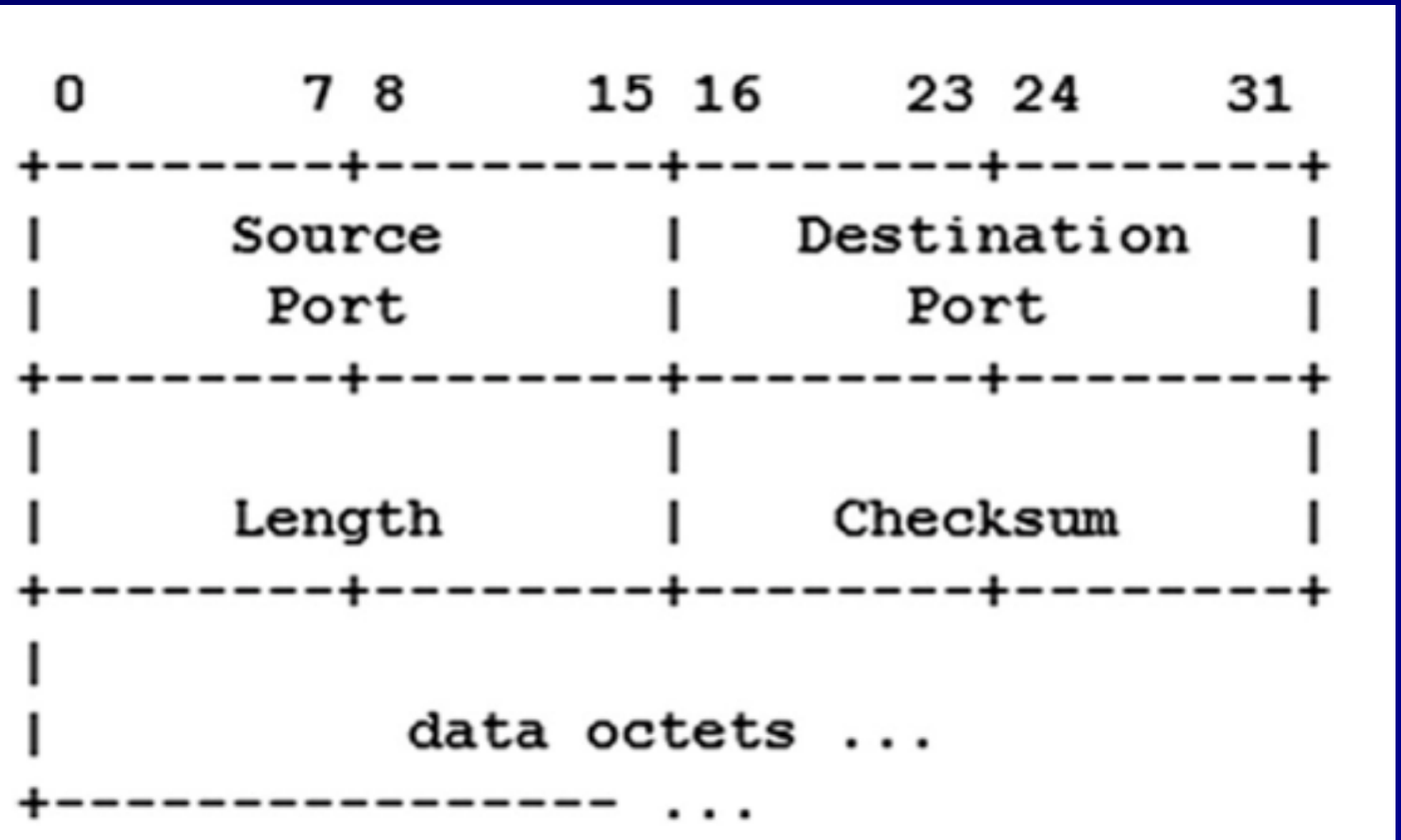


FIGURE 5.9 UDP Packet [7]

ICMP

- **Internet Control Message Protocol**
- **Used to troubleshoot and report error conditions**
- **PING**
  - **Sends an ICMP Echo Request**
  - **Gets an ICMP Echo Reply**
- **Traceroute**
  - **Sends packets with low TTL**
  - **Tracks ICMP Time Exceeded replies**

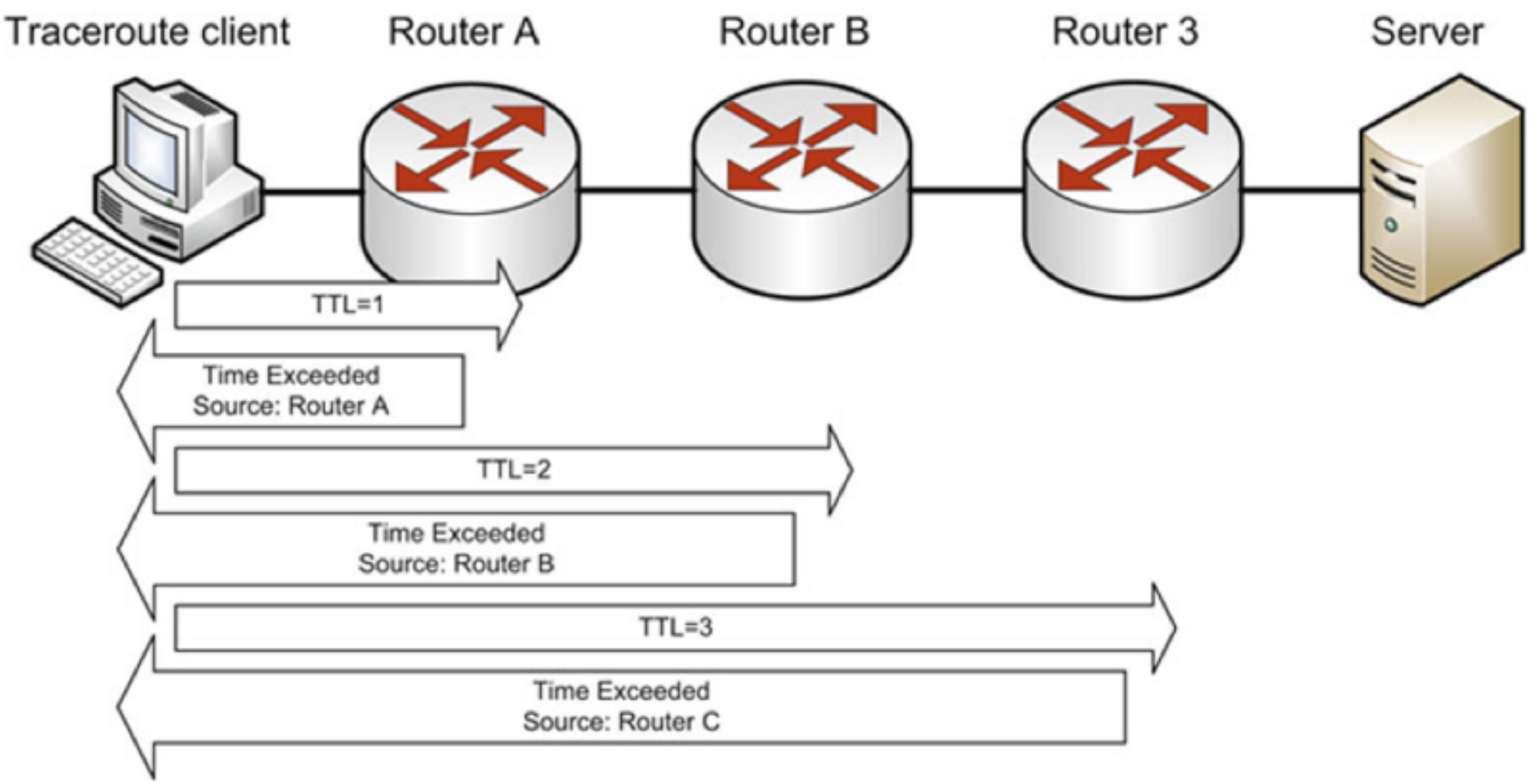


FIGURE 5.10 Traceroute

Traceroute

- **Unix and Cisco send UDP packets**
- **Microsoft sends ICMP packets**

Application Layer TCP/IP Protocols and Concepts

- **Telnet**
  - **Terminal emulation**
  - **Sends command-lines**
  - **No encryption**
- **SSH (Secure Shell)**
  - **Encrypted replacement for Telnet**

Application Layer TCP/IP Protocols and Concepts

- **FTP (File Transfer Protocol)**
  - **Sends passwords unencrypted**
  - **Uses ports 20 and 21 on the server**
  - **Problems for firewalls (link Ch 5b)**
    - **Active FTP initiates the port 20 connection from the server, not the client**
    - **Passive FTP uses an arbitrary ephemeral port on the server**

Application Layer TCP/IP Protocols and Concepts

- **TFTP (Trivial File Transfer Protocol)**
  - **Uses UDP port 69**
  - **No authentication at all**
  - **No encryption**
  - **Used to update firmware in routers and IP phones**

Application Layer TCP/IP Protocols and Concepts

- **SSH (Secure Shell)**
  - **Secure replacement for Telnet**
  - **And FTP and the unix "r" commands**
    - **rlogin, rshell, etc.**
  - **Includes SFTP and SCP**
  - **Can be used as a secure tunnel for other protocols, such as HTTP**
  - **Uses TCP port 22**
  - **SSHv1 is old and vulnerable, SSHv2 is the current standard**

Application Layer TCP/IP Protocols and Concepts

- **SMTP (Simple Mail Transfer Protocol)**
  - **Uses TCP port 25**
  - **Used to send email between servers**
- **POP (Post Office Protocol)**
  - **TCP port 110**
  - **Used to download email to a local client like Eudora or Outlook**
- **IMAP (Internet Message Access Protocol)**
  - **TCP port 132**
  - **Used to download email to a local client like Eudora or Outlook**

Application Layer TCP/IP Protocols and Concepts

- **DNS (Domain Name System)**
  - **Uses UDP and TCP 53**
  - **Large responses require TCP 53**
    - **Zone transfers**
    - **DNSSEC-signed records**
  - **Resolves domain names like *ccsf.edu* to IP addresses**

Application Layer TCP/IP Protocols and Concepts

- **DNS Server Types**
  - **SOA (Start of Authority)**
    - **Contains the master record for a zone**
  - **Recursive server**
    - **If it doesn't have the requested data, it will ask other servers**
  - **Caching server**
    - **Stores recently resolved names**

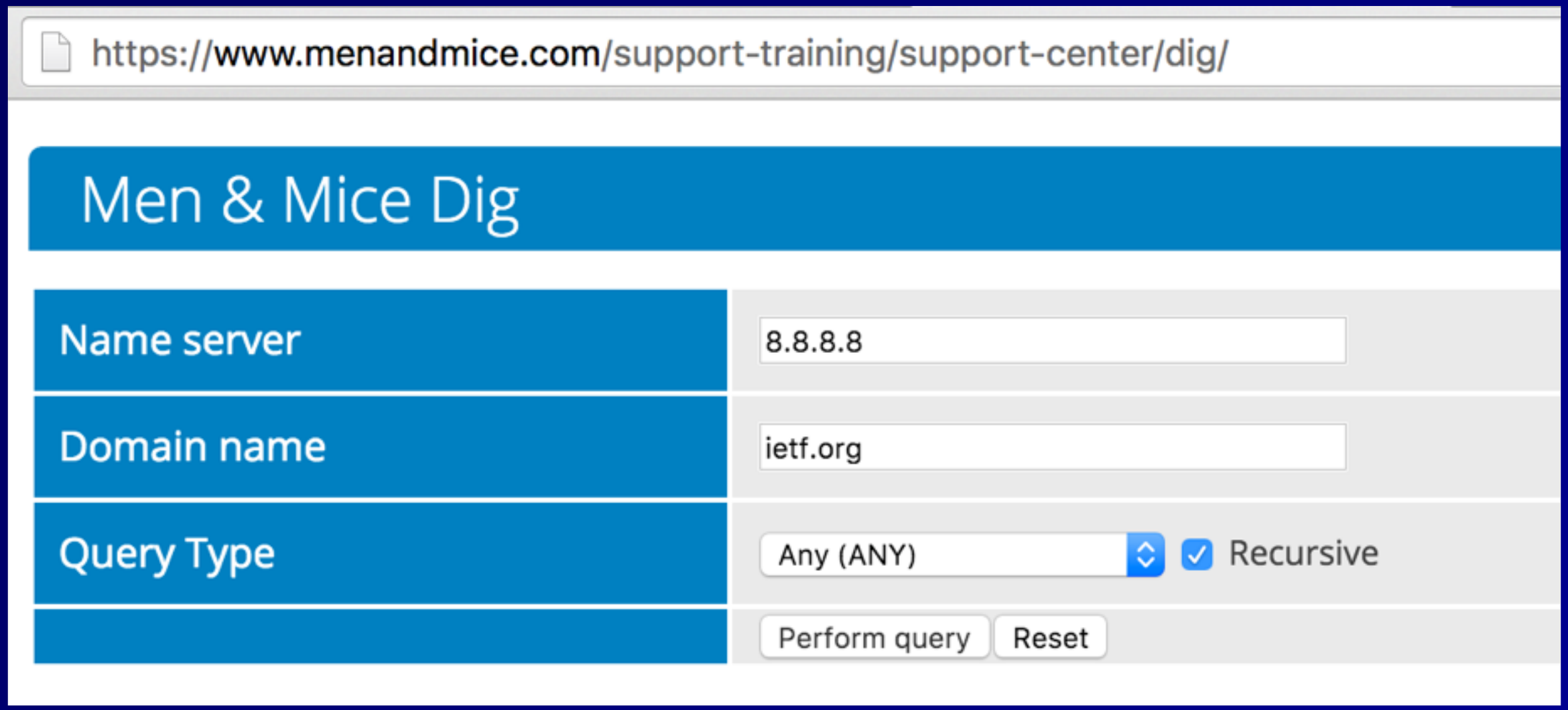
Application Layer TCP/IP Protocols and Concepts

- **DNS Weaknesses**
  - **Uses UDP**
  - **No authentication**
  - **Security relies on a 16-bit source port and a 16-bit DNS query ID**
  - **If attackers can guess both numbers, they can poison a DNS sever cache**

Application Layer TCP/IP Protocols and Concepts

- **DNSSEC**
  - **Domain Name Server Security Extensions**
  - **Adds authentication and integrity to DNS responses**
  - **Uses public key encryption**
  - **No confidentiality**
  - **Like a digital signature**
- **Slowly being rolled out across the Internet**

Online Dig



- **Link Ch 5c**

RRSIG Contains Signature

Result

```
;; Truncated, retrying in TCP mode.
; <<>> DiG 9.8.1-P1 <<>> @8.8.8.8 ietf.org ANY +m
; (1 server found)
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 31532
;; flags: qr rd ra; QUERY: 1, ANSWER: 25, AUTHORITY: 0, ADDITIONAL: 0
;; QUESTION SECTION:
;ietf.org. IN ANY
;; ANSWER SECTION:
ietf.org.  1798  IN  SOA ns0.amsl.com. glen.amsl.com. (
1200000317 ; serial
1800 ; refresh (30 minutes)
1800 ; retry (30 minutes)
604800 ; expire (1 week)
1800 ; minimum (30 minutes)
)
ietf.org.  1798  IN  RRSIG SPF 5 2 1800 20170213210805 (
20160214200831 40452 ietf.org.
MDUn1yjQuyHc15QDf2TtCJXDt36mFJ8GMqEh+xKfv1Zq
4ZNbAqsLQDR6sFWlf72fvi8l7mmECzgtwtmKcfNRN1Ke
C/5fGPnl1QEqKcAY7K7rwG+M/jTHFxtGSQ9uNsKh3Dgo
BYXMFmvGRTchLjHN73l04vphCOYolW0zYKBzhmLTH1G5
otbEKHjZVvHhi9EpfLkXLnM6bzK4iGmI3pXkn3owCOEr
jyJTt3cRhEPlw4phzWB5/ixYgfSN0AOJZNEKDS/IoL7D
R937IkHaBppcFjCpLuCjj24bSpmIJQpCWlVKXRquqxDw
puxhR0pPNEKHnR5CkhjsucKBeL8UVShAkw== )
```

Application Layer TCP/IP Protocols and Concepts

- **SNMP**
  - **Simple Network Management Protocol**
  - **Used to monitor and control network devices**
  - **Uses UDP port 161**
    - **SNMPv1 and v2 send "community strings" in plaintext**
      - **Defaults are "public" and "private"**
    - **SNMPv3 adds encryption; much more secure**
    - **Many networks still use SNMPv2**

Application Layer TCP/IP Protocols and Concepts

- **HTTP**
  - **Hypertext Transfer Protocol**
  - **TCP port 80**
  - **No encryption**
- **HTTPS**
  - **Hypertext Transfer Protocol Secure**
  - **TCP port 443**
  - **Encrypted with SSL/TLS**

Application Layer TCP/IP Protocols and Concepts

- **BOOTP**
  - **Bootstrap protocol**
  - **Enables a BIOS to boot from the network**
    - **BIOS gets an IP address from BOOTP**
    - **Then uses TFTP to load the OS**
    - **Uses ports UDP 67 for servers and UDP 68 for clients**

Application Layer TCP/IP Protocols and Concepts

- **DHCP**
  - **Intended to replace BOOTP**
  - **Can deliver IP address, DNS server, default gateway, and more**
  - **Uses ports UDP 67 for servers and UDP 68 for clients**