Network Protocol Analysis

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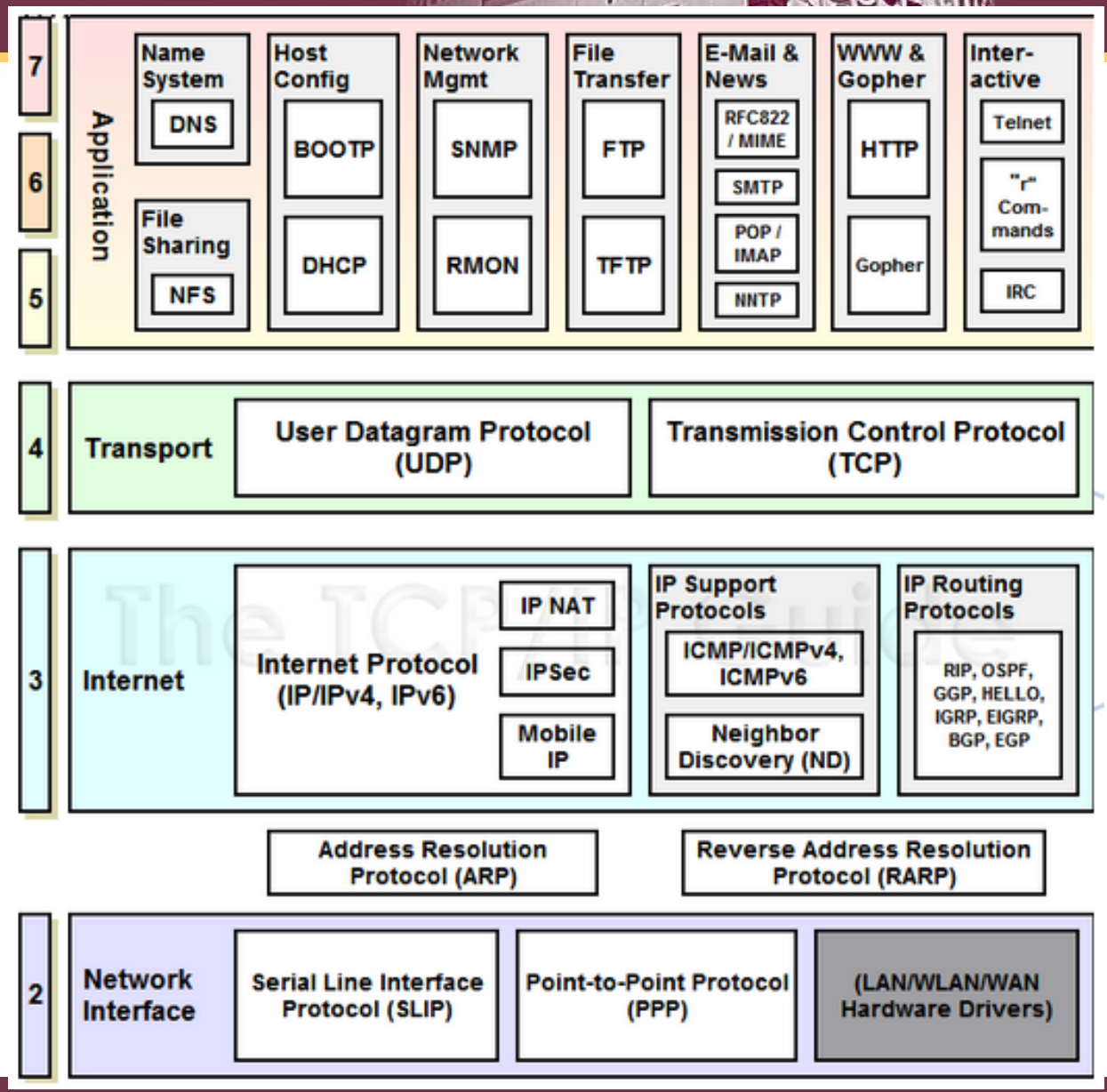
Protocol Analysis

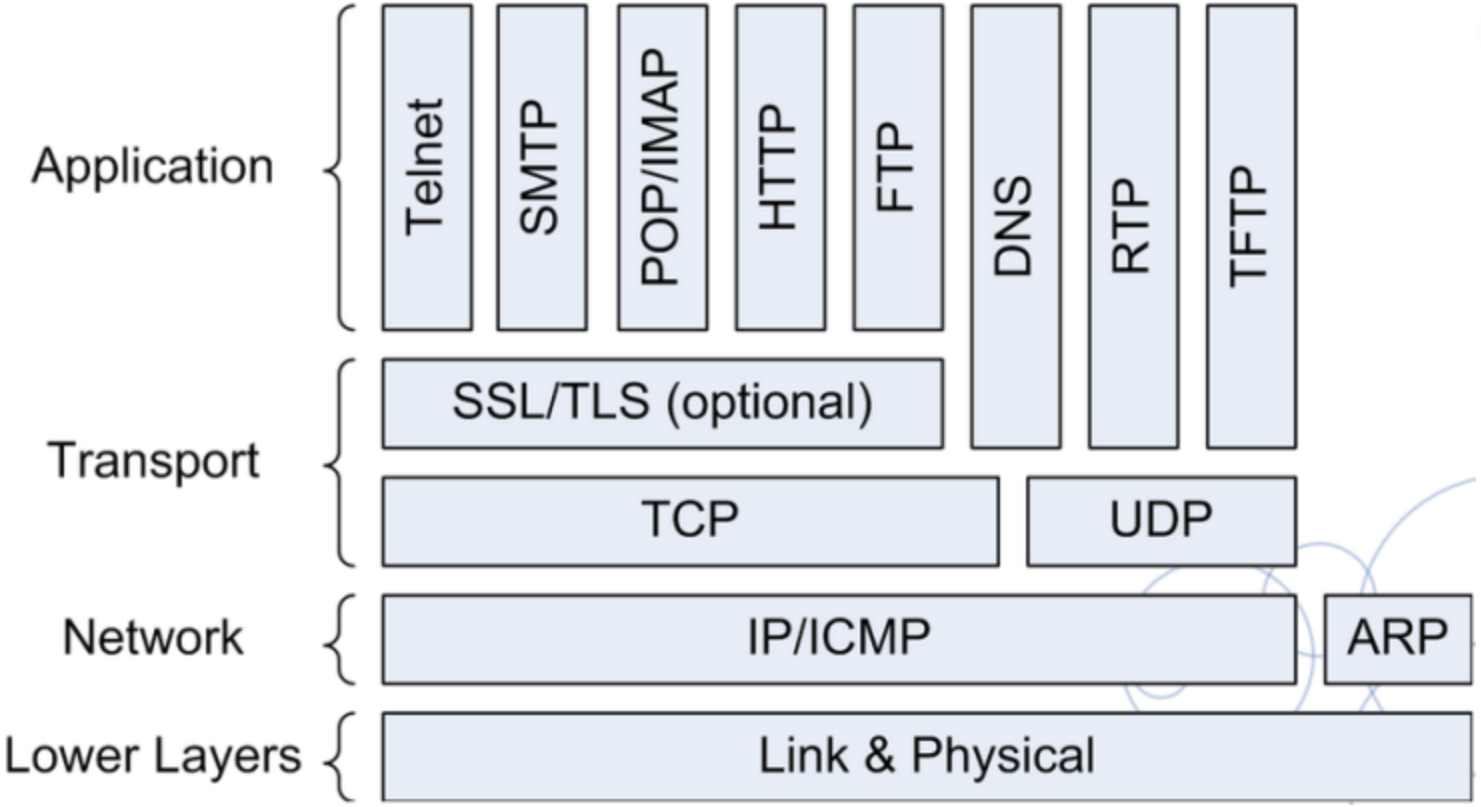
- Purpose: to identify and analyze network problems.
- What are problems?
  - Bad performance, unusual traffic/packets, malicious payload, and potential vulnerabilities
- How do we solve it?
  - Instrument the code :
    - difficult task, network programming skills required.
  - Use available tools: Ethereal, tcpdump/tshark, wireshark, etc.
  - Write your own tool: libpcap

TCP/IP Protocol Suite in OSI

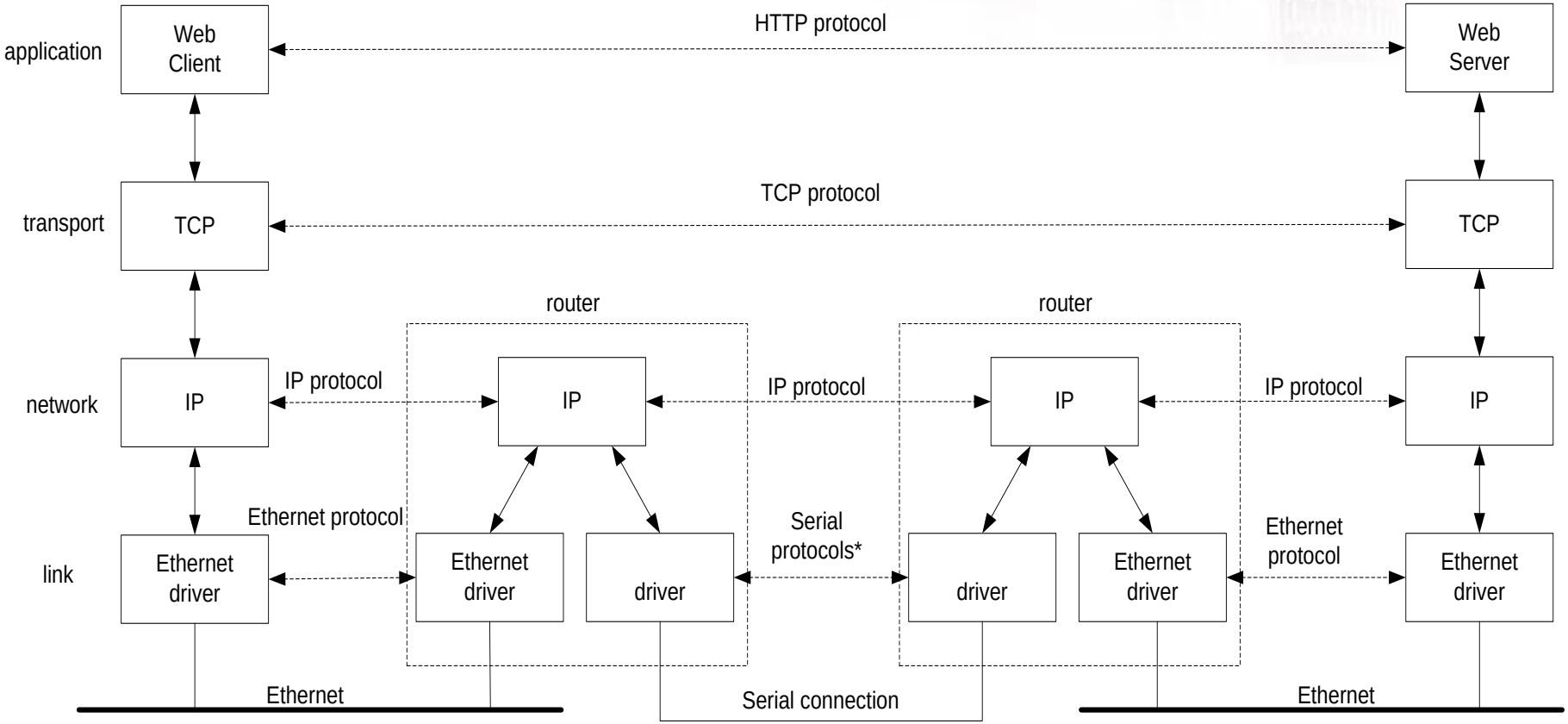


Courtesy of tcpipguide.com

TCP/IP (4 layer model)



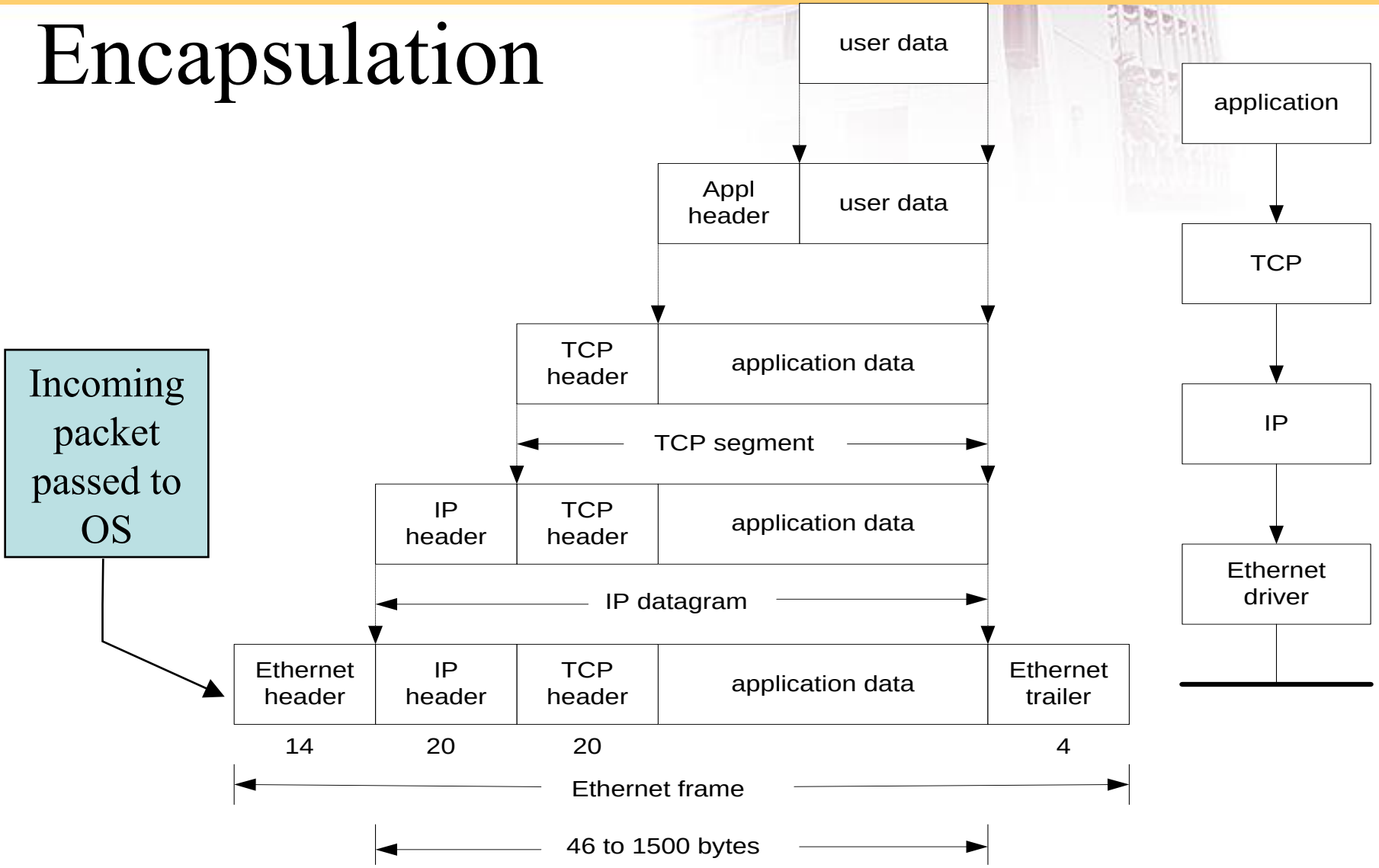
Network inter-connection



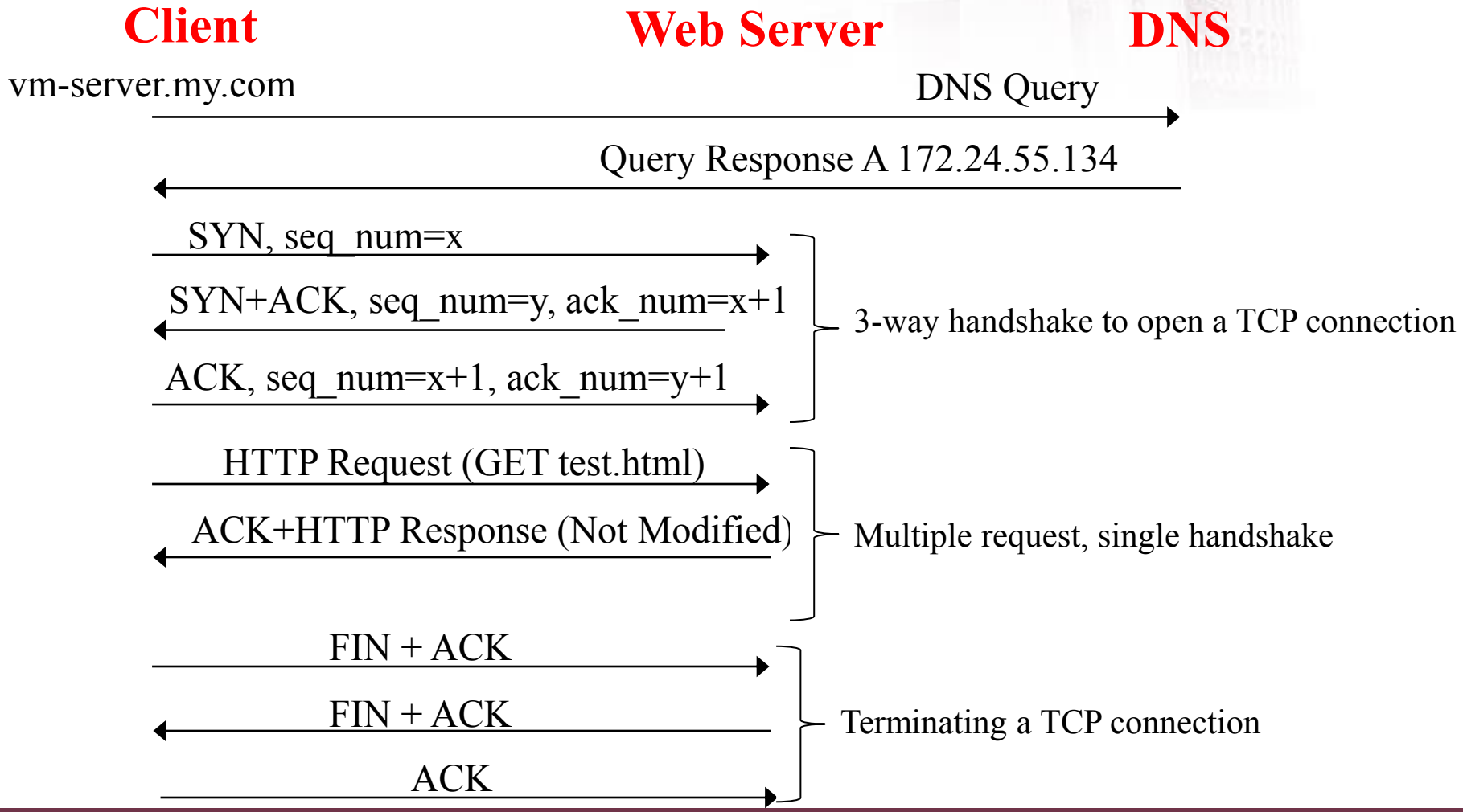
Two networks connected with two routers

* (Cisco support: EIA/TIA-232, EIA/TIA-449, V.35, X.21 and EIA-530 etc.)

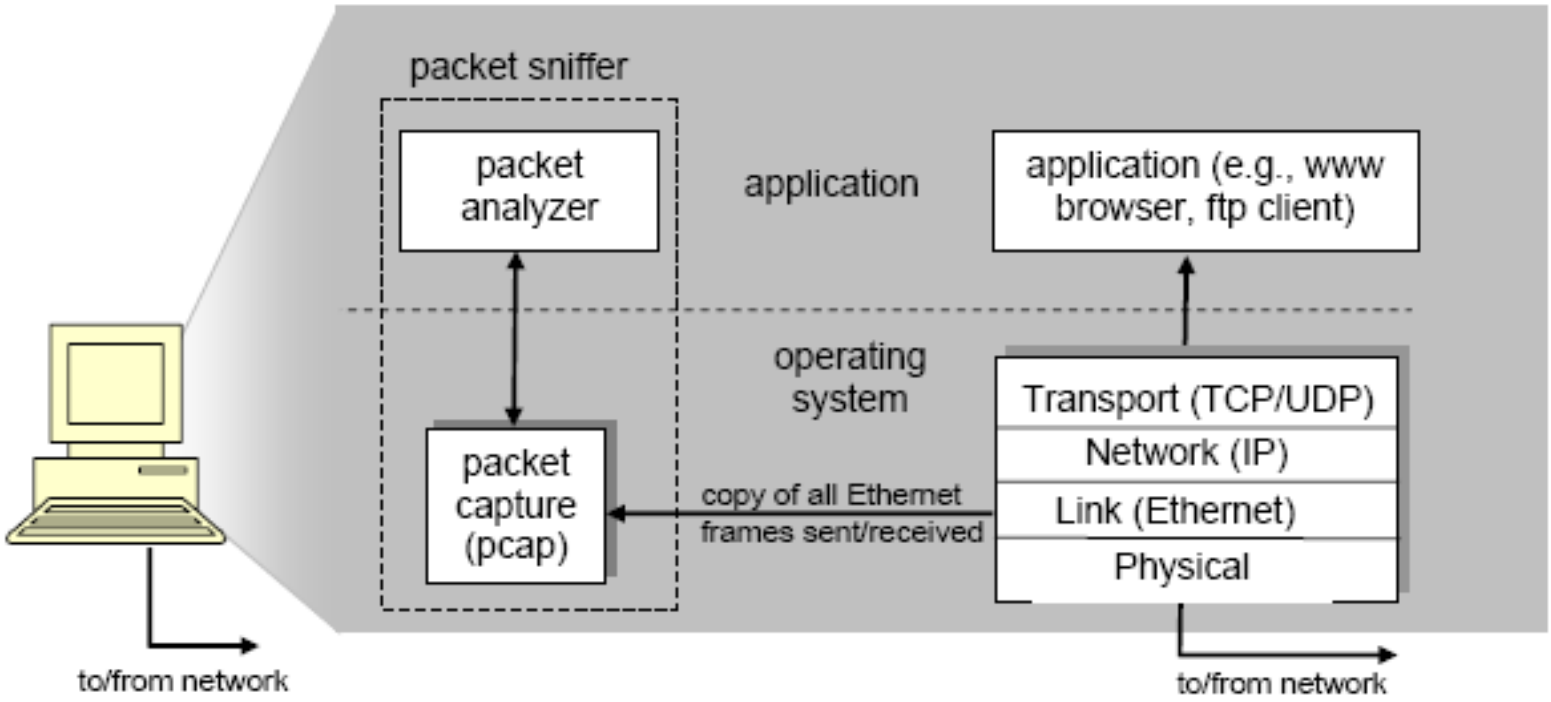
Encapsulation

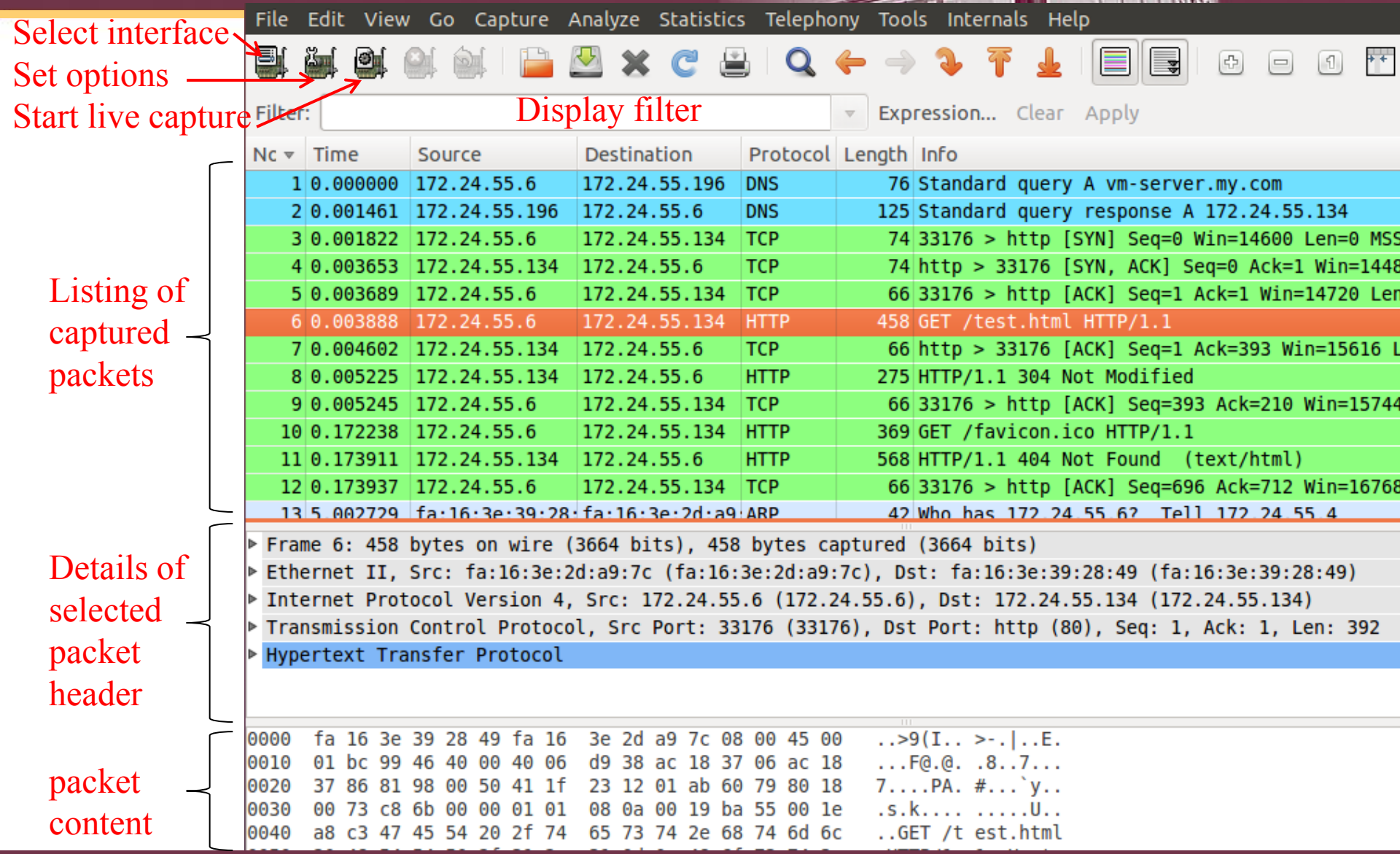


WWW Request/Response Example



Wireshark System Overview

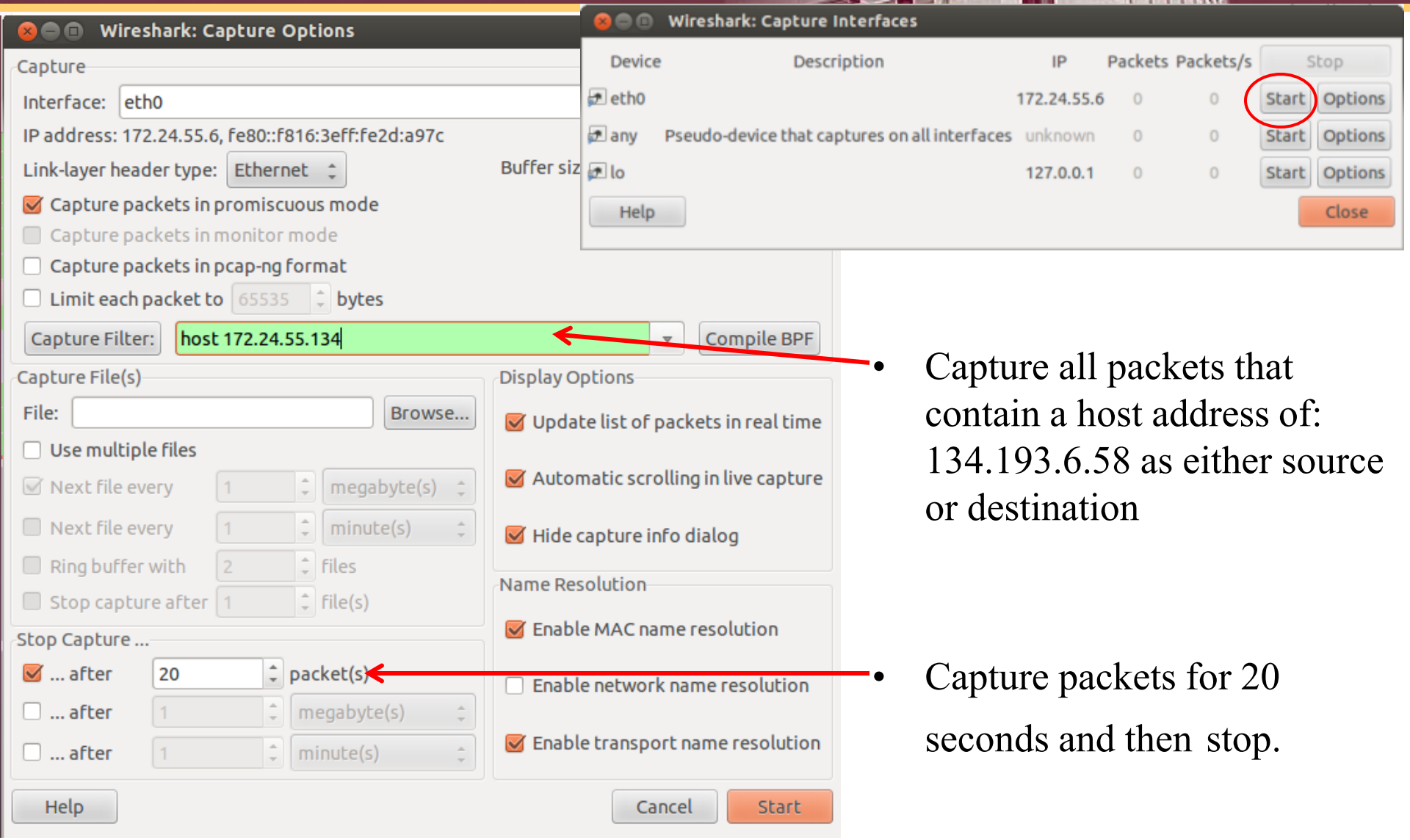




Listing of captured packets

Details of selected packet header

packet content



- Capture all packets that contain a host address of: 134.193.6.58 as either source or destination

- Capture packets for 20 seconds and then stop.

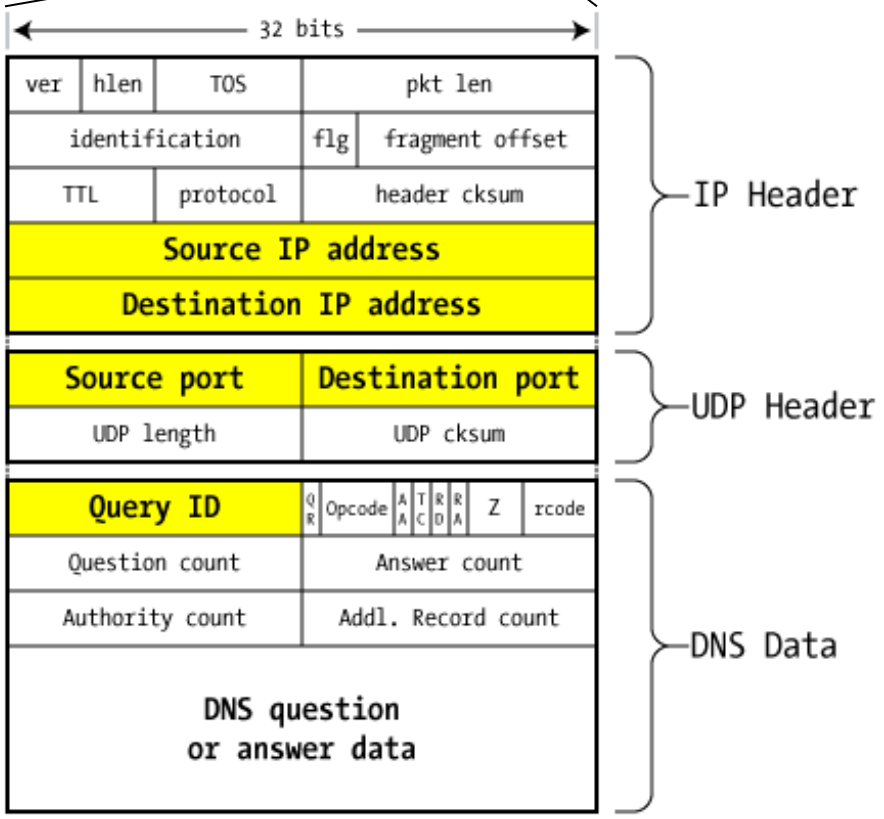
Sample Filters

- Capture Filter: (protocol)(direction)(hosts)(value)(logic op)(other)
  - `dst host 134.193.6.58`
  - `dst host 134.193.6.58 and dst port 12345`
  - `src host 134.193.15.9 && dst net 216.92.131.0`
  - `host 134.193.6.58 and ip proto tcp`
  - `dest host 134.193.6.58 && ip proto icmp`
- Display Filter:
  (protocol).(string1).(string2)(compare op)(value)(logic op)(other)
  - `dns || tcp`
  - `ip.addr == 10.0.1.1`
  - `ip.src != 10.1.2.3 or ip.dst != 10.4.5.6`
  - `tcp.port == 22`
  - `tcp.dstport == 25`
  - `tcp.flags.syn == 0x02`

Ethernet Frame and DNS Packet on the wire

Ethernet Frame

Preamble	Destination MAC address	Source MAC address	Type/Length	User Data	Frame Check Sequence (FCS)
8	6	6	2	46 - 1500	4



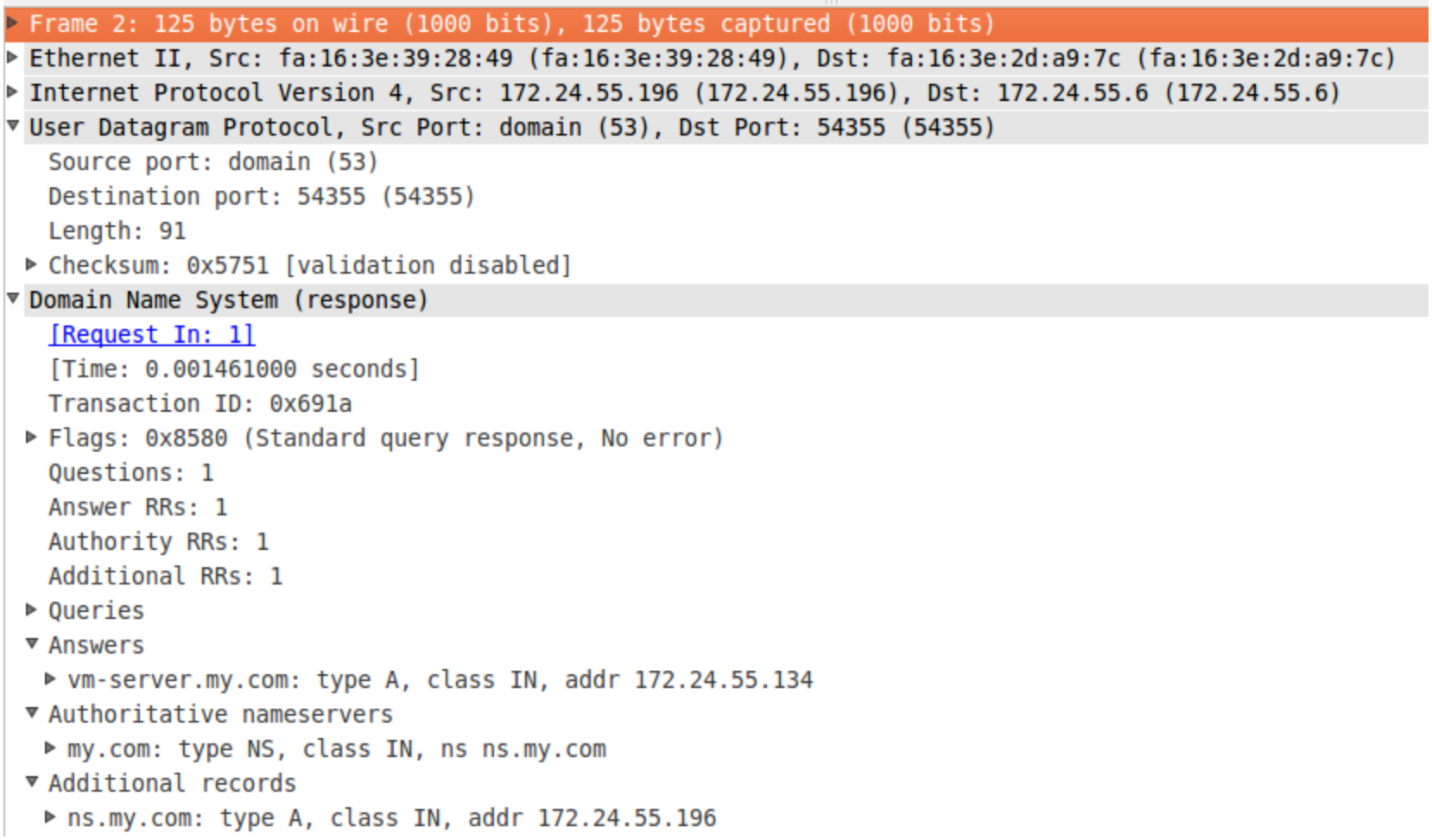
Well-known common ports

Port	TCP/UDP	Protocol Direction	Description	Additional Info
23	TCP	Inbound/Outbound	Telnet for mgmt port	
22	TCP	Inbound/Outbound	SSH for mgmt port	Also used for SoL to CiMC
80	TCP	Inbound	HTTP to mgmt port	
443	TCP	Inbound	HTTPS to mgmt port	
161	UDP	Inbound	SNMP Poll	
162	UDP	Outbound	SNMP Trap	
623	UDP	Inbound	IPMI to CiMC	
2068	TCP	Inbound	KVM	
69	UDP	Outbound	TFTP	File Transfer
1812/1813	UDP	Outbound	RADIUS	Authentication
49	TCP	Outbound	TACACS	Authentication
389	TCP	Outbound	LDAP	Directory Authentication
123	TCP	Outbound	NTP	Time Sync
25	TCP	Outbound	SMTP	Call Home
514	UDP	Outbound	Syslog	External logging
53	UDP	Outbound	DNS	Name Resolution
115/20	TCP	Outbound	SFTP	File Transfer

DNS Query Packet

```
▶ Frame 1: 76 bytes on wire (608 bits), 76 bytes captured (608 bits)
▼ Ethernet II, Src: fa:16:3e:2d:a9:7c (fa:16:3e:2d:a9:7c), Dst: fa:16:3e:39:28:49 (fa:16:3e:39:28:49)
  ▶ Destination: fa:16:3e:39:28:49 (fa:16:3e:39:28:49)
  ▶ Source: fa:16:3e:2d:a9:7c (fa:16:3e:2d:a9:7c)
    Type: IP (0x0800)
▶ Internet Protocol Version 4, Src: 172.24.55.6 (172.24.55.6), Dst: 172.24.55.196 (172.24.55.196)
▼ User Datagram Protocol, Src Port: 54355 (54355), Dst Port: domain (53)
    Source port: 54355 (54355)
    Destination port: domain (53)
    Length: 42
  ▶ Checksum: 0xc736 [validation disabled]
▼ Domain Name System (query)
    [Response In: 2]
    Transaction ID: 0x691a
  ▶ Flags: 0x0100 (Standard query)
    Questions: 1
    Answer RRs: 0
    Authority RRs: 0
    Additional RRs: 0
  ▼ Queries
    ▼ vm-server.my.com: type A, class IN
        Name: vm-server.my.com
        Type: A (Host address)
        Class: IN (0x0001)
```

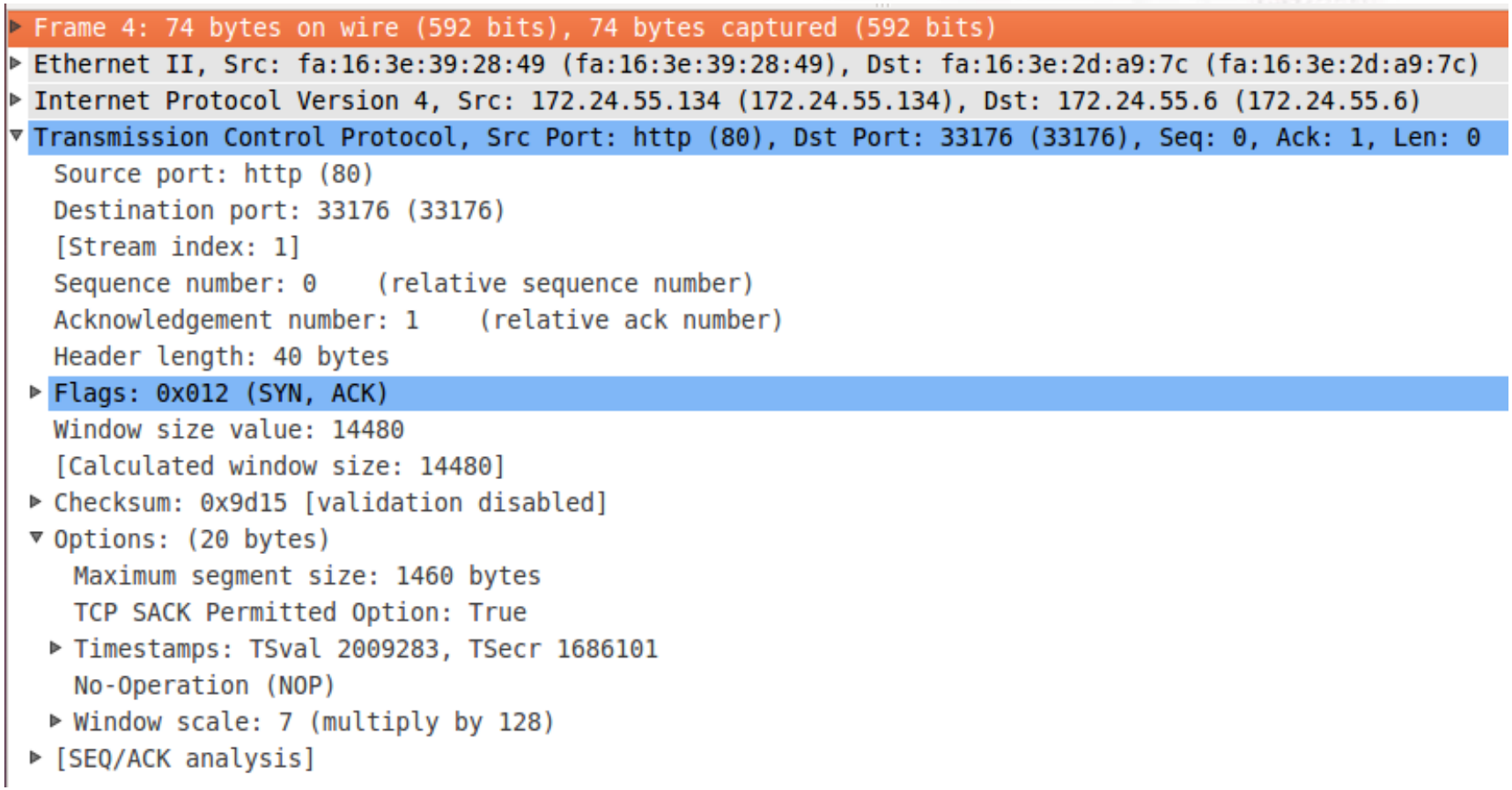
DNS Response Packet



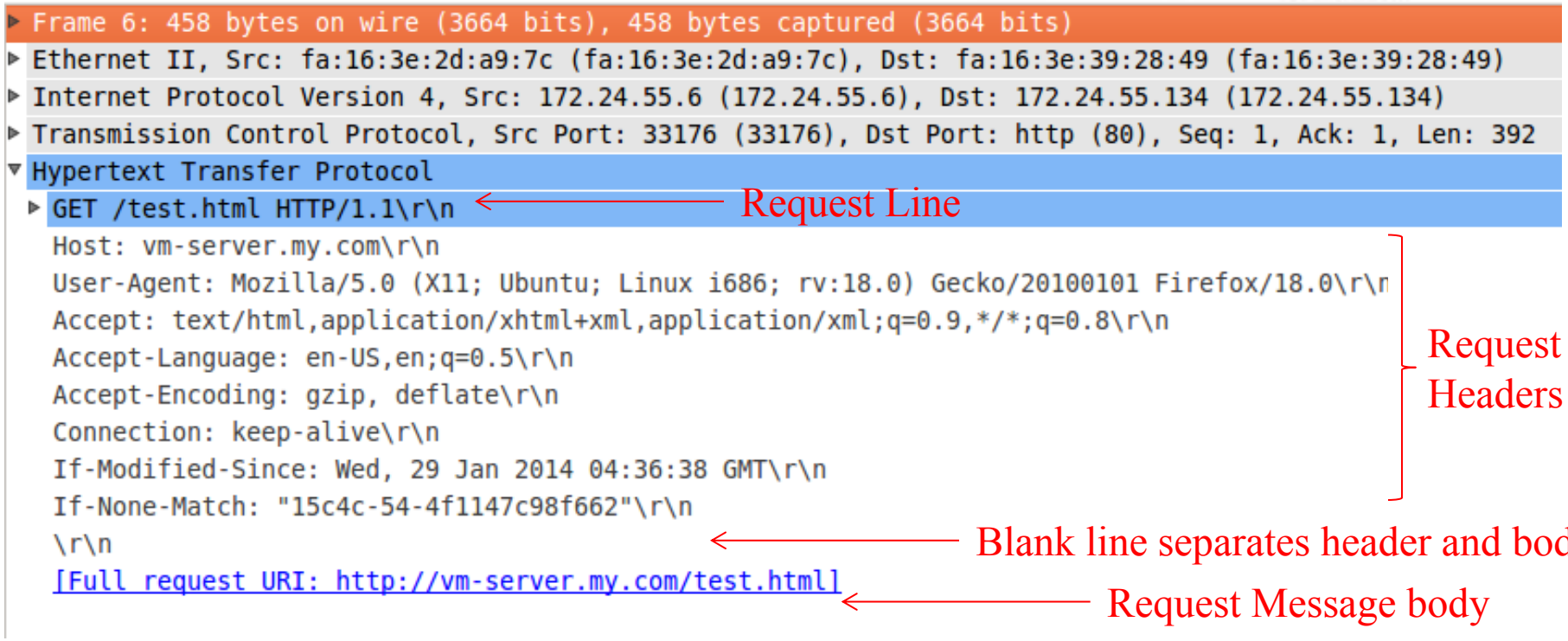
TCP connection request

```
▶ Frame 3: 74 bytes on wire (592 bits), 74 bytes captured (592 bits)
▶ Ethernet II, Src: fa:16:3e:2d:a9:7c (fa:16:3e:2d:a9:7c), Dst: fa:16:3e:39:28:49 (fa:16:3e:39:28:49)
▶ Internet Protocol Version 4, Src: 172.24.55.6 (172.24.55.6), Dst: 172.24.55.134 (172.24.55.134)
▼ Transmission Control Protocol, Src Port: 33176 (33176), Dst Port: http (80), Seq: 0, Len: 0
    Source port: 33176 (33176)
    Destination port: http (80)
    [Stream index: 1]
    Sequence number: 0    (relative sequence number)
    Header length: 40 bytes
  ▶ Flags: 0x002 (SYN)
    Window size value: 14600
    [Calculated window size: 14600]
  ▶ Checksum: 0xc6eb [validation disabled]
  ▼ Options: (20 bytes)
      Maximum segment size: 1460 bytes
      TCP SACK Permitted Option: True
    ▶ Timestamps: TSval 1686101, TSecr 0
      No-Operation (NOP)
    ▶ Window scale: 7 (multiply by 128)
```

TCP connection response

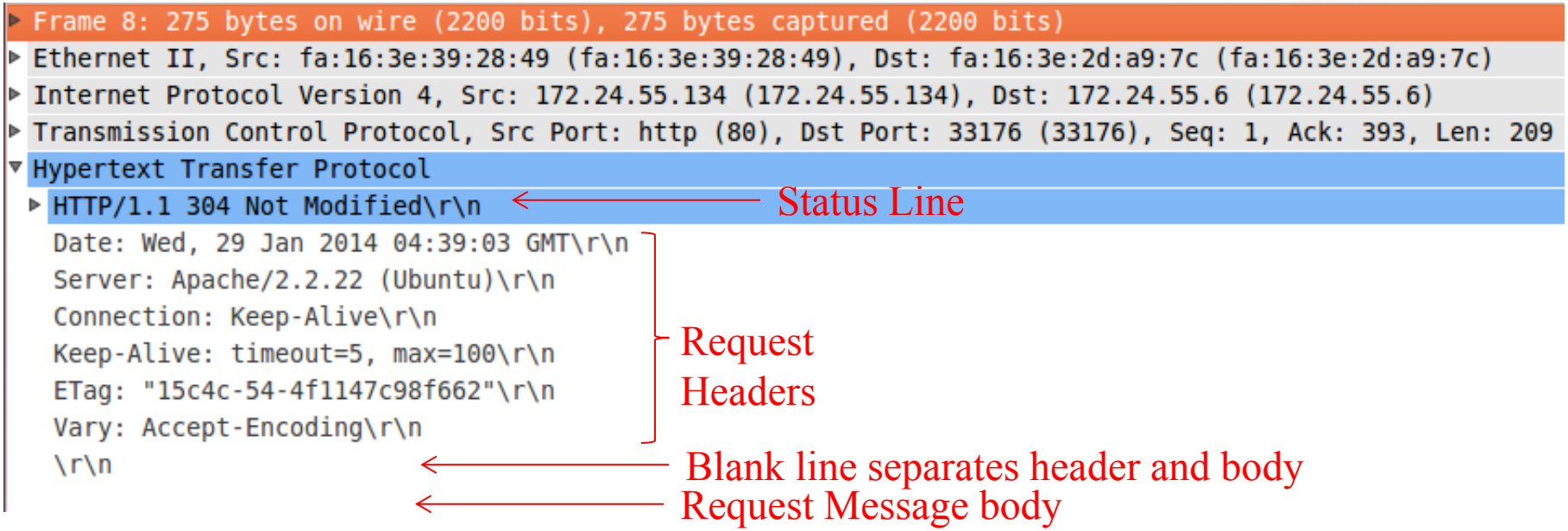


Initial HTTP request for page



HTTP Request Methods: GET, POST, PUT,…

Initial HTTP response



- The status code is a 3-digit number: 1xx (Informational), 2xx (Success), 3xx (Redirection), 4xx (Client Error), 5xx (Server Error).
- 304 Not Modified: In response to the If-Modified-Since conditional GET request, the server notifies that the resource requested has not been modified.

Client's TCP SYN Packet

3	0.001822	172.24.55.6	172.24.55.134	TCP	74	33176 > http [SYN] Seq=0 Win=14600 Len=0 MSS=1460 SACK_PERM
4	0.003653	172.24.55.134	172.24.55.6	TCP	74	http > 33176 [SYN, ACK] Seq=0 Ack=1 Win=14480 Len=0 MSS=146
5	0.003689	172.24.55.6	172.24.55.134	TCP	66	33176 > http [ACK] Seq=1 Ack=1 Win=14720 Len=0 TSval=168610
6	0.003888	172.24.55.6	172.24.55.134	HTTP	458	GET /test.html HTTP/1.1
7	0.004602	172.24.55.134	172.24.55.6	TCP	66	http > 33176 [ACK] Seq=1 Ack=393 Win=15616 Len=0 TSval=2009
8	0.005225	172.24.55.134	172.24.55.6	HTTP	275	HTTP/1.1 304 Not Modified
9	0.005245	172.24.55.6	172.24.55.134	TCP	66	33176 > http [ACK] Seq=393 Ack=210 Win=15744 Len=0 TSval=16

```
▶ Frame 3: 74 bytes on wire (592 bits), 74 bytes captured (592 bits)
▶ Ethernet II, Src: fa:16:3e:2d:a9:7c (fa:16:3e:2d:a9:7c), Dst: fa:16:3e:39:28:49 (fa:16:3e:39:28:49)
▶ Internet Protocol Version 4, Src: 172.24.55.6 (172.24.55.6), Dst: 172.24.55.134 (172.24.55.134)
▼ Transmission Control Protocol, Src Port: 33176 (33176), Dst Port: http (80), Seq: 0, Len: 0
    Source port: 33176 (33176)
    Destination port: http (80)
    [Stream index: 1]
    Sequence number: 0    (relative sequence number)
    Header length: 40 bytes
  ▶ Flags: 0x002 (SYN)
    Window size value: 14600
    [Calculated window size: 14600]
  ▶ Checksum: 0xc6eb [validation disabled]
  ▶ Options: (20 bytes)
```

Client's sequence number, c_sn=0

Server's TCP SYN+ACK Packet

3	0.001822	172.24.55.6	172.24.55.134	TCP	74	33176 > http [SYN] Seq=0 Win=14600 Len=0 MSS=1460 SACK_PERM
4	0.003653	172.24.55.134	172.24.55.6	TCP	74	http > 33176 [SYN, ACK] Seq=0 Ack=1 Win=14480 Len=0 MSS=146
5	0.003689	172.24.55.6	172.24.55.134	TCP	66	33176 > http [ACK] Seq=1 Ack=1 Win=14720 Len=0 TSval=168610
6	0.003888	172.24.55.6	172.24.55.134	HTTP	458	GET /test.html HTTP/1.1
7	0.004602	172.24.55.134	172.24.55.6	TCP	66	http > 33176 [ACK] Seq=1 Ack=393 Win=15616 Len=0 TSval=2009
8	0.005225	172.24.55.134	172.24.55.6	HTTP	275	HTTP/1.1 304 Not Modified
9	0.005245	172.24.55.6	172.24.55.134	TCP	66	33176 > http [ACK] Seq=393 Ack=210 Win=15744 Len=0 TSval=16

```
▶ Frame 4: 74 bytes on wire (592 bits), 74 bytes captured (592 bits)
▶ Ethernet II, Src: fa:16:3e:39:28:49 (fa:16:3e:39:28:49), Dst: fa:16:3e:2d:a9:7c (fa:16:3e:2d:a9:7c)
▶ Internet Protocol Version 4, Src: 172.24.55.134 (172.24.55.134), Dst: 172.24.55.6 (172.24.55.6)
▼ Transmission Control Protocol, Src Port: http (80), Dst Port: 33176 (33176), Seq: 0, Ack: 1, Len: 0
    Source port: http (80)
    Destination port: 33176 (33176)
    [Stream index: 1]
    Sequence number: 0    (relative sequence number)
    Acknowledgement number: 1    (relative ack number)
    Header length: 40 bytes
  ▶ Flags: 0x012 (SYN, ACK)
    Window size value: 14480
    [Calculated window size: 14480]
  ▶ Checksum: 0x9d15 [validation disabled]
  ▶ Options: (20 bytes)
  ▶ [SEQ/ACK analysis]
```

Server's sequence number, s_sn = 0

Acknowledge client's packet, ack=c_sn+1=1

Client's ACK Packet

3	0.001822	172.24.55.6	172.24.55.134	TCP	74	33176 > http [SYN] Seq=0 Win=14600 Len=0 MSS=1460 SACK_PERM
4	0.003653	172.24.55.134	172.24.55.6	TCP	74	http > 33176 [SYN, ACK] Seq=0 Ack=1 Win=14480 Len=0 MSS=146
5	0.003689	172.24.55.6	172.24.55.134	TCP	66	33176 > http [ACK] Seq=1 Ack=1 Win=14720 Len=0 TSval=168610
6	0.003888	172.24.55.6	172.24.55.134	HTTP	458	GET /test.html HTTP/1.1
7	0.004602	172.24.55.134	172.24.55.6	TCP	66	http > 33176 [ACK] Seq=1 Ack=393 Win=15616 Len=0 TSval=2009
8	0.005225	172.24.55.134	172.24.55.6	HTTP	275	HTTP/1.1 304 Not Modified
9	0.005245	172.24.55.6	172.24.55.134	TCP	66	33176 > http [ACK] Seq=393 Ack=210 Win=15744 Len=0 TSval=16

```
▶ Frame 5: 66 bytes on wire (528 bits), 66 bytes captured (528 bits)
▶ Ethernet II, Src: fa:16:3e:2d:a9:7c (fa:16:3e:2d:a9:7c), Dst: fa:16:3e:39:28:49 (fa:16:3e:39:28:49)
▶ Internet Protocol Version 4, Src: 172.24.55.6 (172.24.55.6), Dst: 172.24.55.134 (172.24.55.134)
▼ Transmission Control Protocol, Src Port: 33176 (33176), Dst Port: http (80), Seq: 1, Ack: 1, Len: 0
    Source port: 33176 (33176)
    Destination port: http (80)
    [Stream index: 1]
    Sequence number: 1    (relative sequence number)
    Acknowledgement number: 1    (relative ack number)
    Header length: 32 bytes
  ▶ Flags: 0x010 (ACK)
    Window size value: 115
    [Calculated window size: 14720]
    [Window size scaling factor: 128]
  ▶ Checksum: 0xc6e3 [validation disabled]
  ▶ Options: (12 bytes)
```

client's sequence number, c_sn+1 = 1

Acknowledge server's packet, ack=s_sn+1=1

HTTP Request Packet

3	0.001822	172.24.55.6	172.24.55.134	TCP	74	33176 > http [SYN] Seq=0 Win=14600 Len=0 MSS=1460 SACK_PERM
4	0.003653	172.24.55.134	172.24.55.6	TCP	74	http > 33176 [SYN, ACK] Seq=0 Ack=1 Win=14480 Len=0 MSS=146
5	0.003689	172.24.55.6	172.24.55.134	TCP	66	33176 > http [ACK] Seq=1 Ack=1 Win=14720 Len=0 TSval=168610
6	0.003888	172.24.55.6	172.24.55.134	HTTP	458	GET /test.html HTTP/1.1
7	0.004602	172.24.55.134	172.24.55.6	TCP	66	http > 33176 [ACK] Seq=1 Ack=393 Win=15616 Len=0 TSval=2009
8	0.005225	172.24.55.134	172.24.55.6	HTTP	275	HTTP/1.1 304 Not Modified
9	0.005245	172.24.55.6	172.24.55.134	TCP	66	33176 > http [ACK] Seq=393 Ack=210 Win=15744 Len=0 TSval=168

```
▶ Frame 6: 458 bytes on wire (3664 bits), 458 bytes captured (3664 bits)
▶ Ethernet II, Src: fa:16:3e:2d:a9:7c (fa:16:3e:2d:a9:7c), Dst: fa:16:3e:39:28:49 (fa:16:3e:39:28:49)
▶ Internet Protocol Version 4, Src: 172.24.55.6 (172.24.55.6), Dst: 172.24.55.134 (172.24.55.134)
▼ Transmission Control Protocol, Src Port: 33176 (33176), Dst Port: http (80), Seq: 1, Ack: 1, Len: 392
    Source port: 33176 (33176)
    Destination port: http (80)
    [Stream index: 1]
    Sequence number: 1    (relative sequence number)
    [Next sequence number: 393    (relative sequence number)]
    Acknowledgement number: 1    (relative ack number)
    Header length: 32 bytes
  ▶ Flags: 0x018 (PSH, ACK)
    Window size value: 115
    [Calculated window size: 14720]
    [Window size scaling factor: 128]
  ▶ Checksum: 0xc86b [validation disabled]
```

c_sn= 1, since no data has been transmitted since the last packet.

n_sn= sn+len

ack=1, since no data has been received from server, either.

ACK from Server

3	0.001822	172.24.55.6	172.24.55.134	TCP	74	33176 > http [SYN] Seq=0 Win=14600 Len=0 MSS=1460 SACK_PERM
4	0.003653	172.24.55.134	172.24.55.6	TCP	74	http > 33176 [SYN, ACK] Seq=0 Ack=1 Win=14480 Len=0 MSS=146
5	0.003689	172.24.55.6	172.24.55.134	TCP	66	33176 > http [ACK] Seq=1 Ack=1 Win=14720 Len=0 TSval=168610
6	0.003888	172.24.55.6	172.24.55.134	HTTP	458	GET /test.html HTTP/1.1
7	0.004602	172.24.55.134	172.24.55.6	TCP	66	http > 33176 [ACK] Seq=1 Ack=393 Win=15616 Len=0 TSval=2009
8	0.005225	172.24.55.134	172.24.55.6	HTTP	275	HTTP/1.1 304 Not Modified
9	0.005245	172.24.55.6	172.24.55.134	TCP	66	33176 > http [ACK] Seq=393 Ack=210 Win=15744 Len=0 TSval=168

```
▶ Frame 7: 66 bytes on wire (528 bits), 66 bytes captured (528 bits)
▶ Ethernet II, Src: fa:16:3e:39:28:49 (fa:16:3e:39:28:49), Dst: fa:16:3e:2d:a9:7c (fa:16:3e:2d:a9:7c)
▶ Internet Protocol Version 4, Src: 172.24.55.134 (172.24.55.134), Dst: 172.24.55.6 (172.24.55.6)
▼ Transmission Control Protocol, Src Port: http (80), Dst Port: 33176 (33176), Seq: 1, Ack: 393, Len: 0
    Source port: http (80)
    Destination port: 33176 (33176)
    [Stream index: 1]
    Sequence number: 1    (relative sequence number)
    Acknowledgement number: 393    (relative ack number)
    Header length: 32 bytes
  ▶ Flags: 0x010 (ACK)
    Window size value: 122
    [Calculated window size: 15616]
    [Window size scaling factor: 128]
  ▶ Checksum: 0x0270 [validation disabled]
  ▶ Options: (12 bytes)
  ▶ [SEQ/ACK analysis]
```

s_sn= 1, since no data has been transmitted since the last packet.

ack=len(payload in the client's request) + 1

HTTP Response Packet

3	0.001822	172.24.55.6	172.24.55.134	TCP	74	33176 > http [SYN] Seq=0 Win=14600 Len=0 MSS=1460 SACK_PERM
4	0.003653	172.24.55.134	172.24.55.6	TCP	74	http > 33176 [SYN, ACK] Seq=0 Ack=1 Win=14480 Len=0 MSS=146
5	0.003689	172.24.55.6	172.24.55.134	TCP	66	33176 > http [ACK] Seq=1 Ack=1 Win=14720 Len=0 TSval=168610
6	0.003888	172.24.55.6	172.24.55.134	HTTP	458	GET /test.html HTTP/1.1
7	0.004602	172.24.55.134	172.24.55.6	TCP	66	http > 33176 [ACK] Seq=1 Ack=393 Win=15616 Len=0 TSval=2009
8	0.005225	172.24.55.134	172.24.55.6	HTTP	275	HTTP/1.1 304 Not Modified
9	0.005245	172.24.55.6	172.24.55.134	TCP	66	33176 > http [ACK] Seq=393 Ack=210 Win=15744 Len=0 TSval=168

```
▶ Frame 8: 275 bytes on wire (2200 bits), 275 bytes captured (2200 bits)
▶ Ethernet II, Src: fa:16:3e:39:28:49 (fa:16:3e:39:28:49), Dst: fa:16:3e:2d:a9:7c (fa:16:3e:2d:a9:7c)
▶ Internet Protocol Version 4, Src: 172.24.55.134 (172.24.55.134), Dst: 172.24.55.6 (172.24.55.6)
▼ Transmission Control Protocol, Src Port: http (80), Dst Port: 33176 (33176), Seq: 1, Ack: 393, Len: 209
    Source port: http (80)
    Destination port: 33176 (33176)
    [Stream index: 1]
    Sequence number: 1    (relative sequence number)
    [Next sequence number: 210    (relative sequence number)]
    Acknowledgement number: 393    (relative ack number)
    Header length: 32 bytes
  ▶ Flags: 0x018 (PSH, ACK)
    Window size value: 122
    [Calculated window size: 15616]
    [Window size scaling factor: 128]
  ▶ Checksum: 0x374a [validation disabled]
  ▶ Options: (12 bytes)
```

Payload length

s_sn= 1, since no data has been transmitted since the last packet.

Ack number remains the same

ACK from Client

3	0.001822	172.24.55.6	172.24.55.134	TCP	74	33176 > http [SYN] Seq=0 Win=14600 Len=0 MSS=1460 SACK_PERM
4	0.003653	172.24.55.134	172.24.55.6	TCP	74	http > 33176 [SYN, ACK] Seq=0 Ack=1 Win=14480 Len=0 MSS=146
5	0.003689	172.24.55.6	172.24.55.134	TCP	66	33176 > http [ACK] Seq=1 Ack=1 Win=14720 Len=0 TSval=168610
6	0.003888	172.24.55.6	172.24.55.134	HTTP	458	GET /test.html HTTP/1.1
7	0.004602	172.24.55.134	172.24.55.6	TCP	66	http > 33176 [ACK] Seq=1 Ack=393 Win=15616 Len=0 TSval=2009
8	0.005225	172.24.55.134	172.24.55.6	HTTP	275	HTTP/1.1 304 Not Modified
9	0.005245	172.24.55.6	172.24.55.134	TCP	66	33176 > http [ACK] Seq=393 Ack=210 Win=15744 Len=0 TSval=168

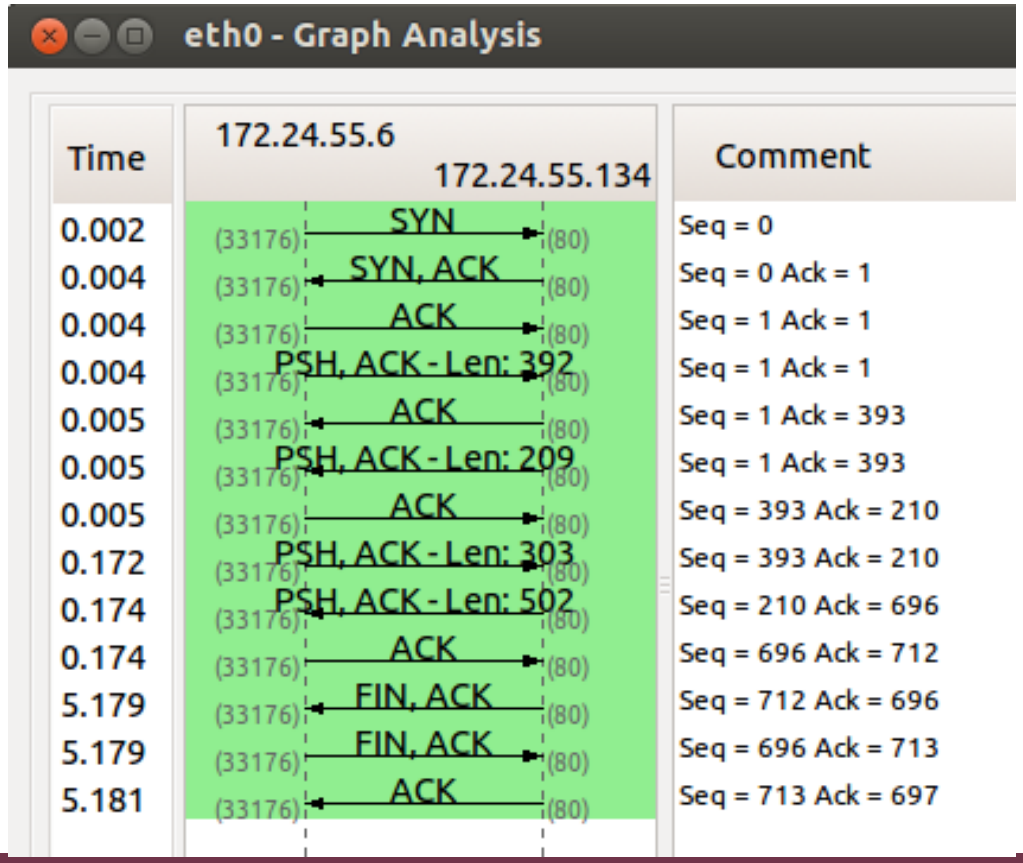
```
▶ Frame 9: 66 bytes on wire (528 bits), 66 bytes captured (528 bits)
▶ Ethernet II, Src: fa:16:3e:2d:a9:7c (fa:16:3e:2d:a9:7c), Dst: fa:16:3e:39:28:49 (fa:16:3e:39:28:49)
▶ Internet Protocol Version 4, Src: 172.24.55.6 (172.24.55.6), Dst: 172.24.55.134 (172.24.55.134)
▼ Transmission Control Protocol, Src Port: 33176 (33176), Dst Port: http (80), Seq: 393, Ack: 210, Len: 0
    Source port: 33176 (33176)
    Destination port: http (80)
    [Stream index: 1]
    Sequence number: 393    (relative sequence number)
    Acknowledgement number: 210    (relative ack number)
    Header length: 32 bytes
  ▶ Flags: 0x010 (ACK)
    Window size value: 123
    [Calculated window size: 15744]
    [Window size scaling factor: 128]
  ▶ Checksum: 0xc6e3 [validation disabled]
  ▶ Options: (12 bytes)
  ▶ [SEQ/ACK analysis]
```

c_sn= c_sn+1

ack=len(payload in the server's response) + 1

TCP Flow

In Wireshark, **Statistics > Flow Graph...**, select **TCP flow** and click **OK**.



Protocol Analysis Process

- Identify the problem "symptoms"
  - What appears to be happening / not happening that is a concern
  - Identify the machines (hosts) involved
  - Identify the protocols involved
  - Set up capture filters to define what packets will be gathered.
  - Capture and analyze packets.

Summary

- Review a popular Internet Service
- Overview of Wireshsark
- Packet Analysis of Internet service communications