Kathará

Lab webserver

web server and browser

Version	1.4
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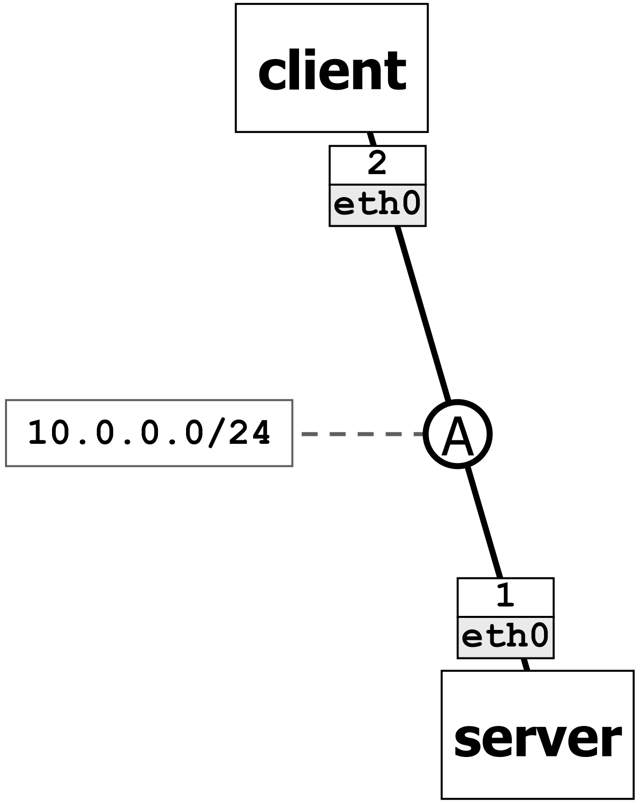
Description	A lab showing the operation of a Web server accessed by a browser client – the TCP perspective – kathara version of a corresponding netkit lab vers. 1.2

Copyright notice

Lab topology

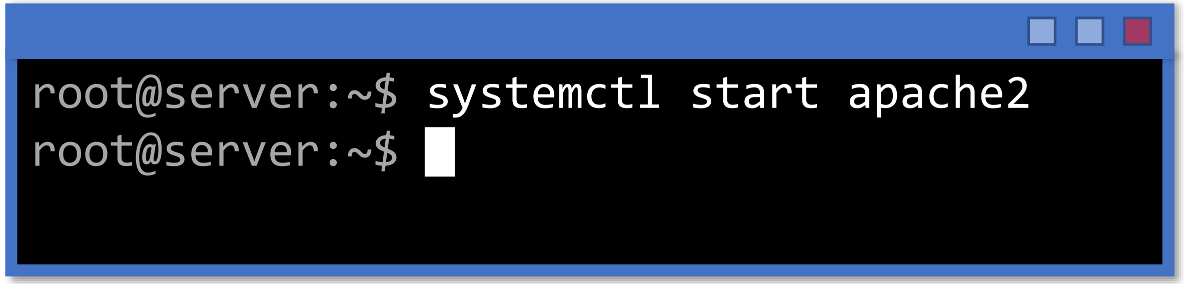


Lab description

- server
  - runs apache2 (with a default configuration)
- client
  - the user can launch a text-based web browser (**`links`**) to check the server operation

The server

- the user can check that apache2 is up and running by using the following command:



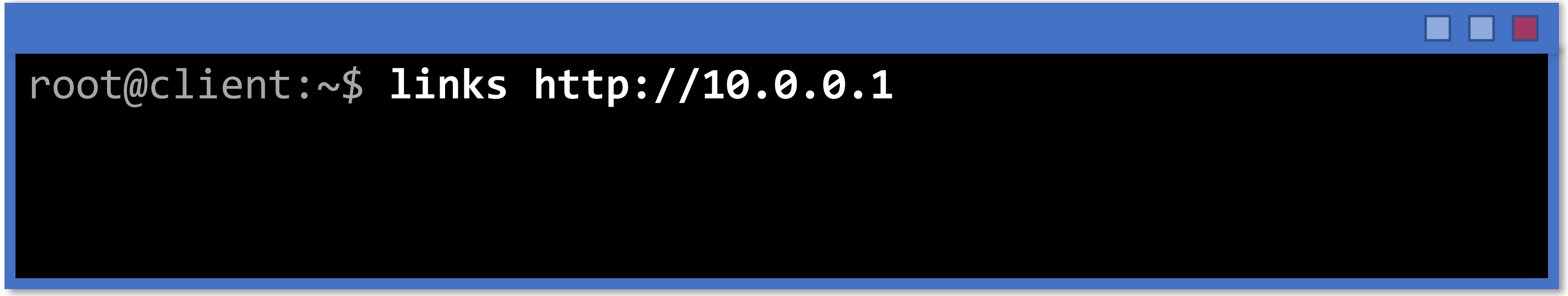
```
root@server:~$ systemctl start apache2
root@server:~$ █
```

- we put a test html page
  - located in **`/var/www/html/index.html`**

```
<html>
  <body>
      <h1>Hello!</h1>
  </body>
</html>
```

The client

- the user is supposed to start the web browser **`links`** on the client



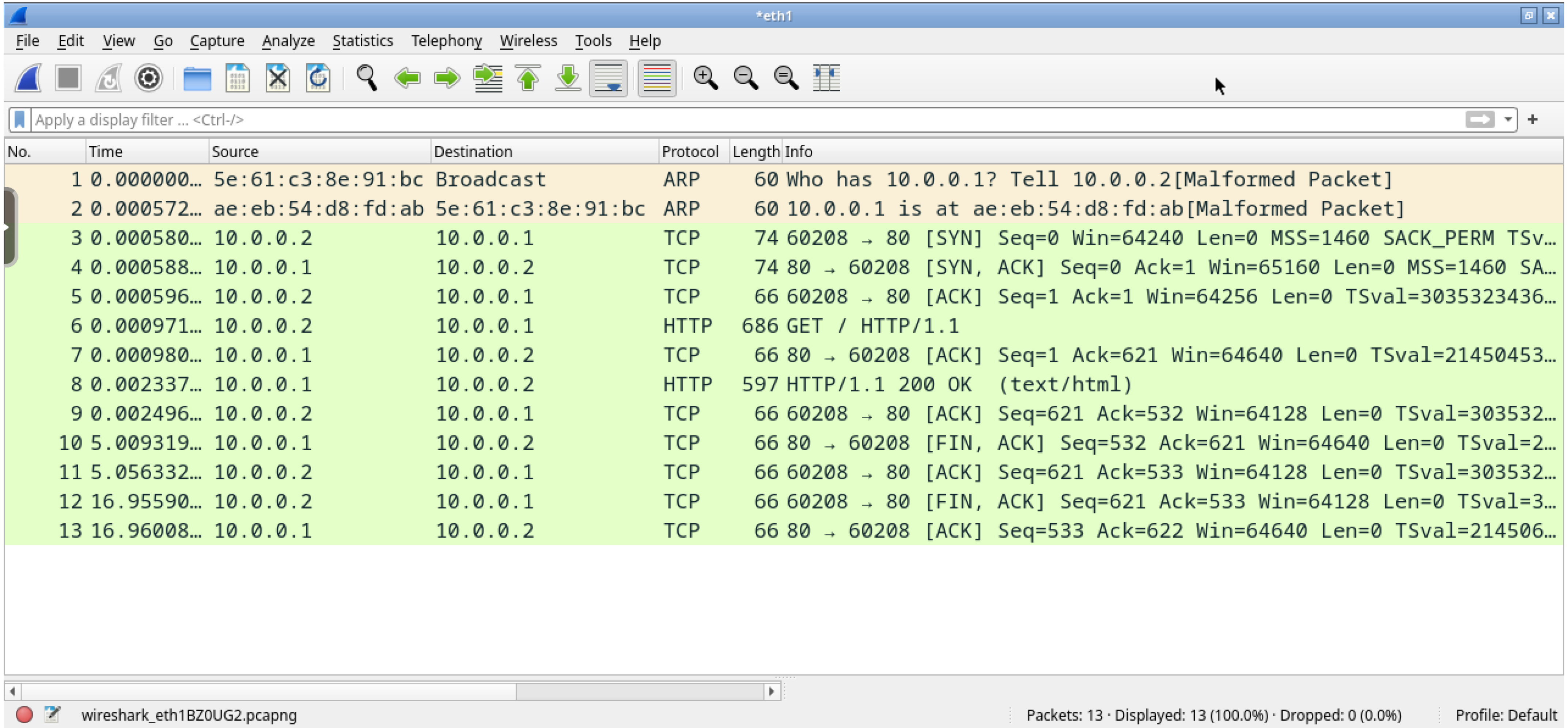
```
root@client:~$ links http://10.0.0.1
```

- you should get a screen saying “Hello!”

let us observe the packets

- perform the following command on the host computer to observe the traffic generated by the http protocol
  - kathara lconfig -n wireshark --add A
- what follows is a list of packets observed on the Ethernet link called A

The 13 captured packets



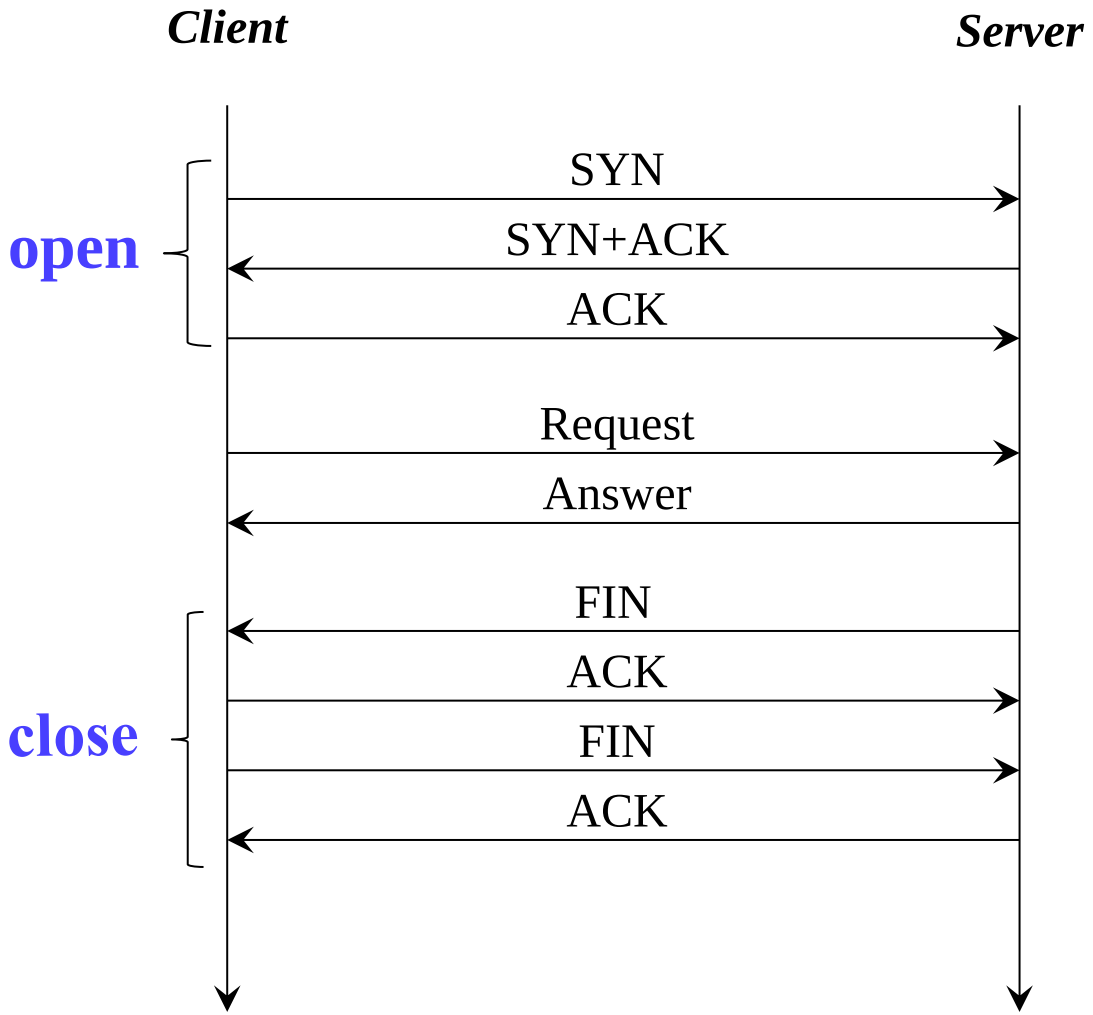
No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000…	5e:61:c3:8e:91:bc	Broadcast	ARP	60	Who has 10.0.0.1? Tell 10.0.0.2[Malformed Packet]
2	0.000572…	ae:eb:54:d8:fd:ab	5e:61:c3:8e:91:bc	ARP	60	10.0.0.1 is at ae:eb:54:d8:fd:ab[Malformed Packet]
3	0.000580…	10.0.0.2	10.0.0.1	TCP	74	60208 → 80 [SYN] Seq=0 Win=64240 Len=0 MSS=1460 SACK_PERM TSv…
4	0.000588…	10.0.0.1	10.0.0.2	TCP	74	80 → 60208 [SYN, ACK] Seq=0 Ack=1 Win=65160 Len=0 MSS=1460 SA…
5	0.000596…	10.0.0.2	10.0.0.1	TCP	66	60208 → 80 [ACK] Seq=1 Ack=1 Win=64256 Len=0 TSval=3035323436…
6	0.000971…	10.0.0.2	10.0.0.1	HTTP	686	GET / HTTP/1.1
7	0.000980…	10.0.0.1	10.0.0.2	TCP	66	80 → 60208 [ACK] Seq=1 Ack=621 Win=64640 Len=0 TSval=21450453…
8	0.002337…	10.0.0.1	10.0.0.2	HTTP	597	HTTP/1.1 200 OK (text/html)
9	0.002496…	10.0.0.2	10.0.0.1	TCP	66	60208 → 80 [ACK] Seq=621 Ack=532 Win=64128 Len=0 TSval=303532…
10	5.009319…	10.0.0.1	10.0.0.2	TCP	66	80 → 60208 [FIN, ACK] Seq=532 Ack=621 Win=64640 Len=0 TSval=2…
11	5.056332…	10.0.0.2	10.0.0.1	TCP	66	60208 → 80 [ACK] Seq=621 Ack=533 Win=64128 Len=0 TSval=303532…
12	16.95590…	10.0.0.2	10.0.0.1	TCP	66	60208 → 80 [FIN, ACK] Seq=621 Ack=533 Win=64128 Len=0 TSval=3…
13	16.96008…	10.0.0.1	10.0.0.2	TCP	66	80 → 60208 [ACK] Seq=533 Ack=622 Win=64640 Len=0 TSval=214506…

wireshark_eth1BZ0UG2.pcapng

Packets: 13 · Displayed: 13 (100.0%) · Dropped: 0 (0.0%)

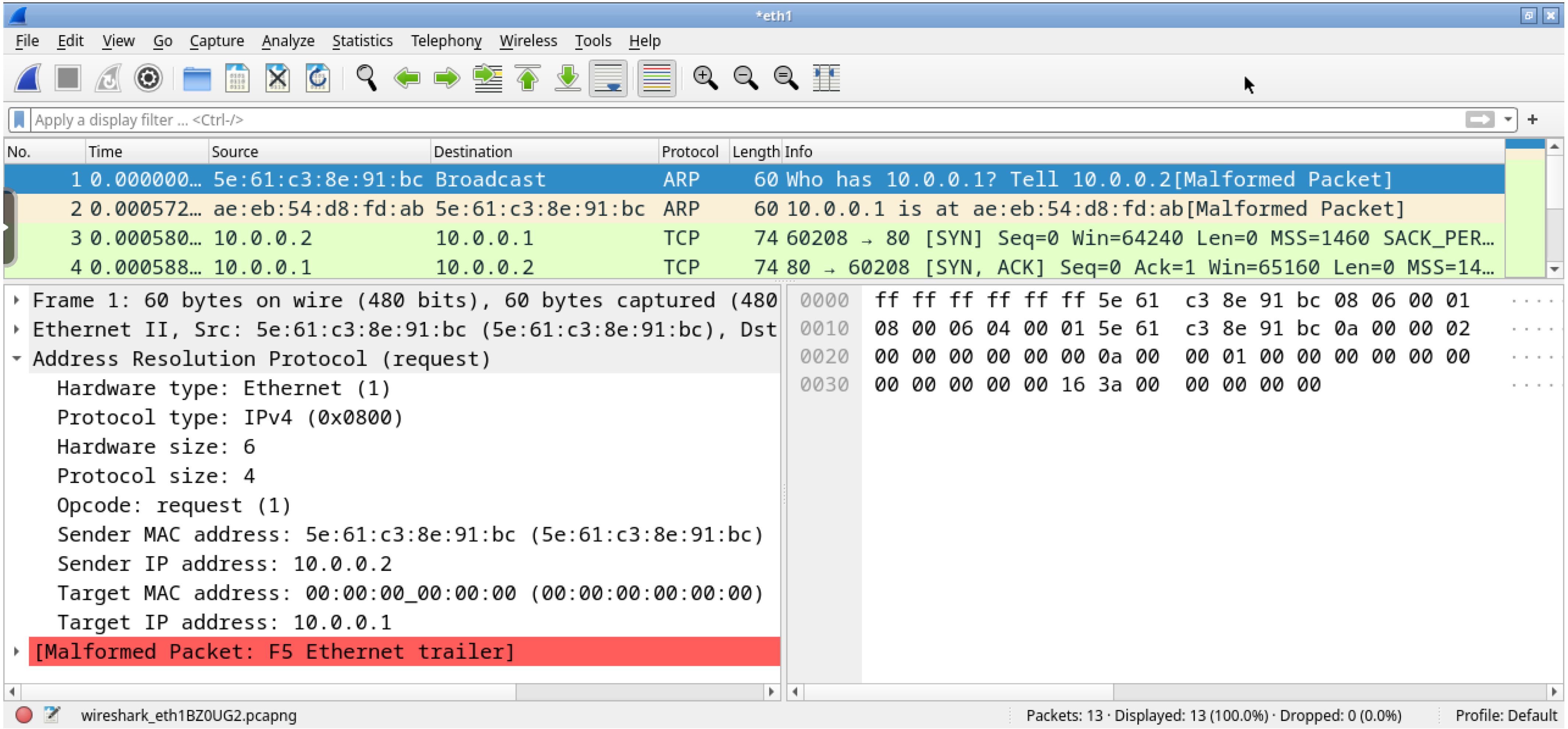
Profile: Default

http basic behaviour



pkt 1 – client→bcast – arp request

arp request: the client looks for the MAC address of the server


*eth1
File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help
Apply a display filter ... <Ctrl-/>

```
No.  Time        Source             Destination        Protocol Length Info
   1 0.000000…   5e:61:c3:8e:91:bc  Broadcast          ARP      60 Who has 10.0.0.1? Tell 10.0.0.2[Malformed Packet]
   2 0.000572…   ae:eb:54:d8:fd:ab  5e:61:c3:8e:91:bc  ARP      60 10.0.0.1 is at ae:eb:54:d8:fd:ab[Malformed Packet]
   3 0.000580…   10.0.0.2           10.0.0.1           TCP      74 60208 → 80 [SYN] Seq=0 Win=64240 Len=0 MSS=1460 SACK_PER…
   4 0.000588…   10.0.0.1           10.0.0.2           TCP      74 80 → 60208 [SYN, ACK] Seq=0 Ack=1 Win=65160 Len=0 MSS=14…
```

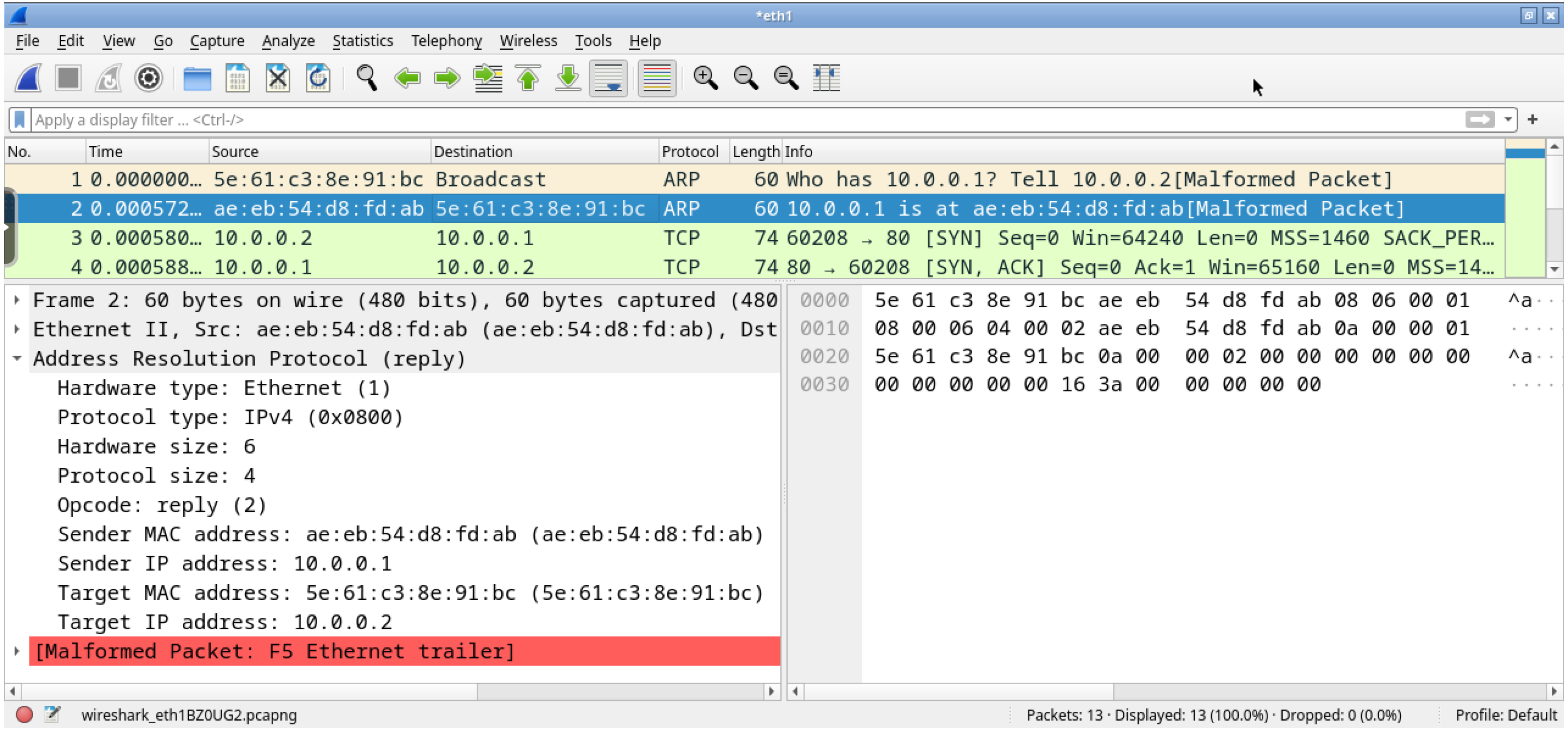
```
› Frame 1: 60 bytes on wire (480 bits), 60 bytes captured (480
› Ethernet II, Src: 5e:61:c3:8e:91:bc (5e:61:c3:8e:91:bc), Dst
⌄ Address Resolution Protocol (request)
    Hardware type: Ethernet (1)
    Protocol type: IPv4 (0x0800)
    Hardware size: 6
    Protocol size: 4
    Opcode: request (1)
    Sender MAC address: 5e:61:c3:8e:91:bc (5e:61:c3:8e:91:bc)
    Sender IP address: 10.0.0.2
    Target MAC address: 00:00:00_00:00:00 (00:00:00:00:00:00)
    Target IP address: 10.0.0.1
› [Malformed Packet: F5 Ethernet trailer]
```

```
0000  ff ff ff ff ff ff 5e 61  c3 8e 91 bc 08 06 00 01   ····
0010  08 00 06 04 00 01 5e 61  c3 8e 91 bc 0a 00 00 02   ····
0020  00 00 00 00 00 00 0a 00  00 01 00 00 00 00 00 00   ····
0030  00 00 00 00 00 16 3a 00  00 00 00 00               ····
```

wireshark_eth1BZ0UG2.pcapng   Packets: 13 · Displayed: 13 (100.0%) · Dropped: 0 (0.0%)   Profile: Default

pkt 2 – client←server – arp reply

arp reply: the server provides its MAC address



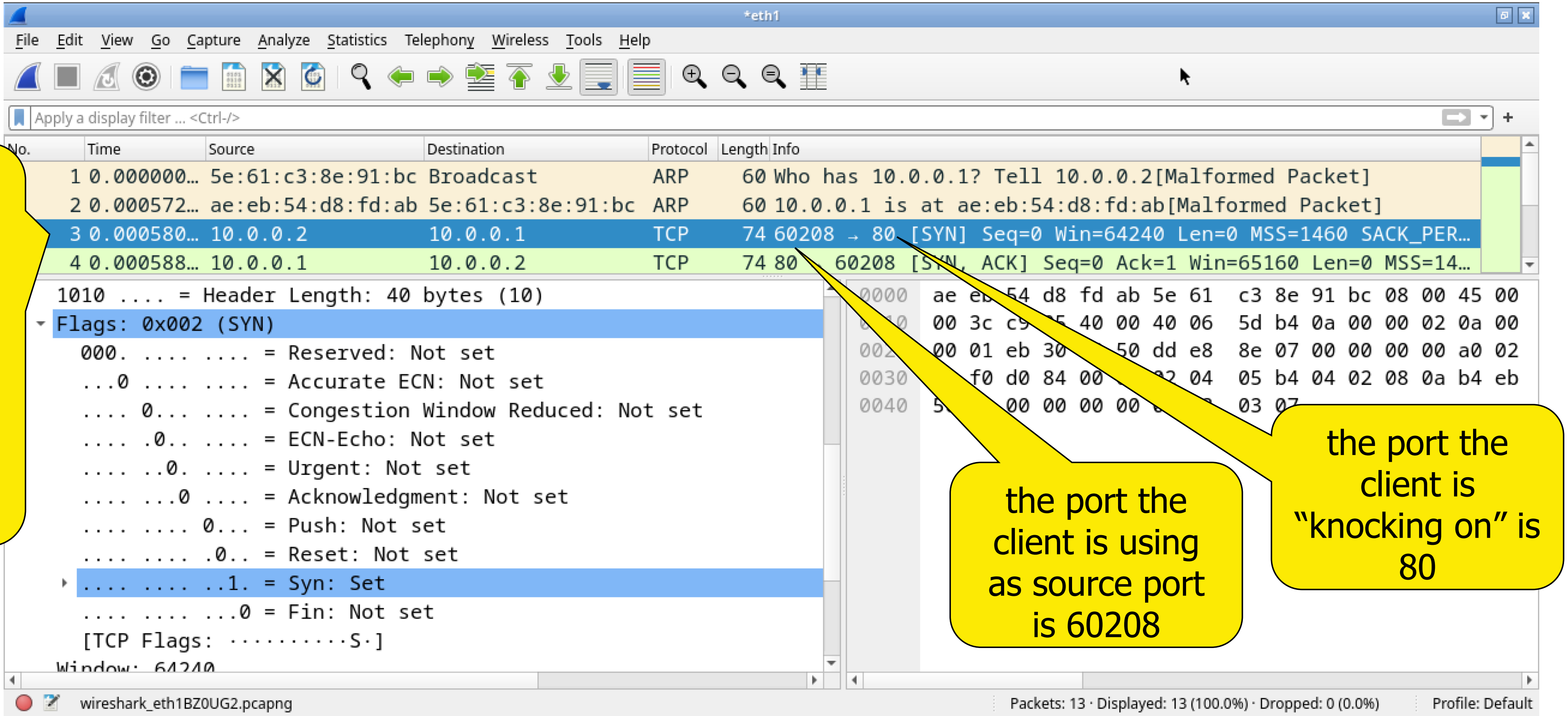
```
No. Time        Source             Destination        Protocol Length Info
  1 0.000000…   5e:61:c3:8e:91:bc  Broadcast          ARP        60 Who has 10.0.0.1? Tell 10.0.0.2[Malformed Packet]
  2 0.000572…   ae:eb:54:d8:fd:ab  5e:61:c3:8e:91:bc  ARP        60 10.0.0.1 is at ae:eb:54:d8:fd:ab[Malformed Packet]
  3 0.000580…   10.0.0.2           10.0.0.1           TCP        74 60208 → 80 [SYN] Seq=0 Win=64240 Len=0 MSS=1460 SACK_PER…
  4 0.000588…   10.0.0.1           10.0.0.2           TCP        74 80 → 60208 [SYN, ACK] Seq=0 Ack=1 Win=65160 Len=0 MSS=14…
```

```
› Frame 2: 60 bytes on wire (480 bits), 60 bytes captured (480
› Ethernet II, Src: ae:eb:54:d8:fd:ab (ae:eb:54:d8:fd:ab), Dst
˅ Address Resolution Protocol (reply)
    Hardware type: Ethernet (1)
    Protocol type: IPv4 (0x0800)
    Hardware size: 6
    Protocol size: 4
    Opcode: reply (2)
    Sender MAC address: ae:eb:54:d8:fd:ab (ae:eb:54:d8:fd:ab)
    Sender IP address: 10.0.0.1
    Target MAC address: 5e:61:c3:8e:91:bc (5e:61:c3:8e:91:bc)
    Target IP address: 10.0.0.2
› [Malformed Packet: F5 Ethernet trailer]
```

```
0000  5e 61 c3 8e 91 bc ae eb  54 d8 fd ab 08 06 00 01   ^a··
0010  08 00 06 04 00 02 ae eb  54 d8 fd ab 0a 00 00 01   ····
0020  5e 61 c3 8e 91 bc 0a 00  00 02 00 00 00 00 00 00   ^a··
0030  00 00 00 00 00 16 3a 00  00 00 00 00               ····
```

wireshark_eth1BZ0UG2.pcapng   Packets: 13 · Displayed: 13 (100.0%) · Dropped: 0 (0.0%)   Profile: Default

pkt 3 – client→server – syn



```
No. Time         Source            Destination       Protocol Length Info
  1 0.000000…  5e:61:c3:8e:91:bc Broadcast         ARP      60 Who has 10.0.0.1? Tell 10.0.0.2[Malformed Packet]
  2 0.000572…  ae:eb:54:d8:fd:ab 5e:61:c3:8e:91:bc ARP      60 10.0.0.1 is at ae:eb:54:d8:fd:ab[Malformed Packet]
  3 0.000580…  10.0.0.2          10.0.0.1          TCP      74 60208 → 80 [SYN] Seq=0 Win=64240 Len=0 MSS=1460 SACK_PER…
  4 0.000588…  10.0.0.1          10.0.0.2          TCP      74 80 → 60208 [SYN, ACK] Seq=0 Ack=1 Win=65160 Len=0 MSS=14…
```

```
 1010 .... = Header Length: 40 bytes (10)
▾ Flags: 0x002 (SYN)
   000. .... .... = Reserved: Not set
   ...0 .... .... = Accurate ECN: Not set
   .... 0... .... = Congestion Window Reduced: Not set
   .... .0.. .... = ECN-Echo: Not set
   .... ..0. .... = Urgent: Not set
   .... ...0 .... = Acknowledgment: Not set
   .... .... 0... = Push: Not set
   .... .... .0.. = Reset: Not set
 ▸ .... .... ..1. = Syn: Set
   .... .... ...0 = Fin: Not set
   [TCP Flags: ··········S·]
 Window: 64240
```

```
0000  ae eb 54 d8 fd ab 5e 61  c3 8e 91 bc 08 00 45 00
0010  00 3c c9 [illegible] 40 00 40 06  5d b4 0a 00 00 02 0a 00
0020  00 01 eb 30 [illegible] 50 dd e8  8e 07 00 00 00 00 a0 02
0030  [illegible] f0 d0 84 00 [illegible] 02 04  05 b4 04 02 08 0a b4 eb
0040  5[illegible] [illegible] 00 00 00 00 [illegible] [illegible]  03 07
```

wireshark_eth1BZ0UG2.pcapng
Packets: 13 · Displayed: 13 (100.0%) · Dropped: 0 (0.0%)
Profile: Default

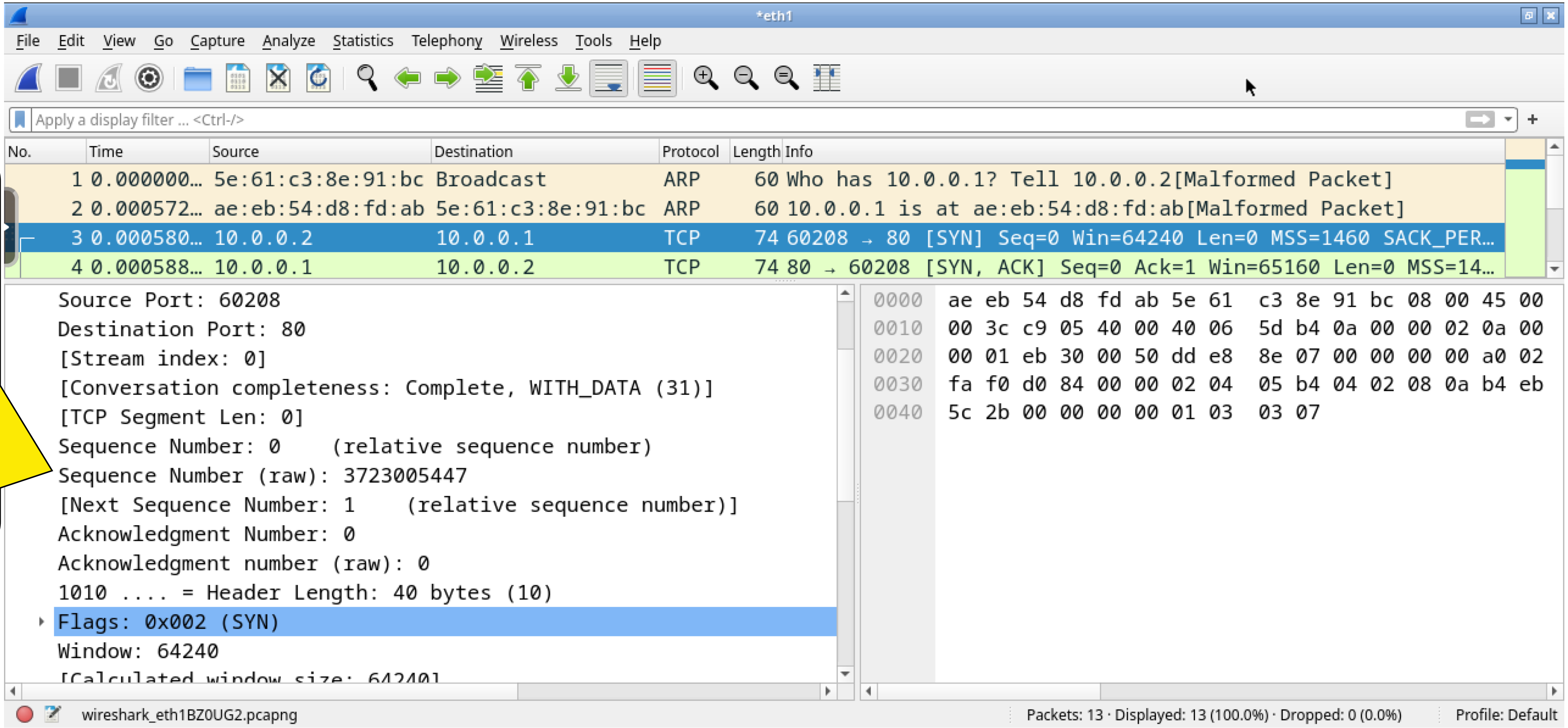
the client starts the three-way-handshake

the port the client is using as source port is 60208

the port the client is “knocking on” is 80

pkt 3 – client→server – initial seq. numb.

the client proposes 3723005447 as its initial sequence number



No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000…	5e:61:c3:8e:91:bc	Broadcast	ARP	60	Who has 10.0.0.1? Tell 10.0.0.2[Malformed Packet]
2	0.000572…	ae:eb:54:d8:fd:ab	5e:61:c3:8e:91:bc	ARP	60	10.0.0.1 is at ae:eb:54:d8:fd:ab[Malformed Packet]
3	0.000580…	10.0.0.2	10.0.0.1	TCP	74	60208 → 80 [SYN] Seq=0 Win=64240 Len=0 MSS=1460 SACK_PER…
4	0.000588…	10.0.0.1	10.0.0.2	TCP	74	80 → 60208 [SYN, ACK] Seq=0 Ack=1 Win=65160 Len=0 MSS=14…

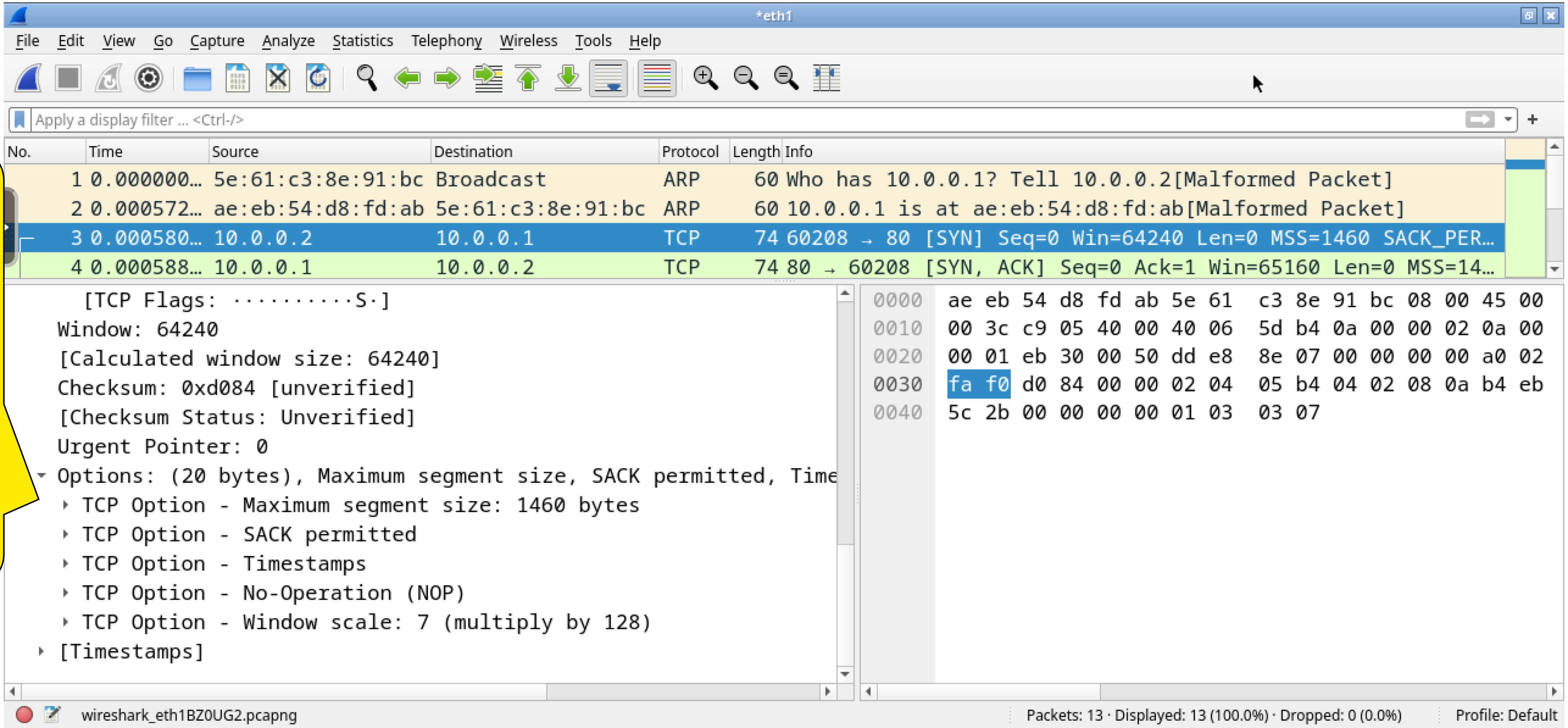
```
Source Port: 60208
Destination Port: 80
[Stream index: 0]
[Conversation completeness: Complete, WITH_DATA (31)]
[TCP Segment Len: 0]
Sequence Number: 0    (relative sequence number)
Sequence Number (raw): 3723005447
[Next Sequence Number: 1    (relative sequence number)]
Acknowledgment Number: 0
Acknowledgment number (raw): 0
1010 .... = Header Length: 40 bytes (10)
Flags: 0x002 (SYN)
Window: 64240
[Calculated window size: 64240]
```

```
0000  ae eb 54 d8 fd ab 5e 61  c3 8e 91 bc 08 00 45 00
0010  00 3c c9 05 40 00 40 06  5d b4 0a 00 00 02 0a 00
0020  00 01 eb 30 00 50 dd e8  8e 07 00 00 00 00 a0 02
0030  fa f0 d0 84 00 00 02 04  05 b4 04 02 08 0a b4 eb
0040  5c 2b 00 00 00 00 01 03  03 07
```

wireshark_eth1BZ0UG2.pcapng   Packets: 13 · Displayed: 13 (100.0%) · Dropped: 0 (0.0%)   Profile: Default

pkt 3 – client→server – MSS option

the client proposes a maximum segment size of 1460 bytes


*eth1
File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help
Apply a display filter ... <Ctrl-/>

```
No.  Time          Source               Destination          Protocol Length Info
   1 0.000000…     5e:61:c3:8e:91:bc    Broadcast            ARP      60 Who has 10.0.0.1? Tell 10.0.0.2[Malformed Packet]
   2 0.000572…     ae:eb:54:d8:fd:ab    5e:61:c3:8e:91:bc    ARP      60 10.0.0.1 is at ae:eb:54:d8:fd:ab[Malformed Packet]
   3 0.000580…     10.0.0.2             10.0.0.1             TCP      74 60208 → 80 [SYN] Seq=0 Win=64240 Len=0 MSS=1460 SACK_PER…
   4 0.000588…     10.0.0.1             10.0.0.2             TCP      74 80 → 60208 [SYN, ACK] Seq=0 Ack=1 Win=65160 Len=0 MSS=14…
```

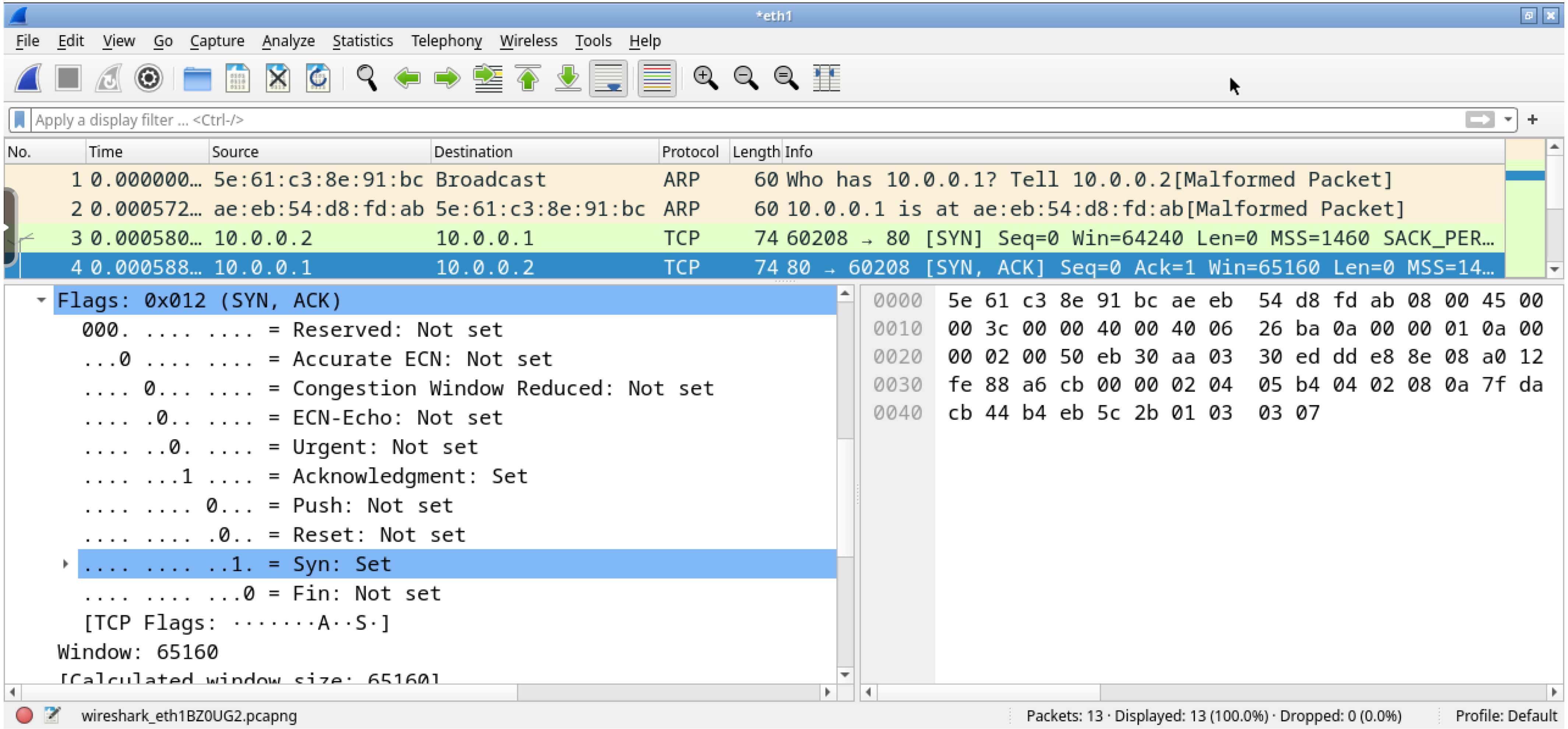
```
    [TCP Flags: ··········S·]
  Window: 64240
  [Calculated window size: 64240]
  Checksum: 0xd084 [unverified]
  [Checksum Status: Unverified]
  Urgent Pointer: 0
▾ Options: (20 bytes), Maximum segment size, SACK permitted, Time
  › TCP Option - Maximum segment size: 1460 bytes
  › TCP Option - SACK permitted
  › TCP Option - Timestamps
  › TCP Option - No-Operation (NOP)
  › TCP Option - Window scale: 7 (multiply by 128)
› [Timestamps]
```

```
0000  ae eb 54 d8 fd ab 5e 61  c3 8e 91 bc 08 00 45 00
0010  00 3c c9 05 40 00 40 06  5d b4 0a 00 00 02 0a 00
0020  00 01 eb 30 00 50 dd e8  8e 07 00 00 00 00 a0 02
0030  fa f0 d0 84 00 00 02 04  05 b4 04 02 08 0a b4 eb
0040  5c 2b 00 00 00 00 01 03  03 07
```

wireshark_eth1BZ0UG2.pcapng   Packets: 13 · Displayed: 13 (100.0%) · Dropped: 0 (0.0%)   Profile: Default

pkt 4 – client←server – syn ack

second packet of the three-way-handshake


*eth1
File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help
Apply a display filter ... <Ctrl-/>

```
No.  Time         Source             Destination        Protocol Length Info
   1 0.000000…    5e:61:c3:8e:91:bc  Broadcast          ARP      60 Who has 10.0.0.1? Tell 10.0.0.2[Malformed Packet]
   2 0.000572…    ae:eb:54:d8:fd:ab  5e:61:c3:8e:91:bc  ARP      60 10.0.0.1 is at ae:eb:54:d8:fd:ab[Malformed Packet]
   3 0.000580…    10.0.0.2           10.0.0.1           TCP      74 60208 → 80 [SYN] Seq=0 Win=64240 Len=0 MSS=1460 SACK_PER…
   4 0.000588…    10.0.0.1           10.0.0.2           TCP      74 80 → 60208 [SYN, ACK] Seq=0 Ack=1 Win=65160 Len=0 MSS=14…
```

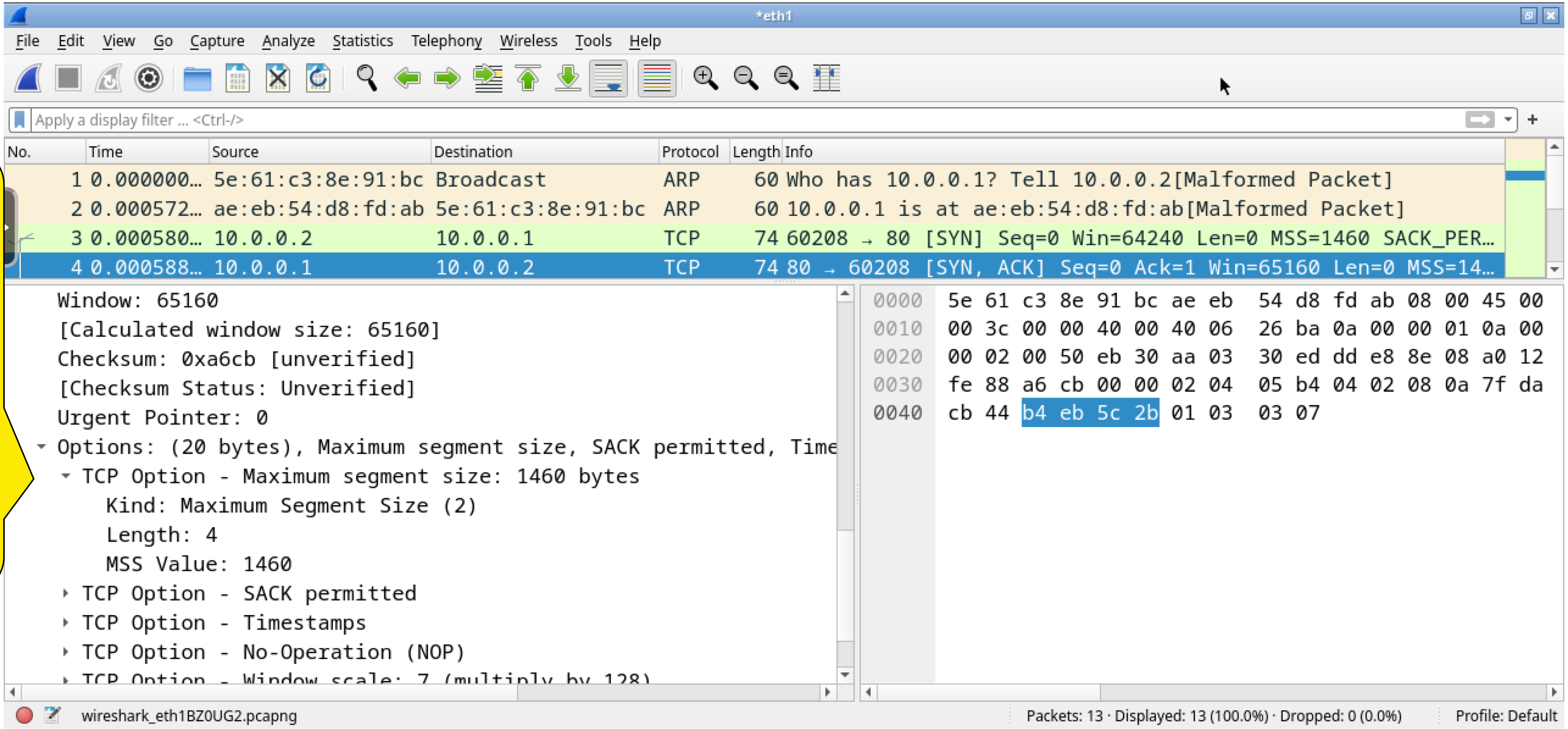
```
Flags: 0x012 (SYN, ACK)
   000. .... .... = Reserved: Not set
   ...0 .... .... = Accurate ECN: Not set
   .... 0... .... = Congestion Window Reduced: Not set
   .... .0.. .... = ECN-Echo: Not set
   .... ..0. .... = Urgent: Not set
   .... ...1 .... = Acknowledgment: Set
   .... .... 0... = Push: Not set
   .... .... .0.. = Reset: Not set
   .... .... ..1. = Syn: Set
   .... .... ...0 = Fin: Not set
   [TCP Flags: ·······A··S·]
Window: 65160
[Calculated window size: 65160]
```

```
0000  5e 61 c3 8e 91 bc ae eb  54 d8 fd ab 08 00 45 00
0010  00 3c 00 00 40 00 40 06  26 ba 0a 00 00 01 0a 00
0020  00 02 00 50 eb 30 aa 03  30 ed dd e8 8e 08 a0 12
0030  fe 88 a6 cb 00 00 02 04  05 b4 04 02 08 0a 7f da
0040  cb 44 b4 eb 5c 2b 01 03  03 07
```

wireshark_eth1BZOUG2.pcapng   Packets: 13 · Displayed: 13 (100.0%) · Dropped: 0 (0.0%)   Profile: Default

pkt 4 – client←server – MSS option

the server proposes a maximum segment size of 1460 bytes too


*eth1
File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help
Apply a display filter ... <Ctrl-/>

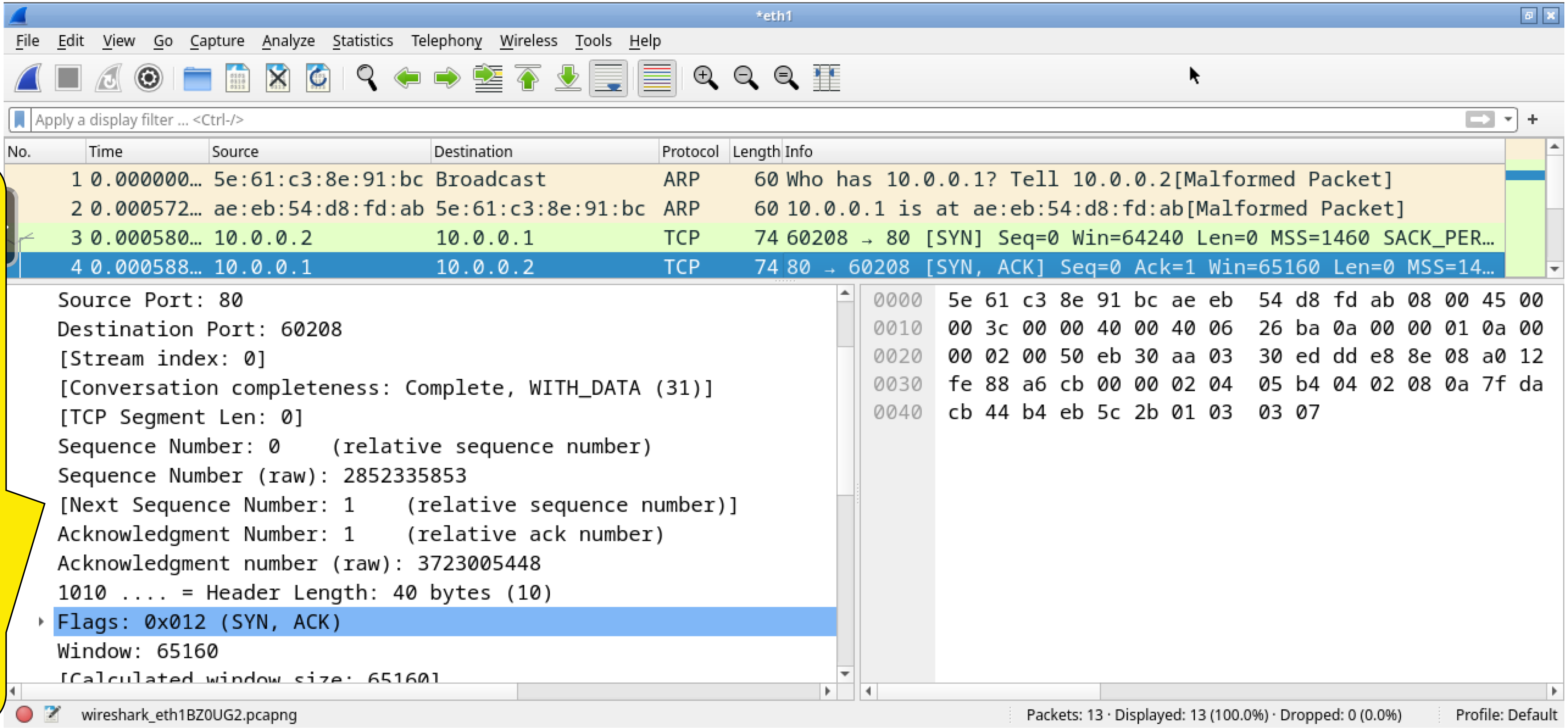
```
No.  Time         Source             Destination        Protocol Length Info
   1 0.000000…   5e:61:c3:8e:91:bc  Broadcast          ARP        60 Who has 10.0.0.1? Tell 10.0.0.2[Malformed Packet]
   2 0.000572…   ae:eb:54:d8:fd:ab  5e:61:c3:8e:91:bc  ARP        60 10.0.0.1 is at ae:eb:54:d8:fd:ab[Malformed Packet]
   3 0.000580…   10.0.0.2           10.0.0.1           TCP        74 60208 → 80 [SYN] Seq=0 Win=64240 Len=0 MSS=1460 SACK_PER…
   4 0.000588…   10.0.0.1           10.0.0.2           TCP        74 80 → 60208 [SYN, ACK] Seq=0 Ack=1 Win=65160 Len=0 MSS=14…
```

```
  Window: 65160
  [Calculated window size: 65160]
  Checksum: 0xa6cb [unverified]
  [Checksum Status: Unverified]
  Urgent Pointer: 0
▾ Options: (20 bytes), Maximum segment size, SACK permitted, Time
  ▾ TCP Option - Maximum segment size: 1460 bytes
      Kind: Maximum Segment Size (2)
      Length: 4
      MSS Value: 1460
  ▸ TCP Option - SACK permitted
  ▸ TCP Option - Timestamps
  ▸ TCP Option - No-Operation (NOP)
  ▸ TCP Option - Window scale: 7 (multiply by 128)
```

```
0000  5e 61 c3 8e 91 bc ae eb  54 d8 fd ab 08 00 45 00
0010  00 3c 00 00 40 00 40 06  26 ba 0a 00 00 01 0a 00
0020  00 02 00 50 eb 30 aa 03  30 ed dd e8 8e 08 a0 12
0030  fe 88 a6 cb 00 00 02 04  05 b4 04 02 08 0a 7f da
0040  cb 44 b4 eb 5c 2b 01 03  03 07
```

wireshark_eth1BZ0UG2.pcapng   Packets: 13 · Displayed: 13 (100.0%) · Dropped: 0 (0.0%)   Profile: Default

pkt 4 – client←server – initial seq. numb.


*eth1
File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help
Apply a display filter ... <Ctrl-/>

```
No.  Time          Source              Destination         Protocol Length Info
   1 0.000000…  5e:61:c3:8e:91:bc  Broadcast          ARP        60 Who has 10.0.0.1? Tell 10.0.0.2[Malformed Packet]
   2 0.000572…  ae:eb:54:d8:fd:ab  5e:61:c3:8e:91:bc  ARP        60 10.0.0.1 is at ae:eb:54:d8:fd:ab[Malformed Packet]
   3 0.000580…  10.0.0.2           10.0.0.1           TCP        74 60208 → 80 [SYN] Seq=0 Win=64240 Len=0 MSS=1460 SACK_PER…
   4 0.000588…  10.0.0.1           10.0.0.2           TCP        74 80 → 60208 [SYN, ACK] Seq=0 Ack=1 Win=65160 Len=0 MSS=14…
```

```
Source Port: 80
Destination Port: 60208
[Stream index: 0]
[Conversation completeness: Complete, WITH_DATA (31)]
[TCP Segment Len: 0]
Sequence Number: 0    (relative sequence number)
Sequence Number (raw): 2852335853
[Next Sequence Number: 1    (relative sequence number)]
Acknowledgment Number: 1    (relative ack number)
Acknowledgment number (raw): 3723005448
1010 .... = Header Length: 40 bytes (10)
Flags: 0x012 (SYN, ACK)
Window: 65160
[Calculated window size: 65160]
```

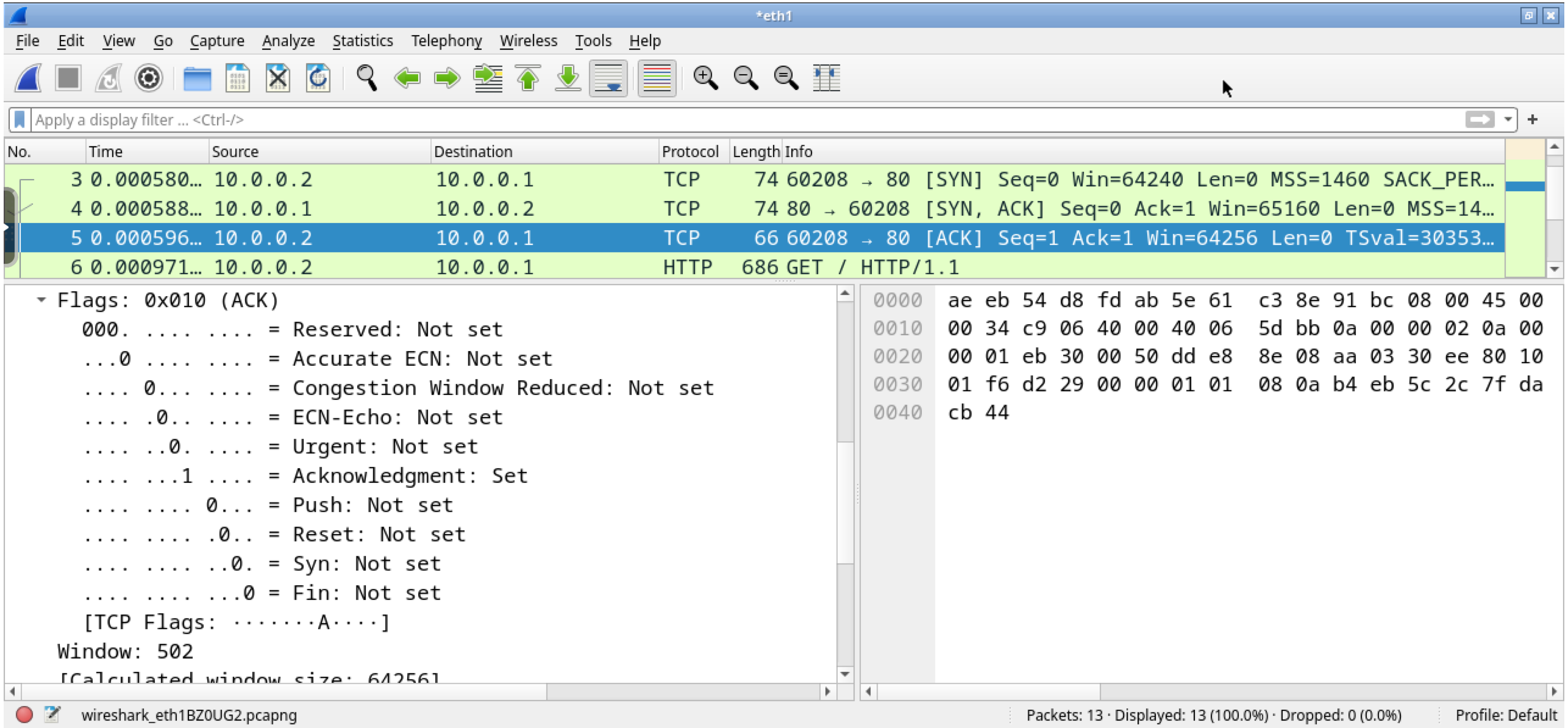
```
0000  5e 61 c3 8e 91 bc ae eb  54 d8 fd ab 08 00 45 00
0010  00 3c 00 00 40 00 40 06  26 ba 0a 00 00 01 0a 00
0020  00 02 00 50 eb 30 aa 03  30 ed dd e8 8e 08 a0 12
0030  fe 88 a6 cb 00 00 02 04  05 b4 04 02 08 0a 7f da
0040  cb 44 b4 eb 5c 2b 01 03  03 07
```

wireshark_eth1BZ0UG2.pcapng   Packets: 13 · Displayed: 13 (100.0%) · Dropped: 0 (0.0%)   Profile: Default

the server proposes 2852335853 as initial sequence number and acks the sequence number proposed by the client

pkt 5 – client→server – ack

third packet of the three-way-handshake


*eth1
File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help
Apply a display filter … <Ctrl-/>

```
No.  Time         Source     Destination  Protocol Length Info
   3 0.000580…  10.0.0.2   10.0.0.1     TCP       74 60208 → 80 [SYN] Seq=0 Win=64240 Len=0 MSS=1460 SACK_PER…
   4 0.000588…  10.0.0.1   10.0.0.2     TCP       74 80 → 60208 [SYN, ACK] Seq=0 Ack=1 Win=65160 Len=0 MSS=14…
   5 0.000596…  10.0.0.2   10.0.0.1     TCP       66 60208 → 80 [ACK] Seq=1 Ack=1 Win=64256 Len=0 TSval=30353…
   6 0.000971…  10.0.0.2   10.0.0.1     HTTP     686 GET / HTTP/1.1
```

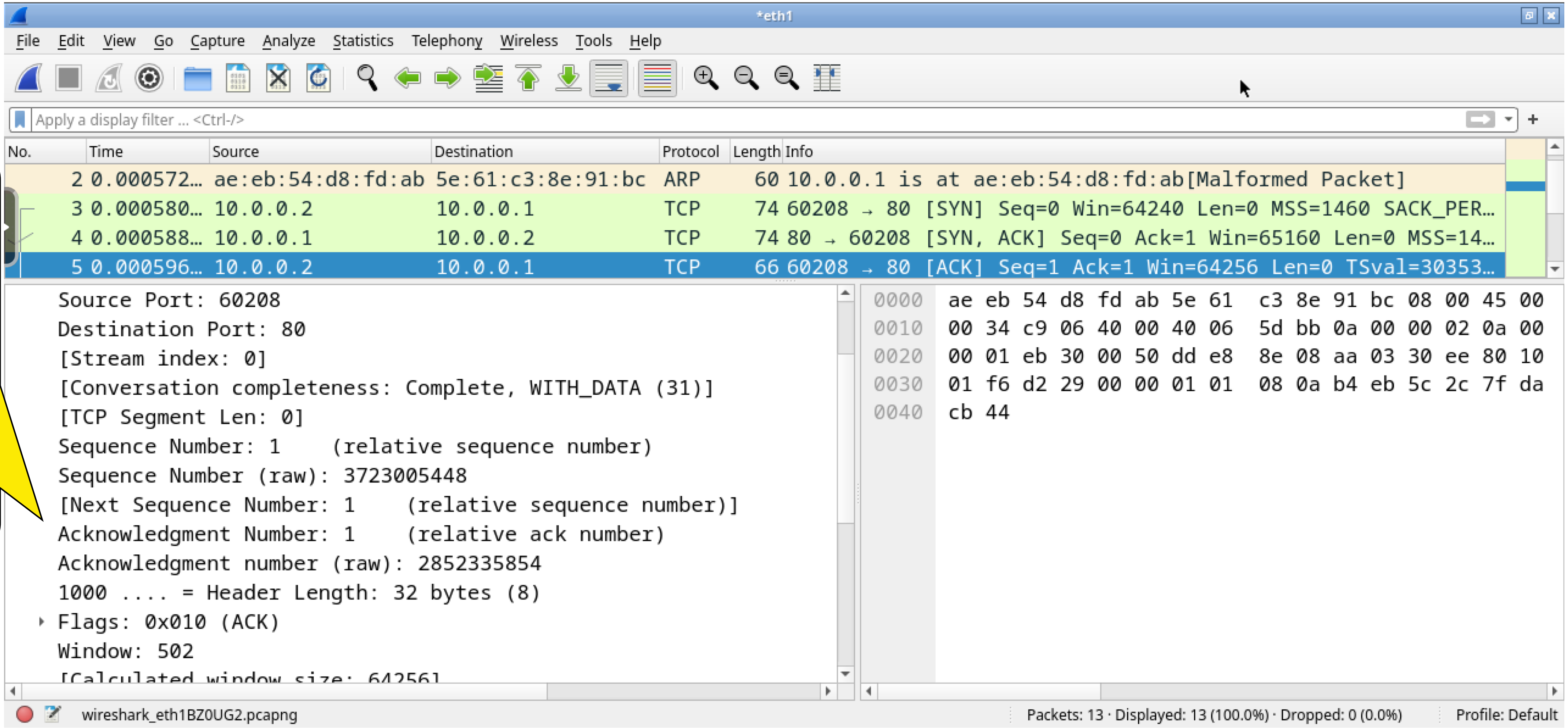
```
  Flags: 0x010 (ACK)
     000. .... .... = Reserved: Not set
     ...0 .... .... = Accurate ECN: Not set
     .... 0... .... = Congestion Window Reduced: Not set
     .... .0.. .... = ECN-Echo: Not set
     .... ..0. .... = Urgent: Not set
     .... ...1 .... = Acknowledgment: Set
     .... .... 0... = Push: Not set
     .... .... .0.. = Reset: Not set
     .... .... ..0. = Syn: Not set
     .... .... ...0 = Fin: Not set
     [TCP Flags: ·······A····]
  Window: 502
  [Calculated window size: 64256]
```

```
0000  ae eb 54 d8 fd ab 5e 61  c3 8e 91 bc 08 00 45 00
0010  00 34 c9 06 40 00 40 06  5d bb 0a 00 00 02 0a 00
0020  00 01 eb 30 00 50 dd e8  8e 08 aa 03 30 ee 80 10
0030  01 f6 d2 29 00 00 01 01  08 0a b4 eb 5c 2c 7f da
0040  cb 44
```

wireshark_eth1BZ0UG2.pcapng   Packets: 13 · Displayed: 13 (100.0%) · Dropped: 0 (0.0%)   Profile: Default

pkt 5 – client→server – ack

the client acks the sequence number proposed by the server


*eth1
File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help
Apply a display filter ... <Ctrl-/>

```
No.  Time         Source             Destination        Protocol Length Info
   2 0.000572…    ae:eb:54:d8:fd:ab  5e:61:c3:8e:91:bc  ARP        60 10.0.0.1 is at ae:eb:54:d8:fd:ab[Malformed Packet]
   3 0.000580…    10.0.0.2           10.0.0.1           TCP        74 60208 → 80 [SYN] Seq=0 Win=64240 Len=0 MSS=1460 SACK_PER…
   4 0.000588…    10.0.0.1           10.0.0.2           TCP        74 80 → 60208 [SYN, ACK] Seq=0 Ack=1 Win=65160 Len=0 MSS=14…
   5 0.000596…    10.0.0.2           10.0.0.1           TCP        66 60208 → 80 [ACK] Seq=1 Ack=1 Win=64256 Len=0 TSval=30353…
```

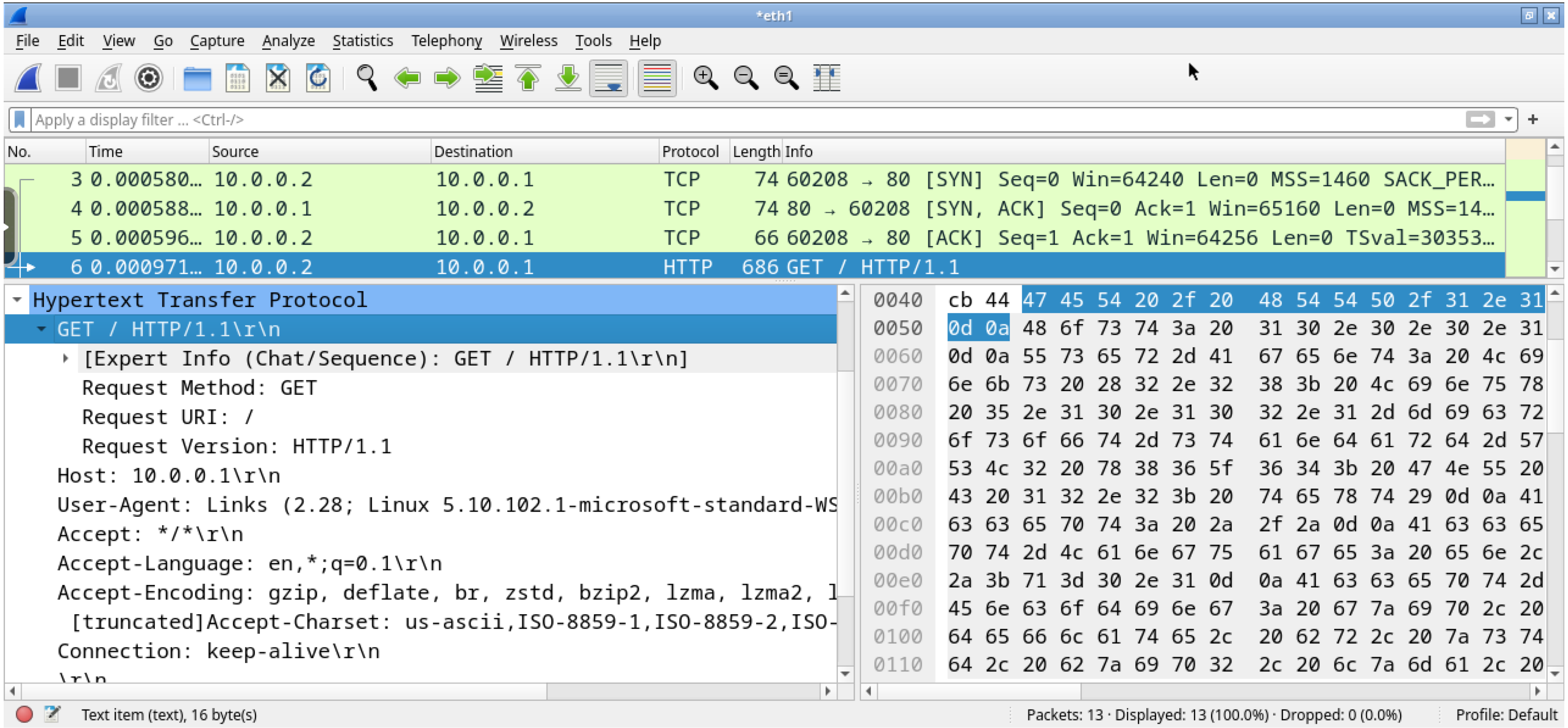
```
  Source Port: 60208
  Destination Port: 80
  [Stream index: 0]
  [Conversation completeness: Complete, WITH_DATA (31)]
  [TCP Segment Len: 0]
  Sequence Number: 1    (relative sequence number)
  Sequence Number (raw): 3723005448
  [Next Sequence Number: 1    (relative sequence number)]
  Acknowledgment Number: 1    (relative ack number)
  Acknowledgment number (raw): 2852335854
  1000 .... = Header Length: 32 bytes (8)
› Flags: 0x010 (ACK)
  Window: 502
  [Calculated window size: 64256]
```

```
0000  ae eb 54 d8 fd ab 5e 61  c3 8e 91 bc 08 00 45 00
0010  00 34 c9 06 40 00 40 06  5d bb 0a 00 00 02 0a 00
0020  00 01 eb 30 00 50 dd e8  8e 08 aa 03 30 ee 80 10
0030  01 f6 d2 29 00 00 01 01  08 0a b4 eb 5c 2c 7f da
0040  cb 44
```

wireshark_eth1BZ0UG2.pcapng   Packets: 13 · Displayed: 13 (100.0%) · Dropped: 0 (0.0%)   Profile: Default

pkt 6 – client→server – http GET

http GET with http version 1.1


*eth1
File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help
Apply a display filter ... <Ctrl-/>

```
No.  Time       Source     Destination  Protocol  Length Info
  3 0.000580… 10.0.0.2   10.0.0.1     TCP        74 60208 → 80 [SYN] Seq=0 Win=64240 Len=0 MSS=1460 SACK_PER…
  4 0.000588… 10.0.0.1   10.0.0.2     TCP        74 80 → 60208 [SYN, ACK] Seq=0 Ack=1 Win=65160 Len=0 MSS=14…
  5 0.000596… 10.0.0.2   10.0.0.1     TCP        66 60208 → 80 [ACK] Seq=1 Ack=1 Win=64256 Len=0 TSval=30353…
  6 0.000971… 10.0.0.2   10.0.0.1     HTTP      686 GET / HTTP/1.1
```

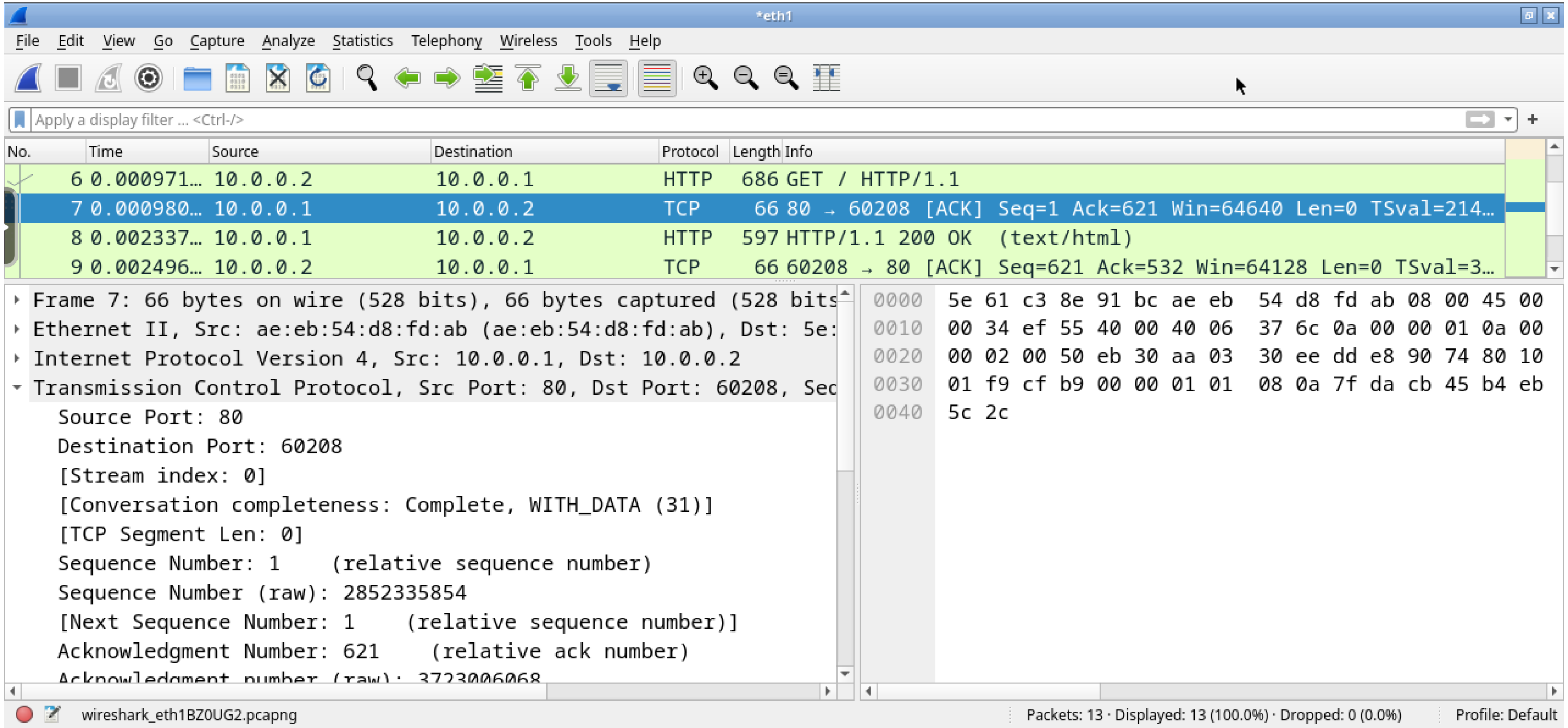
```
▾ Hypertext Transfer Protocol
  ▾ GET / HTTP/1.1\r\n
    ▸ [Expert Info (Chat/Sequence): GET / HTTP/1.1\r\n]
      Request Method: GET
      Request URI: /
      Request Version: HTTP/1.1
    Host: 10.0.0.1\r\n
    User-Agent: Links (2.28; Linux 5.10.102.1-microsoft-standard-WS
    Accept: */*\r\n
    Accept-Language: en,*;q=0.1\r\n
    Accept-Encoding: gzip, deflate, br, zstd, bzip2, lzma, lzma2, l
     [truncated]Accept-Charset: us-ascii,ISO-8859-1,ISO-8859-2,ISO-
    Connection: keep-alive\r\n
    \r\n
```

```
0040  cb 44 47 45 54 20 2f 20  48 54 54 50 2f 31 2e 31
0050  0d 0a 48 6f 73 74 3a 20  31 30 2e 30 2e 30 2e 31
0060  0d 0a 55 73 65 72 2d 41  67 65 6e 74 3a 20 4c 69
0070  6e 6b 73 20 28 32 2e 32  38 3b 20 4c 69 6e 75 78
0080  20 35 2e 31 30 2e 31 30  32 2e 31 2d 6d 69 63 72
0090  6f 73 6f 66 74 2d 73 74  61 6e 64 61 72 64 2d 57
00a0  53 4c 32 20 78 38 36 5f  36 34 3b 20 47 4e 55 20
00b0  43 20 31 32 2e 32 3b 20  74 65 78 74 29 0d 0a 41
00c0  63 63 65 70 74 3a 20 2a  2f 2a 0d 0a 41 63 63 65
00d0  70 74 2d 4c 61 6e 67 75  61 67 65 3a 20 65 6e 2c
00e0  2a 3b 71 3d 30 2e 31 0d  0a 41 63 63 65 70 74 2d
00f0  45 6e 63 6f 64 69 6e 67  3a 20 67 7a 69 70 2c 20
0100  64 65 66 6c 61 74 65 2c  20 62 72 2c 20 7a 73 74
0110  64 2c 20 62 7a 69 70 32  2c 20 6c 7a 6d 61 2c 20
```

Text item (text), 16 byte(s)   Packets: 13 · Displayed: 13 (100.0%) · Dropped: 0 (0.0%)   Profile: Default

pkt 7 – client←server – bytes received

tcp acks the receipt of the bytes of the GET



*eth1
File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help
Apply a display filter … <Ctrl-/>

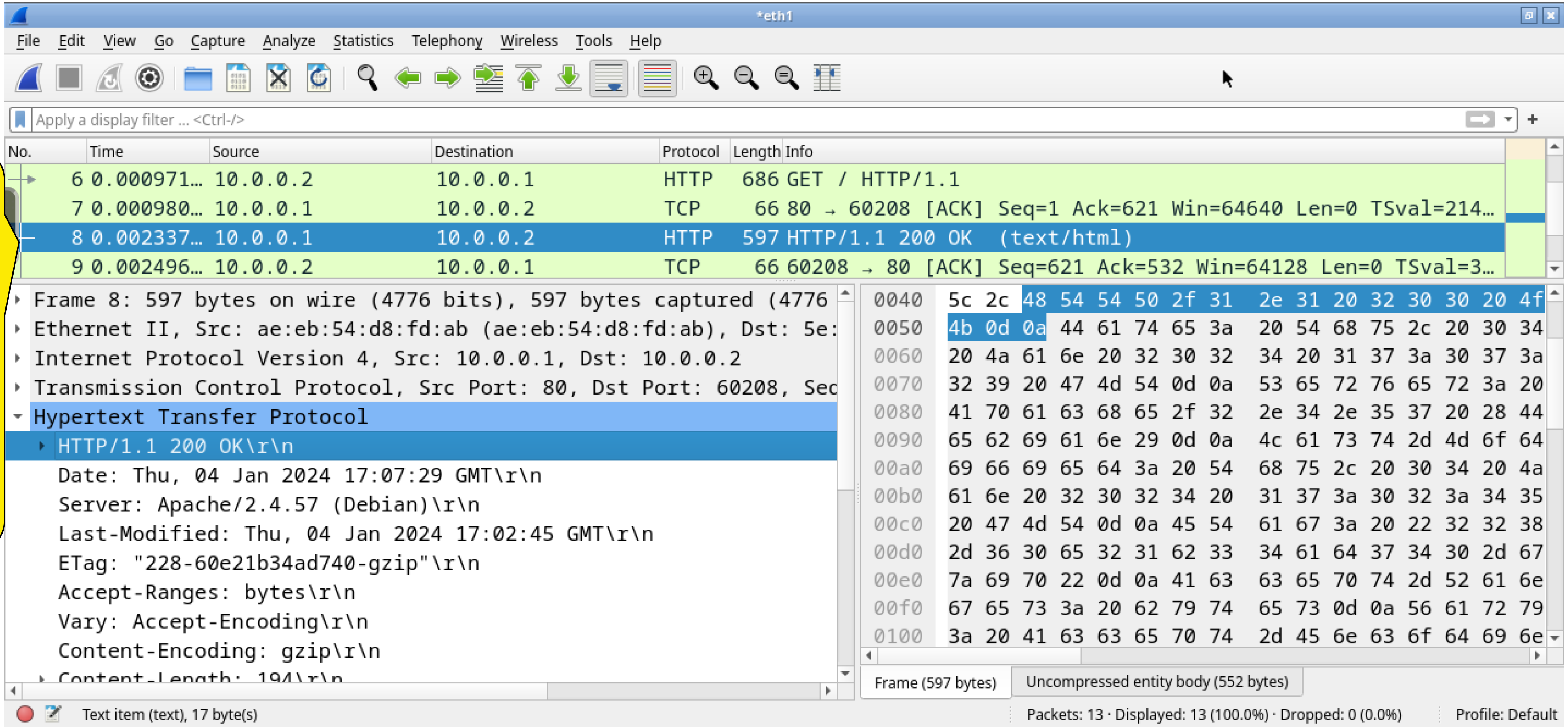
```
No. Time        Source    Destination Protocol Length Info
  6 0.000971…   10.0.0.2  10.0.0.1    HTTP     686 GET / HTTP/1.1
  7 0.000980…   10.0.0.1  10.0.0.2    TCP       66 80 → 60208 [ACK] Seq=1 Ack=621 Win=64640 Len=0 TSval=214…
  8 0.002337…   10.0.0.1  10.0.0.2    HTTP     597 HTTP/1.1 200 OK  (text/html)
  9 0.002496…   10.0.0.2  10.0.0.1    TCP       66 60208 → 80 [ACK] Seq=621 Ack=532 Win=64128 Len=0 TSval=3…
```

```
› Frame 7: 66 bytes on wire (528 bits), 66 bytes captured (528 bits
› Ethernet II, Src: ae:eb:54:d8:fd:ab (ae:eb:54:d8:fd:ab), Dst: 5e:
› Internet Protocol Version 4, Src: 10.0.0.1, Dst: 10.0.0.2
⌄ Transmission Control Protocol, Src Port: 80, Dst Port: 60208, Sec
    Source Port: 80
    Destination Port: 60208
    [Stream index: 0]
    [Conversation completeness: Complete, WITH_DATA (31)]
    [TCP Segment Len: 0]
    Sequence Number: 1    (relative sequence number)
    Sequence Number (raw): 2852335854
    [Next Sequence Number: 1    (relative sequence number)]
    Acknowledgment Number: 621    (relative ack number)
    Acknowledgment number (raw): 3723006068
```

```
0000  5e 61 c3 8e 91 bc ae eb  54 d8 fd ab 08 00 45 00
0010  00 34 ef 55 40 00 40 06  37 6c 0a 00 00 01 0a 00
0020  00 02 00 50 eb 30 aa 03  30 ee dd e8 90 74 80 10
0030  01 f9 cf b9 00 00 01 01  08 0a 7f da cb 45 b4 eb
0040  5c 2c
```

wireshark_eth1BZ0UG2.pcapng   Packets: 13 · Displayed: 13 (100.0%) · Dropped: 0 (0.0%)   Profile: Default

pkt 8 – client←server – resource moves



*eth1
File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help
Apply a display filter ... <Ctrl-/>

```
No.  Time        Source     Destination  Protocol Length Info
  6 0.000971…  10.0.0.2   10.0.0.1     HTTP      686 GET / HTTP/1.1
  7 0.000980…  10.0.0.1   10.0.0.2     TCP        66 80 → 60208 [ACK] Seq=1 Ack=621 Win=64640 Len=0 TSval=214…
  8 0.002337…  10.0.0.1   10.0.0.2     HTTP      597 HTTP/1.1 200 OK  (text/html)
  9 0.002496…  10.0.0.2   10.0.0.1     TCP        66 60208 → 80 [ACK] Seq=621 Ack=532 Win=64128 Len=0 TSval=3…
```

```
▸ Frame 8: 597 bytes on wire (4776 bits), 597 bytes captured (4776
▸ Ethernet II, Src: ae:eb:54:d8:fd:ab (ae:eb:54:d8:fd:ab), Dst: 5e:
▸ Internet Protocol Version 4, Src: 10.0.0.1, Dst: 10.0.0.2
▸ Transmission Control Protocol, Src Port: 80, Dst Port: 60208, Sec
▾ Hypertext Transfer Protocol
  ▸ HTTP/1.1 200 OK\r\n
    Date: Thu, 04 Jan 2024 17:07:29 GMT\r\n
    Server: Apache/2.4.57 (Debian)\r\n
    Last-Modified: Thu, 04 Jan 2024 17:02:45 GMT\r\n
    ETag: "228-60e21b34ad740-gzip"\r\n
    Accept-Ranges: bytes\r\n
    Vary: Accept-Encoding\r\n
    Content-Encoding: gzip\r\n
  ▸ Content-Length: 194\r\n
```

```
0040  5c 2c 48 54 54 50 2f 31  2e 31 20 32 30 30 20 4f
0050  4b 0d 0a 44 61 74 65 3a  20 54 68 75 2c 20 30 34
0060  20 4a 61 6e 20 32 30 32  34 20 31 37 3a 30 37 3a
0070  32 39 20 47 4d 54 0d 0a  53 65 72 76 65 72 3a 20
0080  41 70 61 63 68 65 2f 32  2e 34 2e 35 37 20 28 44
0090  65 62 69 61 6e 29 0d 0a  4c 61 73 74 2d 4d 6f 64
00a0  69 66 69 65 64 3a 20 54  68 75 2c 20 30 34 20 4a
00b0  61 6e 20 32 30 32 34 20  31 37 3a 30 32 3a 34 35
00c0  20 47 4d 54 0d 0a 45 54  61 67 3a 20 22 32 32 38
00d0  2d 36 30 65 32 31 62 33  34 61 64 37 34 30 2d 67
00e0  7a 69 70 22 0d 0a 41 63  63 65 70 74 2d 52 61 6e
00f0  67 65 73 3a 20 62 79 74  65 73 0d 0a 56 61 72 79
0100  3a 20 41 63 63 65 70 74  2d 45 6e 63 6f 64 69 6e
```

Text item (text), 17 byte(s)

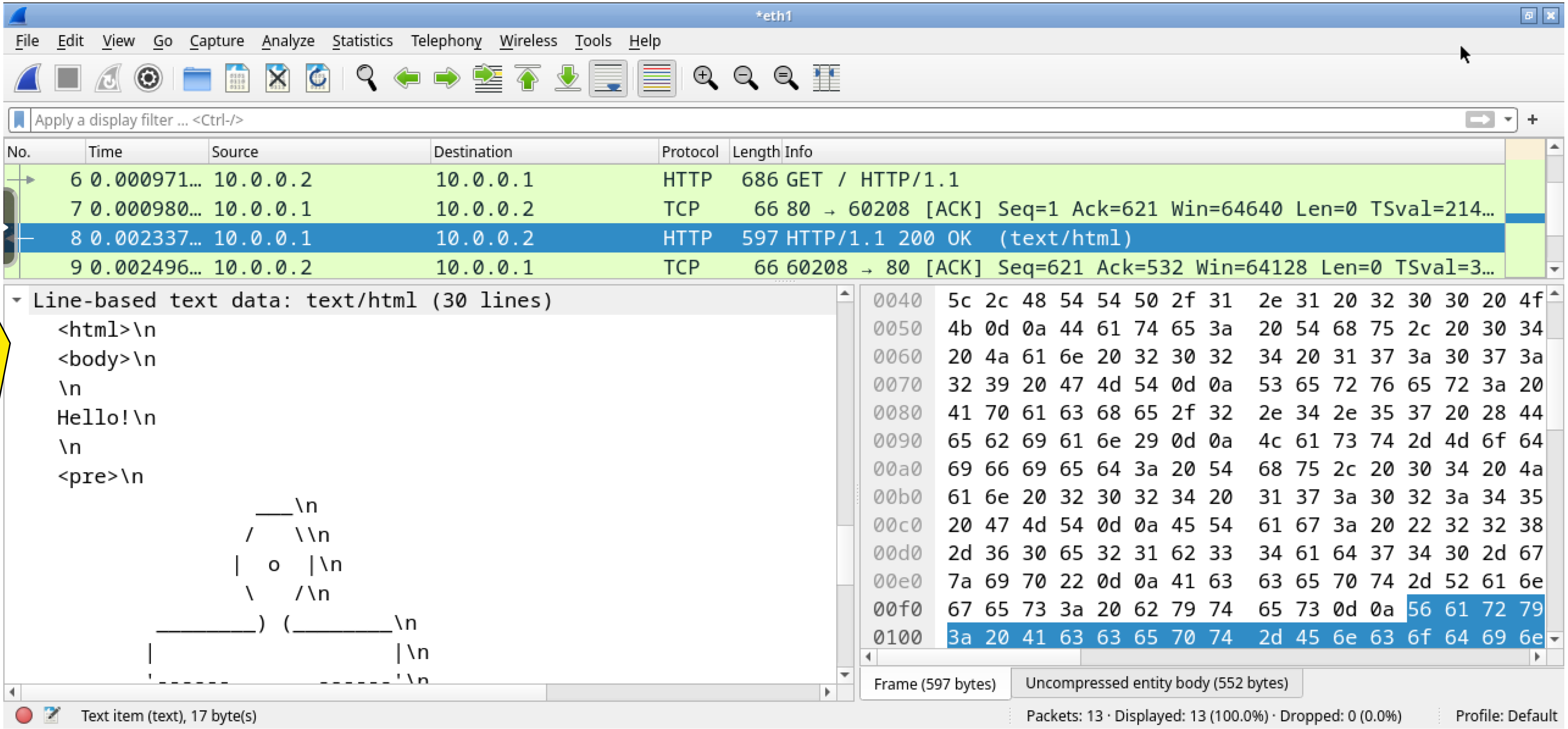
Packets: 13 · Displayed: 13 (100.0%) · Dropped: 0 (0.0%)

Profile: Default

the requested resource

pkt 8 – client←server – resource moves

the requested resource


*eth1
File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help
Apply a display filter ... <Ctrl-/>
Frame (597 bytes)
Uncompressed entity body (552 bytes)

```
No. Time        Source    Destination Protocol Length Info
  6 0.000971… 10.0.0.2  10.0.0.1    HTTP     686 GET / HTTP/1.1
  7 0.000980… 10.0.0.1  10.0.0.2    TCP       66 80 → 60208 [ACK] Seq=1 Ack=621 Win=64640 Len=0 TSval=214…
  8 0.002337… 10.0.0.1  10.0.0.2    HTTP     597 HTTP/1.1 200 OK  (text/html)
  9 0.002496… 10.0.0.2  10.0.0.1    TCP       66 60208 → 80 [ACK] Seq=621 Ack=532 Win=64128 Len=0 TSval=3…
```

```
▾ Line-based text data: text/html (30 lines)
    <html>\n
    <body>\n
    \n
    Hello!\n
    \n
    <pre>\n
                    ___\n
                   /   \\n
                  |  o  |\n
                   \   /\n
            ________) (________\n
            |                  |\n
            '------      ------'\n
```

```
0040  5c 2c 48 54 54 50 2f 31  2e 31 20 32 30 30 20 4f
0050  4b 0d 0a 44 61 74 65 3a  20 54 68 75 2c 20 30 34
0060  20 4a 61 6e 20 32 30 32  34 20 31 37 3a 30 37 3a
0070  32 39 20 47 4d 54 0d 0a  53 65 72 76 65 72 3a 20
0080  41 70 61 63 68 65 2f 32  2e 34 2e 35 37 20 28 44
0090  65 62 69 61 6e 29 0d 0a  4c 61 73 74 2d 4d 6f 64
00a0  69 66 69 65 64 3a 20 54  68 75 2c 20 30 34 20 4a
00b0  61 6e 20 32 30 32 34 20  31 37 3a 30 32 3a 34 35
00c0  20 47 4d 54 0d 0a 45 54  61 67 3a 20 22 32 32 38
00d0  2d 36 30 65 32 31 62 33  34 61 64 37 34 30 2d 67
00e0  7a 69 70 22 0d 0a 41 63  63 65 70 74 2d 52 61 6e
00f0  67 65 73 3a 20 62 79 74  65 73 0d 0a 56 61 72 79
0100  3a 20 41 63 63 65 70 74  2d 45 6e 63 6f 64 69 6e
```

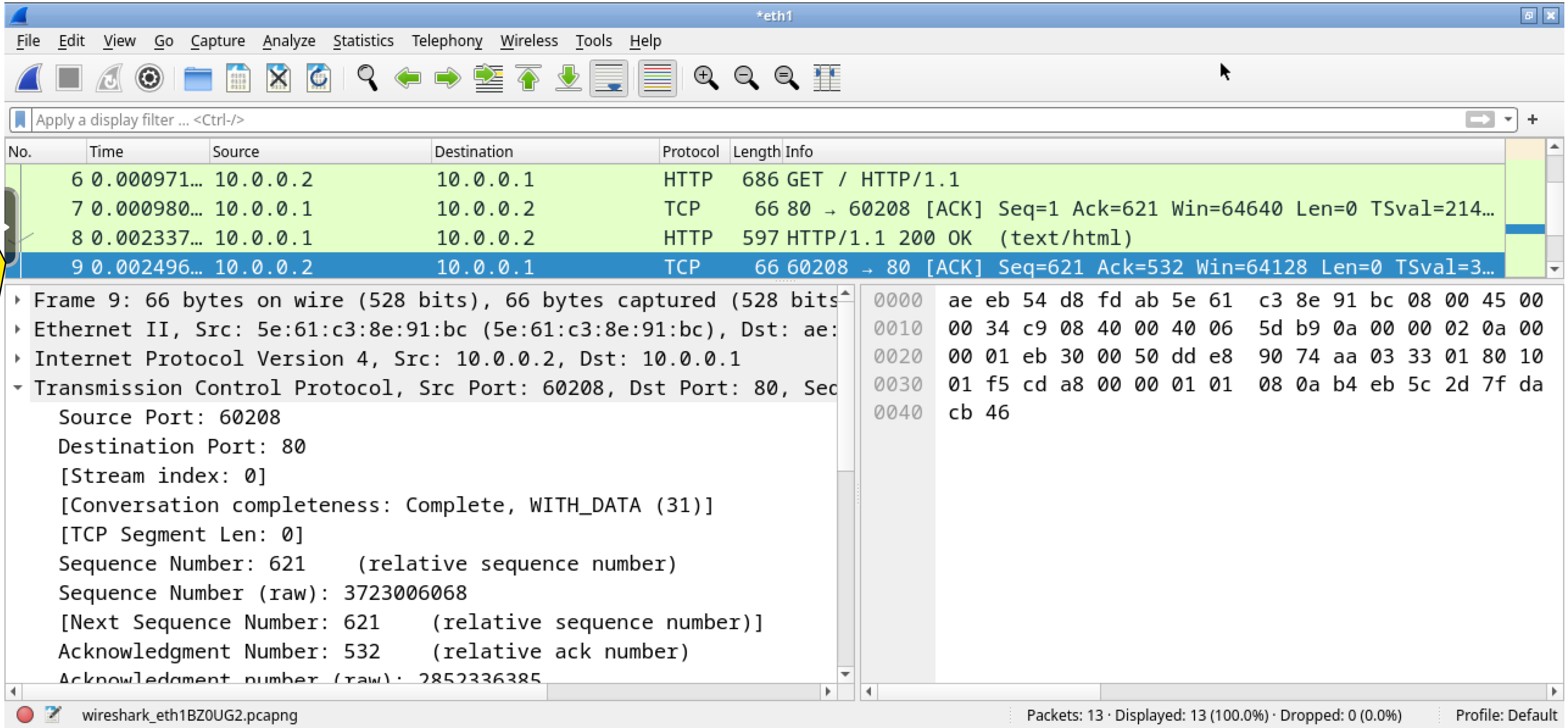
Text item (text), 17 byte(s)

Packets: 13 · Displayed: 13 (100.0%) · Dropped: 0 (0.0%)

Profile: Default

pkt 9 – client→server – bytes received

tcp acks the bytes of the resource



```
No.  Time          Source     Destination  Protocol  Length  Info
   6 0.000971…     10.0.0.2   10.0.0.1     HTTP      686     GET / HTTP/1.1
   7 0.000980…     10.0.0.1   10.0.0.2     TCP        66     80 → 60208 [ACK] Seq=1 Ack=621 Win=64640 Len=0 TSval=214…
   8 0.002337…     10.0.0.1   10.0.0.2     HTTP      597     HTTP/1.1 200 OK  (text/html)
   9 0.002496…     10.0.0.2   10.0.0.1     TCP        66     60208 → 80 [ACK] Seq=621 Ack=532 Win=64128 Len=0 TSval=3…
```

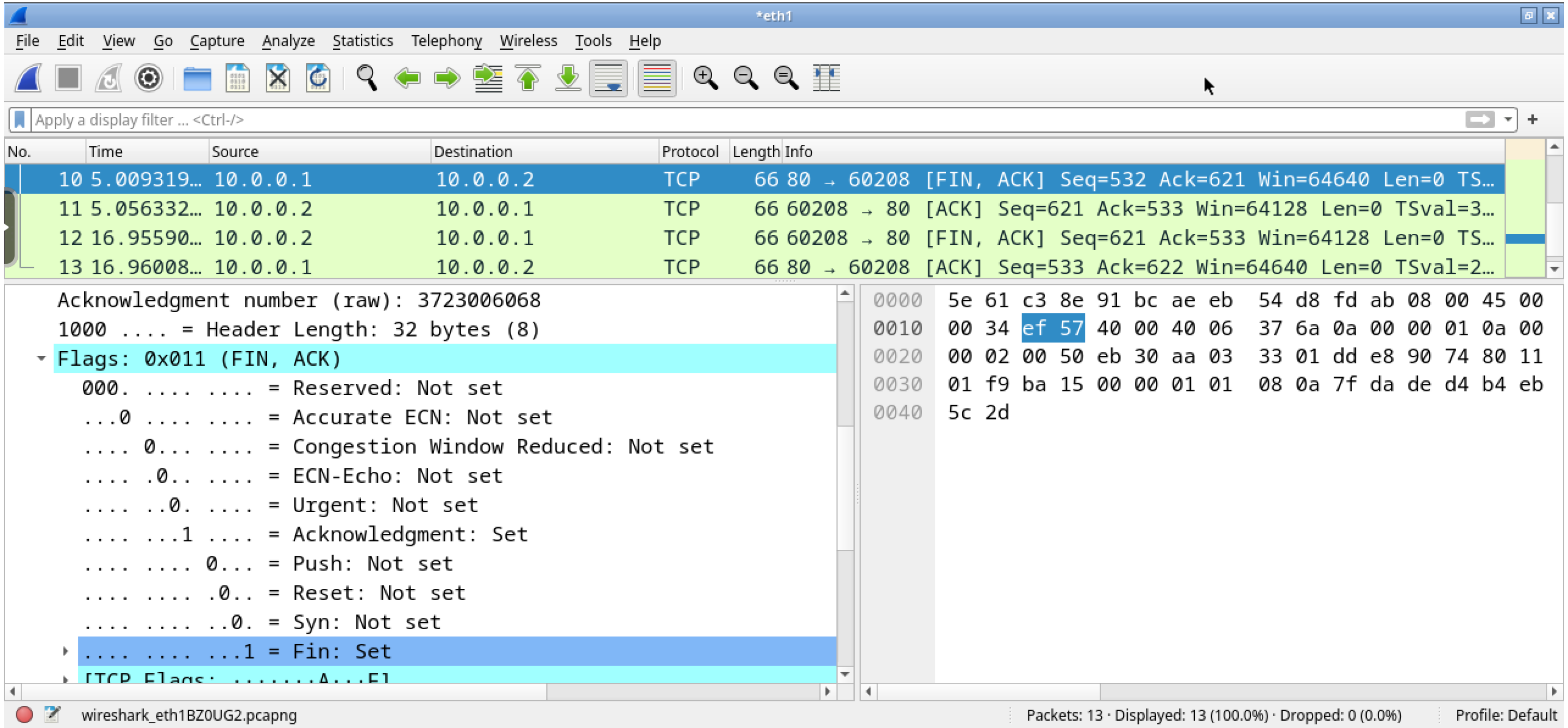
```
› Frame 9: 66 bytes on wire (528 bits), 66 bytes captured (528 bits
› Ethernet II, Src: 5e:61:c3:8e:91:bc (5e:61:c3:8e:91:bc), Dst: ae:
› Internet Protocol Version 4, Src: 10.0.0.2, Dst: 10.0.0.1
⌄ Transmission Control Protocol, Src Port: 60208, Dst Port: 80, Sec
    Source Port: 60208
    Destination Port: 80
    [Stream index: 0]
    [Conversation completeness: Complete, WITH_DATA (31)]
    [TCP Segment Len: 0]
    Sequence Number: 621    (relative sequence number)
    Sequence Number (raw): 3723006068
    [Next Sequence Number: 621    (relative sequence number)]
    Acknowledgment Number: 532    (relative ack number)
    Acknowledgment number (raw): 2852336385
```

```
0000  ae eb 54 d8 fd ab 5e 61  c3 8e 91 bc 08 00 45 00
0010  00 34 c9 08 40 00 40 06  5d b9 0a 00 00 02 0a 00
0020  00 01 eb 30 00 50 dd e8  90 74 aa 03 33 01 80 10
0030  01 f5 cd a8 00 00 01 01  08 0a b4 eb 5c 2d 7f da
0040  cb 46
```

wireshark_eth1BZ0UG2.pcapng   Packets: 13 · Displayed: 13 (100.0%) · Dropped: 0 (0.0%)   Profile: Default

pkt 10 – client←server – fin

request to finish



```
No. Time        Source     Destination  Protocol Length Info
 10 5.009319… 10.0.0.1   10.0.0.2     TCP      66 80 → 60208 [FIN, ACK] Seq=532 Ack=621 Win=64640 Len=0 TS…
 11 5.056332… 10.0.0.2   10.0.0.1     TCP      66 60208 → 80 [ACK] Seq=621 Ack=533 Win=64128 Len=0 TSval=3…
 12 16.95590… 10.0.0.2   10.0.0.1     TCP      66 60208 → 80 [FIN, ACK] Seq=621 Ack=533 Win=64128 Len=0 TS…
 13 16.96008… 10.0.0.1   10.0.0.2     TCP      66 80 → 60208 [ACK] Seq=533 Ack=622 Win=64640 Len=0 TSval=2…
```

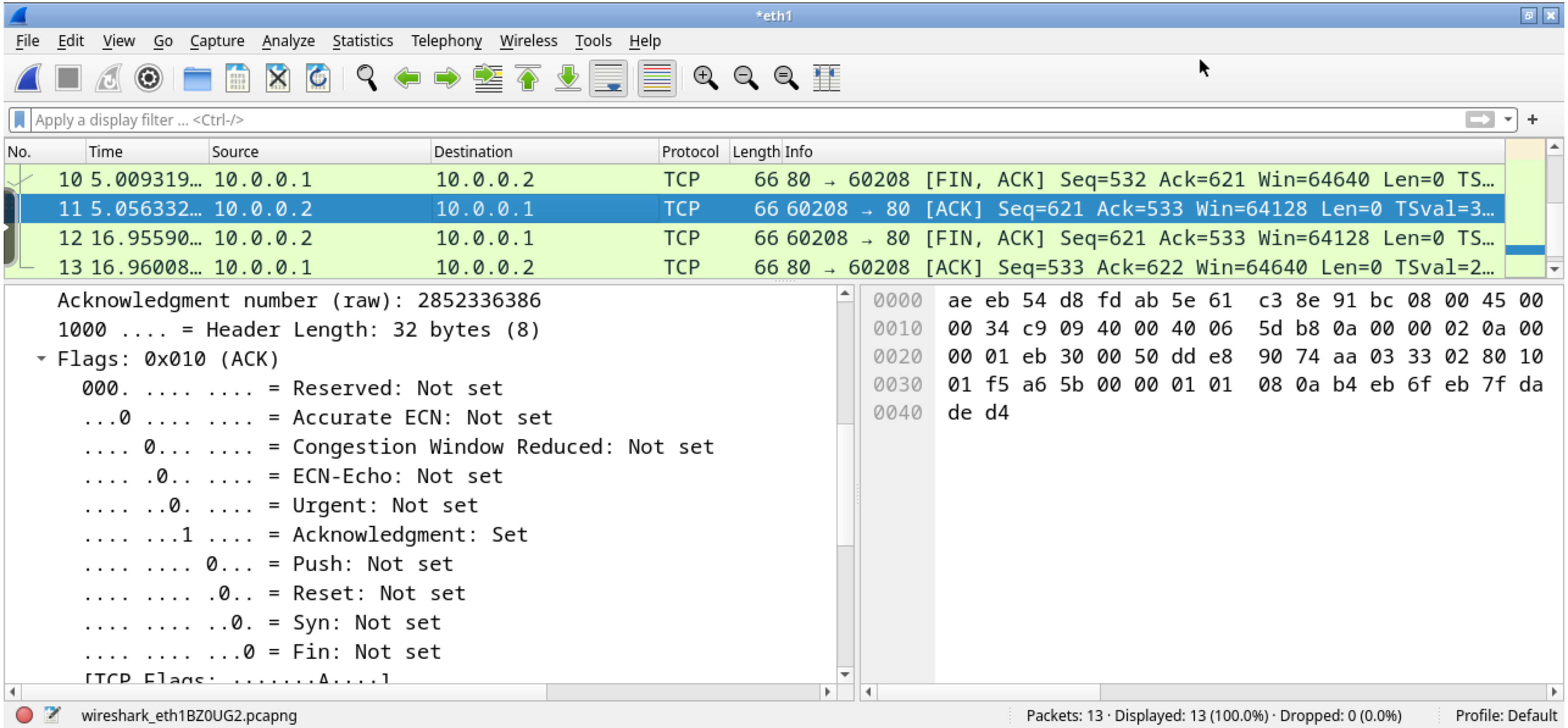
```
  Acknowledgment number (raw): 3723006068
  1000 .... = Header Length: 32 bytes (8)
▾ Flags: 0x011 (FIN, ACK)
    000. .... .... = Reserved: Not set
    ...0 .... .... = Accurate ECN: Not set
    .... 0... .... = Congestion Window Reduced: Not set
    .... .0.. .... = ECN-Echo: Not set
    .... ..0. .... = Urgent: Not set
    .... ...1 .... = Acknowledgment: Set
    .... .... 0... = Push: Not set
    .... .... .0.. = Reset: Not set
    .... .... ..0. = Syn: Not set
  ▸ .... .... ...1 = Fin: Set
  ▸ [TCP Flags: .......A...F]
```

```
0000  5e 61 c3 8e 91 bc ae eb  54 d8 fd ab 08 00 45 00
0010  00 34 ef 57 40 00 40 06  37 6a 0a 00 00 01 0a 00
0020  00 02 00 50 eb 30 aa 03  33 01 dd e8 90 74 80 11
0030  01 f9 ba 15 00 00 01 01  08 0a 7f da de d4 b4 eb
0040  5c 2d
```

wireshark_eth1BZ0UG2.pcapng   Packets: 13 · Displayed: 13 (100.0%) · Dropped: 0 (0.0%)   Profile: Default

pkt 11 – client→server – ack

ack to finish



```
No.  Time        Source     Destination  Protocol  Length Info
  10 5.009319…   10.0.0.1   10.0.0.2     TCP       66 80 → 60208 [FIN, ACK] Seq=532 Ack=621 Win=64640 Len=0 TS…
  11 5.056332…   10.0.0.2   10.0.0.1     TCP       66 60208 → 80 [ACK] Seq=621 Ack=533 Win=64128 Len=0 TSval=3…
  12 16.95590…   10.0.0.2   10.0.0.1     TCP       66 60208 → 80 [FIN, ACK] Seq=621 Ack=533 Win=64128 Len=0 TS…
  13 16.96008…   10.0.0.1   10.0.0.2     TCP       66 80 → 60208 [ACK] Seq=533 Ack=622 Win=64640 Len=0 TSval=2…
```

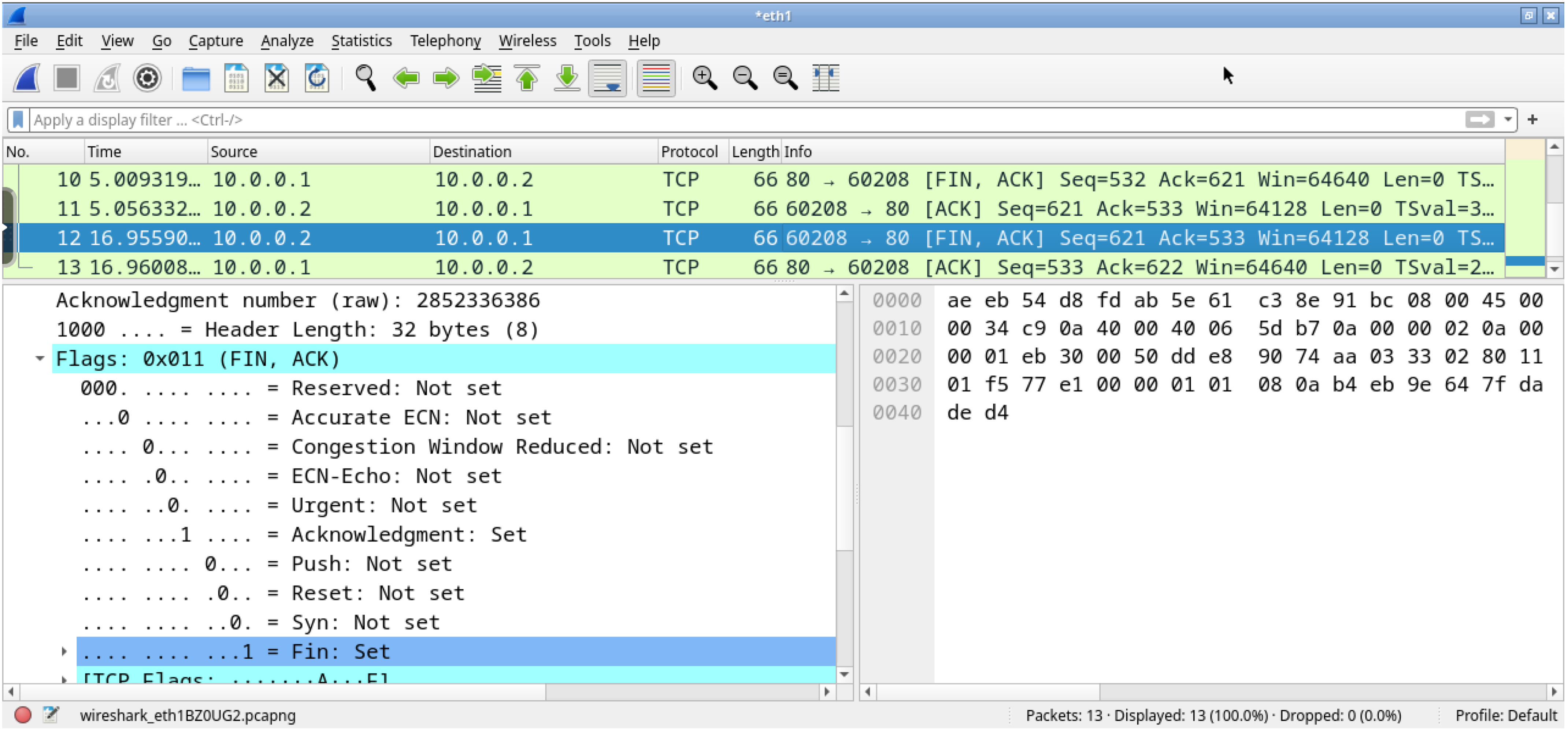
```
    Acknowledgment number (raw): 2852336386
    1000 .... = Header Length: 32 bytes (8)
  ▾ Flags: 0x010 (ACK)
      000. .... .... = Reserved: Not set
      ...0 .... .... = Accurate ECN: Not set
      .... 0... .... = Congestion Window Reduced: Not set
      .... .0.. .... = ECN-Echo: Not set
      .... ..0. .... = Urgent: Not set
      .... ...1 .... = Acknowledgment: Set
      .... .... 0... = Push: Not set
      .... .... .0.. = Reset: Not set
      .... .... ..0. = Syn: Not set
      .... .... ...0 = Fin: Not set
      [TCP Flags: .......A....]
```

```
0000  ae eb 54 d8 fd ab 5e 61  c3 8e 91 bc 08 00 45 00
0010  00 34 c9 09 40 00 40 06  5d b8 0a 00 00 02 0a 00
0020  00 01 eb 30 00 50 dd e8  90 74 aa 03 33 02 80 10
0030  01 f5 a6 5b 00 00 01 01  08 0a b4 eb 6f eb 7f da
0040  de d4
```

wireshark_eth1BZ0UG2.pcapng   Packets: 13 · Displayed: 13 (100.0%) · Dropped: 0 (0.0%)   Profile: Default

pkt 12 – client→server – fin

request to finish


*eth1
File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help
Apply a display filter ... <Ctrl-/>

```
No. Time         Source     Destination  Protocol Length Info
 10 5.009319...  10.0.0.1   10.0.0.2     TCP      66 80 → 60208 [FIN, ACK] Seq=532 Ack=621 Win=64640 Len=0 TS...
 11 5.056332...  10.0.0.2   10.0.0.1     TCP      66 60208 → 80 [ACK] Seq=621 Ack=533 Win=64128 Len=0 TSval=3...
 12 16.95590...  10.0.0.2   10.0.0.1     TCP      66 60208 → 80 [FIN, ACK] Seq=621 Ack=533 Win=64128 Len=0 TS...
 13 16.96008...  10.0.0.1   10.0.0.2     TCP      66 80 → 60208 [ACK] Seq=533 Ack=622 Win=64640 Len=0 TSval=2...
```

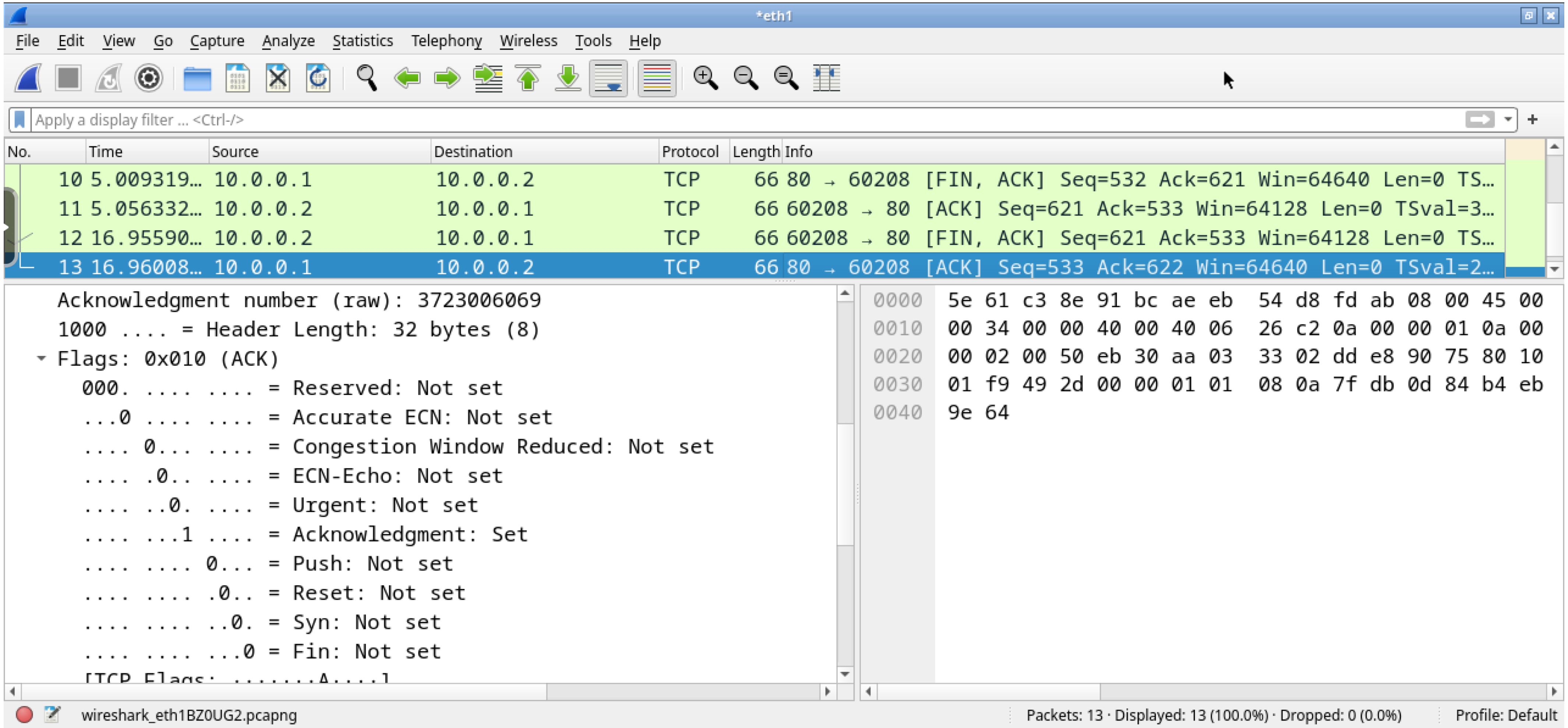
```
    Acknowledgment number (raw): 2852336386
    1000 .... = Header Length: 32 bytes (8)
  ▾ Flags: 0x011 (FIN, ACK)
      000. .... .... = Reserved: Not set
      ...0 .... .... = Accurate ECN: Not set
      .... 0... .... = Congestion Window Reduced: Not set
      .... .0.. .... = ECN-Echo: Not set
      .... ..0. .... = Urgent: Not set
      .... ...1 .... = Acknowledgment: Set
      .... .... 0... = Push: Not set
      .... .... .0.. = Reset: Not set
      .... .... ..0. = Syn: Not set
    ▸ .... .... ...1 = Fin: Set
    ▸ [TCP Flags: .......A...F]
```

```
0000  ae eb 54 d8 fd ab 5e 61  c3 8e 91 bc 08 00 45 00
0010  00 34 c9 0a 40 00 40 06  5d b7 0a 00 00 02 0a 00
0020  00 01 eb 30 00 50 dd e8  90 74 aa 03 33 02 80 11
0030  01 f5 77 e1 00 00 01 01  08 0a b4 eb 9e 64 7f da
0040  de d4
```

wireshark_eth1BZ0UG2.pcapng   Packets: 13 · Displayed: 13 (100.0%) · Dropped: 0 (0.0%)   Profile: Default

pkt 13 – client←server – ack

ack to finish


*eth1
File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help
Apply a display filter … <Ctrl-/>

```
No.  Time         Source      Destination  Protocol  Length Info
  10 5.009319…    10.0.0.1    10.0.0.2     TCP       66 80 → 60208 [FIN, ACK] Seq=532 Ack=621 Win=64640 Len=0 TS…
  11 5.056332…    10.0.0.2    10.0.0.1     TCP       66 60208 → 80 [ACK] Seq=621 Ack=533 Win=64128 Len=0 TSval=3…
  12 16.95590…    10.0.0.2    10.0.0.1     TCP       66 60208 → 80 [FIN, ACK] Seq=621 Ack=533 Win=64128 Len=0 TS…
  13 16.96008…    10.0.0.1    10.0.0.2     TCP       66 80 → 60208 [ACK] Seq=533 Ack=622 Win=64640 Len=0 TSval=2…
```

```
    Acknowledgment number (raw): 3723006069
    1000 .... = Header Length: 32 bytes (8)
  ▾ Flags: 0x010 (ACK)
      000. .... .... = Reserved: Not set
      ...0 .... .... = Accurate ECN: Not set
      .... 0... .... = Congestion Window Reduced: Not set
      .... .0.. .... = ECN-Echo: Not set
      .... ..0. .... = Urgent: Not set
      .... ...1 .... = Acknowledgment: Set
      .... .... 0... = Push: Not set
      .... .... .0.. = Reset: Not set
      .... .... ..0. = Syn: Not set
      .... .... ...0 = Fin: Not set
      [TCP Flags: ·······A····]
```

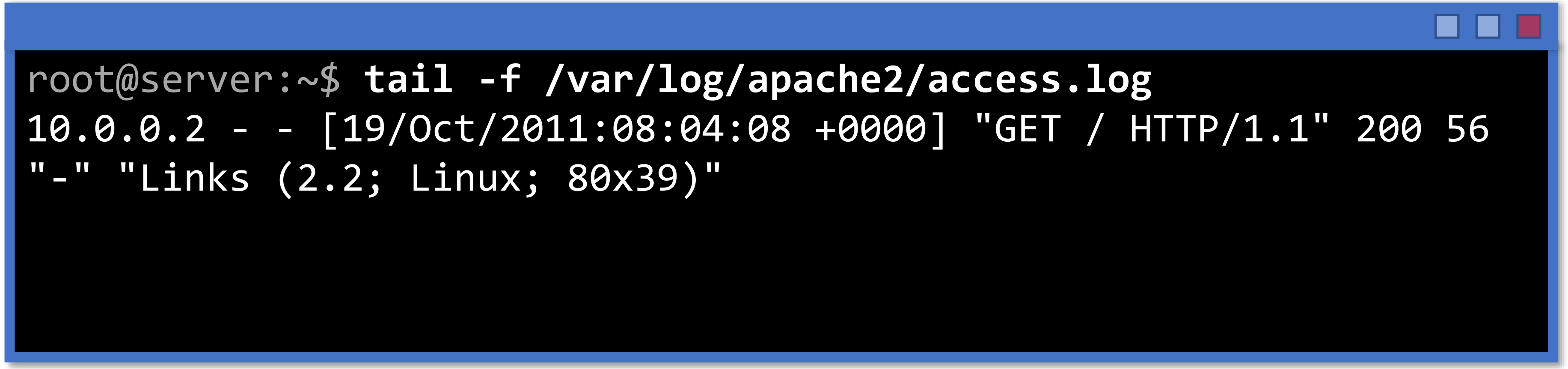
```
0000  5e 61 c3 8e 91 bc ae eb  54 d8 fd ab 08 00 45 00
0010  00 34 00 00 40 00 40 06  26 c2 0a 00 00 01 0a 00
0020  00 02 00 50 eb 30 aa 03  33 02 dd e8 90 75 80 10
0030  01 f9 49 2d 00 00 01 01  08 0a 7f db 0d 84 b4 eb
0040  9e 64
```

wireshark_eth1BZ0UG2.pcapng   Packets: 13 · Displayed: 13 (100.0%) · Dropped: 0 (0.0%)   Profile: Default

extras

The server (again)

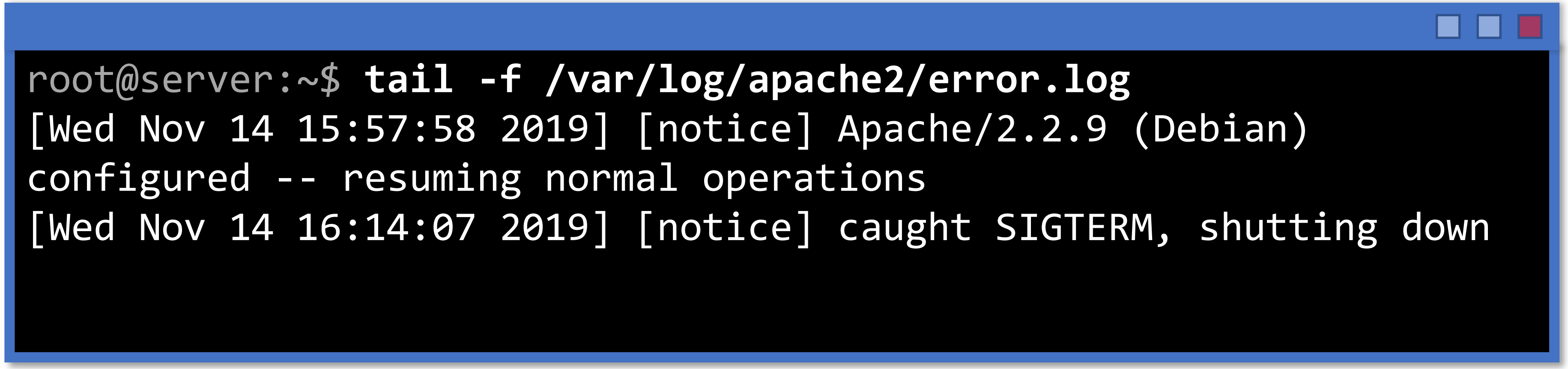
- to monitor accesses to the web server you can use the following command (on the server):



```
root@server:~$ tail -f /var/log/apache2/access.log
10.0.0.2 - - [19/Oct/2011:08:04:08 +0000] "GET / HTTP/1.1" 200 56
"-" "Links (2.2; Linux; 80x39)"
```

The server (again)

- to monitor errors on the web server you can use the following command (on the server):

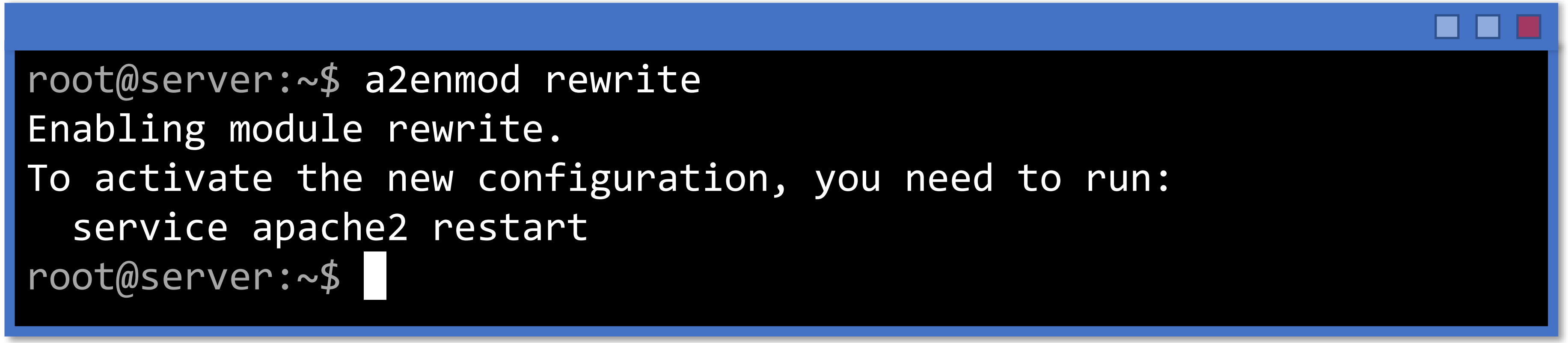


```
root@server:~$ tail -f /var/log/apache2/error.log
[Wed Nov 14 15:57:58 2019] [notice] Apache/2.2.9 (Debian)
configured -- resuming normal operations
[Wed Nov 14 16:14:07 2019] [notice] caught SIGTERM, shutting down
```

- very useful when debugging configurations

Apache modules

- most of apache’s functionalities are built-in
  - retrieve the list using **`apache2 -l`**
- others can be added by enabling modules
  - to enable a module:



```
root@server:~$ a2enmod rewrite
Enabling module rewrite.
To activate the new configuration, you need to run:
  service apache2 restart
root@server:~$ 
```

apache modules

- available modules are located in:
  - **`/etc/apache2/mods-available`**
- enabled modules are located in:
  - **`/etc/apache2/mods-enabled`**
- **`a2enmod`** puts a symbolic link from the relevant file(s) in:
  - **`/etc/apache2/mods-available`** to **`/etc/apache2/mods-enabled`**
- **`a2dismod`** removes these symbolic links

some useful apache modules

`userdir`	enables per-user web sites (this feature does not work with Kathará)
`rewrite`	implements URL rewriting
`proxy`	implements a proxy/gateway
`cgi/cgid`	supports execution of CGI scripts

per-directory configuration

- apache allows configuration changes on a per-directory basis
- creating a special file **`/some/path/.htaccess`** with apache configuration statements applies those statements to all files and subdirectories inside **`/some/path`**
  - **`.htaccess`** files can be nested in a directory tree
    - nested files override their parents

per-directory configuration

- sample configuration statements:
  - restrict access from specific hosts

```
Deny from example.org test.com 10.0.0 192.168.0.0/24
```

  - perform URL rewriting
    - (transparently) redirect to other sites
  - restrict access to a specific subdirectory
  - change name of file containing the default page

```
DirectoryIndex pippo.html
```

  - enable/disable directory indexing

```
Options -Indexes
```

Exercise: per-directory configuration

- when a resource name is not specified in the URL, apache serves **`index.html`** from the requested path
- hands-on:
  - edit file **`/var/www/html/.htaccess`** and add the following directive:

    ```
    DirectoryIndex custom_file.html
    ```
  - rename previously created file **`/var/www/html/index.html`** to **`custom_file.html`**
  - try accessing **`http://10.0.0.1/`** from **`client`**
  - rename **`custom_file.html`** back to **`index.html`** and try accessing the page again