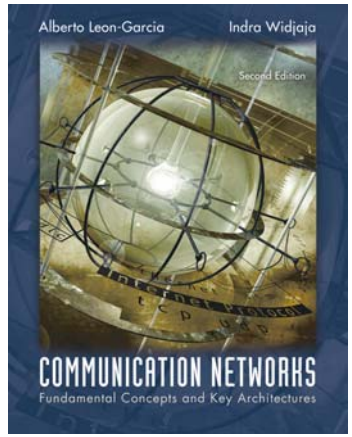
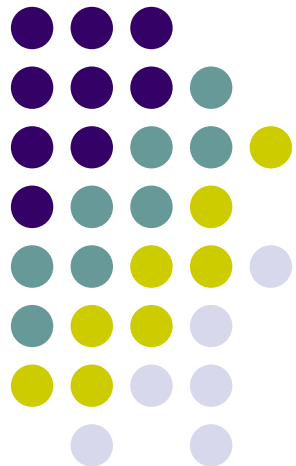
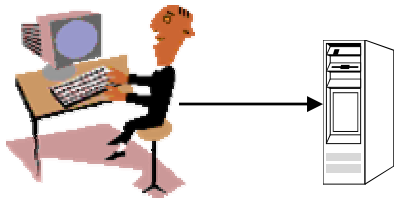
Chapter 2
Applications and Layered Architectures



Chapter Figures



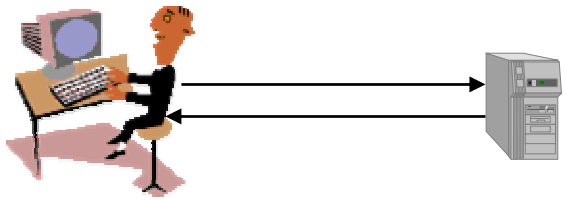
Step:

1. 

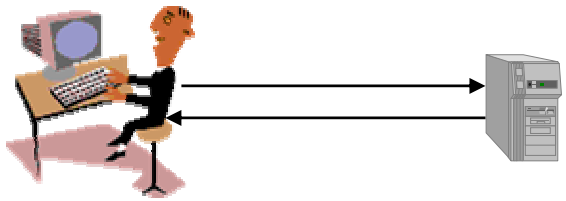
The user clicks on a link to indicate which document is to be retrieved. The browser must determine the Internet address of the machine that contains the document. To do so, the browser sends a query to its local name server.

2.

Once the address is known, the browser establishes a connection to the server process in the specified machine, usually a TCP connection. For the connection to be successful, the specified machine must be ready to accept TCP connections.

3. 

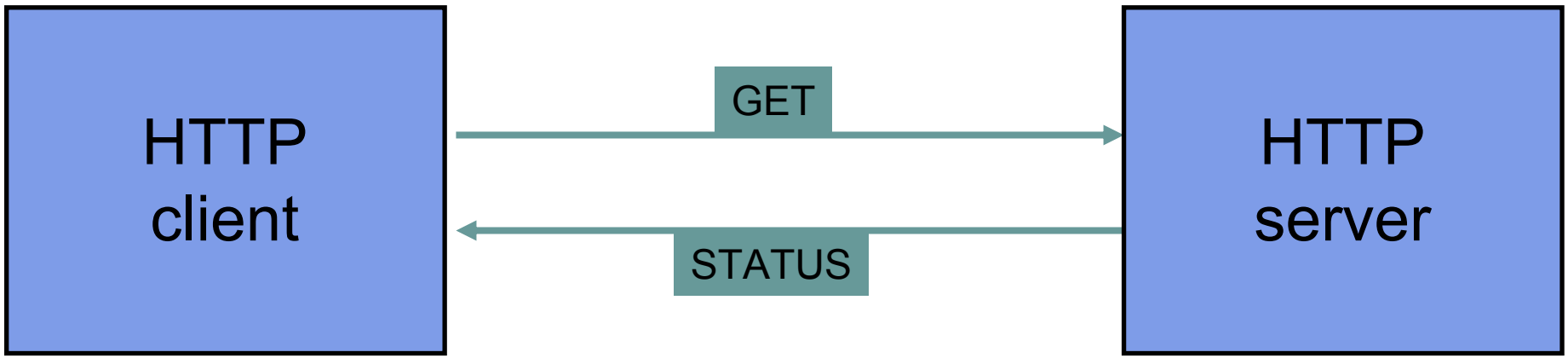
The browser runs a client version of HTTP, which issues a request specifying both the name of the document and the possible document formats it can handle.

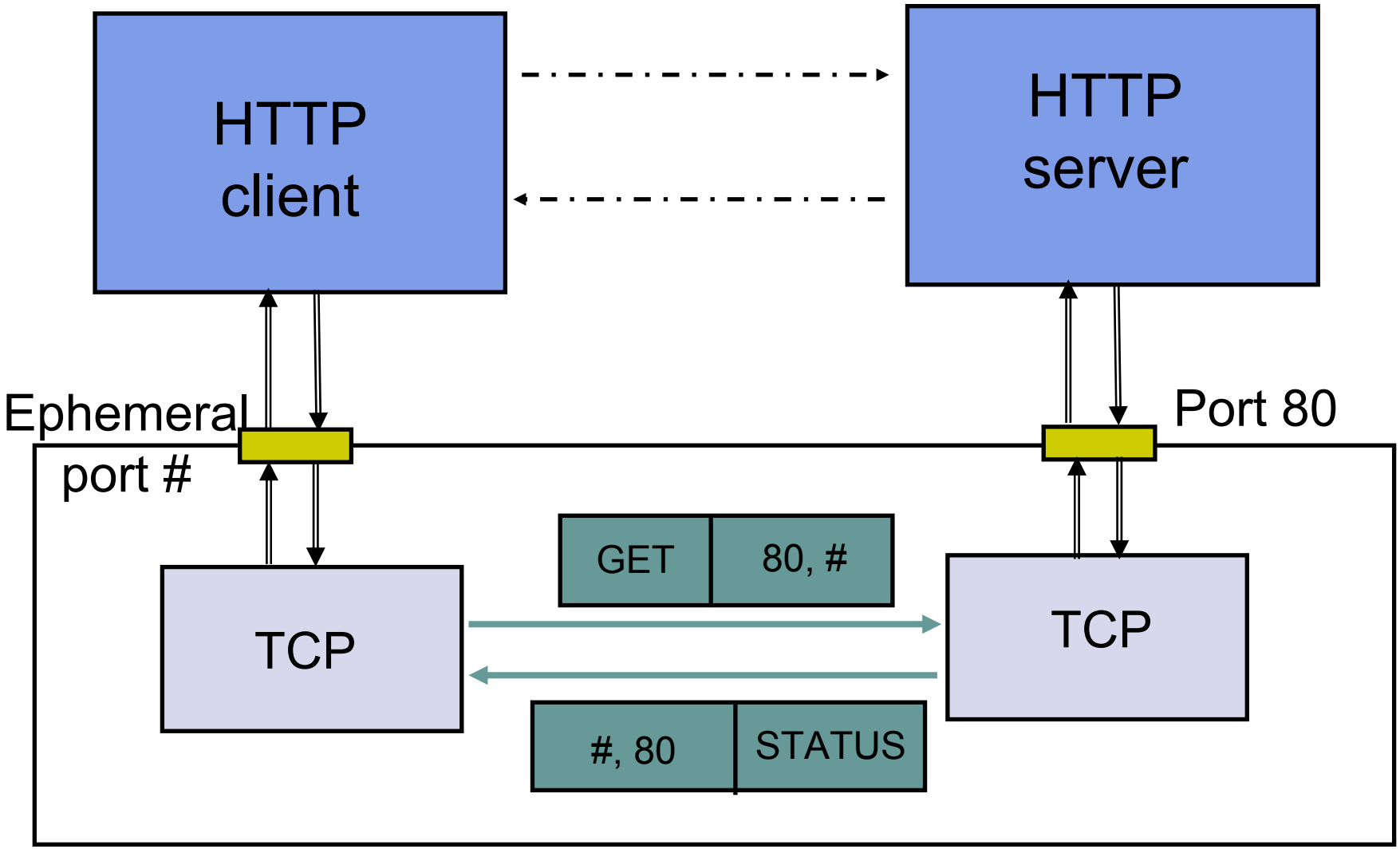
4. – 6. 

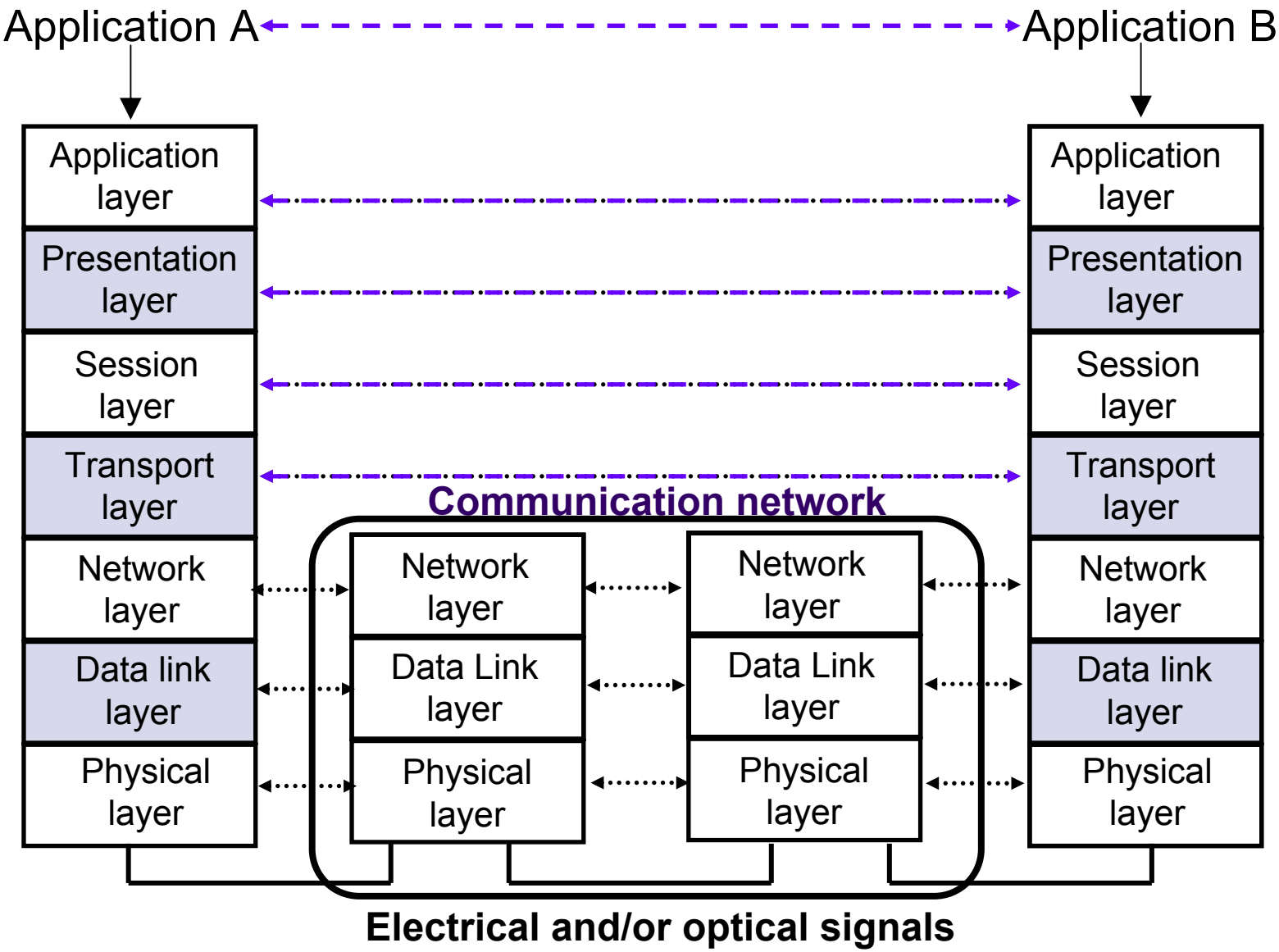
The machine that contains the requested document runs a server version of HTTP. It reacts to the HTTP request by sending an HTTP response which contains the desired document in the appropriate format.

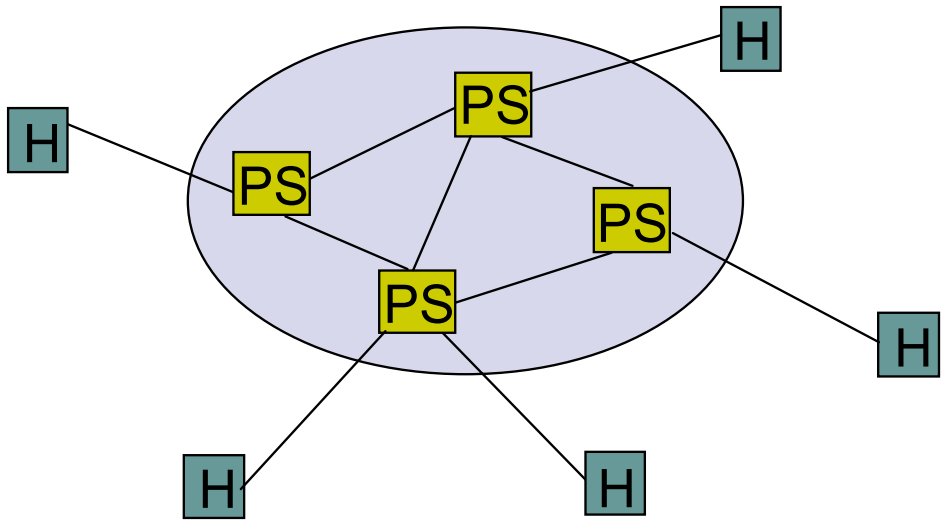
7. – 8.

The user may start to view the document. The TCP connection is closed after a certain timeout period.

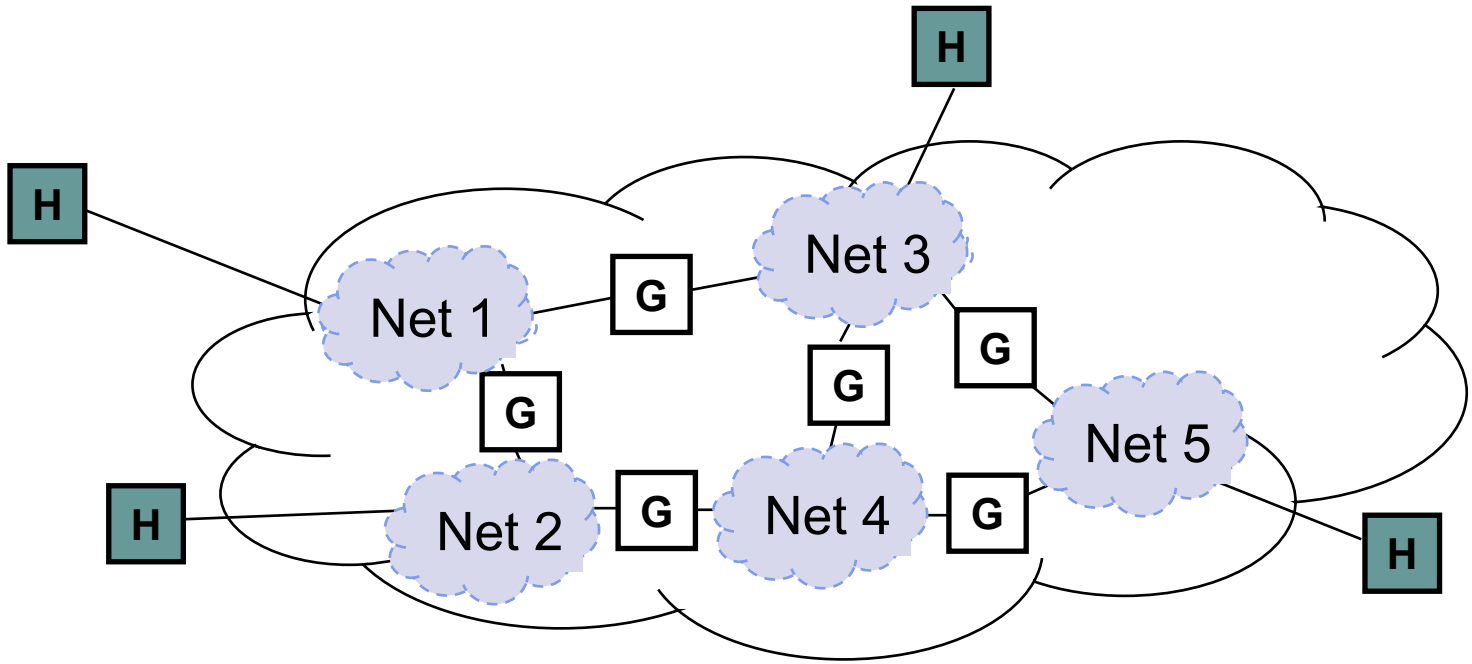

HTTP client
GET
STATUS
HTTP server


HTTP client
HTTP server
Ephemeral port #
Port 80
GET
80, #
TCP
TCP
#, 80
STATUS


Application A
Application B
Application layer
Presentation layer
Session layer
Transport layer
Network layer
Data link layer
Physical layer
Application layer
Presentation layer
Session layer
Transport layer
Network layer
Data link layer
Physical layer
Communication network
Network layer
Data Link layer
Physical layer
Network layer
Data Link layer
Physical layer
Electrical and/or optical signals

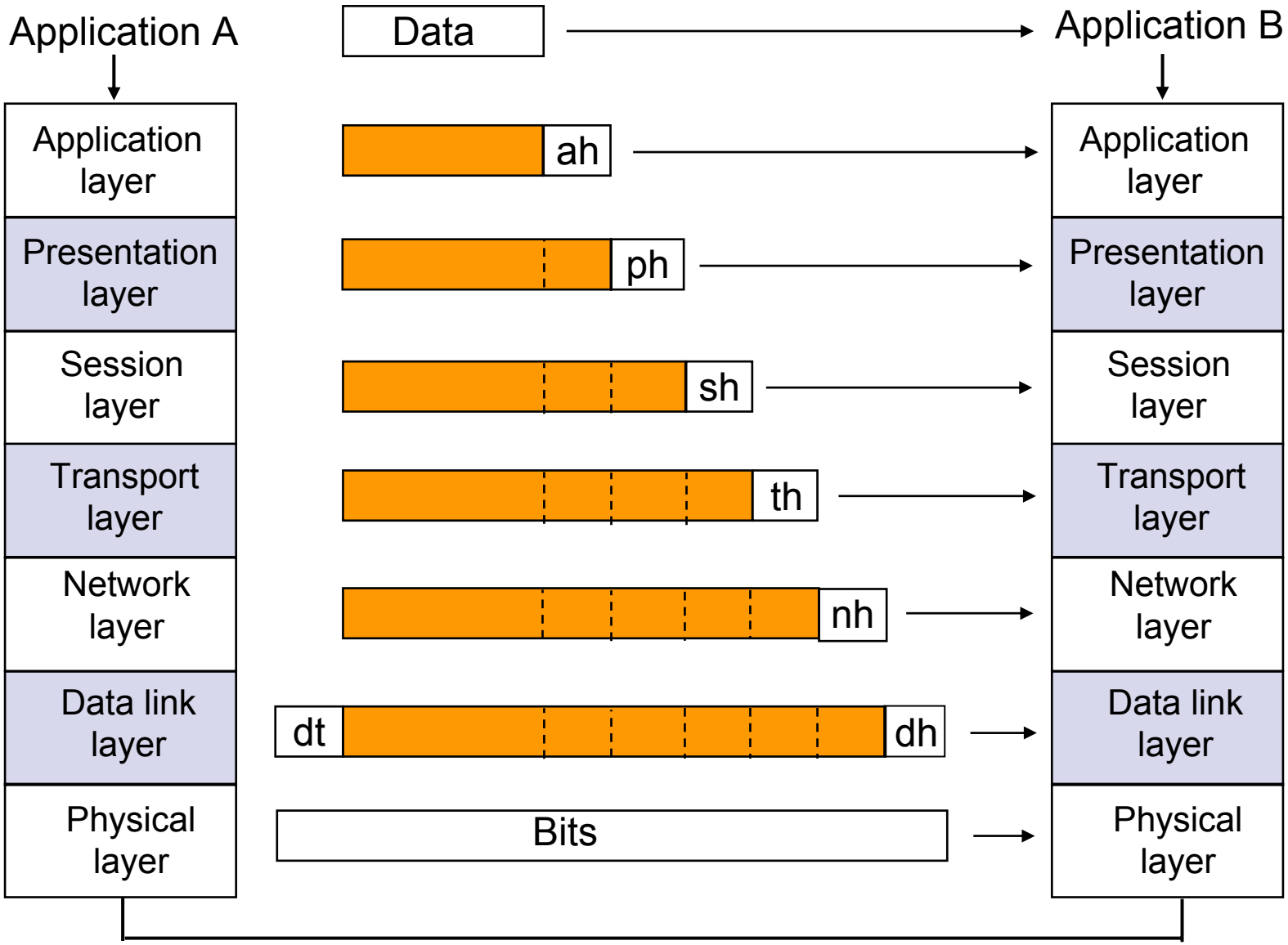


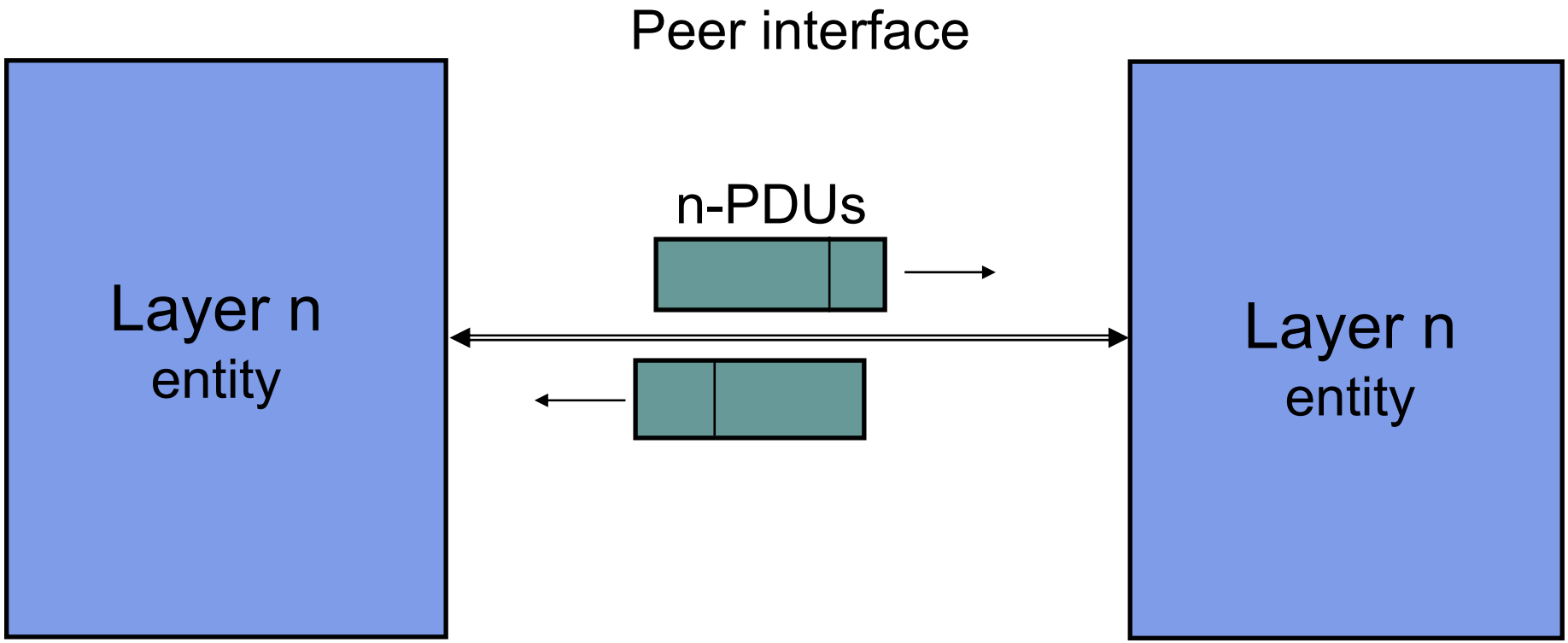
PS = packet switch
H = host

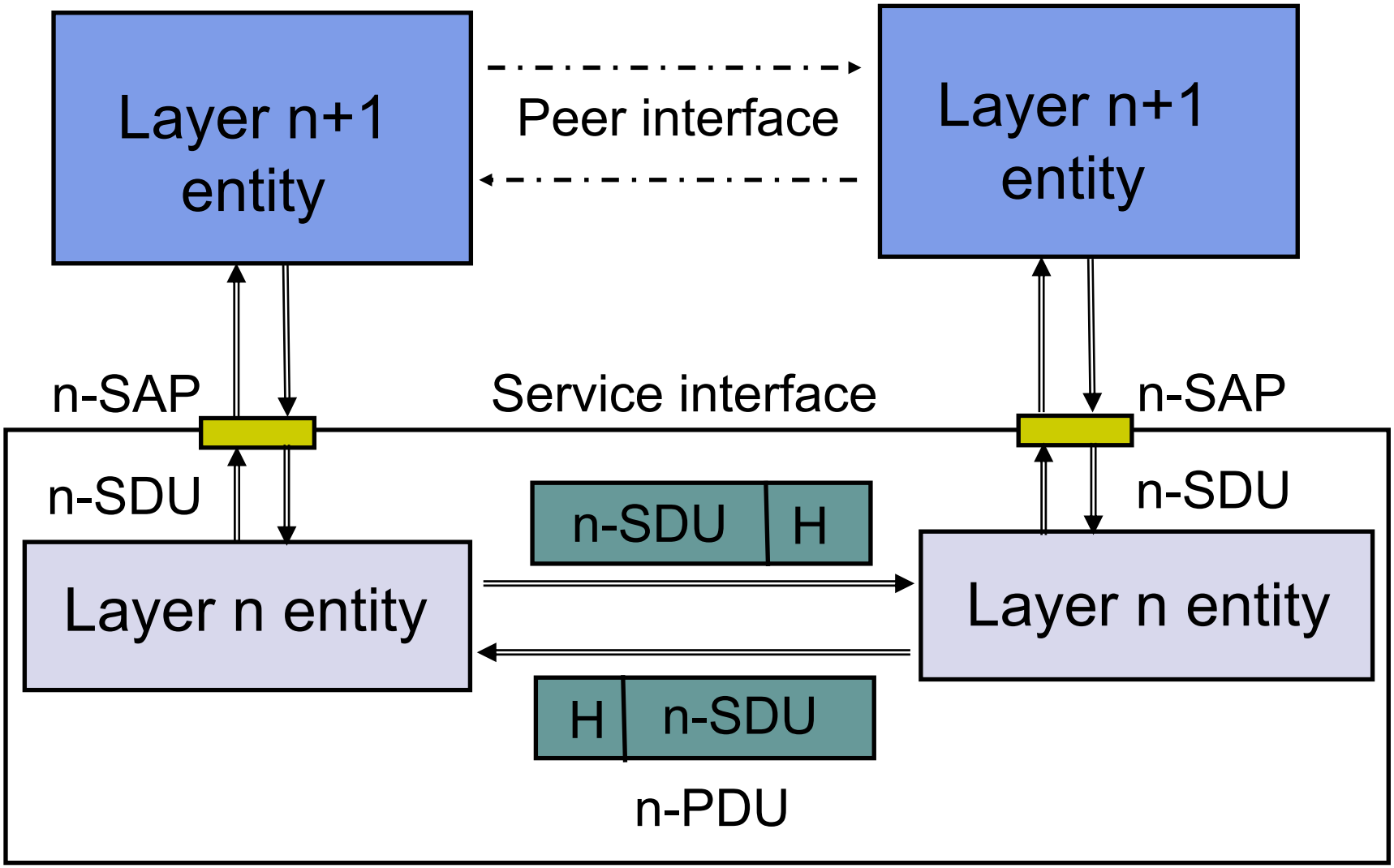


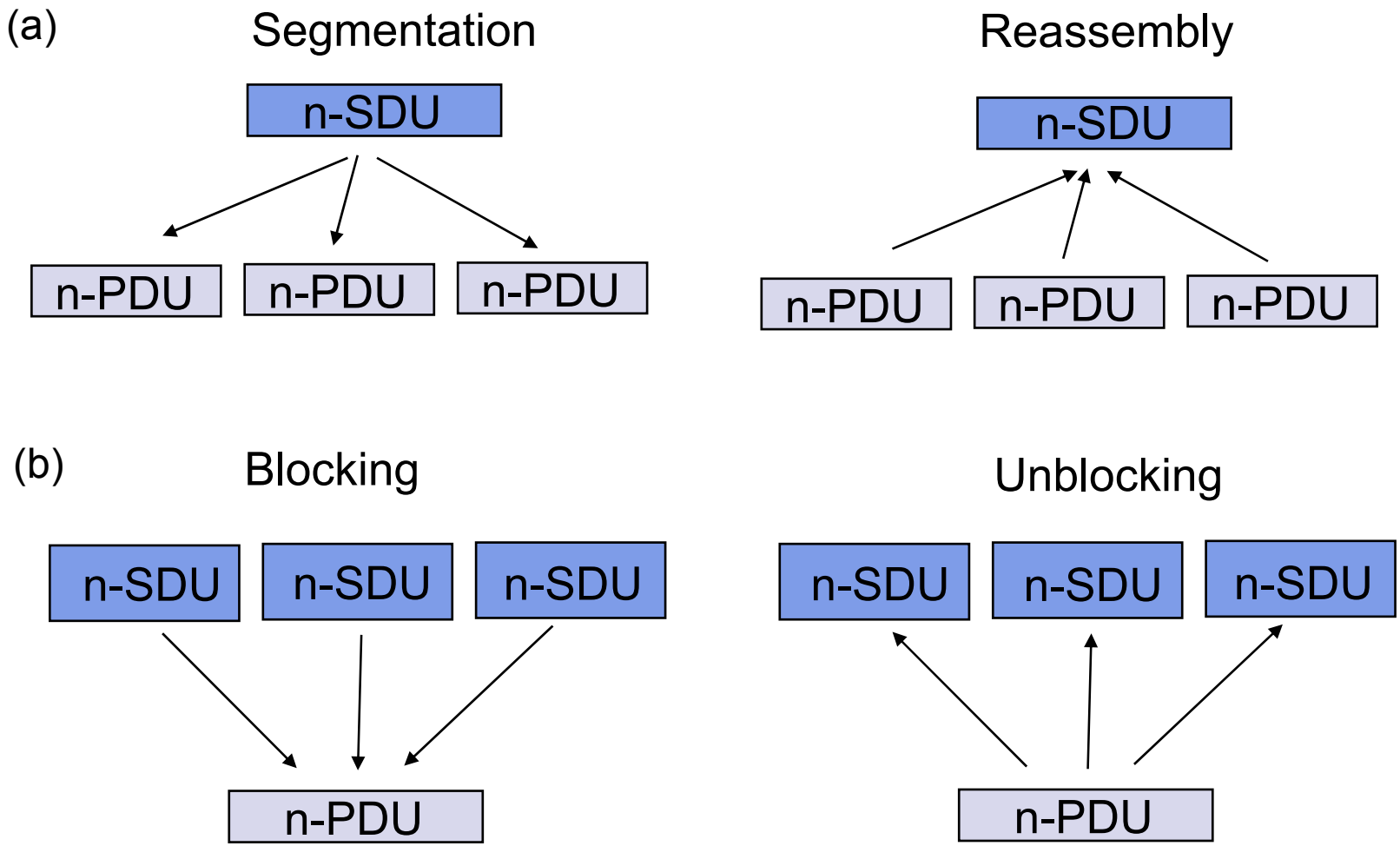
G = gateway/ router

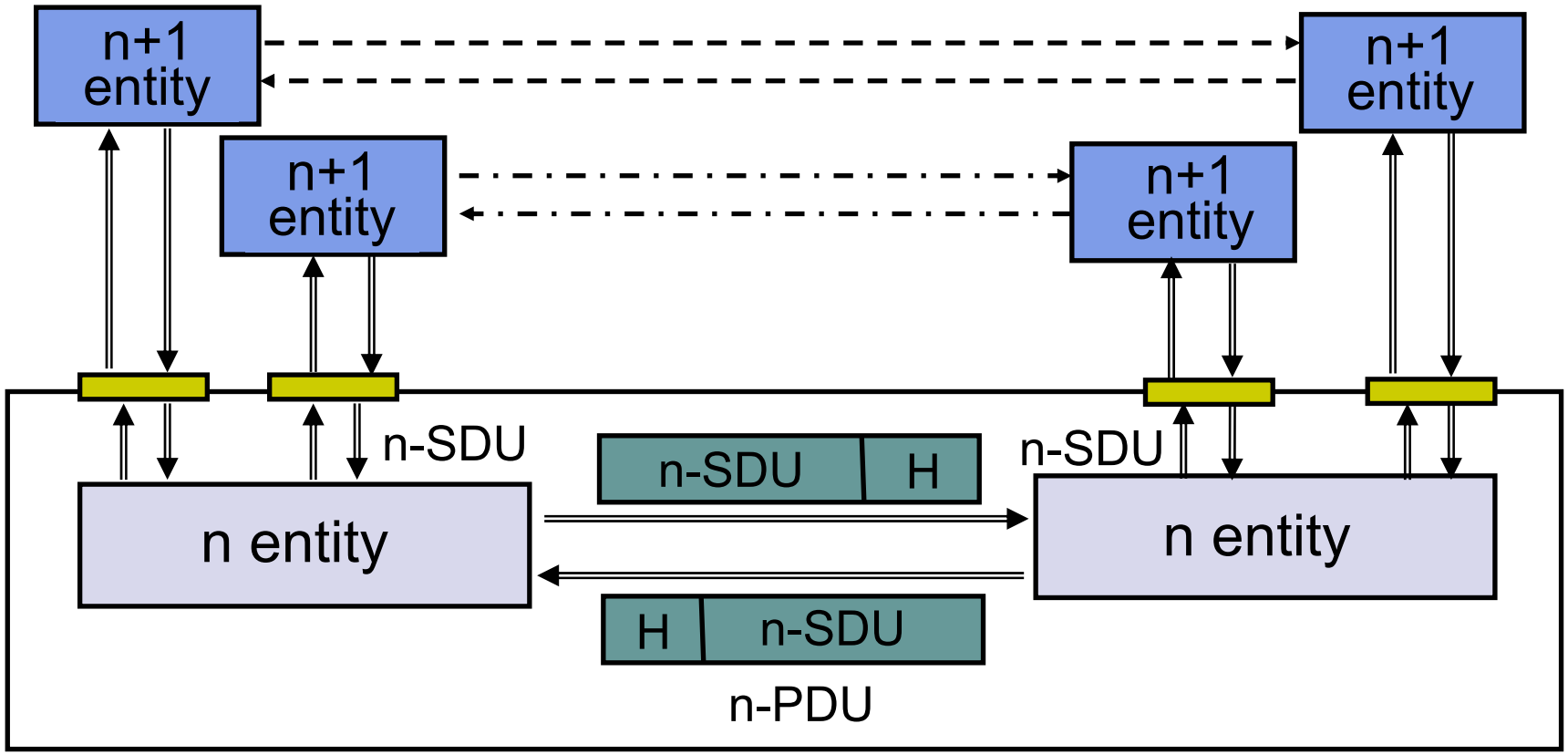
H = host

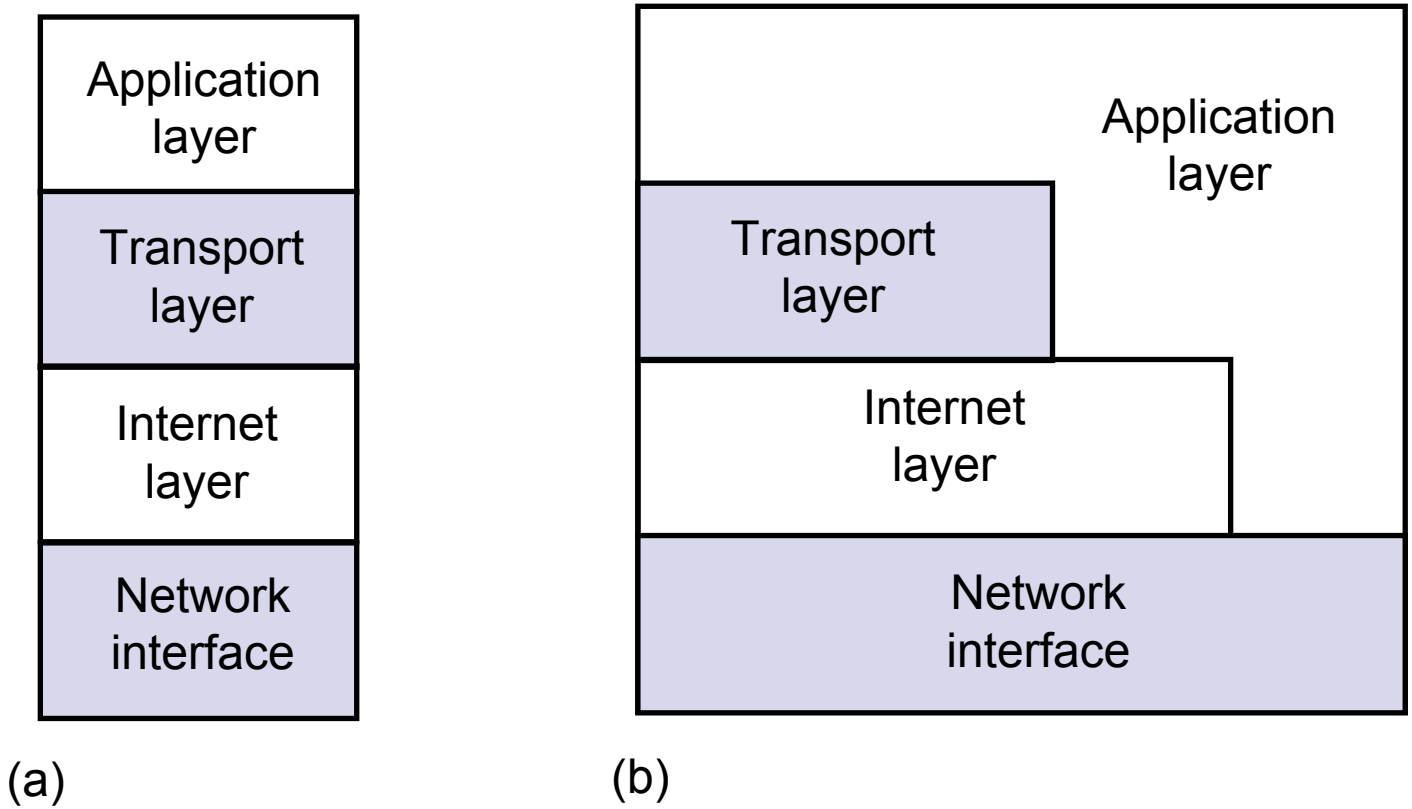

Application A
Data
Application B
Application layer
Presentation layer
Session layer
Transport layer
Network layer
Data link layer
Physical layer
ah
ph
sh
th
nh
dt
dh
Bits
Application layer
Presentation layer
Session layer
Transport layer
Network layer
Data link layer
Physical layer

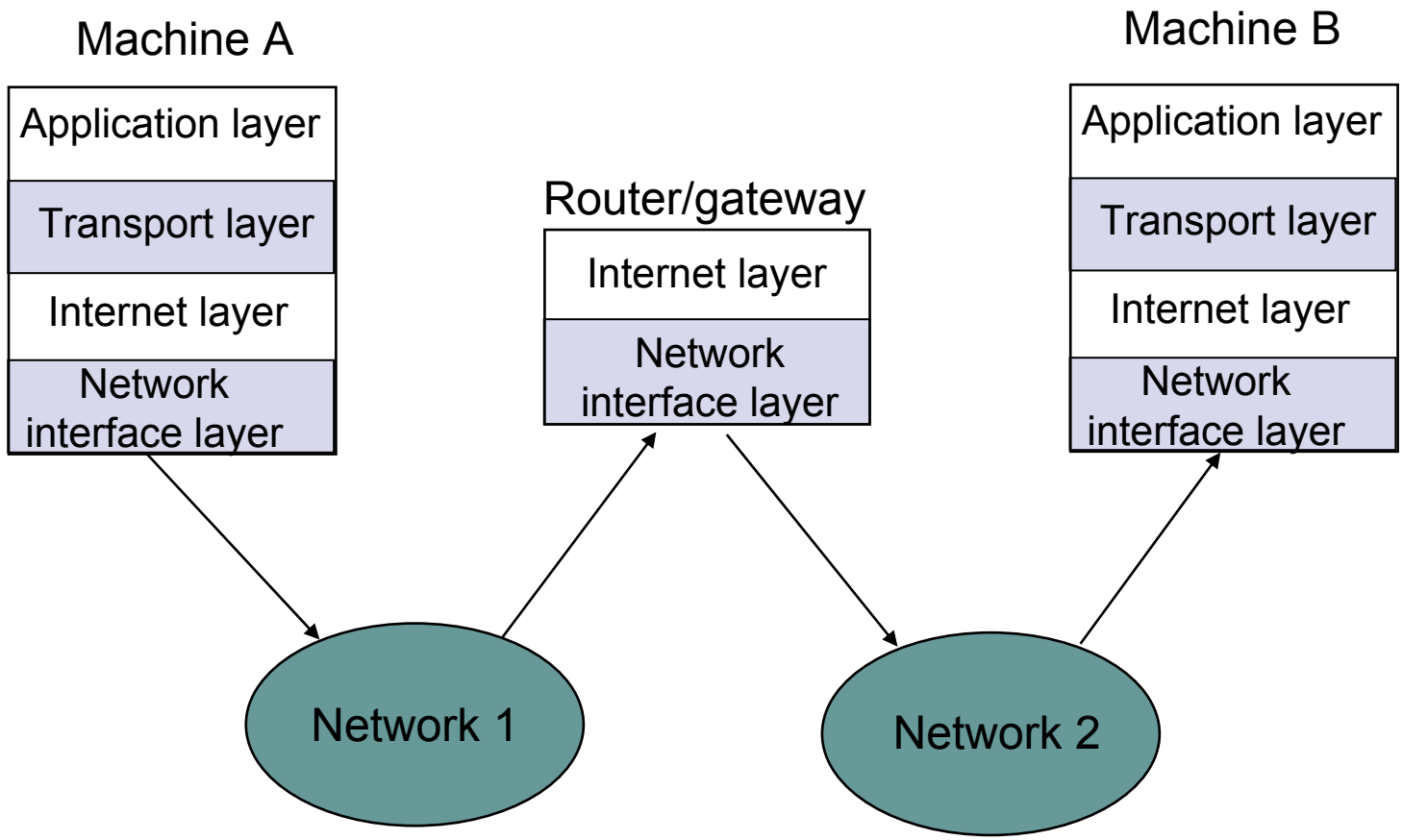

Peer interface
Layer n
entity
n-PDUs
Layer n
entity

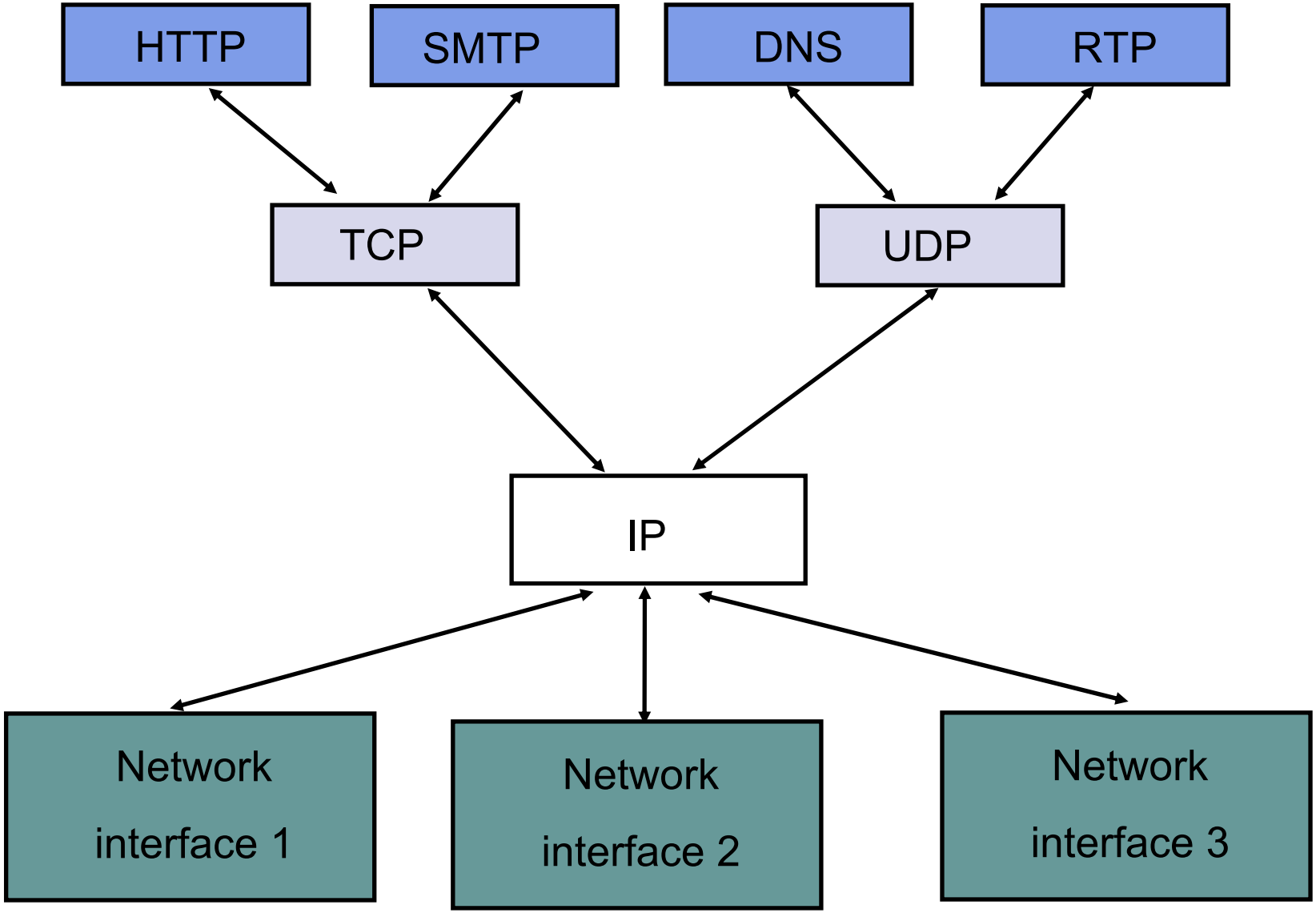

Layer n+1 entity
Peer interface
Layer n+1 entity
n-SAP
Service interface
n-SAP
n-SDU
n-SDU
H
n-SDU
Layer n entity
Layer n entity
H
n-SDU
n-PDU

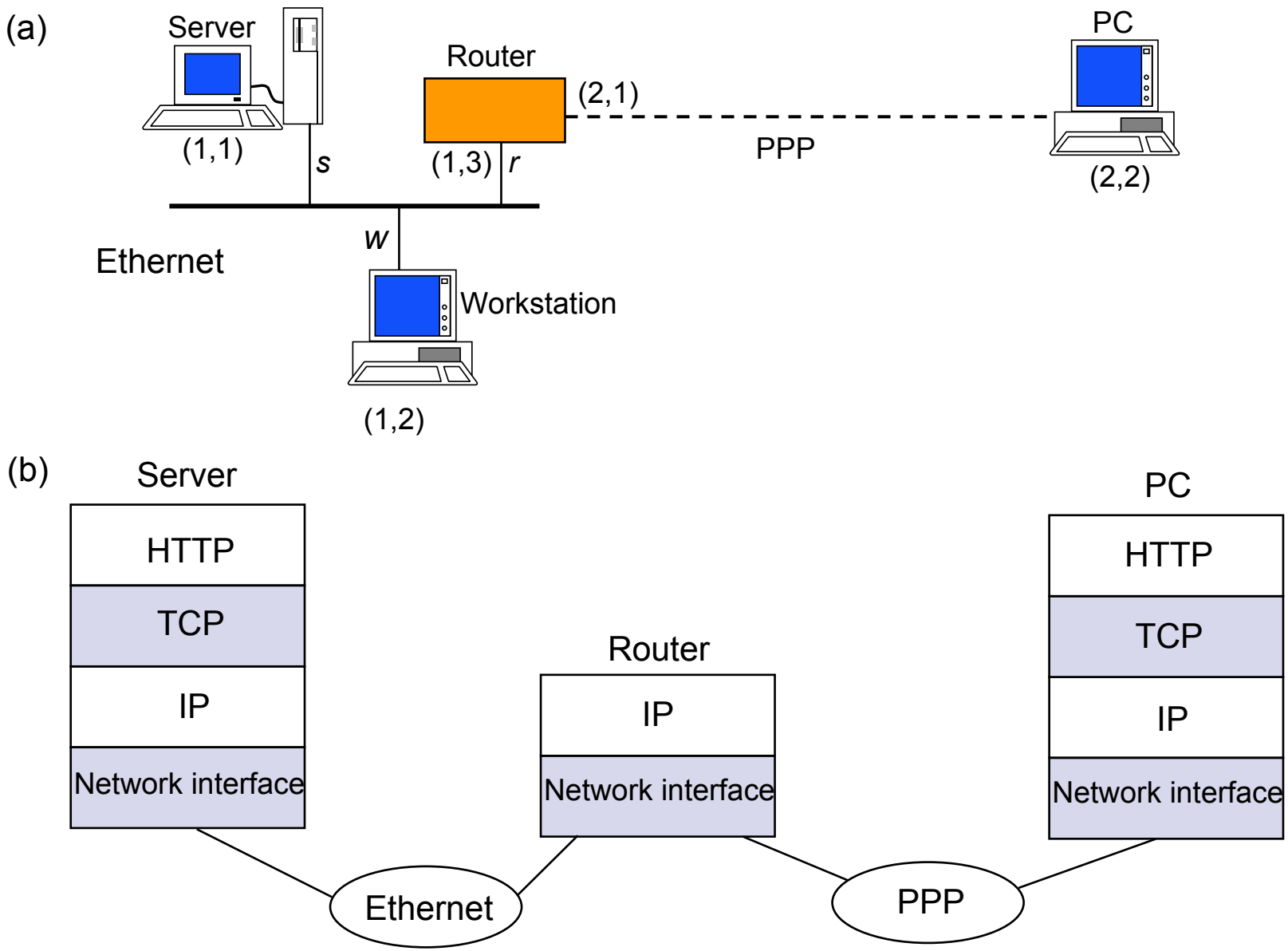

(a)
Segmentation
n-SDU
n-PDU
n-PDU
n-PDU
Reassembly
n-SDU
n-PDU
n-PDU
n-PDU
(b)
Blocking
n-SDU
n-SDU
n-SDU
n-PDU
Unblocking
n-SDU
n-SDU
n-SDU
n-PDU


n+1 entity
n+1 entity
n+1 entity
n+1 entity
n-SDU
n-SDU
H
n-SDU
n entity
n entity
H
n-SDU
n-PDU

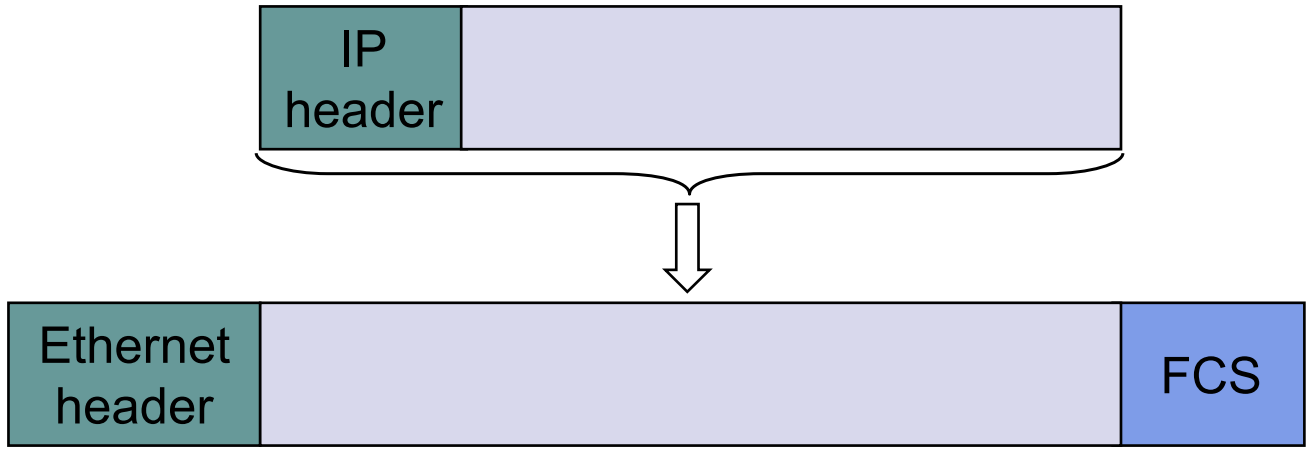

Application layer
Transport layer
Internet layer
Network interface
(a)
Application layer
Transport layer
Internet layer
Network interface
(b)


Machine A
Application layer
Transport layer
Internet layer
Network interface layer
Router/gateway
Internet layer
Network interface layer
Machine B
Application layer
Transport layer
Internet layer
Network interface layer
Network 1
Network 2


HTTP
SMTP
DNS
RTP
TCP
UDP
IP
Network interface 1
Network interface 2
Network interface 3


(a)
Server
Router
PC
(2,1)
(1,1)
s
(1,3)
r
PPP
(2,2)
w
Ethernet
Workstation
(1,2)
(b)
Server
HTTP
TCP
IP
Network interface
Router
IP
Network interface
PC
HTTP
TCP
IP
Network interface
Ethernet
PPP

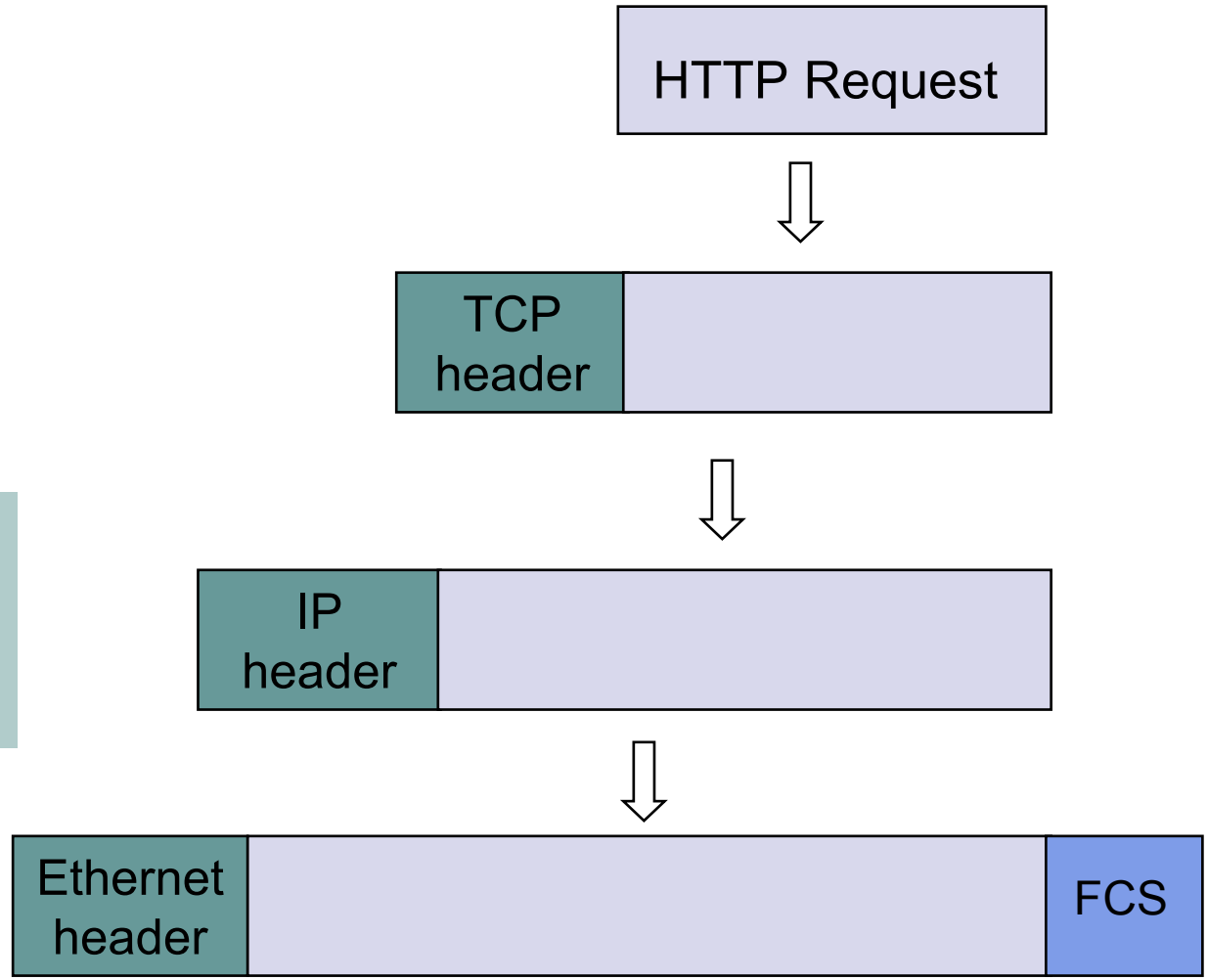
Header contains source and destination physical addresses; network protocol type

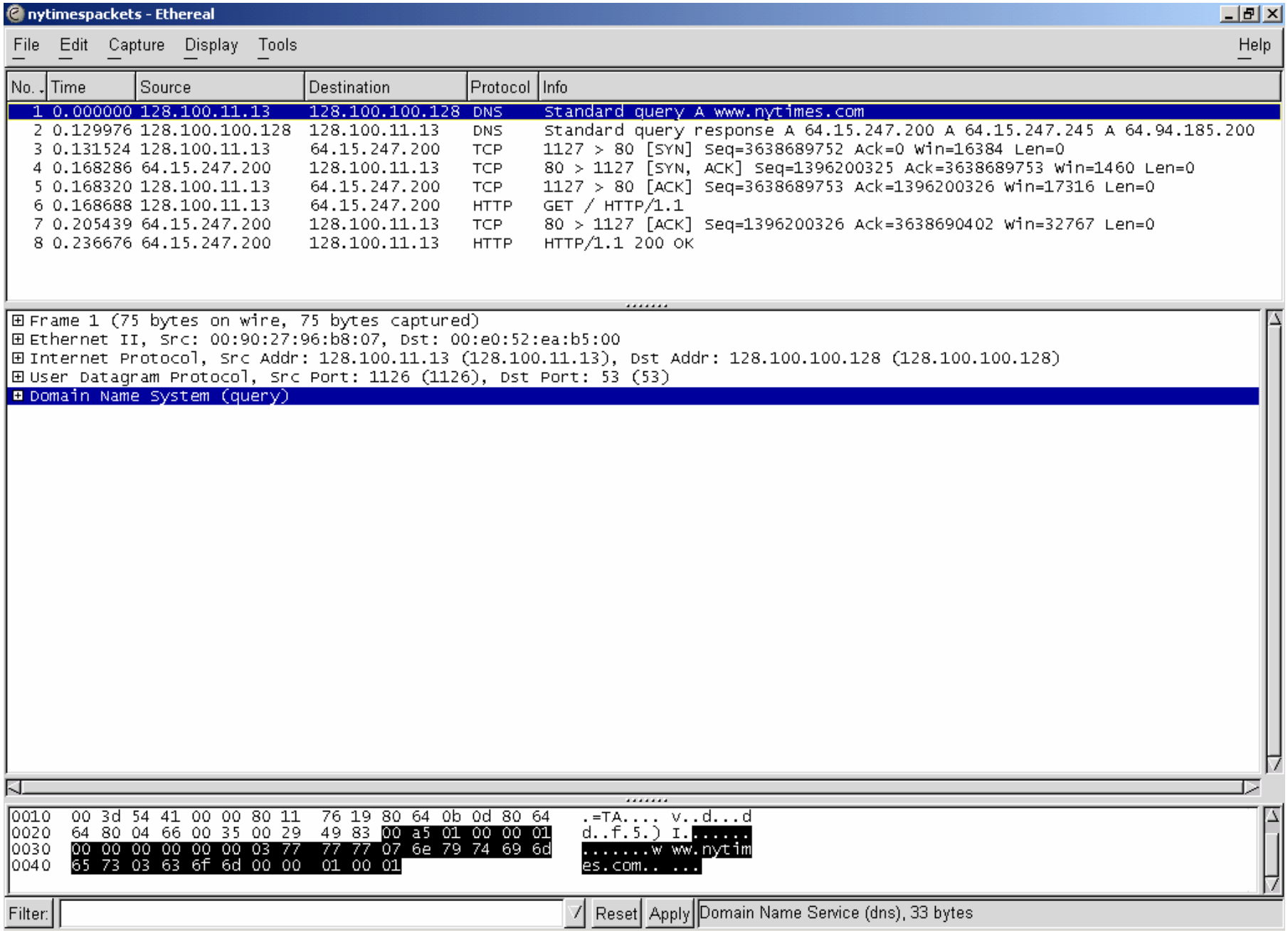


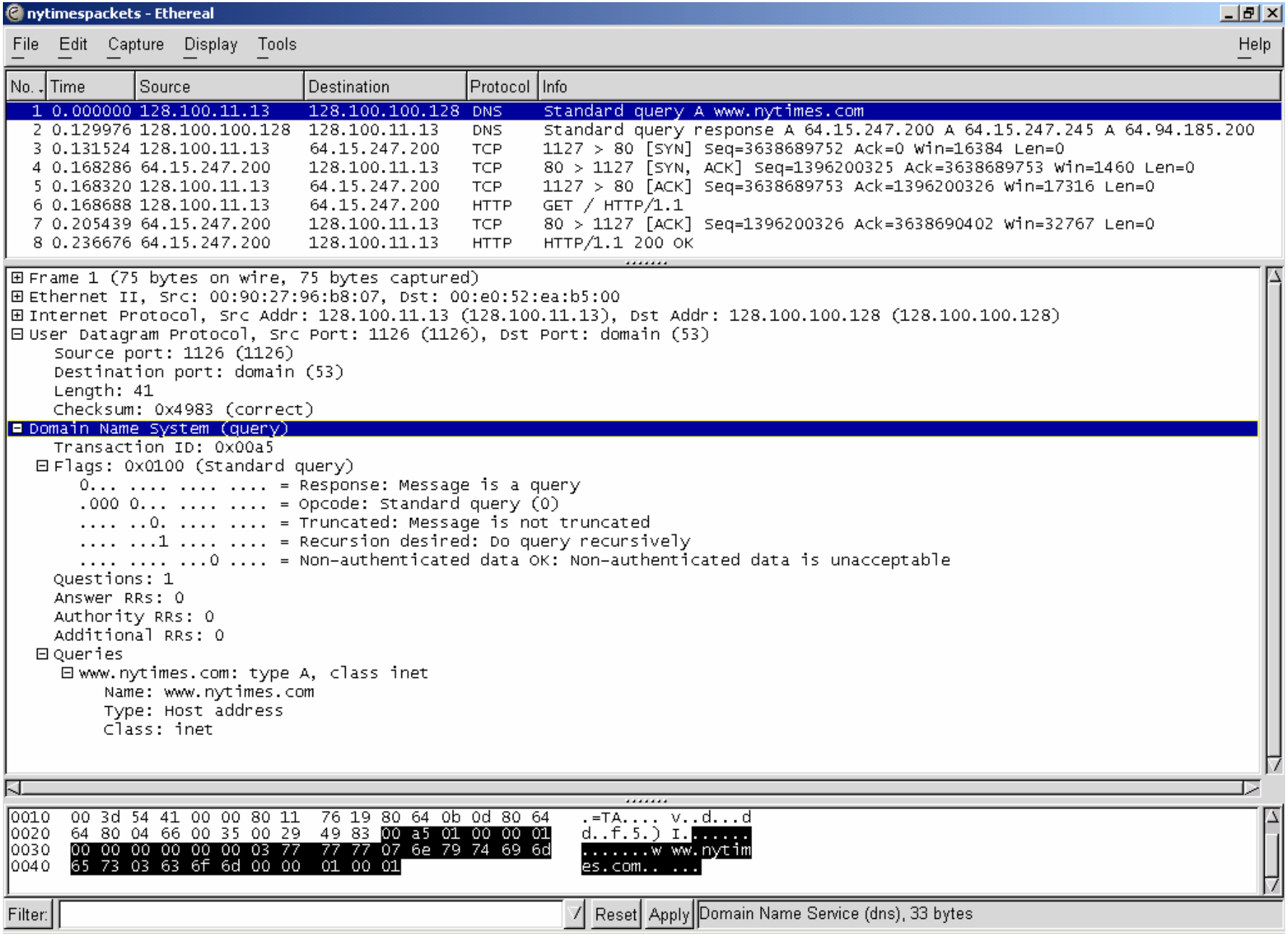
Header contains source & destination port numbers

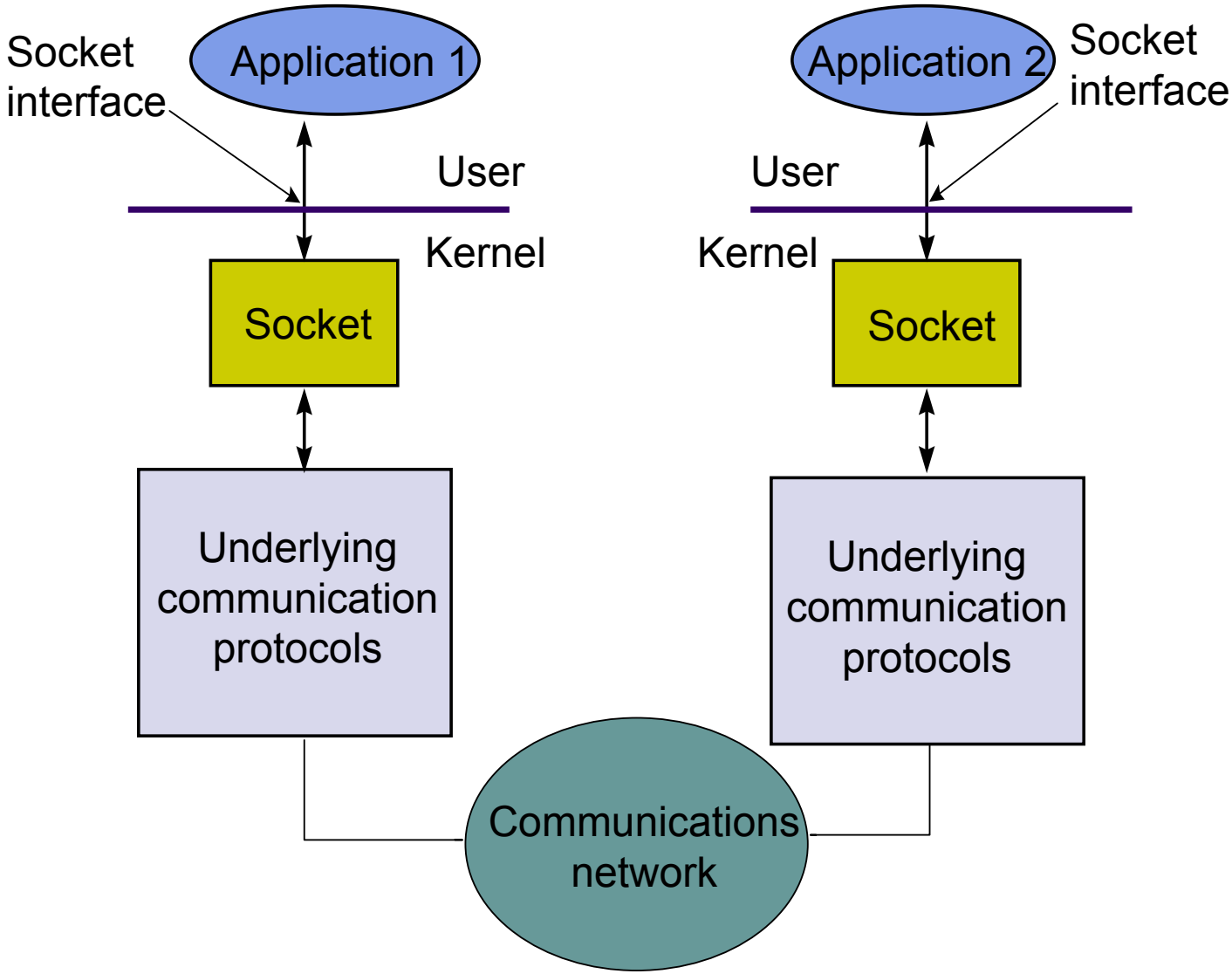
Header contains source and destination IP addresses; transport protocol type

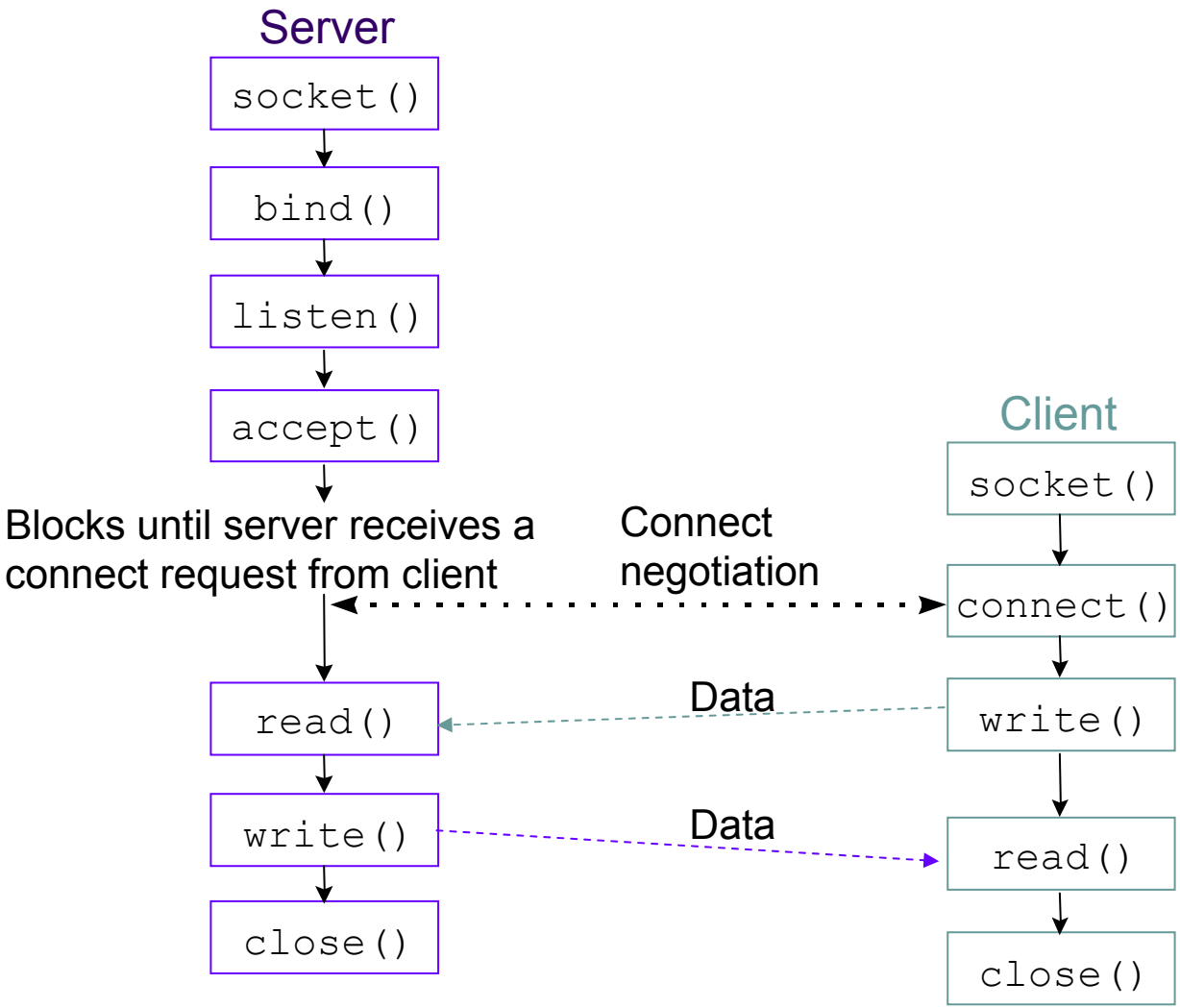
Header contains source & destination physical addresses; network protocol type

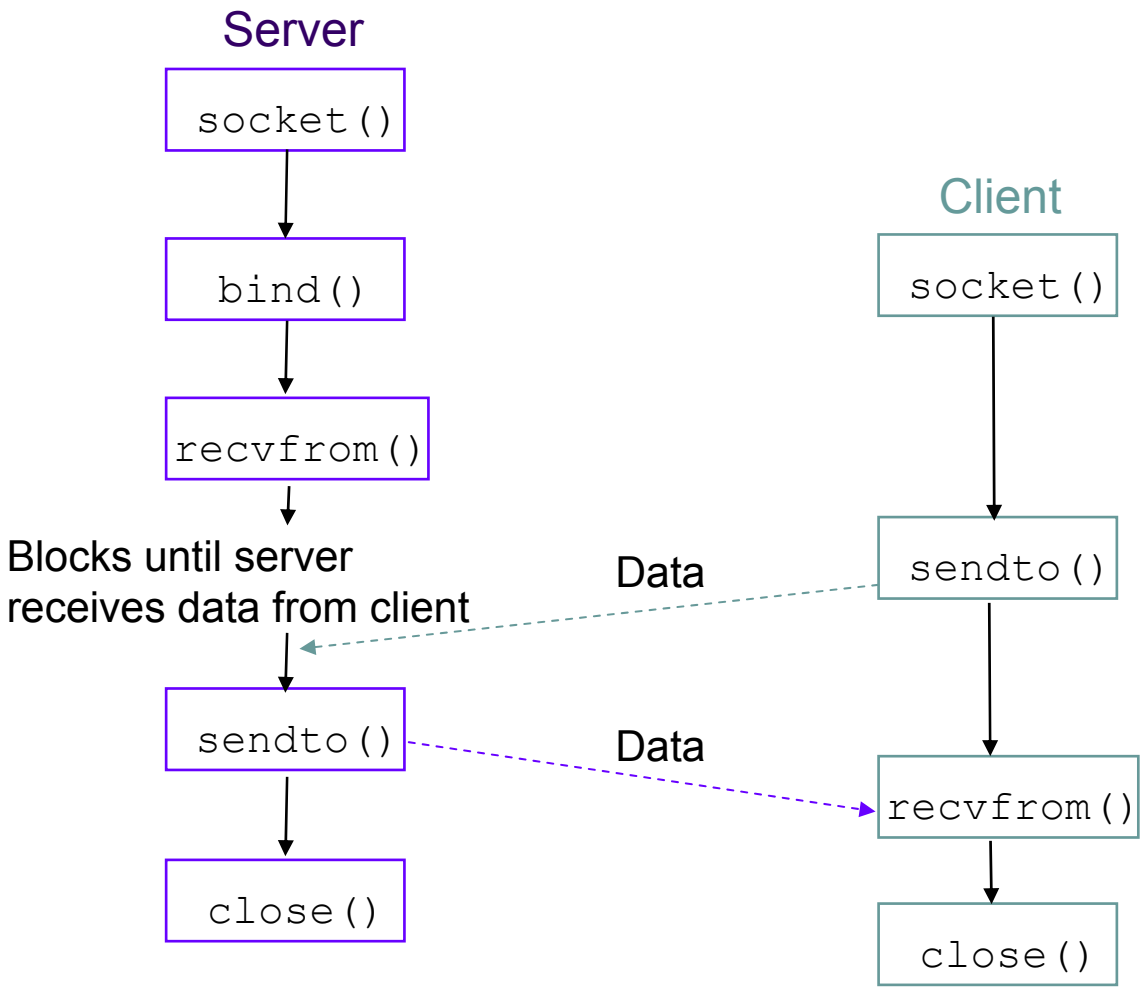


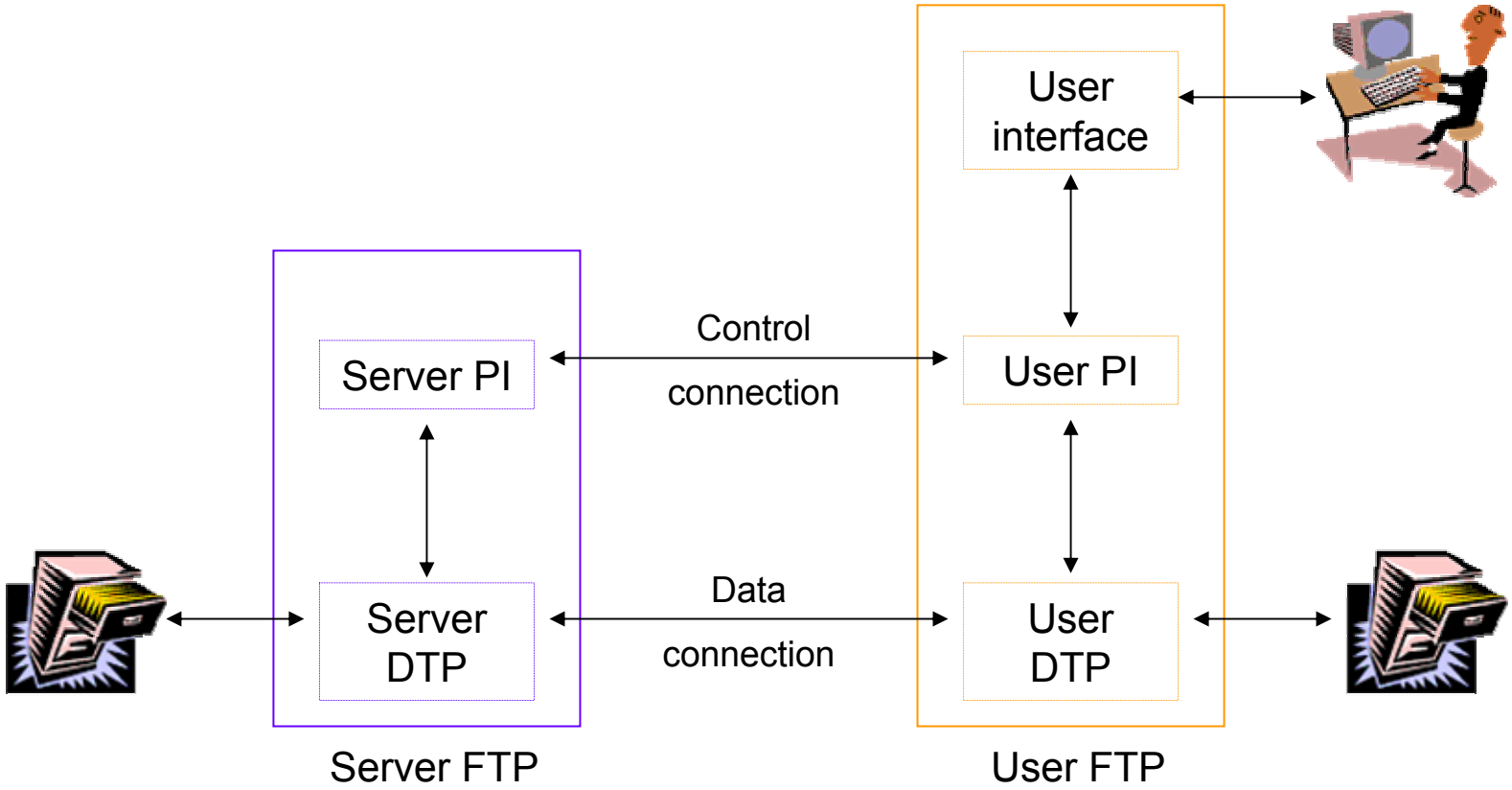

nytimespackets - Ethereal
File Edit Capture Display Tools Help
No. Time Source Destination Protocol Info
1 0.000000 128.100.11.13 128.100.100.128 DNS Standard query A www.nytimes.com
2 0.129976 128.100.100.128 128.100.11.13 DNS Standard query response A 64.15.247.200 A 64.15.247.245 A 64.94.185.200
3 0.131524 128.100.11.13 64.15.247.200 TCP 1127 > 80 [SYN] Seq=3638689752 Ack=0 Win=16384 Len=0
4 0.168286 64.15.247.200 128.100.11.13 TCP 80 > 1127 [SYN, ACK] Seq=1396200325 Ack=3638689753 Win=1460 Len=0
5 0.168320 128.100.11.13 64.15.247.200 TCP 1127 > 80 [ACK] Seq=3638689753 Ack=1396200326 Win=17316 Len=0
6 0.168688 128.100.11.13 64.15.247.200 HTTP GET / HTTP/1.1
7 0.205439 64.15.247.200 128.100.11.13 TCP 80 > 1127 [ACK] Seq=1396200326 Ack=3638690402 Win=32767 Len=0
8 0.236676 64.15.247.200 128.100.11.13 HTTP HTTP/1.1 200 OK
Frame 1 (75 bytes on wire, 75 bytes captured)
Ethernet II, Src: 00:90:27:96:b8:07, Dst: 00:e0:52:ea:b5:00
Internet Protocol, Src Addr: 128.100.11.13 (128.100.11.13), Dst Addr: 128.100.100.128 (128.100.100.128)
User Datagram Protocol, Src Port: 1126 (1126), Dst Port: 53 (53)
Domain Name System (query)
0010 00 3d 54 41 00 00 80 11 76 19 80 64 0b 0d 80 64 .=TA.... v..d...d
0020 64 80 04 66 00 35 00 29 49 83 00 a5 01 00 00 01 d..f.5.) I.......
0030 00 00 00 00 00 00 03 77 77 77 07 6e 79 74 69 6d ....w ww.nytim
0040 65 73 03 63 6f 6d 00 00 01 00 01 es.com.. ...
Filter: Reset Apply Domain Name Service (dns), 33 bytes


nytimespackets - Ethereal
File Edit Capture Display Tools Help
No. Time Source Destination Protocol Info
1 0.000000 128.100.11.13 128.100.100.128 DNS Standard query A www.nytimes.com
2 0.129976 128.100.100.128 128.100.11.13 DNS Standard query response A 64.15.247.200 A 64.15.247.245 A 64.94.185.200
3 0.131524 128.100.11.13 64.15.247.200 TCP 1127 > 80 [SYN] Seq=3638689752 Ack=0 Win=16384 Len=0
4 0.168286 64.15.247.200 128.100.11.13 TCP 80 > 1127 [SYN, ACK] Seq=1396200325 Ack=3638689753 Win=1460 Len=0
5 0.168320 128.100.11.13 64.15.247.200 TCP 1127 > 80 [ACK] Seq=3638689753 Ack=1396200326 Win=17316 Len=0
6 0.168688 128.100.11.13 64.15.247.200 HTTP GET / HTTP/1.1
7 0.205439 64.15.247.200 128.100.11.13 TCP 80 > 1127 [ACK] Seq=1396200326 Ack=3638690402 Win=32767 Len=0
8 0.236676 64.15.247.200 128.100.11.13 HTTP HTTP/1.1 200 OK
Frame 1 (75 bytes on wire, 75 bytes captured)
Ethernet II, Src: 00:90:27:96:b8:07, Dst: 00:e0:52:ea:b5:00
Internet Protocol, Src Addr: 128.100.11.13 (128.100.11.13), Dst Addr: 128.100.100.128 (128.100.100.128)
User Datagram Protocol, Src Port: 1126 (1126), Dst Port: domain (53)
Source port: 1126 (1126)
Destination port: domain (53)
Length: 41
Checksum: 0x4983 (correct)
Domain Name System (query)
Transaction ID: 0x00a5
Flags: 0x0100 (Standard query)
0... .... = Response: Message is a query
.000 0... .... = Opcode: Standard query (0)
.... ..0. .... = Truncated: Message is not truncated
....1 .... = Recursion desired: Do query recursively
....0 .... = Non-authenticated data OK: Non-authenticated data is unacceptable
Questions: 1
Answer RRs: 0
Authority RRs: 0
Additional RRs: 0
Queries
www.nytimes.com: type A, class inet
Name: www.nytimes.com
Type: Host address
Class: inet
0010 00 3d 54 41 00 00 80 11 76 19 80 64 0b 0d 80 64 .=TA.... v..d...d
0020 64 80 04 66 00 35 00 29 49 83 00 a5 01 00 00 01 d..f.5.) I.......
0030 00 00 00 00 00 00 03 77 77 77 07 6e 79 74 69 6d ....w ww.nytim
0040 65 73 03 63 6f 6d 00 00 01 00 01 es.com.. ...
Filter: Reset Apply Domain Name Service (dns), 33 bytes

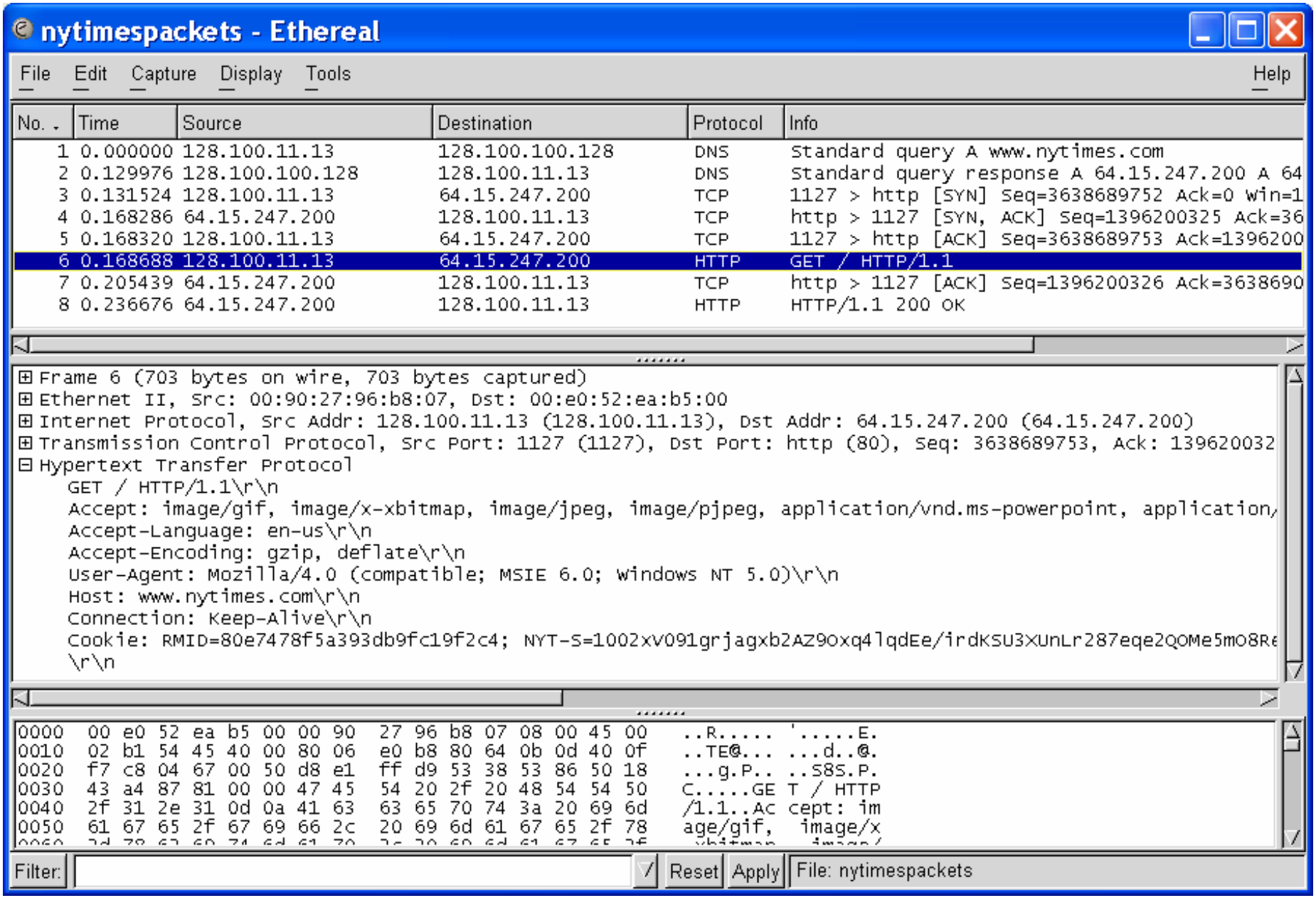

Socket interface
Application 1
User
Kernel
Socket
Underlying communication protocols
Application 2
Socket interface
User
Kernel
Socket
Underlying communication protocols
Communications network

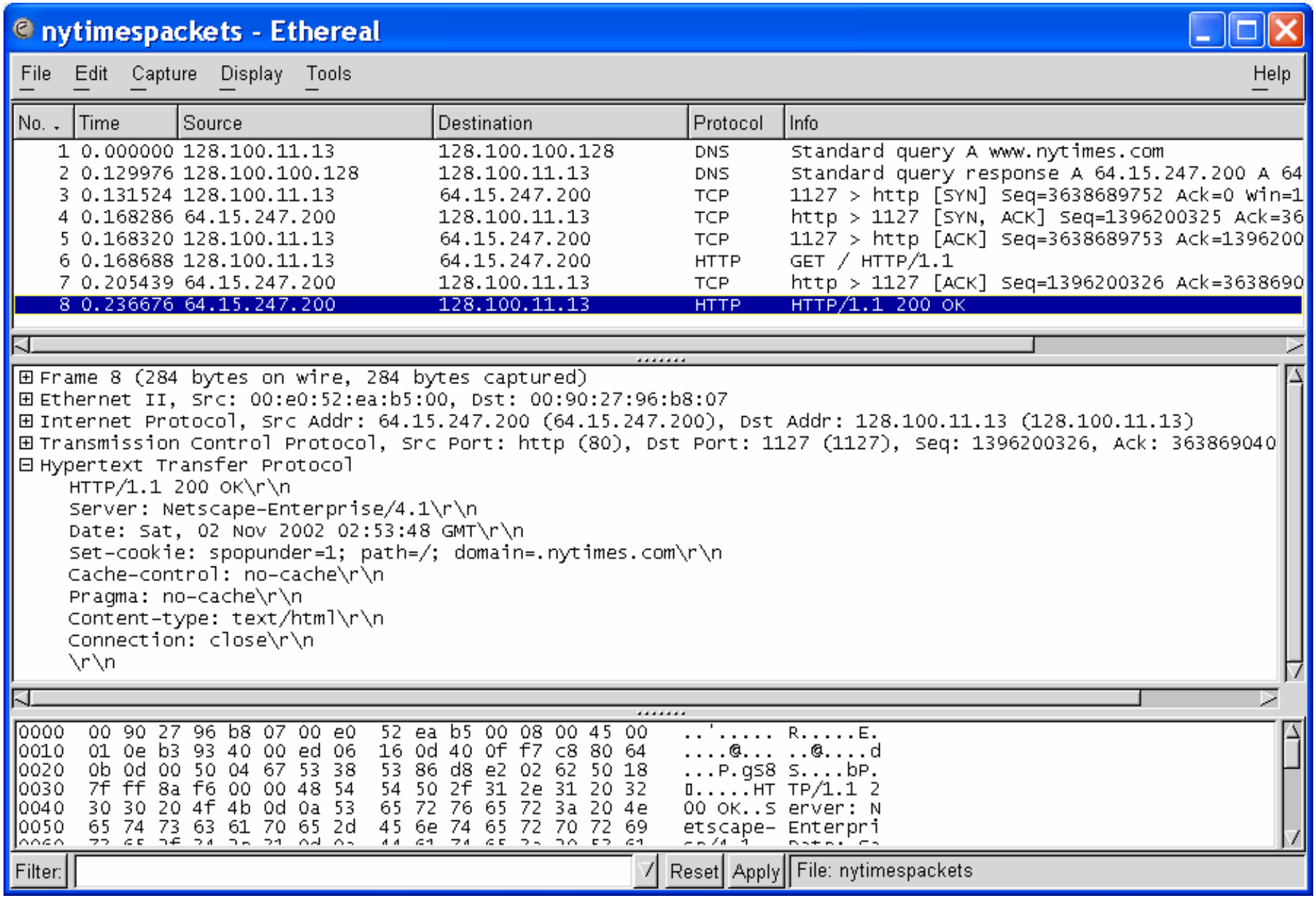

Server
socket()
bind()
listen()
accept()
Blocks until server receives a connect request from client
Connect negotiation
Client
socket()
connect()
Data
read()
write()
Data
write()
read()
close()
close()


Server
socket()
bind()
recvfrom()
Blocks until server
receives data from client
sendto()
close()
Client
socket()
sendto()
recvfrom()
close()
Data
Data



PI = Protocol interface
DTP = Data transfer process


nytimespackets - Ethereal
File Edit Capture Display Tools Help
No. Time Source Destination Protocol Info
1 0.000000 128.100.11.13 128.100.100.128 DNS Standard query A www.nytimes.com
2 0.129976 128.100.100.128 128.100.11.13 DNS Standard query response A 64.15.247.200 A 64
3 0.131524 128.100.11.13 64.15.247.200 TCP 1127 > http [SYN] Seq=3638689752 Ack=0 Win=1
4 0.168286 64.15.247.200 128.100.11.13 TCP http > 1127 [SYN, ACK] Seq=1396200325 Ack=36
5 0.168320 128.100.11.13 64.15.247.200 TCP 1127 > http [ACK] Seq=3638689753 Ack=1396200
6 0.168688 128.100.11.13 64.15.247.200 HTTP GET / HTTP/1.1
7 0.205439 64.15.247.200 128.100.11.13 TCP http > 1127 [ACK] Seq=1396200326 Ack=3638690
8 0.236676 64.15.247.200 128.100.11.13 HTTP HTTP/1.1 200 OK
Frame 6 (703 bytes on wire, 703 bytes captured)
Ethernet II, Src: 00:90:27:96:b8:07, Dst: 00:e0:52:ea:b5:00
Internet Protocol, Src Addr: 128.100.11.13 (128.100.11.13), Dst Addr: 64.15.247.200 (64.15.247.200)
Transmission Control Protocol, Src Port: 1127 (1127), Dst Port: http (80), Seq: 3638689753, Ack: 139620032
Hypertext Transfer Protocol
GET / HTTP/1.1\r\n
Accept: image/gif, image/x-xbitmap, image/jpeg, image/pjpeg, application/vnd.ms-powerpoint, application/
Accept-Language: en-us\r\n
Accept-Encoding: gzip, deflate\r\n
User-Agent: Mozilla/4.0 (compatible; MSIE 6.0; Windows NT 5.0)\r\n
Host: www.nytimes.com\r\n
Connection: Keep-Alive\r\n
Cookie: RMID=80e7478f5a393db9fc19f2c4; NYT-S=1002xV091grjagxb2AZ9Oxq4lqdEe/irdKSU3XUnLr287eqe2QOMe5mO8Re
\r\n
0000 00 e0 52 ea b5 00 00 90 27 96 b8 07 08 00 45 00 ..R..... '.....E.
0010 02 b1 54 45 40 00 80 06 e0 b8 80 64 0b 0d 40 0f ..TE@... ...d..@.
0020 f7 c8 04 67 00 50 d8 e1 ff d9 53 38 53 86 50 18 ...g.P.. ..S8S.P.
0030 43 a4 87 81 00 00 47 45 54 20 2f 20 48 54 54 50 C.....GE T / HTTP
0040 2f 31 2e 31 0d 0a 41 63 63 65 70 74 3a 20 69 6d /1.1..Ac cept: im
0050 61 67 65 2f 67 69 66 2c 20 69 6d 61 67 65 2f 78 age/gif, image/x
Filter: Reset Apply File: nytimespackets


nytimespackets - Ethereal
File Edit Capture Display Tools Help
No. Time Source Destination Protocol Info
1 0.000000 128.100.11.13 128.100.100.128 DNS Standard query A www.nytimes.com
2 0.129976 128.100.100.128 128.100.11.13 DNS Standard query response A 64.15.247.200 A 64
3 0.131524 128.100.11.13 64.15.247.200 TCP 1127 > http [SYN] Seq=3638689752 Ack=0 Win=1
4 0.168286 64.15.247.200 128.100.11.13 TCP http > 1127 [SYN, ACK] Seq=1396200325 Ack=36
5 0.168320 128.100.11.13 64.15.247.200 TCP 1127 > http [ACK] Seq=3638689753 Ack=1396200
6 0.168688 128.100.11.13 64.15.247.200 HTTP GET / HTTP/1.1
7 0.205439 64.15.247.200 128.100.11.13 TCP http > 1127 [ACK] Seq=1396200326 Ack=3638690
8 0.236676 64.15.247.200 128.100.11.13 HTTP HTTP/1.1 200 OK
Frame 8 (284 bytes on wire, 284 bytes captured)
Ethernet II, Src: 00:e0:52:ea:b5:00, Dst: 00:90:27:96:b8:07
Internet Protocol, Src Addr: 64.15.247.200 (64.15.247.200), Dst Addr: 128.100.11.13 (128.100.11.13)
Transmission Control Protocol, Src Port: http (80), Dst Port: 1127 (1127), Seq: 1396200326, Ack: 363869040
Hypertext Transfer Protocol
HTTP/1.1 200 OK\r\n
Server: Netscape-Enterprise/4.1\r\n
Date: Sat, 02 Nov 2002 02:53:48 GMT\r\n
Set-cookie: spopunder=1; path=/; domain=.nytimes.com\r\n
Cache-control: no-cache\r\n
Pragma: no-cache\r\n
Content-type: text/html\r\n
Connection: close\r\n
\r\n
0000 00 90 27 96 b8 07 00 e0 52 ea b5 00 08 00 45 00 ..'..... R.....E.
0010 01 0e b3 93 40 00 ed 06 16 0d 40 0f f7 c8 80 64 ....@... ..@....d
0020 0b 0d 00 50 04 67 53 38 53 86 d8 e2 02 62 50 18 ...P.gS8 S....bP.
0030 7f ff 8a f6 00 00 48 54 54 50 2f 31 2e 31 20 32 ......HT TP/1.1 2
0040 30 30 20 4f 4b 0d 0a 53 65 72 76 65 72 3a 20 4e 00 OK..S erver: N
0050 65 74 73 63 61 70 65 2d 45 6e 74 65 72 70 72 69 etscape- Enterpri
Filter: Reset Apply File: nytimespackets

```
Microsoft(R) Windows DOS
(c)Copyright Microsoft Corp 1990-2001.

C:\DOCUME~1\1>ping nal.toronto.edu

Pinging nal.toronto.edu [128.100.244.3] with 32 bytes of data:

Reply from 128.100.244.3: bytes=32 time=84ms TTL=240
Reply from 128.100.244.3: bytes=32 time=110ms TTL=240
Reply from 128.100.244.3: bytes=32 time=81ms TTL=240
Reply from 128.100.244.3: bytes=32 time=79ms TTL=240

Ping statistics for 128.100.244.3:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 79ms, Maximum = 110ms, Average = 88ms

C:\DOCUME~1\1>
```

```
Tracing route to www.comm.utoronto.ca [128.100.11.60]
over a maximum of 30 hops:

  1     1 ms   <10 ms   <10 ms  192.168.2.1
  2     3 ms     3 ms     3 ms  10.202.128.1
  3     4 ms     3 ms     3 ms  gw04.ym.phub.net.cable.rogers.com [66.185.83.142]
  4     *        *        *     Request timed out.
  5    47 ms    59 ms    66 ms  gw01.bloor.phub.net.cable.rogers.com [66.185.80.230]
  6     3 ms     3 ms    38 ms  gw02.bloor.phub.net.cable.rogers.com [66.185.80.242]
  7     8 ms     3 ms     5 ms  gw01.wlfdle.phub.net.cable.rogers.com [66.185.80.2]
  8     8 ms     7 ms     7 ms  gw02.wlfdle.phub.net.cable.rogers.com [66.185.80.142]
  9     4 ms    10 ms     4 ms  gw01.front.phub.net.cable.rogers.com [66.185.81.18]
 10     6 ms     4 ms     5 ms  ra1sh-ge3-4.mt.bigpipeinc.com [66.244.223.237]
 11    16 ms    17 ms    13 ms  rx0sh-hydro-one-telecom.mt.bigpipeinc.com [66.244.223.246]
 12     7 ms    14 ms     8 ms  142.46.4.2
 13    10 ms     7 ms     6 ms  utorgw.onet.on.ca [206.248.221.6]
 14     7 ms     6 ms    11 ms  mcl-gateway.gw.utoronto.ca [128.100.96.101]
 15     7 ms     5 ms     8 ms  sf-gpb.gw.utoronto.ca [128.100.96.17]
 16     7 ms     7 ms    10 ms  bi15000.ece.utoronto.ca [128.100.96.236]
 17     7 ms     9 ms     9 ms  www.comm.utoronto.ca [128.100.11.60]

Trace complete.
```

```
IPv4 Statistics

  Packets Received                    = 71271
  Received Header Errors              = 0
  Received Address Errors             = 9
  Datagrams Forwarded                 = 0
  Unknown Protocols Received          = 0
  Received Packets Discarded          = 0
  Received Packets Delivered          = 71271
  Output Requests                     = 70138
  Routing Discards                    = 0
  Discarded Output Packets            = 0
  Output Packet No Route              = 0
  Reassembly Required                 = 0
  Reassembly Successful               = 0
  Reassembly Failures                 = 0
  Datagrams Successfully Fragmented   = 0
  Datagrams Failing Fragmentation     = 0
  Fragments Created                   = 0

UDP Statistics for IPv4

  Datagrams Received    = 6810
  No Ports              = 15
  Receive Errors        = 0
  Datagrams Sent        = 6309
```

```
ICMPv4 Statistics

                            Received    Sent
  Messages                  10          6
  Errors                    0           0
  Destination Unreachable   8           1
  Time Exceeded             0           0
  Parameter Problems        0           0
  Source Quenches           0           0
  Redirects                 0           0
  Echos                     0           2
  Echo Replies              2           0
  Timestamps                0           0
  Timestamp Replies         0           0
  Address Masks             0           0
  Address Mask Replies      0           0

TCP Statistics for IPv4

  Active Opens                        = 798
  Passive Opens                       = 17
  Failed Connection Attempts          = 13
  Reset Connections                   = 467
  Current Connections                 = 0
  Segments Received                   = 64443
  Segments Sent                       = 63724
  Segments Retransmitted              = 80
```