CS615 - Aspects of System Administration

Networking II

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Get your instruments and play along!

Start a FreeBSD instance, then log in on it.

```
ami-d0b520b8 --instance-type t1.micro

ssh ec2-user@<instance-name>
```

A simple example

```
$ telnet www.google.com 80
```

A simple example

```
$ telnet www.google.com 80
Trying 172.217.15.68...
Connected to www.google.com.
Escape character is '^]'.
HEAD / HTTP/1.0
```

A simple example

```
$ telnet www.google.com 80
Trying 172.217.15.68...
Connected to www.google.com.
Escape character is '^]'.
HEAD / HTTP/1.0

HTTP/1.0 200 OK
Date: Sun, 25 Feb 2018 18:18:45 GMT
Content-Type: text/html; charset=ISO-8859-1
Server: gws
[...]
```

A simple example

What exactly happens?

A simple example

What exactly happens?

- local host connects to remote host
- sends command
- receives data

A simple example

How exactly do we connect to the remote host?

- look up hostname
- open connection to IP address

A simple example

How exactly do we look up a hostname?

A simple example

```
$ ktrace -i telnet www.google.com 80
Trying 172.217.15.68...
Connected to www.google.com.
Escape character is '^]'.
GET / HTTP/1.0

[...]
$ kdump >trace
```

...open a few files...

```
[...]
   735 ktrace   RET   execve -1 errno 2 No such file or directory
   735 ktrace   CALL  execve(0xbfbfe7e0,0xbfbfed00,0xbfbfed10)
   735 ktrace   NAMI  "/usr/bin/telnet"
   735 ktrace   NAMI  "/libexec/ld-elf.so.1"
   735 telnet   RET   execve 0
[...]
   735 telnet   CALL  open(0x285192e8,0x100000<O_CLOEXEC>,<unused>0x1b6)
   735 telnet   NAMI  "/etc/nsswitch.conf"
   735 telnet   RET   open 3
[...]
   735 telnet   CALL  open(0x285172f5,0x100000<O_CLOEXEC>,<unused>0x1b6)
   735 telnet   NAMI  "/etc/hosts"
   735 telnet   RET   open 3
[...]
   735 telnet   CALL  open(0x28516f79,0x100000<O_CLOEXEC>,<unused>0x1b6)
   735 telnet   NAMI  "/etc/resolv.conf"
   735 telnet   RET   open 3
[...]
   735 telnet   CALL  read(0x3,0x28c31000,0x8000)
   735 telnet   GIO   fd 3 read 70 bytes
       "# Generated by resolvconf
        search ec2.internal
        nameserver 172.16.0.23
```

... query a DNS server ...

```
[...]
   735 telnet   CALL  socket(PF_INET,SOCK_CLOEXEC|SOCK_DGRAM,IPPROTO_IP)
   735 telnet   RET   socket 4
   735 telnet   CALL  connect(0x4,0x28547e64,0x10)
   735 telnet   STRU  struct sockaddr { AF_INET, 172.16.0.23:53 }
   735 telnet   RET   connect 0
   735 telnet   CALL  sendto(0x4,0x28c5f000,0x20,0,0,0)
   735 telnet   GIO   fd 4 wrote 32 bytes
       0x0000 9a70 0100 0001 0000 0000 0000 0377 7777 0667 6f6f 676c  |.p...........w
       0x0016 6503 636f 6d00 0001 0001                               |e.com.....|
[...]
   735 telnet   CALL  recvfrom(0x4,0x28c4f000,0x10000,0,0xbfbfd5d0,0xbfbfd5cc)
   735 telnet   GIO   fd 4 read 60 bytes
       0x0000 d6c6 8180 0001 0001 0000 0000 0377 7777 0667 6f6f 676c  |.............w
       0x0016 6503 636f 6d00 001c 0001 c00c 001c 0001 0000 003c 0010  |e.com.........
       0x002c 2607 f8b0 4004 0807 0000 0000 0000 2004                 |&...@.........
[...]
```

A simple example

How exactly do we look up a hostname?

- look up various local files
- open a connection to a DNS server's IP
- ask DNS server to resolve hostname
- get back IP

And then?

...communicate with the remote host...

```
   735 telnet   GIO   fd 1 wrote 25 bytes
       "Trying 216.58.217.132...
       "
   735 telnet   RET   write 25/0x19
   735 telnet   CALL  socket(PF_INET,SOCK_STREAM,IPPROTO_TCP)
   735 telnet   CALL  connect(0x3,0x28c0f0f0,0x10)
   735 telnet   STRU  struct sockaddr { AF_INET, 216.58.217.132:80 }
[...]
   918 telnet   GIO   fd 0 read 16 bytes
       "HEAD / HTTP/1.0
       "
   918 telnet   RET   read 16/0x10
   918 telnet   CALL  select(0x4,0x28c0d1b8,0x28c0d1c0,0x28c0d1c8,0x80677b8)
   918 telnet   RET   select 1
   918 telnet   CALL  sendto(0x3,0x8068048,0x11,0,0,0)
   918 telnet   GIO   fd 3 wrote 17 bytes
       "HEAD / HTTP/1.0\r
       "
[...]
   918 telnet   RET   select 1
   918 telnet   CALL  recvfrom(0x3,0x8068870,0x400,0,0,0)
   918 telnet   GIO   fd 3 read 665 bytes
       "HTTP/1.0 200 OK\r
        Date: Sun, 25 Feb 2018 18:55:15 GMT\r
```

Ok, so how does this work?

- determine which nameserver to query
- ask who has a route to the nameserver
- open socket to well defined port on remote IP
- send queries
- open socket to requested port on remote IP

Let's collect some data...

```
laptop$ ssh ec2-user@<instance-name>
$ su
# script commands.out
# ifconfig -a
# route -n get default
# cat /etc/resolv.conf
# tcpdump -w tcpdump.out port not 22 >&/dev/null &
# arp -d -a
# ping -n -c 3 8.8.8.8
# ktrace -i telnet www.google.com 80
HEAD / HTTP/1.0
# kill %1
# kdump > kdump.out
# exit
# exit
$ exit
laptop$ scp ec2-user@<instance-name>:*out /tmp/
```

A simple example

Finding the next hop:

```
$ tcpdump -t -n -r /tmp/tcpdump.out arp
reading from file tcpdump.out, link-type EN10MB (Ethernet)
ARP, Request who-has 10.234.105.193 tell 10.234.105.225, length 28
ARP, Reply 10.234.105.193 is-at fe:ff:ff:ff:ff:ff, length 28
ARP, Request who-has 10.234.105.225 tell 10.234.105.193, length 28
ARP, Reply 10.234.105.225 is-at 22:00:0a:ea:69:e1, length 28
```

A simple example

Performing the DNS query:

```
$ tcpdump -t -n -r tcpdump.out udp port 53
reading from file tcpdump.out, link-type EN10MB (Ethernet)
IP 10.234.105.225.12637 > 172.16.0.23.53: 32409+ A? www.google.com. (32)
IP 172.16.0.23.53 > 10.234.105.225.12637: 32409 1/0/0 A 172.217.12.228 (48)
IP 10.234.105.225.33347 > 172.16.0.23.53: 49414+ AAAA? www.google.com. (32)
IP 172.16.0.23.53 > 10.234.105.225.33347: 49414 1/0/0 AAAA 2607:f8b0:4004:807::2004 (
```

A simple example

Establishing the connection to the server:

```
$ tcpdump -t -n -r tcpdump.out tcp port 80
IP 10.234.105.225.50194 > 172.217.15.68.80: Flags [S],
        seq 1054601677, win 65535, options [...], length 0
IP 172.217.15.68.80 > 10.234.105.225.50194: Flags [S.],
        seq 230054466, ack 1054601678, win 42408, options [...], length 0
IP 10.234.105.225.50194 > 172.217.15.68.80: Flags [.],
        ack 1, win 1026, options [...], length 0
```

A simple example

Sending the HTTP request:

```
IP 10.234.105.225.50194 > 172.217.15.68.80: Flags [P.],
        seq 1:18, ack 1, win 1026, options [...], length 17
IP 172.217.15.68.80 > 10.234.105.225.50194: Flags [.],
        ack 18, win 166, options [...], length 0
IP 10.234.105.225.50194 > 172.217.15.68.80: Flags [P.],
        seq 18:20, ack 1, win 1026, options [...], length 2
IP 172.217.15.68.80 > 10.234.105.225.50194: Flags [.],
        ack 20, win 166, options [...], length 0
```

A simple example

Receiving the HTTP response:

```
IP 172.217.15.68.80 > 10.234.105.225.50194: Flags [P.],
        seq 1:666, ack 20, win 166, options [...], length 665
IP 10.234.105.225.50194 > 172.217.15.68.80: Flags [.],
        ack 667, win 1015, options [...], length 0
```

A simple example

Terminating the connection:

```
IP 172.217.15.68.80 > 10.234.105.225.50194: Flags [F.],
        seq 666, ack 20, win 166, options [...], length 0
IP 10.234.105.225.50194 > 172.217.15.68.80: Flags [F.],
        seq 20, ack 667, win 1026, options [...], length 0
IP 172.217.15.68.80 > 10.234.105.225.50194: Flags [.],
        ack 21, win 166, options [...], length 0
```

Notables from this simple example

“Simple” is, as usual, relative.

Notables from this simple example

"Simple" is, as usual, relative.

- host configuration assumed
- network architecture (internal or across the internet) not relevant (here)
- even simple examples cross multiple layers and protocols (HTTP, DNS; TCP, UDP, ARP)
- we haven't even scratched the surface

TCP/IP Basics: Protocol Layers

	Layer	Function
4.	Application Layer	End-User application programs
3.	Transport Layer	Delivery of data to applications
2.	Network Layer	Basic communication, addressing, and routing
1.	Link Layer	Network Hardware and device drivers
	Physical Layer	Cable or physical medium

Examples of protocols for each layer:

- Simple Mail Transfer Protocol (RFC 821)
  Hypertext Transfer Protocol (RFC 2616)
- Transmission Control Protocol (RFC 793, tcp(4))
  User Datagram Protocol (RFC 768; udp(4))
- Internet Protocol (RFC 791; ip(4))
  Internet Control Message Protocol (RFC 792; icmp(4))
- Address Resolution Protocol (RFC 826; arp(4))

TCP/IP Basics: Protocol Layers (OSI Model)

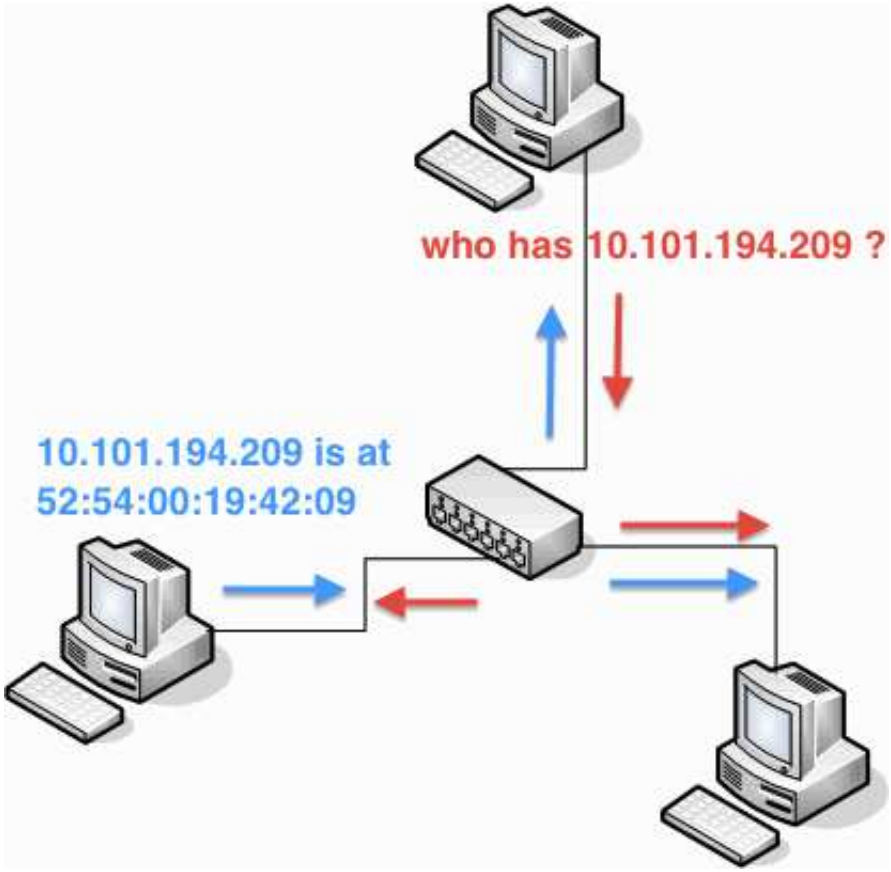
OSI Model			
	Data unit	**Layer**	**Function**
Host layers	Data	7. Application	Network process to application
		6. Presentation	Data representation, encryption and decryption, convert machine dependent data to machine independent data
		5. Session	Interhost communication, managing sessions between applications
	Segments	4. Transport	End-to-end connections, reliability and flow control
Media layers	Packet/Datagram	3. Network	Path determination and logical addressing
	Frame	2. Data link	Physical addressing
	Bit	1. Physical	Media, signal and binary transmission

TCP/IP Basics: ARP

Ethernet Address Resolution Protocol
– or –
Converting Network Protocol Addresses to 48-bit Ethernet Address for Transmission on Ethernet Hardware

```
$ arp -a
falcon.srcit.stevens-tech.edu (155.246.89.89) at 00:07:e9:09:ca:10 [ether] on eth0
grohl.srcit.stevens-tech.edu (155.246.89.9) at 00:16:3e:cf:6b:5b [ether] on eth0
hoth.srcit.stevens-tech.edu (155.246.89.10) at 00:1e:68:8e:79:d8 [ether] on eth0
cinema.srcit.stevens-tech.edu (155.246.89.67) at 00:25:90:1e:05:51 [ether] on eth0
vlan16.cc.stevens-tech.edu (155.246.89.1) at 00:00:5e:00:01:02 [ether] on eth0
vader.srcit.stevens-tech.edu (155.246.89.5) at 00:23:8b:a9:dd:60 [ether] on eth0
nirvana.phy.stevens-tech.edu (155.246.89.33) at 00:1e:68:0f:99:a2 [ether] on eth0
```

TCP/IP Basics: ARP



TCP/IP Basics: ARP

Ethernet Address Resolution Protocol
– or –
Converting Network Protocol Addresses to 48-bit Ethernet Address for Transmission on Ethernet Hardware

```
ARP, Request who-has 10.114.62.1 tell 10.114.63.209, length 28
ARP, Reply 10.114.62.1 is-at fe:ff:ff:ff:ff:ff, length 28
ARP, Request who-has 10.114.63.209 (ff:ff:ff:ff:ff:ff) tell 0.0.0.0, length 28
ARP, Reply 10.114.63.209 is-at 12:31:3d:04:30:23, length 28
ARP, Request who-has 10.114.63.209 (ff:ff:ff:ff:ff:ff) tell 0.0.0.0, length 28
ARP, Reply 10.114.63.209 is-at 12:31:3d:04:30:23, length 28
ARP, Request who-has 10.114.63.209 (ff:ff:ff:ff:ff:ff) tell 0.0.0.0, length 28
ARP, Reply 10.114.63.209 is-at 12:31:3d:04:30:23, length 28
```

TCP/IP Basics: ND

Neighbor Discovery Protocol

```
$ ndp -n -a
Neighbor                                Linklayer Address  Netif Expire      S Flags
2001:470:30:84:e276:63ff:fe72:3900  e0:76:63:72:39:00  xennet0 permanent R
fe80::21b:21ff:fe45:bf54%xennet0    00:1b:21:45:bf:54  xennet0 21m52s    S R
fe80::21b:21ff:fe7a:7269%xennet0    00:1b:21:7a:72:69  xennet0 23h59m59s S R
fe80::e276:63ff:fe72:3900%xennet0   e0:76:63:72:39:00  xennet0 permanent R
fe80::1%lo0                          (incomplete)      lo0     permanent R
$
```

TCP/IP Basics: ND

Neighbor Discovery Protocol

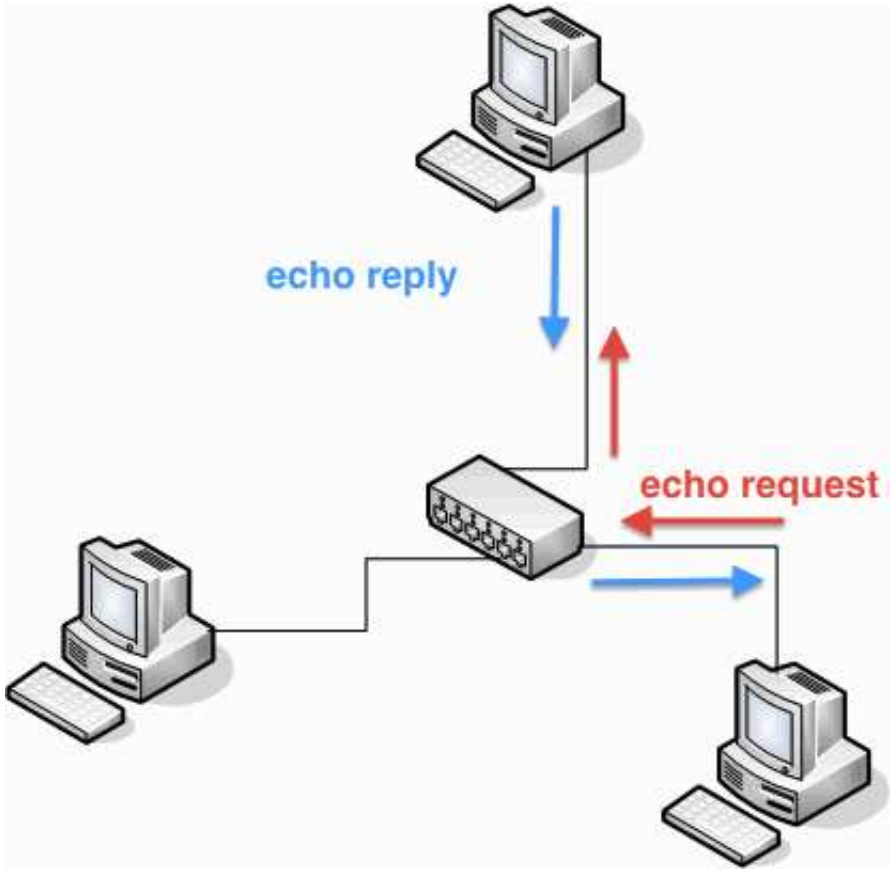
```
IP6 fe80::21b:21ff:fe7a:7269 > ff02::1:ff62:3400: ICMP6,
        neighbor solicitation, who has 2001:470:30:84:e276:63ff:fe62:3400, length 32
IP6 2001:470:30:84:e276:63ff:fe72:3900 > ff02::1:ff7a:7269: ICMP6,
        neighbor solicitation, who has fe80::21b:21ff:fe7a:7269, length 32
IP6 fe80::21b:21ff:fe7a:7269 > 2001:470:30:84:e276:63ff:fe72:3900:
        ICMP6, neighbor advertisement, tgt is fe80::21b:21ff:fe7a:7269, length 32
```

TCP/IP Basics: ICMP

Internet Control Message Protocol

```
$ ping -c 3 www.yahoo.com
PING any-fp.wa1.b.yahoo.com (67.195.160.76): 56 data bytes
64 bytes from 67.195.160.76: icmp_seq=0 ttl=53 time=30.888 ms
64 bytes from 67.195.160.76: icmp_seq=1 ttl=53 time=23.193 ms
64 bytes from 67.195.160.76: icmp_seq=2 ttl=53 time=25.433 ms

----any-fp.wa1.b.yahoo.com PING Statistics----
3 packets transmitted, 3 packets received, 0.0% packet loss
round-trip min/avg/max/stddev = 23.193/26.505/30.888/3.958 ms
$
```

TCP/IP Basics: ICMP: Ping



TCP/IP Basics: ICMP

Internet Control Message Protocol

```
$ tcpdump -r tcpdump.out -n icmp
IP 10.234.84.220 > 207.237.69.79: ICMP echo request
IP 207.237.69.79 > 10.234.84.220: ICMP echo reply
IP 10.234.84.220 > 207.237.69.79: ICMP echo request
IP 207.237.69.79 > 10.234.84.220: ICMP echo reply
IP 10.234.84.220 > 207.237.69.79: ICMP echo request
IP 207.237.69.79 > 10.234.84.220: ICMP echo reply
```

TCP/IP Basics: ICMP6

Internet Control Message Protocol for IPv6

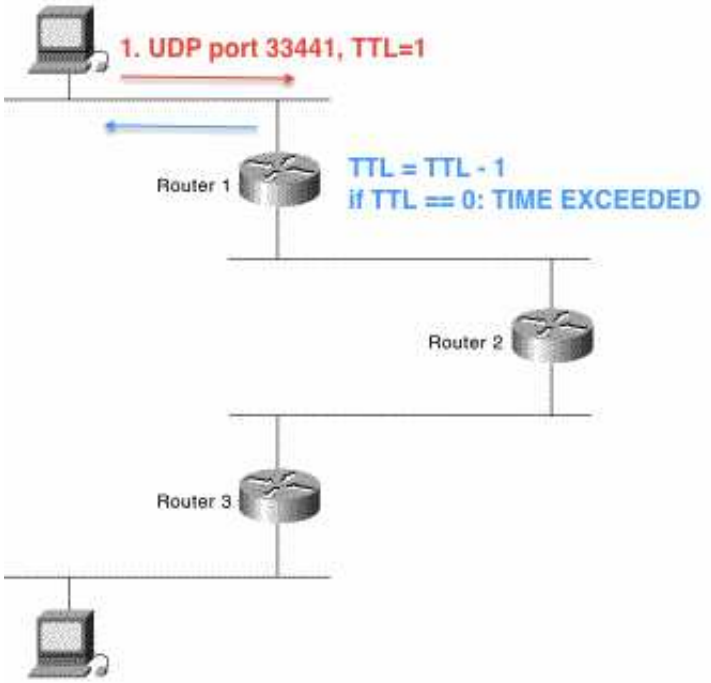
```
$ ping6 -c 3 www.netbsd.org
PING6(56=40+8+8 bytes) 2001:470:30:84:204:d7b0:0:1 -->
                       2001:4f8:3:7:2e0:81ff:fe52:9a6b
16 bytes from 2001:4f8:3:7:2e0:81ff:fe52:9a6b, icmp_seq=0 hlim=57 time=74.316 ms
16 bytes from 2001:4f8:3:7:2e0:81ff:fe52:9a6b, icmp_seq=1 hlim=57 time=71.260 ms
16 bytes from 2001:4f8:3:7:2e0:81ff:fe52:9a6b, icmp_seq=2 hlim=57 time=71.321 ms

--- www.netbsd.org ping6 statistics ---
3 packets transmitted, 3 packets received, 0.0% packet loss
round-trip min/avg/max/std-dev = 71.260/72.299/74.316/1.747 ms
```

TCP/IP Basics: ICMP6

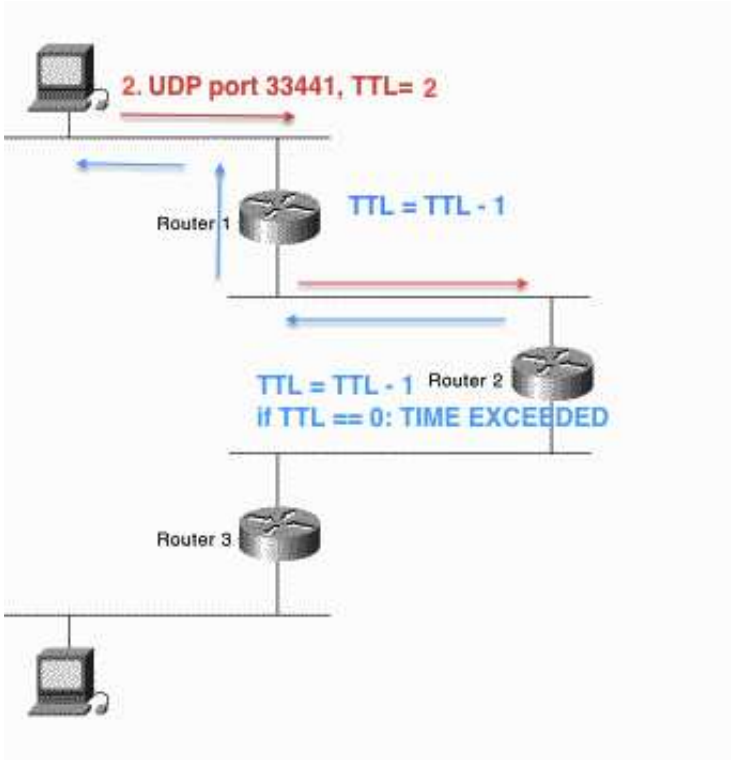
Internet Control Message Protocol for IPv6

```
IP6 2001:470:30:84:204:d7b0:0:1 >
   2001:4f8:3:7:2e0:81ff:fe52:9a6b: ICMP6, echo reque st, seq 0, length 16
IP6 2001:4f8:3:7:2e0:81ff:fe52:9a6b >
   2001:470:30:84:204:d7b0:0:1: ICMP6, echo reply , seq 0, length 16
IP6 2001:470:30:84:204:d7b0:0:1 >
   2001:4f8:3:7:2e0:81ff:fe52:9a6b: ICMP6, echo request, seq 1, length 16
IP6 2001:4f8:3:7:2e0:81ff:fe52:9a6b >
   2001:470:30:84:204:d7b0:0:1: ICMP6, echo reply , seq 1, length 16
IP6 2001:470:30:84:204:d7b0:0:1 >
   2001:4f8:3:7:2e0:81ff:fe52:9a6b: ICMP6, echo reque st, seq 2, length 16
IP6 2001:4f8:3:7:2e0:81ff:fe52:9a6b >
   2001:470:30:84:204:d7b0:0:1: ICMP6, echo reply , seq 2, length 16
```

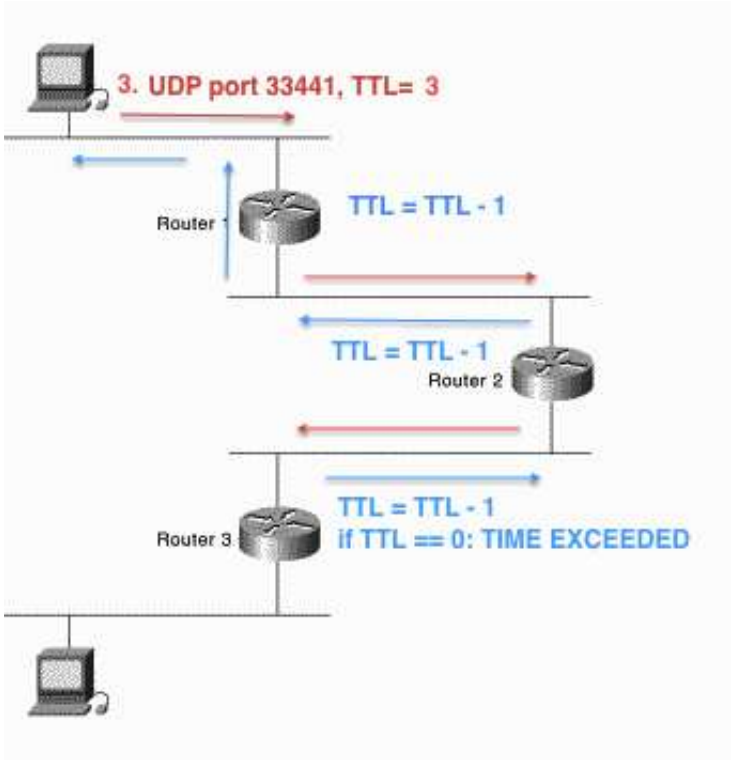
TCP/IP Basics: ICMP: Traceroute



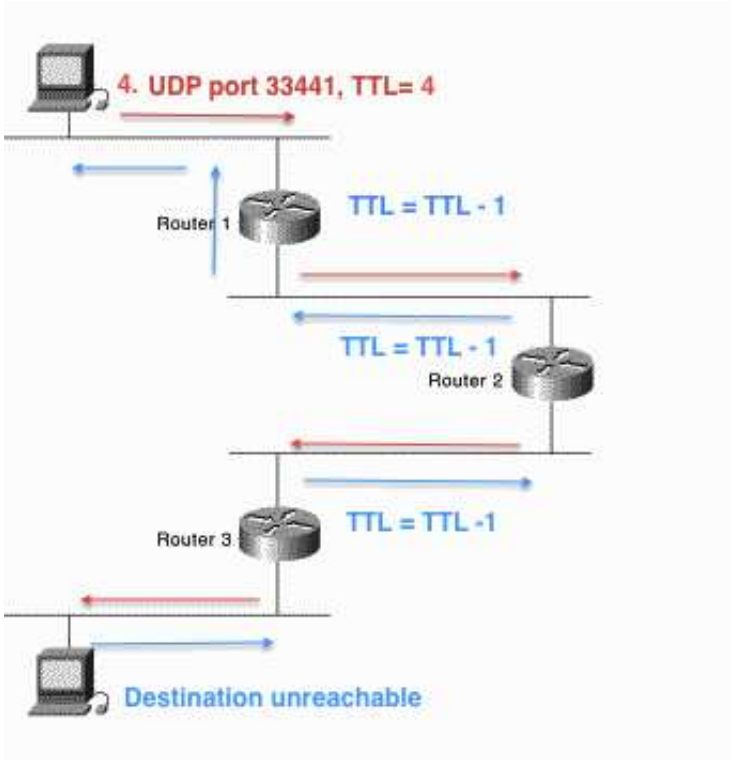
TCP/IP Basics: ICMP: Traceroute



TCP/IP Basics: ICMP: Traceroute



TCP/IP Basics: ICMP: Traceroute



TCP/IP Basics: ICMP

Internet Control Message Protocol

```
$ traceroute www.netbsd.org
traceroute to www.netbsd.org (204.152.190.12), 64 hops max, 40 byte packets
 1  eth2-3a.core1.nav.nyc.access.net (166.84.0.1)  0.256 ms  0.165 ms 0.181 ms
 2  l3v1.nyc.access.net (166.84.66.14)  1.570 ms  1.556 ms  1.437 ms
 3  gige-g3-3.core1.nyc4.he.net (209.51.171.25)  4.963 ms  2.422 ms  1.457 ms
 4  10gigabitethernet2-3.core1.ash1.he.net (72.52.92.86)  8.423 ms  8.769 ms  7.683 m
 5  10gigabitethernet1-2.core1.atl1.he.net (184.105.213.110)  21.898 ms 19.647 ms  19
 6  isc.gige-g2-1.core1.atl1.he.net (216.66.0.50)  77.465 ms  77.921 ms 80.519 ms
 7  iana.r1.atl1.isc.org (199.6.12.1)  77.302 ms  78.230 ms  81.782 ms
 8  int-0-5-0-1.r1.pao1.isc.org (149.20.65.37)  81.860 ms  83.780 ms 84.160 ms
 9  int-0-0-1-0.r1.sql1.isc.org (149.20.65.10)  81.543 ms  80.193 ms 84.434 ms
10  www.netbsd.org (204.152.190.12)  81.986 ms  81.008 ms  82.604 ms
$
```

TCP/IP Basics: ICMP

Internet Control Message Protocol

```
IP (tos 0x0, ttl 1, id 44866, offset 0, flags [none], proto UDP (17), length 40)
    166.84.7.99.44865 > 149.20.53.86.33435: [udp sum ok] UDP, length 12
IP (tos 0xc0, ttl 64, id 48796, offset 0, flags [none], proto ICMP (1), length 68)
    166.84.0.1 > 166.84.7.99: ICMP time exceeded in-transit, length 48
IP (tos 0x0, ttl 2, id 44869, offset 0, flags [none], proto UDP (17), length 40)
    166.84.7.99.44865 > 149.20.53.86.33438: [udp sum ok] UDP, length 12
IP (tos 0x0, ttl 3, id 44872, offset 0, flags [none], proto UDP (17), length 40)
    166.84.7.99.44865 > 149.20.53.86.33441: [udp sum ok] UDP, length 12
IP (tos 0x0, ttl 4, id 44875, offset 0, flags [none], proto UDP (17), length 40)
    166.84.7.99.44865 > 149.20.53.86.33444: [udp sum ok] UDP, length 12
IP (tos 0x0, ttl 252, id 6760, offset 0, flags [none], proto ICMP (1), length 56)
    154.24.25.109 > 166.84.7.99: ICMP time exceeded in-transit, length 36
...
IP (tos 0x0, ttl 248, id 0, offset 0, flags [none], proto ICMP (1), length 56)
    149.20.53.86 > 166.84.7.99: ICMP 149.20.53.86 udp port 33482 unreachable, length
```

TCP/IP Basics: ICMP6

Internet Control Message Protocol for IPv6

```
$ traceroute6 www.netbsd.org
traceroute6 to www.netbsd.org (2001:4f8:3:7:2e0:81ff:fe52:9a6b) from
    2001:470:30:84:204:d7b0:0:1, 64 hops max, 12 byte packets
 1  router.vc.panix.com  0.271 ms  0.282 ms  0.155 ms
 2  2001:470:30::a654:420e  5.459 ms  1.251 ms  1.073 ms
 3  gige-g3-3.core1.nyc4.he.net  1.288 ms  2.001 ms  10.176 ms
 4  10gigabitethernet8-3.core1.chi1.he.net  26.603 ms  20.532 ms  25.029 ms
 5  2001:470:1:34::2  72.033 ms  72.377 ms  72.686 ms
 6  iana.r1.ord1.isc.org  76.288 ms  72.773 ms  71.481 ms
 7  int-0-0-1-8.r1.pao1.isc.org  73.027 ms  76.489 ms  77.507 ms
 8  int-0-0-1-0.r2.sql1.isc.org  73.555 ms  75.367 ms  74.769 ms
 9  www.NetBSD.org  72.036 ms  72.522 ms  71.39 ms
$
```

TCP/IP Basics: ICMP6

Internet Control Message Protocol for IPv6

```
IP6 2001:470:30:84:204:d7b0:0:1.51749 >
        2001:4f8:3:7:2e0:81ff:fe52:9a6b.33435: UDP, length 12
IP6 2001:470:30:84::3 > 2001:470:30:84:204:d7b0:0:1:
        ICMP6, time exceeded in-transit [|icmp6]
IP6 2001:470:30:84:204:d7b0:0:1.51749 >
        2001:4f8:3:7:2e0:81ff:fe52:9a6b.33436: UDP, length 12
[...]
IP6 2001:470:30:84:204:d7b0:0:1.51749 >
        2001:4f8:3:7:2e0:81ff:fe52:9a6b.33461: UDP, length 12
IP6 2001:4f8:3:7:2e0:81ff:fe52:9a6b >
        2001:470:30:84:204:d7b0:0:1: ICMP6, destination unreachable[|icmp6]
```

TCP/IP Basics: TCP

Transmission Control Protocol

```
$ telnet www.google.com 80
Trying 173.194.73.99...
Connected to www.google.com.
Escape character is '^]'.
GET / HTTP/1.0
```

TCP/IP Basics: TCP

Transmission Control Protocol

```
IP 166.84.7.99.58356 > 67.195.160.76.80: S
      2267539609:2267539609(0) win 32768
      <mss 1460,nop,wscale 3,sackOK,nop,nop,nop,nop,timestamp 10>
IP 67.195.160.76.80 > 166.84.7.99.58356: S
      3229501874:3229501874(0) ack 2267539610 win 5792
      <mss 1440,sackOK,timestamp 1241180702 1,nop,wscale 8>
IP 166.84.7.99.58356 > 67.195.160.76.80: .
      ack 1 win 4197 <nop,nop,timestamp 1 1241180702>
IP 166.84.7.99.58356 > 67.195.160.76.80: P
      1:17(16) ack 1 win 4197 <nop,nop,timestamp 9 1241180702>
IP 67.195.160.76.80 > 166.84.7.99.58356: .
      ack 17 win 23 <nop,nop,timestamp 12411848 53 9>
```

TCP/IP Basics: TCP

Transmission Control Protocol over IPv6

```
$ telnet www.netbsd.org 80
Trying 2001:4f8:3:7:2e0:81ff:fe52:9a6b...
Connected to www.netbsd.org.
Escape character is '^]'.
GET / HTTP/1.0
```

TCP/IP Basics: TCP

Transmission Control Protocol IPv6

```
IP6 2001:470:30:84:204:d7b0:0:1.58334 >
      2001:4f8:3:7:2e0:81ff:fe52:9a6b.80: S 3232473102:3232473102(0)
      win 32768 <mss 1440,nop,wscale3,sackOK,nop,nop,nop,nop,timestamp 1[|tcp]>
IP6 2001:4f8:3:7:2e0:81ff:fe52:9a6b.80 >
      2001:470:30:84:204:d7b0:0:1.58334: S 4139493123:4139493123(0)
      ack 3232473103 win 32768
IP6 2001:470:30:84:204:d7b0:0:1.58334 >
      2001:4f8:3:7:2e0:81ff:fe52:9a6b.80: . ack 1 win 4140
IP6 2001:470:30:84:204:d7b0:0:1.58334 >
      2001:4f8:3:7:2e0:81ff:fe52:9a6b.80: P 1:17(16) ack 1 win 4140
IP6 2001:4f8:3:7:2e0:81ff:fe52:9a6b.80 >
      2001:470:30:84:204:d7b0:0:1.58334: . ack 17 win 33120
```

TCP/IP Basics: UDP

User Datagram Protocol

```
$ nslookup www.yahoo.com
Server: 155.246.1.20
Address: 155.246.1.20#53

Non-authoritative answer:
www.yahoo.com        canonical name = fp3.wg1.b.yahoo.com.
fp3.wg1.b.yahoo.com       canonical name = any-fp3-lfb.wa1.b.yahoo.com.
any-fp3-lfb.wa1.b.yahoo.com        canonical name = any-fp3-real.wa1.b.yahoo.com.
Name: any-fp3-real.wa1.b.yahoo.com
Address: 98.139.183.24

$
```

TCP/IP Basics: UDP

User Datagram Protocol

```
IP (tos 0x0, ttl 64, id 0, offset 0, flags [none],
    proto UDP (17), length 59) panix.netmeister.org.49164 >
        cache2.ns.access.net.domain: 28557+ A? www.yahoo.com. (31)

IP (tos 0x0, ttl 63, id 1862, offset 0, flags [none],
    proto UDP (17), length 207) cache2.ns.access.net.domain >
        panix.netmeister.org.49164: 28557 4/2/2
            www.yahoo.com. CNAME fp3.wg1.b.yahoo.com.[|domain]
```

TCP/IP Basics: UDP

User Datagram Protocol over IPv6

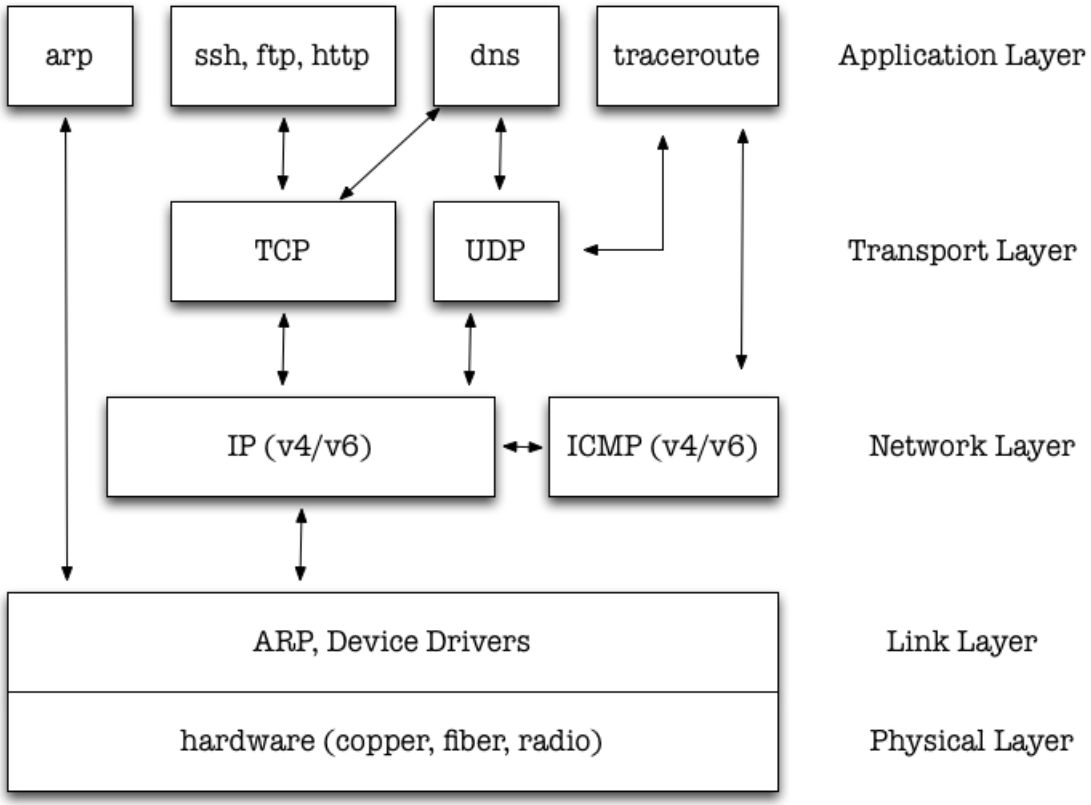
```
$ dig -6 @2001:470:20::2 www.yahoo.com

;; ANSWER SECTION:
www.yahoo.com.          300     IN      CNAME   fp3.wg1.b.yahoo.com.
fp3.wg1.b.yahoo.com.    60      IN      CNAME   any-fp3-lfb.wa1.b.yahoo.com.
any-fp3-lfb.wa1.b.yahoo.com. 300 IN     CNAME   any-fp3-real.wa1.b.yahoo.com.
any-fp3-real.wa1.b.yahoo.com. 60 IN     A       98.139.183.24

;; Query time: 51 msec
;; SERVER: 2001:470:20::2#53(2001:470:20::2)
;; WHEN: Sat Mar  3 22:49:44 2012
;; MSG SIZE  rcvd: 128
```

TCP/IP Basics: UDP

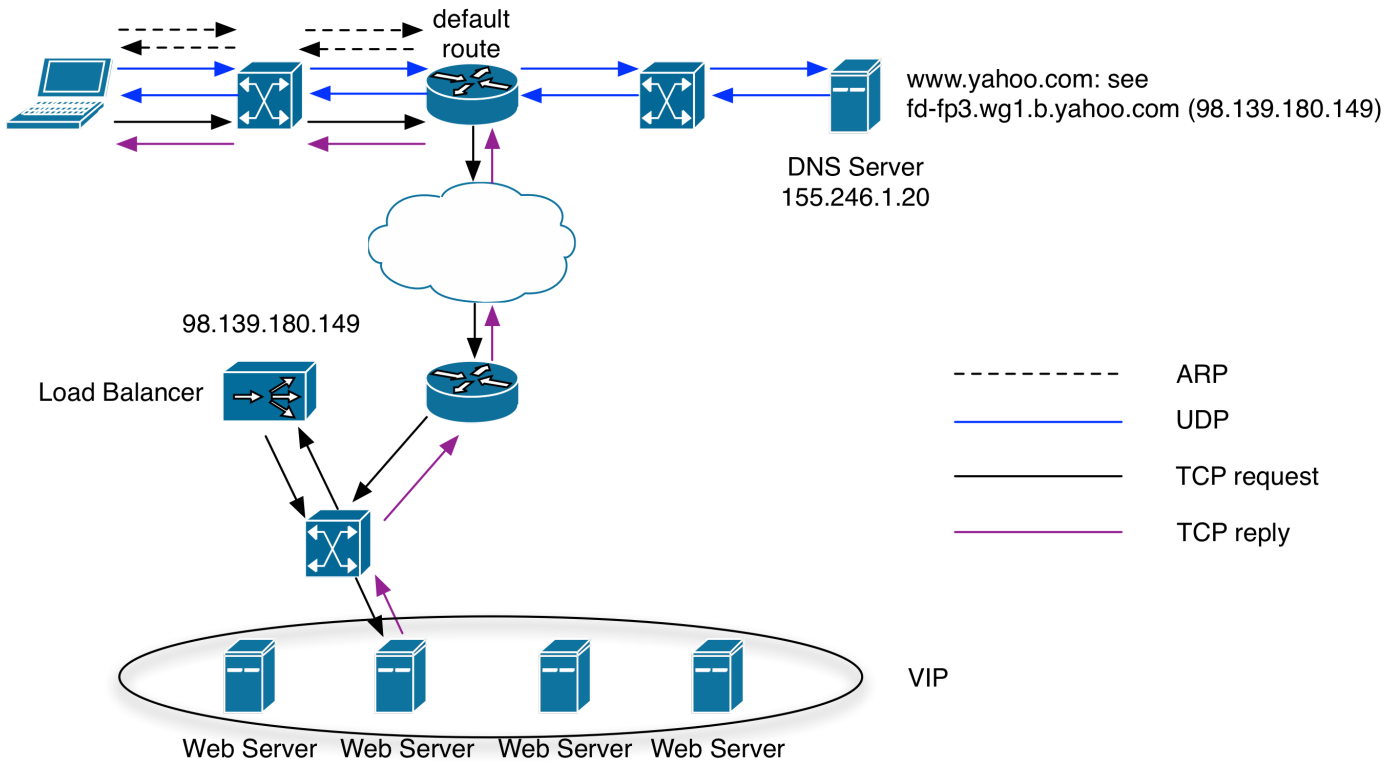
User Datagram Protocol over IPv6

```
IP6 (hlim 64, next-header: UDP (17), length: 39)
       2001:470:30:84:204:d7b0:0:1.65037 > 2001:470:20::2.53:
       [udp sum ok] 18545+ A? www.yahoo.com. (31)

IP6 (hlim 61, next-header: UDP (17), length: 119)
       2001:470:20::2.53 > 2001:470:30:84:204:d7b0:0:1.65037:
       18545 4/0/0 www.yahoo.com.[|domain]
```

TCP/IP Basics: Putting it all together



Networking


default
route
www.yahoo.com: see
fd-fp3.wg1.b.yahoo.com (98.139.180.149)
DNS Server
155.246.1.20
98.139.180.149
Load Balancer
ARP
UDP
TCP request
TCP reply
VIP
Web Server
Web Server
Web Server
Web Server

Homework

`https://www.cs.stevens.edu/~jschauma/615/s18-hw4.html`

Reading

- `tcpdump(8)`
- `ktrace(1)` / `strace(1)`
- `tcp(4)`/`ip(4)`
- `netstat(1)`
- `nslookup(1)`