last time (1)

assignment Q&A

multi-level page table lookup

unreliable networks

"best effort" model of the internet

- limited message size
- sometimes messages lost
- sometimes messages delayed/reordered
- sometimes messages corrupted

last time (2)

sequence numbers

acknowledgments

- someone needs to resend after timeout
- can get lost, that's okay

checksums

some themes in anonymous feedback

pagetable difficulty

lab difficulty

quizzes: how many/etc.

Quiz Q3

1 first-level page table with

- a valid entry pointing to a second-level page table with 512 valid entries
- a valid entry pointing to a second-level page table with (1000-512) valid entries and a few invalid entries and 510 invalid entries

three 4096-byte page tables

Quiz Q4

0x120008 = PTBR + VPN part 1 × PTE size =
0x1200000 + VPN part 1 × 8 → VPN part 1 = 1

0x123040 =
PPN from 1st level × page size + VPN part 2 × PTE size →
VPN part 2 = 8

0x6010 =
PPN from 2nd level × page size + page offset → page offset = 0x10

Quiz Q5

"It then runs a function, whose machine code is loaded at addresses 0x2040-0x2072, which writes 3 8-byte values to the stack at addresses 0xFFF8, 0xFFF0, and 0xFFE8."

page at 0x2000–0x2FFF

- code loaded on first instruction's page fault
- can't tell processor about only part of page being loaded

page at 0xF000–0xFFFF

- whole page of stack allocated on first access

HW difficulty

"...I feel like several components of the assignment we have not fully learned and some we just learned about in lecture today. Additionally, I think while a checkpoint is a reasonable idea, we could all benefit from the extra time and just have the first two parts be due next week. I have been in office hours the last two days and it seems like barely any students know what is going on."

"While the quiz made sense and was related to the lectures and readings, this homework assignment has a lot of things that you need to rely on TA's or word of mouth for. For example, how would we know that we need to memset after posix_memalign if we don't even know how to look that up..."

"I feel like the content of the lectures is too far removed from what we are asked to do in the homeworks...."

mistakes I made with homework (1)

overestimated C familiarity from CSO1

- a lot of problems from C pointer issues
- fails in ways that are not intuitive, especially if you aren't checking every step
- why I assumed understanding manpage for posix_memalign was not big deal
- future: warmup assignment should probably review C pointer stuff somehow
- b/c of this, put halfway point of assignment at wrong place

in future semesters, need to plan more lecture time for virtual memory

mistakes I made with homework (2)

some things in writeup are/were too easy to miss

- page table entry format
- physical page number v physical address
- what things need to be allocated

need more structure re: testing

- students just using code in assignment + autograder was not the intention
- seems like (based on submissions) many students writing a lot of code before testing it, rather than testing in small pieces

pagetable grading

submission 1 (25% of normal homework)

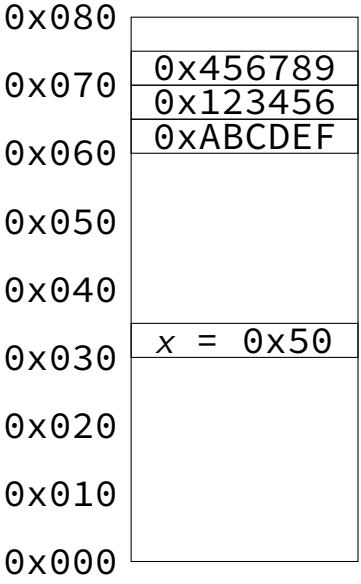
- 32% LEVELS = 1 reasonable attempt
- 64% reasonable attempt on two other items
- 3% code style

submission 2 (25% of normal homework)

- 50% everything present
- 40% LEVELS = 1 functionality
- 10% LEVELS > 1 functionality

submission 3 (200% of normal homework)

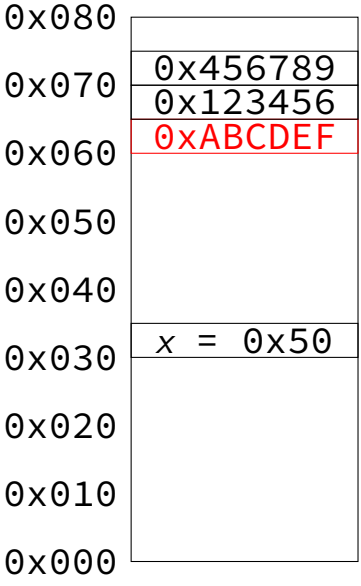
some pointer stuff




```
size_t x = 0x50;
```

~~`**x`~~ (compile-time error)

some pointer stuff



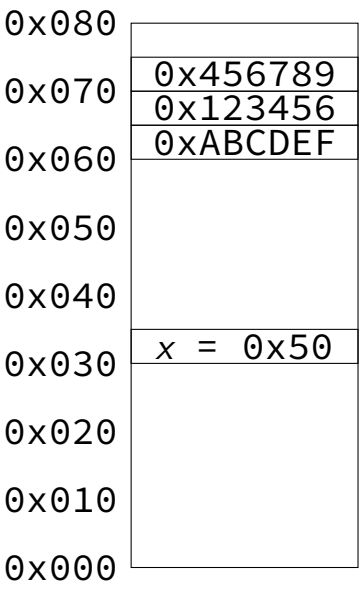

```
size_t x = 0x50;
```

~~`*x`~~ (compile-time error)

```
size_t *ptr;
ptr = (size_t *) x;
*ptr == 0xABCDEF
```

```
*((size_t *) x) == 0xABCDEF
```

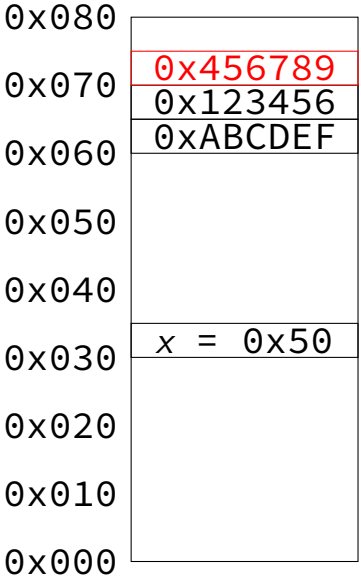
some pointer stuff




```
size_t x = 0x50;
```

~~`x[2]`~~ (compile-time error)

some pointer stuff



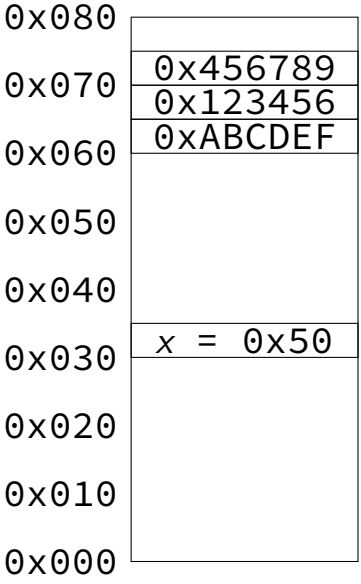

```
size_t x = 0x50;
```

~~`x[2]`~~ (compile-time error)

```
size_t addr = x + 16;
size_t *ptr;
ptr = (size_t *) addr;
*ptr == 0x456789
```

```
size_t *ptr;
ptr = (size_t *) x;
ptr[2] == 0x456789
```

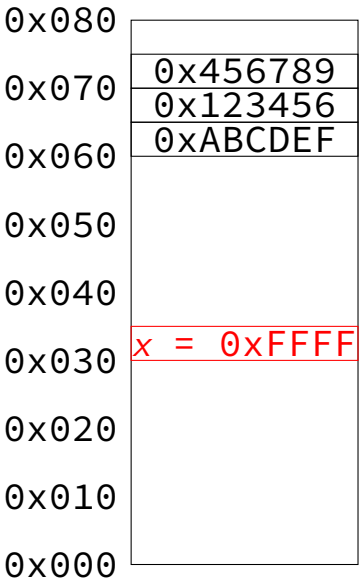
some pointer stuff




```
size_t x = 0x50;

void change_arg(size_t *arg) {
    *arg = 0xFFFF;
}
```

some pointer stuff

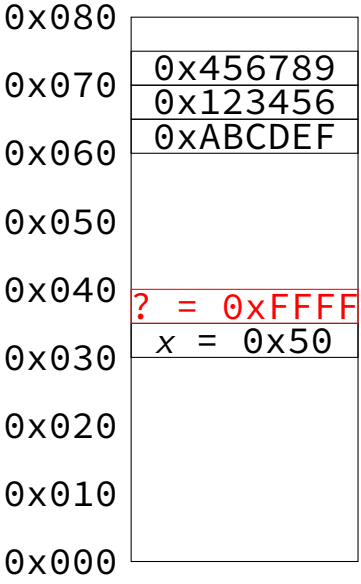



```
size_t x = 0x50;

void change_arg(size_t *arg) {
    *arg = 0xFFFF;
}

change_arg(&x);
change_arg((size_t*) 0x30);
```

some pointer stuff

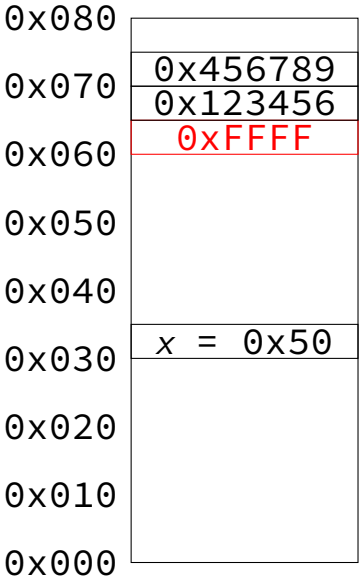



```
size_t x = 0x50;

void change_arg(size_t *arg) {
    *arg = 0xFFFF;
}

change_arg(&x + 1);
change_arg((size_t*) 0x38);
```

some pointer stuff

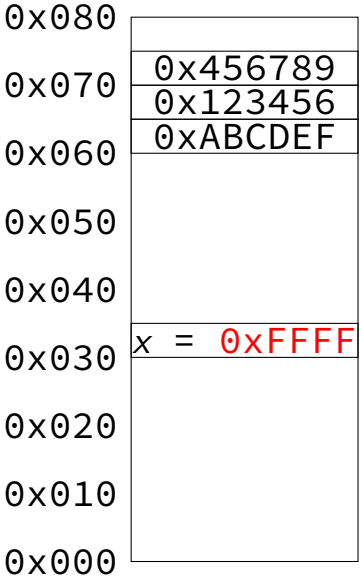



```
size_t x = 0x50;

void change_arg(size_t *arg) {
    *arg = 0xFFFF;
}

change_arg((size_t *) x);
change_arg((size_t *) 0x50);
```

some pointer stuff

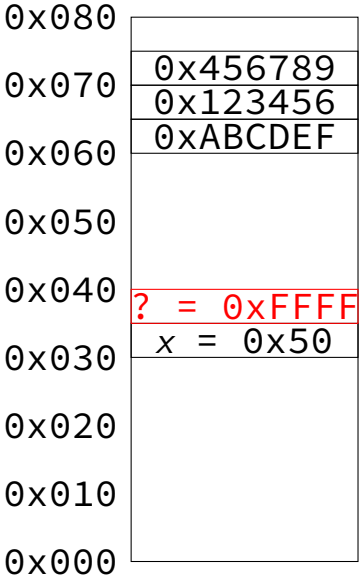



```
void *x = (void *) 0x50

void change_arg(void **arg) {
     *arg = (void *) 0xFFFF;
}

change_arg((void **) &x);
change_arg((void **) 0x30);
```

some pointer stuff

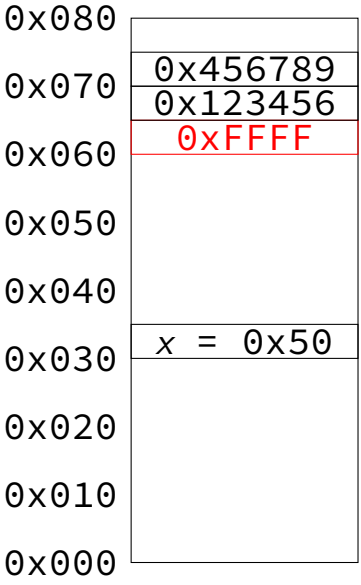



```
void *x = (void *) 0x50

void change_arg(void **arg) {
    *arg = (void *) 0xFFFF;
}

change_arg(&x + 1);
change_arg((void **) 0x38);
```

some pointer stuff




```
void *x = (void *) 0x50

void change_arg(void **arg) {
     *arg = (void *) 0xFFFF;
}

change_arg((void **) x);
change_arg((void **) 0x50);
```

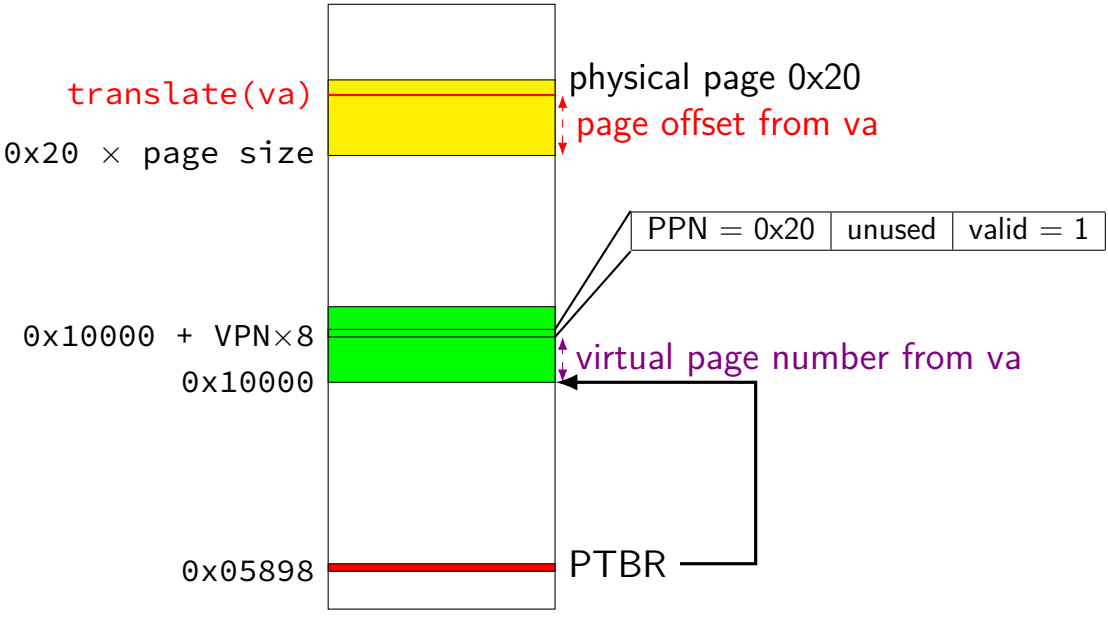
address/page table entry format

(with POBITS=12, LEVELS=1)

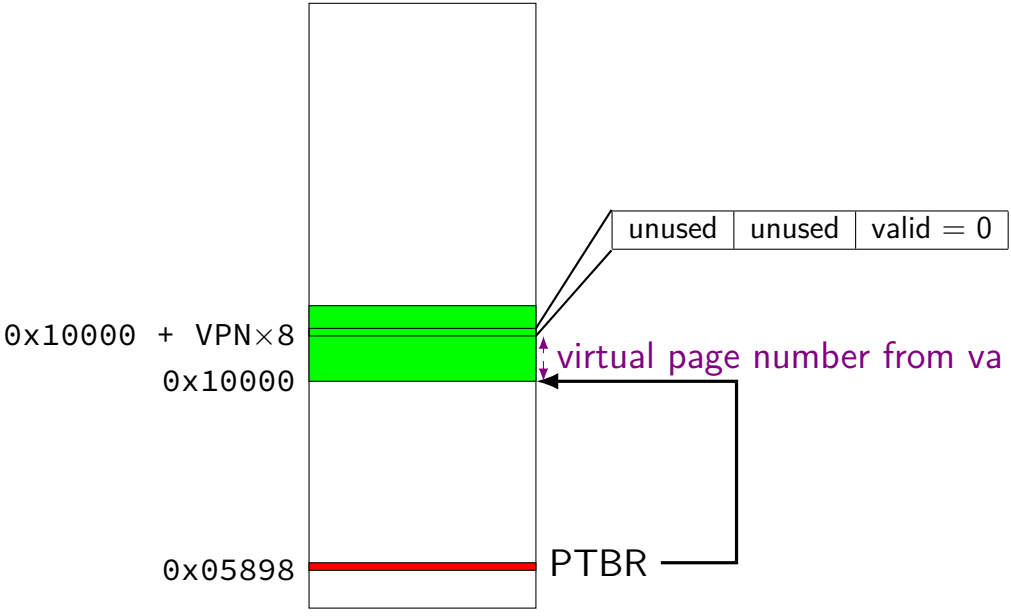
	bits 63–21	bits 20–12	bits 11–1	bit 0
page table entry	physical page number		unused	valid bit
virtual address	unused	virtual page number	page offset	
physical address	physical page number		page offset	

in assignment: value from posix_memalign = physical address

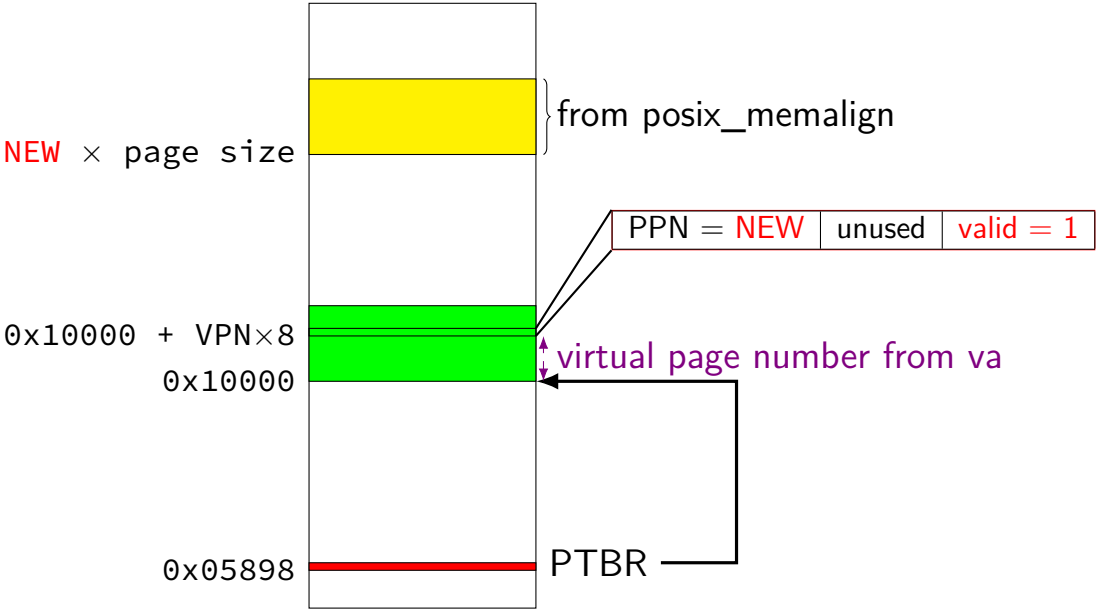
pa = translate(va)



page_allocate(va)



page_allocate(va)



next week's lab

code review your submission 2 with other students

must be in person!

can't attend lab? talk to me!

use the feedback to improve your submission 3

lab difficulty

"I wish we could at least get more explanation for what is going on in the networking lab. I understood Tuesday's lecture enough to at least get the concept, but the lab write-up itself was pretty opaque and it felt like we were being thrown into the deep end to actually implement the networking. I spent the whole 75 minutes in lab just going over the reading and trying to figure out what exactly we were supposed to do..."

lab difficulty

was surprised by confusion re: recvd() function + setTimeout()

- oops! should have realized you haven't seen these kinds of interfaces before

probably need an introduction to this type of interface in lecture in the future

callback-based programming (1)

```
/* library code you don't write */
void mainLoop() {
    while (true) {
        Event event = getNextEvent();
        if (event.type == RECIEVED) {
            recvd(...);
        } else if (event.type == TIMEOUT) {
            (event.timeout_function)(...);
        }
        ...
    }
}
```

callback-based programming (2)

```
/* your code, called by library */
void recvd(...) {
    ...
    setTimeout(..., timerCallback, ...);
}

void timerCalback(...) {
    ...
}
```

callback-based programming

writing scripts in a webpage

many graphical user interface libraries

sometimes servers that handle lots of connections

protocol

GET0 — start

other end acknowledges by giving data
if they don't acknowledge, you need to send again

ACKn

request message n + 1 by acknowledging message n
not quite same purpose as acknowledgments in lecture examples
(in lab, the respoonse is your 'acknowledgment' of your request;
you retry if you don't get it)

feedback re: quizzes

"I would appreciate if the quizzes were a little longer. We learn a lot in this class and I don't think 5 questions (sometimes with no partial credit) is the best representation of our skills."

"would you ever consider dropping the lowest quiz grade?"

"I've found that the quizzes are incredibly difficult...I feel that the scope of the quizzes is way beyond the lecture material and readings...Maybe lecture material and/or readings could more closely align with the quiz questions, so that we are better prepared."

layers

application	HTTP, SSH, SMTP, ...	application-defined meanings
transport	TCP, UDP, ...	reach correct program, reliablity/streams
network	IPv4, IPv6, ...	reach correct machine (across networks)
link	Ethernet, Wi-Fi, ...	coordinate shared wire/radio
physical	...	encode bits for wire/radio

layers

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more than four layers?

sometimes more layers above 'application'

e.g. HTTPS:
HTTP (app layer) on TLS (another app layer) on TCP (network) on ...

e.g. DNS over HTTPS:
DNS (app layer) on HTTP on on TLS on TCP on ...

e.g. SFTP:
SFTP (app layer??) on SSH (another app layer) on TCP on ...

e.g. HTTP over OpenVPN:
HTTP on TCP on IP on OpenVPN on UDP on different IP on ...

names and addresses

name	address
logical identifier	location/how to locate
variable `counter`	memory address `0x7FFF9430`
DNS name `www.virginia.edu`	IPv4 address `128.143.22.36`
DNS name `mail.google.com`	IPv4 address `216.58.217.69`
DNS name `mail.google.com`	IPv6 address `2607:f8b0:4004:80b::2005`
DNS name `reiss-t3620.cs.virginia.edu`	IPv4 address `128.143.67.91`
DNS name `reiss-t3620.cs.virginia.edu`	MAC address `18:66:da:2e:7f:da`
service name `https`	port number 443
service name `ssh`	port number 22

layers

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physical	...	encode bits for wire/radio

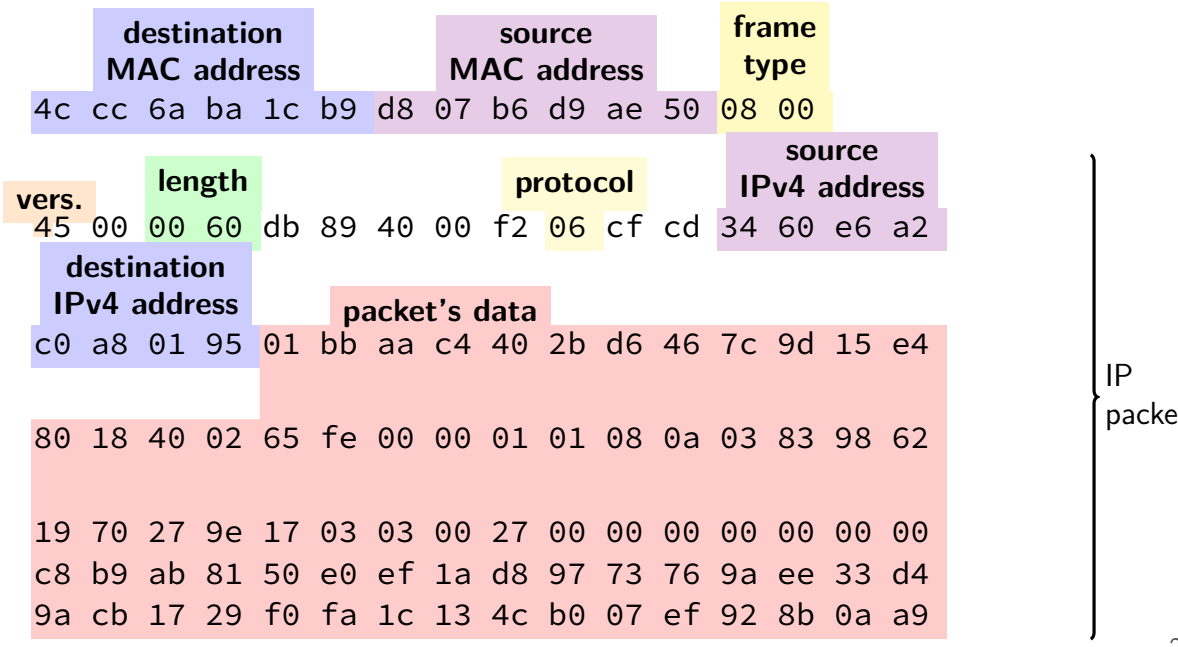
an Ethernet frame

destination MAC address	source MAC address	frame type
4c cc 6a ba 1c b9	d8 07 b6 d9 ae 50	08 00

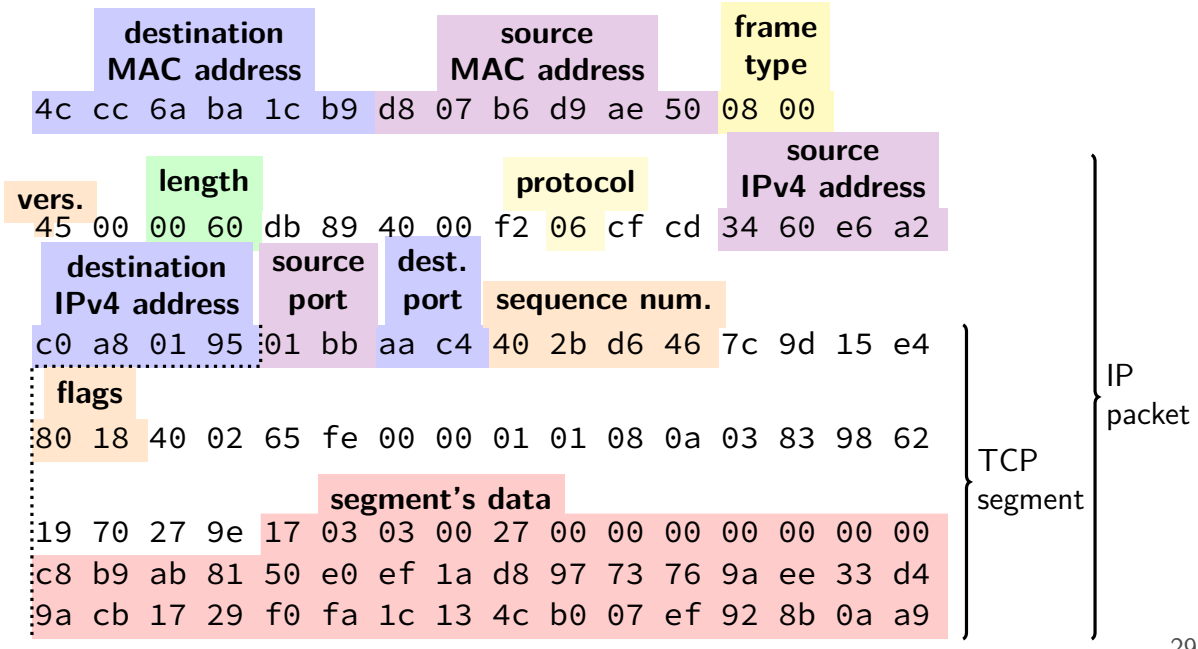
frame's data

```
45 00 00 60 db 89 40 00 f2 06 cf cd 34 60 e6 a2

c0 a8 01 95 01 bb aa c4 40 2b d6 46 7c 9d 15 e4

80 18 40 02 65 fe 00 00 01 01 08 0a 03 83 98 62

19 70 27 9e 17 03 03 00 27 00 00 00 00 00 00 00
c8 b9 ab 81 50 e0 ef 1a d8 97 73 76 9a ee 33 d4
9a cb 17 29 f0 fa 1c 13 4c b0 07 ef 92 8b 0a a9
```

an Ethernet frame



an Ethernet frame



the link layer

Ethernet, Wi-Fi, Bluetooth, DOCSIS (cable modems), ...

allows send/recv messages to machines on "same" network segment

- typically: wireless range+channel or connected to a single switch/router
- could be larger (if *bridging* multiple network segments)
- could be smaller (switch/router uses "virtual LANs")

typically: source+destination specified with MAC addresses

- MAC = media access control
- usually manufacturer assigned / hard-coded into device
- unique address per port/wifi transmitter/etc.

can specify destination of "anyone" (called *broadcast*)

messages usually called "frames"

link layer quality of service

if frame gets...

event	on Ethernet	on WiFi
collides with another	detected + may resend	resend
not received	lose silently	resent
header corrupted	usually discard silently	usually resend
data corrupted	usually discard silently	usually resend
too long	not allowed to send	not allowed to send
reordered (v. other messages)	received out of order	received out of order
destination unknown	lose silently	usually resend??
too much being sent	discard excess?	discard excess?

link layer reliablity?

Ethernet + Wifi have checksums

Q1: Why doesn't this give us uncorrupted messages?
Why do we still have checksums at the higher layers?

Q2: What's a benefit of doing this if we're also doing it in the higher layer?

layers

application	HTTP, SSH, SMTP, ...	application-defined meanings
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link	Ethernet, Wi-Fi, ...	coordinate shared wire/radio
physical	...	encode bits for wire/radio

the network layer

the Internet Protocool (IP) version 4 or version 6

- there are also others, but quite uncommon today

allows send messages to/recv messages from other networks

- "internetwork"

messages usually called "packets"

network layer quality of service

if packet ...

event	on IPv4/v6
collides with another	out of scope — handled by link layer
not received	lost silently
header corrupted	usually discarded silently
data corrupted	received corrupted
too long	dropped with notice or “fragmented” + recombined
reordered (v. other messages)	received out of order
destination unknown	usually dropped with notice
too much being sent	discard excess

network layer quality of service

if packet ...

event	on IPv4/v6
collides with another	out of scope — handled by link layer
not received	lost silently
header corrupted	usually discarded silently
data corrupted	received corrupted
too long	dropped with notice or "fragmented" + recombined
reordered (v. other messages)	received out of order
destination unknown	usually dropped with notice
too much being sent	discard excess

includes dropped by link layer
(e.g. if detected corrupted there)

IPv4 addresses

32-bit numbers

typically written like 128.143.67.11

- four 8-bit decimal values separated by dots
- first part is most significant
- same as $128 \cdot 256^3 + 143 \cdot 256^2 + 67 \cdot 256 + 11 = 2\,156\,782\,459$

organizations get blocks of IPs

- e.g. UVa has 128.143.0.0–128.143.255.255
- e.g. Google has 216.58.192.0–216.58.223.255 and 74.125.0.0–74.125.255.255 and 35.192.0.0–35.207.255.255

some IPs reserved for non-Internet use (127.*, 10.*, 192.168.*)

IPv6 addresses

IPv6 like IPv4, but with 128-bit numbers

written in hex, 16-bit parts, seperated by colons (`:`)

strings of 0s represented by double-colons (`::`)

typically given to users in blocks of 2^{80} or 2^{64} addresses

- no need for address translation?

`2607:f8b0:400d:c00::6a` =
`2607:f8b0:400d:0c00:0000:0000:0000:006a`

- $\texttt{2607f8b0400d0c0000000000000006a}_{\text{SIXTEEN}}$

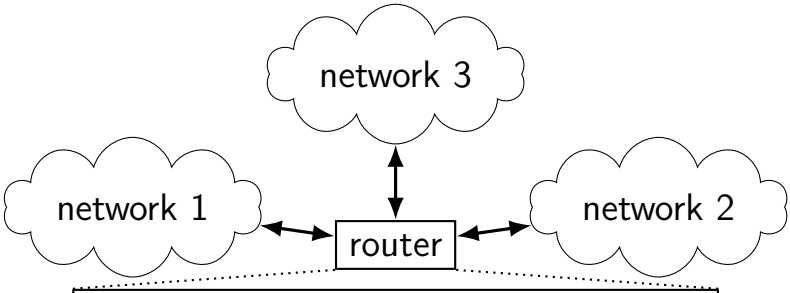
selected special IPv6 addresses

`::1` = localhost

anything starting with `fe80` = link-local addresses

never forwarded by routers

IPv4 addresses and routing tables



if I receive data for...	send it to...
128.143.0.0—128.143.255.255	network 1
192.107.102.0–192.107.102.255	network 1
...	...
4.0.0.0–7.255.255.255	network 2
64.8.0.0–64.15.255.255	network 2
...	...
anything else	network 3

selected special IPv4 addresses

127.0.0.0 — 127.255.255.255 — localhost

- AKA loopback
- the machine we're on
- typically only 127.0.0.1 is used

192.168.0.0–192.168.255.255 and
10.0.0.0–10.255.255.255 and
172.16.0.0–172.31.255.255

- "private" IP addresses
- not used on the Internet
- commonly connected to Internet with network address translation
- also 100.64.0.0–100.127.255.255 (but with restrictions)

169.254.0.0-169.254.255.255

- link-local addresses — 'never' forwarded by routers

layers

application	HTTP, SSH, SMTP, ...	application-defined meanings
transport	TCP, UDP, ...	reach correct program, reliablity/streams
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link	Ethernet, Wi-Fi, ...	coordinate shared wire/radio
physical	...	encode bits for wire/radio

port numbers

we run multiple programs on a machine

- IP addresses identifying machine — not enough

port numbers

we run multiple programs on a machine

- IP addresses identifying machine — not enough

so, add 16-bit *port numbers*

- think: multiple PO boxes at address

port numbers

we run multiple programs on a machine

- IP addresses identifying machine — not enough

so, add 16-bit *port numbers*

- think: multiple PO boxes at address

0–49151: typically assigned for particular services

- 80 = http, 443 = https, 22 = ssh, ...

49152–65535: allocated on demand

- default "return address" for client connecting to server

UDP v TCP

UDP: messages sent to program, but no reliablity/streams

- get assigned port number
- SOCK_DGRAM with socket() instead of SOCK_STREAM
- can sendto()/recvfrom() multiple other programs with one socket
  - (but don't have to)
- send messages which are limited in size, unreliable

TCP: stream to other program

- need to bind() + listen() + accept() or connect() to setup connection
- one socket per connection
- read/write bytes — divided into messages automatically
- reliable — acknowledgments/resending handled for you

UDP sockets on IPv4

```
int fd = socket(AF_INET, SOCK_DGRAM, 0);
struct sockaddr_in my_addr= ...;
bind(fd, &my_addr, sizeof(my_addr))
...
struct sockaddr_in to_addr = ...;
sendto(fd, data, data_size, 0 /* flags */,
    &to_addr, sizeof(to_addr));
struct sockaddr_in from_addr = ...;
recvfrom(fd, &buffer[0], buffer_size, 0,
    &from_addr, sizeof(from_addr));
...
/* or connect() to set default sendto address
```

connections in TCP/IP

connection identified by *5-tuple*

used by OS to lookup "where is the socket?"

(protocol=TCP/UDP, local IP addr., local port, remote IP addr., remote port)

local IP address, port number can be set with `bind()` function

typically always done for servers, not done for clients

system will choose default if you don't

connections on my desktop

```
cr4bd@reiss-t3620>/u/cr4bd
$ netstat --inet --inet6 --numeric
Active Internet connections (w/o servers)
Proto Recv-Q Send-Q Local Address           Foreign Address         State
tcp        0      0 128.143.67.91:49202     128.143.63.34:22        ESTABLISHE
tcp        0      0 128.143.67.91:803       128.143.67.236:2049     ESTABLISHE
tcp        0      0 128.143.67.91:50292     128.143.67.226:22       TIME_WAIT
tcp        0      0 128.143.67.91:54722     128.143.67.236:2049     TIME_WAIT
tcp        0      0 128.143.67.91:52002     128.143.67.236:111      TIME_WAIT
tcp        0      0 128.143.67.91:732       128.143.67.236:63439    TIME_WAIT
tcp        0      0 128.143.67.91:40664     128.143.67.236:2049     TIME_WAIT
tcp        0      0 128.143.67.91:54098     128.143.67.236:111      TIME_WAIT
tcp        0      0 128.143.67.91:49302     128.143.67.236:63439    TIME_WAIT
tcp        0      0 128.143.67.91:50236     128.143.67.236:111      TIME_WAIT
tcp        0      0 128.143.67.91:22        172.27.98.20:49566      ESTABLISHE
tcp        0      0 128.143.67.91:51000     128.143.67.236:111      TIME_WAIT
tcp        0      0 127.0.0.1:50438         127.0.0.1:631           ESTABLISHE
tcp        0      0 127.0.0.1:631           127.0.0.1:50438         ESTABLISHE
```

non-connection sockets

TCP servers waiting for connections +
UDP sockets with no particular remote host

Linux: OS keeps 5-tuple with “wildcard” remote address

“listening” sockets on my desktop

```
cr4bd@reiss-t3620>/u/cr4bd
$ netstat --inet --inet6 --numeric --listen
Active Internet connections (only servers)
Proto Recv-Q Send-Q Local Address           Foreign Address         State
tcp        0      0 127.0.0.1:38537         0.0.0.0:*               LISTEN
tcp        0      0 127.0.0.1:36777         0.0.0.0:*               LISTEN
tcp        0      0 0.0.0.0:41099           0.0.0.0:*               LISTEN
tcp        0      0 0.0.0.0:45291           0.0.0.0:*               LISTEN
tcp        0      0 127.0.0.1:51949         0.0.0.0:*               LISTEN
tcp        0      0 127.0.0.1:41071         0.0.0.0:*               LISTEN
tcp        0      0 0.0.0.0:111             0.0.0.0:*               LISTEN
tcp        0      0 127.0.0.1:32881         0.0.0.0:*               LISTEN
tcp        0      0 127.0.0.1:38673         0.0.0.0:*               LISTEN
....
tcp6       0      0 :::42689                :::*                    LISTEN
udp        0      0 128.143.67.91:60001     0.0.0.0:*
udp        0      0 128.143.67.91:60002     0.0.0.0:*
...
udp6       0      0 :::59938                :::*
```

TCP state machine

TIME_WAIT, ESTABLISHED, ...?

OS tracks "state" of TCP connection

- am I just starting the connection?
- is other end ready to get data?
- am I trying to close the connection?
- do I need to resend something?

standardized set of state names

TIME_WAIT

remember delayed messages?

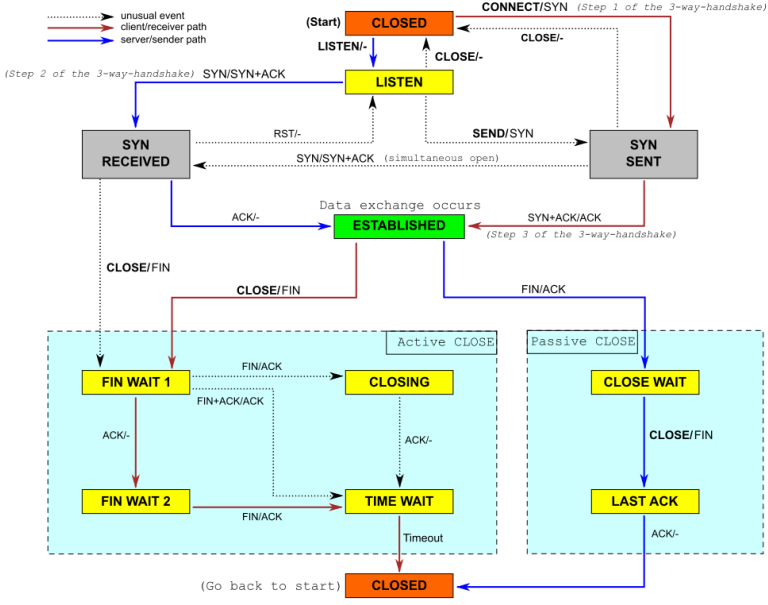
problem for TCP ports

if I reuse port number, I can get message from old connection

solution: TIME_WAIT to make sure connection really done

- done after sending last message in connection

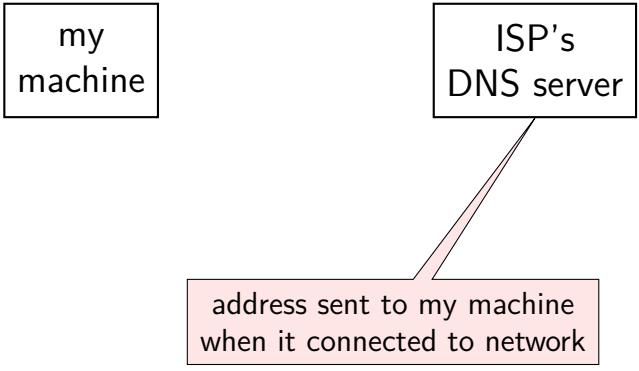
TCP state machine picture



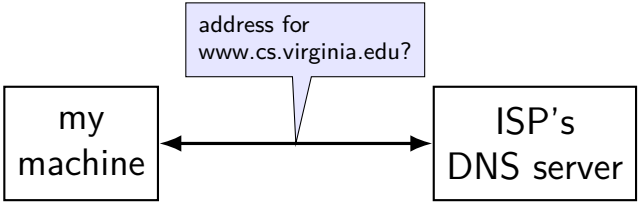
names and addresses

name	address
logical identifier	location/how to locate
variable `counter`	memory address `0x7FFF9430`
DNS name `www.virginia.edu`	IPv4 address `128.143.22.36`
DNS name `mail.google.com`	IPv4 address `216.58.217.69`
DNS name `mail.google.com`	IPv6 address `2607:f8b0:4004:80b::2005`
DNS name `reiss-t3620.cs.virginia.edu`	IPv4 address `128.143.67.91`
DNS name `reiss-t3620.cs.virginia.edu`	MAC address `18:66:da:2e:7f:da`
service name `https`	port number 443
service name `ssh`	port number 22

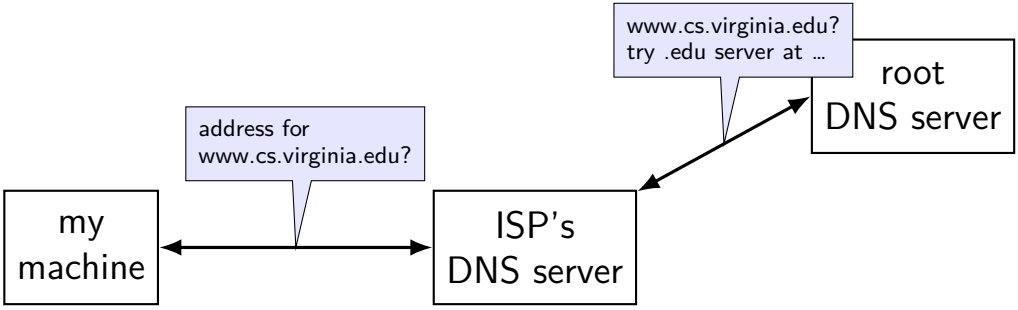
DNS: distributed database



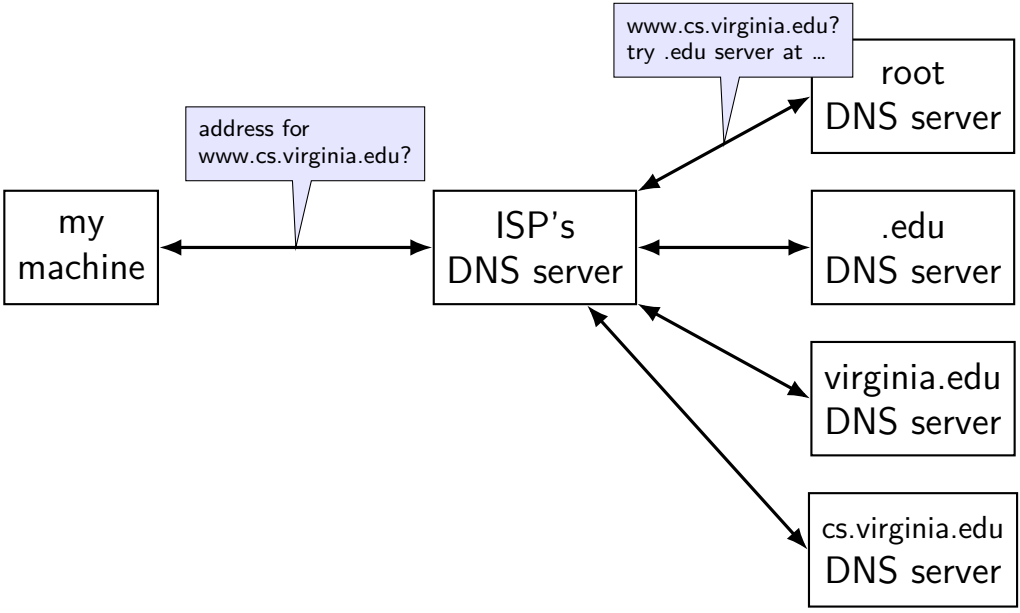
DNS: distributed database



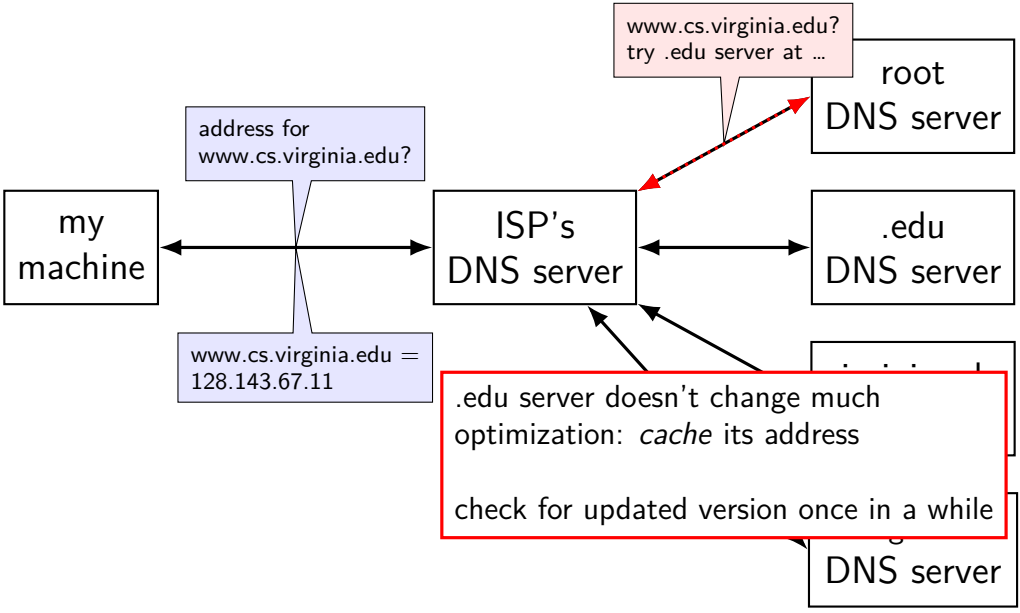
DNS: distributed database



DNS: distributed database



DNS: distributed database



querying the root

```
$ dig @a.root-servers.net www.cs.virginia.edu
...
edu.                    172800      IN      NS      b.edu-servers.net.
edu.                    172800      IN      NS      f.edu-servers.net.
edu.                    172800      IN      NS      i.edu-servers.net.
edu.                    172800      IN      NS      a.edu-servers.net.
...
b.edu-servers.net.      172800      IN      A       192.33.14.30
b.edu-servers.net.      172800      IN      AAAA       2001:503:231d::2:30
f.edu-servers.net.      172800      IN      A       192.35.51.30
f.edu-servers.net.      172800      IN      AAAA       2001:503:d414::30
...
```

querying the edu

```
$ dig @b.edu-servers.net www.cs.virginia.edu
...
;; AUTHORITY SECTION:
virginia.edu.                 172800        IN        NS        nom.virginia.edu.
virginia.edu.                 172800        IN        NS        uvaarpa.virginia.edu.
virginia.edu.                 172800        IN        NS        eip-01-aws.net.virginia.edu.

;; ADDITIONAL SECTION:
nom.virginia.edu.         172800        IN        A        128.143.107.101
uvaarpa.virginia.edu.         172800        IN        A        128.143.107.117
eip-01-aws.net.virginia.edu. 172800 IN        A        44.234.207.10
```

querying virginia.edu

```
$ dig @nom.virginia.edu www.cs.virginia.edu
...
;; AUTHORITY SECTION:
cs.virginia.edu.        3600        IN        NS        coresrv01.cs.virginia.edu.

;; ADDITIONAL SECTION:
coresrv01.cs.virginia.edu. 3600        IN        A        128.143.67.11
```

querying cs.virginia.edu

```
$ dig @coresrv01.cs.virginia.edu
...
;; ANSWER SECTION:
www.cs.Virginia.EDU.        172800        IN        A        128.143.67.11

;; AUTHORITY SECTION:
cs.Virginia.EDU.        172800        IN        NS        coresrv01.cs.Virginia.EDU.
...
```

querying typical ISP's resolver

```
$ dig www.cs.virginia.edu
...
;; ANSWER SECTION:
www.cs.Virginia.EDU.          7183        IN        A        128.143.67.11
..
```

cached response

valid for 7183 more seconds

after that everyone needs to check again

names and addresses

name	address
logical identifier	location/how to locate
variable `counter`	memory address `0x7FFF9430`
DNS name `www.virginia.edu`	IPv4 address `128.143.22.36`
DNS name `mail.google.com`	IPv4 address `216.58.217.69`
DNS name `mail.google.com`	IPv6 address `2607:f8b0:4004:80b::2005`
DNS name `reiss-t3620.cs.virginia.edu`	IPv4 address `128.143.67.91`
DNS name `reiss-t3620.cs.virginia.edu`	MAC address `18:66:da:2e:7f:da`
service name `https`	port number 443
service name `ssh`	port number 22

two types of addresses?

MAC addreses: on link layer

IP addresses: on network layer

how do we know which MAC address to use?

a table on my desktop

my desktop:

```
$ arp -an
? (128.143.67.140) at 3c:e1:a1:18:bd:5f [ether] on enp0s31f6
? (128.143.67.236) at <incomplete> on enp0s31f6
? (128.143.67.11) at 30:e1:71:5f:39:10 [ether] on enp0s31f6
? (128.143.67.92) at <incomplete> on enp0s31f6
? (128.143.67.5) at d4:be:d9:b0:99:d1 [ether] on enp0s31f6
```

...

how is that table made?

ask machines on local network (same switch)

“Who has 128.148.67.140”

the correct one replies

what about non-local machines?

when configuring network specify:

range of addresses to expect on local network

- 128.148.67.0-128.148.67.255 on my desktop
- "netmask"

gateway machine to send to for things outside my local network

- 128.143.67.1 on my desktop
- my desktop looks up the corresponding MAC address

routes on my desktop

```
$ /sbin/route -n
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
0.0.0.0         128.143.67.1    0.0.0.0         UG    100    0        0 enp0s31f6
128.143.67.0    0.0.0.0         255.255.255.0   U     100    0        0 enp0s31f6
169.254.0.0     0.0.0.0         255.255.0.0     U     1000   0        0 enp0s31f6
```

URL / URIs

Uniform Resource Locators (URL)

tells how to find “resource” on network

Unifrom Resources Identifiers

superset of URLs

URI examples

```
https://kytos02.cs.virginia.edu:443/cs3130-spring2023/
                quizzes/quiz.php?qid=02#q2

https://kytos02.cs.virginia.edu/cs3130-spring2023/
                quizzes/quiz.php?qid=02

https://www.cs.virginia.edu/

sftp://cr4bd@portal.cs.virginia.edu/u/cr4bd/file.txt

tel:+1-434-982-2200
```

URI generally

`scheme://authority/path?query#fragment`

scheme: — what protocol

//authority/

authoirty = user@host:port OR host:port OR user@host OR host

path

which resource

?query — usually key/value pairs

#fragment — place in resource

most components (sometimes) optional

URLs and HTTP (1)

`http://www.foo.com:80/foo/bar?quux#q1`

lookup IP address of www.foo.com

connect via TCP to port 80:

```
GET /foo/bar?quux HTTP/1.1
Host: www.foo.com:80
```

exercise: why include the Host there?

autoconfiguration

problem: how does my machine get IP address

otherwise:

- have sysadmin type one in?
- just choose one?
- ask someone on local network to assign it

autoconfiguration

problem: how does my machine get IP address

otherwise:

- have sysadmin type one in?
- just choose one?
- ask someone on local network to assign it

DHCP high-level

protocol done over UDP

but since we don't have IP address yet, use `0.0.0.0`

and since we don't know server address, use `255.255.255.255`
= "everyone on the local network"

local server replies to request with address + time limit

firewalls

don't want to expose network service to everyone?

solutions:

- service picky about who it accepts connections from
- filters in OS on machine with services
- filters on router

later two called "firewalls"

firewall rules examples?

ALLOW tcp port 443 (https) FROM everyone

ALLOW tcp port 22 (ssh) FROM my desktop's IP address

BLOCK tcp port 22 (ssh) FROM everyone else

ALLOW from address X to address Y

...

spoofing

if I only allow connections from my desktop's IP addresses, how would you attack this?

hint: how do we know what address messages come from?

backup slides