# CSE 333
# Section 7

Client-side Networking

UNIVERSITY of WASHINGTON

# Logistics

Due Today:

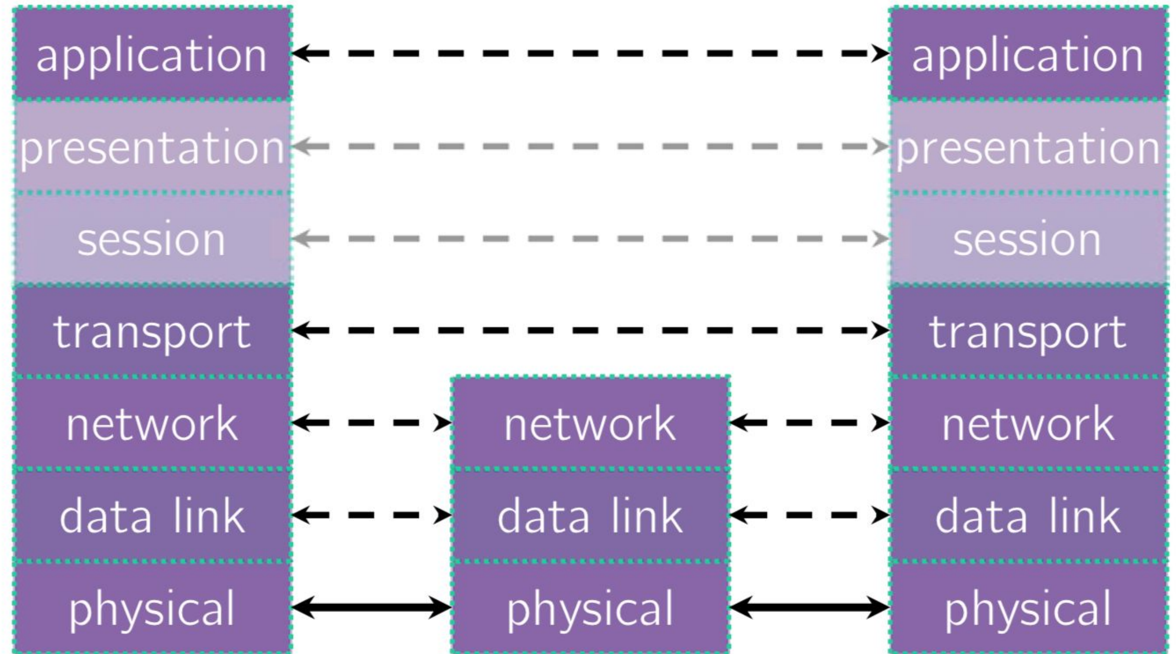
Homework 3 @ 11:59 pm

Due Wednesday:

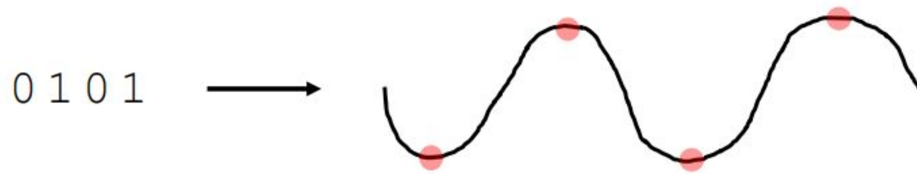
Exercise 10 @ 11 am

# Networking - At a High Level

# Computer Networks: A 7-ish Layer Cake

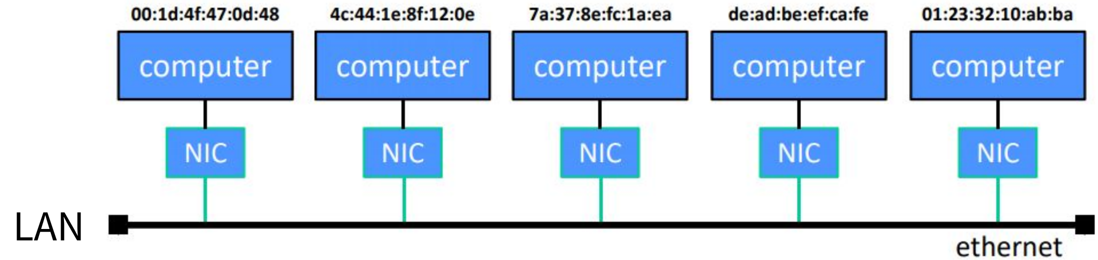


# Computer Networks: A 7-ish Layer Cake



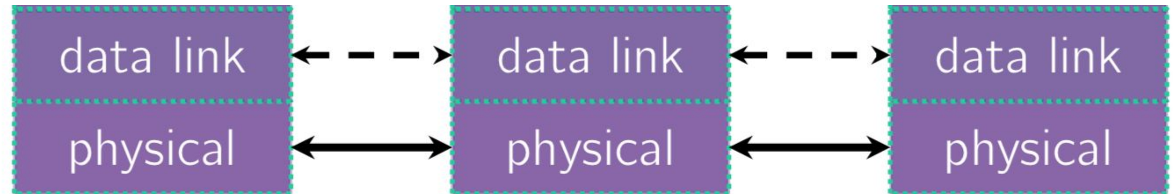

bit encoding at signal level

# Computer Networks: A 7-ish Layer Cake

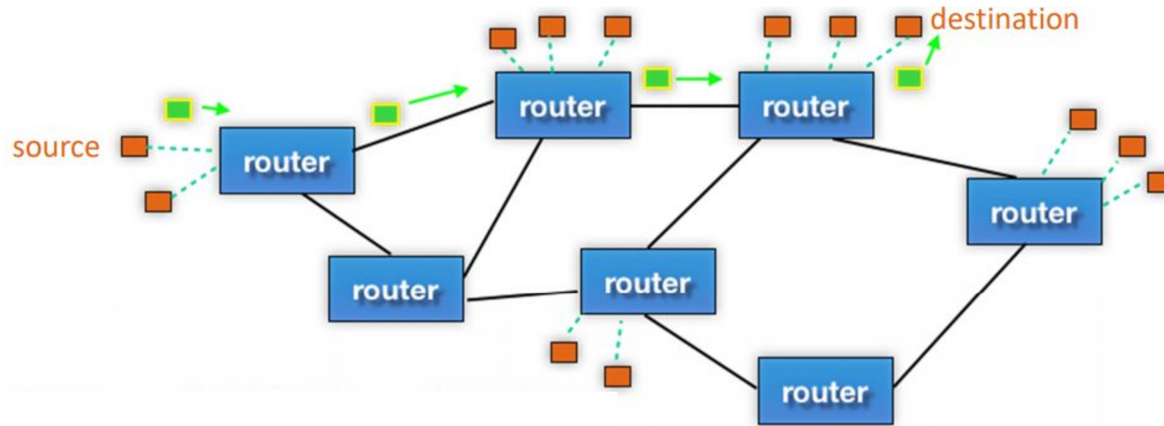



multiple computers on a local network

bit encoding at signal level



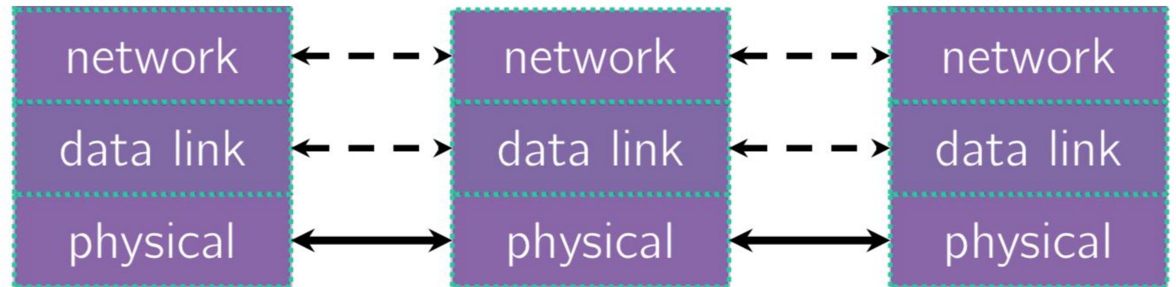
# Computer Networks: A 7-ish Layer Cake




routing of packets across networks

multiple computers on a local network

bit encoding at signal level



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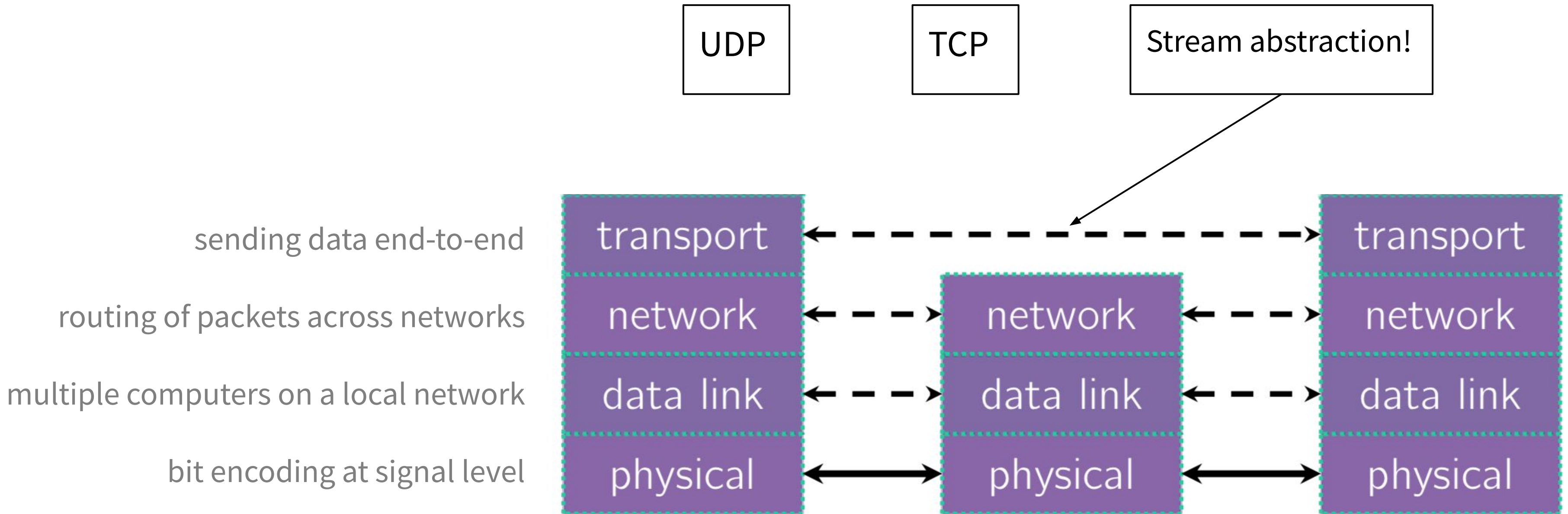
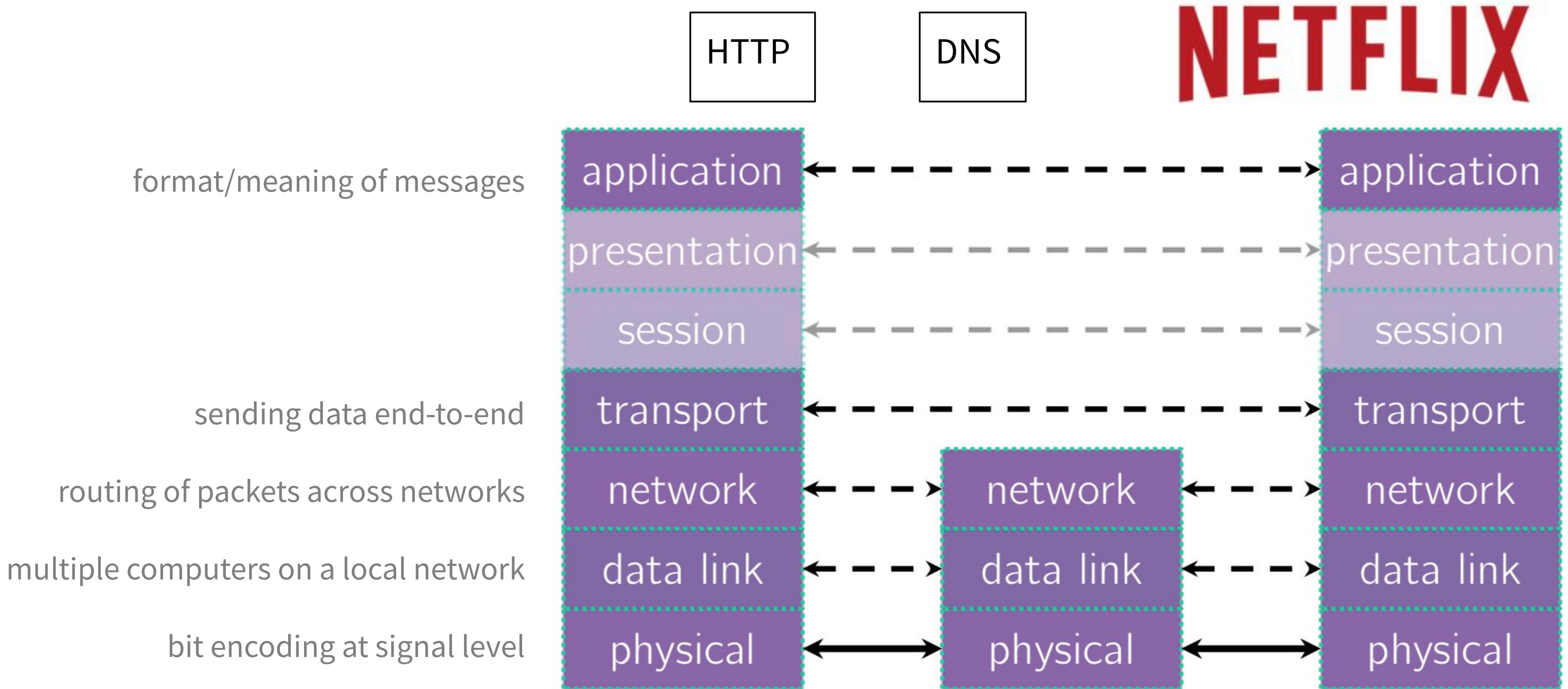
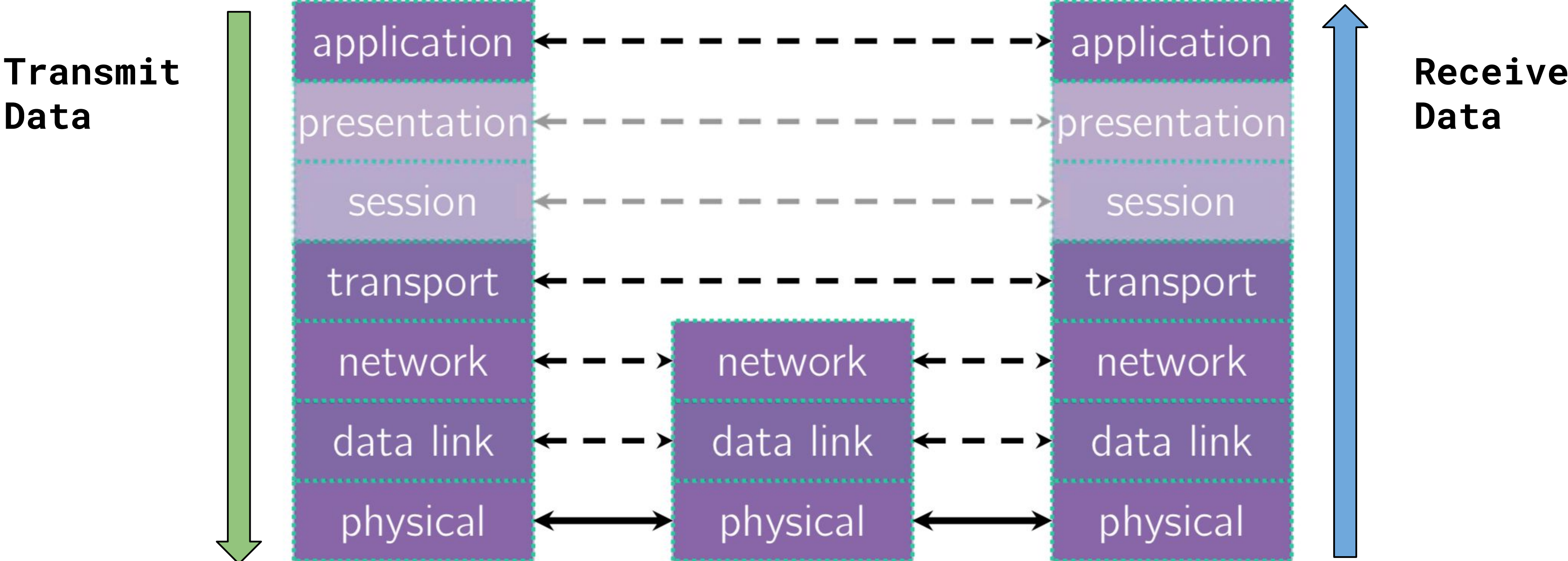


# Computer Networks: A 7-ish Layer Cake



# Data flow

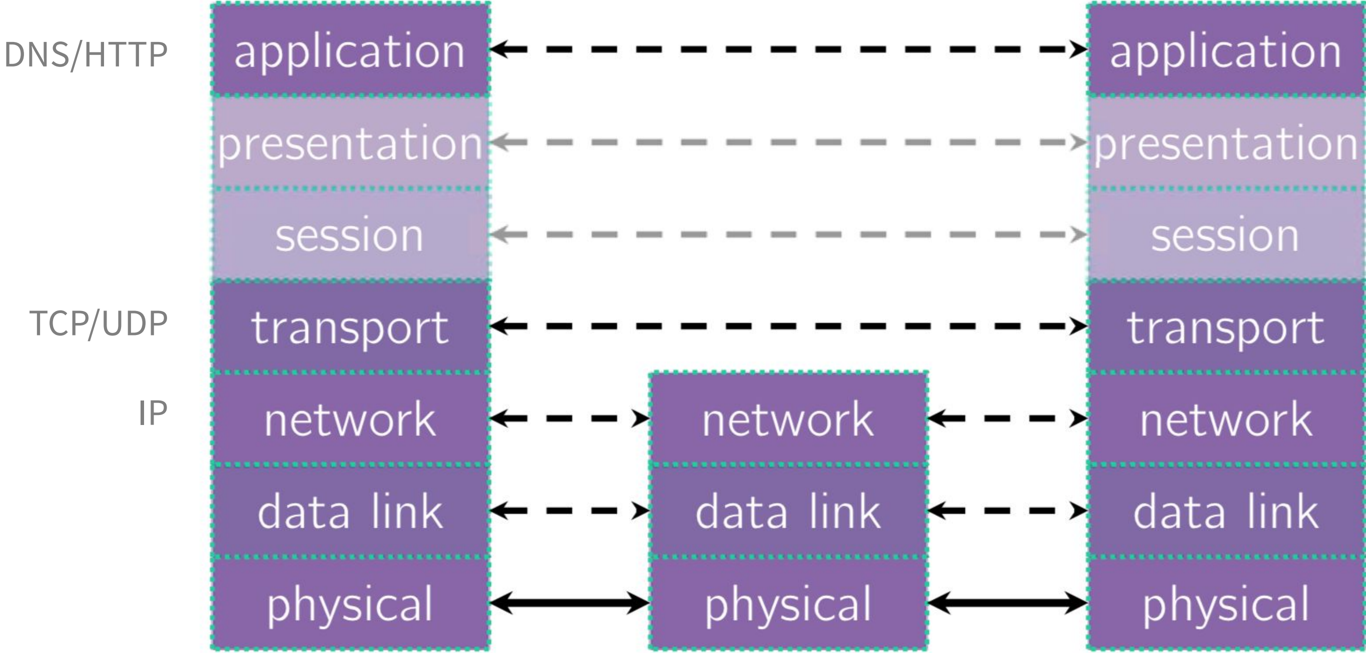


# Exercise 1

# Exercise 1

- DNS: Translating between IP addresses and host names. (Application Layer)
- IP: Routing packets across the Internet. (Network Layer)
- TCP: Reliable, stream-based networking on top of IP. (Transport Layer)
- UDP: Unreliable, packet-based networking on top of IP. (Transport Layer)
- HTTP: Sending websites and data over the Internet. (Application Layer)

# Exercise 1



# TCP versus UDP

**Transmission Control Protocol (TCP)**

- Connection oriented Service
- Reliable and Ordered
- Flow control

Potential applications:

- Websites
- Email

**User Datagram Protocol (UDP)**

- Connectionless service
- Unreliable packet delivery
- Faster (usually lower latency)
- No feedback

Potential applications:

- VOIP
- Multiplayer gaming

# Client-side Networking Preview

Let’s say you want to talk to your friend, but you’ve both lost your phones so you’ll have to do something a little… old fashioned

You know your friend is waiting somewhere for you to contact them. How can you do that?

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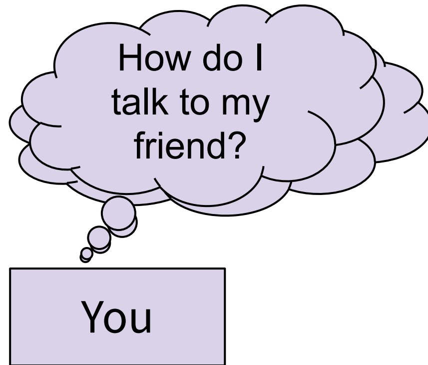
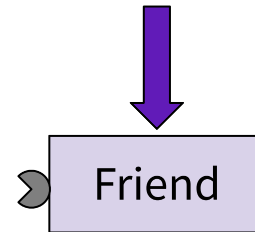
1. Figure out their current address



## You know your friend is waiting somewhere for you to contact them. How can you do that?

1. Figure out their current address
2. Get a cup

# You know your friend is waiting somewhere for you to contact them. How can you do that?

1. Figure out their current address
2. Get a cup
3. Connect a string between your two cups

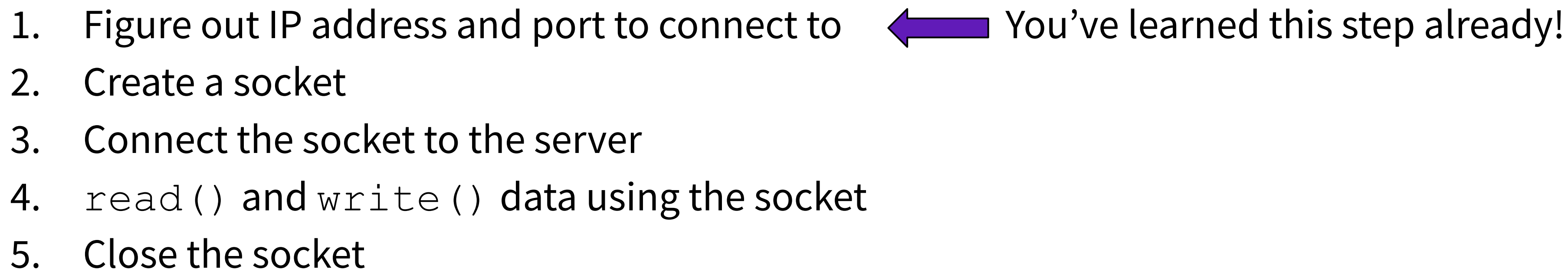
# You know your friend is waiting somewhere for you to contact them. How can you do that?

1. Figure out their current address
2. Get a cup
3. Connect a string between your two cups
4. Talk!

# You know your friend is waiting somewhere for you to contact them. How can you do that?

1. Figure out their current address
2. Get a cup
3. Connect a string between your two cups
4. Talk!
5. Clean up your cup and string

# Client-side Networking Steps



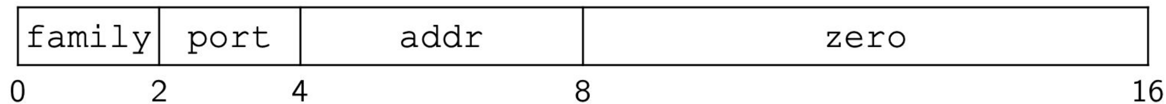

More details in tomorrow's lecture!

# Sockets and DNS Lookup

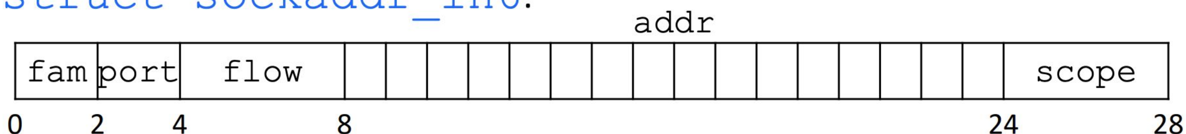
# Sockets

- Just a file descriptor for network communication
- Types of Sockets
  - Stream sockets (TCP)
  - Datagram sockets (UDP)
- Each socket is associated with **a port number** and **an IP address**
  - Both port and address are stored in network byte order (big endian)

`struct sockaddr_in`:

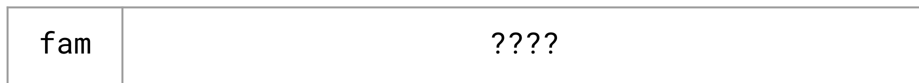



`struct sockaddr_in6`:



# Sockets

**struct sockaddr** (pointer to this struct is used as parameter type in system calls)




....

**struct sockaddr_in** (IPv4)

16

**struct sockaddr_in6** (IPv6)

28

**struct sockaddr_storage**

Big enough to hold either

# Byte Ordering and Endianness

- **N**etwork Byte Order (Big Endian)
  - The most significant byte is stored in the highest address
- **H**ost byte order
  - Might be big or little endian, depending on the hardware
- To convert between orderings, we can use
  - `uint16_t htons (uint16_t hostlong);`
  - `uint16_t ntohs (uint16_t hostlong);`

  - `uint32_t htonl (uint32_t hostlong);`
  - `uint32_t ntohl (uint32_t hostlong);`

# getaddrinfo()

```
// Figure out what IP address and port to talk to
// returns 0 on success, negative number on failure
int getaddrinfo(const char *hostname,    // hostname to lookup
        const char *servname,            // service name
        const struct addrinfo *hints,    // desired output (optional)
        struct addrinfo **res);          // results structure


// Frees memory allocated by getaddrinfo()
void freeaddrinfo(struct addrinfo *ai);
```

# getaddrinfo()

- Performs a **DNS Lookup** for a hostname
- Use “hints” to specify constraints (`struct addrinfo *`)
- Get back a linked list of `struct addrinfo` results

```
int getaddrinfo(const char *hostname,
                const char *service,
                const struct addrinfo *hints,
                struct addrinfo **res);
```

# getaddrinfo() - Interpreting Results

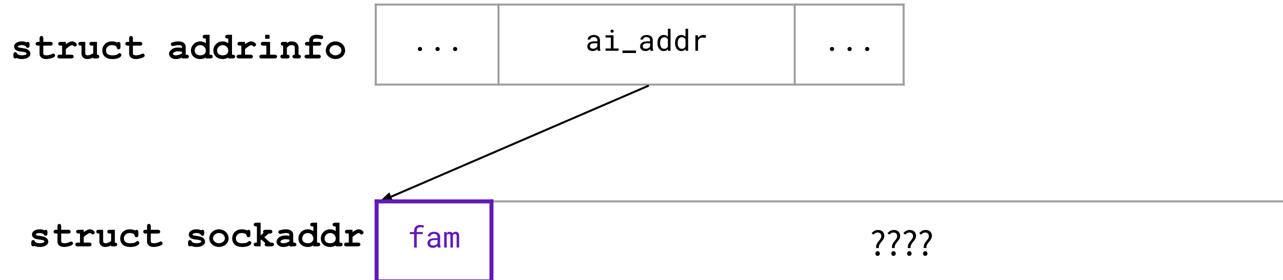
```
struct addrinfo {
    int ai_flags; // additional flags
    int ai_family; // AF_INET, AF_INET6, AF_UNSPEC
    int ai_socktype; // SOCK_STREAM, SOCK_DGRAM, 0
    int ai_protocol; // IPPROTO_TCP, IPPROTO_UDP, 0
    size_t ai_addrlen; // length of socket addr in bytes
    struct sockaddr* ai_addr; // pointer to socket addr
    char* ai_canonname; // canonical name
    struct addrinfo* ai_next; // can form a linked list
};
```

- `ai_addr` points to a `struct sockaddr` describing the socket address

# getaddrinfo() - Interpreting Results

With a `struct sockaddr*`:

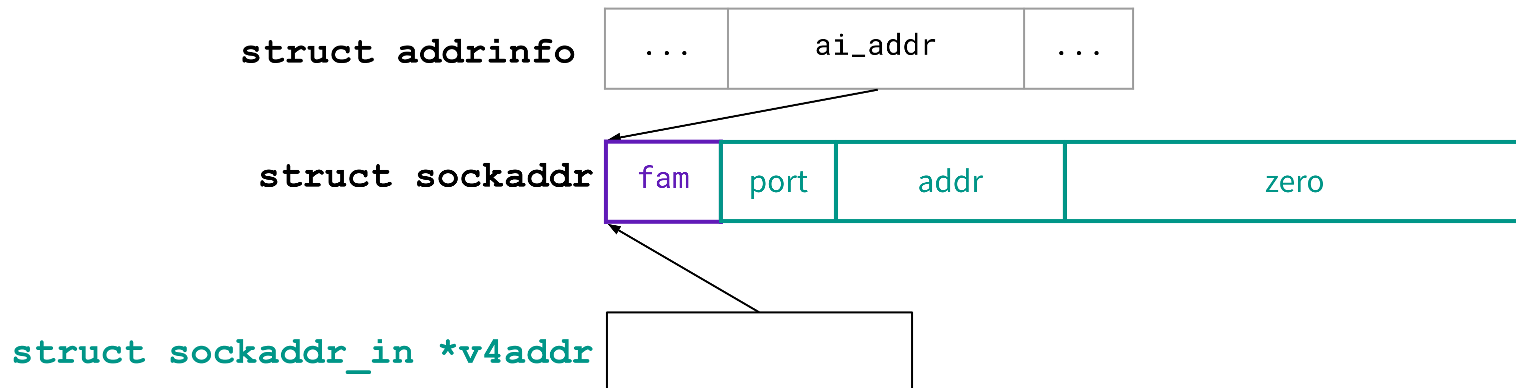
- The field `sa_family` describes if it is IPv4 or IPv6



# getaddrinfo() - Interpreting Results

With a `struct sockaddr*`:

- The field `sa_family` describes if it is IPv4 or IPv6
- Cast to `struct sockaddr_in*` (v4) or `struct sockaddr_in6*` (v6) to access/modify specific fields



# getaddrinfo() - Interpreting Results

With a `struct sockaddr*`:

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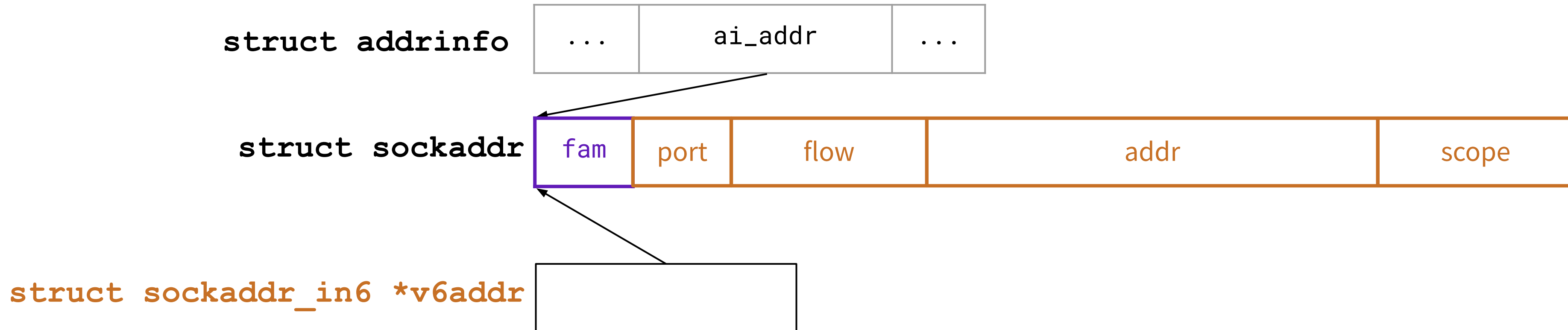

# getaddrinfo() - Interpreting Results

With a `struct sockaddr*`:

- The field `sa_family` describes if it is IPv4 or IPv6
- Cast to `struct sockaddr_in*` (v4) or `struct sockaddr_in6*` (v6) to access/modify specific fields
- Store results in a `struct sockaddr_storage` to have a space big enough for either

**`struct sockaddr_storage`**

# POSIX Review

# read()

```
// returns amount read, 0 for EOF, -1 on failure (errno set)
ssize_t read(int fd, void *buf, size_t count);
```

What might a return value of 0 for `read()` mean in the context of networking?

If `read()` returns 0 when reading from a socket this indicates that the network connection was closed. Note this is different from a failure occurring!

Where will `int fd` come from when dealing with the network?

When reading (or writing) across the network we use a socket to abstract away the networking details. This socket is identified by an integer value that we can use with POSIX functions.

# write()

```
// returns amount written, -1 on failure (errno set)
ssize_t write(int fd, void *buf, size_t count);
```

What values of errno are recoverable?

`EINTR` and `EAGAIN`

Can `write()` return 0?

In general `write()` will not return 0 but it is possible in a few cases. For networking, a return value of less than `count` such as 0 can be an indicator that the connection was closed.

# POSIX Exercise

```
int main(int argc, char **argv) {
  int socket_fd;
  char readbuf[512];
  int res;
  ... // Assume code to set up the network connection is included
  // Read data from the server until the connection is closed
  while (_________________________________ != 0) {
    if (res == -1) {
      if(______________________________) {continue;}
      ____________________
      return EXIT_FAILURE;
    }
    // Write the data we read to stdout
    int pos = 0;
    while (res > 0) {
      int write_res = _______________________________________
      if (write_res == -1) {
        if (_______________________________) {continue;}
        ____________________
        return EXIT_FAILURE;
      }
      res -= write_res;
      pos += write_res;
  }
  ____________________
  return EXIT_SUCCESS;
}
```

```
int main(int argc, char **argv) {
  int socket_fd;
  char readbuf[512];
  int res;
  ... // Assume code to set up the network connection is included
  // Read data from the server until the connection is closed
  while ((res = read(socket_fd, readbuf, 512))  != 0) {
    if (res == -1) {
      if(errno == EINTR || errno == EAGAIN ) {continue;}
      close(socket_fd);
      return EXIT_FAILURE;
    }
    // Write the data we read to stdout
    int pos = 0;
    while (res > 0) {
      int write_res =  write(STDOUT_FILENO, readbuf + pos, res);
      if (write_res == -1) {
        if (errno == EINTR || errno == EAGAIN ) {continue;}
          close(socket_fd);
          return EXIT_FAILURE;
      }
      res -= write_res;
      pos += write_res;
  }
  close(socket_fd)
  return EXIT_SUCCESS;
}
```

# Exercise 10 Demo

# Steps for Testing

Set up server:

- `$nc -l <port num> > <output file name>`
- I.e., `$nc -l 2048 > output.bytes`

Connect to server:

- `$./ex10 <server name> <port num> <local file>`
- I.e., `$./ex10 attu7 2048 test.txt`

# Testing Notes

- Pick your favorite 4-digit number for the port - don’t use the one from the spec as you may run into conflicts if someone else is using it!
- Have to start server over each time you test
- Can use `localhost` as the server name if running on same machine (i.e., attu7)