CSE 333
Section 8

Client-Side Networking

Logistics

Friday, Feb 26 (tomorrow):

HW3 @ 12pm

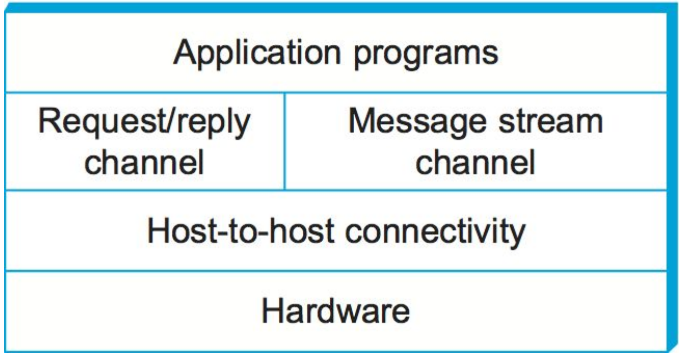
Computer Networks: layers of abstraction

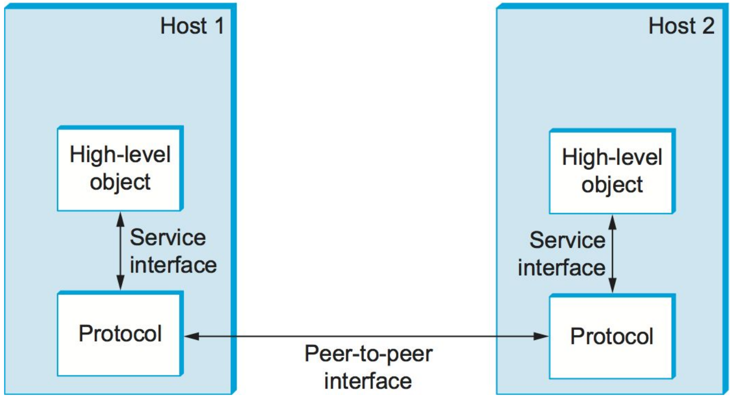
- How to connect computers by having hosts/processes communicates?
- A high-level requirement with lots of specifics involved
  - How to physically send data (in bits/bytes)?
  - structure and semantics of data
  - identification of hosts
  - etc.
- Application programmers don't want to deal with all these.
- The common way to build system is through layers of abstractions
  - Each layer implements a part of the problem and provides an interface for the higher layers
  - Decomposes the problem and brings modularity (e.g. many types of services at same layer depending on requirement.)

(adapted from https://book.systemsapproach.org/foundation/architecture.html)

Computer Networks: layers of abstraction

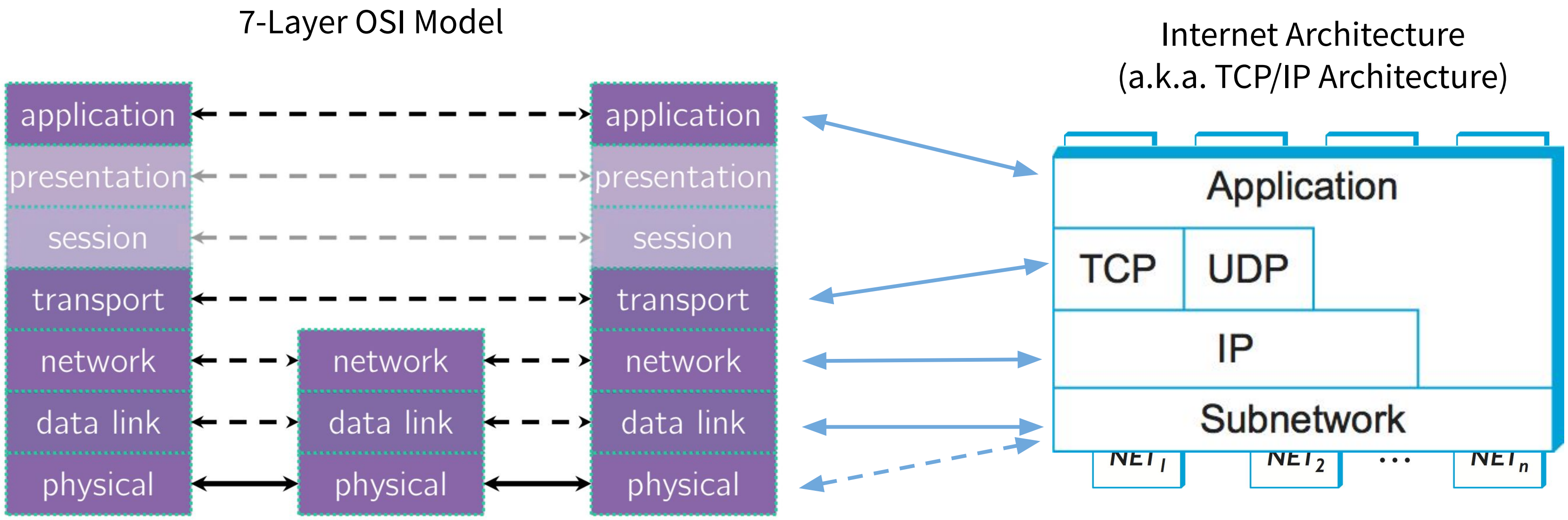
- In networking context, abstract objects making up the layers are called protocols
- A protocol specifies
  - a service interface to high-level protocol/object (i.e. set of operations they can use)
  - a peer interface for syntax and semantics of messages between peers of the same protocol
- What would be a good set of layers offering useful service while being efficient?





(adapted from https://book.systemsapproach.org/foundation/architecture.html)

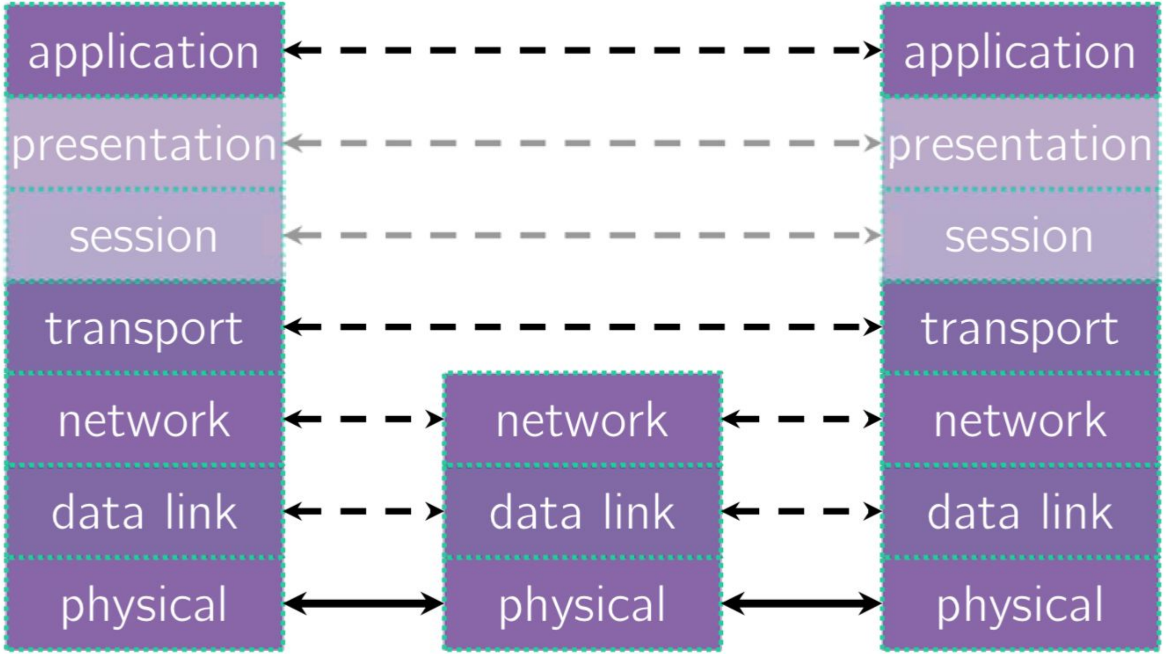
Computer Networks: architectures



- We introduce the 7-Layer OSI architecture, skipping presentation and session layers.
- Modern Internet is based on the Internet Architecture, but layers map well to the OSI model.

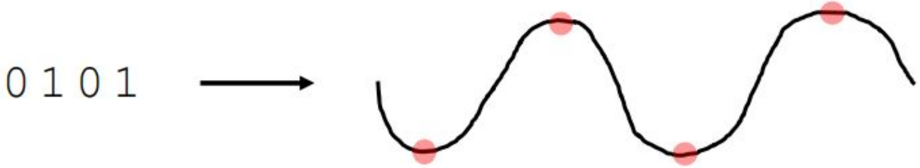
(adapted from https://book.systemsapproach.org/foundation/architecture.html)

Computer Networks: A 7-ish Layer Cake



Computer Networks: A 7-ish Layer Cake

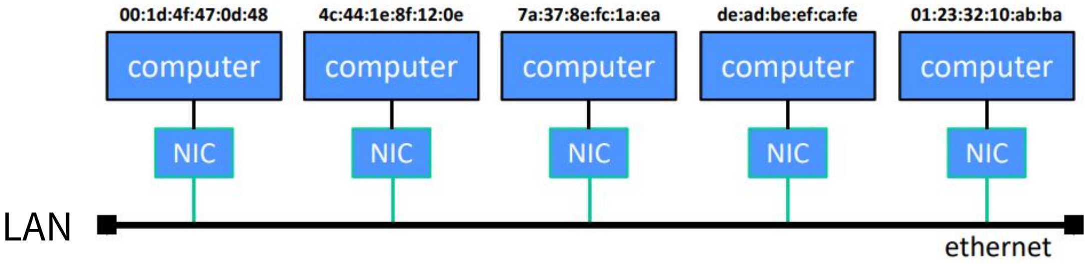
- Transmit signal through physical medium
- Bits from high/low voltage, frequency, etc.



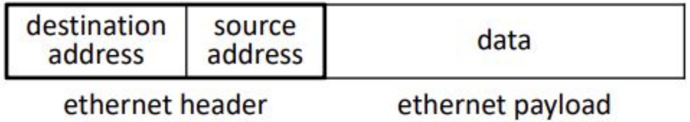
bit encoding at signal level

Computer Networks: A 7-ish Layer Cake

- Specifies communication with other nodes on a link
- "Packetized" stream of bits into frames



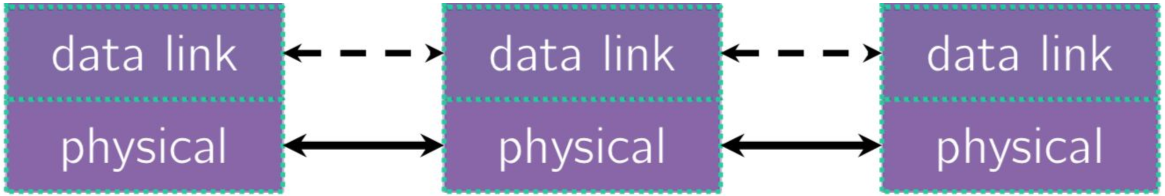
ethernet frame



implemented by network adaptors and device drivers

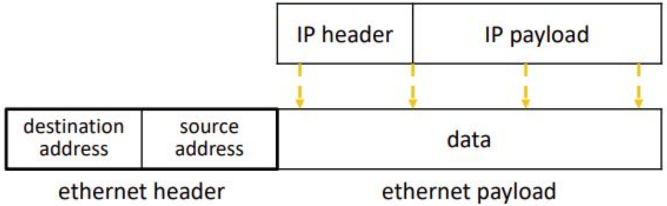
multiple computers on a local network

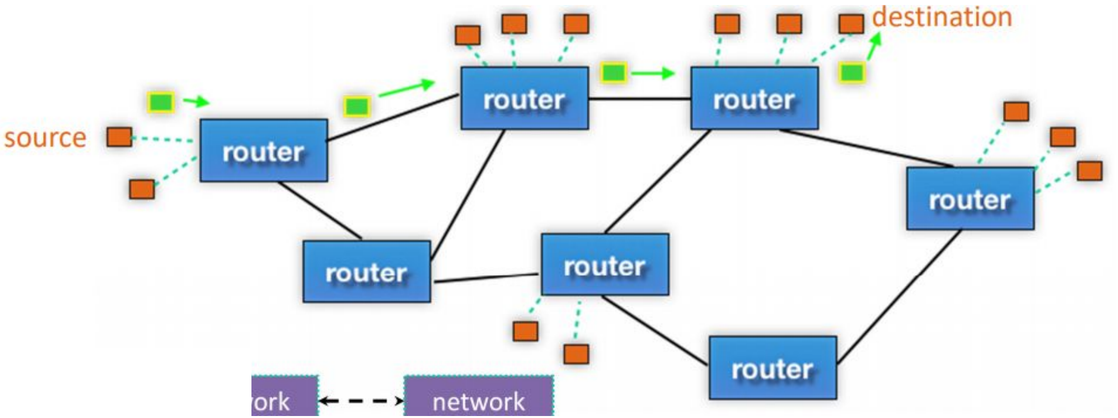
bit encoding at signal level



Computer Networks: A 7-ish Layer Cake

- Interconnect different network types
- Routers implements up to this layer
- IP packets within payload of data link's packet (frame)

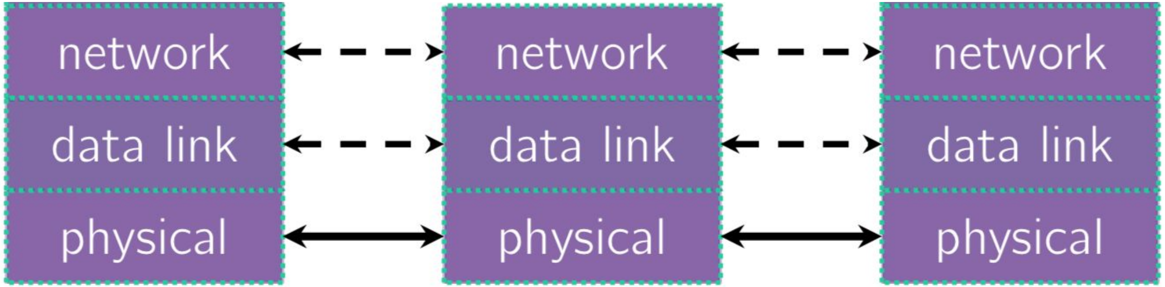




routing of packets across networks

multiple computers on a local network

bit encoding at signal level



Computer Networks: A 7-ish Layer Cake

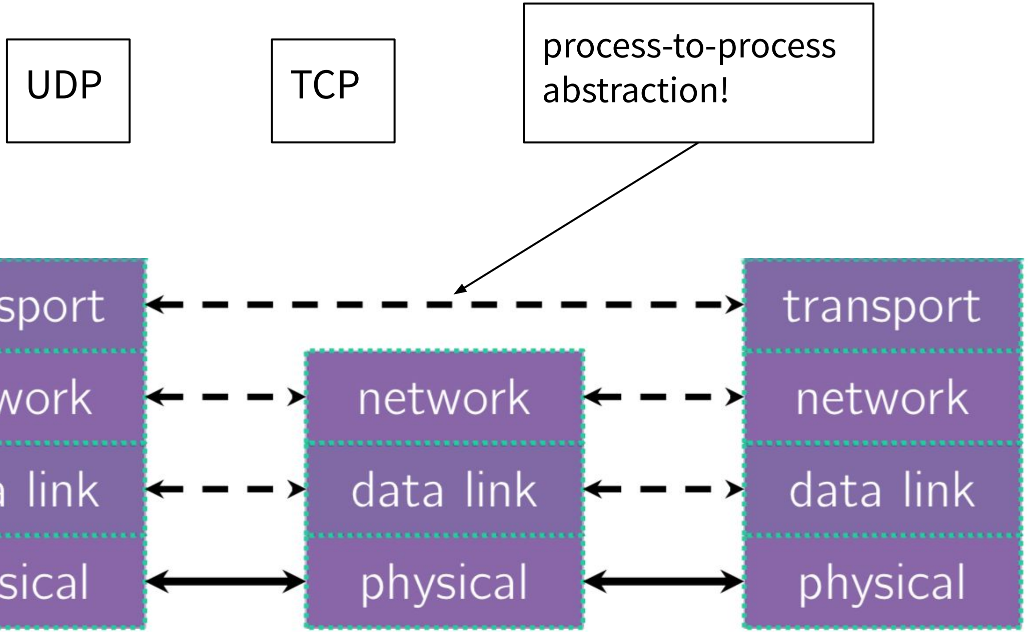
- Runs only on end hosts
- Provides process-to-process abstraction
- Again, packets nested inside payload of IP packets

sending data end-to-end

routing of packets across networks

multiple computers on a local network

bit encoding at signal level



Computer Networks: A 7-ish Layer Cake

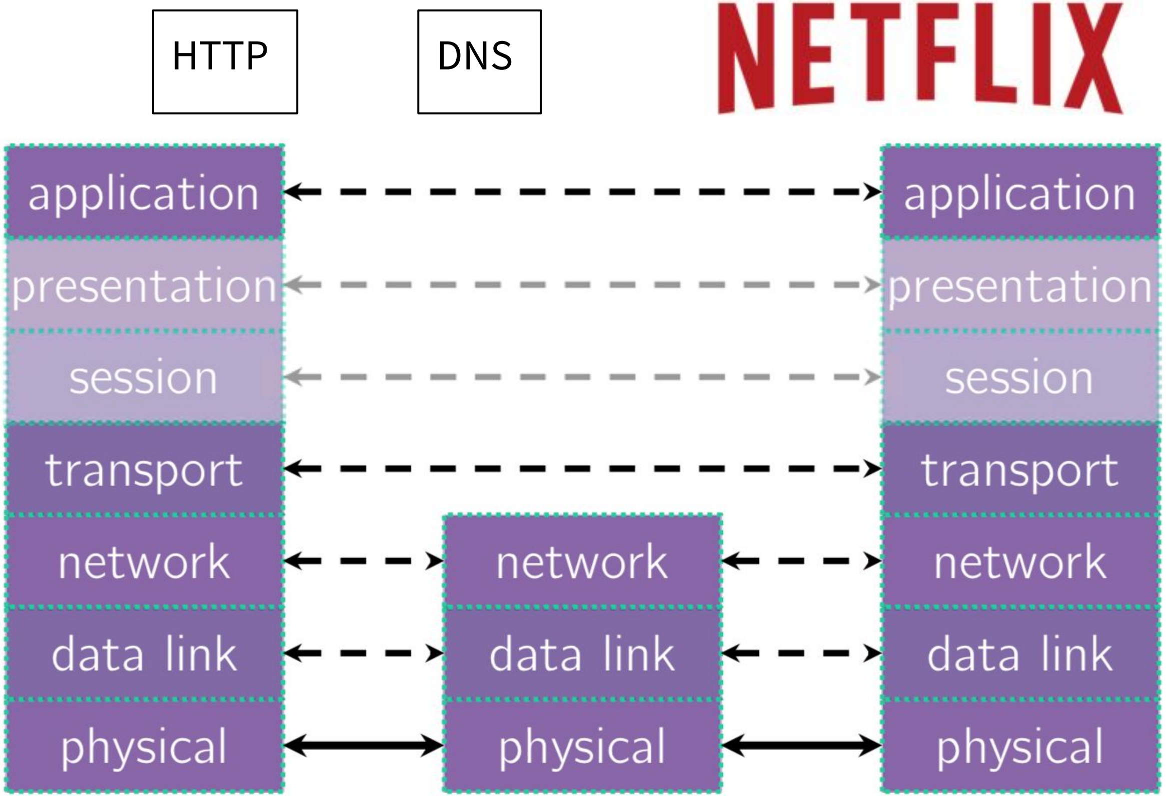
format/meaning of high-level messages

sending data end-to-end

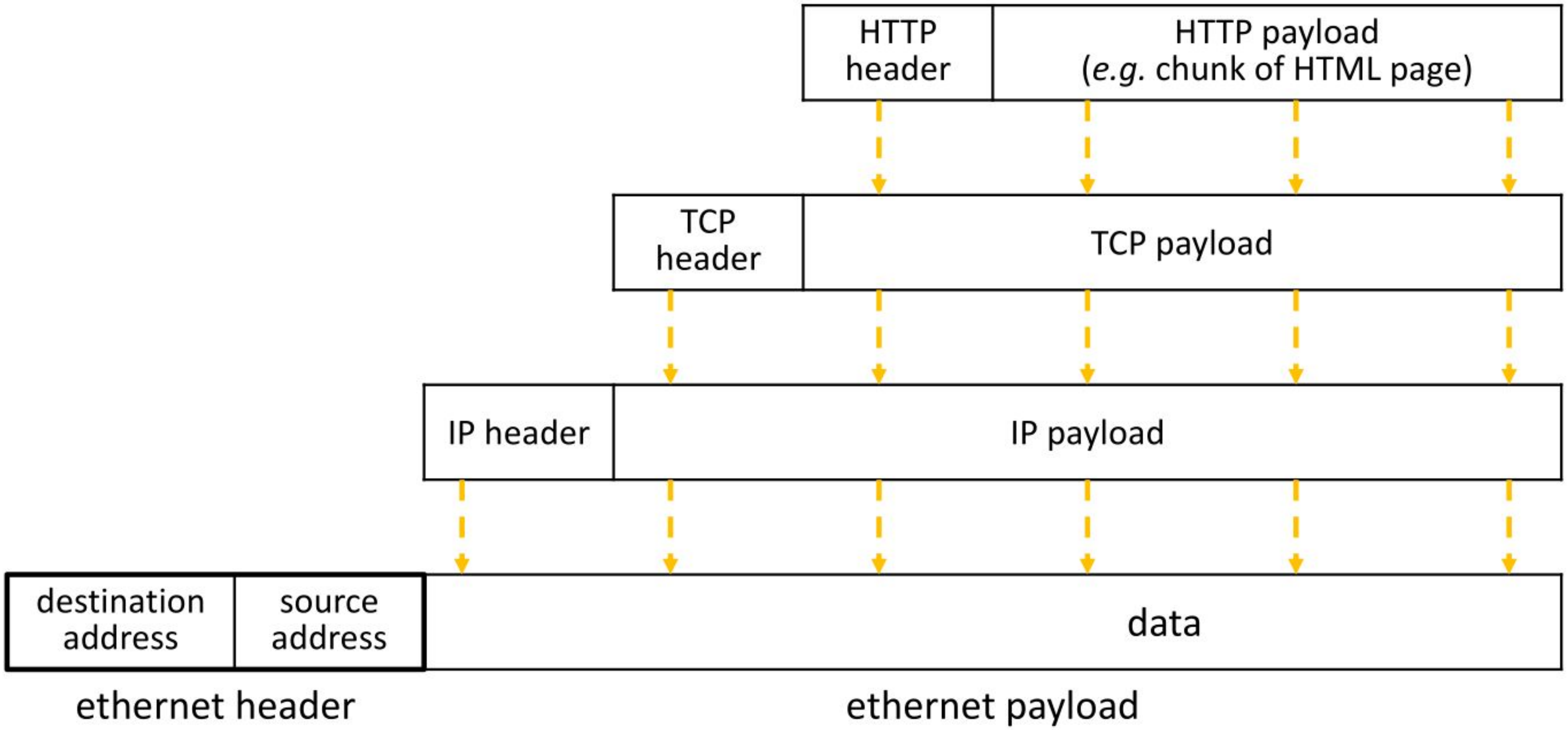
routing of packets across networks

multiple computers on a local network

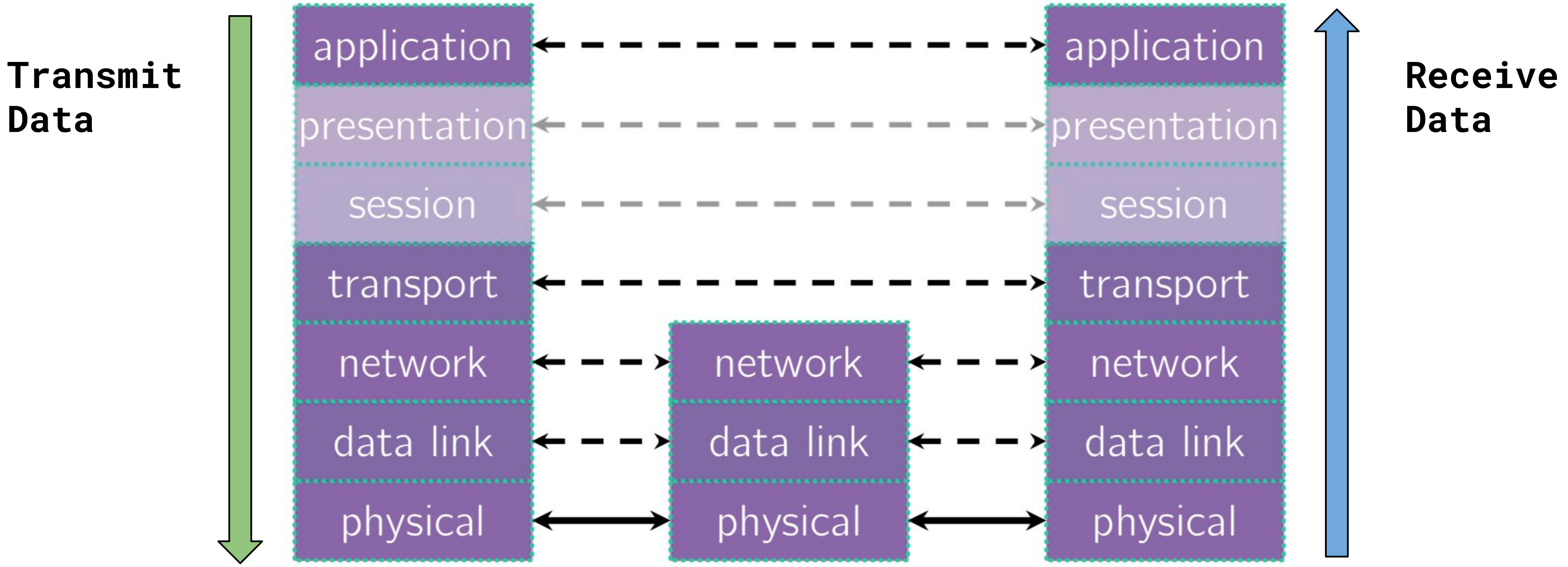
bit encoding at signal level



Packet encapsulation



Data flow



Transmit
Data
application
presentation
session
transport
network
data link
physical
network
data link
physical
application
presentation
session
transport
network
data link
physical
Receive
Data

Exercise 1

Exercise 1

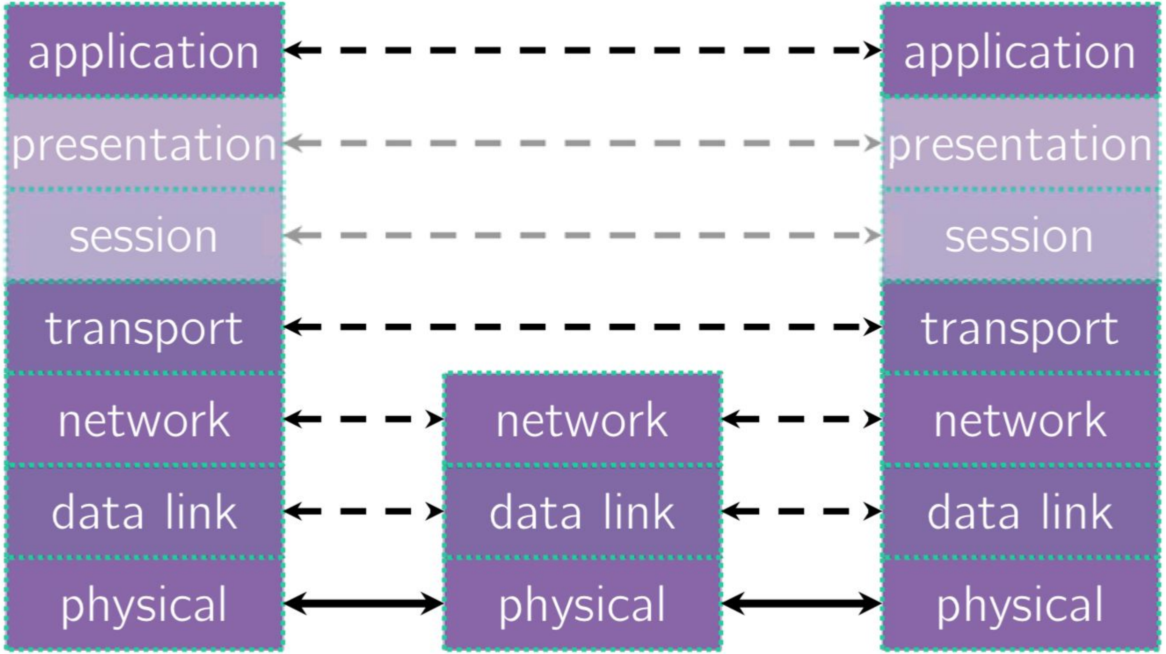
format/meaning of messages

sending data end-to-end

routing of packets across networks

multiple computers on a local network

bit encoding at signal level



Exercise 1

Vote in Zoom!

yes = application layer

no = transport layer

go slower = network layer

go faster = link layer

- 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)

TCP versus UDP

Transmission Control Protocol(TCP)

- Connection oriented Service
- Reliable and Ordered
- Flow control

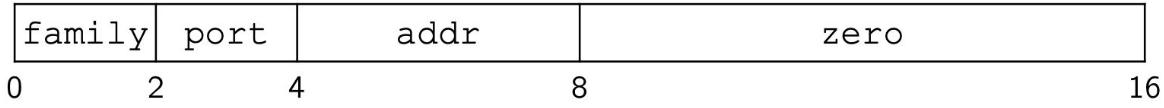
User Datagram Protocol(UDP)

- Connectionless service
- Unreliable packet delivery
- Faster
- No feedback

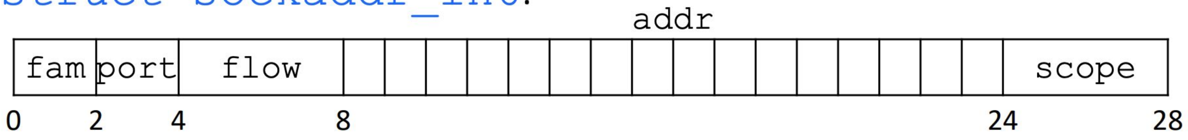
Sockets

- Just a file descriptor for network communication
  - processes communicate with the outside through I/O operations
  - sockets API enables access to the TCP/UDP transport protocol
  - transport protocol provides abstraction of processes over network
- 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)

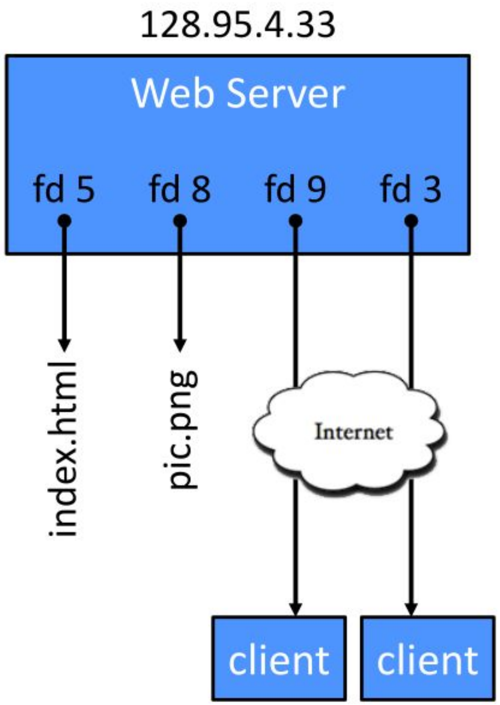
`struct sockaddr_in`:



`struct sockaddr_in6`:



File Descriptor Table



OS's File Descriptor Table for the Process

File Descriptor	Type	Connection
0	pipe	stdin (console)
1	pipe	stdout (console)
2	pipe	stderr (console)
3	TCP socket	local: 128.95.4.33:80 remote: 44.1.19.32:7113
5	file	index.html
8	file	pic.png
9	TCP socket	local: 128.95.4.33:80 remote: 102.12.3.4:5544

Sockets/Address

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

fam	????

....

struct sockaddr_in (IPv4)

fam	port	addr	zero

16

struct sockaddr_in6 (IPv6)

fam	port	flow	addr	scope

28

struct sockaddr_storage

fam	

Big enough to hold either

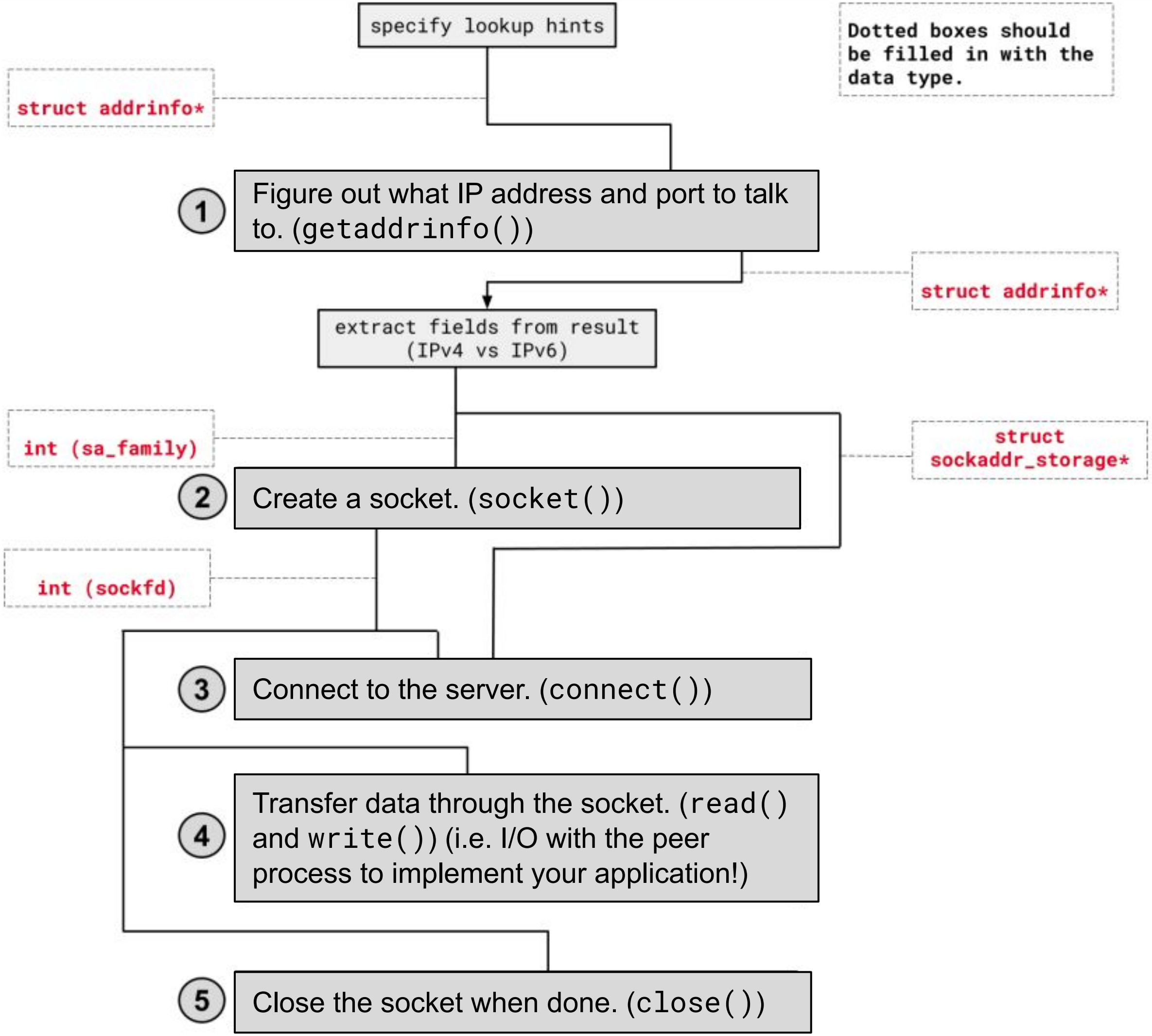
Byte Ordering and Endianness

- **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

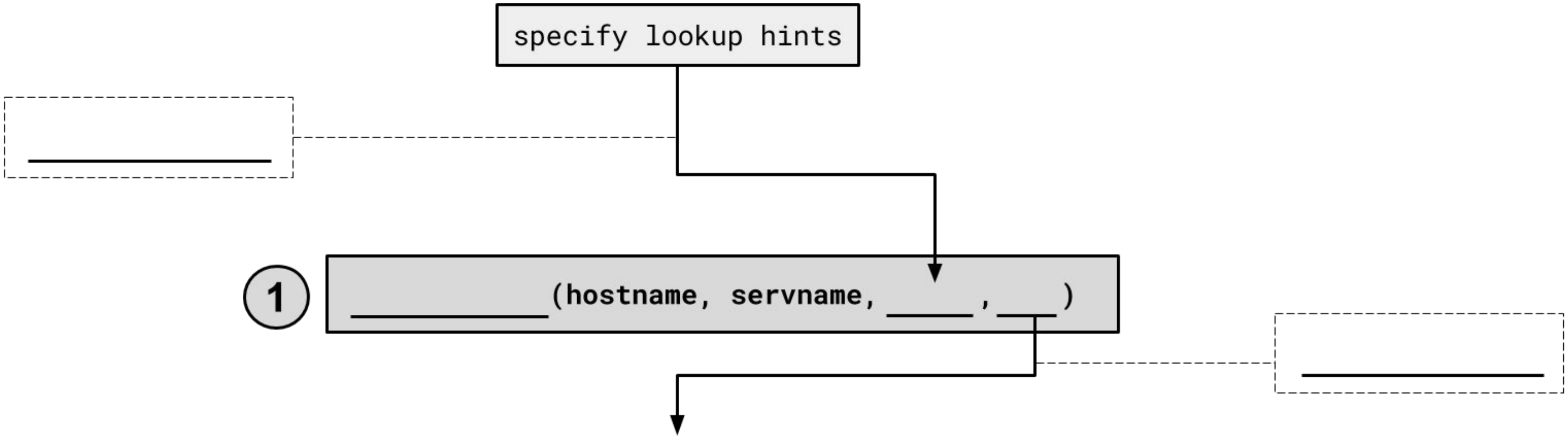
```
- uint16_t htons (uint16_t hostlong);
- uint16_t ntohs (uint16_t hostlong);

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

Exercise 2

client-side example



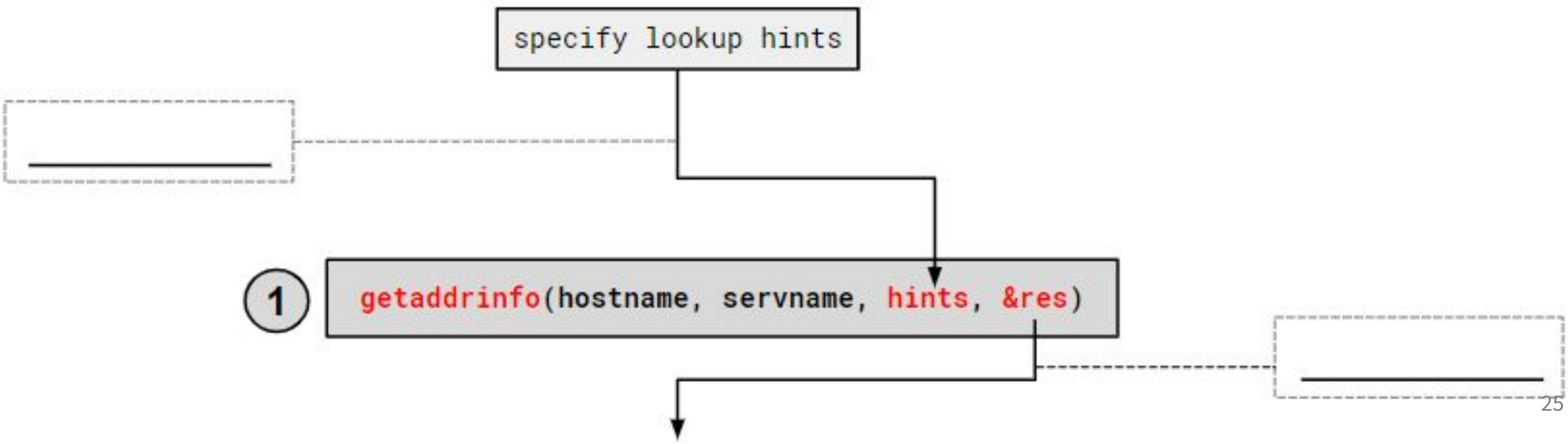
1.



1. getaddrinfo()

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

- Performs a **DNS Lookup** for a hostname



1. getaddrinfo()

```
int getaddrinfo(const char *hostname,
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```
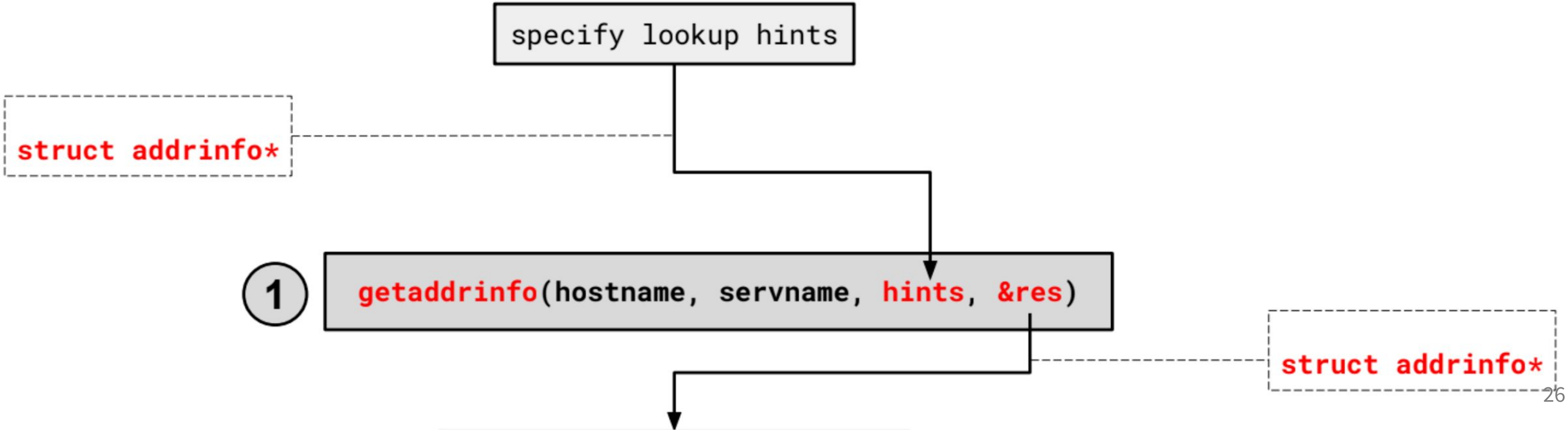

- Performs a **DNS Lookup** for a hostname
- Use "hints" to specify constraints (`struct addrinfo *`)
- Get back a linked list of `struct addrinfo` results



Network Addresses

- For IPv4, an IP address is a 4-byte tuple
  - e.g., 128.95.4.1 (80:5f:04:01 in hex)

- For IPv6, an IP address is a 16-byte tuple
  - e.g., 2d01:0db8:f188:0000:0000:0000:0000:1f33
  - 2d01:0db8:f188::1f33 in shorthand

DNS – Domain Name System/Service

- A hierarchical distributed naming system any resource connected to the Internet or a private network.

- Resolves queries for names into IP addresses.

- The sockets API lets you convert between the two.
  - Aside: getnameinfo() is the inverse of getaddrinfo()

- Is on the application layer on the Internet protocol suite.

- POSIX form of resolving DNS names is **getaddrinfo()**
  - dig +trace attu.cs.washington.edu shown later

1. getaddrinfo() - Interpreting Results

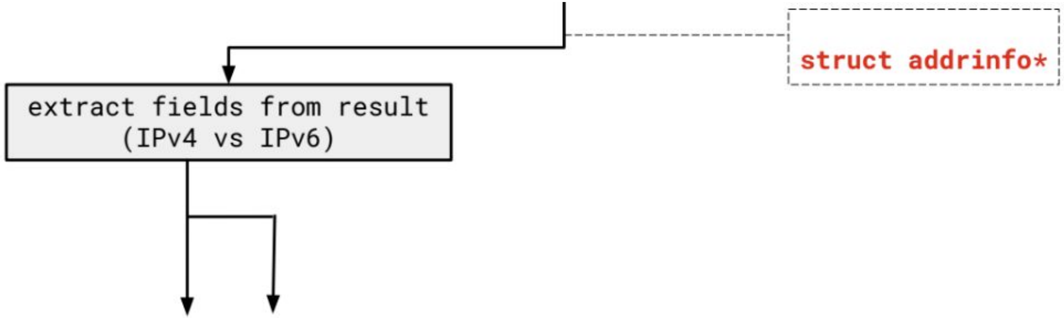
```
struct addrinfo {
    int ai_flags; // additional flags
    int ai_family; // AF_INET, AF_INET6, AF_UNSPEC
    int ai_socktype; // SOCK_STREAM, SOCK_DGRAM, 0
    int ai_protocol; // IPPROTO_TCP, IPPROTO_UDP, 0
    size_t ai_addrlen; // length of socket addr in bytes
    struct sockaddr* ai_addr; // 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

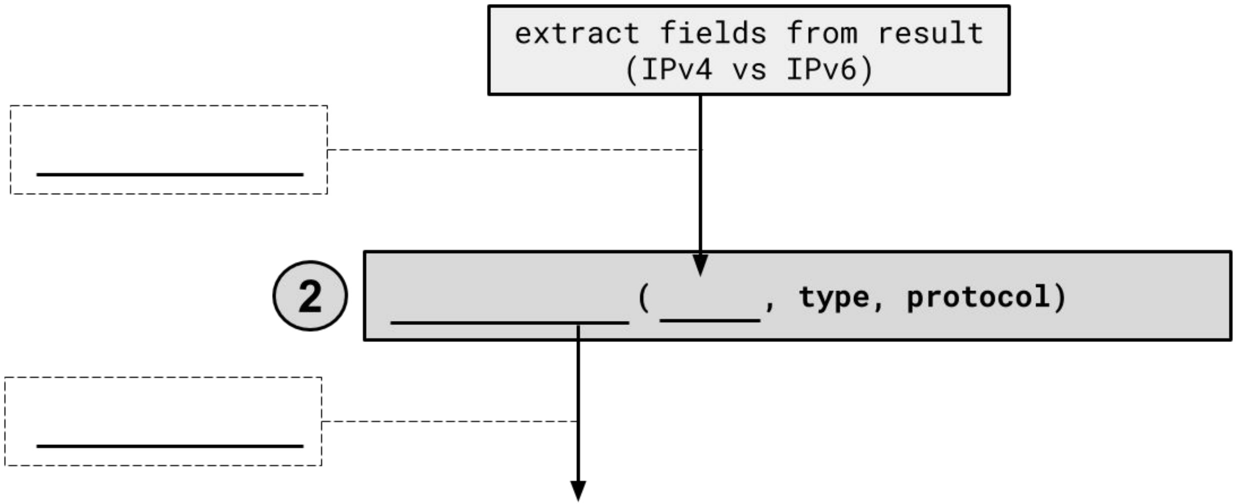
1. getaddrinfo() - Interpreting Results

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



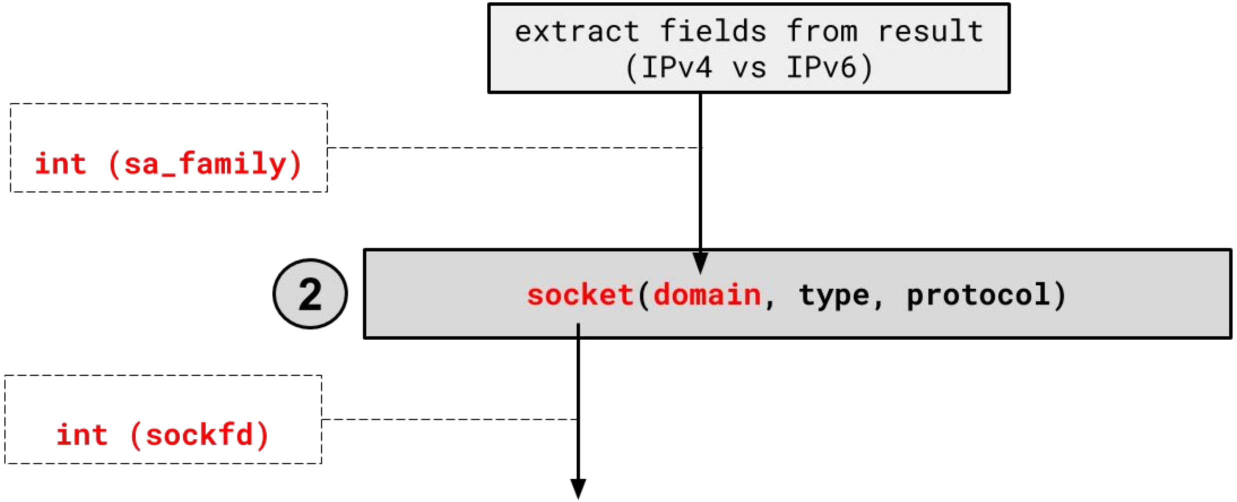
2.



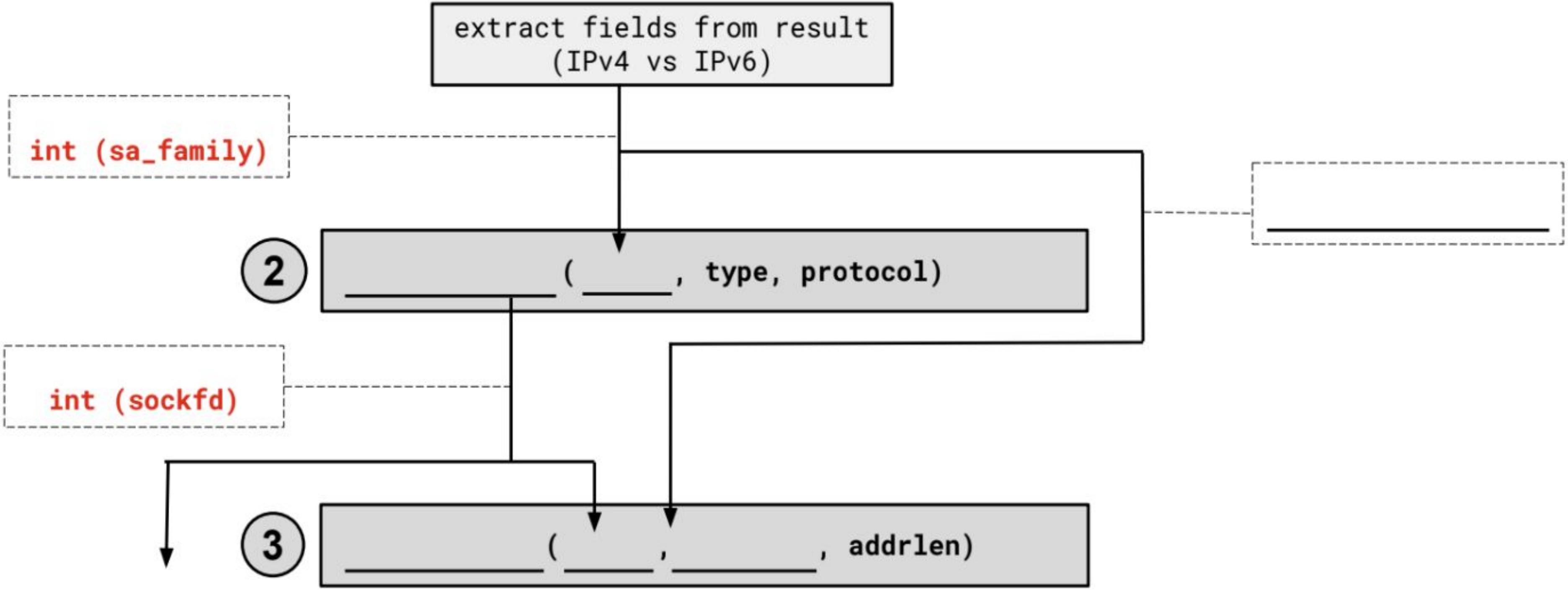
2. socket()

```
int socket(int domain,      // AF_INET, AF_INET6
           int type,        // SOCK_STREAM (TCP)
           int protocol);   // 0
```

- Creates a "raw" socket, ready to be bound
- Returns file descriptor (`sockfd`) on success, `-1` on failure



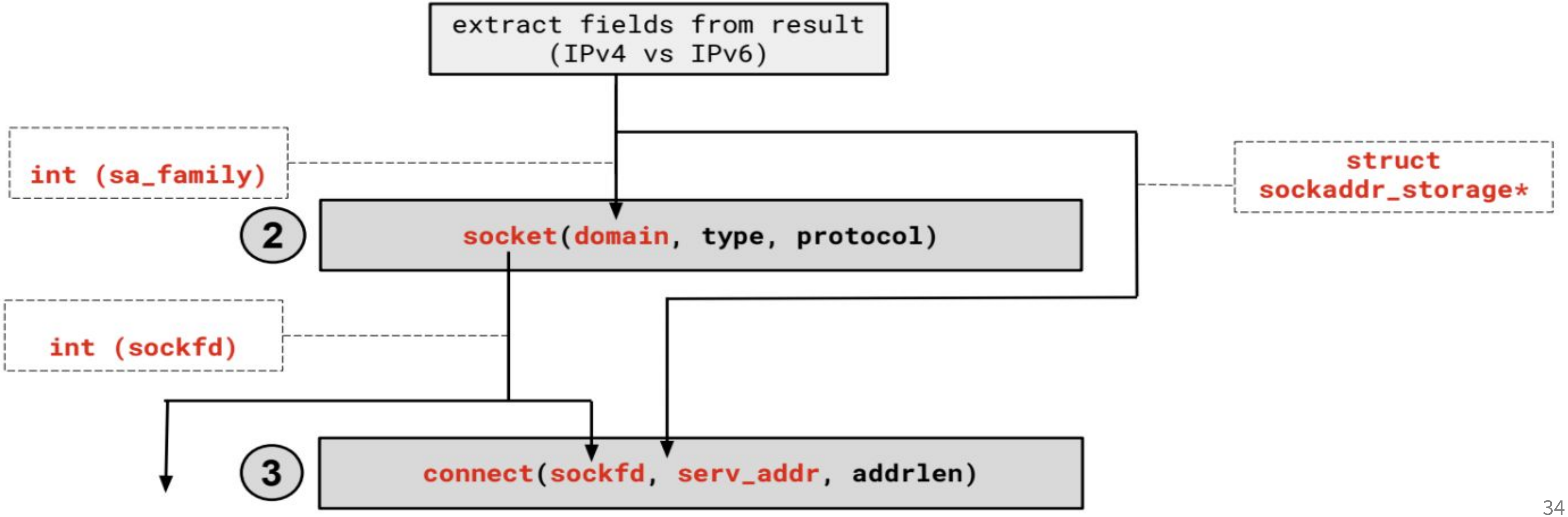
3.


extract fields from result (IPv4 vs IPv6)
int (sa_family)
2
(____, type, protocol)
int (sockfd)
3
(____, ________, addrlen)

3. connect()

```
int connect  (int sockfd,              // from 2
              const struct sockaddr *serv_addr, // from 1
              socklen_t addrlen) ;      // size of serv_addr
```

- Connects an available socket to a specified address
- Returns 0 on success, -1 on failure



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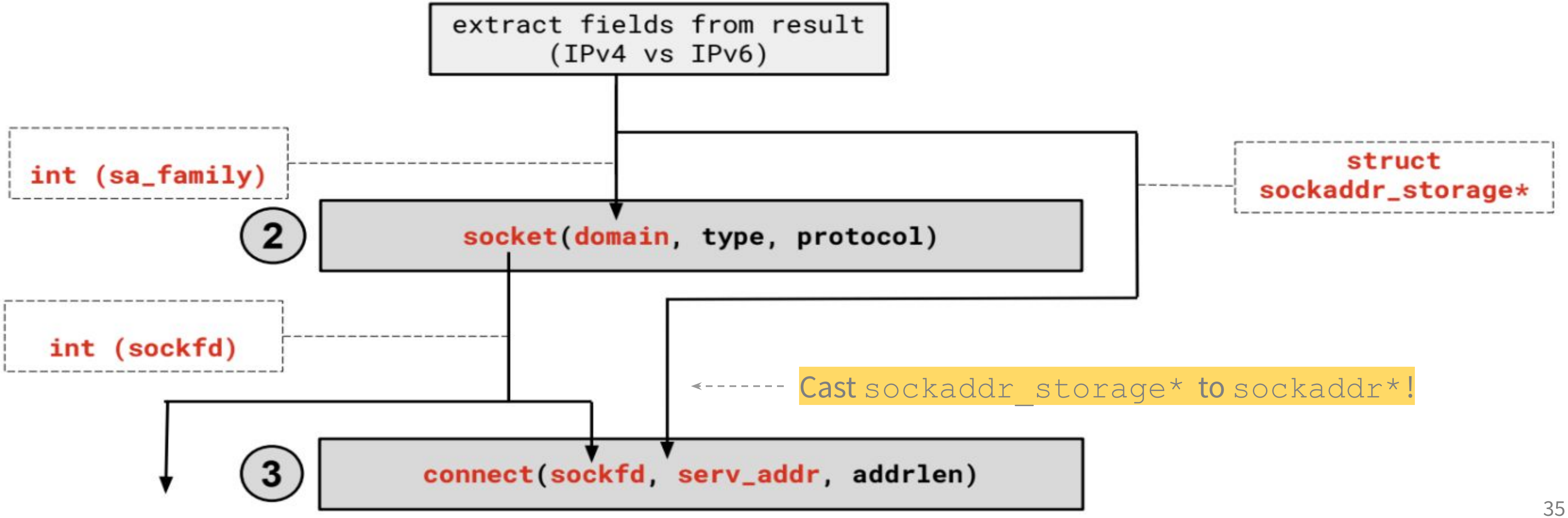

4. read/write and 5. close

- Thanks to the file descriptor abstraction, use as normal!
- `read` from and `write` to a buffer, the OS will take care of sending/receiving data across the network
- Make sure to `close` the fd afterward