CIT 5950

Recitation 10

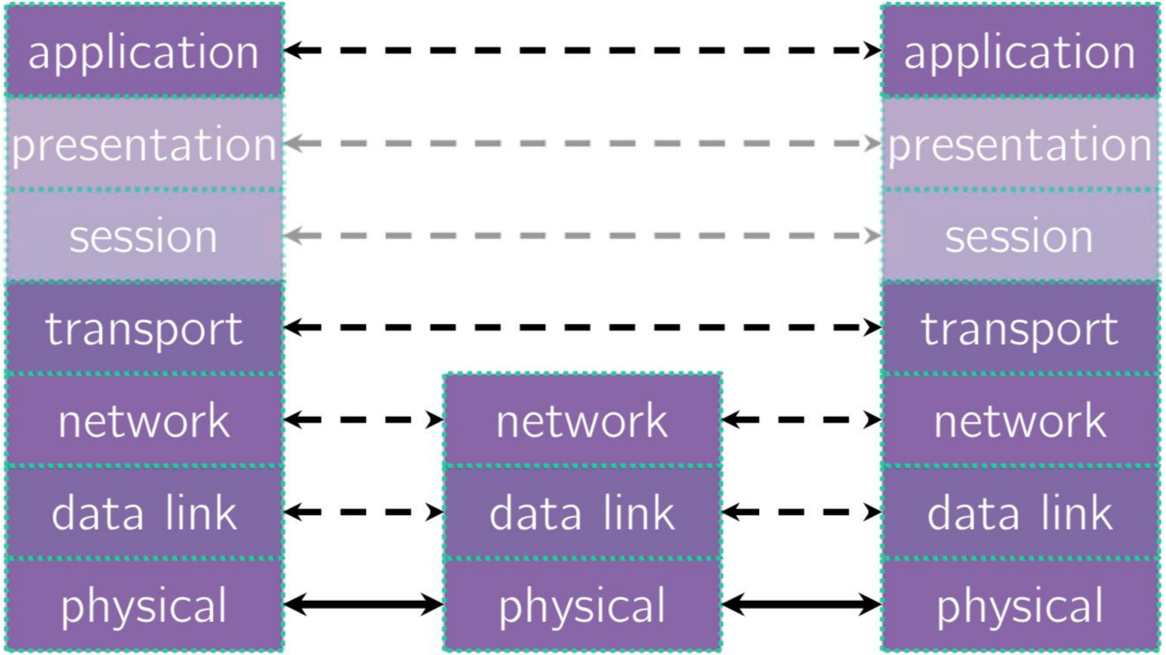
Intro to Networking & Sockets

Logistics

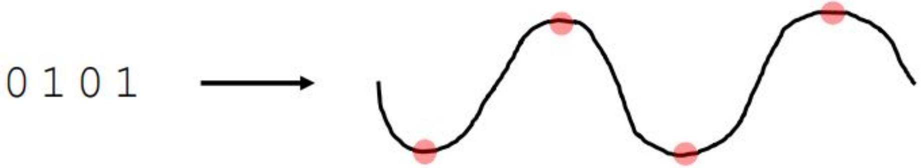
- Recommended due date for HW3: Monday, April 3rd, 11:59PM
- Please start ASAP

Networking - At a High Level

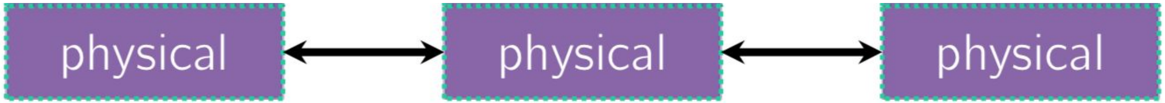
Computer Networks: A 7-ish Layer Cake



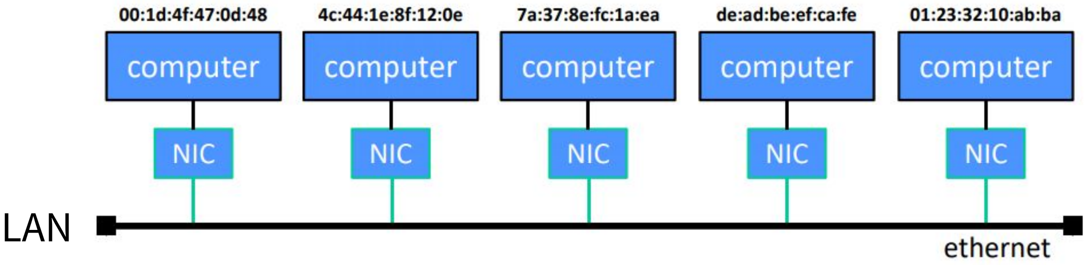
Computer Networks: A 7-ish Layer Cake



bit encoding at signal level

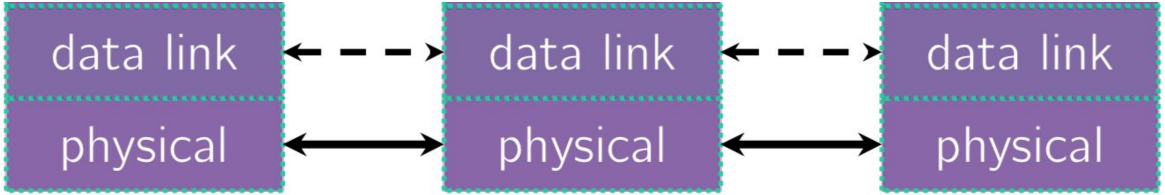


Computer Networks: A 7-ish Layer Cake

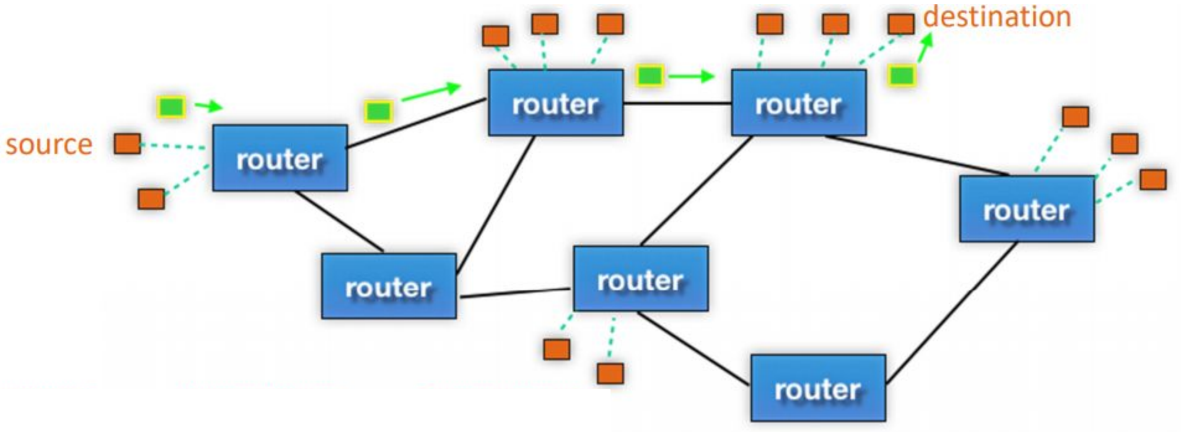


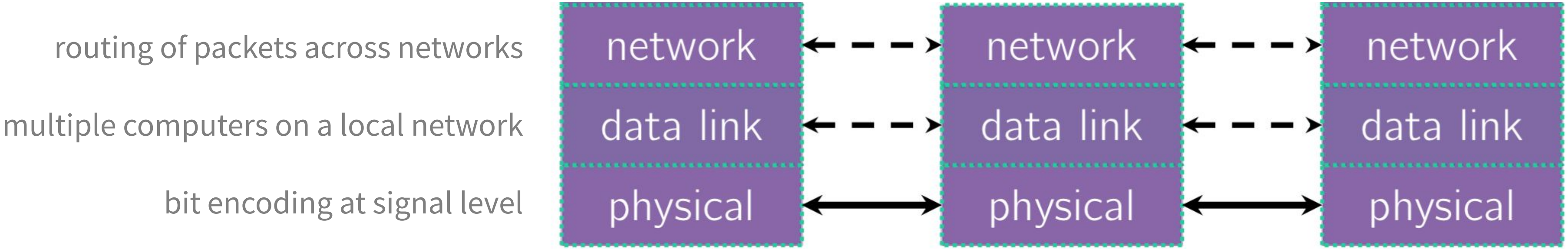
multiple computers on a local network

bit encoding at signal level



Computer Networks: A 7-ish Layer Cake



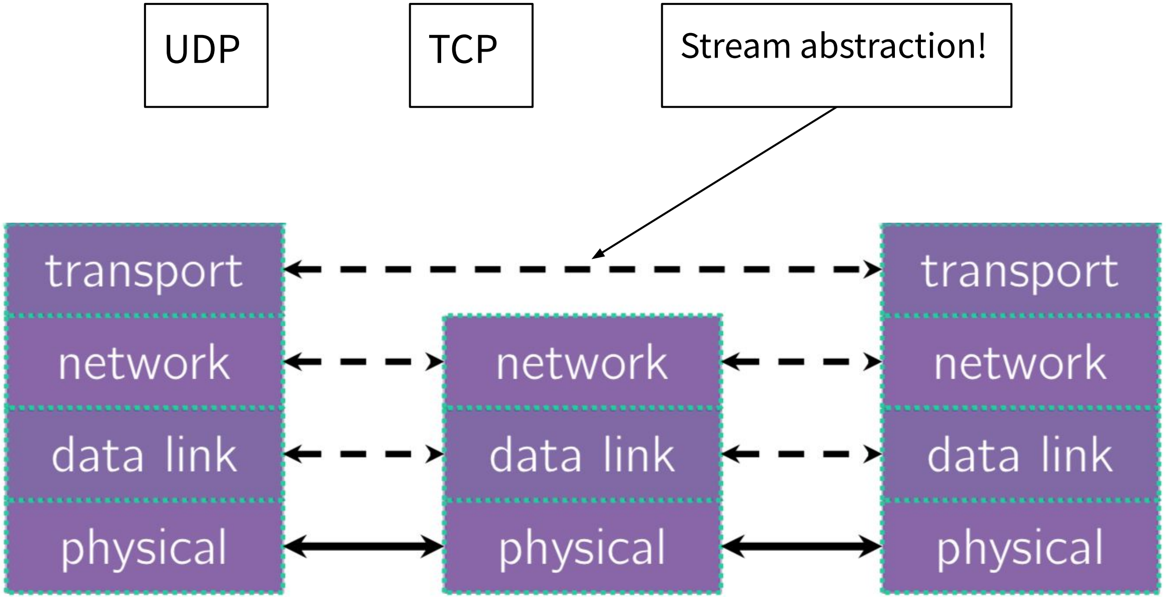


routing of packets across networks — network ↔ network ↔ network

multiple computers on a local network — data link ↔ data link ↔ data link

bit encoding at signal level — physical ↔ physical ↔ physical

Computer Networks: A 7-ish Layer Cake



UDP

TCP

Stream abstraction!

sending data end-to-end

routing of packets across networks

multiple computers on a local network

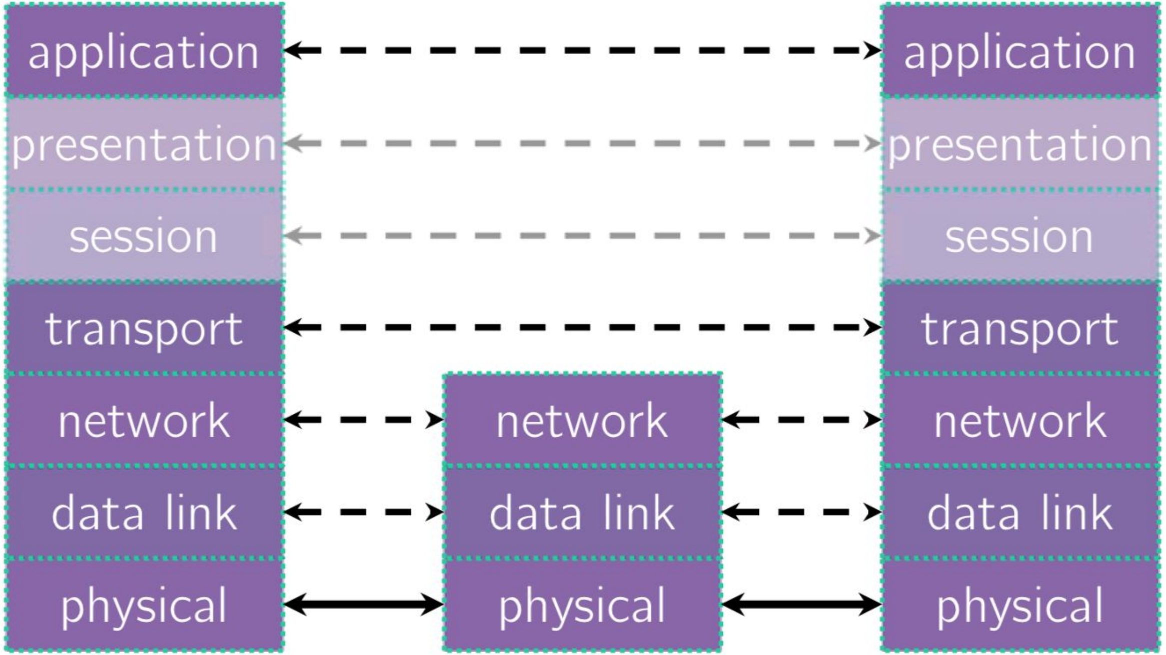
bit encoding at signal level

Computer Networks: A 7-ish Layer Cake

HTTP

DNS

NETFLIX



application ↔ application

presentation ↔ presentation

session ↔ session

transport ↔ transport

network ↔ network ↔ network

data link ↔ data link ↔ data link

physical ↔ physical ↔ physical

format/meaning of messages

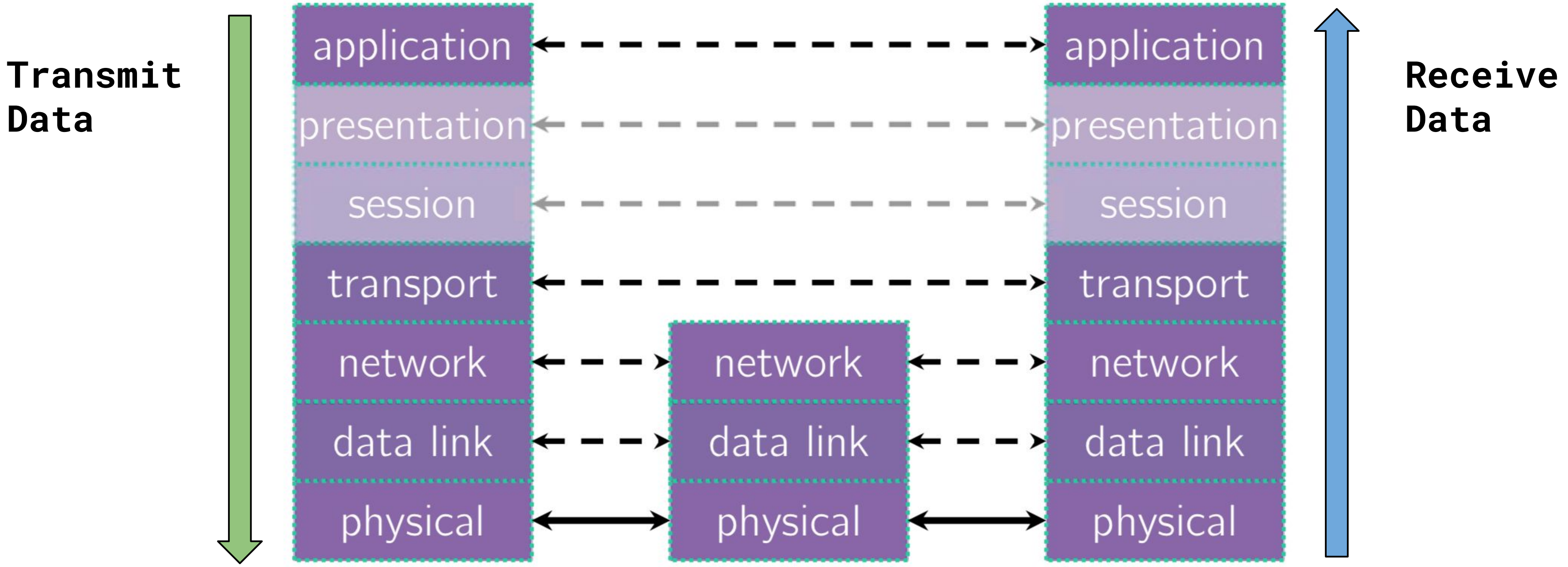
sending data end-to-end

routing of packets across networks

multiple computers on a local network

bit encoding at signal level

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

What are the following protocols used for?

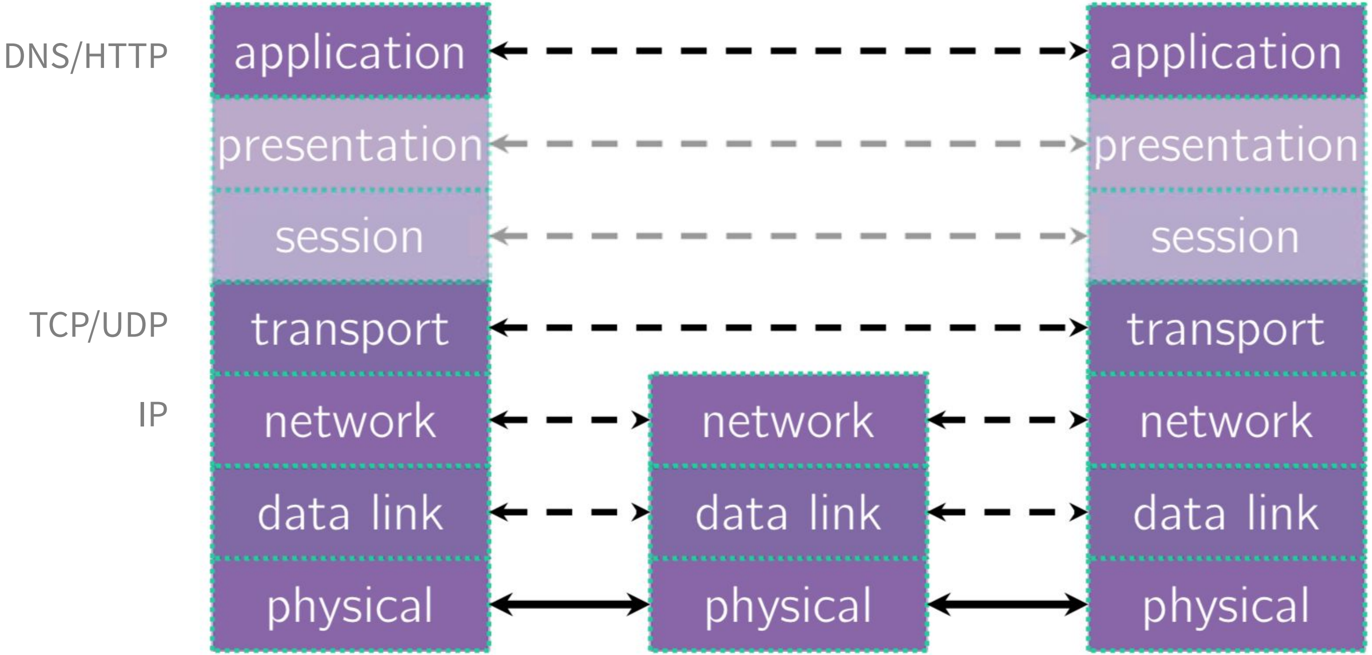
- DNS:
- IP:
- TCP:
- UDP:
- HTTP:

Bonus: In what layer of the networking stack are they found?

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


DNS/HTTP
TCP/UDP
IP
application
presentation
session
transport
network
data link
physical
network
data link
physical
application
presentation
session
transport
network
data link
physical

TCP versus UDP

Transmission Control Protocol(TCP)

- Connection oriented Service
- Reliable and Ordered
- Flow control

User Datagram Protocol(UDP)

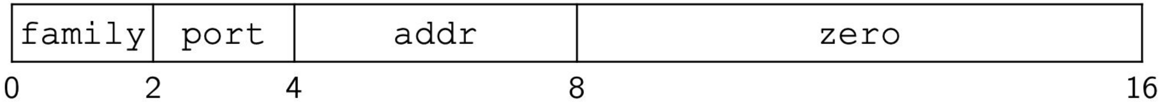
- Connectionless service
- Unreliable packet delivery
- Faster
- No feedback

Client-side Networking

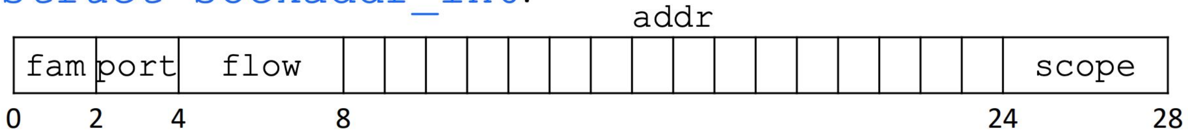
Sockets

- 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`:

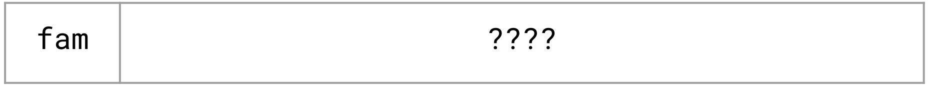


`struct sockaddr_in6`:



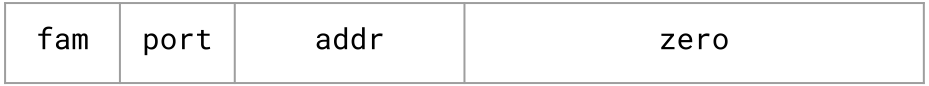
Sockets

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



....

struct sockaddr_in (IPv4)



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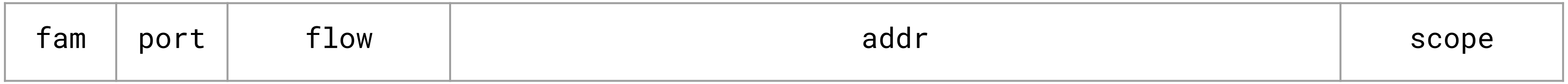
struct sockaddr_in6 (IPv6)



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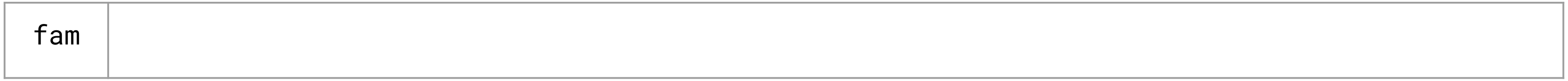
struct sockaddr_storage



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);`

Networking methods

```
// 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);
```

Networking methods

```
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 have linked list of records
}
```

- `ai_addr` points to a `struct sockaddr` describing a socket address, can be IPv4 or IPv6

Networking methods

```
// Creates a socket
// returns file descriptor on success, -1 on failure (errno set)
int socket(int domain,      // AF_INET, AF_INET6, etc.
        int type,           // SOCK_STREAM, SOCK_DGRAM, etc.
        int protocol);      // usually 0
```

```
 // Connects to the server
 // returns 0 on success, -1 on failure (errno set)
 int connect(int sockfd,                  // socket file descriptor
          struct sockaddr *serv_addr,     // socket addr of server
          socklen_t addrlen);             // size of serv_addr
```

Networking methods

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

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

// returns 0 for success, -1 on failure (errno set)
int close(int fd);
```

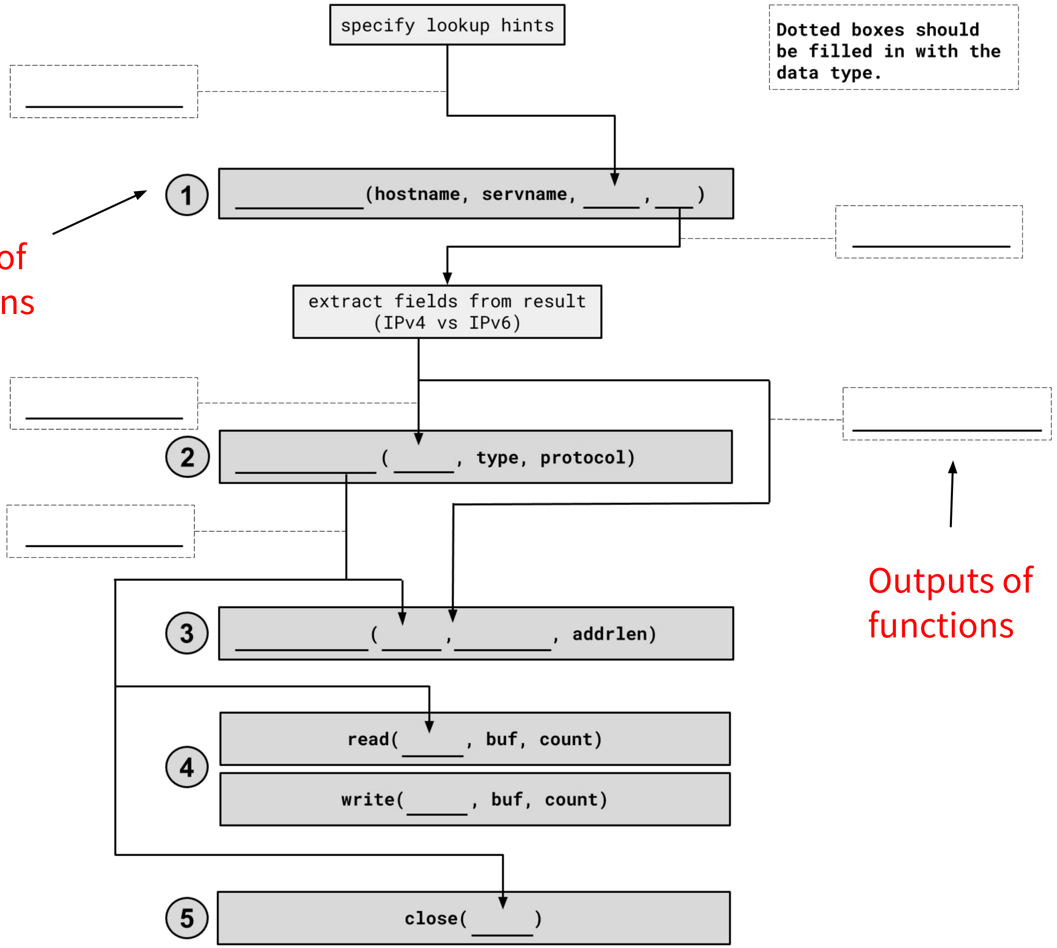
- Same POSIX methods we used for file I/O!
  (so they require the same error checking...)

Exercise 2

This diagram depicts the basic skeleton of a C++ program for client-side networking, with arrows representing the flow of data between them.

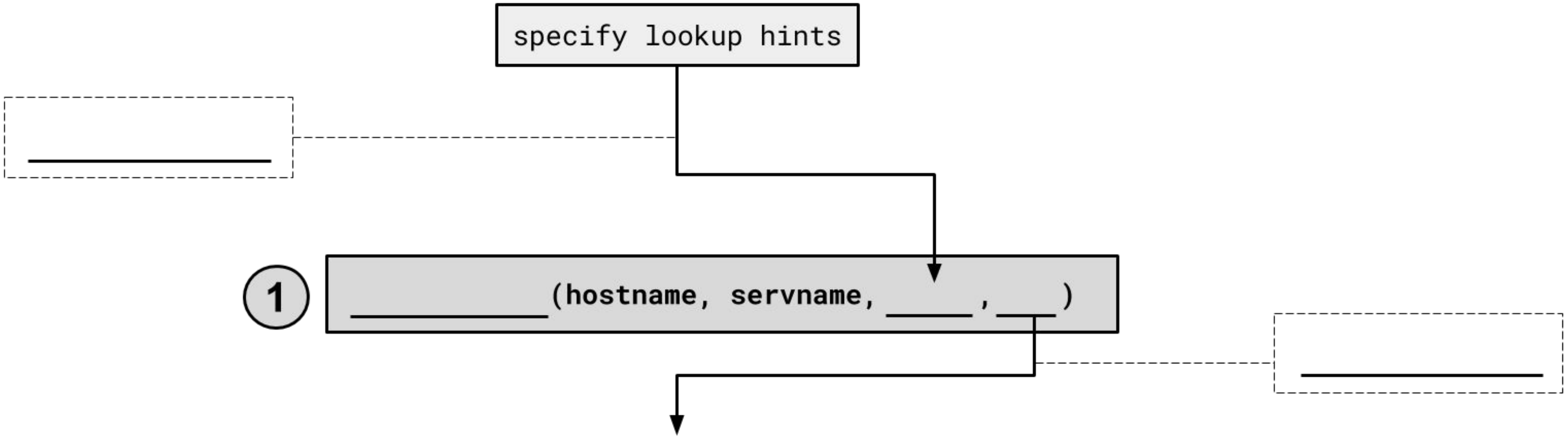
Fill in the names of the functions being called, and the arguments being passed.

Then, **for each arrow in the diagram, fill in the type and/or data that it represents.**



specify lookup hints
Dotted boxes should be filled in with the data type.
Inputs of functions
1
__________(hostname, servname, _____, ___)
extract fields from result (IPv4 vs IPv6)
2
__________(_____, type, protocol)
Outputs of functions
3
__________(_____, _________, addrlen)
4
read(______, buf, count)
write(______, buf, count)
5
close(______)

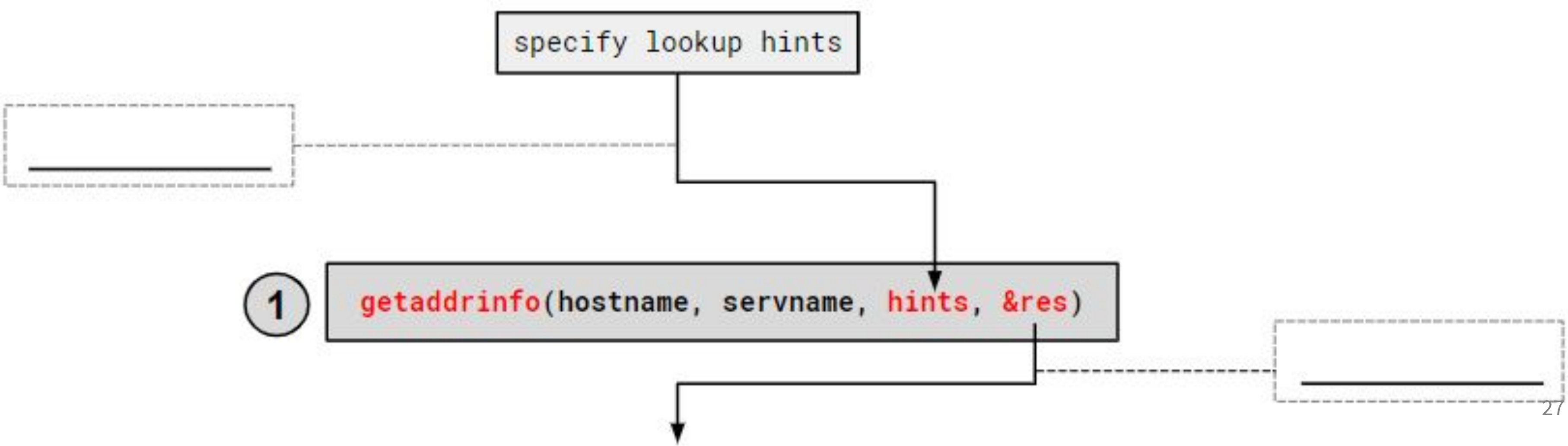
1.



1. getaddrinfo()

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

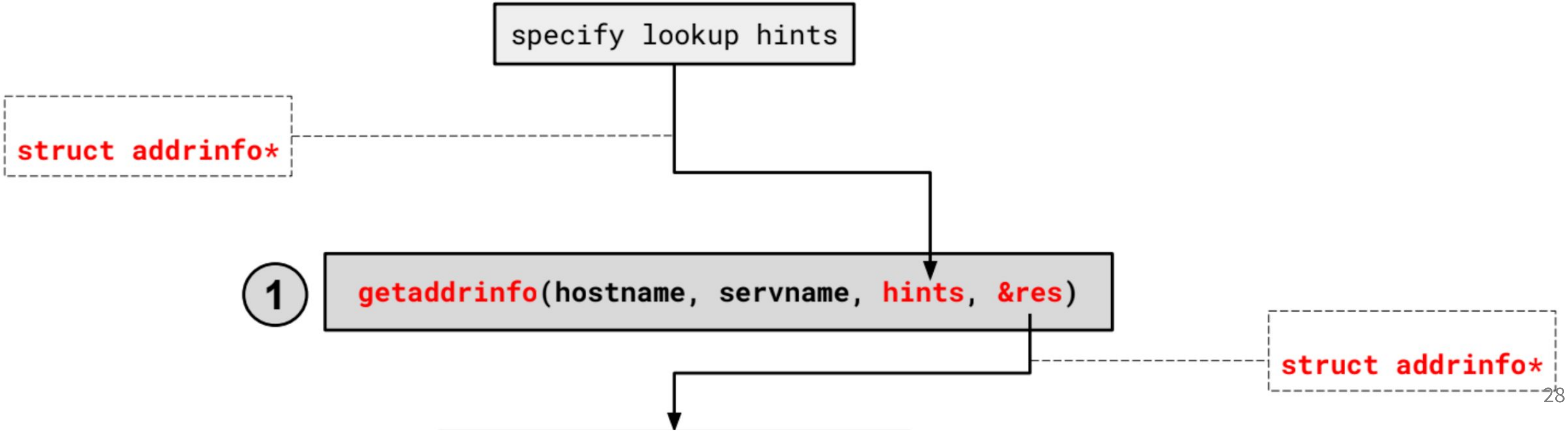
- Performs a **DNS Lookup** for a hostname



1. getaddrinfo()

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

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



1. getaddrinfo() - Interpreting Results

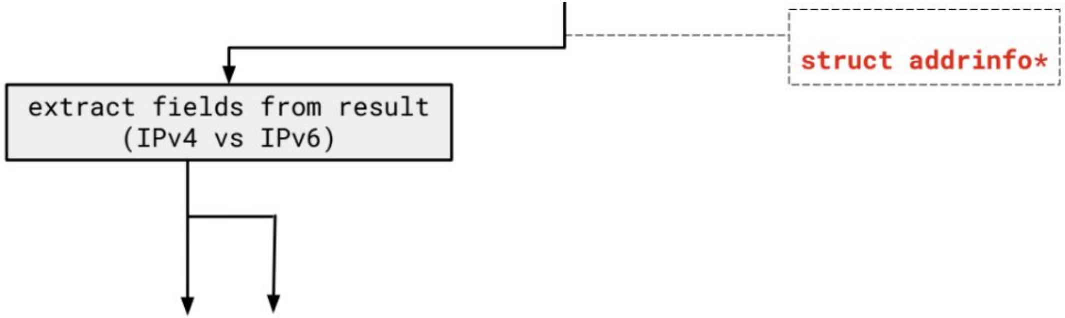
```
struct addrinfo {
    int ai_flags; // additional flags
    int ai_family; // AF_INET, AF_INET6, AF_UNSPEC
    int ai_socktype; // SOCK_STREAM, SOCK_DGRAM, 0
    int ai_protocol; // IPPROTO_TCP, IPPROTO_UDP, 0
    size_t ai_addrlen; // length of socket addr in bytes
    struct sockaddr* ai_addr;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

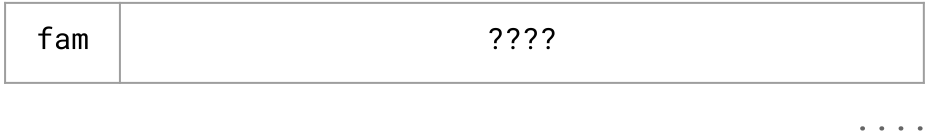
With a `struct sockaddr*`:

- 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

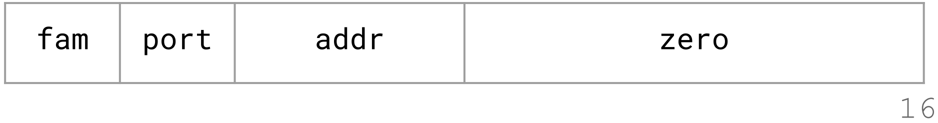


1. getaddrinfo() - Interpreting Results

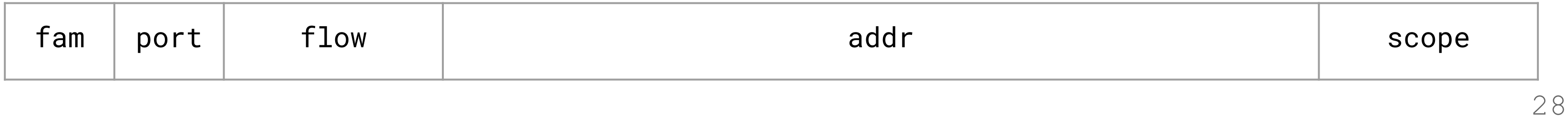
struct sockaddr (pointer to this struct is used as parameter type in system calls)



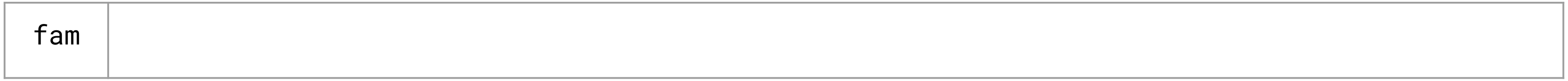
struct sockaddr_in (IPv4)



struct sockaddr_in6 (IPv6)

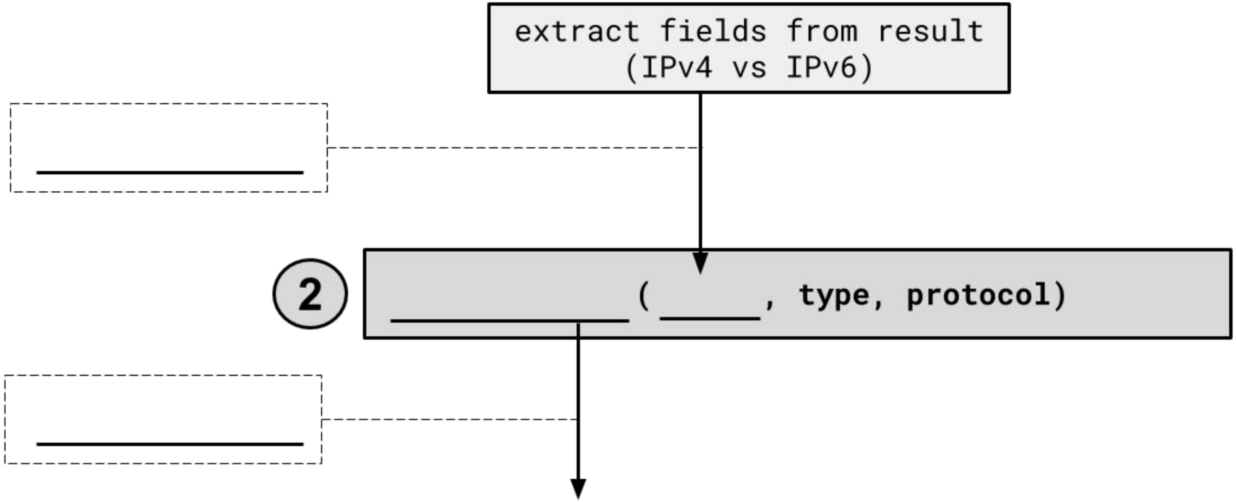


struct sockaddr_storage



Big enough to hold either

2.

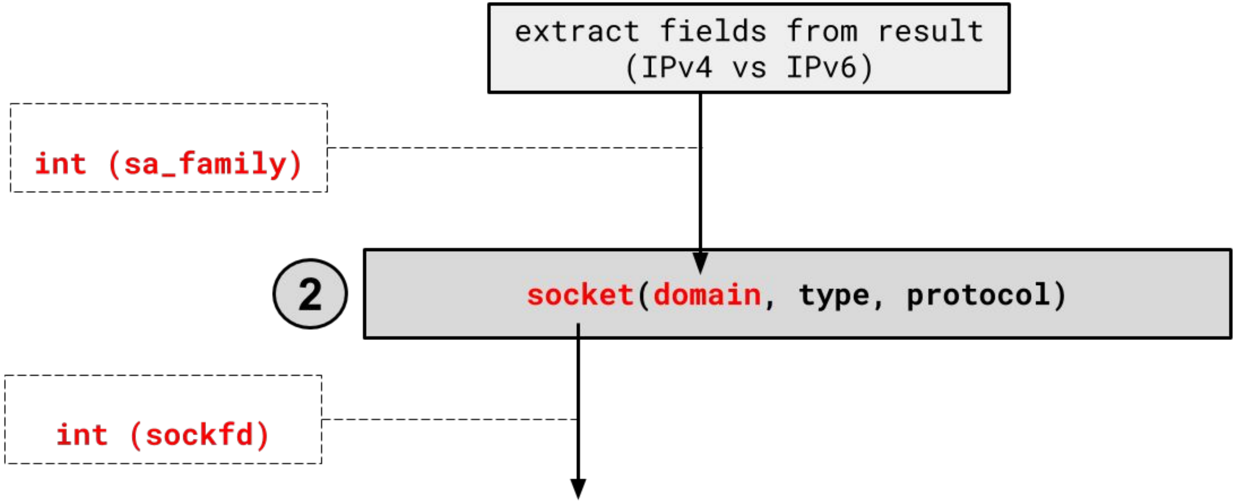


extract fields from result
(IPv4 vs IPv6)
2
______________(______, type, protocol)

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



extract fields from result
(IPv4 vs IPv6)

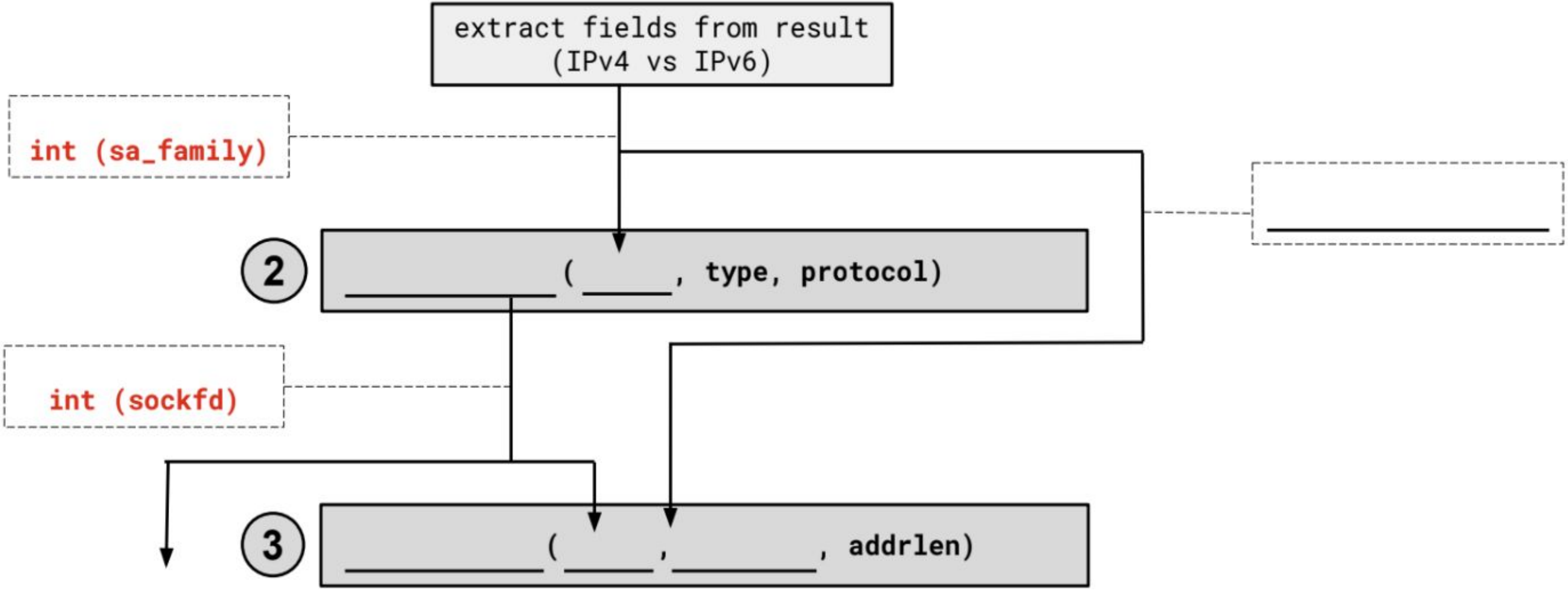
int (sa_family)

2

socket(domain, type, protocol)

int (sockfd)

3.

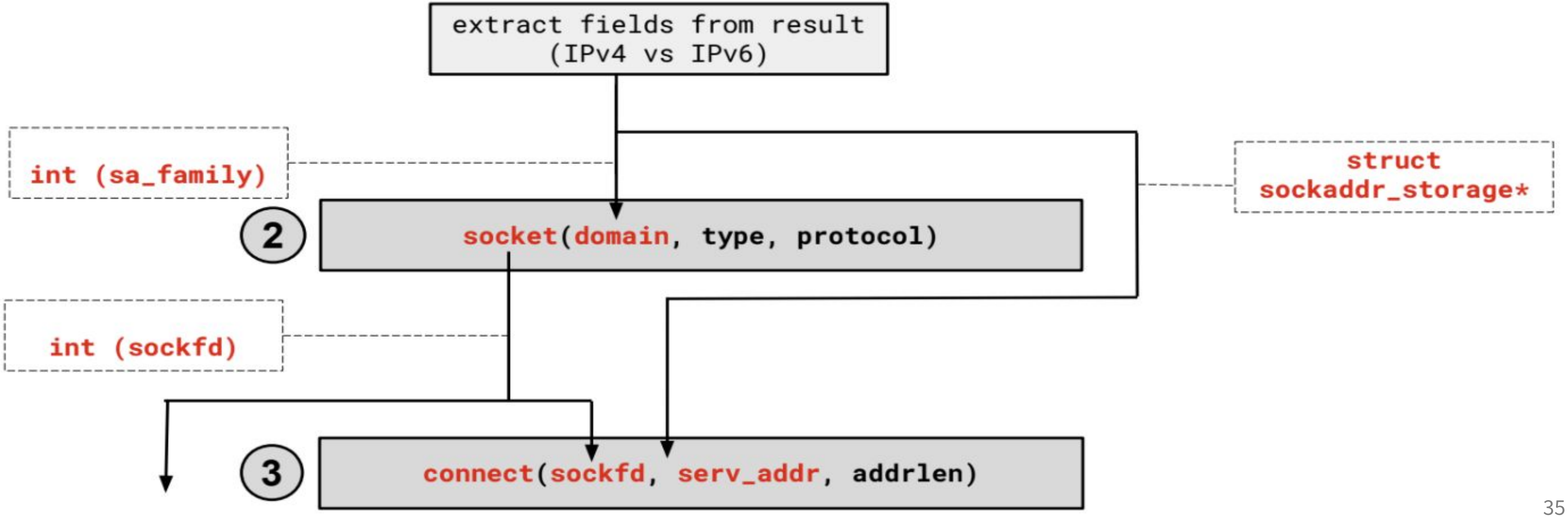


extract fields from result (IPv4 vs IPv6)
int (sa_family)
2
__________(_____, type, protocol)
____
int (sockfd)
3
__________(_____,_________, addrlen)

3. connect()

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

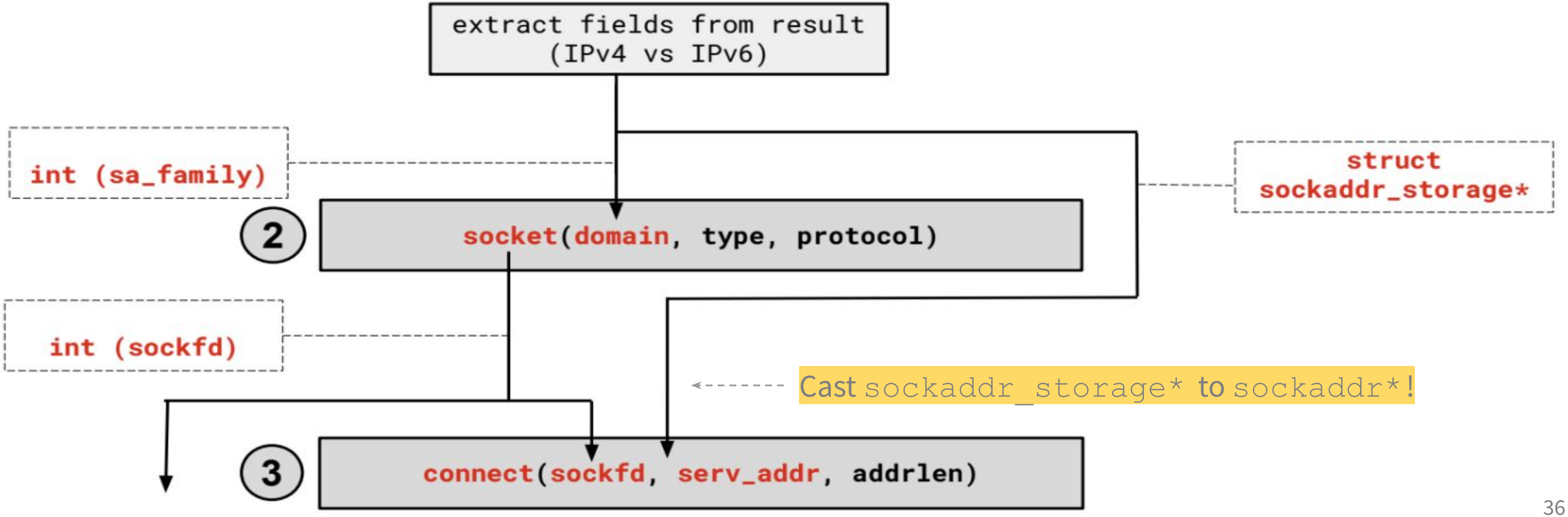
- Connects an available socket to a specified address
- Returns 0 on success, -1 on failure


extract fields from result
(IPv4 vs IPv6)
int (sa_family)
struct
sockaddr_storage*
2
socket(domain, type, protocol)
int (sockfd)
3
connect(sockfd, serv_addr, addrlen)

3. connect()

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

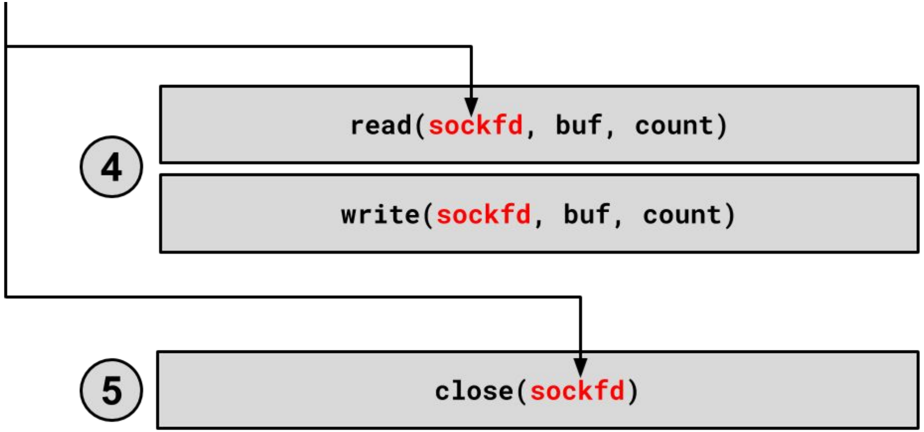
- Connects an available socket to a specified address
- Returns 0 on success, -1 on failure

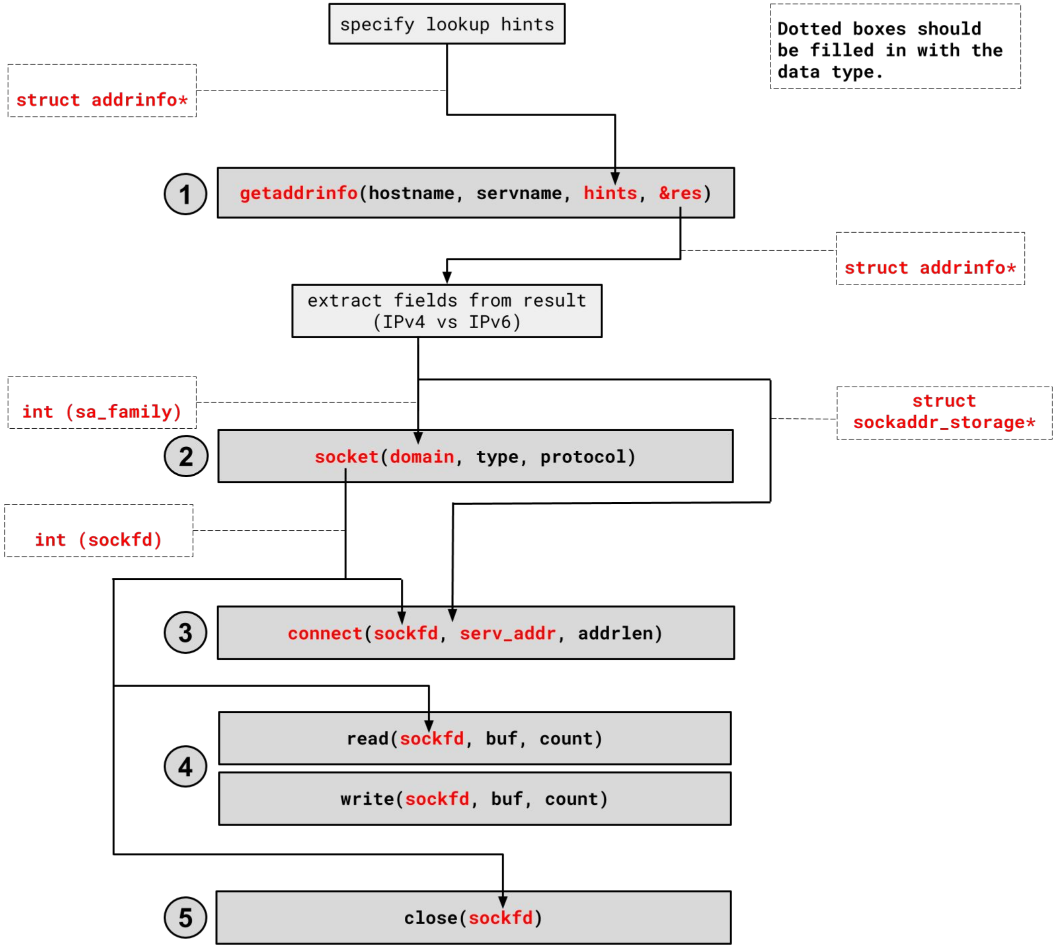

extract fields from result
(IPv4 vs IPv6)
int (sa_family)
struct sockaddr_storage*
2
socket(domain, type, protocol)
int (sockfd)
3
connect(sockfd, serv_addr, addrlen)

Cast `sockaddr_storage*` to `sockaddr*`!

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





Dotted boxes should be filled in with the data type.

specify lookup hints

struct addrinfo*

1 getaddrinfo(hostname, servname, hints, &res)

struct addrinfo*

extract fields from result (IPv4 vs IPv6)

int (sa_family)

struct sockaddr_storage*

2 socket(domain, type, protocol)

int (sockfd)

3 connect(sockfd, serv_addr, addrlen)

4 read(sockfd, buf, count)

write(sockfd, buf, count)

5 close(sockfd)