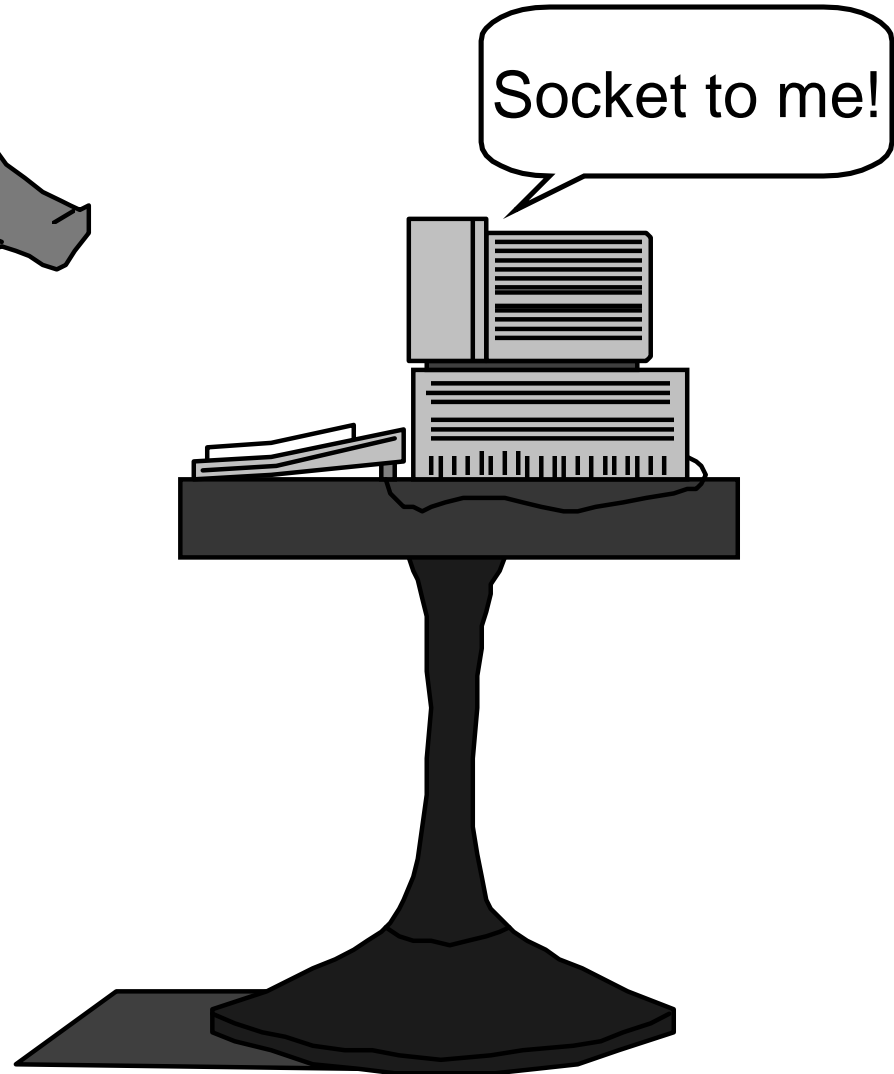
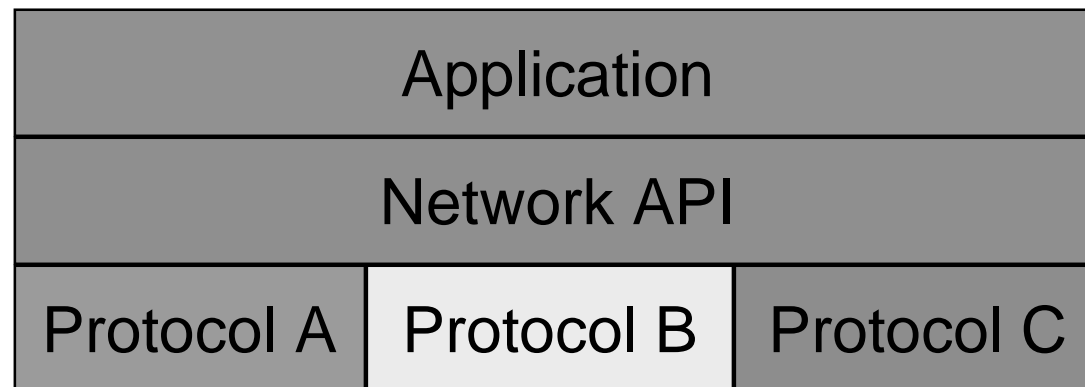


Sockets Programming



Network Application Programming Interface (API)

- The services provided by the operating system that provide the interface between application and protocol software.



Network API

- Generic Programming Interface.
- Support for message oriented and connection oriented communication.
- Work with existing I/O services (when this makes sense).
- Operating System independence.

Generic Programming Interface

- Support multiple communication protocol suites (families).
- Address (endpoint) representation independence.
- Provide special services for Client and Server?

TCP/IP

- TCP/IP does not include an API definition.
- There are a variety of APIs for use with TCP/IP:
 - Sockets
 - TLI, XTI
 - Winsock
 - MacTCP

Functions needed:

- Specify local and remote communication endpoints
- Initiate a connection
- Wait for incoming connection
- Send and receive data
- Terminate a connection gracefully
- Error handling

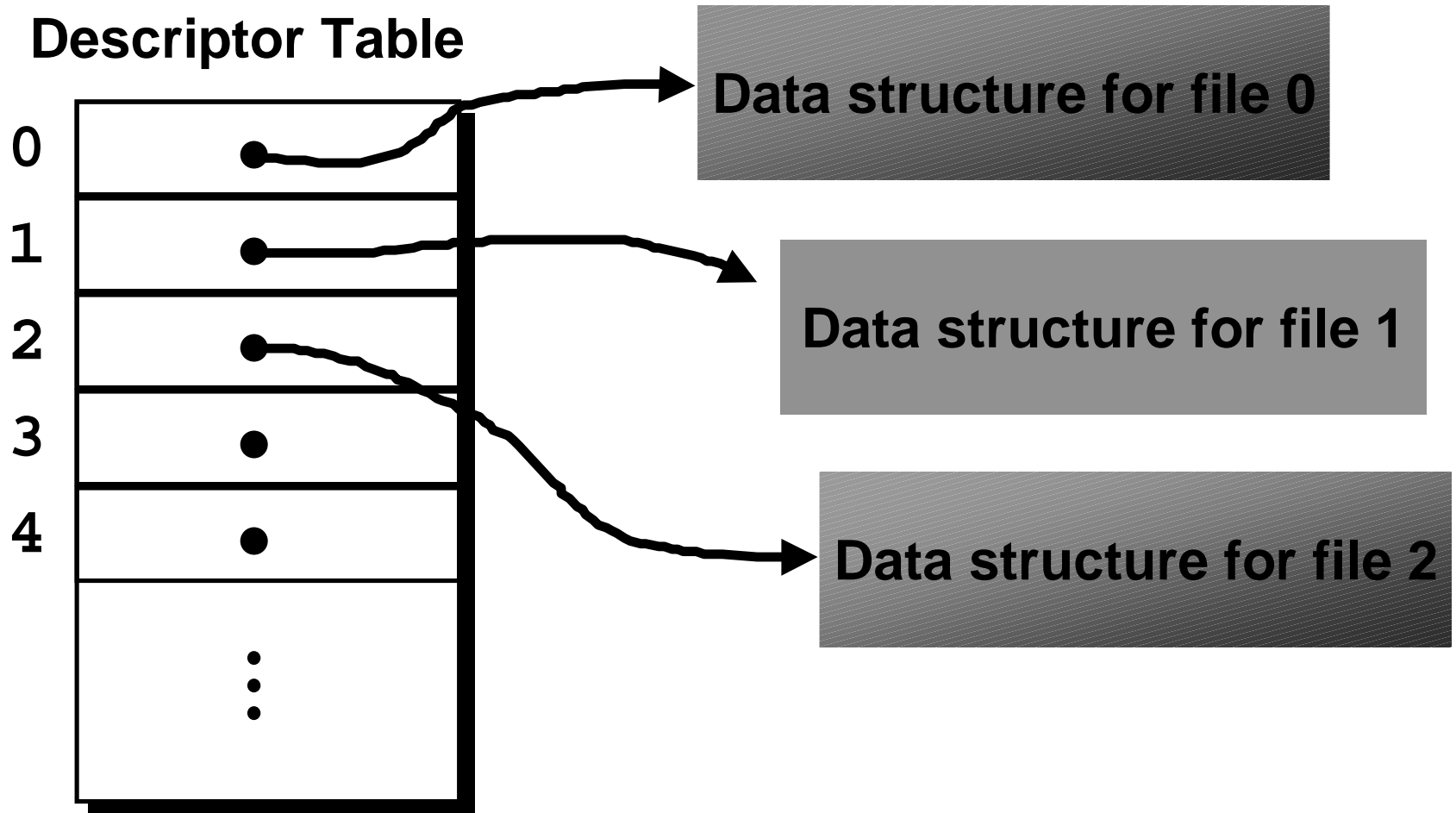
Berkeley Sockets

- Generic:
 - support for multiple protocol families.
 - address representation independence
- Uses existing I/O programming interface as much as possible.

Socket

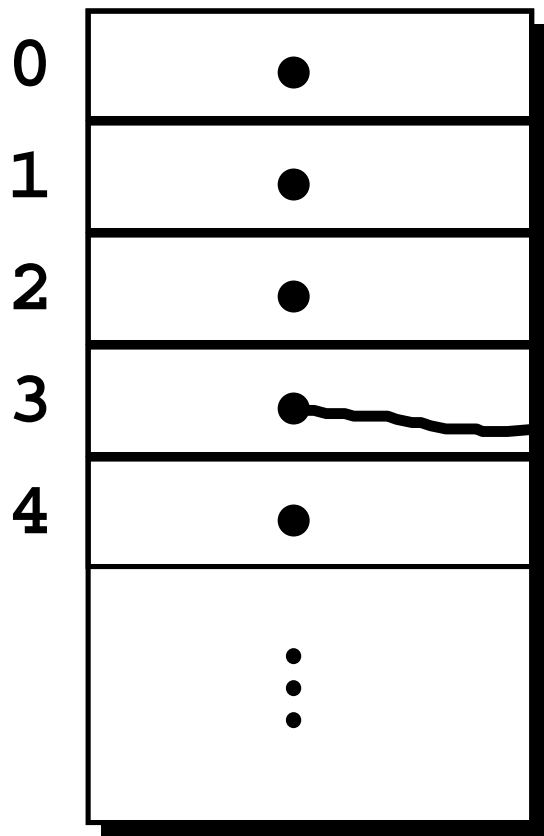
- A socket is an abstract representation of a communication endpoint.
- Sockets work with Unix I/O services just like files, pipes & FIFOs.
- Sockets (obviously) have special needs:
 - establishing a connection
 - specifying communication endpoint addresses

Unix Descriptor Table



Socket Descriptor Data Structure

Descriptor Table



Family: PF_INET
Service: SOCK_STREAM
Local IP: 111.22.3.4
Remote IP: 123.45.6.78
Local Port: 2249
Remote Port: 3726

Creating a Socket

```
int socket(int family,int type,int proto);
```

- `family` specifies the protocol family (PF_INET for TCP/IP).
- `type` specifies the type of service (SOCK_STREAM, SOCK_DGRAM).
- `protocol` specifies the specific protocol (usually 0 which means the default).

socket()

- The socket() system call returns a socket descriptor (small integer) or a -1 on error.
- socket() allocates resources needed for a communication endpoint - but it does not deal with endpoint addressing.

Specifying an Endpoint Address

- Remember that the sockets API is generic.
- There must be a generic way to specify endpoint addresses.
- TCP/IP requires an IP address and a port number for each endpoint address.
- Other protocol suites (families) may use other schemes.

POSIX data types

<code>int8_t</code>	signed 8bit int
<code>uint8_t</code>	unsigned 8 bit int
<code>int16_t</code>	signed 16 bit int
<code>uint16_t</code>	unsigned 16 bit int
<code>int32_t</code>	signed 32 bit int
<code>uint32_t</code>	unsigned 32 bit int

`u_char, u_short, u_int, u_long`

More POSIX data types

<code>sa_family_t</code>	address family
<code>socklen_t</code>	length of struct
<code>in_addr_t</code>	IPv4 address
<code>in_port_t</code>	IP port number

Generic socket addresses

```
struct sockaddr {  
    uint8_t      sa_len;  
    sa_family_t  sa_family;  
    char         sa_data[14];  
};
```

← Used by kernel

- `sa_family` specifies the address type.
- `sa_data` specifies the address value.

sockaddr

- An address that will allow me to use sockets to communicate with my kids.
- address type **AF_DAVESKIDS**
- address values:

Andrea	1	Mom	5
Jeff	2	Dad	6
Robert	3	Dog	7
Emily	4		

AF_DAVESKIDS

- Initializing a sockaddr structure to point to Robert:

```
struct sockaddr robster;
```

```
robster.sa_family = AF_DAVESKIDS;
```

```
robster.sa_data[0] = 3;
```

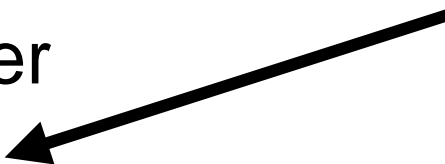
Really old picture! →



AF_INET

- For AF_DAVESKIDS we only needed 1 byte to specify the address.
- For AF_INET we need:
 - 16 bit port number
 - 32 bit IP address

IPv4 only!



struct sockaddr_in (IPv4)

```
struct sockaddr_in {  
    uint8_t          sin_len;  
    sa_family_t     sin_family;  
    in_port_t       sin_port;  
    struct in_addr   sin_addr;  
    char            sin_zero[8];  
};
```

struct in_addr

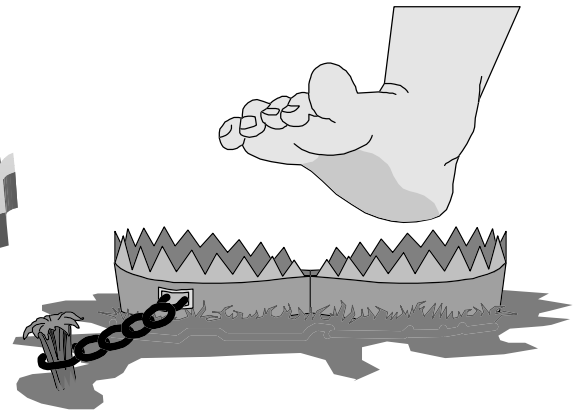
```
struct in_addr {  
    in_addr_t    s_addr;  
};
```

`in_addr` just provides a name for the 'C' type associated with IP addresses.

Network Byte Order

- All values stored in a `sockaddr_in` must be in network byte order.
 - `sin_port` a TCP/IP port number.
 - `sin_addr` an IP address.

**Common Mistake:
Ignoring Network Byte Order**



Network Byte Order Functions

'h' : host byte order

'n' : network byte order

's' : short (16bit)

'l' : long (32bit)

```
uint16_t htons(uint16_t);
```

```
uint16_t ntohs(uint16_t);
```

```
uint32_t htonl(uint32_t);
```

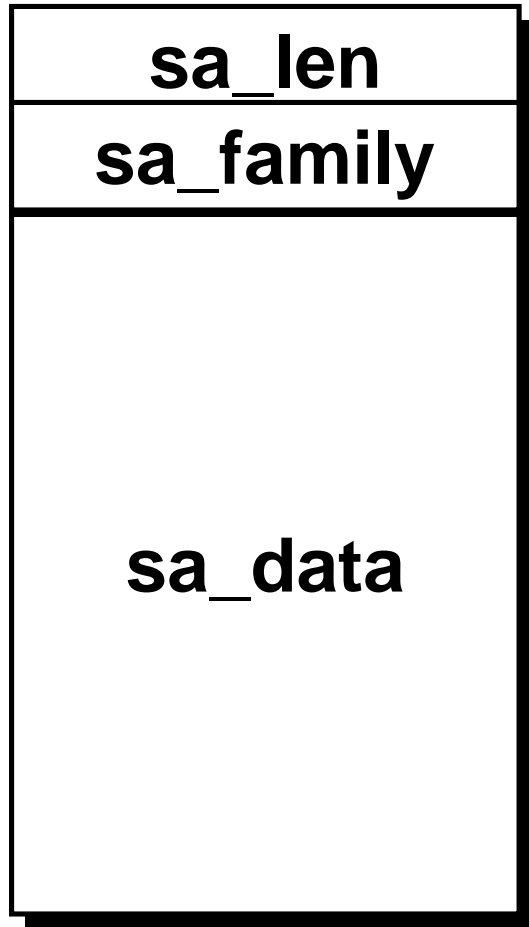
```
uint32_t ntohl(uint32_t);
```

TCP/IP Addresses

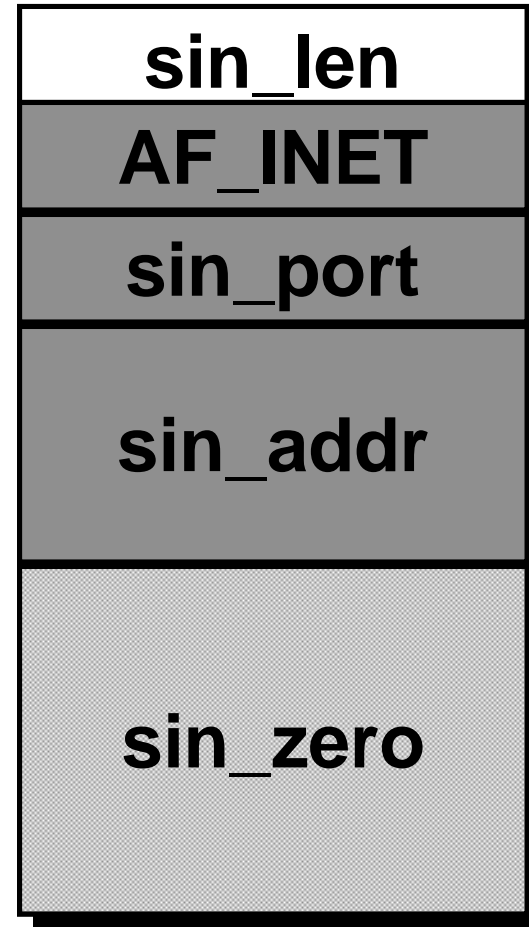
- We don't need to deal with `sockaddr` structures since we will only deal with a real protocol family.
- We can use `sockaddr_in` structures.

BUT: The C functions that make up the sockets API expect structures of type `sockaddr`.

sockaddr




sockaddr_in



Assigning an address to a socket

- The `bind()` system call is used to assign an address to an existing socket.

```
int bind( int sockfd,  
const!  const struct sockaddr *myaddr,  
        int addrlen);
```

- `bind` returns 0 if successful or -1 on error.

`bind()`

- calling `bind()` assigns the address specified by the `sockaddr` structure to the socket descriptor.
- You can give `bind()` a `sockaddr_in` structure:

```
bind( mysock,  
      (struct sockaddr*) &myaddr,  
      sizeof(myaddr) );
```

bind() Example

```
int mysock;  
struct sockaddr_in myaddr;  
  
mysock = socket(PF_INET, SOCK_STREAM, 0);  
myaddr.sin_family = AF_INET;  
myaddr.sin_port = htons( portnum );  
myaddr.sin_addr = htonl( ipaddress);  
  
bind(mysock, &myaddr, sizeof(myaddr));
```

Uses for `bind()`

- There are a number of uses for `bind()`:
 - Server would like to bind to a well known address (port number).
 - Client can bind to a specific port.
 - Client can ask the O.S. to assign any available port number.

Port schmort - who cares ?

- Clients typically don't care what port they are assigned.
- When you call bind you can tell it to assign you any available port:\

```
myaddr.port = htons(0);
```

What is my IP address ?

- How can you find out what your IP address is so you can tell `bind()` ?
- There is no realistic way for you to know the right IP address to give `bind()` - what if the computer has multiple network interfaces?
- specify the IP address as: `INADDR_ANY` , this tells the OS to take care of things.

IPv4 Address Conversion

```
int inet_aton( char *, struct in_addr *);
```

Convert ASCII dotted-decimal IP address to network byte order 32 bit value. Returns 1 on success, 0 on failure.

```
char *inet_ntoa(struct in_addr);
```

Convert network byte ordered value to ASCII dotted-decimal.

Other socket system calls

- General Use
 - `read()`
 - `write()`
 - `close()`

- Connection-oriented (TCP)
 - `connect()`
 - `listen()`
 - `accept()`

- Connectionless (UDP)
 - `send()`
 - `recv()`