SOCKET INTRODUCTION

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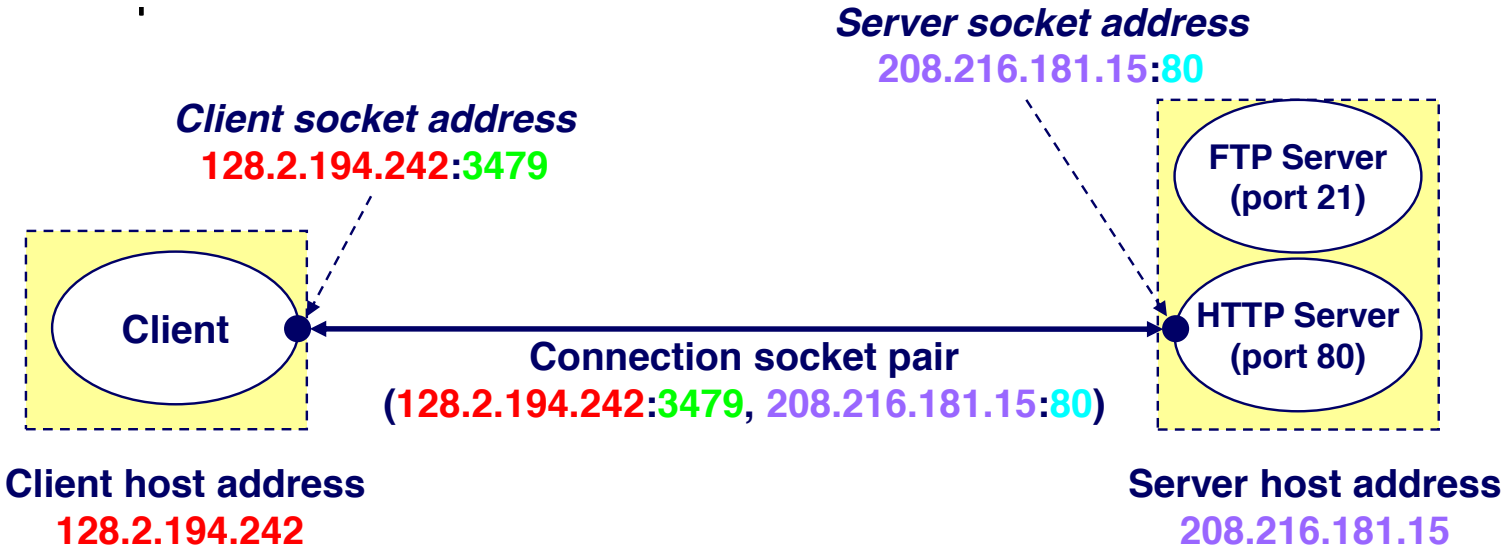
- Stream Socket
- Datagram Socket
- APIs for managing names and IP addresses
- Socket Address Structures

Socket

- What is a socket ?
- *Sockets* (in plural) are
  - application programming interface (API) at transport layer in TCP/IP stack
  - application may send and receive data through socket



Socket: how to use

- Setup socket
  - Where is the remote machine (IP address, hostname)
  - What service gets the data (port)
- Send and Receive
  - Designed just like any other I/O in unix
  - send – write
  - recv -- read
- Close the socket

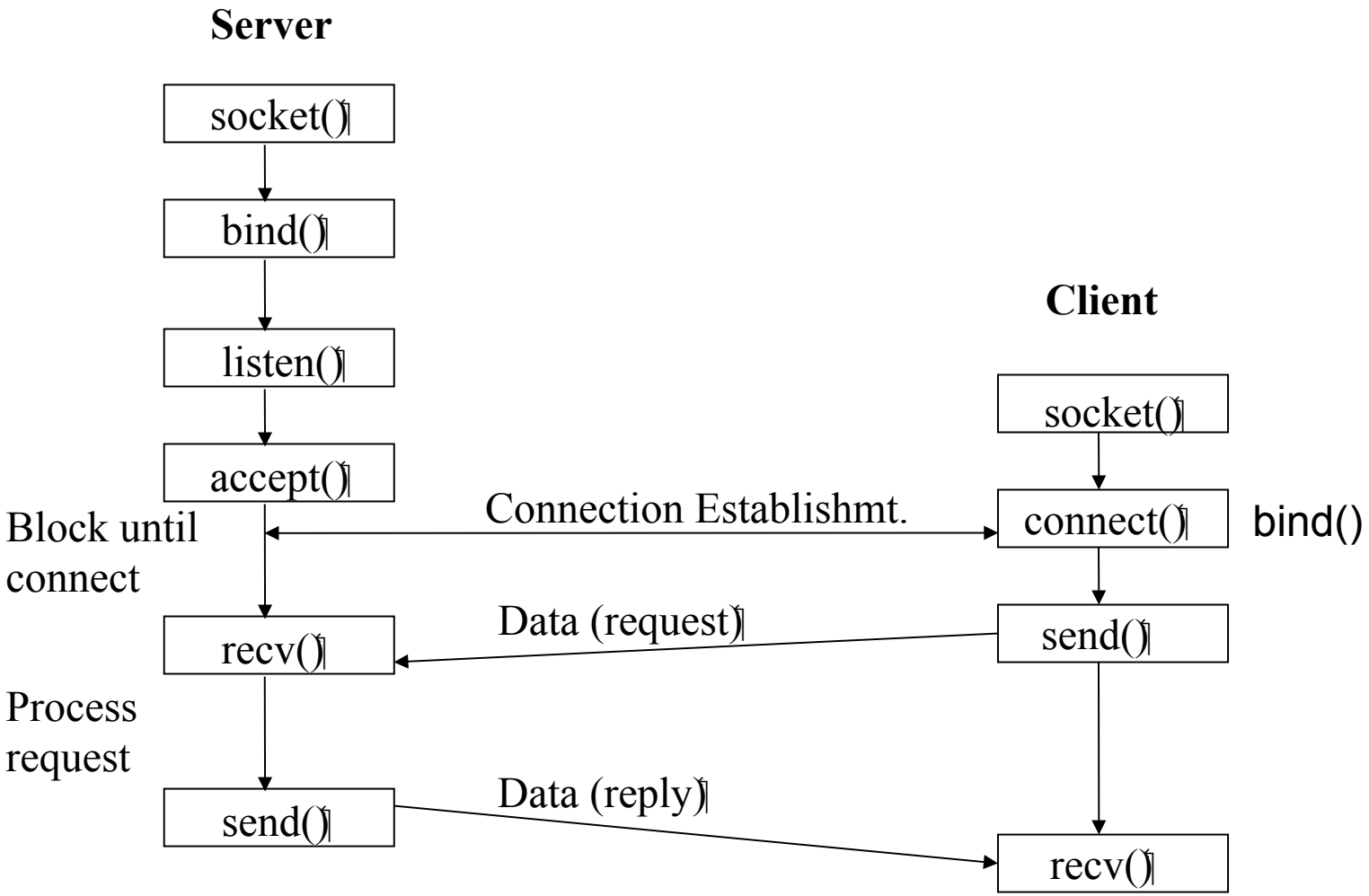
Socket types

- The main types of sockets in TCP/IP are
  - *stream sockets*
    - use TCP as the end-to-end protocol (with IP underneath) and thus provide a reliable byte-stream service
  - *datagram sockets*
    - use UDP (again, with IP underneath) and thus provide a ***best-effort*** datagram service
- Socket Address :
  - Combination of host name/Adress IP + transport port

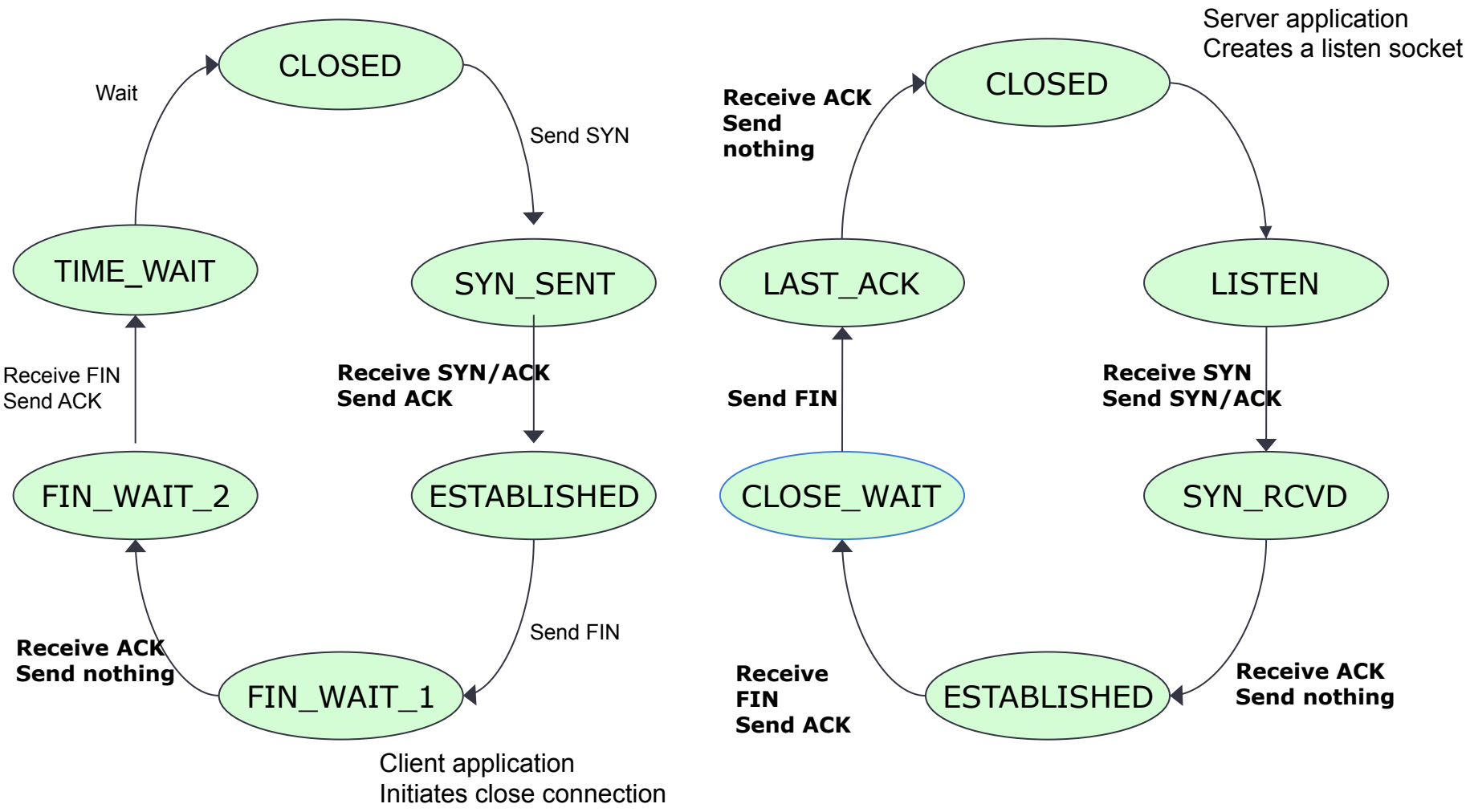
Stream sockets (TCP)

- TCP provides connections between clients and servers
- TCP also provides reliability :
  - Acknowledgment
  - Error control
  - Flow control
  - Congestion control
- TCP connection is full-duplex
  - Send and receive data over single connection.

Stream sockets (TCP): working flow



Life cycle of TCP connection



Stream Socket API in C

- socket()
  - creates a socket of a given domain, type, protocol (buy a phone)
  - Returns a file descriptor (called a socket ID)
- bind()
  - Assigns a name to the socket (get a telephone number)
  - Associate a socket with an IP address and port number (Eg : 192.168.1.1:80)
- accept()
  - server accepts a connection request from a client (answer phone)
  - There are basically three styles of using accept:
    - *Iterating server*: Only one socket is opened at a time.
    - *Forking server*: After an accept, a child process is forked off to handle the connection.
    - *Concurrent single server*: use select to simultaneously wait on all open socketIds, and waking up the process only when new data arrives

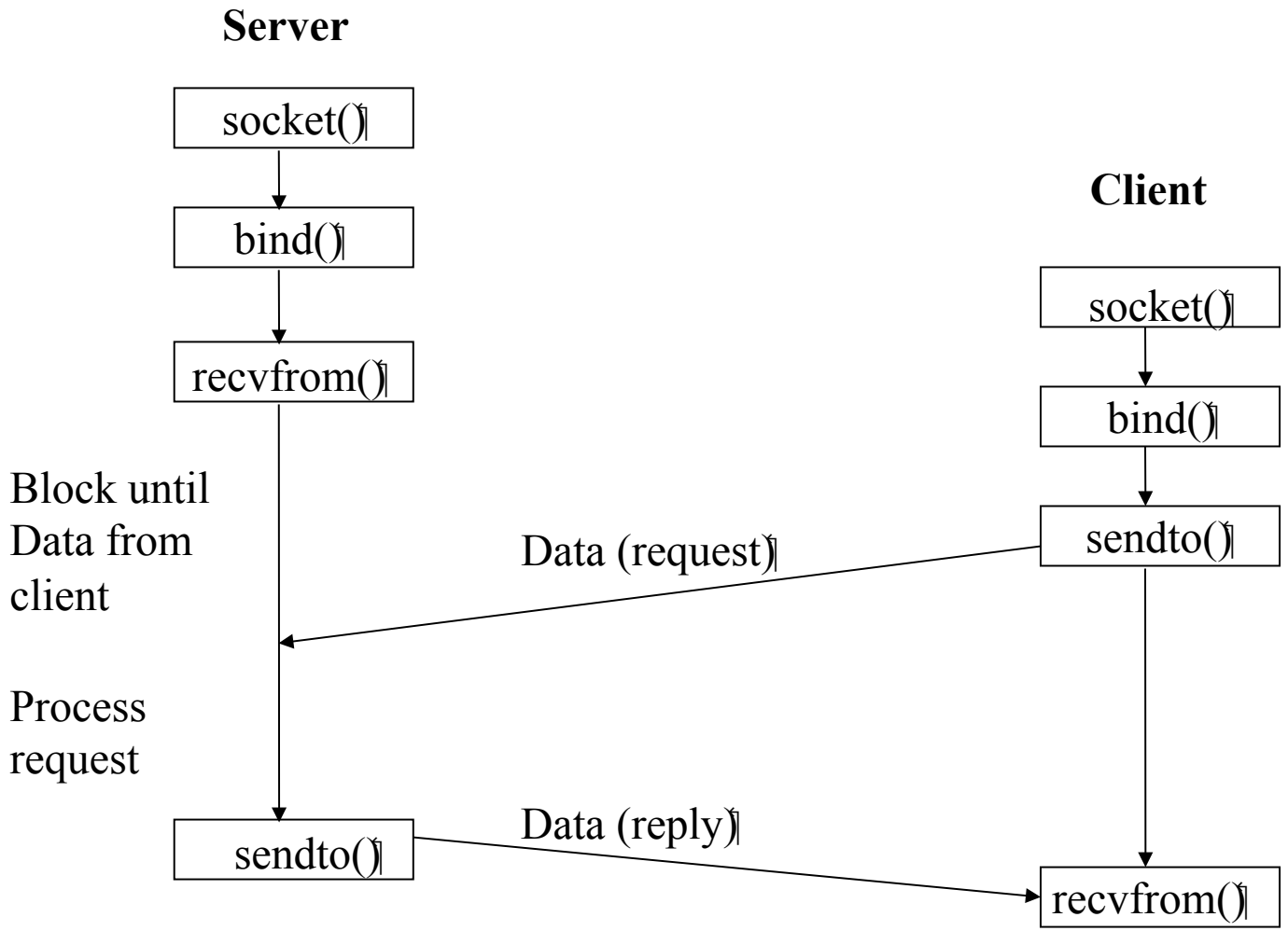
Stream Socket API in C

- connect()
  - Client requests a connection request to a server
  - This is the first of the client calls
- send()
  - write data to connection → to the parterner (speak)
- recv()
  - read data from connection → from the parterner (listen)
- close()
  - close a socket descriptor (end the call)

Datagram Socket (UDP)

- UDP is a simple transport-layer protocol
- If a datagram is errored or lost, it won't be automatically retransmitted (can process in application)
- UDP provides a *connectionless* service, as there need not be any long-term relationship between a UDP client and server

Datagram Socket (UDP)



Socket programming API in C

- Packages:
- Can be found under /usr/include
  - Ex: /usr/include/i386-linux-gnu
- <stdio.h>
  - input and output of basic C programs.
- <sys/types.h>
  - Contains definitions of data types used in system calls. These types are used in the next two include files.
- <sys/socket.h>
  - Includes definitions of structures needed for sockets.
- <netinet/in.h>
  - contains constants and structures needed for internet domain addresses.

Socket Address Structures

- Most socket functions require a pointer to a socket address structure as an argument.
- Each supported protocol suite defines its own socket address structure.
- A Socket Address Structure is a structure which has information of a socket to create or connect with it
- Types of socket address structures
  - IPv4
  - IPv6

IPv4 socket address structure

```
#include <netinet/in.h>
struct in_addr {
    in_addr_t s_addr;        /* 32-bit IPv4 address */
                             /* network byte ordered */
};

struct sockaddr_in {
  uint8_t sin_len;           /* length of structure */
  sa_family_t sin_family;    /* AF_INET */
  in_port_t sin_port;        /* 16-bit TCP or UDP port number */
                             /* network byte ordered */
  struct in_addr sin_addr;   /* 32-bit IPv4 address */
                             /* network byte ordered */
  char sin_zero[8];          /* unused */
};
```

- **in_addr_t** is equivalent to the type **uint32_t**
- **uint8_t, uint16_t, unint_32_t:** Integer type with a width of exactly 8, 16, 32 bits.

IPv6 socket address structure

```
#include <netinet/in.h>
struct in6_addr {
uint8_t s6_addr[16];   /* 128-bit IPv6 address */
                       /* network byte ordered */ };

#define SIN6_LEN       /* required for compile-time tests */

struct sockaddr_in6 {
    uint8_t sin6_len;     /* length of this struct  */
    sa_family_t sin6_family; /* AF_INET6 */
    in_port_t sin6_port;          /* transport layer port# */
                          /* network byte ordered */
    uint32_t sin6_flowinfo;       /* flow information, undefined */
    struct in6_addr sin6_addr; /* IPv6 address */
                               /* network byte ordered */
     uint32_t sin6_scope_id;   /* set of interfaces for a scope */ };
```

APIs for managing names and IP addresses

- Auxiliary APIs:
  - All binary values are network byte ordered
  - *htons, htonl, ntohs, ntohl*: ***byte ordering***
  - *inet_ntoa(), inet_aton(), inet_addr* : Convert IP addresses from a dots-and-number string (eg : 192.168.1.1) to a struct in_addr and back
  - *inet pton, inet ntop*: conversion of IP numbers between presentation and strings

List of Address and Name APIs

#include <sys/socket.h>

- **getprotobyname()**
  - Retrieve the protocol name and number corresponding to a protocol name.
- **getprotobynumber()**
  - Retrieve the protocol name and number corresponding to a protocol number.
- **getservbyname()**
  - Retrieve the service name and port corresponding to a service name.
- **getservbyport()**
  - Retrieve the service name and port corresponding to a port.

Address Access/Conversion Functions

- struct hostent* gethostbyname (const char* hostname);
  - Translate DNS host name to IP address (uses DNS)
- struct hostent* gethostbyaddr (const char* addr, size_t len, int family);
  - Translate IP address to DNS host name (not secure)
- int gethostname (char* name, size_t namelen);
  - Read host's name (use with **gethostbyname** to find local IP)
- getprotobyname()
  - Retrieve the protocol name and number corresponding to a protocol name.
- getprotobynumber()
  - Retrieve the protocol name and number corresponding to a protocol number.
- getservbyname()
  - Retrieve the service name and port corresponding to a service name.
- getservbyport()
  - Retrieve the service name and port corresponding to a port.

getservbyname()

- Get service information corresponding to a service name and protocol.

```
#include <netdb.h>
#include <sys/socket.h>
struct servent *getservbyname (const char *servname, const
                                char *protoname);
```

- servname
  - A pointer to a service name.
- protoname
  - An optional pointer to a protocol name.
  - If this is NULL, getservbyname() returns the first service entry for which the name matches the s_name or one of the s_aliases.
  - Otherwise getservbyname() matches both the name and the proto.
- Returns
  - non-null pointer if OK
  - NULL on error

```
struct servent *sptr;
sptr = getservbyname("ftp", "tcp");
```

struct servent

```
struct servent {
   char *s_name;          /* official service name */
   char **s_aliases;      /* alias list */
   int s_port;            /* port number, network-byte order */
   char *s_proto;         /* protocol to use */
};
```

- s_name
  - Official name of the service.
- s_aliases
  - A NULL-terminated array of alternate names.
- s_port
  - The port number at which the service may be contacted. Port numbers are returned in network byte order.
- s_proto
  - The name of the protocol to use when contacting the service.

getservbyport

- Get service information corresponding to a port and protocol.

```
#include <netdb.h>
#include <sys/socket.h>
struct servent *getservbyport (int port, const char *protoname);
```

- port
  - The port for a service, in network byte order.
- protoname
  - An optional pointer to a protocol name.
  - If this is NULL, getservbyport() returns the first service entry for which the port matches the s_port.
  - Otherwise getservbyport() matches both the port and the proto.
- Return
  - non-null pointer if OK
  - NULL on error

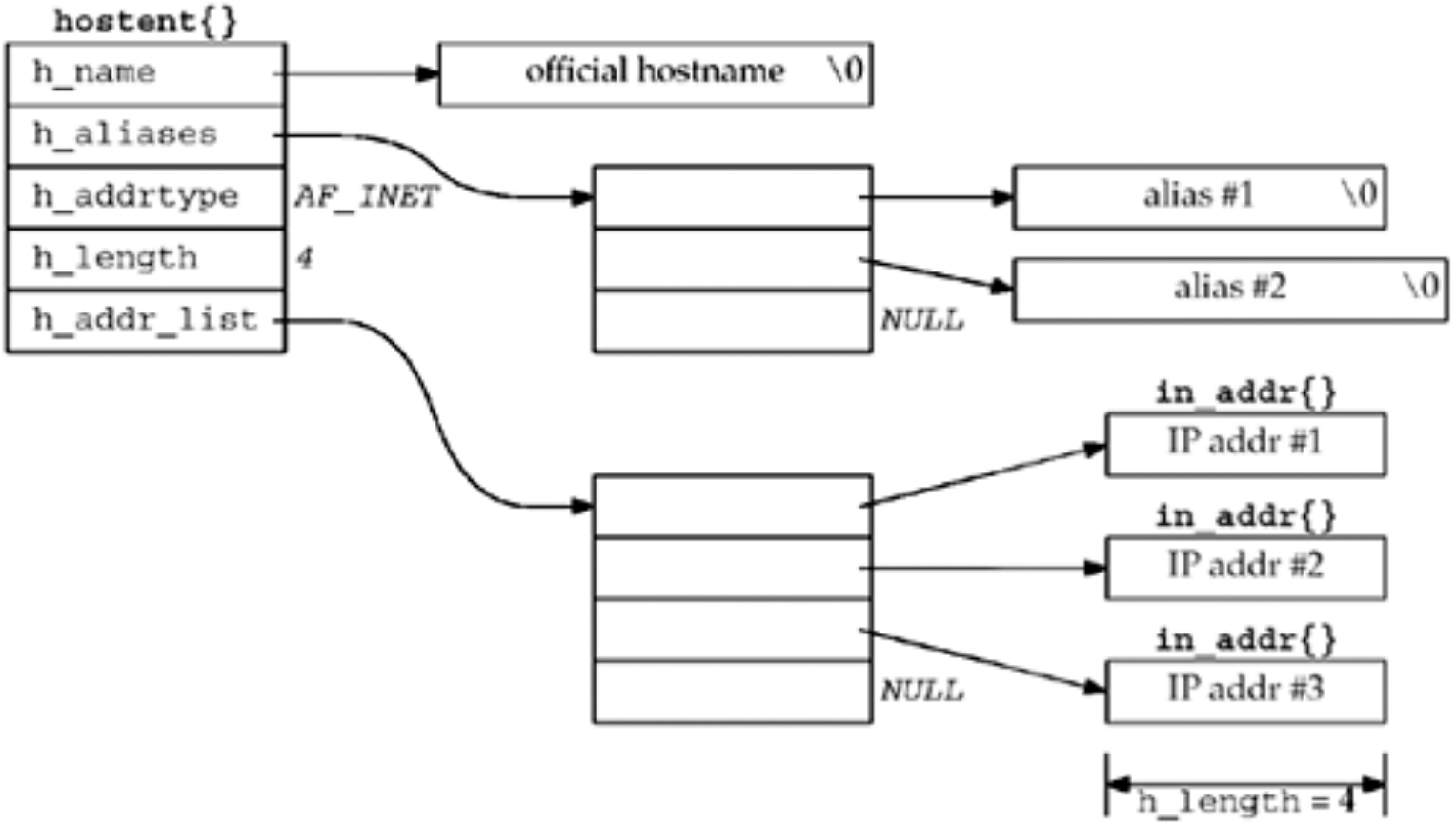
```
struct servent *sptr;
sptr = getservbyport (htons (53), "udp");
```

struct hostent

```
struct hostent {
      char   *h_name;       /* official (canonical) name of host */
      char   **h_aliases;   /* pointer to array of pointers to
                               alias names */
      int     h_addrtype;   /* host address type: AF_INET */
      int     h_length;     /* length of address: 4 */
      char   **h_addr_list; /* ptr to array of ptrs with IPv4 addrs */
};
```

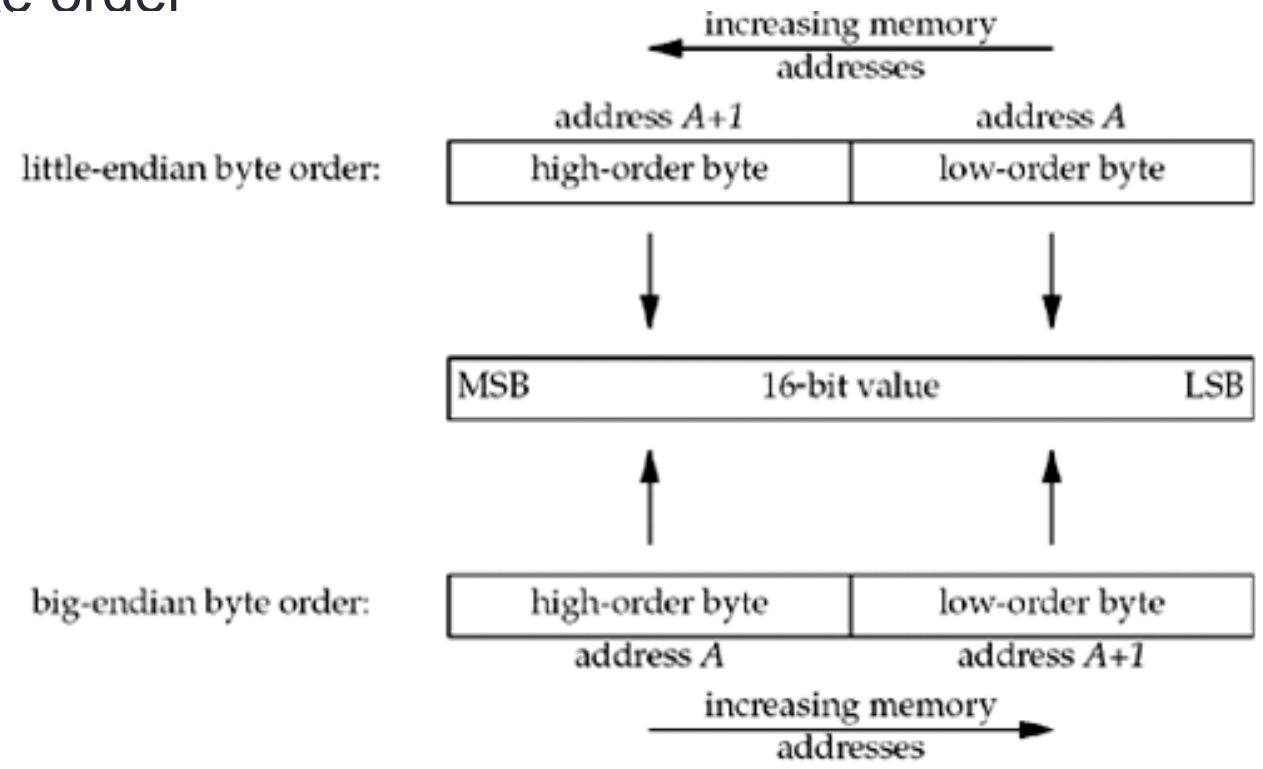
- what is this struct hostent that gets returned?
- It has a number of fields that contain information about the host in question.

struct hostent



Byte Ordering

- There are two ways to store the two bytes in memory
  - little-endian byte order
  - big-endian byte order



Byte Ordering (cont)

- There is no standard between these two byte orderings
  - The Internet protocols use big-endian byte ordering
  - Host order can be big- or little-endian
    - X86: little-endian
    - SPARC: big-endian
- Conversion
  - *htons(), htonl()*: host to network short/long
  - *ntohs(), ntohl()*: network order to host short/long
- What need to be converted?
  - Addresses, port why?
    - Because destination host reads address, TCP/UDP port number from IP, TCP packets sent from source.
  - etc.

htons(), htonl(), ntohs(), ntohl()

- Convert multi-byte integer types from host byte order to network byte order

```
#include <netinet/in.h>

uint32_t htonl(u_long hostlong);  // host to network long
uint16_t htons(u_short hostshort);// host to network short
uint32_t ntohl(u_long netlong);   // network to host long
uint16_t ntohs(u_short netshort); // network to host short
```

- Each function returns the converted value.

IP address conversion Functions

- char* inet_ntoa (struct in_addr inaddr);
  - Translate IP address to ASCII dotted-decimal notation (e.g., “128.32.36.37”); not thread-safe
- in_addr_t inet_addr (const char* strptr);
  - Translate dotted-decimal notation to IP address; returns -1 on failure, thus cannot handle broadcast value “255.255.255.255”
- int inet_aton (const char* strptr, struct in_addr inaddr);
  - Translate dotted-decimal notation to IP address; returns 1 on success, 0 on failure

inet_aton()

#include <arpa/inet.h>

int inet_aton(const char *cp, struct in_addr *inp)

- Convert IP addresses from a dots-and-number string to a struct in_addr
- Return:
  - The value non-zero if the address is valid
  - The value 0 if the address is invalid

```
struct in_addr someAddr;
if(inet_aton("10.0.0.1", someAddr))
        printf("The address is valid");
else printf ("The address is invalid");
```

inet_ntoa()

#include <arpa/inet.h>

char *inet_ntoa(struct in_addr *in*);

- Convert IP addresses from a struct in_addr to a dots-and-number string
- Return: the dots-and-numbers string

```
struct in_addr someAddr;
if(inet_aton("10.0.0.1", someAddr))
        printf("The address is valid");
else printf ("The address is invalid");
char *addrStr;
addrStr = inet_ntoa(someAddr);
```

IPv4

- Developed in APRANET (1960s)
- 32-bit number
- Divided into classes that describe the portion of the address assigned to the network (netID) and the portion assigned to endpoints (hosten)
  - A : netID – 8 bit
  - B : netID – 16 bit
  - C : netID – 24 bit
  - D : use for multicast
  - E : use for experiments

IPv6

- IPv6 address is 128 bits
  - To subdivide the available addresses into a hierarchy of routing domains that reflect the Internet's topology
- IPv6 address is typically expressed in 16-bit chunks displayed as hexadecimal numbers separated by colons

  Example : 21DA:00D3:0000:2F3B:02AA:00FF:FE28:9C5A

  or : 21DA:D3:0:2F3B:2AA:FF:FE28:9C5A

New APIs for IPv6

- Those APIs only supports IPv4 but IPv6 will be replace IPv4 in the future, so we need APIs supporting IPv6
- They are
  - getaddrinfo
  - getnameinfo
- These APIs have replaced the IPv4 specific routines