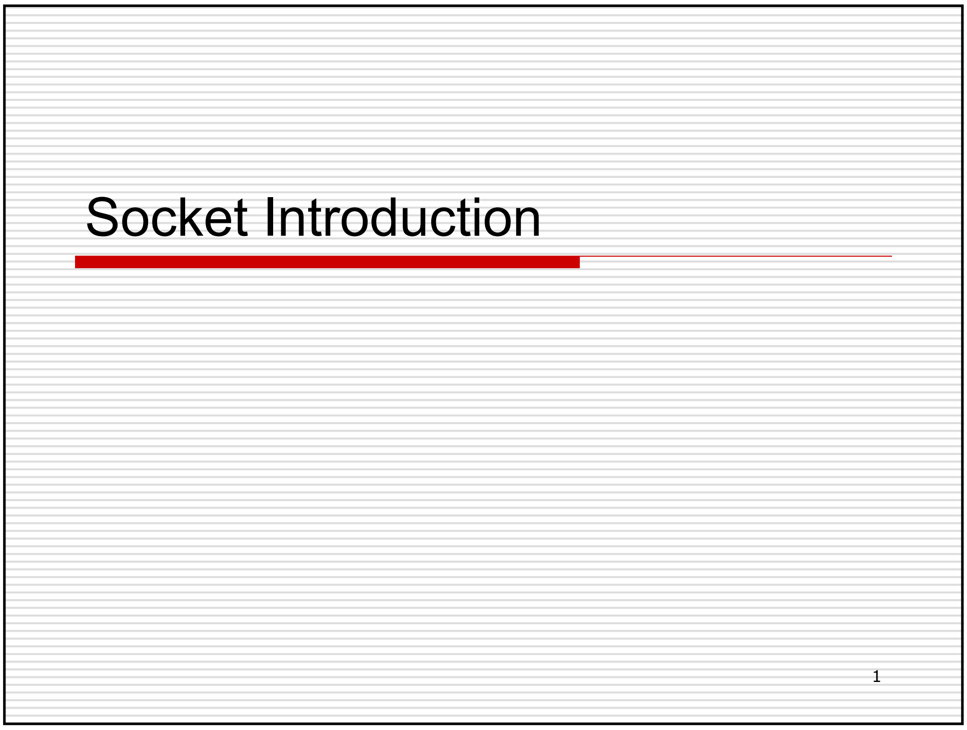
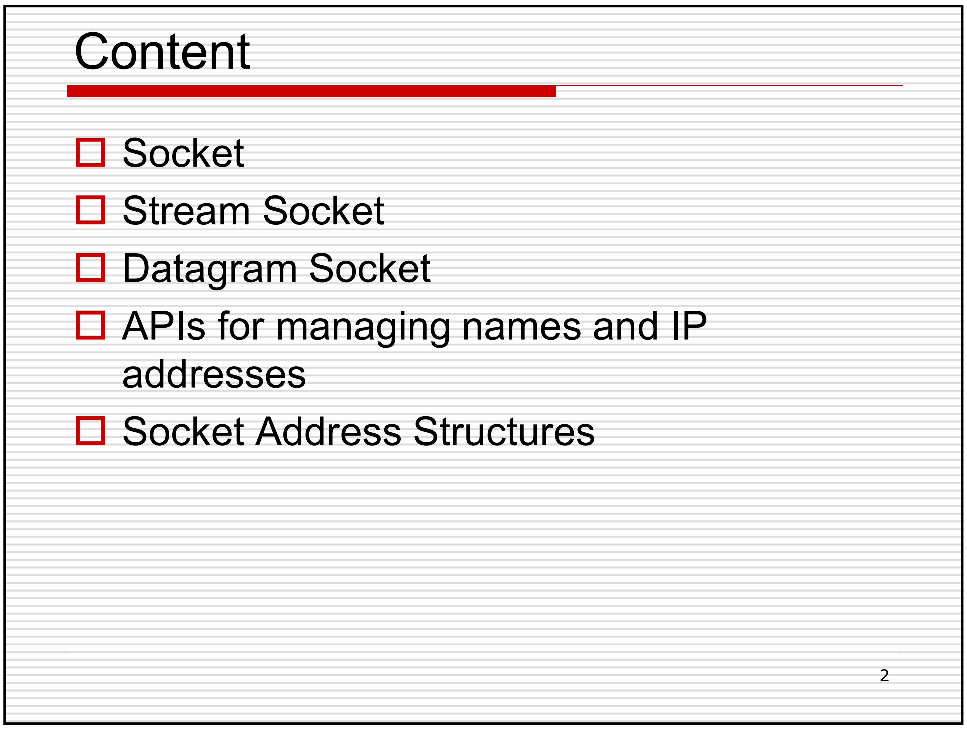


# Socket Introduction



## Content

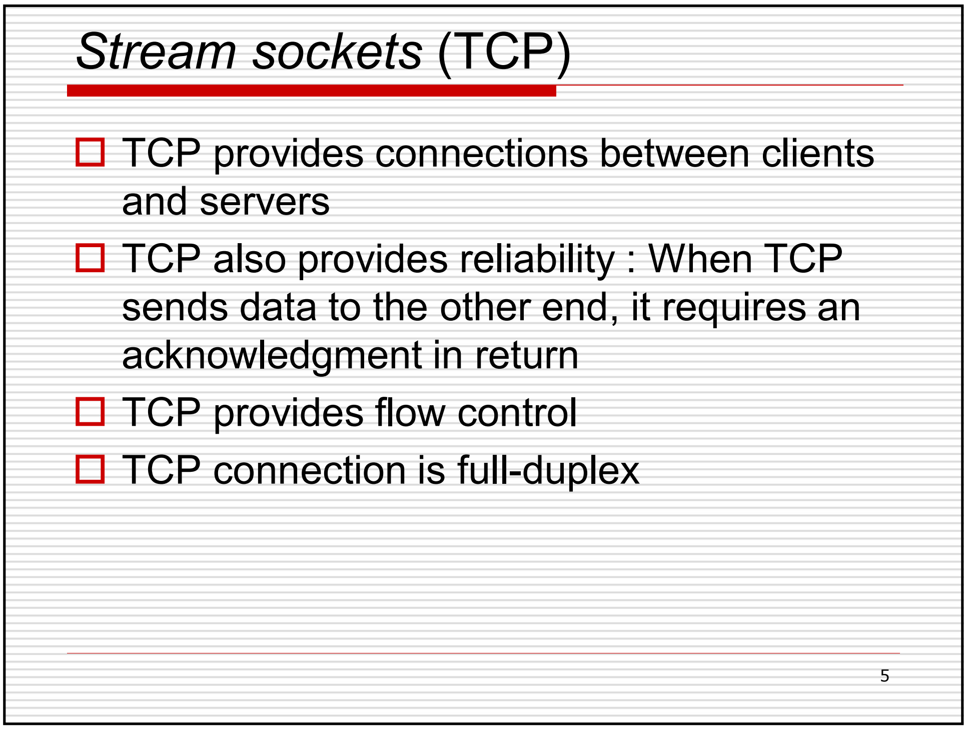
- □ Socket
- □ Stream Socket
- □ Datagram Socket
- □ APIs for managing names and IP addresses
- □ Socket Address Structures

## Socket

- □ What is a socket ?
- □ *Sockets* (in plural) are an application programming interface (API) application program and the TCP/IP stack
- □ A *socket* is an abstraction through which an application may send and receive data
- □ A socket allows an application to plug in to the network and communicate with other applications that are plugged in to the same network.

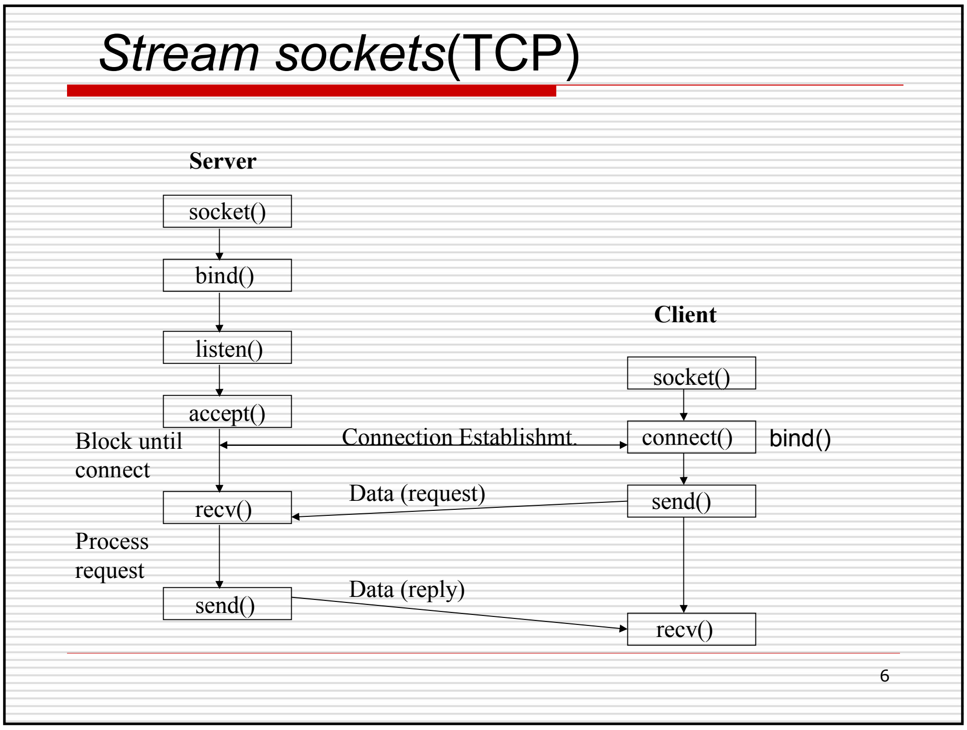
## Socket (cont)

- □ 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 : include host name and port



## *Stream sockets* (TCP)

- TCP provides connections between clients and servers
- TCP also provides reliability : When TCP sends data to the other end, it requires an acknowledgment in return
- TCP provides flow control
- TCP connection is full-duplex



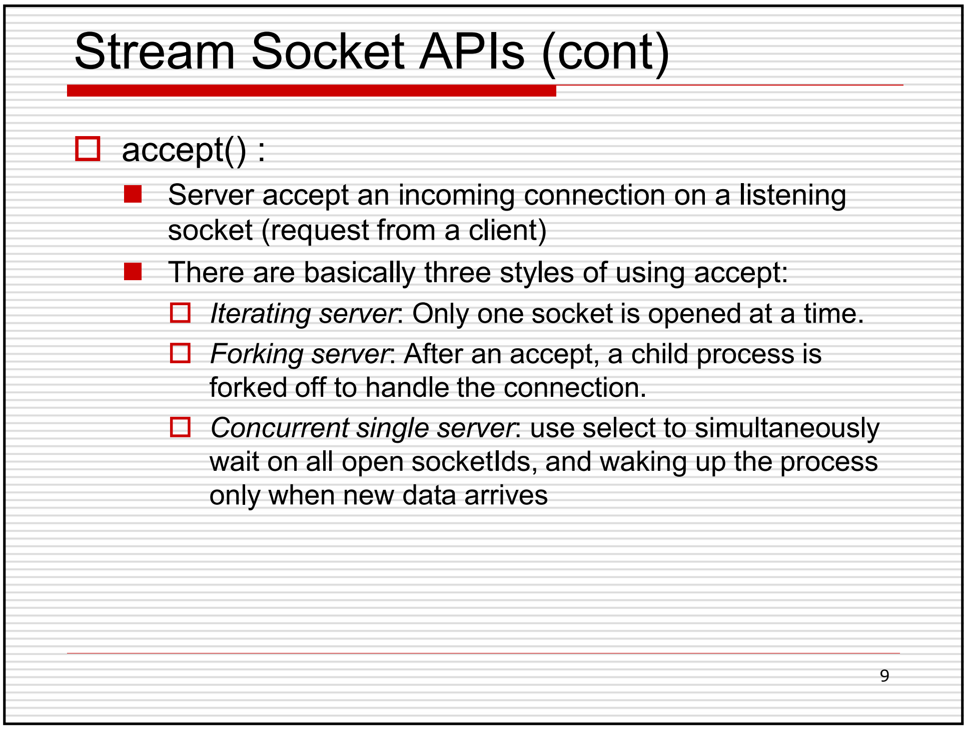
## *Stream sockets*(TCP)

# Stream Socket APIs

- □ *socket*: creates a socket of a given domain, type, protocol (buy a phone)
- □ *bind*: assigns a name to the socket (get a telephone number)
- □ *listen*: specifies the number of pending connections that can be queued for a server socket. (call waiting allowance)
- □ *accept*: server accepts a connection request from a client (answer phone)
- □ *connect*: client requests a connection request to a server (call)
- □ *send*: write to connection (speak)
- □ *recv* : read from connection (listen)
- □ *close*: close a socket descriptor (end the call)

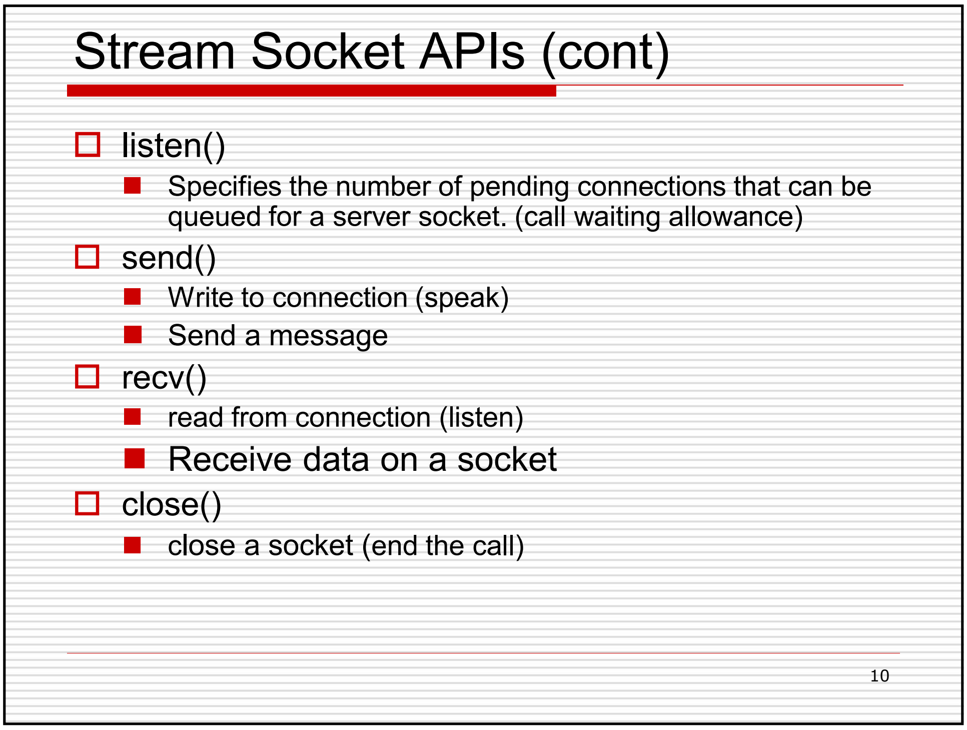
# Stream Socket APIs (cont)

- □ 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)
- □ connect()
  - ■ Client requests a connection request to a server
  - ■ This is the first of the client calls



## Stream Socket APIs (cont)

- accept() :
  - Server accept an incoming connection on a listening socket (request from a client)
  - 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



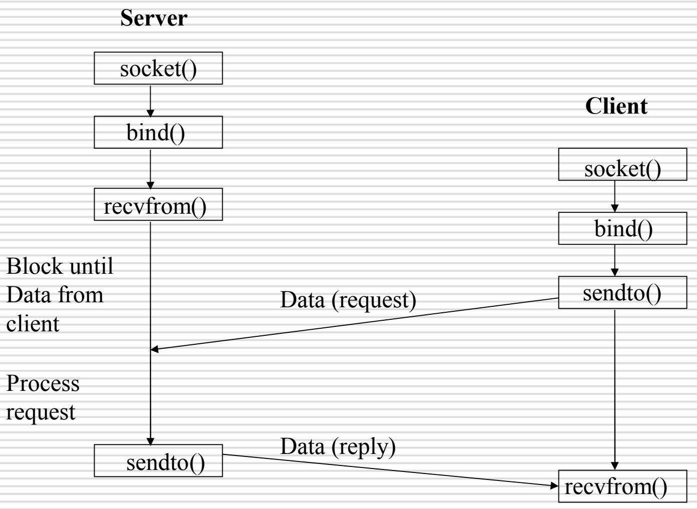
## Stream Socket APIs (cont)

- listen()
  - Specifies the number of pending connections that can be queued for a server socket. (call waiting allowance)
- send()
  - Write to connection (speak)
  - Send a message
- recv()
  - read from connection (listen)
  - Receive data on a socket
- close()
  - close a socket (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)



**Server**

socket()

bind()

recvfrom()

Block until Data from client

Process request

sendto()

**Client**

socket()

bind()

sendto()

recvfrom()

Data (request)

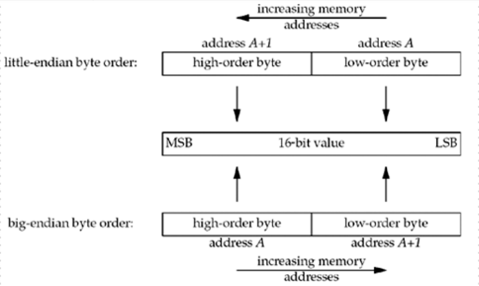
Data (reply)

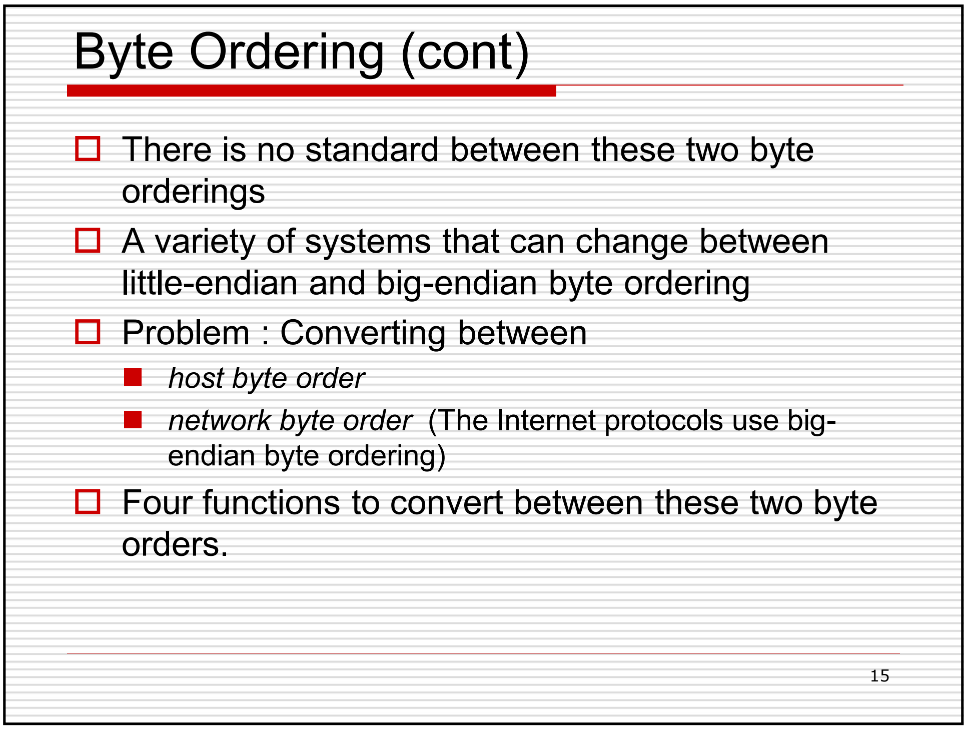
# APIs for managing names and IP addresses

- We next consider a number of auxiliary APIs:
  - *gethostname*: Returns the name of the system
  - gethostbyname : Get an IP address for a hostname, or vice-versa
  - *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

# Byte Ordering

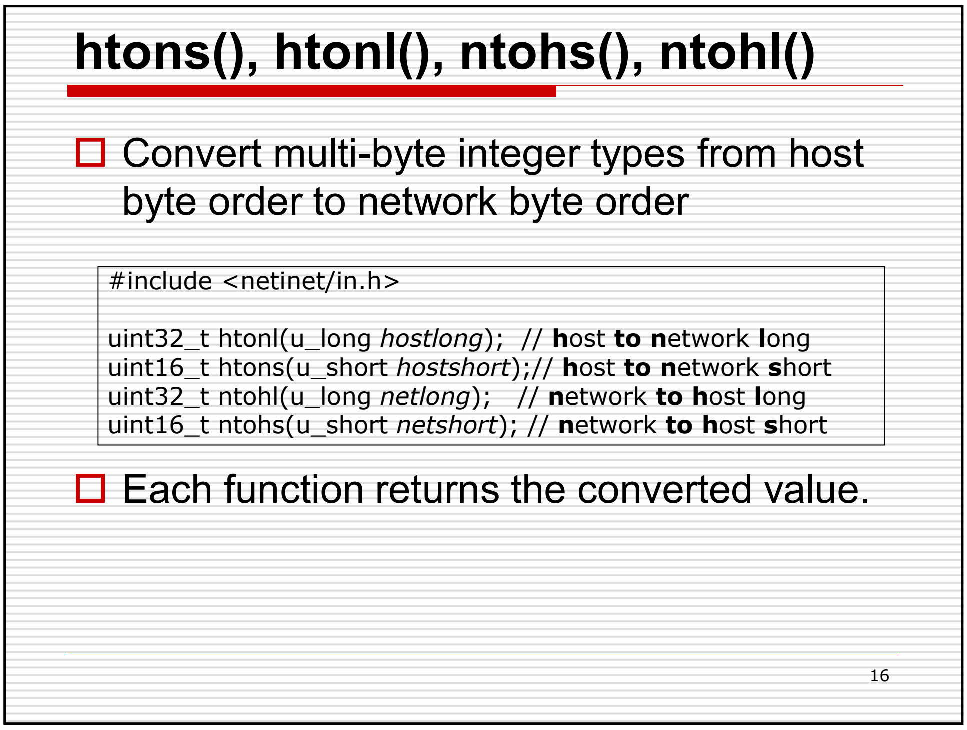
- There are two ways to store the two bytes in memory
  - little-endian byte order
  - big-endian byte order





# Byte Ordering (cont)

- There is no standard between these two byte orderings
- A variety of systems that can change between little-endian and big-endian byte ordering
- Problem : Converting between
  - *host byte order*
  - *network byte order* (The Internet protocols use big-endian byte ordering)
- Four functions to convert between these two byte orders.

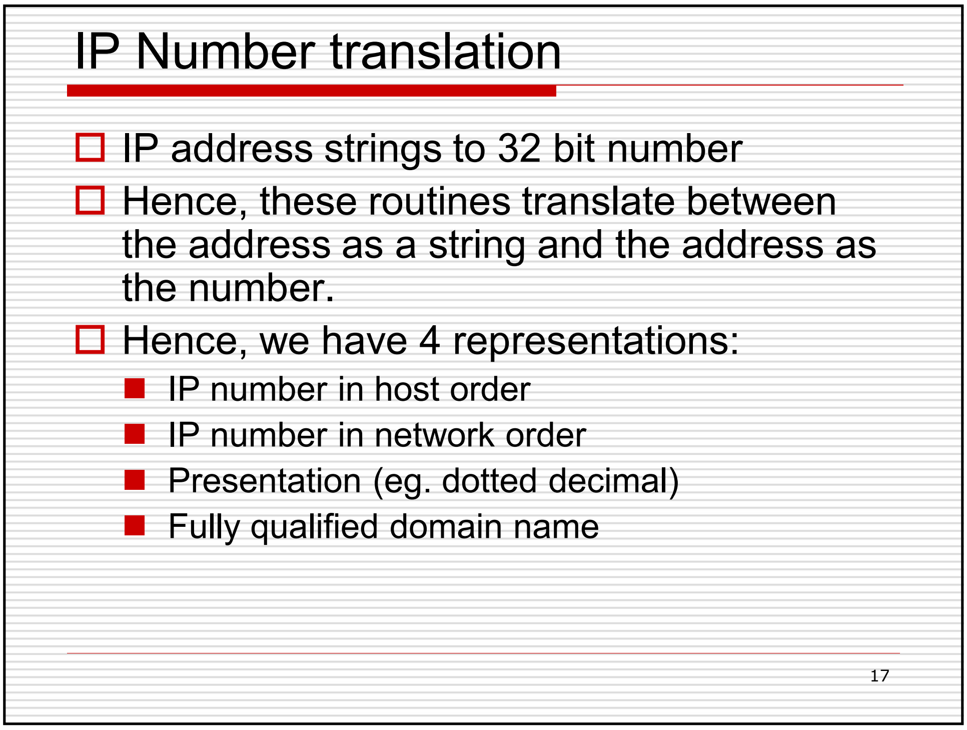


# htons(), htonl(), ntohs(), ntohl()

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

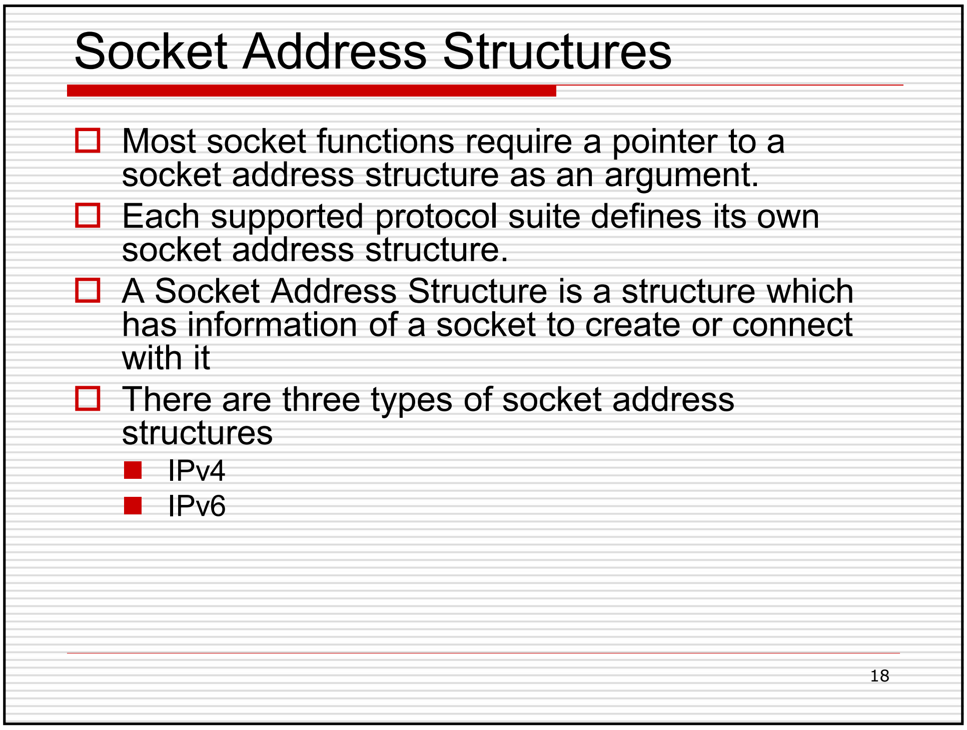
```
#include <netinet/in.h>

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.



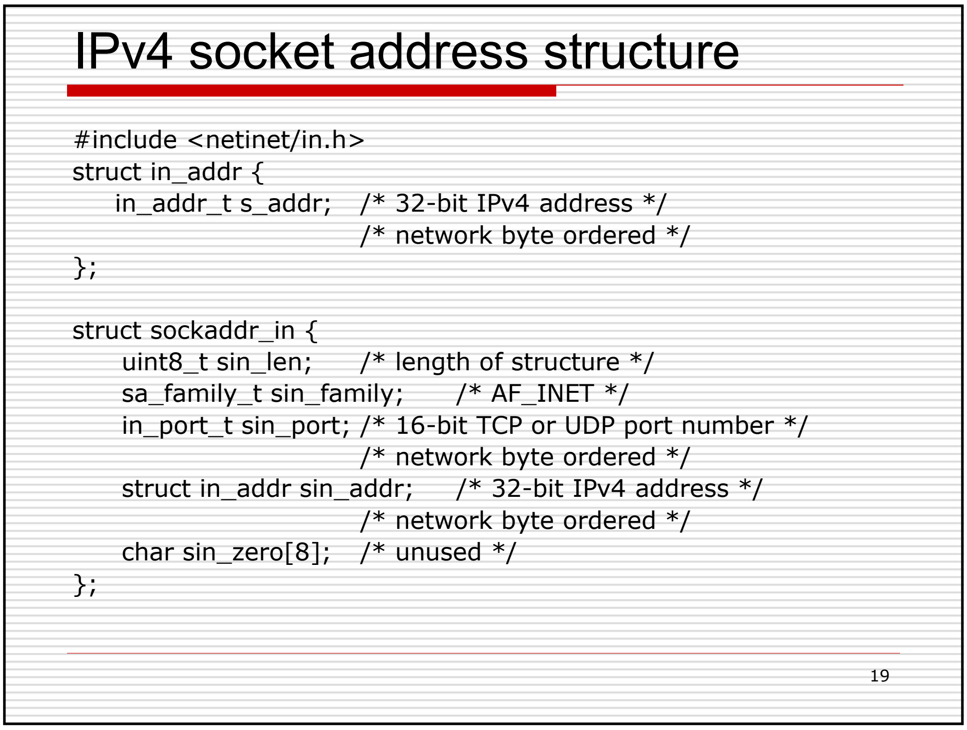
## IP Number translation

- IP address strings to 32 bit number
- Hence, these routines translate between the address as a string and the address as the number.
- Hence, we have 4 representations:
  - IP number in host order
  - IP number in network order
  - Presentation (eg. dotted decimal)
  - Fully qualified domain name



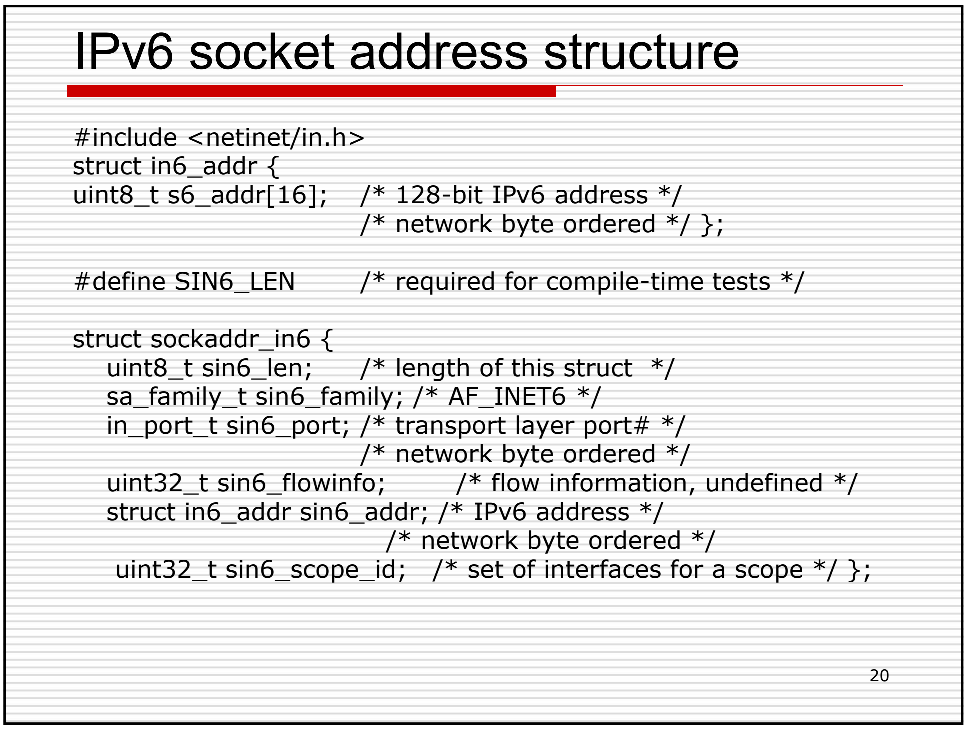
## Socket Address Structures

- 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
- There are three types of socket address structures
  - IPv4
  - IPv6



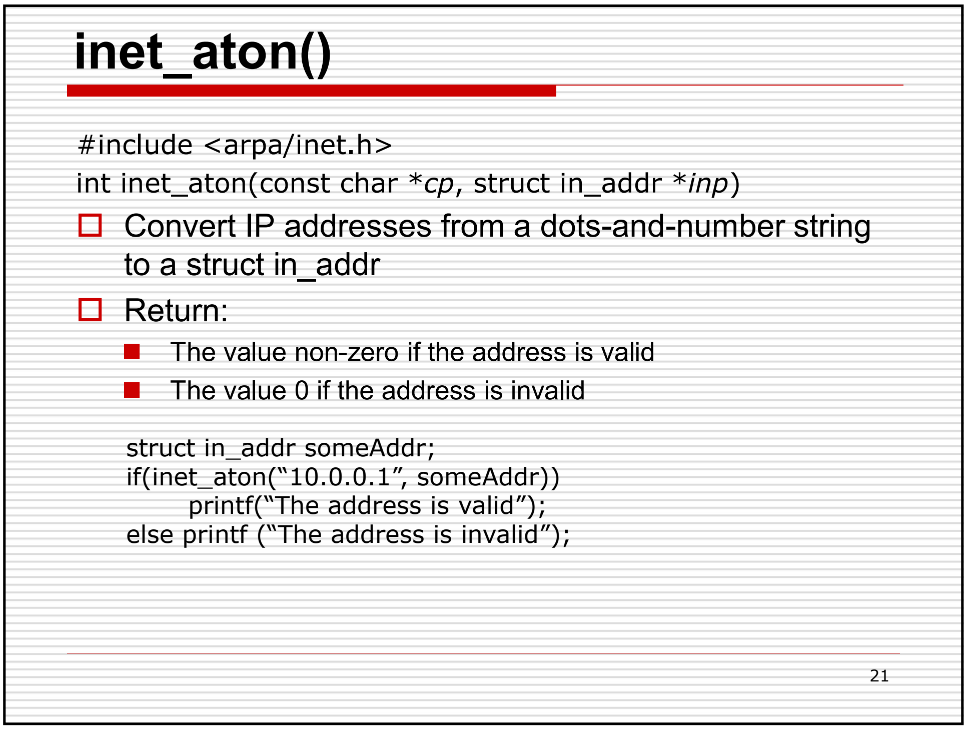
## IPv4 socket address structure

```
#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 */
};
```



## 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 */ };
```

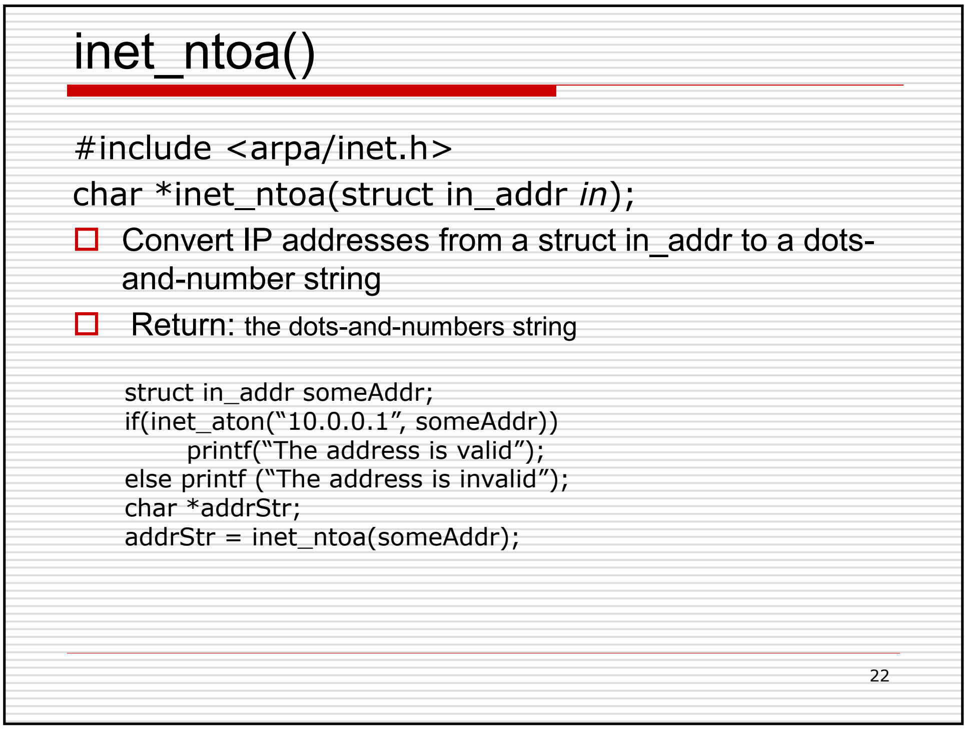


# inet_aton()

#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”);
```

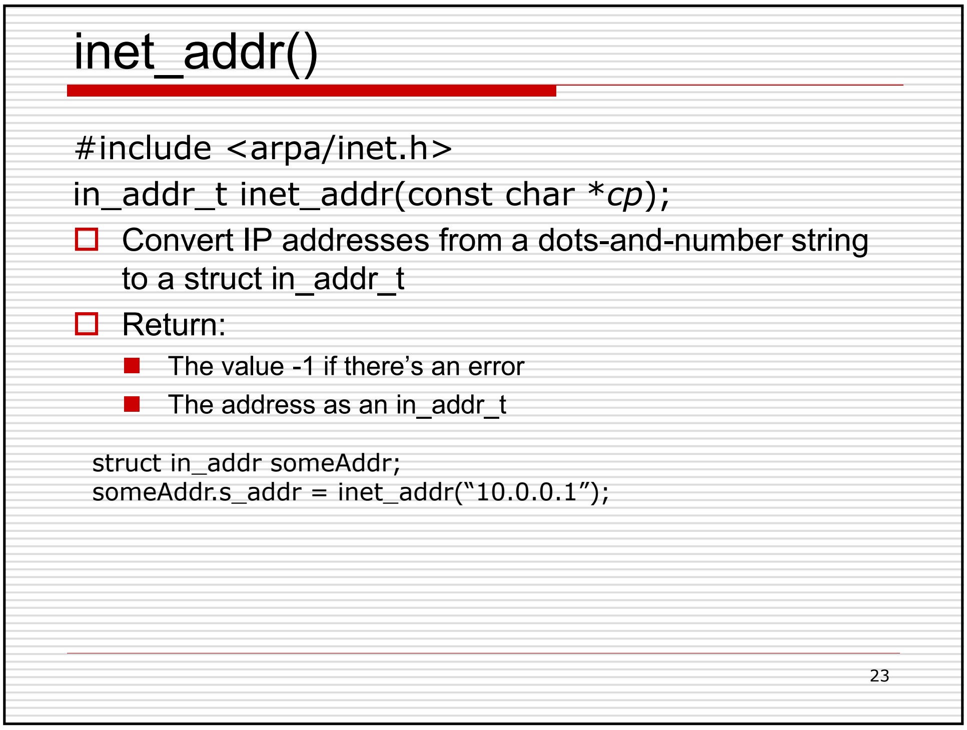


# inet_ntoa()

#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);
```



## inet_addr()

#include <arpa/inet.h>

in_addr_t inet_addr(const char **cp*);

- Convert IP addresses from a dots-and-number string to a struct in_addr_t
- Return:
  - The value -1 if there's an error
  - The address as an in_addr_t

```
struct in_addr someAddr;
someAddr.s_addr = inet_addr("10.0.0.1");
```

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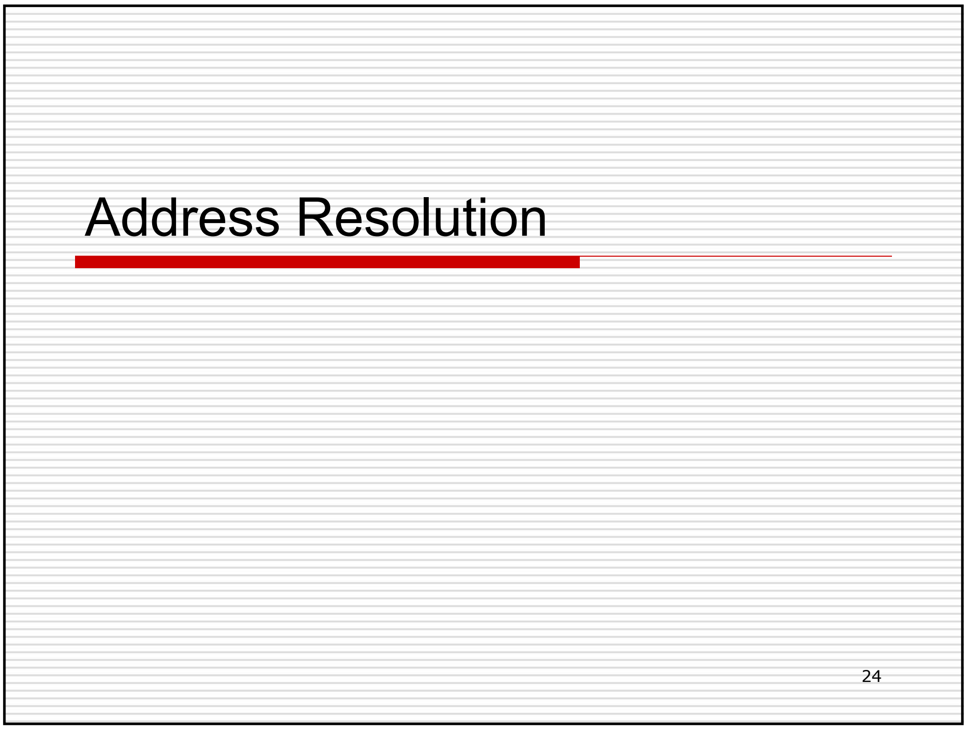

## Address Resolution

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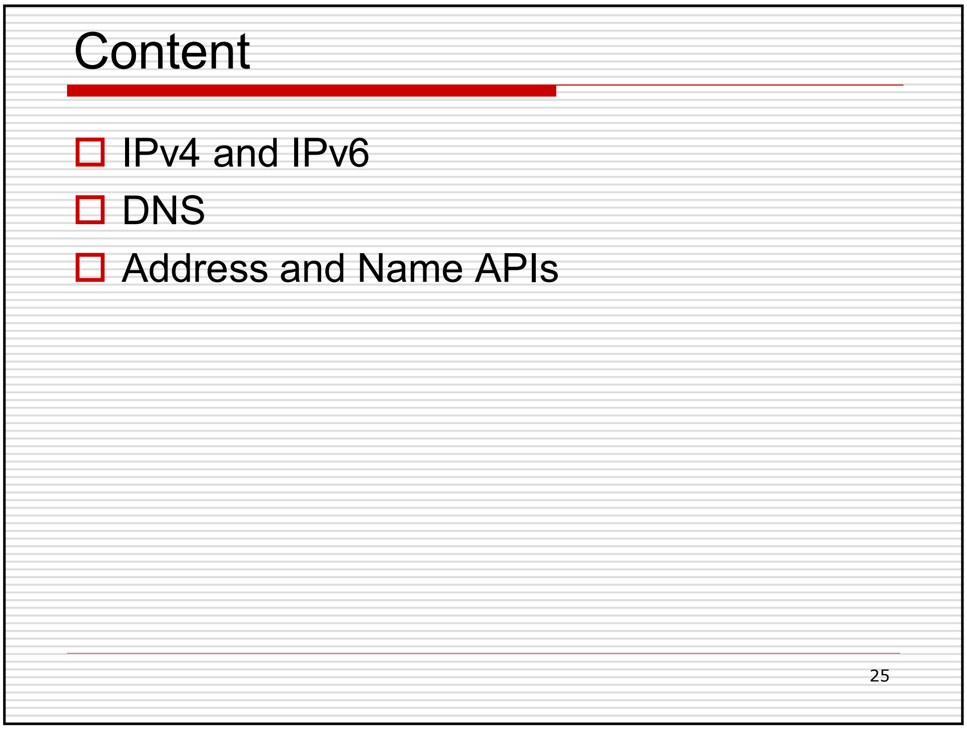
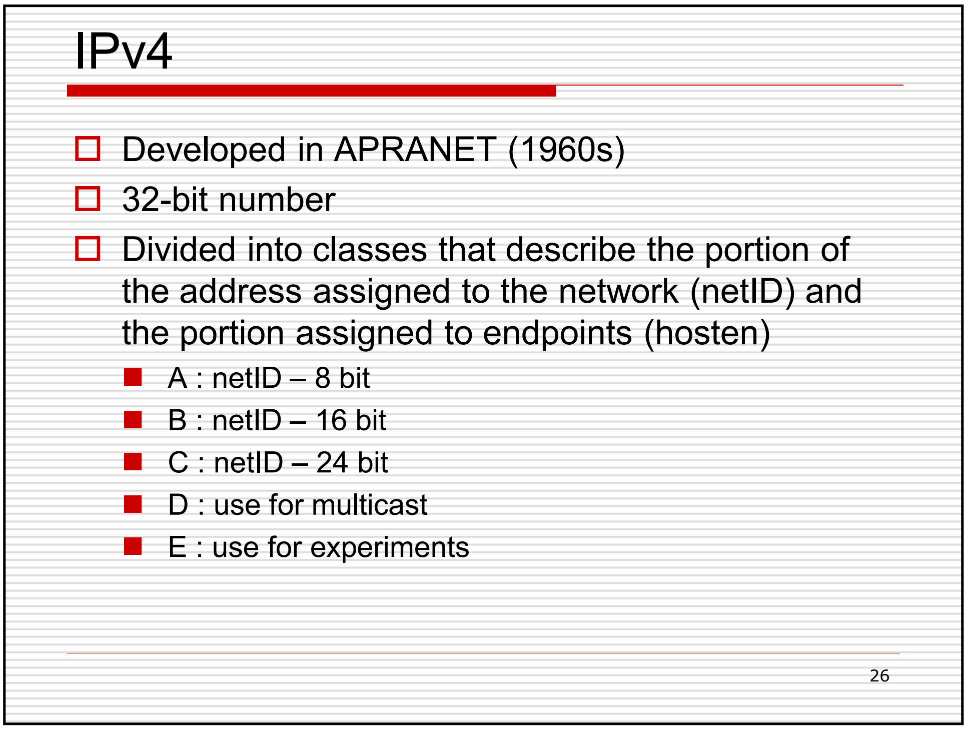


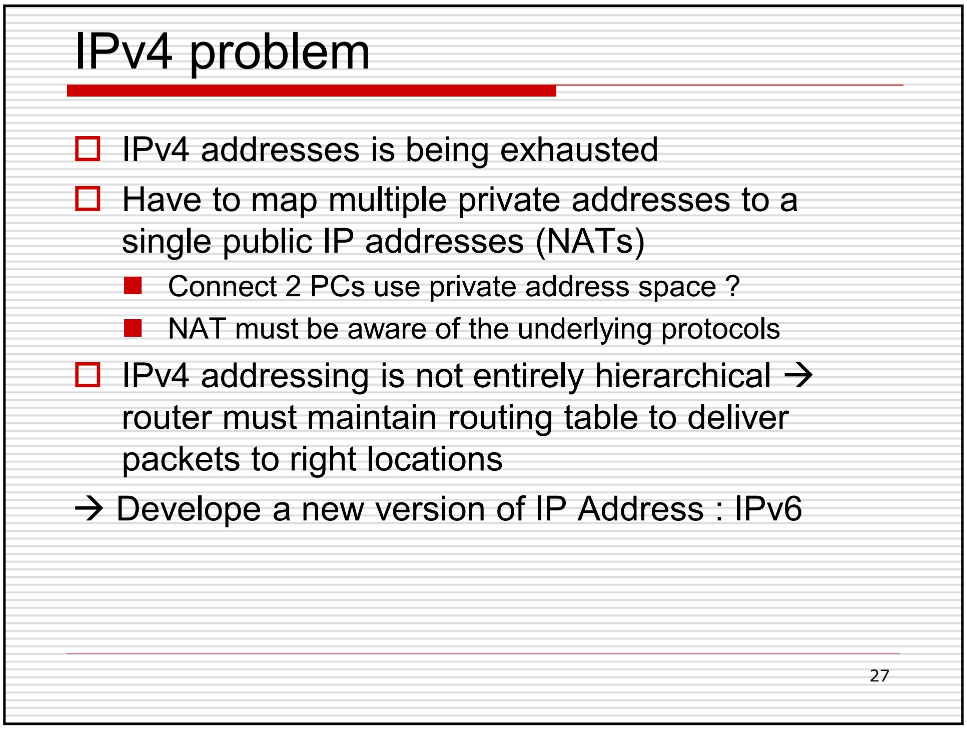
## Content

- □ IPv4 and IPv6
- □ DNS
- □ Address and Name APIs



## IPv4

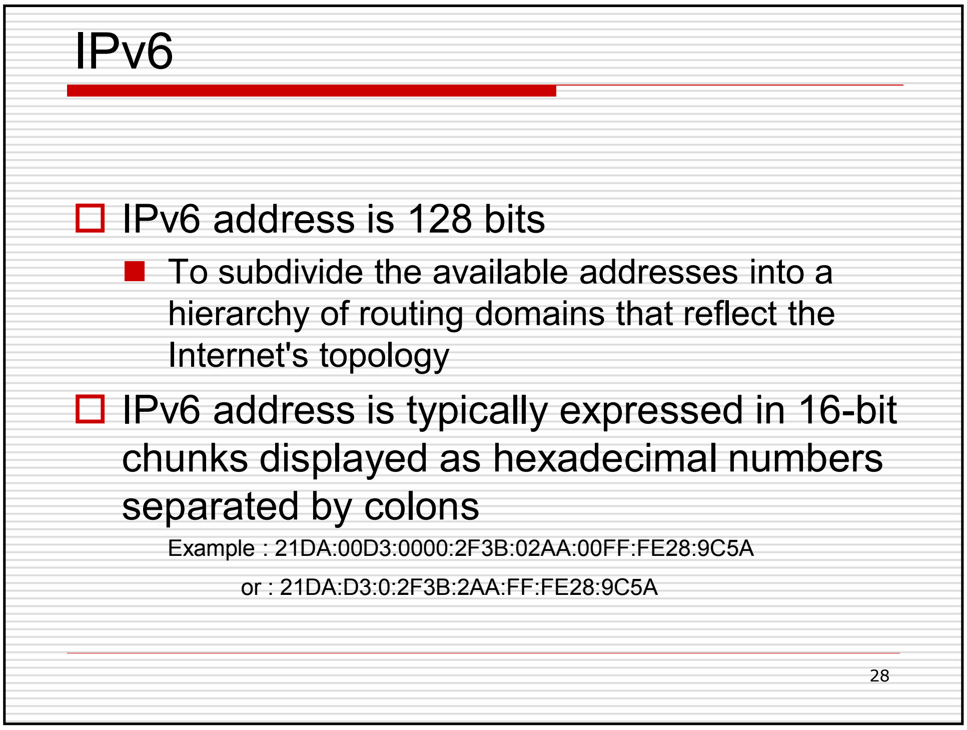
- □ Developed in APRANET (1960s)
- □ 32-bit number
- □ Divided into classes that describe the portion of the address assigned to the network (netID) and the portion assigned to endpoints (hosten)
  - A : netID – 8 bit
  - B : netID – 16 bit
  - C : netID – 24 bit
  - D : use for multicast
  - E : use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



## IPv4 problem

- □ IPv4 addresses is being exhausted
- □ Have to map multiple private addresses to a single public IP addresses (NATs)
  - ■ Connect 2 PCs use private address space ?
  - ■ NAT must be aware of the underlying protocols
- □ IPv4 addressing is not entirely hierarchical → router must maintain routing table to deliver packets to right locations

→ Develope a new version of IP Address : IPv6

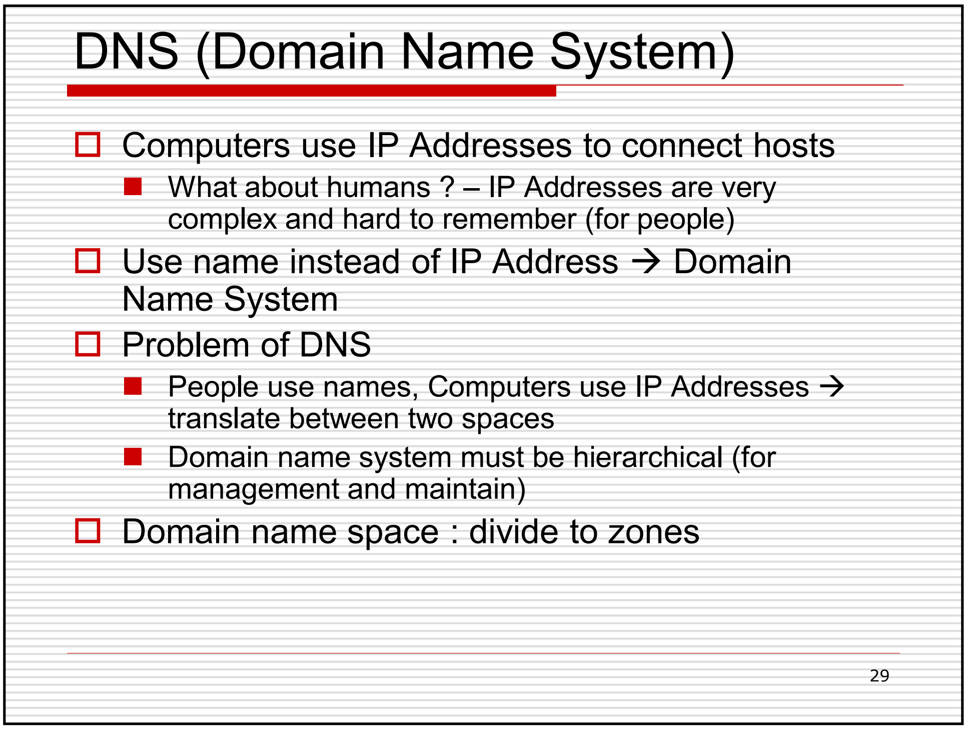


## IPv6

- □ 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

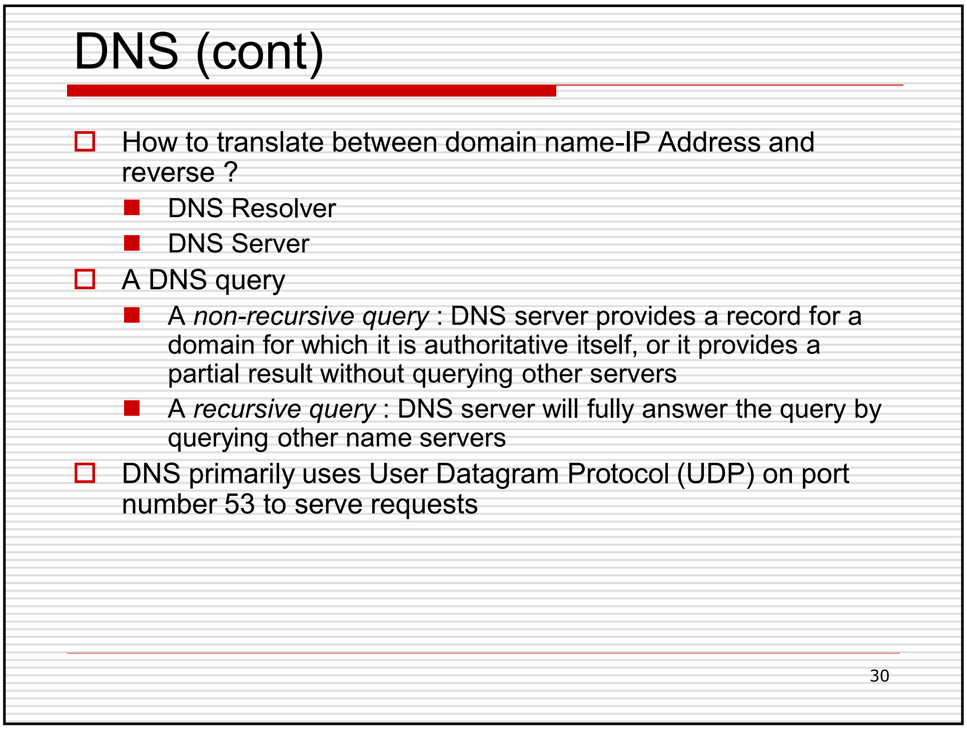
Example : 21DA:00D3:0000:2F3B:02AA:00FF:FE28:9C5A

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



## DNS (Domain Name System)

- □ Computers use IP Addresses to connect hosts
  - ■ What about humans ? – IP Addresses are very complex and hard to remember (for people)
- □ Use name instead of IP Address → Domain Name System
- □ Problem of DNS
  - ■ People use names, Computers use IP Addresses → translate between two spaces
  - ■ Domain name system must be hierarchical (for management and maintain)
- □ Domain name space : divide to zones

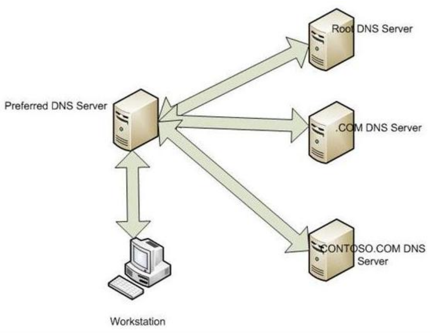


## DNS (cont)

- □ How to translate between domain name-IP Address and reverse ?
  - ■ DNS Resolver
  - ■ DNS Server
- □ A DNS query
  - ■ A *non-recursive query* : DNS server provides a record for a domain for which it is authoritative itself, or it provides a partial result without querying other servers
  - ■ A *recursive query* : DNS server will fully answer the query by querying other name servers
- □ DNS primarily uses User Datagram Protocol (UDP) on port number 53 to serve requests

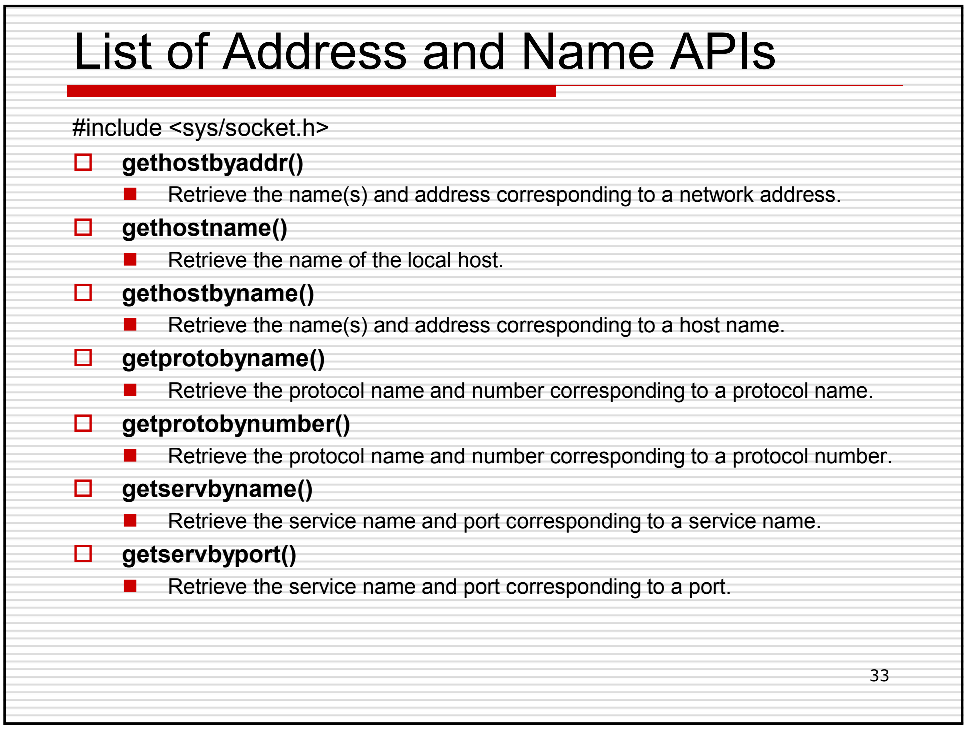
# DNS (cont)

- Address resolution mechanism
  - Local system is pre-configured with the known addresses of the root server in a file of *root hints*
  - Query one of the root servers to find the server authoritative for the next level down
  - Querying level down server for the address of a DNS server with detailed knowledge of the lower level domain until reach the DNS Server return final address



# DNS (cont)

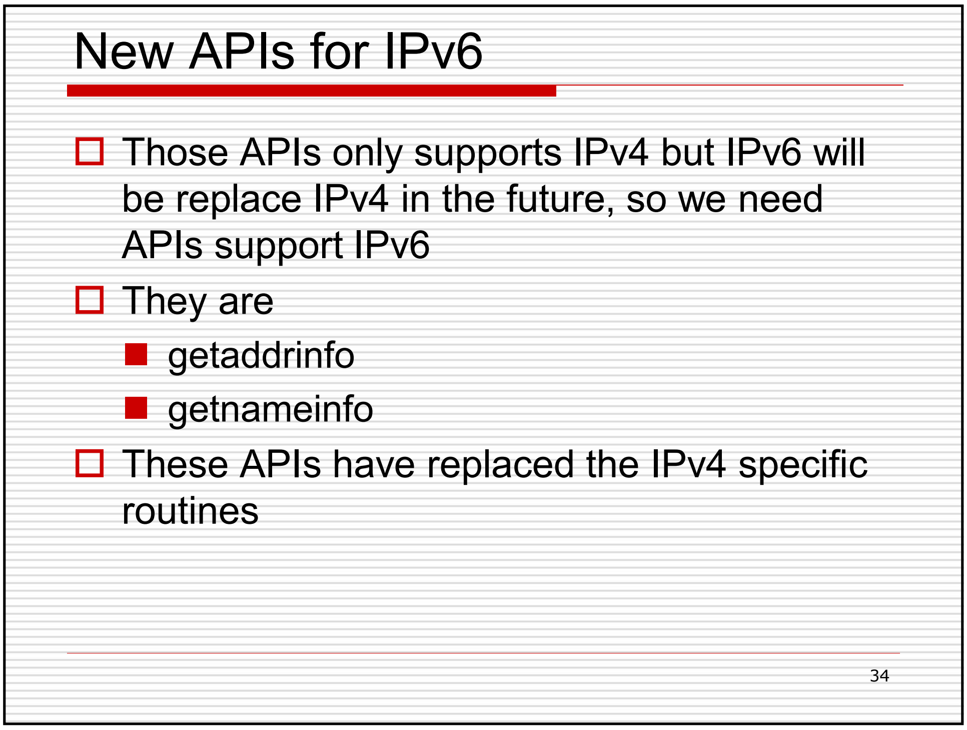
- A *Resource Record* (RR) is the basic data element in the domain name system
- All records use the common format specified in RFC 1035 (in IP networks)
- **RR (Resource record) fields**
  - NAME (variable)
    - Name of the node to which this record pertains.
  - TYPE (2)
    - Type of RR. For example, MX is type 15
  - CLASS (2)
    - Class code
  - TTL (4)
    - Unsigned time in seconds that RR stays valid
  - RDLENGTH (2)
    - Length of RDATA field
  - RDATA (variable)
    - Additional RR-specific data



## List of Address and Name APIs

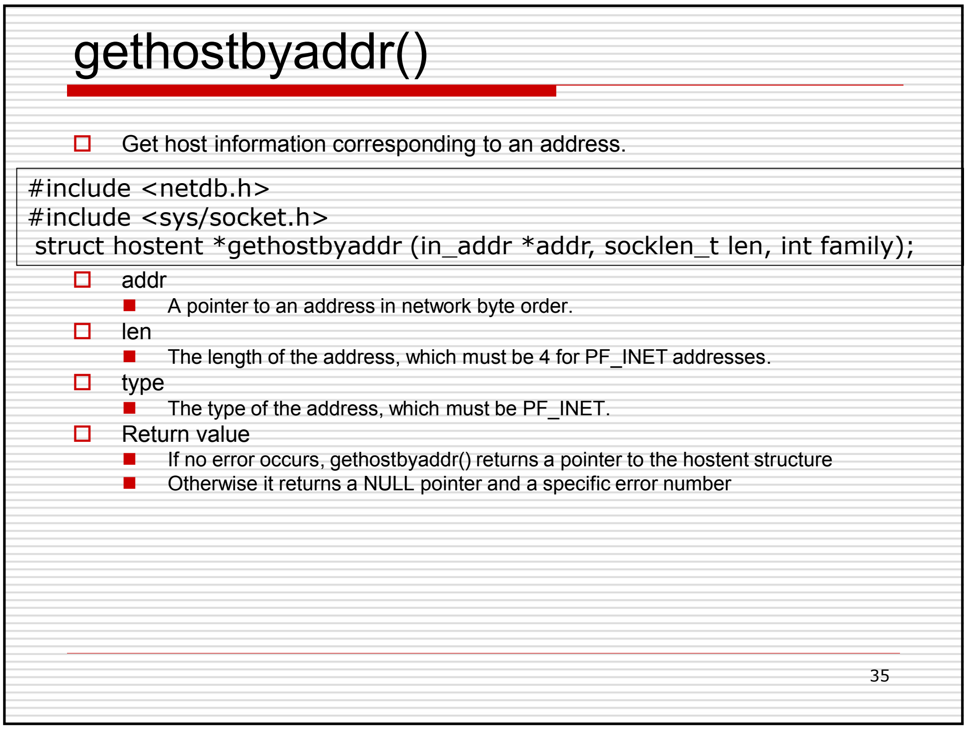
#include <sys/socket.h>

- □ **gethostbyaddr()**
  - Retrieve the name(s) and address corresponding to a network address.
- □ **gethostname()**
  - Retrieve the name of the local host.
- □ **gethostbyname()**
  - Retrieve the name(s) and address corresponding to a host name.
- □ **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.



## New APIs for IPv6

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

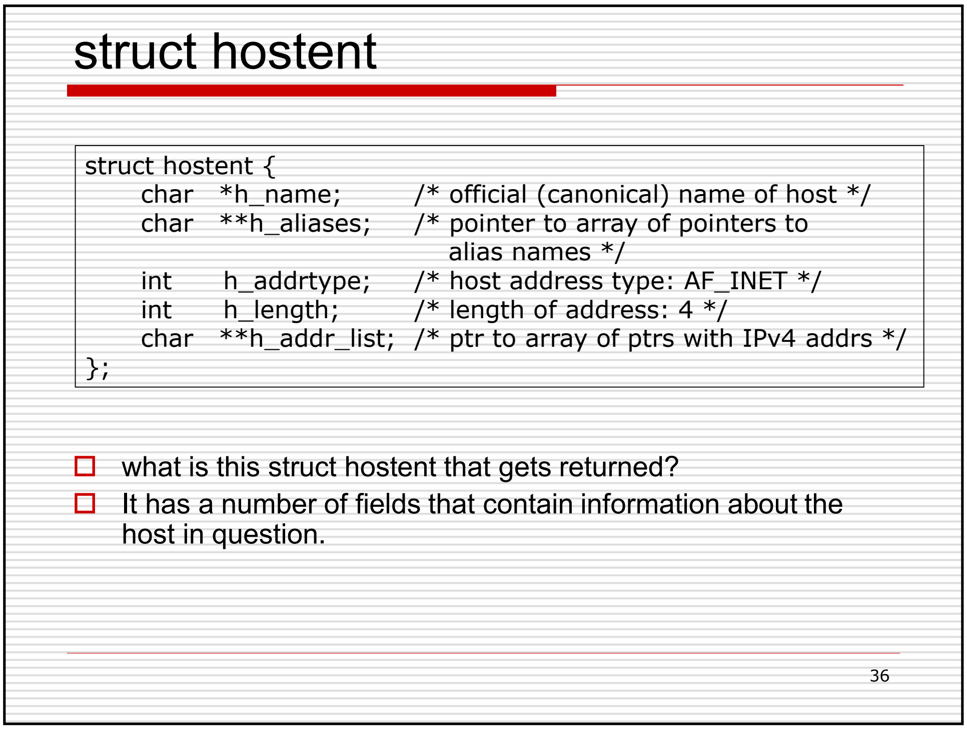


# gethostbyaddr()

- □ Get host information corresponding to an address.

```
#include <netdb.h>
#include <sys/socket.h>
 struct hostent *gethostbyaddr (in_addr *addr, socklen_t len, int family);
```

- □ addr
  - A pointer to an address in network byte order.
- □ len
  - The length of the address, which must be 4 for PF_INET addresses.
- □ type
  - The type of the address, which must be PF_INET.
- □ Return value
  - If no error occurs, gethostbyaddr() returns a pointer to the hostent structure
  - Otherwise it returns a NULL pointer and a specific error number

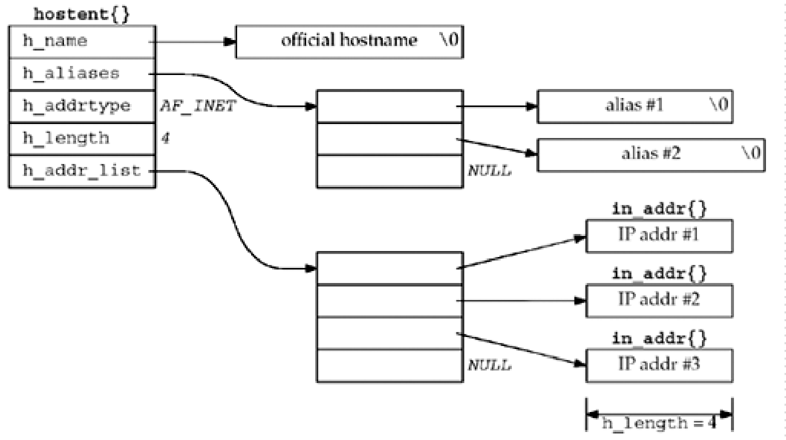


# struct hostent

```
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

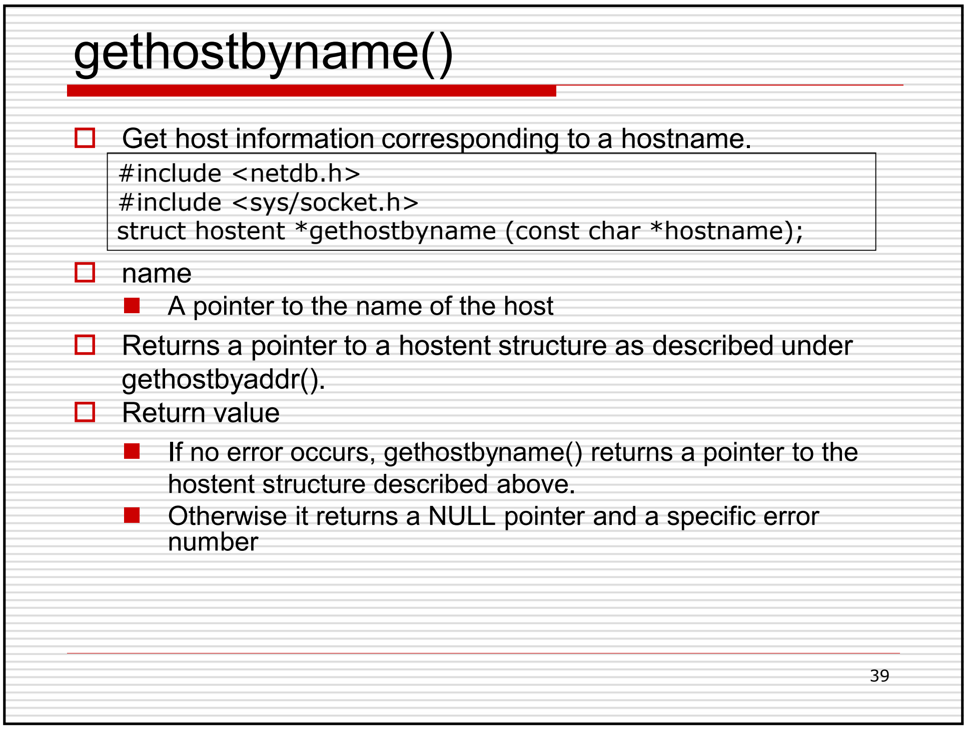


# gethostname()

- Return the standard host name for the local machine.

```
#include <sys/unistd.h>
#include <sys/socket.h>
int gethostname(char *name, size_t len);
```

- name
  - A pointer to a buffer that will receive the host name.
- Len
  - The length of the buffer
- Return value
  - If no error occurs, gethostname() return 0
  - Otherwise it returns SOCKET_ERROR and a specific error code



# gethostbyname()

- Get host information corresponding to a hostname.

```
#include <netdb.h>
#include <sys/socket.h>
struct hostent *gethostbyname (const char *hostname);
```

- name
  - A pointer to the name of the host
- Returns a pointer to a hostent structure as described under gethostbyaddr().
- Return value
  - If no error occurs, gethostbyname() returns a pointer to the hostent structure described above.
  - Otherwise it returns a NULL pointer and a specific error number

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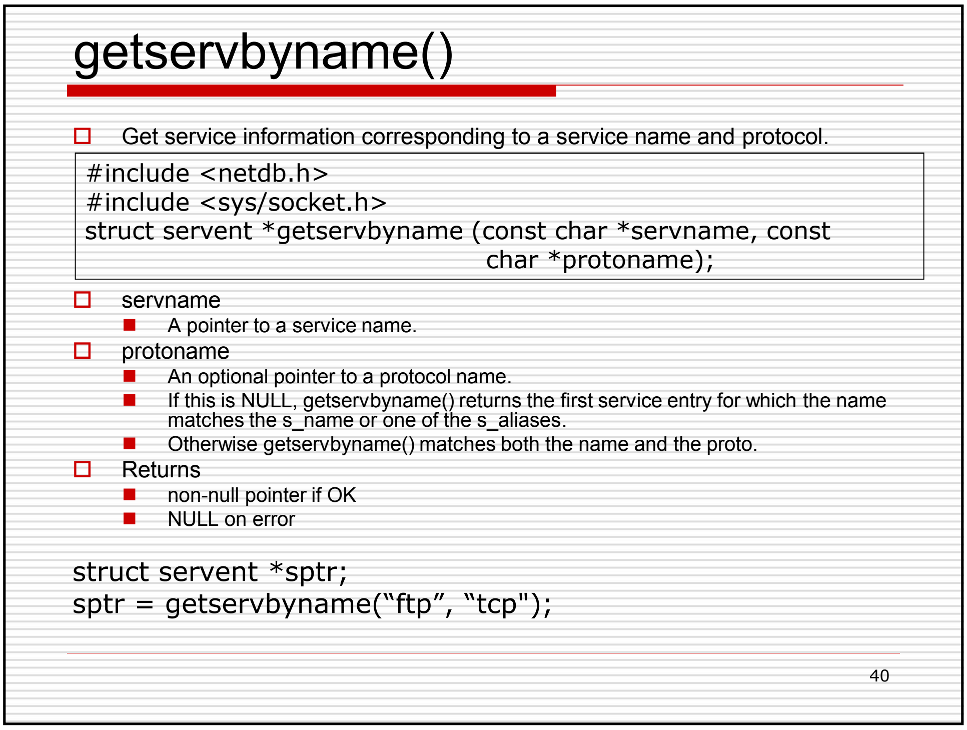

# getservbyname()

- 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");
```

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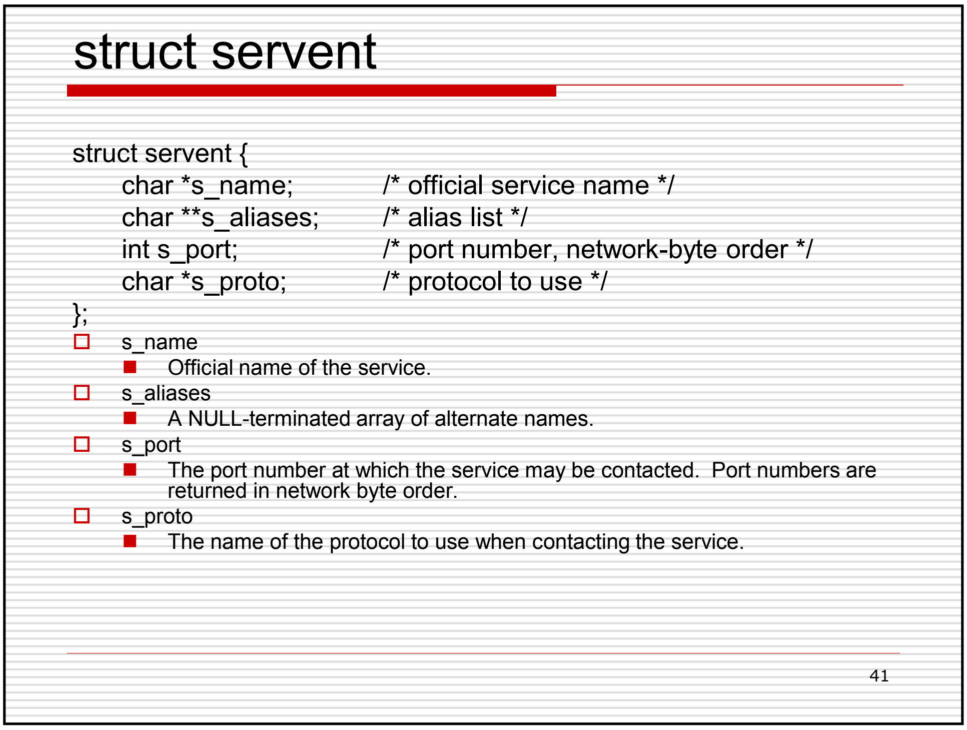
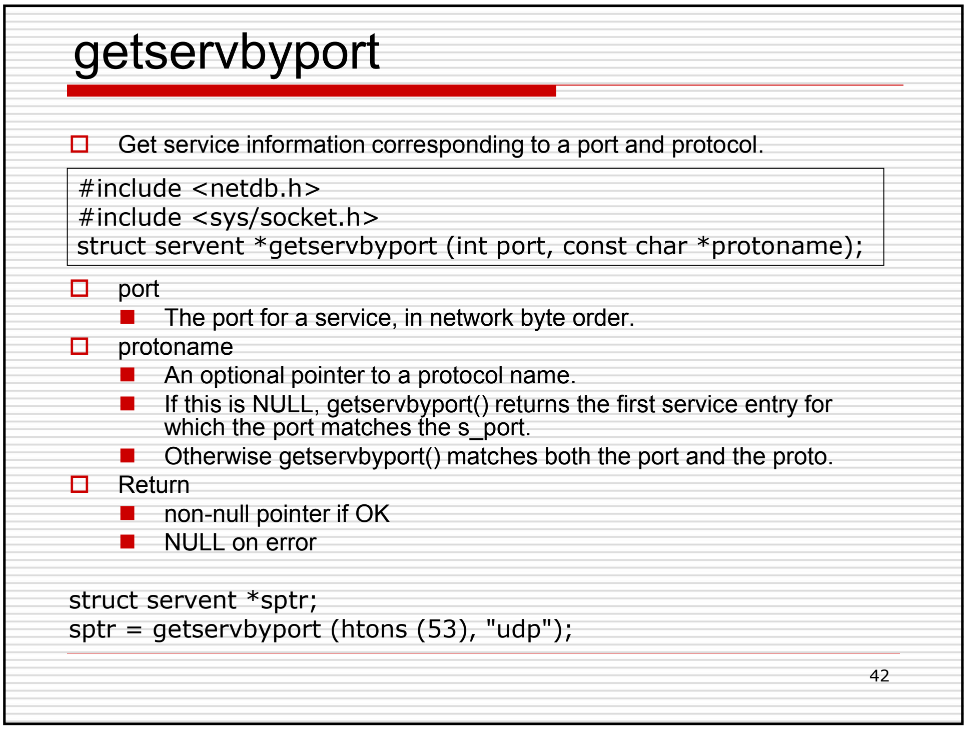


## struct servent

```
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");
```