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Sockets of both types must specify a **5-tuple**:

Type	*Protocol*	*Local-Addr* *Local-Process*	*Foreign-Addr* *Foreign-Process*
connection oriented server	socket()	bind()	listen(), accept()
connection oriented client	socket()	connect()	
connectionless server	socket()	bind()	recvfrom()
connectionless client	socket()	bind()	sendto()

Connection-Oriented Setup

Server	*Client*	*Description*
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close()	close()	closes associated file descriptor

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- If you want reliable, properly sequenced packets, don’t re-invent the wheel: use connection-oriented communications

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	SOCK_RDM	reliably delivered packet, (but not sequencing)

socket(), con’t.

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Valid Type/Domain/Protocol Combinations

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SOCK_RAW		IP	√
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SOCK_RAW		IP	√
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- SOCK_RAW sockets resemble SOCK_DGRAMs; they send datagrams via sendto()/recvfrom() (common use: ping)

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	SOCK_RAW	IPPROTO_RAW	
AF_NS	SOCK_STREAM	NSPROTO_SPP	
	SOCK_SEQPACKET	NSPROTO_SPP	
	SOCK_RAW	NSPROTO_ERROR	
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	SOCK_RAW	IPPROTO_ICMP	ICMP
	SOCK_RAW	IPPROTO_RAW	(raw)
AF_NS	SOCK_STREAM	NSPROTO_SPP	SPP
	SOCK_SEQPACKET	NSPROTO_SPP	SPP
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SPP	Sequenced Packet Protocol (a Xerox Network Systems protocol for reliable flow-controlled packet delivery)

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- Each layer only interacts directly with the layer directly beneath it

OSI Layers

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Data Unit	*Layer*	*Function*
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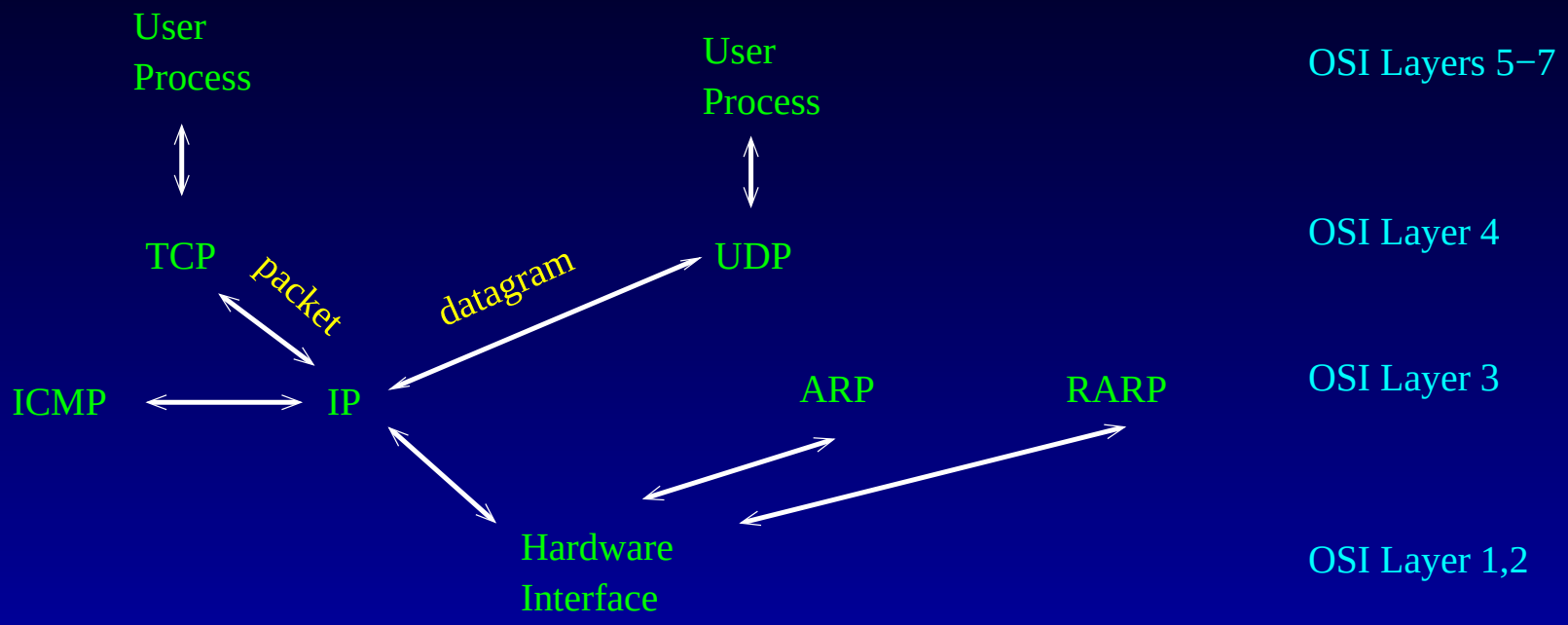
Frame	2. Data link	Physical addressing
Bit	1. Physical	Media, signal, and binary transmission

Layers and Protocols



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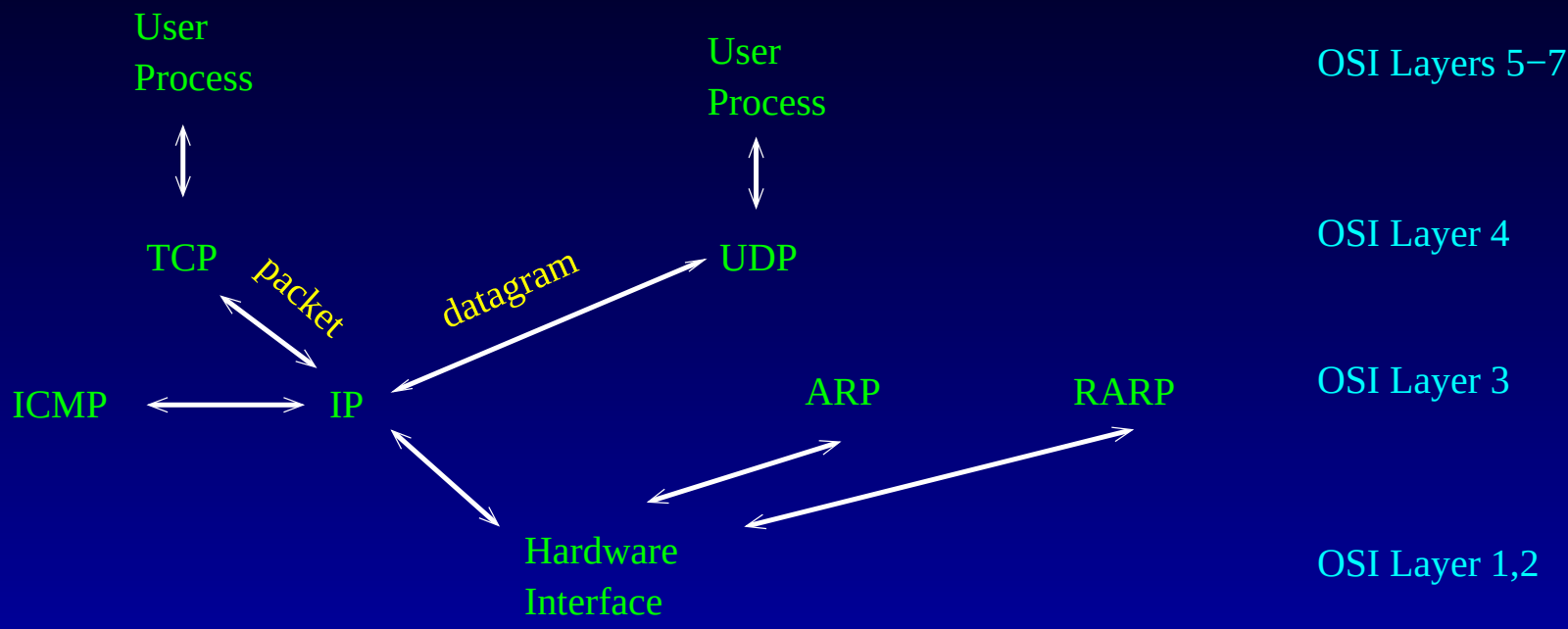

- IP handles routing. May fragment a packet into multiple packets if the next network can't handle the packet's size, but it will be re-assembled upon delivery
- If IP packets arrive so fast that they are discarded, the IP module will send a quench IPCMP to the source

Transport Layer

Feature	*IP*	*UDP*	*TCP*

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connection-oriented			√

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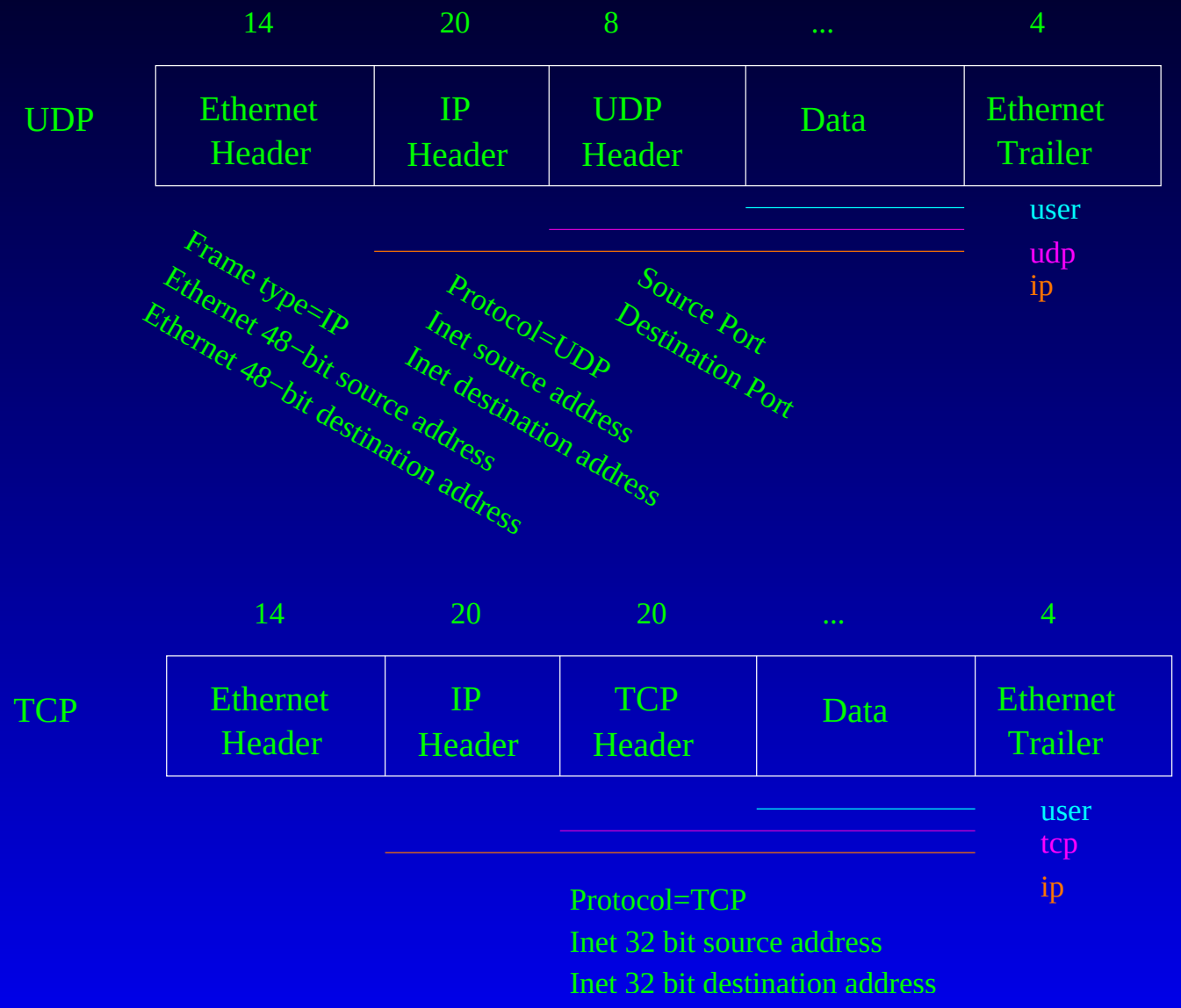
duplicate detection			√
sequencing			√
flow control			√

Transport Layer

Feature	*IP*	*UDP*	*TCP*
connection-oriented			√
message boundaries	√	√	
data checksum		optional	√
+ acknowledge			√
timeout to re-transmit			√
duplicate detection			√
sequencing			√
flow control			√

UDP provides port numbers and an optional checksum over IP

Data Packaging



Clearly, transmission of user data is most efficient when the data section is as large as possible.

Sockets: bind()

#include <sys/types.h>

#include <sys/socket.h> *(1-tuple → 3-tuple)*

int bind(int sockfd, const struct sockaddr *addr,socklen_t addrlen);

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- For addrlen: use sizeof()
- server: sin_addr.s_addr= htonl(INADDR_ANY);
- client: sin_addr= *(((struct in_addr *) gethostbyname(...))->h_addr); *(obsolete - see getaddrinfo())*

Sockets: bind(), con't.

- For Unix-style *(local)* addr:

```
struct sockaddr {
  short sun_family; // AF_UNIX
  char  sun_path[]; // unix pathname
  }
```

- For Internet-style addr:

```
struct sockaddr_in {
  short          sin_family; // AF_INET
  u_short        port;       // port number
  struct in_addr sin_addr;
  }
```

Use a cast to pass in_addr structure pointers to bind():

```
(struct sockaddr *)&sockaddrin
```

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- The socket referred to by sockfd is a passive socket; ie. it needs accept() to complete the 5-tuple
- If a connection request arrives, but the backlog queue is full, the client may receive a -1/ECONNREFUSED error.

sockaddr

```
struct sockaddr {
  unsigned short sa_family;     // address family, AF_xxx
  char           sa_data[14];   // 14 bytes of protocol address
  }
struct in_addr {                // IPv4 sockets
  unsigned long  s_addr;        // load this with inet_pton()
  }
struct sockaddr_in6 {           // IPv6 sockets
  u_int16_t      sin6_family;   // address family, AF_INET6
  u_int16_t      sin6_port;     // port number, in network byte order
  u_int32_t      sin6_scope_id; // scope id
  }
struct in6_addr {               // IPv6 address
  unsigned char  s6_addr[16];   // load with inet_pton()
  }
```

Many socket functions use one of the above structures cast to a pointer to `struct sockaddr`.

Utilities: inet_pton()

#include <arpa/inet.h>

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dst Destination structure address; for AF_INET: must be sizeof(struct in_addr) bytes long (4 bytes).

For AF_INET6: must be sizeof(struct in6_addr) bytes long (16 bytes)

Sockets: connect()

(1-tuple → 5-tuple)

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- Connectionless sockets may use sa_family set to AF_UNSPEC to dissolve the association.

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(3-tuple → 5-tuple)

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- If no pending connections are on the queue, but sockaddr is non-blocking, accept() will return a -1/EAGAIN.

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- Equivalent to sendto(sockfd,buf,len,flags,NULL,0) (see next slide)

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- If the message is too long, sendto() will return an error EMSGSIZE; the message is not transmitted.

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- Returns -1 on failure, or a positive qty of bytes actually received (which may be less than those sent!)

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- Returns like recv()
- Primarily for SOCK_DGRAM (datagrams)

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SHUT_RD	further reading (receptions) disallowed
SHUT_WR	further writing (transmissions) disallowed
SHUT_RDWR	subsequent reading and writing via sockfd is disallowed

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- If fd is the last file descriptor holding open the file, then resources associated with the open file descriptor are freed.

(see connection.c packet.c)

Utilities: gethostbyname()

```
#include <netdb.h>
extern int h_errno;
struct hostent *gethostbyname(const char *name);
#define h_addr h_addr_list[0]
```

name the name of the host, using IPv4 standard dot notation or in IPv6 notation; in either colon or dot notation accepted.

- Returns a struct hostent *(see next slide)*
- A host may have more than one address if it is “multihomed” (ie. the machine has more than one internet interface, each with its own address)
- Considered to be obsolete; use getaddrinfo() instead

Utilities: The hostent Structure

```
struct hostent {
  char  *h_name;       // official name of host
  char **h_aliases;    // alias list
  int    h_length;     // length of address
  char **h_addr_host;  // list of addresses from name server
                       // (a NULL terminated list)
  }
```

Socket Code Fragment

```
struct sockaddr_in  sin; // internet socket addressing
struct hostent     *phostent= NULL;

// open a socket for clients
sktfd= socket(AF_INET,SOCK_STREAM,0);

// initialize the sockaddr_in
memset(&sin,0x00,sizeof(struct sockaddr_in));
sin.sin_family = AF_INET;
sin.sin_addr   = *((struct in_addr *) phostent->h_addr;
sin.sin_port   = htons((u_short) port);

// get a hostent structure
phostent       = gethostbyname(hostname);

// connect
if(connect(sktfd,(struct sockaddr*) &sin,sizeof(sin)) < 0){
  perror("");
  }
```

Utilities: IP and Name Lookups

Transformation	Obsolete Functions	New Functions
name → IP	gethostbyname()	getaddrinfo()
IP → name	gethostbyaddr()	getnameinfo()

The newer functions can use IPv4 or IPv6 transparently, and they can handle services such as “http” as well as port numbers.

Utilities: getaddrinfo()

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

void freeaddrinfo(struct addrinfo *res);

node numerical network address or a hostname string

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service sets the port; service name (see man 5 services). May be null.

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```
struct addrinfo {
  int                 ai_flags;
  int                 ai_family;
  int                 ai_socktype;
  int                 ai_protocol;
  size_t              ai_addrlen;
  struct sockaddr   * ai_addr;
  char              * ai_canonname;
  struct addrinfo   * ai_next;
  }
```

see next slide

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(see using_getaddrinfo.c)

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- The function is re-entrant, and allows programs to avoid IPv4 vs IPv6 dependencies

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- Returns a structure of type hostent (see previous slide)

Utilities: getservbyname()

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struct servent {
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Utilities: Byte Ordering

#include <arpa/inet.h>

#include <netinet/in.h> **(some require this header file instead)**

uint32_t htonl(uint32_t hostlong);

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Utilities: Byte Operations

SysV
```
#include <string.h>
void *memcpy(void *dest, const void *src, size_t n);
void *memmove(void *dest, const void *src, size_t n);
void *memset(void *s, int c, size_t n);
int memcmp(const void *s1, const void *s2, size_t n);
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BSD
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* void bzero(void *s, size_t n);
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Utilities: Address Conversion

```
#include <sys/socket.h>
#include <netinet/in.h>
#include <arpa/inet.h>
int inet_aton(const char *cp, struct in_addr *inp);
char *inet_ntoa(struct in_addr in);
in_addr_t inet_network(const char *cp);
```

inet_aton() converts an IPv4 number and dot notation string into a struct in_addr structure.

Returns non-zero if valid, 0 otherwise.

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struct in_addr inet_network() returns the following structure:

```
typedef uint32_t in_addr_t;
struct in_addr {
  in_addr_t s_addr;
  };
```

Utilities: getpeername()

```
#include <sys/socket.h>
int getpeername(int sockfd, struct sockaddr *addr, socklen_t *addrlen);
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sockfd an open socket descriptor

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The getpeername() function converts a socket file descriptor into a sockaddr-based peername.

Utilities: gethostname()

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#include <unistd.h>
int gethostname(char *name, size_t len);
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- It may or may not have a terminating null byte in such a case.

Ports

Reserved ports	1 -1023

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  Only the superuser privileged processes are allowed to bind an address with this sort of port to a socket.
- See /etc/services for a list of service names, ports, and protocol (ie. whether it uses udp or tcp)