3.1 Introduction

This chapter begins the description of the sockets API. We begin with socket address structures, which will be found in almost every example in the text. These structures can be passed in two directions: from the process to the kernel, and from the kernel to the process. The latter case is an example of a value-result argument, and we will encounter other examples of these arguments throughout the text.

The address conversion functions convert between a text representation of an address and the binary value that goes into a socket address structure. Most existing IPv4 code uses `inet_addr` and `inet_ntoa`, but two new functions, `inet_pton` and `inet_ntop`, handle both IPv4 and IPv6.

One problem with these address conversion functions is that they are dependent on the type of address being converted: IPv4 or IPv6. We will develop a set of functions whose names begin with `sock_` that work with socket address structures in a protocol-independent fashion. We will use these throughout the text to make our code protocol-independent.

[Team LiB] PREVIOUS NEXT

3.2 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. The names of these structures begin with `sockaddr_` and end with a unique suffix for each protocol suite.

IPv4 Socket Address Structure

An IPv4 socket address structure, commonly called an "Internet socket address structure," is named `sockaddr_in` and is defined by including the `<netinet/in.h>` header. Figure 3.1 shows the POSIX definition.

Figure 3.1 The Internet (IPv4) socket address structure: `sockaddr_in`.

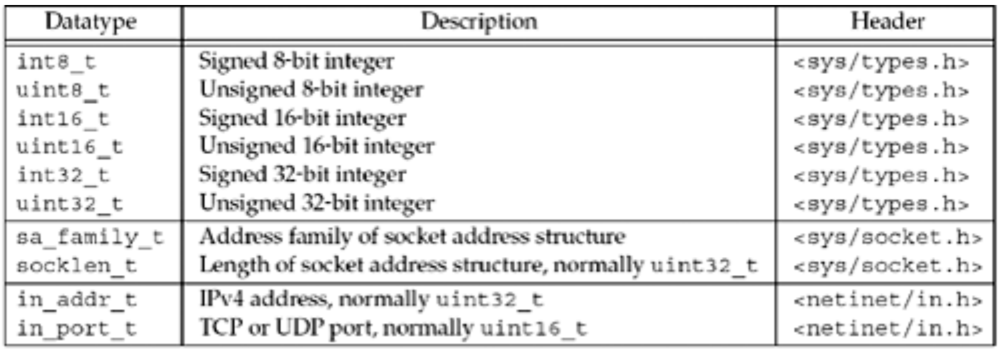
```
struct in_addr {
  in_addr_t   s_addr;           /* 32-bit IPv4 address */
                                /* network byte ordered */
};

struct sockaddr_in {
  uint8_t         sin_len;      /* length of structure (16) */
  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 */
};
```

There are several points we need to make about socket address structures in general using this example:

- The length member, `sin_len`, was added with 4.3BSD-Reno, when support for the OSI protocols was added (Figure 1.15). Before this release, the first member was `sin_family`, which was historically an `unsigned short`. Not all vendors support a length field for socket address structures and the POSIX specification does not require this member. The datatype that we show, `uint8_t`, is typical, and POSIX-compliant systems provide datatypes of this form (Figure 3.2).

  Figure 3.2. Datatypes required by the POSIX specification.

Datatype	Description	Header
`int8_t`	Signed 8-bit integer	`<sys/types.h>`
`uint8_t`	Unsigned 8-bit integer	`<sys/types.h>`
`int16_t`	Signed 16-bit integer	`<sys/types.h>`
`uint16_t`	Unsigned 16-bit integer	`<sys/types.h>`
`int32_t`	Signed 32-bit integer	`<sys/types.h>`
`uint32_t`	Unsigned 32-bit integer	`<sys/types.h>`
`sa_family_t`	Address family of socket address structure	`<sys/socket.h>`
`socklen_t`	Length of socket address structure, normally `uint32_t`	`<sys/socket.h>`
`in_addr_t`	IPv4 address, normally `uint32_t`	`<netinet/in.h>`
`in_port_t`	TCP or UDP port, normally `uint16_t`	`<netinet/in.h>`

  Having a length field simplifies the handling of variable-length socket address structures.

- Even if the length field is present, we need never set it and need never examine it, unless we are dealing with routing sockets (Chapter 18). It is used within the kernel by the routines that deal with socket address structures from various protocol families (e.g., the routing table code).

  > The four socket functions that pass a socket address structure from the process to the kernel, `bind`, `connect`, `sendto`, and `sendmsg`, all go through the `sockargs` function in a Berkeley-derived implementation (p. 452 of TCPv2). This function copies the socket address structure from the process and explicitly sets its `sin_len` member to the size of the structure that was passed as an argument to these four functions. The five socket functions that pass a socket address structure from the kernel to the process, `accept`, `recvfrom`, `recvmsg`, `getpeername`, and `getsockname`, all set the `sin_len` member before returning to the process.
  >
  > Unfortunately, there is normally no simple compile-time test to determine whether an implementation defines a length field for its socket address structures. In our code, we test our own `HAVE_SOCKADDR_SA_LEN` constant (Figure

D.2), but whether to define this constant or not requires trying to compile a simple test program that uses this optional structure member and seeing if the compilation succeeds or not. We will see in Figure 3.4 that IPv6 implementations are required to define `SIN6_LEN` if socket address structures have a length field. Some IPv4 implementations provide the length field of the socket address structure to the application based on a compile-time option (e.g., `_SOCKADDR_LEN`). This feature provides compatibility for older programs.

- The POSIX specification requires only three members in the structure: `sin_family`, `sin_addr`, and `sin_port`. It is acceptable for a POSIX-compliant implementation to define additional structure members, and this is normal for an Internet socket address structure. Almost all implementations add the `sin_zero` member so that all socket address structures are at least 16 bytes in size.
- We show the POSIX datatypes for the `s_addr`, `sin_family`, and `sin_port` members. The `in_addr_t` datatype must be an unsigned integer type of at least 32 bits, `in_port_t` must be an unsigned integer type of at least 16 bits, and `sa_family_t` can be any unsigned integer type. The latter is normally an 8-bit unsigned integer if the implementation supports the length field, or an unsigned 16-bit integer if the length field is not supported. Figure 3.2 lists these three POSIX-defined datatypes, along with some other POSIX datatypes that we will encounter.
- You will also encounter the datatypes `u_char`, `u_short`, `u_int`, and `u_long`, which are all unsigned. The POSIX specification defines these with a note that they are obsolete. They are provided for backward compatibility.
- Both the IPv4 address and the TCP or UDP port number are always stored in the structure in network byte order. We must be cognizant of this when using these members. We will say more about the difference between host byte order and network byte order in Section 3.4.
- The 32-bit IPv4 address can be accessed in two different ways. For example, if `serv` is defined as an Internet socket address structure, then `serv.sin_addr` references the 32-bit IPv4 address as an `in_addr` structure, while `serv.sin_addr.s_addr` references the same 32-bit IPv4 address as an `in_addr_t` (typically an unsigned 32-bit integer). We must be certain that we are referencing the IPv4 address correctly, especially when it is used as an argument to a function, because compilers often pass structures differently from integers.

  The reason the `sin_addr` member is a structure, and not just an `in_addr_t`, is historical. Earlier releases (4.2BSD) defined the `in_addr` structure as a `union` of various structures, to allow access to each of the 4 bytes and to both of the 16-bit values contained within the 32-bit IPv4 address. This was used with class A, B, and C addresses to fetch the appropriate bytes of the address. But with the advent of subnetting and then the disappearance of the various address classes with classless addressing (Section A.4), the need for the `union` disappeared. Most systems today have done away with the `union` and just define `in_addr` as a structure with a single `in_addr_t` member.

- The `sin_zero` member is unused, but we *always* set it to 0 when filling in one of these structures. By convention, we always set the entire structure to 0 before filling it in, not just the `sin_zero` member.

  Although most uses of the structure do not require that this member be 0, when binding a non-wildcard IPv4 address, this member must be 0 (pp. 731–732 of TCPv2).

- Socket address structures are used only on a given host: The structure itself is not communicated between different hosts, although certain fields (e.g., the IP address and port) are used for communication.

Generic Socket Address Structure

A socket address structures is *always* passed by reference when passed as an argument to any socket functions. But any socket function that takes one of these pointers as an argument must deal with socket address structures from *any* of the supported protocol families.

A problem arises in how to declare the type of pointer that is passed. With ANSI C, the solution is simple: `void *` is the generic pointer type. But, the socket functions predate ANSI C and the solution chosen in 1982 was to define a *generic* socket address structure in the `<sys/socket.h>` header, which we show in Figure 3.3.

Figure 3.3 The generic socket address structure: `sockaddr`.

```
struct sockaddr {
  uint8_t      sa_len;
  sa_family_t  sa_family;    /* address family: AF_xxx value */
  char         sa_data[14];  /* protocol-specific address */
};
```

The socket functions are then defined as taking a pointer to the generic socket address structure, as shown here in the ANSI C function prototype for the `bind` function:

```
int bind(int, struct sockaddr *, socklen_t);
```

This requires that any calls to these functions must cast the pointer to the protocol-specific socket address structure to be a pointer to a generic socket address structure. For example,

```
struct sockaddr_in  serv;      /* IPv4 socket address structure */

/* fill in serv{} */

bind(sockfd, (struct sockaddr *) &serv, sizeof(serv));
```

If we omit the cast "(`struct sockaddr *`)," the C compiler generates a warning of the form "warning: passing arg 2 of 'bind' from incompatible pointer type," assuming the system's headers have an ANSI C prototype for the `bind` function.

From an application programmer's point of view, the *only* use of these generic socket address structures is to cast pointers to protocol-specific structures.

> Recall in Section 1.2 that in our `unp.h` header, we define `SA` to be the string "`struct sockaddr`" just to shorten the code that we must write to cast these pointers.
>
> From the kernel's perspective, another reason for using pointers to generic socket address structures as arguments is that the kernel must take the caller's pointer, cast it to a `struct sockaddr *`, and then look at the value of `sa_family` to determine the type of the structure. But from an application programmer's perspective, it would be simpler if the pointer type was `void *`, omitting the need for the explicit cast.

IPv6 Socket Address Structure

The IPv6 socket address is defined by including the `<netinet/in.h>` header, and we show it in Figure 3.4.

Figure 3.4 IPv6 socket address structure: `sockaddr_in6`.

```
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 (28) */
  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 */
};
```

> The extensions to the sockets API for IPv6 are defined in RFC 3493 [Gilligan et al. 2003].

Note the following points about Figure 3.4:

- The `SIN6_LEN` constant must be defined if the system supports the length member for socket address structures.
- The IPv6 family is `AF_INET6`, whereas the IPv4 family is `AF_INET`.
- The members in this structure are ordered so that if the `sockaddr_in6` structure is 64-bit aligned, so is the 128-bit `sin6_addr` member. On some 64-bit processors, data accesses of 64-bit values are optimized if stored on a 64-bit boundary.
- The `sin6_flowinfo` member is divided into two fields:
  - The low-order 20 bits are the flow label
  - The high-order 12 bits are reserved

  The flow label field is described with Figure A.2. The use of the flow label field is still a research topic.
- The `sin6_scope_id` identifies the scope zone in which a scoped address is meaningful, most commonly an interface index for a link-local address (Section A.5).

New Generic Socket Address Structure

A new generic socket address structure was defined as part of the IPv6 sockets API, to overcome some of the shortcomings of the existing `struct sockaddr`. Unlike the `struct sockaddr`, the new `struct sockaddr_storage` is large enough to hold any socket address type supported by the system. The `sockaddr_storage` structure is defined by including the `<netinet/in.h>` header, which we show in Figure 3.5.

Figure 3.5 The storage socket address structure: `sockaddr_storage`.

```
struct sockaddr_storage {
  uint8_t      ss_len;       /* length of this struct (implementation dependent) */
  sa_family_t  ss_family;    /* address family: AF_xxx value */
  /* implementation-dependent elements to provide:
   * a) alignment sufficient to fulfill the alignment requirements of
   *    all socket address types that the system supports.
   * b) enough storage to hold any type of socket address that the
   *    system supports.
   */
};
```

The `sockaddr_storage` type provides a generic socket address structure that is different from `struct sockaddr` in two ways:

a. If any socket address structures that the system supports have alignment requirements, the `sockaddr_storage` provides the strictest alignment requirement.

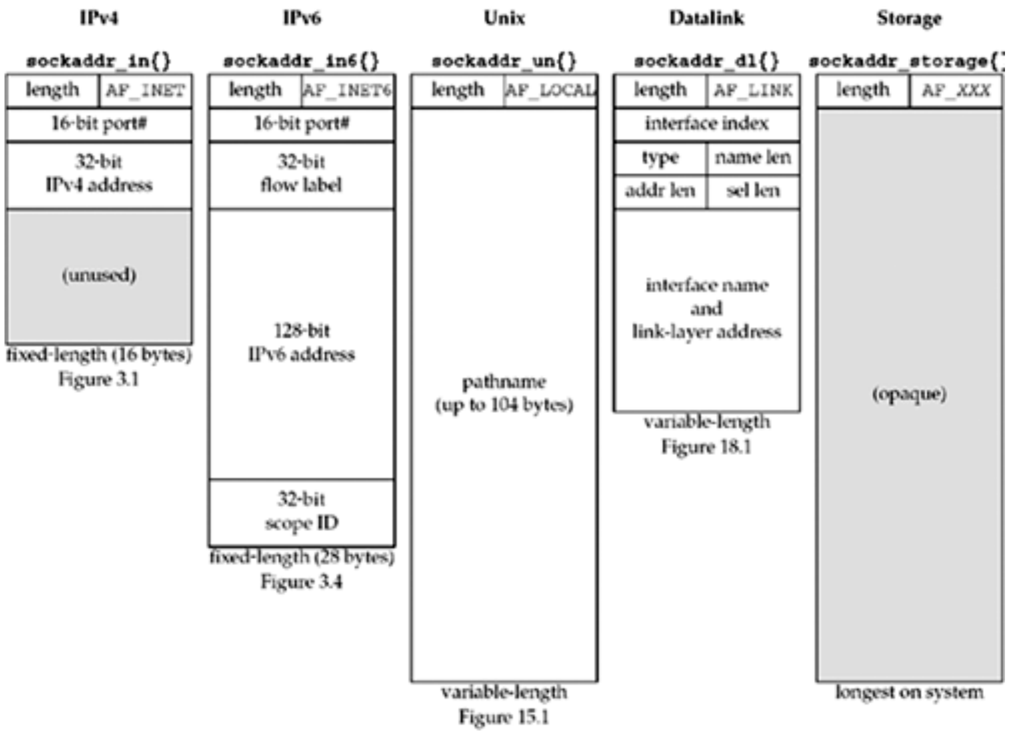
b. The `sockaddr_storage` is large enough to contain any socket address structure that the system supports.

Note that the fields of the `sockaddr_storage` structure are opaque to the user, except for `ss_family` and `ss_len` (if present). The `sockaddr_storage` must be cast or copied to the appropriate socket address structure for the address given in `ss_family` to access any other fields.

Comparison of Socket Address Structures

Figure 3.6 shows a comparison of the five socket address structures that we will encounter in this text: IPv4, IPv6, Unix domain (Figure 15.1), datalink (Figure 18.1), and storage. In this figure, we assume that the socket address structures all contain a one-byte length field, that the family field also occupies one byte, and that any field that must be at least some number of bits is exactly that number of bits.

Figure 3.6. Comparison of various socket address structures.



Two of the socket address structures are fixed-length, while the Unix domain structure and the datalink structure are variable-length. To handle variable-length structures, whenever we pass a pointer to a socket address structure as an argument to one of the socket functions, we pass its length as another argument. We show the size in bytes (for the 4.4BSD implementation) of the fixed-length structures beneath each structure.

> The `sockaddr_un` structure itself is not variable-length (Figure 15.1), but the amount of information—the pathname within the structure—is variable-length. When passing pointers to these structures, we must be careful how we handle the length field, both the length field in the socket address structure itself (if supported by the implementation) and the length to and from the kernel.

This figure shows the style that we follow throughout the text: structure names are always shown in a bolder font, followed by braces, as in **`sockaddr_in{}`**.

We noted earlier that the length field was added to all the socket address structures with the 4.3BSD Reno release. Had the length field been present with the original release of sockets, there would be no need for the length argument to all the socket functions: the third argument to `bind` and `connect`, for example. Instead, the size of the structure could be contained in the length field of the structure.

[Team LiB] PREVIOUS NEXT

3.3 Value-Result Arguments

We mentioned that when a socket address structure is passed to any socket function, it is always passed by reference. That is, a pointer to the structure is passed. The length of the structure is also passed as an argument. But the way in which the length is passed depends on which direction the structure is being passed: from the process to the kernel, or vice versa.

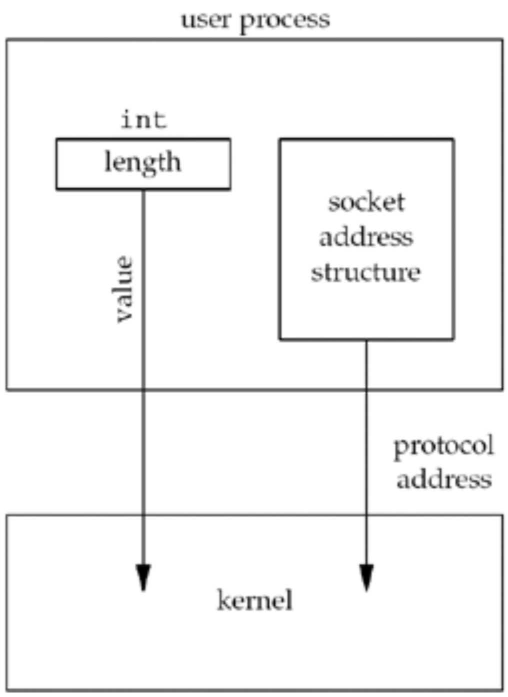
1. Three functions, `bind`, `connect`, and `sendto`, pass a socket address structure from the process to the kernel. One argument to these three functions is the pointer to the socket address structure and another argument is the integer size of the structure, as in

```
struct sockaddr_in serv;

/* fill in serv{} */
connect (sockfd, (SA *) &serv, sizeof(serv));
```

   Since the kernel is passed both the pointer and the size of what the pointer points to, it knows exactly how much data to copy from the process into the kernel. Figure 3.7 shows this scenario.

Figure 3.7. Socket address structure passed from process to kernel.



   We will see in the next chapter that the datatype for the size of a socket address structure is actually `socklen_t` and not `int`, but the POSIX specification recommends that `socklen_t` be defined as `uint32_t`.

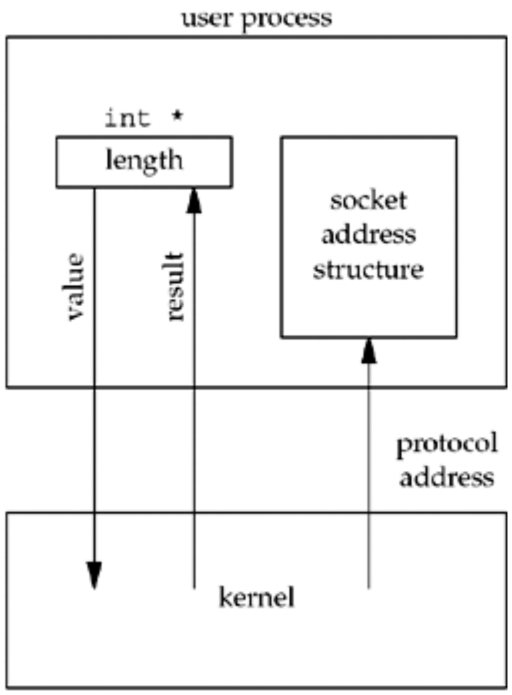
2. Four functions, `accept`, `recvfrom`, `getsockname`, and `getpeername`, pass a socket address structure from the kernel to the process, the reverse direction from the previous scenario. Two of the arguments to these four functions are the pointer to the socket address structure along with a pointer to an integer containing the size of the structure, as in

```
struct sockaddr_un  cli;   /* Unix domain */
socklen_t  len;

len = sizeof(cli);         /* len is a value */
getpeername(unixfd, (SA *) &cli, &len);
/* len may have changed */
```

   The reason that the size changes from an integer to be a pointer to an integer is because the size is both a *value* when the function is called (it tells the kernel the size of the structure so that the kernel does not write past the end of the structure when filling it in) and a *result* when the function returns (it tells the process how much information the kernel actually stored in the structure). This type of argument is called a *value-result* argument. Figure 3.8 shows this scenario.

Figure 3.8. Socket address structure passed from kernel to process.



We will see an example of value-result arguments in Figure 4.11.

> We have been talking about socket address structures being passed between the process and the kernel. For an implementation such as 4.4BSD, where all the socket functions are system calls within the kernel, this is correct. But in some implementations, notably System V, socket functions are just library functions that execute as part of a normal user process. How these functions interface with the protocol stack in the kernel is an implementation detail that normally does not affect us. Nevertheless, for simplicity, we will continue to talk about these structures as being passed between the process and the kernel by functions such as `bind` and `connect`. (We will see in Section C.1 that System V implementations do indeed pass socket address structures between processes and the kernel, but as part of `STREAMS` messages.)
>
> Two other functions pass socket address structures: `recvmsg` and `sendmsg` (Section 14.5). But, we will see that the length field is not a function argument but a structure member.

When using value-result arguments for the length of socket address structures, if the socket address structure is fixed-length (Figure 3.6), the value returned by the kernel will always be that fixed size: 16 for an IPv4 `sockaddr_in` and 28 for an IPv6 `sockaddr_in6`, for example. But with a variable-length socket address structure (e.g., a Unix domain `sockaddr_un`), the value returned can be less than the maximum size of the structure (as we will see with Figure 15.2).

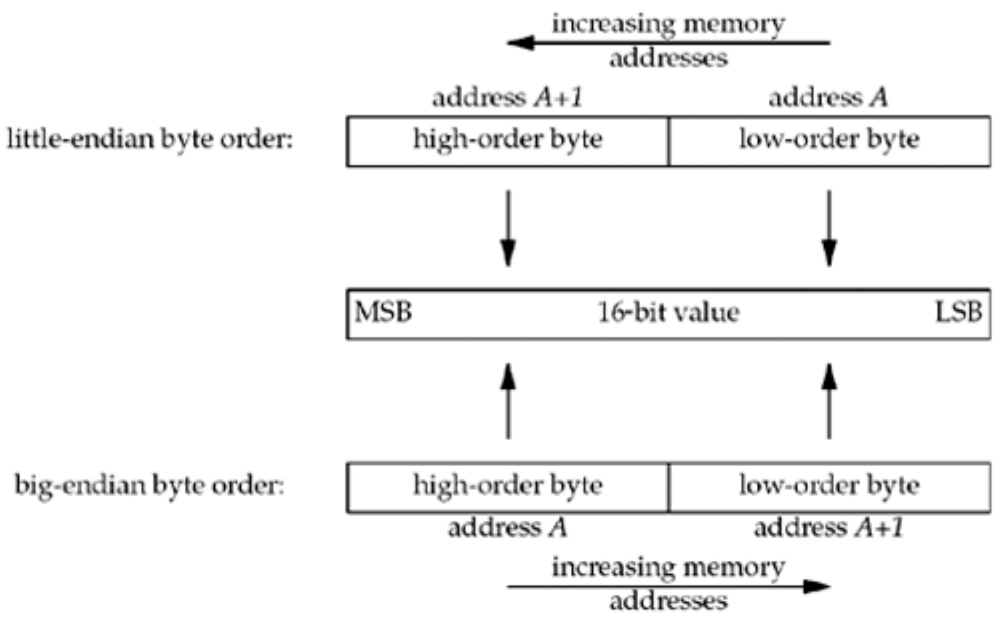
With network programming, the most common example of a value-result argument is the length of a returned socket address structure. But, we will encounter other value-result arguments in this text:

- The middle three arguments for the `select` function (Section 6.3)
- The length argument for the `getsockopt` function (Section 7.2)
- The `msg_namelen` and `msg_controllen` members of the `msghdr` structure, when used with `recvmsg` (Section 14.5)
- The `ifc_len` member of the `ifconf` structure (Figure 17.2)
- The first of the two length arguments for the `sysctl` function (Section 18.4)

3.4 Byte Ordering Functions

Consider a 16-bit integer that is made up of 2 bytes. There are two ways to store the two bytes in memory: with the low-order byte at the starting address, known as *little-endian* byte order, or with the high-order byte at the starting address, known as *big-endian* byte order. We show these two formats in Figure 3.9.

Figure 3.9. Little-endian byte order and big-endian byte order for a 16-bit integer.



In this figure, we show increasing memory addresses going from right to left in the top, and from left to right in the bottom. We also show the most significant bit (MSB) as the leftmost bit of the 16-bit value and the least significant bit (LSB) as the rightmost bit.

> The terms "little-endian" and "big-endian" indicate which end of the multibyte value, the little end or the big end, is stored at the starting address of the value.

Unfortunately, there is no standard between these two byte orderings and we encounter systems that use both formats. We refer to the byte ordering used by a given system as the *host byte order*. The program shown in Figure 3.10 prints the host byte order.

Figure 3.10 Program to determine host byte order.

intro/byteorder.c

```
#include     "unp.h"

int
main(int argc, char **argv)
{
    union {
        short   s;
        char    c[sizeof(short)];
    } un;

    un.s = 0x0102;
    printf("%s: ", CPU_VENDOR_OS);
    if (sizeof(short) == 2) {
        if (un.c[0] == 1 && un.c[1] == 2)
            printf("big-endian\n");
        else if (un.c[0] == 2 && un.c[1] == 1)
            printf("little-endian\n");
        else
            printf("unknown\n");
    } else
        printf("sizeof(short) = %d\n", sizeof(short));
20     exit(0);
21 }
```

We store the two-byte value `0x0102` in the short integer and then look at the two consecutive bytes, `c[0]` (the address *A* in Figure 3.9) and `c[1]` (the address *A+1* in Figure 3.9), to determine the byte order.

The string `CPU_VENDOR_OS` is determined by the GNU `autoconf` program when the software in this book is configured, and it identifies the CPU type, vendor, and OS release. We show some examples here in the output from this program when run on the various systems in Figure 1.16.

```
freebsd4 % byteorder
i386-unknown-freebsd4.8: little-endian

macosx % byteorder
powerpc-apple-darwin6.6: big-endian

freebsd5 % byteorder
sparc64-unknown-freebsd5.1: big-endian

aix % byteorder
powerpc-ibm-aix5.1.0.0: big-endian

hpux % byteorder
hppa1.1-hp-hpux11.11: big-endian

linux % byteorder
i586-pc-linux-gnu: little-endian

solaris % byteorder
sparc-sun-solaris2.9: big-endian
```

We have talked about the byte ordering of a 16-bit integer; obviously, the same discussion applies to a 32-bit integer.

> There are currently a variety of systems that can change between little-endian and big-endian byte ordering, sometimes at system reset, sometimes at run-time.

We must deal with these byte ordering differences as network programmers because networking protocols must specify a *network byte order*. For example, in a TCP segment, there is a 16-bit port number and a 32-bit IPv4 address. The sending protocol stack and the receiving protocol stack must agree on the order in which the bytes of these multibyte fields will be transmitted. The Internet protocols use big-endian byte ordering for these multibyte integers.

In theory, an implementation could store the fields in a socket address structure in host byte order and then convert to and from the network byte order when moving the fields to and from the protocol headers, saving us from having to worry about this detail. But, both history and the POSIX specification say that certain fields in the socket address structures must be maintained in network byte order. Our concern is therefore converting between host byte order and network byte order. We use the following four functions to convert between these two byte orders.

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

uint16_t htons(uint16_t host16bitvalue) ;

uint32_t htonl(uint32_t host32bitvalue) ;

                                        Both return: value in network byte order

uint16_t ntohs(uint16_t net16bitvalue) ;

uint32_t ntohl(uint32_t net32bitvalue) ;

                                           Both return: value in host byte order
```

In the names of these functions, `h` stands for *host*, `n` stands for *network*, `s` stands for *short*, and `l` stands for *long*. The terms "short" and "long" are historical artifacts from the Digital VAX implementation of 4.2BSD. We should instead think of `s` as a 16-bit value (such as a TCP or UDP port number) and `l` as a 32-bit value (such as an IPv4 address). Indeed, on the 64-bit Digital Alpha, a long integer occupies 64 bits, yet the `htonl` and `ntohl` functions operate on 32-bit values.

When using these functions, we do not care about the actual values (big-endian or little-endian) for the host byte order and the network byte order. What we must do is call the appropriate function to convert a given value between the host and network byte order. On those systems that have the same byte ordering as the Internet protocols (big-endian), these four functions are usually defined as null macros.

We will talk more about the byte ordering problem, with respect to the data contained in a network packet as opposed to the fields in the protocol headers, in Section 5.18 and Exercise 5.8.

We have not yet defined the term "byte." We use the term to mean an 8-bit quantity since almost all current computer systems use 8-bit bytes. Most Internet standards use the term *octet* instead of byte to mean an 8-bit quantity. This started in the early days of TCP/IP because much of the early work was done on systems such as the DEC-10, which did not use 8-bit bytes.

Another important convention in Internet standards is bit ordering. In many Internet standards, you will see "pictures" of packets that look similar to the following (this is the first 32 bits of the IPv4 header from RFC 791):

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Version|  IHL  |Type of Service|          Total Length         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

This represents four bytes in the order in which they appear on the wire; the leftmost bit is the most significant. However, the numbering starts with zero assigned to the most significant bit. This is a notation that you should become familiar with to make it easier to read protocol definitions in RFCs.

> A common network programming error in the 1980s was to develop code on Sun workstations (big-endian Motorola 68000s) and forget to call any of these four functions. The code worked fine on these workstations, but would not work when ported to little-endian machines (such as VAXes).

[Team LiB] PREVIOUS NEXT

3.5 Byte Manipulation Functions

There are two groups of functions that operate on multibyte fields, without interpreting the data, and without assuming that the data is a null-terminated C string. We need these types of functions when dealing with socket address structures because we need to manipulate fields such as IP addresses, which can contain bytes of 0, but are not C character strings. The functions beginning with `str` (for string), defined by including the `<string.h>` header, deal with null-terminated C character strings.

The first group of functions, whose names begin with `b` (for byte), are from 4.2BSD and are still provided by almost any system that supports the socket functions. The second group of functions, whose names begin with `mem` (for memory), are from the ANSI C standard and are provided with any system that supports an ANSI C library.

We first show the Berkeley-derived functions, although the only one we use in this text is `bzero`. (We use it because it has only two arguments and is easier to remember than the three-argument `memset` function, as explained on p. 8.) You may encounter the other two functions, `bcopy` and `bcmp`, in existing applications.

```
#include <strings.h>

void bzero(void *dest, size_t nbytes);

void bcopy(const void *src, void *dest, size_t nbytes);

int bcmp(const void *ptr1, const void *ptr2, size_t nbytes);

                                        Returns: 0 if equal, nonzero if unequal
```

This is our first encounter with the ANSI C `const` qualifier. In the three uses here, it indicates that what is pointed to by the pointer with this qualification, *src, ptr1*, and *ptr2*, is not modified by the function. Worded another way, the memory pointed to by the `const` pointer is read but not modified by the function.

`bzero` sets the specified number of bytes to 0 in the destination. We often use this function to initialize a socket address structure to 0. `bcopy` moves the specified number of bytes from the source to the destination. `bcmp` compares two arbitrary byte strings. The return value is zero if the two byte strings are identical; otherwise, it is nonzero.

The following functions are the ANSI C functions:

```
#include <string.h>

void *memset(void *dest, int c, size_t len);

void *memcpy(void *dest, const void *src, size_t nbytes);

int memcmp(const void *ptr1, const void *ptr2, size_t nbytes);

                              Returns: 0 if equal, <0 or >0 if unequal (see text)
```

`memset` sets the specified number of bytes to the value *c* in the destination. `memcpy` is similar to `bcopy`, but the order of the two pointer arguments is swapped. `bcopy` correctly handles overlapping fields, while the behavior of `memcpy` is undefined if the source and destination overlap. The ANSI C `memmove` function must be used when the fields overlap.

One way to remember the order of the two pointers for `memcpy` is to remember that they are written in the same left-to-right order as an assignment statement in C:

dest = *src*;

One way to remember the order of the final two arguments to `memset` is to realize that all of the ANSI C `memXXX` functions require a length argument, and it is always the final argument.

`memcmp` compares two arbitrary byte strings and returns 0 if they are identical. If not identical, the return value is either greater than 0 or less than 0, depending on whether the first unequal byte pointed to by *ptr1* is greater than or less than the corresponding byte pointed to by *ptr2*. The comparison is done assuming the two unequal bytes are `unsigned chars`.