Beej's Guide to Network Programming
Using Internet Sockets

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1. Intro

Hey! Socket programming got you down? Is this stuff just a little too difficult to figure out from the **man** pages? You want to do cool Internet programming, but you don't have time to wade through a gob of `structs` trying to figure out if you have to call **`bind()`** before you **`connect()`**, etc., etc.

Well, guess what! I've already done this nasty business, and I'm dying to share the information with everyone! You've come to the right place. This document should give the average competent C programmer the edge s/he needs to get a grip on this networking noise.

1.1. Audience

This document has been written as a tutorial, not a reference. It is probably at its best when read by individuals who are just starting out with socket programming and are looking for a foothold. It is certainly not the *complete* guide to sockets programming, by any means.

Hopefully, though, it'll be just enough for those man pages to start making sense... `:-)`

1.2. Platform and Compiler

The code contained within this document was compiled on a Linux PC using Gnu's **gcc** compiler. It should, however, build on just about any platform that uses **gcc**. Naturally, this doesn't apply if you're programming for Windows—see the section on Windows programming, below.

1.3. Official Homepage

This official location of this document is `http://beej.us/guide/bgnet/`.

1.4. Note for Solaris/SunOS Programmers

When compiling for Solaris or SunOS, you need to specify some extra command-line switches for linking in the proper libraries. In order to do this, simply add "`-lnsl -lsocket -lresolv`" to the end of the compile command, like so:

```
$ cc -o server server.c -lnsl -lsocket -lresolv
```

If you still get errors, you could try further adding a "`-lxnet`" to the end of that command line. I don't know what that does, exactly, but some people seem to need it.

Another place that you might find problems is in the call to **`setsockopt()`**. The prototype differs from that on my Linux box, so instead of:

```
int yes=1;
```

enter this:

```
char yes='1';
```

As I don't have a Sun box, I haven't tested any of the above information—it's just what people have told me through email.

1.5. Note for Windows Programmers

At this point in the guide, historically, I've done a bit of bagging on Windows, simply due to the fact that I don't like it very much. But I should really be fair and tell you that Windows has a huge install base and is obviously a perfectly fine operating system.

They say absence makes the heart grow fonder, and in this case, I believe it to be true. (Or maybe it's age.) But what I can say is that after a decade-plus of not using Microsoft OSes for my personal work, I'm much happier! As such, I can sit back and safely say, "Sure, feel free to use Windows!" ...Ok yes, it does make me grit my teeth to say that.

So I still encourage you to try Linux[1], BSD[2], or some flavor of Unix, instead.

But people like what they like, and you Windows folk will be pleased to know that this information is generally applicable to you guys, with a few minor changes, if any.

One cool thing you can do is install Cygwin[3], which is a collection of Unix tools for Windows. I've heard on the grapevine that doing so allows all these programs to compile unmodified.

But some of you might want to do things the Pure Windows Way. That's very gutsy of you, and this is what you have to do: run out and get Unix immediately! No, no—I'm kidding. I'm supposed to be Windows-friendly(er) these days...

This is what you'll have to do (unless you install Cygwin!): first, ignore pretty much all of the system header files I mention in here. All you need to include is:

```
#include <winsock.h>
```

Wait! You also have to make a call to **`WSAStartup()`** before doing anything else with the sockets library. The code to do that looks something like this:

```
#include <winsock.h>

{
    WSADATA wsaData;   // if this doesn't work
    //WSAData wsaData; // then try this instead

    if (WSAStartup(MAKEWORD(1, 1), &wsaData) != 0) {
        fprintf(stderr, "WSAStartup failed.\n");
        exit(1);
    }
```

You also have to tell your compiler to link in the Winsock library, usually called *`wsock32.lib`* or *`winsock32.lib`* or some-such. Under VC++, this can be done through the `Project` menu, under `Settings...`. Click the `Link` tab, and look for the box titled "Object/library modules". Add "wsock32.lib" to that list.

Or so I hear.

Finally, you need to call **`WSACleanup()`** when you're all through with the sockets library. See your online help for details.

Once you do that, the rest of the examples in this tutorial should generally apply, with a few exceptions. For one thing, you can't use **`close()`** to close a socket—you need to use **`closesocket()`**, instead. Also, **`select()`** only works with socket descriptors, not file descriptors (like `0` for `stdin`).

There is also a socket class that you can use, `CSocket`. Check your compilers help pages for more information.

To get more information about Winsock, read the Winsock FAQ[4] and go from there.

Finally, I hear that Windows has no **`fork()`** system call which is, unfortunately, used in some of my examples. Maybe you have to link in a POSIX library or something to get it to work, or you can use **`CreateProcess()`** instead. **`fork()`** takes no arguments, and **`CreateProcess()`** takes about 48 billion arguments. If you're not up to that, the **`CreateThread()`** is a little easier to digest...unfortunately a discussion about multithreading is beyond the scope of this document. I can only talk about so much, you know!

1.6. Email Policy

I'm generally available to help out with email questions so feel free to write in, but I can't guarantee a response. I lead a pretty busy life and there are times when I just can't answer a

1. `http://www.linux.com/`
2. `http://www.bsd.org/`
3. `http://www.cygwin.com/`
4. `http://tangentsoft.net/wskfaq/`

question you have. When that's the case, I usually just delete the message. It's nothing personal; I just won't ever have the time to give the detailed answer you require.

As a rule, the more complex the question, the less likely I am to respond. If you can narrow down your question before mailing it and be sure to include any pertinent information (like platform, compiler, error messages you're getting, and anything else you think might help me troubleshoot), you're much more likely to get a response. For more pointers, read ESR's document, How To Ask Questions The Smart Way[5].

If you don't get a response, hack on it some more, try to find the answer, and if it's still elusive, then write me again with the information you've found and hopefully it will be enough for me to help out.

Now that I've badgered you about how to write and not write me, I'd just like to let you know that I *fully* appreciate all the praise the guide has received over the years. It's a real morale boost, and it gladdens me to hear that it is being used for good! `:-)` Thank you!

1.7. Mirroring

You are more than welcome to mirror this site, whether publicly or privately. If you publicly mirror the site and want me to link to it from the main page, drop me a line at `beej@beej.us`.

1.8. Note for Translators

If you want to translate the guide into another language, write me at `beej@beej.us` and I'll link to your translation from the main page. Feel free to add your name and contact info to the translation.

Please note the license restrictions in the Copyright and Distribution section, below.

Sorry, but due to space constraints, I cannot host the translations myself.

1.9. Copyright and Distribution

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Contact `beej@beej.us` for more information.

5. `http://www.catb.org/~esr/faqs/smart-questions.html`

2. What is a socket?

You hear talk of “sockets” all the time, and perhaps you are wondering just what they are exactly. Well, they're this: a way to speak to other programs using standard Unix file descriptors.

What?

Ok—you may have heard some Unix hacker state, “Jeez, *everything* in Unix is a file!” What that person may have been talking about is the fact that when Unix programs do any sort of I/O, they do it by reading or writing to a file descriptor. A file descriptor is simply an integer associated with an open file. But (and here's the catch), that file can be a network connection, a FIFO, a pipe, a terminal, a real on-the-disk file, or just about anything else. Everything in Unix *is* a file! So when you want to communicate with another program over the Internet you're gonna do it through a file descriptor, you'd better believe it.

“Where do I get this file descriptor for network communication, Mr. Smarty-Pants?” is probably the last question on your mind right now, but I'm going to answer it anyway: You make a call to the **`socket()`** system routine. It returns the socket descriptor, and you communicate through it using the specialized **`send()`** and **`recv()`** (**man send**, **man recv**) socket calls.

“But, hey!” you might be exclaiming right about now. “If it's a file descriptor, why in the name of Neptune can't I just use the normal **`read()`** and **`write()`** calls to communicate through the socket?” The short answer is, “You can!” The longer answer is, “You can, but **`send()`** and **`recv()`** offer much greater control over your data transmission.”

What next? How about this: there are all kinds of sockets. There are DARPA Internet addresses (Internet Sockets), path names on a local node (Unix Sockets), CCITT X.25 addresses (X.25 Sockets that you can safely ignore), and probably many others depending on which Unix flavor you run. This document deals only with the first: Internet Sockets.

2.1. Two Types of Internet Sockets

What's this? There are two types of Internet sockets? Yes. Well, no. I'm lying. There are more, but I didn't want to scare you. I'm only going to talk about two types here. Except for this sentence, where I'm going to tell you that “Raw Sockets” are also very powerful and you should look them up.

All right, already. What are the two types? One is “Stream Sockets”; the other is “Datagram Sockets”, which may hereafter be referred to as “`SOCK_STREAM`” and “`SOCK_DGRAM`”, respectively. Datagram sockets are sometimes called “connectionless sockets”. (Though they can be **`connect()`**'d if you really want. See **`connect()`**, below.)

Stream sockets are reliable two-way connected communication streams. If you output two items into the socket in the order “1, 2”, they will arrive in the order “1, 2” at the opposite end. They will also be error-free. I'm so certain, in fact, they will be error-free, that I'm just going to put my fingers in my ears and chant *la la la la* if anyone tries to claim otherwise.

What uses stream sockets? Well, you may have heard of the **telnet** application, yes? It uses stream sockets. All the characters you type need to arrive in the same order you type them, right? Also, web browsers use the HTTP protocol which uses stream sockets to get pages. Indeed, if you telnet to a web site on port 80, and type “`GET / HTTP/1.0`” and hit RETURN twice, it'll dump the HTML back at you!

How do stream sockets achieve this high level of data transmission quality? They use a protocol called “The Transmission Control Protocol”, otherwise known as “TCP” (see RFC

793[6] for extremely detailed info on TCP.) TCP makes sure your data arrives sequentially and error-free. You may have heard "TCP" before as the better half of "TCP/IP" where "IP" stands for "Internet Protocol" (see RFC 791[7].) IP deals primarily with Internet routing and is not generally responsible for data integrity.

Cool. What about Datagram sockets? Why are they called connectionless? What is the deal, here, anyway? Why are they unreliable? Well, here are some facts: if you send a datagram, it may arrive. It may arrive out of order. If it arrives, the data within the packet will be error-free.

Datagram sockets also use IP for routing, but they don't use TCP; they use the "User Datagram Protocol", or "UDP" (see RFC 768[8].)

Why are they connectionless? Well, basically, it's because you don't have to maintain an open connection as you do with stream sockets. You just build a packet, slap an IP header on it with destination information, and send it out. No connection needed. They are generally used either when a TCP stack is unavailable or when a few dropped packets here and there don't mean the end of the Universe. Sample applications: **tftp**, **bootp**, multiplayer games, streaming audio, video conferencing, etc.

"Wait a minute! **tftp** and **bootp** are used to transfer binary applications from one host to another! Data can't be lost if you expect the application to work when it arrives! What kind of dark magic is this?"

Well, my human friend, **tftp** and similar programs have their own protocol on top of UDP. For example, the tftp protocol says that for each packet that gets sent, the recipient has to send back a packet that says, "I got it!" (an "ACK" packet.) If the sender of the original packet gets no reply in, say, five seconds, he'll re-transmit the packet until he finally gets an ACK. This acknowledgment procedure is very important when implementing reliable `SOCK_DGRAM` applications.

For unreliable applications like games, you just ignore the dropped packets, or perhaps try to cleverly compensate for them. (Quake players will know the manifestation this effect by the technical term: *#%$@* lag*.)

2.2. Low level Nonsense and Network Theory

Since I just mentioned layering of protocols, it's time to talk about how networks really work, and to show some examples of how `SOCK_DGRAM` packets are built. Practically, you can probably skip this section. It's good background, however.

Data Encapsulation.

Hey, kids, it's time to learn about *Data Encapsulation*! This is very very important. It's so important that you might just learn about it if you take the networks course here at Chico State `;-)`. Basically, it says this: a packet is born, the packet is wrapped ("encapsulated") in a header (and rarely a footer) by the first protocol (say, the TFTP protocol), then the whole thing (TFTP header included) is encapsulated again by the next protocol (say, UDP), then again by the next (IP), then again by the final protocol on the hardware (physical) layer (say, Ethernet).

6. `http://tools.ietf.org/html/rfc793`
7. `http://tools.ietf.org/html/rfc791`
8. `http://tools.ietf.org/html/rfc768`

When another computer receives the packet, the hardware strips the Ethernet header, the kernel strips the IP and UDP headers, the TFTP program strips the TFTP header, and it finally has the data.

Now I can finally talk about the infamous *Layered Network Model* (aka "ISO/OSI"). This Network Model describes a system of network functionality that has many advantages over other models. For instance, you can write sockets programs that are exactly the same without caring how the data is physically transmitted (serial, thin Ethernet, AUI, whatever) because programs on lower levels deal with it for you. The actual network hardware and topology is transparent to the socket programmer.

Without any further ado, I'll present the layers of the full-blown model. Remember this for network class exams:

- Application
- Presentation
- Session
- Transport
- Network
- Data Link
- Physical

The Physical Layer is the hardware (serial, Ethernet, etc.). The Application Layer is just about as far from the physical layer as you can imagine—it's the place where users interact with the network.

Now, this model is so general you could probably use it as an automobile repair guide if you really wanted to. A layered model more consistent with Unix might be:

- Application Layer (*telnet, ftp, etc.*)
- Host-to-Host Transport Layer (*TCP, UDP*)
- Internet Layer (*IP and routing*)
- Network Access Layer (*Ethernet, ATM, or whatever*)

At this point in time, you can probably see how these layers correspond to the encapsulation of the original data.

See how much work there is in building a simple packet? Jeez! And you have to type in the packet headers yourself using "**cat**"! Just kidding. All you have to do for stream sockets is **`send()`** the data out. All you have to do for datagram sockets is encapsulate the packet in the method of your choosing and **`sendto()`** it out. The kernel builds the Transport Layer and Internet Layer on for you and the hardware does the Network Access Layer. Ah, modern technology.

So ends our brief foray into network theory. Oh yes, I forgot to tell you everything I wanted to say about routing: nothing! That's right, I'm not going to talk about it at all. The router strips the packet to the IP header, consults its routing table, blah blah blah. Check out the IP RFC[9] if you really really care. If you never learn about it, well, you'll live.

9. `http://tools.ietf.org/html/rfc791`

3. `structs` and Data Handling

Well, we're finally here. It's time to talk about programming. In this section, I'll cover various data types used by the sockets interface, since some of them are a real bear to figure out.

First the easy one: a socket descriptor. A socket descriptor is the following type:

```
int
```

Just a regular `int`.

Things get weird from here, so just read through and bear with me. Know this: there are two byte orderings: most significant byte (sometimes called an "octet") first, or least significant byte first. The former is called "Network Byte Order". Some machines store their numbers internally in Network Byte Order, some don't. When I say something has to be in Network Byte Order, you have to call a function (such as **`htons()`**) to change it from "Host Byte Order". If I don't say "Network Byte Order", then you must leave the value in Host Byte Order.

(For the curious, "Network Byte Order" is also known as "Big-Endian Byte Order".)

My First Struct™—`struct sockaddr`. This structure holds socket address information for many types of sockets:

```
struct sockaddr {
    unsigned short    sa_family;    // address family, AF_xxx
    char              sa_data[14];  // 14 bytes of protocol address
};
```

`sa_family` can be a variety of things, but it'll be `AF_INET` for everything we do in this document. *`sa_data`* contains a destination address and port number for the socket. This is rather unwieldy since you don't want to tediously pack the address in the *`sa_data`* by hand.

To deal with `struct sockaddr`, programmers created a parallel structure: `struct sockaddr_in` ("in" for "Internet".)

```
struct sockaddr_in {
    short int          sin_family;  // Address family
    unsigned short int sin_port;    // Port number
    struct in_addr     sin_addr;    // Internet address
    unsigned char      sin_zero[8]; // Same size as struct sockaddr
};
```

This structure makes it easy to reference elements of the socket address. Note that *`sin_zero`* (which is included to pad the structure to the length of a `struct sockaddr`) should be set to all zeros with the function **`memset()`**. Also, and this is the *important* bit, a pointer to a `struct sockaddr_in` can be cast to a pointer to a `struct sockaddr` and vice-versa. So even though **`connect()`** wants a `struct sockaddr*`, you can still use a `struct sockaddr_in` and cast it at the last minute! Also, notice that *`sin_family`* corresponds to *`sa_family`* in a `struct sockaddr` and should be set to "`AF_INET`". Finally, the *`sin_port`* and *`sin_addr`* must be in *Network Byte Order*!

"But," you object, "how can the entire structure, `struct in_addr sin_addr`, be in Network Byte Order?" This question requires careful examination of the structure `struct in_addr`, one of the worst unions alive:

```
// Internet address (a structure for historical reasons)
struct in_addr {
    uint32_t s_addr; // that's a 32-bit int (4 bytes)
};
```

Well, it *used* to be a union, but now those days seem to be gone. Good riddance. So if you have declared *`ina`* to be of type `struct sockaddr_in`, then *`ina.sin_addr.s_addr`* references the 4-byte IP address (in Network Byte Order). Note that even if your system still

uses the God-awful union for `struct in_addr`, you can still reference the 4-byte IP address in exactly the same way as I did above (this due to `#defines`.)

3.1. Convert the Natives!

We've now been lead right into the next section. There's been too much talk about this Network to Host Byte Order conversion—now is the time for action!

All righty. There are two types that you can convert: `short` (two bytes) and `long` (four bytes). These functions work for the `unsigned` variations as well. Say you want to convert a `short` from Host Byte Order to Network Byte Order. Start with "h" for "host", follow it with "to", then "n" for "network", and "s" for "short": h-to-n-s, or **`htons()`** (read: "Host to Network Short").

It's almost too easy...

You can use every combination of "n", "h", "s", and "l" you want, not counting the really stupid ones. For example, there is NOT a **`stolh()`** ("Short to Long Host") function—not at this party, anyway. But there are:

`htons()`	**h**ost **to** **n**etwork **s**hort
`htonl()`	**h**ost **to** **n**etwork **l**ong
`ntohs()`	**n**etwork **to** **h**ost **s**hort
`ntohl()`	**n**etwork **to** **h**ost **l**ong

Now, you may think you're wising up to this. You might think, "What do I do if I have to change byte order on a `char`?" Then you might think, "Uh, never mind." You might also think that since your 68000 machine already uses network byte order, you don't have to call **`htonl()`** on your IP addresses. You would be right, *BUT* if you try to port to a machine that has reverse network byte order, your program will fail. Be portable! This is a Unix world! (As much as Bill Gates would like to think otherwise.) Remember: put your bytes in Network Byte Order before you put them on the network.

A final point: why do *`sin_addr`* and *`sin_port`* need to be in Network Byte Order in a `struct sockaddr_in`, but *`sin_family`* does not? The answer: *`sin_addr`* and *`sin_port`* get encapsulated in the packet at the IP and UDP layers, respectively. Thus, they must be in Network Byte Order. However, the *`sin_family`* field is only used by the kernel to determine what type of address the structure contains, so it must be in Host Byte Order. Also, since *`sin_family`* does *not* get sent out on the network, it can be in Host Byte Order.

3.2. IP Addresses and How to Deal With Them

Fortunately for you, there are a bunch of functions that allow you to manipulate IP addresses. No need to figure them out by hand and stuff them in a `long` with the `<<` operator.

First, let's say you have a `struct sockaddr_in ina`, and you have an IP address "`10.12.110.57`" that you want to store into it. The function you want to use, **`inet_addr()`**, converts an IP address in numbers-and-dots notation into an unsigned long. The assignment can be made as follows:

```
ina.sin_addr.s_addr = inet_addr("10.12.110.57");
```

Notice that **`inet_addr()`** returns the address in Network Byte Order already—you don't have to call **`htonl()`**. Swell!

Now, the above code snippet isn't very robust because there is no error checking. See, **`inet_addr()`** returns `-1` on error. Remember binary numbers? `(unsigned)-1` just happens to correspond to the IP address `255.255.255.255`! That's the broadcast address! Wrongo. Remember to do your error checking properly.

Actually, there's a cleaner interface you can use instead of **`inet_addr()`**: it's called **`inet_aton()`** ("aton" means "ascii to network"):

```
#include <sys/socket.h>
#include <netinet/in.h>
#include <arpa/inet.h>

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

And here's a sample usage, while packing a `struct sockaddr_in` (this example will make more sense to you when you get to the sections on **`bind()`** and **`connect()`**.)

```
struct sockaddr_in my_addr;

my_addr.sin_family = AF_INET;         // host byte order
my_addr.sin_port = htons(MYPORT);     // short, network byte order
inet_aton("10.12.110.57", &(my_addr.sin_addr));
memset(my_addr.sin_zero, '\0', sizeof my_addr.sin_zero);
```

`inet_aton()`, *unlike practically every other socket-related function*, returns non-zero on success, and zero on failure. And the address is passed back in *`inp`*.

Unfortunately, not all platforms implement **`inet_aton()`** so, although its use is preferred, the older more common **`inet_addr()`** is used in this guide.

All right, now you can convert string IP addresses to their binary representations. What about the other way around? What if you have a `struct in_addr` and you want to print it in numbers-and-dots notation? In this case, you'll want to use the function **`inet_ntoa()`** ("ntoa" means "network to ascii") like this:

```
printf("%s", inet_ntoa(ina.sin_addr));
```

That will print the IP address. Note that **`inet_ntoa()`** takes a `struct in_addr` as an argument, not a `long`. Also notice that it returns a pointer to a char. This points to a statically stored char array within **`inet_ntoa()`** so that each time you call **`inet_ntoa()`** it will overwrite the last IP address you asked for. For example:

```
char *a1, *a2;

a1 = inet_ntoa(ina1.sin_addr);  // this is 192.168.4.14
a2 = inet_ntoa(ina2.sin_addr);  // this is 10.12.110.57
printf("address 1: %s\n",a1);
printf("address 2: %s\n",a2);
```

will print:

```
address 1: 10.12.110.57
address 2: 10.12.110.57
```

If you need to save the address, **`strcpy()`** it to your own character array.

That's all on this topic for now. Later, you'll learn to convert a string like "whitehouse.gov" into its corresponding IP address (see DNS, below.)

3.2.1. Private (Or Disconnected) Networks

Lots of places have a firewall that hides the network from the rest of the world for their own protection. And often times, the firewall translates "internal" IP addresses to "external" (that everyone else in the world knows) IP addresses using a process called *Network Address Translation*, or NAT.

Are you getting nervous yet? "Where's he going with all this weird stuff?"

Well, relax and buy yourself a drink, because as a beginner, you don't even have to worry about NAT, since it's done for you transparently. But I wanted to talk about the network behind the firewall in case you started getting confused by the network numbers you were seeing.

For instance, I have a firewall at home. I have two static IP addresses allocated to me by the DSL company, and yet I have seven computers on the network. How is this possible? Two computers can't share the same IP address, or else the data wouldn't know which one to go to!

The answer is: they don't share the same IP addresses. They are on a private network with 24 million IP addresses allocated to it. They are all just for me. Well, all for me as far as anyone else is concerned. Here's what's happening:

If I log into a remote computer, it tells me I'm logged in from 64.81.52.10 (not my real IP). But if I ask my local computer what it's IP address is, it says 10.0.0.5. Who is translating the IP address from one to the other? That's right, the firewall! It's doing NAT!

10.*x*.*x*.*x* is one of a few reserved networks that are only to be used either on fully disconnected networks, or on networks that are behind firewalls. The details of which private network numbers are available for you to use are outlined in RFC 1918[10], but some common ones you'll see are 10.*x*.*x*.*x* and 192.168.*x*.*x*, where *x* is 0-255, generally. Less common is 172.*y*.*x*.*x*, where *y* goes between 16 and 31.

Networks behind a NATing firewall don't *need* to be on one of these reserved networks, but they commonly are.

10. `http://tools.ietf.org/html/rfc1918`

4. System Calls or Bust

This is the section where we get into the system calls that allow you to access the network functionality of a Unix box. When you call one of these functions, the kernel takes over and does all the work for you automagically.

The place most people get stuck around here is what order to call these things in. In that, the **man** pages are no use, as you've probably discovered. Well, to help with that dreadful situation, I've tried to lay out the system calls in the following sections in *exactly* (approximately) the same order that you'll need to call them in your programs.

That, coupled with a few pieces of sample code here and there, some milk and cookies (which I fear you will have to supply yourself), and some raw guts and courage, and you'll be beaming data around the Internet like the Son of Jon Postel!

4.1. `socket()`—Get the File Descriptor!

I guess I can put it off no longer—I have to talk about the **`socket()`** system call. Here's the breakdown:

```
#include <sys/types.h>
#include <sys/socket.h>

int socket(int domain, int type, int protocol);
```

But what are these arguments? First, *`domain`* should be set to "`PF_INET`". Next, the *`type`* argument tells the kernel what kind of socket this is: `SOCK_STREAM` or `SOCK_DGRAM`. Finally, just set *`protocol`* to "`0`" to have **`socket()`** choose the correct protocol based on the *`type`*. (Notes: there are many more *`domain`*s than I've listed. There are many more *`type`*s than I've listed. See the **`socket()`** man page. Also, there's a "better" way to get the *`protocol`*, but specifying `0` works in 99.9% of all cases. See the **`getprotobyname()`** man page if you're curious.)

`socket()` simply returns to you a socket descriptor that you can use in later system calls, or `-1` on error. The global variable *`errno`* is set to the error's value (see the **`perror()`** man page.)

(This `PF_INET` thing is a close relative of the `AF_INET` that you used when initializing the *`sin_family`* field in your `struct sockaddr_in`. In fact, they're so closely related that they actually have the same value, and many programmers will call **`socket()`** and pass `AF_INET` as the first argument instead of **`PF_INET`**. Now, get some milk and cookies, because it's times for a story. Once upon a time, a long time ago, it was thought that maybe a address family (what the "AF" in "`AF_INET`" stands for) might support several protocols that were referred to by their protocol family (what the "PF" in "`PF_INET`" stands for). That didn't happen. And they all lived happily ever after, The End. So the most correct thing to do is to use `AF_INET` in your `struct sockaddr_in` and `PF_INET` in your call to **`socket()`**.)

Fine, fine, fine, but what good is this socket? The answer is that it's really no good by itself, and you need to read on and make more system calls for it to make any sense.

4.2. `bind()`—What port am I on?

Once you have a socket, you might have to associate that socket with a port on your local machine. (This is commonly done if you're going to **`listen()`** for incoming connections on a specific port—MUDs do this when they tell you to "telnet to x.y.z port 6969".) The port number is used by the kernel to match an incoming packet to a certain process's socket descriptor. If you're going to only be doing a **`connect()`**, this may be unnecessary. Read it anyway, just for kicks.

Here is the synopsis for the **bind()** system call:

```
#include <sys/types.h>
#include <sys/socket.h>

int bind(int sockfd, struct sockaddr *my_addr, int addrlen);
```

sockfd is the socket file descriptor returned by **socket()**. *my_addr* is a pointer to a `struct sockaddr` that contains information about your address, namely, port and IP address. *addrlen* can be set to `sizeof *my_addr` or `sizeof(struct sockaddr)`.

Whew. That's a bit to absorb in one chunk. Let's have an example:

```
#include <string.h>
#include <sys/types.h>
#include <sys/socket.h>
#include <netinet/in.h>
#include <arpa/inet.h>

#define MYPORT 3490

int main(void)
{
    int sockfd;
    struct sockaddr_in my_addr;

    sockfd = socket(PF_INET, SOCK_STREAM, 0); // do some error checking!

    my_addr.sin_family = AF_INET;         // host byte order
    my_addr.sin_port = htons(MYPORT);     // short, network byte order
    my_addr.sin_addr.s_addr = inet_addr("10.12.110.57");
    memset(my_addr.sin_zero, '\0', sizeof my_addr.sin_zero);

    // don't forget your error checking for bind():
    bind(sockfd, (struct sockaddr *)&my_addr, sizeof my_addr);
    .
    .
    .
```

There are a few things to notice here: *my_addr.sin_port* is in Network Byte Order. So is *my_addr.sin_addr.s_addr*. Another thing to watch out for is that the header files might differ from system to system. To be sure, you should check your local **man** pages.

Lastly, on the topic of **bind()**, I should mention that some of the process of getting your own IP address and/or port can be automated:

```
my_addr.sin_port = 0; // choose an unused port at random
my_addr.sin_addr.s_addr = INADDR_ANY;  // use my IP address
```

See, by setting *my_addr.sin_port* to zero, you are telling **bind()** to choose the port for you. Likewise, by setting *my_addr.sin_addr.s_addr* to `INADDR_ANY`, you are telling it to automatically fill in the IP address of the machine the process is running on.

If you are into noticing little things, you might have seen that I didn't put `INADDR_ANY` into Network Byte Order! Naughty me. However, I have inside info: `INADDR_ANY` is really zero! Zero still has zero on bits even if you rearrange the bytes. However, purists will point out that there could be a parallel dimension where `INADDR_ANY` is, say, 12 and that my code won't work there. That's okay with me:

```
my_addr.sin_port = htons(0); // choose an unused port at random
my_addr.sin_addr.s_addr = htonl(INADDR_ANY);  // use my IP address
```

Now we're so portable you probably wouldn't believe it. I just wanted to point that out, since most of the code you come across won't bother running `INADDR_ANY` through **htonl()**.

bind() also returns `-1` on error and sets *errno* to the error's value.

Another thing to watch out for when calling **bind()**: don't go underboard with your port numbers. All ports below 1024 are RESERVED (unless you're the superuser)! You can have any port number above that, right up to 65535 (provided they aren't already being used by another program.)

Sometimes, you might notice, you try to rerun a server and **bind()** fails, claiming "Address already in use." What does that mean? Well, a little bit of a socket that was connected is still hanging around in the kernel, and it's hogging the port. You can either wait for it to clear (a minute or so), or add code to your program allowing it to reuse the port, like this:

```
int yes=1;
//char yes='1'; // Solaris people use this

// lose the pesky "Address already in use" error message
if (setsockopt(listener,SOL_SOCKET,SO_REUSEADDR,&yes,sizeof(int)) == -1) {
    perror("setsockopt");
    exit(1);
}
```

One small extra final note about **bind()**: there are times when you won't absolutely have to call it. If you are **connect()**ing to a remote machine and you don't care what your local port is (as is the case with **telnet** where you only care about the remote port), you can simply call **connect()**, it'll check to see if the socket is unbound, and will **bind()** it to an unused local port if necessary.

4.3. connect()—Hey, you!

Let's just pretend for a few minutes that you're a telnet application. Your user commands you (just like in the movie *TRON*) to get a socket file descriptor. You comply and call **socket()**. Next, the user tells you to connect to "`10.12.110.57`" on port "`23`" (the standard telnet port.) Yow! What do you do now?

Lucky for you, program, you're now perusing the section on **connect()**—how to connect to a remote host. So read furiously onward! No time to lose!

The **connect()** call is as follows:

```
#include <sys/types.h>
#include <sys/socket.h>

int connect(int sockfd, struct sockaddr *serv_addr, int addrlen);
```

sockfd is our friendly neighborhood socket file descriptor, as returned by the **socket()** call, *serv_addr* is a `struct sockaddr` containing the destination port and IP address, and *addrlen* can be set to `sizeof *serv_addr` or `sizeof(struct sockaddr)`.

Isn't this starting to make more sense? Let's have an example:

```
#include <string.h>
#include <sys/types.h>
#include <sys/socket.h>
#include <netinet/in.h>

#define DEST_IP   "10.12.110.57"
#define DEST_PORT 23

int main(void)
{
    int sockfd;
    struct sockaddr_in dest_addr;   // will hold the destination addr

    sockfd = socket(PF_INET, SOCK_STREAM, 0); // do some error checking!

    dest_addr.sin_family = AF_INET;          // host byte order
    dest_addr.sin_port = htons(DEST_PORT);   // short, network byte order
```

```
    dest_addr.sin_addr.s_addr = inet_addr(DEST_IP);
    memset(dest_addr.sin_zero, '\0', sizeof dest_addr.sin_zero);

    // don't forget to error check the connect()!
    connect(sockfd, (struct sockaddr *)&dest_addr, sizeof dest_addr);
    .
    .
    .
```

Again, be sure to check the return value from **`connect()`**—it'll return `-1` on error and set the variable *`errno`*.

Also, notice that we didn't call **`bind()`**. Basically, we don't care about our local port number; we only care where we're going (the remote port). The kernel will choose a local port for us, and the site we connect to will automatically get this information from us. No worries.

4.4. `listen()`—Will somebody please call me?

Ok, time for a change of pace. What if you don't want to connect to a remote host. Say, just for kicks, that you want to wait for incoming connections and handle them in some way. The process is two step: first you **`listen()`**, then you **`accept()`** (see below.)

The listen call is fairly simple, but requires a bit of explanation:

```
int listen(int sockfd, int backlog);
```

`sockfd` is the usual socket file descriptor from the **`socket()`** system call. *`backlog`* is the number of connections allowed on the incoming queue. What does that mean? Well, incoming connections are going to wait in this queue until you **`accept()`** them (see below) and this is the limit on how many can queue up. Most systems silently limit this number to about 20; you can probably get away with setting it to `5` or `10`.

Again, as per usual, **`listen()`** returns `-1` and sets *`errno`* on error.

Well, as you can probably imagine, we need to call **`bind()`** before we call **`listen()`** or the kernel will have us listening on a random port. Bleah! So if you're going to be listening for incoming connections, the sequence of system calls you'll make is:

```
socket();
bind();
listen();
/* accept() goes here */
```

I'll just leave that in the place of sample code, since it's fairly self-explanatory. (The code in the **`accept()`** section, below, is more complete.) The really tricky part of this whole sha-bang is the call to **`accept()`**.

4.5. `accept()`—"Thank you for calling port 3490."

Get ready—the **`accept()`** call is kinda weird! What's going to happen is this: someone far far away will try to **`connect()`** to your machine on a port that you are **`listen()`**ing on. Their connection will be queued up waiting to be **`accept()`**ed. You call **`accept()`** and you tell it to get the pending connection. It'll return to you a *brand new socket file descriptor* to use for this single connection! That's right, suddenly you have *two socket file descriptors* for the price of one! The original one is still listening on your port and the newly created one is finally ready to **`send()`** and **`recv()`**. We're there!

The call is as follows:

```
#include <sys/types.h>
#include <sys/socket.h>

int accept(int sockfd, struct sockaddr *addr, socklen_t *addrlen);
```

sockfd is the **listen()**ing socket descriptor. Easy enough. *addr* will usually be a pointer to a local `struct sockaddr_in`. This is where the information about the incoming connection will go (and with it you can determine which host is calling you from which port). *addrlen* is a local integer variable that should be set to `sizeof *addr` or `sizeof(struct sockaddr_in)` before its address is passed to **accept()**. Accept will not put more than that many bytes into *addr*. If it puts fewer in, it'll change the value of *addrlen* to reflect that.

Guess what? **accept()** returns `-1` and sets *errno* if an error occurs. Betcha didn't figure that.

Like before, this is a bunch to absorb in one chunk, so here's a sample code fragment for your perusal:

```
#include <string.h>
#include <sys/types.h>
#include <sys/socket.h>
#include <netinet/in.h>

#define MYPORT 3490    // the port users will be connecting to

#define BACKLOG 10     // how many pending connections queue will hold

int main(void)
{
    int sockfd, new_fd;  // listen on sock_fd, new connection on new_fd
    struct sockaddr_in my_addr;    // my address information
    struct sockaddr_in their_addr; // connector's address information
    int sin_size;

    sockfd = socket(PF_INET, SOCK_STREAM, 0); // do some error checking!

    my_addr.sin_family = AF_INET;         // host byte order
    my_addr.sin_port = htons(MYPORT);     // short, network byte order
    my_addr.sin_addr.s_addr = INADDR_ANY; // auto-fill with my IP
    memset(my_addr.sin_zero, '\0', sizeof my_addr.sin_zero);

    // don't forget your error checking for these calls:
    bind(sockfd, (struct sockaddr *)&my_addr, sizeof my_addr);

    listen(sockfd, BACKLOG);

    sin_size = sizeof their_addr;
    new_fd = accept(sockfd, (struct sockaddr *)&their_addr, &sin_size);
    .
    .
    .
```

Again, note that we will use the socket descriptor *new_fd* for all **send()** and **recv()** calls. If you're only getting one single connection ever, you can **close()** the listening *sockfd* in order to prevent more incoming connections on the same port, if you so desire.

4.6. send() and recv()—Talk to me, baby!

These two functions are for communicating over stream sockets or connected datagram sockets. If you want to use regular unconnected datagram sockets, you'll need to see the section on **sendto()** and **recvfrom()**, below.

The **send()** call:

```
int send(int sockfd, const void *msg, int len, int flags);
```

sockfd is the socket descriptor you want to send data to (whether it's the one returned by **socket()** or the one you got with **accept()**.) *msg* is a pointer to the data you want to send,

and *len* is the length of that data in bytes. Just set *flags* to 0. (See the **send()** man page for more information concerning flags.)

Some sample code might be:

```
char *msg = "Beej was here!";
int len, bytes_sent;
.
.
.
len = strlen(msg);
bytes_sent = send(sockfd, msg, len, 0);
.
.
.
```

send() returns the number of bytes actually sent out—*this might be less than the number you told it to send!* See, sometimes you tell it to send a whole gob of data and it just can't handle it. It'll fire off as much of the data as it can, and trust you to send the rest later. Remember, if the value returned by **send()** doesn't match the value in *len*, it's up to you to send the rest of the string. The good news is this: if the packet is small (less than 1K or so) it will *probably* manage to send the whole thing all in one go. Again, -1 is returned on error, and *errno* is set to the error number.

The **recv()** call is similar in many respects:

```
int recv(int sockfd, void *buf, int len, unsigned int flags);
```

sockfd is the socket descriptor to read from, *buf* is the buffer to read the information into, *len* is the maximum length of the buffer, and *flags* can again be set to 0. (See the **recv()** man page for flag information.)

recv() returns the number of bytes actually read into the buffer, or -1 on error (with *errno* set, accordingly.)

Wait! **recv()** can return 0. This can mean only one thing: the remote side has closed the connection on you! A return value of 0 is **recv()**'s way of letting you know this has occurred.

There, that was easy, wasn't it? You can now pass data back and forth on stream sockets! Whee! You're a Unix Network Programmer!

4.7. sendto() and recvfrom()—Talk to me, DGRAM-style

"This is all fine and dandy," I hear you saying, "but where does this leave me with unconnected datagram sockets?" No problemo, amigo. We have just the thing.

Since datagram sockets aren't connected to a remote host, guess which piece of information we need to give before we send a packet? That's right! The destination address! Here's the scoop:

```
int sendto(int sockfd, const void *msg, int len, unsigned int flags,
           const struct sockaddr *to, socklen_t tolen);
```

As you can see, this call is basically the same as the call to **send()** with the addition of two other pieces of information. *to* is a pointer to a `struct sockaddr` (which you'll probably have as a `struct sockaddr_in` and cast it at the last minute) which contains the destination IP address and port. *tolen*, an `int` deep-down, can simply be set to `sizeof *to` or `sizeof(struct sockaddr)`.

Just like with **send()**, **sendto()** returns the number of bytes actually sent (which, again, might be less than the number of bytes you told it to send!), or -1 on error.

Equally similar are **recv()** and **recvfrom()**. The synopsis of **recvfrom()** is:

```
int recvfrom(int sockfd, void *buf, int len, unsigned int flags,
             struct sockaddr *from, int *fromlen);
```

Again, this is just like **recv()** with the addition of a couple fields. *from* is a pointer to a local `struct sockaddr` that will be filled with the IP address and port of the originating machine. *fromlen* is a pointer to a local `int` that should be initialized to `sizeof *from` or `sizeof(struct sockaddr)`. When the function returns, *fromlen* will contain the length of the address actually stored in *from*.

recvfrom() returns the number of bytes received, or `-1` on error (with *errno* set accordingly.)

Remember, if you **connect()** a datagram socket, you can then simply use **send()** and **recv()** for all your transactions. The socket itself is still a datagram socket and the packets still use UDP, but the socket interface will automatically add the destination and source information for you.

4.8. close() and shutdown()—Get outta my face!

Whew! You've been **send()**ing and **recv()**ing data all day long, and you've had it. You're ready to close the connection on your socket descriptor. This is easy. You can just use the regular Unix file descriptor **close()** function:

```
close(sockfd);
```

This will prevent any more reads and writes to the socket. Anyone attempting to read or write the socket on the remote end will receive an error.

Just in case you want a little more control over how the socket closes, you can use the **shutdown()** function. It allows you to cut off communication in a certain direction, or both ways (just like **close()** does.) Synopsis:

```
int shutdown(int sockfd, int how);
```

sockfd is the socket file descriptor you want to shutdown, and *how* is one of the following:

`0`	Further receives are disallowed
`1`	Further sends are disallowed
`2`	Further sends and receives are disallowed (like **close()**)

shutdown() returns `0` on success, and `-1` on error (with *errno* set accordingly.)

If you deign to use **shutdown()** on unconnected datagram sockets, it will simply make the socket unavailable for further **send()** and **recv()** calls (remember that you can use these if you **connect()** your datagram socket.)

It's important to note that **shutdown()** doesn't actually close the file descriptor—it just changes its usability. To free a socket descriptor, you need to use **close()**.

Nothing to it.

(Except to remember that if you're using Windows and Winsock that you should call **closesocket()** instead of **close()**.)

4.9. getpeername()—Who are you?

This function is so easy.

It's so easy, I almost didn't give it it's own section. But here it is anyway.

The function **getpeername()** will tell you who is at the other end of a connected stream socket. The synopsis:

```
#include <sys/socket.h>

int getpeername(int sockfd, struct sockaddr *addr, int *addrlen);
```

sockfd is the descriptor of the connected stream socket, *addr* is a pointer to a `struct sockaddr` (or a `struct sockaddr_in`) that will hold the information about the other side of the connection, and *addrlen* is a pointer to an `int`, that should be initialized to `sizeof *addr` or `sizeof(struct sockaddr)`.

The function returns `-1` on error and sets *errno* accordingly.

Once you have their address, you can use **`inet_ntoa()`** or **`gethostbyaddr()`** to print or get more information. No, you can't get their login name. (Ok, ok. If the other computer is running an ident daemon, this is possible. This, however, is beyond the scope of this document. Check out RFC 1413[11] for more info.)

4.10. `gethostname()`—Who am I?

Even easier than **`getpeername()`** is the function **`gethostname()`**. It returns the name of the computer that your program is running on. The name can then be used by **`gethostbyname()`**, below, to determine the IP address of your local machine.

What could be more fun? I could think of a few things, but they don't pertain to socket programming. Anyway, here's the breakdown:

```
#include <unistd.h>

int gethostname(char *hostname, size_t size);
```

The arguments are simple: *hostname* is a pointer to an array of chars that will contain the hostname upon the function's return, and *size* is the length in bytes of the *hostname* array.

The function returns `0` on successful completion, and `-1` on error, setting *errno* as usual.

4.11. DNS—You say “whitehouse.gov”, I say “63.161.169.137”

In case you don't know what DNS is, it stands for “Domain Name Service”. In a nutshell, you tell it what the human-readable address is for a site, and it'll give you the IP address (so you can use it with **`bind()`**, **`connect()`**, **`sendto()`**, or whatever you need it for.) This way, when someone enters:

```
$ telnet whitehouse.gov
```

telnet can find out that it needs to **`connect()`** to “63.161.169.137”.

But how does it work? You'll be using the function **`gethostbyname()`**:

```
#include <netdb.h>

struct hostent *gethostbyname(const char *name);
```

As you see, it returns a pointer to a `struct hostent`, the layout of which is as follows:

```
struct hostent {
    char    *h_name;
    char    **h_aliases;
    int     h_addrtype;
    int     h_length;
    char    **h_addr_list;
};
#define h_addr h_addr_list[0]
```

And here are the descriptions of the fields in the `struct hostent`:

h_name	Official name of the host.
h_aliases	A NULL-terminated array of alternate names for the host.
h_addrtype	The type of address being returned; usually *AF_INET*.
h_length	The length of the address in bytes.

11. http://tools.ietf.org/html/rfc1413

h_addr_list	A zero-terminated array of network addresses for the host. Host addresses are in Network Byte Order.
h_addr	The first address in *h_addr_list*.

gethostbyname() returns a pointer to the filled `struct hostent`, or NULL on error. (But *errno* is *not* set—*h_errno* is set instead. See **herror()**, below.)

But how is it used? Sometimes (as we find from reading computer manuals), just spewing the information at the reader is not enough. This function is certainly easier to use than it looks.

Here's an example program[12]:

```
/*
** getip.c -- a hostname lookup demo
*/

#include <stdio.h>
#include <stdlib.h>
#include <errno.h>
#include <netdb.h>
#include <sys/types.h>
#include <sys/socket.h>
#include <netinet/in.h>
#include <arpa/inet.h>

int main(int argc, char *argv[])
{
    struct hostent *h;

    if (argc != 2) {  // error check the command line
        fprintf(stderr,"usage: getip address\n");
        exit(1);
    }

    if ((h=gethostbyname(argv[1])) == NULL) {  // get the host info
        herror("gethostbyname");
        exit(1);
    }

    printf("Host name  : %s\n", h->h_name);
    printf("IP Address : %s\n", inet_ntoa(*((struct in_addr *)h->h_addr)));

   return 0;
}
```

With **gethostbyname()**, you can't use **perror()** to print error message (since *errno* is not used). Instead, call **herror()**.

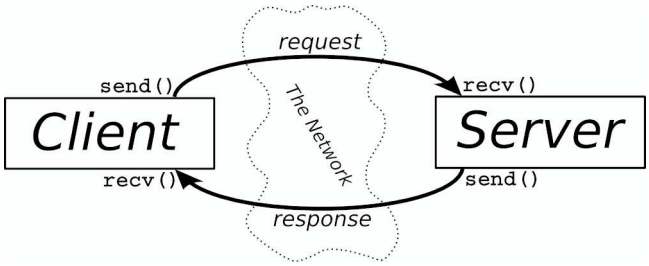
It's pretty straightforward. You simply pass the string that contains the machine name ("whitehouse.gov") to **gethostbyname()**, and then grab the information out of the returned `struct hostent`.

The only possible weirdness might be in the printing of the IP address, above. *h->h_addr* is a `char*`, but **inet_ntoa()** wants a `struct in_addr` passed to it. So I cast *h->h_addr* to a `struct in_addr*`, then dereference it to get at the data.

12. http://beej.us/guide/bgnet/examples/getip.c

5. Client-Server Background

It's a client-server world, baby. Just about everything on the network deals with client processes talking to server processes and vice-versa. Take **telnet**, for instance. When you connect to a remote host on port 23 with telnet (the client), a program on that host (called **telnetd**, the server) springs to life. It handles the incoming telnet connection, sets you up with a login prompt, etc.



Client-Server Interaction.

The exchange of information between client and server is summarized in the above diagram.

Note that the client-server pair can speak `SOCK_STREAM`, `SOCK_DGRAM`, or anything else (as long as they're speaking the same thing.) Some good examples of client-server pairs are **telnet/telnetd**, **ftp/ftpd**, or **bootp/bootpd**. Every time you use **ftp**, there's a remote program, **ftpd**, that serves you.

Often, there will only be one server on a machine, and that server will handle multiple clients using **`fork()`**. The basic routine is: server will wait for a connection, **`accept()`** it, and **`fork()`** a child process to handle it. This is what our sample server does in the next section.

5.1. A Simple Stream Server

All this server does is send the string "`Hello, World!\n`" out over a stream connection. All you need to do to test this server is run it in one window, and telnet to it from another with:

```
$ telnet remotehostname 3490
```

where `remotehostname` is the name of the machine you're running it on.

The server code[13]: (Note: a trailing backslash on a line means that the line is continued on the next.)

```
/*
** server.c -- a stream socket server demo
*/

#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>
#include <errno.h>
#include <string.h>
#include <sys/types.h>
#include <sys/socket.h>
#include <netinet/in.h>
#include <arpa/inet.h>
#include <sys/wait.h>
#include <signal.h>

#define MYPORT 3490 // the port users will be connecting to
```

13. `http://beej.us/guide/bgnet/examples/server.c`

```
#define BACKLOG 10   // how many pending connections queue will hold

void sigchld_handler(int s)
{
    while(waitpid(-1, NULL, WNOHANG) > 0);
}

int main(void)
{
    int sockfd, new_fd;  // listen on sock_fd, new connection on new_fd
    struct sockaddr_in my_addr; // my address information
    struct sockaddr_in their_addr; // connector's address information
    socklen_t sin_size;
    struct sigaction sa;
    int yes=1;

    if ((sockfd = socket(AF_INET, SOCK_STREAM, 0)) == -1) {
        perror("socket");
        exit(1);
    }

    if (setsockopt(sockfd, SOL_SOCKET, SO_REUSEADDR, &yes, sizeof(int)) == -1) {
        perror("setsockopt");
        exit(1);
    }

    my_addr.sin_family = AF_INET;         // host byte order
    my_addr.sin_port = htons(MYPORT);     // short, network byte order
    my_addr.sin_addr.s_addr = INADDR_ANY; // automatically fill with my IP
    memset(my_addr.sin_zero, '\0', sizeof my_addr.sin_zero);

    if (bind(sockfd, (struct sockaddr *)&my_addr, sizeof my_addr) == -1) {
        perror("bind");
        exit(1);
    }

    if (listen(sockfd, BACKLOG) == -1) {
        perror("listen");
        exit(1);
    }

    sa.sa_handler = sigchld_handler; // reap all dead processes
    sigemptyset(&sa.sa_mask);
    sa.sa_flags = SA_RESTART;
    if (sigaction(SIGCHLD, &sa, NULL) == -1) {
        perror("sigaction");
        exit(1);
    }

    while(1) {  // main accept() loop
        sin_size = sizeof their_addr;
        if ((new_fd = accept(sockfd, (struct sockaddr *)&their_addr, \
                &sin_size)) == -1) {
            perror("accept");
            continue;
        }
        printf("server: got connection from %s\n", \
            inet_ntoa(their_addr.sin_addr));
        if (!fork()) { // this is the child process
            close(sockfd); // child doesn't need the listener
            if (send(new_fd, "Hello, world!\n", 14, 0) == -1)
                perror("send");
            close(new_fd);
            exit(0);
```

```
        }
        close(new_fd);  // parent doesn't need this
    }

    return 0;
}
```

In case you're curious, I have the code in one big **`main()`** function for (I feel) syntactic clarity. Feel free to split it into smaller functions if it makes you feel better.

(Also, this whole **`sigaction()`** thing might be new to you—that's ok. The code that's there is responsible for reaping zombie processes that appear as the **`fork()`**ed child processes exit. If you make lots of zombies and don't reap them, your system administrator will become agitated.)

You can get the data from this server by using the client listed in the next section.

5.2. A Simple Stream Client

This guy's even easier than the server. All this client does is connect to the host you specify on the command line, port 3490. It gets the string that the server sends.

The client source [14]:

```
/*
** client.c -- a stream socket client demo
*/

#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>
#include <errno.h>
#include <string.h>
#include <netdb.h>
#include <sys/types.h>
#include <netinet/in.h>
#include <sys/socket.h>

#define PORT 3490 // the port client will be connecting to

#define MAXDATASIZE 100 // max number of bytes we can get at once

int main(int argc, char *argv[])
{
    int sockfd, numbytes;
    char buf[MAXDATASIZE];
    struct hostent *he;
    struct sockaddr_in their_addr; // connector's address information

    if (argc != 2) {
        fprintf(stderr,"usage: client hostname\n");
        exit(1);
    }

    if ((he=gethostbyname(argv[1])) == NULL) {  // get the host info
        herror("gethostbyname");
        exit(1);
    }

    if ((sockfd = socket(PF_INET, SOCK_STREAM, 0)) == -1) {
        perror("socket");
        exit(1);
    }

    their_addr.sin_family = AF_INET;    // host byte order
```

14. http://beej.us/guide/bgnet/examples/client.c

```
    their_addr.sin_port = htons(PORT);  // short, network byte order
    their_addr.sin_addr = *((struct in_addr *)he->h_addr);
    memset(their_addr.sin_zero, '\0', sizeof their_addr.sin_zero);

    if (connect(sockfd, (struct sockaddr *)&their_addr,
                                          sizeof their_addr) == -1) {
        perror("connect");
        exit(1);
    }

    if ((numbytes=recv(sockfd, buf, MAXDATASIZE-1, 0)) == -1) {
        perror("recv");
        exit(1);
    }

    buf[numbytes] = '\0';

    printf("Received: %s",buf);

    close(sockfd);

    return 0;
}
```

Notice that if you don't run the server before you run the client, **`connect()`** returns "Connection refused". Very useful.

5.3. Datagram Sockets

I really don't have that much to talk about here, so I'll just present a couple of sample programs: *`talker.c`* and *`listener.c`*.

listener sits on a machine waiting for an incoming packet on port 4950. **talker** sends a packet to that port, on the specified machine, that contains whatever the user enters on the command line.

Here is the source for *`listener.c`*[15]:

```
/*
** listener.c -- a datagram sockets "server" demo
*/

#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>
#include <errno.h>
#include <string.h>
#include <sys/types.h>
#include <sys/socket.h>
#include <netinet/in.h>
#include <arpa/inet.h>

#define MYPORT 4950 // the port users will be connecting to

#define MAXBUFLEN 100

int main(void)
{
    int sockfd;
    struct sockaddr_in my_addr; // my address information
    struct sockaddr_in their_addr; // connector's address information
    socklen_t addr_len;
    int numbytes;
    char buf[MAXBUFLEN];
```

15. http://beej.us/guide/bgnet/examples/listener.c

```
    if ((sockfd = socket(AF_INET, SOCK_DGRAM, 0)) == -1) {
        perror("socket");
        exit(1);
    }

    my_addr.sin_family = AF_INET;         // host byte order
    my_addr.sin_port = htons(MYPORT);     // short, network byte order
    my_addr.sin_addr.s_addr = INADDR_ANY; // automatically fill with my IP
    memset(my_addr.sin_zero, '\0', sizeof my_addr.sin_zero);

    if (bind(sockfd, (struct sockaddr *)&my_addr, sizeof my_addr) == -1) {
        perror("bind");
        exit(1);
    }

    addr_len = sizeof their_addr;
    if ((numbytes = recvfrom(sockfd, buf, MAXBUFLEN-1 , 0,
        (struct sockaddr *)&their_addr, &addr_len)) == -1) {
        perror("recvfrom");
        exit(1);
    }

    printf("got packet from %s\n",inet_ntoa(their_addr.sin_addr));
    printf("packet is %d bytes long\n",numbytes);
    buf[numbytes] = '\0';
    printf("packet contains \"%s\"\n",buf);

    close(sockfd);

    return 0;
}
```

Notice that in our call to **`socket()`** we're finally using `SOCK_DGRAM`. Also, note that there's no need to **`listen()`** or **`accept()`**. This is one of the perks of using unconnected datagram sockets!

Next comes the source for *`talker.c`*[16]:

```
/*
** talker.c -- a datagram "client" demo
*/

#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>
#include <errno.h>
#include <string.h>
#include <sys/types.h>
#include <sys/socket.h>
#include <netinet/in.h>
#include <arpa/inet.h>
#include <netdb.h>

#define SERVERPORT 4950 // the port users will be connecting to

int main(int argc, char *argv[])
{
    int sockfd;
    struct sockaddr_in their_addr; // connector's address information
    struct hostent *he;
    int numbytes;

    if (argc != 3) {
```

16. `http://beej.us/guide/bgnet/examples/talker.c`

```
        fprintf(stderr,"usage: talker hostname message\n");
        exit(1);
    }

    if ((he=gethostbyname(argv[1])) == NULL) {  // get the host info
        herror("gethostbyname");
        exit(1);
    }

    if ((sockfd = socket(AF_INET, SOCK_DGRAM, 0)) == -1) {
        perror("socket");
        exit(1);
    }

    their_addr.sin_family = AF_INET;     // host byte order
    their_addr.sin_port = htons(SERVERPORT); // short, network byte order
    their_addr.sin_addr = *((struct in_addr *)he->h_addr);
    memset(their_addr.sin_zero, '\0', sizeof their_addr.sin_zero);

    if ((numbytes = sendto(sockfd, argv[2], strlen(argv[2]), 0,
             (struct sockaddr *)&their_addr, sizeof their_addr)) == -1) {
        perror("sendto");
        exit(1);
    }

    printf("sent %d bytes to %s\n", numbytes, inet_ntoa(their_addr.sin_addr));

    close(sockfd);

    return 0;
}
```

And that's all there is to it! Run **listener** on some machine, then run **talker** on another. Watch them communicate! Fun G-rated excitement for the entire nuclear family!

Except for one more tiny detail that I've mentioned many times in the past: connected datagram sockets. I need to talk about this here, since we're in the datagram section of the document. Let's say that **talker** calls **`connect()`** and specifies the **listener**'s address. From that point on, **talker** may only sent to and receive from the address specified by **`connect()`**. For this reason, you don't have to use **`sendto()`** and **`recvfrom()`**; you can simply use **`send()`** and **`recv()`**.

6. Slightly Advanced Techniques

These aren't *really* advanced, but they're getting out of the more basic levels we've already covered. In fact, if you've gotten this far, you should consider yourself fairly accomplished in the basics of Unix network programming! Congratulations!

So here we go into the brave new world of some of the more esoteric things you might want to learn about sockets. Have at it!

6.1. Blocking

Blocking. You've heard about it—now what the heck is it? In a nutshell, "block" is techie jargon for "sleep". You probably noticed that when you run **listener**, above, it just sits there until a packet arrives. What happened is that it called **`recvfrom()`**, there was no data, and so **`recvfrom()`** is said to "block" (that is, sleep there) until some data arrives.

Lots of functions block. **`accept()`** blocks. All the **`recv()`** functions block. The reason they can do this is because they're allowed to. When you first create the socket descriptor with **`socket()`**, the kernel sets it to blocking. If you don't want a socket to be blocking, you have to make a call to **`fcntl()`**:

```
#include <unistd.h>
#include <fcntl.h>
.
.
.
sockfd = socket(PF_INET, SOCK_STREAM, 0);
fcntl(sockfd, F_SETFL, O_NONBLOCK);
.
.
.
```

By setting a socket to non-blocking, you can effectively "poll" the socket for information. If you try to read from a non-blocking socket and there's no data there, it's not allowed to block—it will return `-1` and *`errno`* will be set to `EWOULDBLOCK`.

Generally speaking, however, this type of polling is a bad idea. If you put your program in a busy-wait looking for data on the socket, you'll suck up CPU time like it was going out of style. A more elegant solution for checking to see if there's data waiting to be read comes in the following section on **`select()`**.

6.2. `select()`—Synchronous I/O Multiplexing

This function is somewhat strange, but it's very useful. Take the following situation: you are a server and you want to listen for incoming connections as well as keep reading from the connections you already have.

No problem, you say, just an **`accept()`** and a couple of **`recv()`**s. Not so fast, buster! What if you're blocking on an **`accept()`** call? How are you going to **`recv()`** data at the same time? "Use non-blocking sockets!" No way! You don't want to be a CPU hog. What, then?

`select()` gives you the power to monitor several sockets at the same time. It'll tell you which ones are ready for reading, which are ready for writing, and which sockets have raised exceptions, if you really want to know that.

Without any further ado, I'll offer the synopsis of **`select()`**:

```
#include <sys/time.h>
#include <sys/types.h>
#include <unistd.h>

int select(int numfds, fd_set *readfds, fd_set *writefds,
```

```
            fd_set *exceptfds, struct timeval *timeout);
```

The function monitors "sets" of file descriptors; in particular *readfds*, *writefds*, and *exceptfds*. If you want to see if you can read from standard input and some socket descriptor, *sockfd*, just add the file descriptors `0` and *sockfd* to the set *readfds*. The parameter *numfds* should be set to the values of the highest file descriptor plus one. In this example, it should be set to *sockfd+1*, since it is assuredly higher than standard input (`0`).

When **`select()`** returns, *readfds* will be modified to reflect which of the file descriptors you selected which is ready for reading. You can test them with the macro **`FD_ISSET()`**, below.

Before progressing much further, I'll talk about how to manipulate these sets. Each set is of the type `fd_set`. The following macros operate on this type:

`FD_SET(int fd, fd_set *set);`	Add *fd* to the *set*.
`FD_CLR(int fd, fd_set *set);`	Remove *fd* from the *set*.
`FD_ISSET(int fd, fd_set *set);`	Return true if *fd* is in the *set*.
`FD_ZERO(fd_set *set);`	Clear all entries from the *set*.

Finally, what is this weirded out `struct timeval`? Well, sometimes you don't want to wait forever for someone to send you some data. Maybe every 96 seconds you want to print "Still Going..." to the terminal even though nothing has happened. This time structure allows you to specify a timeout period. If the time is exceeded and **`select()`** still hasn't found any ready file descriptors, it'll return so you can continue processing.

The `struct timeval` has the follow fields:

```
struct timeval {
    int tv_sec;     // seconds
    int tv_usec;    // microseconds
};
```

Just set *tv_sec* to the number of seconds to wait, and set *tv_usec* to the number of microseconds to wait. Yes, that's *micro*seconds, not milliseconds. There are 1,000 microseconds in a millisecond, and 1,000 milliseconds in a second. Thus, there are 1,000,000 microseconds in a second. Why is it "usec"? The "u" is supposed to look like the Greek letter μ (Mu) that we use for "micro". Also, when the function returns, *timeout* *might* be updated to show the time still remaining. This depends on what flavor of Unix you're running.

Yay! We have a microsecond resolution timer! Well, don't count on it. You'll probably have to wait some part of your standard Unix timeslice no matter how small you set your `struct timeval`.

Other things of interest: If you set the fields in your `struct timeval` to `0`, **`select()`** will timeout immediately, effectively polling all the file descriptors in your sets. If you set the parameter *timeout* to NULL, it will never timeout, and will wait until the first file descriptor is ready. Finally, if you don't care about waiting for a certain set, you can just set it to NULL in the call to **`select()`**.

The following code snippet[17] waits 2.5 seconds for something to appear on standard input:

```
/*
** select.c -- a select() demo
*/

#include <stdio.h>
#include <sys/time.h>
#include <sys/types.h>
#include <unistd.h>
```

17. `http://beej.us/guide/bgnet/examples/select.c`

```
#define STDIN 0  // file descriptor for standard input

int main(void)
{
    struct timeval tv;
    fd_set readfds;

    tv.tv_sec = 2;
    tv.tv_usec = 500000;

    FD_ZERO(&readfds);
    FD_SET(STDIN, &readfds);

    // don't care about writefds and exceptfds:
    select(STDIN+1, &readfds, NULL, NULL, &tv);

    if (FD_ISSET(STDIN, &readfds))
        printf("A key was pressed!\n");
    else
        printf("Timed out.\n");

    return 0;
}
```

If you're on a line buffered terminal, the key you hit should be RETURN or it will time out anyway.

Now, some of you might think this is a great way to wait for data on a datagram socket—and you are right: it *might* be. Some Unices can use select in this manner, and some can't. You should see what your local man page says on the matter if you want to attempt it.

Some Unices update the time in your `struct timeval` to reflect the amount of time still remaining before a timeout. But others do not. Don't rely on that occurring if you want to be portable. (Use **`gettimeofday()`** if you need to track time elapsed. It's a bummer, I know, but that's the way it is.)

What happens if a socket in the read set closes the connection? Well, in that case, **`select()`** returns with that socket descriptor set as "ready to read". When you actually do **`recv()`** from it, **`recv()`** will return `0`. That's how you know the client has closed the connection.

One more note of interest about **`select()`**: if you have a socket that is **`listen()`**ing, you can check to see if there is a new connection by putting that socket's file descriptor in the *`readfds`* set.

And that, my friends, is a quick overview of the almighty **`select()`** function.

But, by popular demand, here is an in-depth example. Unfortunately, the difference between the dirt-simple example, above, and this one here is significant. But have a look, then read the description that follows it.

This program[18] acts like a simple multi-user chat server. Start it running in one window, then **telnet** to it ("**telnet hostname 9034**") from multiple other windows. When you type something in one **telnet** session, it should appear in all the others.

```
/*
** selectserver.c -- a cheezy multiperson chat server
*/

#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <unistd.h>
#include <sys/types.h>
```

18. `http://beej.us/guide/bgnet/examples/selectserver.c`

```
#include <sys/socket.h>
#include <netinet/in.h>
#include <arpa/inet.h>

#define PORT 9034   // port we're listening on

int main(void)
{
    fd_set master;   // master file descriptor list
    fd_set read_fds; // temp file descriptor list for select()
    struct sockaddr_in myaddr;     // server address
    struct sockaddr_in remoteaddr; // client address
    int fdmax;        // maximum file descriptor number
    int listener;     // listening socket descriptor
    int newfd;        // newly accept()ed socket descriptor
    char buf[256];    // buffer for client data
    int nbytes;
    int yes=1;        // for setsockopt() SO_REUSEADDR, below
    socklen_t addrlen;
    int i, j;

    FD_ZERO(&master);    // clear the master and temp sets
    FD_ZERO(&read_fds);

    // get the listener
    if ((listener = socket(PF_INET, SOCK_STREAM, 0)) == -1) {
        perror("socket");
        exit(1);
    }

    // lose the pesky "address already in use" error message
    if (setsockopt(listener, SOL_SOCKET, SO_REUSEADDR, &yes, \
        sizeof(int)) == -1) {

        perror("setsockopt");
        exit(1);
    }

    // bind
    myaddr.sin_family = AF_INET;
    myaddr.sin_addr.s_addr = INADDR_ANY;
    myaddr.sin_port = htons(PORT);
    memset(myaddr.sin_zero, '\0', sizeof myaddr.sin_zero);
    if (bind(listener, (struct sockaddr *)&myaddr, sizeof myaddr) == -1) {
        perror("bind");
        exit(1);
    }

    // listen
    if (listen(listener, 10) == -1) {
        perror("listen");
        exit(1);
    }

    // add the listener to the master set
    FD_SET(listener, &master);

    // keep track of the biggest file descriptor
    fdmax = listener; // so far, it's this one

    // main loop
    for(;;) {
        read_fds = master; // copy it
        if (select(fdmax+1, &read_fds, NULL, NULL, NULL) == -1) {
```

```
            perror("select");
            exit(1);
        }

        // run through the existing connections looking for data to read
        for(i = 0; i <= fdmax; i++) {
            if (FD_ISSET(i, &read_fds)) { // we got one!!
                if (i == listener) {
                    // handle new connections
                    addrlen = sizeof remoteaddr;
                    if ((newfd = accept(listener, \
                        (struct sockaddr *)&remoteaddr, &addrlen)) == -1) {

                        perror("accept");
                    } else {
                        FD_SET(newfd, &master); // add to master set
                        if (newfd > fdmax) {    // keep track of the maximum
                            fdmax = newfd;
                        }
                        printf("selectserver: new connection from %s on " \
                            "socket %d\n", \
                            inet_ntoa(remoteaddr.sin_addr), newfd);
                    }
                } else {
                    // handle data from a client
                    if ((nbytes = recv(i, buf, sizeof buf, 0)) <= 0) {
                        // got error or connection closed by client
                        if (nbytes == 0) {
                            // connection closed
                            printf("selectserver: socket %d hung up\n", i);
                        } else {
                            perror("recv");
                        }
                        close(i); // bye!
                        FD_CLR(i, &master); // remove from master set
                    } else {
                        // we got some data from a client
                        for(j = 0; j <= fdmax; j++) {
                            // send to everyone!
                            if (FD_ISSET(j, &master)) {
                                // except the listener and ourselves
                                if (j != listener && j != i) {
                                    if (send(j, buf, nbytes, 0) == -1) {
                                        perror("send");
                                    }
                                }
                            }
                        }
                    }
                } // it's SO UGLY!
            }
        }
    }

    return 0;
}
```

Notice I have two file descriptor sets in the code: *`master`* and *`read_fds`*. The first, *`master`*, holds all the socket descriptors that are currently connected, as well as the socket descriptor that is listening for new connections.

The reason I have the *`master`* set is that **`select()`** actually *changes* the set you pass into it to reflect which sockets are ready to read. Since I have to keep track of the connections from

one call of **`select()`** to the next, I must store these safely away somewhere. At the last minute, I copy the *`master`* into the *`read_fds`*, and then call **`select()`**.

But doesn't this mean that every time I get a new connection, I have to add it to the *`master`* set? Yup! And every time a connection closes, I have to remove it from the *`master`* set? Yes, it does.

Notice I check to see when the *`listener`* socket is ready to read. When it is, it means I have a new connection pending, and I **`accept()`** it and add it to the *`master`* set. Similarly, when a client connection is ready to read, and **`recv()`** returns `0`, I know the client has closed the connection, and I must remove it from the *`master`* set.

If the client **`recv()`** returns non-zero, though, I know some data has been received. So I get it, and then go through the *`master`* list and send that data to all the rest of the connected clients.

And that, my friends, is a less-than-simple overview of the almighty **`select()`** function.

In addition, here is a bonus afterthought: there is another function called **`poll()`** which behaves much the same way **`select()`** does, but with a different system for managing the file descriptor sets. Check it out!

6.3. Handling Partial `send()`s

Remember back in the section about **`send()`**, above, when I said that **`send()`** might not send all the bytes you asked it to? That is, you want it to send 512 bytes, but it returns 412. What happened to the remaining 100 bytes?

Well, they're still in your little buffer waiting to be sent out. Due to circumstances beyond your control, the kernel decided not to send all the data out in one chunk, and now, my friend, it's up to you to get the data out there.

You could write a function like this to do it, too:

```
#include <sys/types.h>
#include <sys/socket.h>

int sendall(int s, char *buf, int *len)
{
    int total = 0;        // how many bytes we've sent
    int bytesleft = *len; // how many we have left to send
    int n;

    while(total < *len) {
        n = send(s, buf+total, bytesleft, 0);
        if (n == -1) { break; }
        total += n;
        bytesleft -= n;
    }

    *len = total; // return number actually sent here

    return n==-1?-1:0; // return -1 on failure, 0 on success
}
```

In this example, *`s`* is the socket you want to send the data to, *`buf`* is the buffer containing the data, and *`len`* is a pointer to an `int` containing the number of bytes in the buffer.

The function returns `-1` on error (and *`errno`* is still set from the call to **`send()`**.) Also, the number of bytes actually sent is returned in *`len`*. This will be the same number of bytes you asked it to send, unless there was an error. **`sendall()`** will do it's best, huffing and puffing, to send the data out, but if there's an error, it gets back to you right away.

For completeness, here's a sample call to the function:

```
char buf[10] = "Beej!";
int len;
```

```
len = strlen(buf);
if (sendall(s, buf, &len) == -1) {
    perror("sendall");
    printf("We only sent %d bytes because of the error!\n", len);
}
```

What happens on the receiver's end when part of a packet arrives? If the packets are variable length, how does the receiver know when one packet ends and another begins? Yes, real-world scenarios are a royal pain in the donkeys. You probably have to *encapsulate* (remember that from the data encapsulation section way back there at the beginning?) Read on for details!

6.4. Serialization—How to Pack Data

It's easy enough to send text data across the network, you're finding, but what happens if you want to send some "binary" data like `ints` or `floats`? It turns out you have a few options.

1. Convert the number into text with a function like **`sprintf()`**, then send the text. The receiver will parse the text back into a number using a function like **`strtol()`**.
2. Just send the data raw, passing a pointer to the data to **`send()`**.
3. Encode the number into a portable binary form. The receiver will decode it.

Sneak preview! Tonight only!
[*Curtain raises*]
Beej says, "I prefer Method Three, above!"
[*THE END*]

Actually, they all have their drawbacks and advantages, but, like I said, in general, I prefer the third method. First, though, let's talk about some of the drawbacks and advantages to the other two.

The first method, encoding the numbers as text before sending, has the advantage that you can easily print and read the data that's coming over the wire. Sometimes a human-readable protocol is excellent to use in a non-bandwidth-intensive situation, such as with Internet Relay Chat (IRC)[19]. However, it has the disadvantage that it is slow to convert, and the results almost always take up more space than the original number!

Method two: passing the raw data. This one is quite easy (but dangerous!): just take a pointer to the data to send, and call send with it.

```
double d = 3490.15926535;

send(s, &d, sizeof d, 0);  /* DANGER--non-portable! */
```

The receiver gets it like this:

```
double d;

recv(s, &d, sizeof d, 0);  /* DANGER--non-portable! */
```

Fast, simple—what's not to like? Well, it turns out that not all architectures represent a `double` (or `int`) for that matter with the same bit representation or even the same byte ordering! The code is decidedly non-portable. (Hey—maybe you don't need portability, in which case this is nice and fast.)

When packing integer types, we've already seen how the **`htons()`**-class of functions can help keep things portable by transforming the numbers into Network Byte Order, and how that's

19. `http://en.wikipedia.org/wiki/Internet_Relay_Chat`

the Right Thing to do. Unfortunately, there are no similar functions for `float` types. Is all hope lost?

Fear not! (Were you afraid there for a second? No? Not even a little bit?) There is something we can do: we can pack (or "marshal", or "serialize", or one of a thousand million other names) the data into a known binary format that the receiver can unpack on the remote side.

What do I mean by "known binary format"? Well, we've already seen the **`htons()`** example, right? It changes (or "encodes", if you want to think of it that way) a number from whatever the host format is into Network Byte Order. To reverse (unencode) the number, the receiver calls **`ntohs()`**.

But didn't I just get finished saying there wasn't any such function for other non-integer types? Yes. I did. And since there's no standard way in C to do this, it's a bit of a pickle (that a gratuitous pun there for you Python fans).

The thing to do is to pack the data into a known format and send that over the wire for decoding. For example, to pack `float`s, here's something quick and dirty with plenty of room for improvement: [20]

```
#include <stdint.h>

uint32_t htonf(float f)
{
    uint32_t p;
    uint32_t sign;

    if (f < 0) { sign = 1; f = -f; }
    else { sign = 0; }

    p = ((((uint32_t)f)&0x7fff)<<16) | (sign<<31); // whole part and sign
    p |= (uint32_t)(((f - (int)f) * 65536.0f))&0xffff; // fraction

    return p;
}

float ntohf(uint32_t p)
{
    float f = ((p>>16)&0x7fff); // whole part
    f += (p&0xffff) / 65536.0f; // fraction

    if (((p>>31)&0x1) == 0x1) { f = -f; } // sign bit set

    return f;
}
```

The above code is sort of a naive implementation that stores a `float` in a 32-bit number. The high bit (31) is used to store the sign of the number ("1" means negative), and the next seven bits (30-16) are used to store the whole number portion of the `float`. Finally, the remaining bits (15-0) are used to store the fractional portion of the number.

Usage is fairly straightforward:

```
#include <stdio.h>

int main(void)
{
    float f = 3.1415926, f2;
    uint32_t netf;

    netf = htonf(f);  // convert to "network" form
    f2 = ntohf(netf); // convert back to test
```

20. `http://beej.us/guide/bgnet/examples/pack.c`

```
    printf("Original: %f\n", f);        // 3.141593
    printf(" Network: 0x%08X\n", netf); // 0x0003243F
    printf("Unpacked: %f\n", f2);       // 3.141586

    return 0;
}
```

On the plus side, it's small, simple, and fast. On the minus side, it's not an efficient use of space and the range is severely restricted—try storing a number greater-than 32767 in there and it won't be very happy! You can also see in the above example that the last couple decimal places are not correctly preserved.

What can we do instead? Well, *The* Standard for storing floating point numbers is known as IEEE-754[21]. Most computers use this format internally for doing floating point math, so in those cases, strictly speaking, conversion wouldn't need to be done. But if you want your source code to be portable, that's an assumption you can't necessarily make.

Here's some code that encodes floats and doubles into IEEE-754 format[22]. (Mostly—it doesn't encode NaN or Infinity, but it could be modified to do that.)

```
#define pack754_32(f) (pack754((f), 32, 8))
#define pack754_64(f) (pack754((f), 64, 11))
#define unpack754_32(i) (unpack754((i), 32, 8))
#define unpack754_64(i) (unpack754((i), 64, 11))

long long pack754(long double f, unsigned bits, unsigned expbits)
{
    long double fnorm;
    int shift;
    long long sign, exp, significand;
    unsigned significandbits = bits - expbits - 1; // -1 for sign bit

    if (f == 0.0) return 0; // get this special case out of the way

    // check sign and begin normalization
    if (f < 0) { sign = 1; fnorm = -f; }
    else { sign = 0; fnorm = f; }

    // get the normalized form of f and track the exponent
    shift = 0;
    while(fnorm >= 2.0) { fnorm /= 2.0; shift++; }
    while(fnorm < 1.0) { fnorm *= 2.0; shift--; }
    fnorm = fnorm - 1.0;

    // calculate the binary form (non-float) of the significand data
    significand = fnorm * ((1LL<<significandbits) + 0.5f);

    // get the biased exponent
    exp = shift + ((1<<(expbits-1)) - 1); // shift + bias

    // return the final answer
    return (sign<<(bits-1)) | (exp<<(bits-expbits-1)) | significand;
}

long double unpack754(long long i, unsigned bits, unsigned expbits)
{
    long double result;
    long long shift;
    unsigned bias;
    unsigned significandbits = bits - expbits - 1; // -1 for sign bit

    if (i == 0) return 0.0;
```

21. http://en.wikipedia.org/wiki/IEEE_754
22. http://beej.us/guide/bgnet/examples/ieee754.c

```
    // pull the significand
    result = (i&((1LL<<significandbits)-1)); // mask
    result /= (1LL<<significandbits); // convert back to float
    result += 1.0f; // add the one back on

    // deal with the exponent
    bias = (1<<(expbits-1)) - 1;
    shift = ((i>>significandbits)&((1LL<<expbits)-1)) - bias;
    while(shift > 0) { result *= 2.0; shift--; }
    while(shift < 0) { result /= 2.0; shift++; }

    // sign it
    result *= (i>>(bits-1))&1? -1.0: 1.0;

    return result;
}
```

I put some handy macros up there at the top for packing and unpacking 32-bit (probably a `float`) and 64-bit (probably a `double`) numbers, but the **`pack754()`** function could be called directly and told to encode *`bits`*-worth of data (*`expbits`* of which are reserved for the normalized number's exponent.)

Here's sample usage:

```
#include <stdio.h>
#include <stdint.h> // defines uintN_t types

int main(void)
{
    float f = 3.1415926, f2;
    double d = 3.14159265358979323, d2;
    uint32_t fi;
    uint64_t di;

    fi = pack754_32(f);
    f2 = unpack754_32(fi);

    di = pack754_64(d);
    d2 = unpack754_64(di);

    printf("float before : %.7f\n", f);
    printf("float encoded: 0x%08X\n", fi);
    printf("float after  : %.7f\n\n", f2);

    printf("double before : %.20lf\n", d);
    printf("double encoded: 0x%016llX\n", di);
    printf("double after  : %.20lf\n", d2);

    return 0;
}
```

The above code produces this output:

```
float before : 3.1415925
float encoded: 0x40490FDA
float after  : 3.1415925

double before : 3.14159265358979311600
double encoded: 0x400921FB54442D18
double after  : 3.14159265358979311600
```

Another question you might have is how do you pack `structs`? Unfortunately for you, the compiler is free to put padding all over the place in a `struct`, and that means you can't

portably send the whole thing over the wire in one chunk. (Aren't you getting sick of hearing "can't do this", "can't do that"? Sorry! To quote a friend, "Whenever anything goes wrong, I always blame Microsoft." This one might not be Microsoft's fault, admittedly, but my friend's statement is completely true.)

Back to it: the best way to send the `struct` over the wire is to pack each field independently and then unpack them into the `struct` when they arrive on the other side.

That's a lot of work, is what you're thinking. Yes, it is. One thing you can do is write a helper function to help pack the data for you. It'll be fun! Really!

In the book "The Practice of Programming[23]" by Kernighan and Pike, they implement **`printf()`**-like functions called **`pack()`** and **`unpack()`** that do exactly this. I'd link to them, but apparently those functions aren't online with the rest of the source from the book.

(The Practice of Programming is an excellent read. Zeus saves a kitten every time I recommend it.)

At this point, I'm going to drop a pointer to the BSD-licensed Typed Parameter Language C API[24] which I've never used, but looks completely respectable. Python and Perl programmers will want to check out their language's **`pack()`** and **`unpack()`** functions for accomplishing the same thing. And Java has a big-ol' Serializable interface that can be used in a similar way.

But if you want to write your own packing utility in C, K&P's trick is to use variable argument lists to make **`printf()`**-like functions to build the packets. Here's a version I cooked up[25] on my own based on that which hopefully will be enough to give you an idea of how such a thing can work.

(This code references the **`pack754()`** functions, above. The **`packi*()`** functions operate like the familiar **`htons()`** family, except they pack into a `char` array instead of another integer.)

```
#include <ctype.h>
#include <stdarg.h>
#include <string.h>

/*
** packi16() -- store a 16-bit int into a char buffer (like htons())
*/
void packi16(unsigned char *buf, unsigned int i)
{
    *buf++ = i>>8; *buf++ = i;
}

/*
** packi32() -- store a 32-bit int into a char buffer (like htonl())
*/
void packi32(unsigned char *buf, unsigned long i)
{
    *buf++ = i>>24; *buf++ = i>>16;
    *buf++ = i>>8;  *buf++ = i;
}

/*
** unpacki16() -- unpack a 16-bit int from a char buffer (like ntohs())
*/
unsigned int unpacki16(unsigned char *buf)
{
    return (buf[0]<<8) | buf[1];
}

/*
** unpacki32() -- unpack a 32-bit int from a char buffer (like ntohl())
```

23. http://cm.bell-labs.com/cm/cs/tpop/
24. http://tpl.sourceforge.net/
25. http://beej.us/guide/bgnet/examples/pack2.c

```
*/
unsigned long unpacki32(unsigned char *buf)
{
    return (buf[0]<<24) | (buf[1]<<16) | (buf[2]<<8) | buf[3];
}

/*
** pack() -- store data dictated by the format string in the buffer
**
**  h - 16-bit              l - 32-bit
**  c - 8-bit char          f - float, 32-bit
**  s - string (16-bit length is automatically prepended)
*/
size_t pack(unsigned char *buf, char *format, ...)
{
    va_list ap;
    int h;
    int l;
    char c;
    float f;
    char *s;
    size_t size = 0, len;

    va_start(ap, format);

    for(; *format != '\0'; format++) {
        switch(*format) {
        case 'h': // 16-bit
            size += 2;
            h = va_arg(ap, int); // promoted
            packi16(buf, h);
            buf += 2;
            break;

        case 'l': // 32-bit
            size += 4;
            l = va_arg(ap, int);
            packi32(buf, l);
            buf += 4;
            break;

        case 'c': // 8-bit
            size += 1;
            c = va_arg(ap, int); // promoted
            *buf++ = (c>>0)&0xff;
            break;

        case 'f': // float
            size += 4;
            f = va_arg(ap, double); // promoted
            l = pack754_32(f); // convert to IEEE 754
            packi32(buf, l);
            buf += 4;
            break;

        case 's': // string
            s = va_arg(ap, char*);
            len = strlen(s);
            size += len + 2;
            packi16(buf, len);
            buf += 2;
            memcpy(buf, s, len);
            buf += len;
            break;
```

```
        }
    }

    va_end(ap);

    return size;
}

/*
** unpack() -- unpack data dictated by the format string into the buffer
*/
void unpack(unsigned char *buf, char *format, ...)
{
    va_list ap;
    short *h;
    int *l;
    int pf;
    char *c;
    float *f;
    char *s;
    size_t len, count, maxstrlen=0;

    va_start(ap, format);

    for(; *format != '\0'; format++) {
        switch(*format) {
        case 'h': // 16-bit
            h = va_arg(ap, short*);
            *h = unpacki16(buf);
            buf += 2;
            break;

        case 'l': // 32-bit
            l = va_arg(ap, int*);
            *l = unpacki32(buf);
            buf += 4;
            break;

        case 'c': // 8-bit
            c = va_arg(ap, char*);
            *c = *buf++;
            break;

        case 'f': // float
            f = va_arg(ap, float*);
            pf = unpacki32(buf);
            buf += 4;
            *f = unpack754_32(pf);
            break;

        case 's': // string
            s = va_arg(ap, char*);
            len = unpacki16(buf);
            buf += 2;
            if (maxstrlen > 0 && len > maxstrlen) count = maxstrlen - 1;
            else count = len;
            memcpy(s, buf, count);
            s[count] = '\0';
            buf += len;
            break;

        default:
            if (isdigit(*format)) { // track max str len
                maxstrlen = maxstrlen * 10 + (*format-'0');
```

```
            }
        }

        if (!isdigit(*format)) maxstrlen = 0;
    }

    va_end(ap);
}
```

And here is a demonstration program[26] of the above code that packs some data into *buf* and then unpacks it into variables. Note that when calling **unpack()** with a string argument (format specifier "s"), it's wise to put a maximum length count in front of it to prevent a buffer overrun, e.g. "96s". Be wary when unpacking data you get over the network—a malicious user might send badly-constructed packets in an effort to attack your system!

```
#include <stdio.h>

int main(void)
{
    unsigned char buf[1024];
    char magic;
    short monkeycount;
    long altitude;
    float absurdityfactor;
    char *s = "Great unmitigated Zot!  You've found the Runestaff!";
    char s2[96];
    size_t packetsize, ps2;

    packetsize = pack(buf, "chhlsf", 'B', 0, 37, -5, s, -3490.6677);
    packi16(buf+1, packetsize); // store packet size in packet for kicks

    printf("packet is %d bytes\n", packetsize);

    unpack(buf, "chhl96sf", &magic, &ps2, &monkeycount, &altitude, s2,
        &absurdityfactor);

    printf("'%c' %d %d %ld \"%s\" %f\n", magic, ps2, monkeycount, altitude,
        s2, absurdityfactor);

    return 0;
}
```

Whether you roll your own code or use someone else's, it's a good idea to have a general set of data packing routines for the sake of keeping bugs in check, rather than packing each bit by hand each time.

When packing the data, what's a good format to use? Excellent question. Fortunately, RFC 4506[27], the External Data Representation Standard, already defines binary formats for a bunch of different types, like floating point types, integer types, arrays, raw data, etc. I suggest conforming to that if you're going to roll the data yourself. But you're not obligated to. The Packet Police are not right outside your door. At least, I don't *think* they are.

In any case, encoding the data somehow or another before you send it is the right way of doing things!

6.5. Son of Data Encapsulation

What does it really mean to encapsulate data, anyway? In the simplest case, it means you'll stick a header on there with either some identifying information or a packet length, or both.

What should your header look like? Well, it's just some binary data that represents whatever you feel is necessary to complete your project.

26. http://beej.us/guide/bgnet/examples/pack2.c
27. http://tools.ietf.org/html/rfc4506

Wow. That's vague.

Okay. For instance, let's say you have a multi-user chat program that uses `SOCK_STREAM`s. When a user types ("says") something, two pieces of information need to be transmitted to the server: what was said and who said it.

So far so good? "What's the problem?" you're asking.

The problem is that the messages can be of varying lengths. One person named "tom" might say, "Hi", and another person named "Benjamin" might say, "Hey guys what is up?"

So you **`send()`** all this stuff to the clients as it comes in. Your outgoing data stream looks like this:

```
t o m H i B e n j a m i n H e y g u y s w h a t i s u p ?
```

And so on. How does the client know when one message starts and another stops? You could, if you wanted, make all messages the same length and just call the **`sendall()`** we implemented, above. But that wastes bandwidth! We don't want to **`send()`** 1024 bytes just so "tom" can say "Hi".

So we *encapsulate* the data in a tiny header and packet structure. Both the client and server know how to pack and unpack (sometimes referred to as "marshal" and "unmarshal") this data. Don't look now, but we're starting to define a *protocol* that describes how a client and server communicate!

In this case, let's assume the user name is a fixed length of 8 characters, padded with `'\0'`. And then let's assume the data is variable length, up to a maximum of 128 characters. Let's have a look a sample packet structure that we might use in this situation:

1. `len` (1 byte, unsigned)—The total length of the packet, counting the 8-byte user name and chat data.
2. `name` (8 bytes)—The user's name, NUL-padded if necessary.
3. `chatdata` (*n*-bytes)—The data itself, no more than 128 bytes. The length of the packet should be calculated as the length of this data plus 8 (the length of the name field, above).

Why did I choose the 8-byte and 128-byte limits for the fields? I pulled them out of the air, assuming they'd be long enough. Maybe, though, 8 bytes is too restrictive for your needs, and you can have a 30-byte name field, or whatever. The choice is up to you.

Using the above packet definition, the first packet would consist of the following information (in hex and ASCII):

```
   0A     74 6F 6D 00 00 00 00 00      48 69
(length)  T  o  m    (padding)         H  i
```

And the second is similar:

```
   18     42 65 6E 6A 61 6D 69 6E      48 65 79 20 67 75 79 73 20 77 ...
(length)  B  e  n  j  a  m  i  n       H  e  y     g  u  y  s     w  ...
```

(The length is stored in Network Byte Order, of course. In this case, it's only one byte so it doesn't matter, but generally speaking you'll want all your binary integers to be stored in Network Byte Order in your packets.)

When you're sending this data, you should be safe and use a command similar to **`sendall()`**, above, so you know all the data is sent, even if it takes multiple calls to **`send()`** to get it all out.

Likewise, when you're receiving this data, you need to do a bit of extra work. To be safe, you should assume that you might receive a partial packet (like maybe we receive "`18 42 65`

`6E 6A`" from Benjamin, above, but that's all we get in this call to **`recv()`**). We need to call **`recv()`** over and over again until the packet is completely received.

But how? Well, we know the number of bytes we need to receive in total for the packet to be complete, since that number is tacked on the front of the packet. We also know the maximum packet size is 1+8+128, or 137 bytes (because that's how we defined the packet.)

There are actually a couple things you can do here. Since you know every packet starts off with a length, you can call **`recv()`** just to get the packet length. Then once you have that, you can call it again specifying exactly the remaining length of the packet (possibly repeatedly to get all the data) until you have the complete packet. The advantage of this method is that you only need a buffer large enough for one packet, while the disadvantage is that you need to call **`recv()`** at least twice to get all the data.

Another option is just to call **`recv()`** and say the amount you're willing to receive is the maximum number of bytes in a packet. Then whatever you get, stick it onto the back of a buffer, and finally check to see if the packet is complete. Of course, you might get some of the next packet, so you'll need to have room for that.

What you can do is declare an array big enough for two packets. This is your work array where you will reconstruct packets as they arrive.

Every time you **`recv()`** data, you'll append it into the work buffer and check to see if the packet is complete. That is, the number of bytes in the buffer is greater than or equal to the length specified in the header (+1, because the length in the header doesn't include the byte for the length itself.) If the number of bytes in the buffer is less than 1, the packet is not complete, obviously. You have to make a special case for this, though, since the first byte is garbage and you can't rely on it for the correct packet length.

Once the packet is complete, you can do with it what you will. Use it, and remove it from your work buffer.

Whew! Are you juggling that in your head yet? Well, here's the second of the one-two punch: you might have read past the end of one packet and onto the next in a single **`recv()`** call. That is, you have a work buffer with one complete packet, and an incomplete part of the next packet! Bloody heck. (But this is why you made your work buffer large enough to hold *two* packets—in case this happened!)

Since you know the length of the first packet from the header, and you've been keeping track of the number of bytes in the work buffer, you can subtract and calculate how many of the bytes in the work buffer belong to the second (incomplete) packet. When you've handled the first one, you can clear it out of the work buffer and move the partial second packet down the to front of the buffer so it's all ready to go for the next **`recv()`**.

(Some of you readers will note that actually moving the partial second packet to the beginning of the work buffer takes time, and the program can be coded to not require this by using a circular buffer. Unfortunately for the rest of you, a discussion on circular buffers is beyond the scope of this article. If you're still curious, grab a data structures book and go from there.)

I never said it was easy. Ok, I did say it was easy. And it is; you just need practice and pretty soon it'll come to you naturally. By Excalibur I swear it!

6.6. Broadcast Packets—Hello, World!

So far, this guide has talked about sending data from one host to one other host. But it is possible, I insist, that you can, with the proper authority, send data to multiple hosts *at the same time*!

With UDP (only UDP, not TCP) and standard IPv4, this is done through a mechanism called *broadcasting*. With IPv6 (not appearing in this guide...yet), broadcasting isn't supported,

and you have to resort to the often superior technique of *multicasting*. But enough of the starry-eyed future—we're stuck in the 32-bit present.

But wait! You can't just run off and start broadcasting willy-nilly; You have to set the socket option `SO_BROADCAST` before you can send a broadcast packet out on the network. It's like a one of those little plastic covers they put over the missile launch switch! That's just how much power you hold in your hands!

But seriously, though, there is a danger to using broadcast packets, and that is: every system that receives a broadcast packet must undo all the onion-skin layers of data encapsulation until it finds out what port the data is destined to. And then it hands the data over or discards it. In either case, it's a lot of work for each machine that receives the broadcast packet, and since it is all of them on the local network, that could be a lot of machines doing a lot of unnecessary work. When the game Doom first came out, this was a complaint about its network code.

Yes, I said the local network. There is more than one way to skin a cat... wait a minute. Is there really more than one way to skin a cat? What kind of expression is that? Uh, and likewise, there is more than one way to send a broadcast packet, but the broadcast packets will usually be restricted to your local network no matter how you send them.

So now to the meat and potatoes of the whole thing: how do you specify the destination address for a broadcast message? There are two common ways.

1. Send the data to your broadcast address. This is your network number with all one-bits set for the host portion of the address. For instance, at home my network is 192.168.1.0, my netmask is 255.255.255.0, so the last byte of the address is my host number (because the first three bytes, according to the netmask, are the network number). So my broadcast address is 192.168.1.255. Under Unix, the **ifconfig** command will actually give you all this data. (If you're curious, the bitwise logic to get your broadcast address is *`network_number`* OR (NOT *`netmask`*).)
2. Send the data to the "global" broadcast address. This is 255.255.255.255, aka `INADDR_BROADCAST`. Many machines will automatically bitwise AND this with your network number to convert it to a network broadcast address, but some won't. It varies.

So what happens if you try to send data on the broadcast address without first setting the `SO_BROADCAST` socket option? Well, let's fire up good old **talker** and **listener** and see what happens.

```
$ talker 192.168.1.2 foo
sent 3 bytes to 192.168.1.2
$ talker 192.168.1.255 foo
sendto: Permission denied
$ talker 255.255.255.255 foo
sendto: Permission denied
```

Yes, it's not happy at all...because we didn't set the `SO_BROADCAST` socket option. Do that, and now you can **`sendto()`** anywhere you want!

In fact, that's the *only difference* between a UDP application that can broadcast and one that can't. So let's take the old **talker** application and add one section that sets the `SO_BROADCAST` socket option. We'll call this program *`broadcaster.c`*[28]:

```
/*
** broadcaster.c -- a datagram "client" like talker.c, except
**                  this one can broadcast
*/
```

28. `http://beej.us/guide/bgnet/examples/broadcaster.c`

```
#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>
#include <errno.h>
#include <string.h>
#include <sys/types.h>
#include <sys/socket.h>
#include <netinet/in.h>
#include <arpa/inet.h>
#include <netdb.h>

#define SERVERPORT 4950 // the port users will be connecting to

int main(int argc, char *argv[])
{
    int sockfd;
    struct sockaddr_in their_addr; // connector's address information
    struct hostent *he;
    int numbytes;
    int broadcast = 1;
    //char broadcast = '1'; // if that doesn't work, try this

    if (argc != 3) {
        fprintf(stderr,"usage: broadcaster hostname message\n");
        exit(1);
    }

    if ((he=gethostbyname(argv[1])) == NULL) {  // get the host info
        herror("gethostbyname");
        exit(1);
    }

    if ((sockfd = socket(AF_INET, SOCK_DGRAM, 0)) == -1) {
        perror("socket");
        exit(1);
    }

    // this call is the difference between this program and talker.c:
    if (setsockopt(sockfd, SOL_SOCKET, SO_BROADCAST, &broadcast,
        sizeof broadcast) == -1) {
        perror("setsockopt (SO_BROADCAST)");
        exit(1);
    }

    their_addr.sin_family = AF_INET;     // host byte order
    their_addr.sin_port = htons(SERVERPORT); // short, network byte order
    their_addr.sin_addr = *((struct in_addr *)he->h_addr);
    memset(their_addr.sin_zero, '\0', sizeof their_addr.sin_zero);

    if ((numbytes=sendto(sockfd, argv[2], strlen(argv[2]), 0,
             (struct sockaddr *)&their_addr, sizeof their_addr)) == -1) {
        perror("sendto");
        exit(1);
    }

    printf("sent %d bytes to %s\n", numbytes, inet_ntoa(their_addr.sin_addr));

    close(sockfd);

    return 0;
}
```

What's different between this and a “normal” UDP client/server situation? Nothing! (With the exception of the client being allowed to send broadcast packets in this case.) As such, go ahead and run the old UDP **listener** program in one window, and **broadcaster** in another. You should be now be able to do all those sends that failed, above.

```
$ talker 192.168.1.2 foo
sent 3 bytes to 192.168.1.2
$ talker 192.168.1.255 foo
sent 3 bytes to 192.168.1.255
$ talker 255.255.255.255 foo
sent 3 bytes to 255.255.255.255
```

And you should see **listener** responding that it got the packets.

Well, that's kind of exciting. But now fire up **listener** on another machine next to you on the same network so that you have two copies going, one on each machine, and run **broadcaster** again with your broadcast address... Hey! Both **listener**s get the packet even though you only called **`sendto()`** once! Cool!

If the **listener** gets data you send directly to it, but not data on the broadcast address, it could be that you have a firewall on your local machine that is blocking the packets. (Yes, Pat and Bapper, thank you for realizing before I did that this is why my sample code wasn't working. I told you I'd mention you in the guide, and here you are. So *nyah*.)

Again, be careful with broadcast packets. Since every machine on the LAN will be forced to deal with the packet whether it **`recvfrom()`**s it or not, it can present quite a load to the entire computing network. They are definitely to be used sparingly and appropriately.

7. Common Questions

Where can I get those header files?

If you don't have them on your system already, you probably don't need them. Check the manual for your particular platform. If you're building for Windows, you only need to `#include <winsock.h>`.

What do I do when `bind()` reports "Address already in use"?

You have to use **`setsockopt()`** with the `SO_REUSEADDR` option on the listening socket. Check out the section on **`bind()`** and the section on **`select()`** for an example.

How do I get a list of open sockets on the system?

Use the **netstat**. Check the **man** page for full details, but you should get some good output just typing:

```
$ netstat
```

The only trick is determining which socket is associated with which program. `:-)`

How can I view the routing table?

Run the **route** command (in */sbin* on most Linuxes) or the command **netstat -r**.

How can I run the client and server programs if I only have one computer? Don't I need a network to write network programs?

Fortunately for you, virtually all machines implement a loopback network "device" that sits in the kernel and pretends to be a network card. (This is the interface listed as "`lo`" in the routing table.)

Pretend you're logged into a machine named "`goat`". Run the client in one window and the server in another. Or start the server in the background ("**server &**") and run the client in the same window. The upshot of the loopback device is that you can either **client goat** or **client localhost** (since "`localhost`" is likely defined in your */etc/hosts* file) and you'll have the client talking to the server without a network!

In short, no changes are necessary to any of the code to make it run on a single non-networked machine! Huzzah!

How can I tell if the remote side has closed connection?

You can tell because **`recv()`** will return `0`.

How do I implement a "ping" utility? What is ICMP? Where can I find out more about raw sockets and `SOCK_RAW`?

All your raw sockets questions will be answered in W. Richard Stevens' UNIX Network Programming books. See the books section of this guide.

How do I build for Windows?

First, delete Windows and install Linux or BSD. `};-)`. No, actually, just see the section on building for Windows in the introduction.

How do I build for Solaris/SunOS? I keep getting linker errors when I try to compile!

The linker errors happen because Sun boxes don't automatically compile in the socket libraries. See the section on building for Solaris/SunOS in the introduction for an example of how to do this.

Why does `select()` keep falling out on a signal?

Signals tend to cause blocked system calls to return `-1` with *`errno`* set to `EINTR`. When you set up a signal handler with **`sigaction()`**, you can set the flag `SA_RESTART`, which is supposed to restart the system call after it was interrupted.

Naturally, this doesn't always work.

My favorite solution to this involves a `goto` statement. You know this irritates your professors to no end, so go for it!

```
select_restart:
if ((err = select(fdmax+1, &readfds, NULL, NULL, NULL)) == -1) {
    if (errno == EINTR) {
        // some signal just interrupted us, so restart
        goto select_restart;
    }
    // handle the real error here:
    perror("select");
}
```

Sure, you don't *need* to use `goto` in this case; you can use other structures to control it. But I think the `goto` statement is actually cleaner.

How can I implement a timeout on a call to `recv()`?

Use **`select()`**! It allows you to specify a timeout parameter for socket descriptors that you're looking to read from. Or, you could wrap the entire functionality in a single function, like this:

```
#include <unistd.h>
#include <sys/time.h>
#include <sys/types.h>
#include <sys/socket.h>

int recvtimeout(int s, char *buf, int len, int timeout)
{
    fd_set fds;
    int n;
    struct timeval tv;

    // set up the file descriptor set
    FD_ZERO(&fds);
    FD_SET(s, &fds);

    // set up the struct timeval for the timeout
    tv.tv_sec = timeout;
    tv.tv_usec = 0;

    // wait until timeout or data received
    n = select(s+1, &fds, NULL, NULL, &tv);
    if (n == 0) return -2; // timeout!
    if (n == -1) return -1; // error

    // data must be here, so do a normal recv()
    return recv(s, buf, len, 0);
}
.
.
```

```
.
// Sample call to recvtimeout():
n = recvtimeout(s, buf, sizeof buf, 10); // 10 second timeout

if (n == -1) {
    // error occurred
    perror("recvtimeout");
}
else if (n == -2) {
    // timeout occurred
} else {
    // got some data in buf
}
.
.
.
```

Notice that **recvtimeout()** returns -2 in case of a timeout. Why not return 0? Well, if you recall, a return value of 0 on a call to **recv()** means that the remote side closed the connection. So that return value is already spoken for, and -1 means "error", so I chose -2 as my timeout indicator.

How do I encrypt or compress the data before sending it through the socket?

One easy way to do encryption is to use SSL (secure sockets layer), but that's beyond the scope of this guide. (Check out the OpenSSL project[29] for more info.)

But assuming you want to plug in or implement your own compressor or encryption system, it's just a matter of thinking of your data as running through a sequence of steps between both ends. Each step changes the data in some way.

1. server reads data from file (or wherever)
2. server encrypts/compresses data (you add this part)
3. server **send()**s encrypted data

Now the other way around:

1. client **recv()**s encrypted data
2. client decrypts/decompresses data (you add this part)
3. client writes data to file (or wherever)

If you're going to compress and encrypt, just remember to compress first. :-)

Just as long as the client properly undoes what the server does, the data will be fine in the end no matter how many intermediate steps you add.

So all you need to do to use my code is to find the place between where the data is read and the data is sent (using **send()**) over the network, and stick some code in there that does the encryption.

What is this "PF_INET" I keep seeing? Is it related to AF_INET?

Yes, yes it is. See the section on **socket()** for details.

29. http://www.openssl.org/

How can I write a server that accepts shell commands from a client and executes them?

For simplicity, lets say the client **`connect()`**s, **`send()`**s, and **`close()`**s the connection (that is, there are no subsequent system calls without the client connecting again.)

The process the client follows is this:

1. **`connect()`** to server
2. **`send("/sbin/ls > /tmp/client.out")`**
3. **`close()`** the connection

Meanwhile, the server is handling the data and executing it:

1. **`accept()`** the connection from the client
2. **`recv(str)`** the command string
3. **`close()`** the connection
4. **`system(str)`** to run the command

Beware! Having the server execute what the client says is like giving remote shell access and people can do things to your account when they connect to the server. For instance, in the above example, what if the client sends "**rm -rf ~**"? It deletes everything in your account, that's what!

So you get wise, and you prevent the client from using any except for a couple utilities that you know are safe, like the **foobar** utility:

```
if (!strncmp(str, "foobar", 6)) {
    sprintf(sysstr, "%s > /tmp/server.out", str);
    system(sysstr);
}
```

But you're still unsafe, unfortunately: what if the client enters "**foobar; rm -rf ~**"? The safest thing to do is to write a little routine that puts an escape ("\") character in front of all non-alphanumeric characters (including spaces, if appropriate) in the arguments for the command.

As you can see, security is a pretty big issue when the server starts executing things the client sends.

I'm sending a slew of data, but when I `recv()`, it only receives 536 bytes or 1460 bytes at a time. But if I run it on my local machine, it receives all the data at the same time. What's going on?

You're hitting the MTU—the maximum size the physical medium can handle. On the local machine, you're using the loopback device which can handle 8K or more no problem. But on Ethernet, which can only handle 1500 bytes with a header, you hit that limit. Over a modem, with 576 MTU (again, with header), you hit the even lower limit.

You have to make sure all the data is being sent, first of all. (See the **`sendall()`** function implementation for details.) Once you're sure of that, then you need to call **`recv()`** in a loop until all your data is read.

Read the section Son of Data Encapsulation for details on receiving complete packets of data using multiple calls to **`recv()`**.

I'm on a Windows box and I don't have the `fork()` system call or any kind of `struct sigaction`. What to do?

If they're anywhere, they'll be in POSIX libraries that may have shipped with your compiler. Since I don't have a Windows box, I really can't tell you the answer, but I seem to remember that Microsoft has a POSIX compatibility layer and that's where **`fork()`** would be. (And maybe even `sigaction`.)

Search the help that came with VC++ for "fork" or "POSIX" and see if it gives you any clues.

If that doesn't work at all, ditch the **`fork()`**/`sigaction` stuff and replace it with the Win32 equivalent: **`CreateProcess()`**. I don't know how to use **`CreateProcess()`**—it takes a bazillion arguments, but it should be covered in the docs that came with VC++.

I'm behind a firewall—how do I let people outside the firewall know my IP address so they can connect to my machine?

Unfortunately, the purpose of a firewall is to prevent people outside the firewall from connecting to machines inside the firewall, so allowing them to do so is basically considered a breach of security.

This isn't to say that all is lost. For one thing, you can still often **`connect()`** through the firewall if it's doing some kind of masquerading or NAT or something like that. Just design your programs so that you're always the one initiating the connection, and you'll be fine.

If that's not satisfactory, you can ask your sysadmins to poke a hole in the firewall so that people can connect to you. The firewall can forward to you either through it's NAT software, or through a proxy or something like that.

Be aware that a hole in the firewall is nothing to be taken lightly. You have to make sure you don't give bad people access to the internal network; if you're a beginner, it's a lot harder to make software secure than you might imagine.

Don't make your sysadmin mad at me. `;-)`

How do I write a packet sniffer? How do I put my Ethernet interface into promiscuous mode?

For those not in the know, when a network card is in "promiscuous mode", it will forward ALL packets to the operating system, not just those that were addressed to this particular machine. (We're talking Ethernet-layer addresses here, not IP addresses--but since ethernet is lower-layer than IP, all IP addresses are effectively forwarded as well. See the section Low Level Nonsense and Network Theory for more info.)

This is the basis for how a packet sniffer works. It puts the interface into promiscuous mode, then the OS gets every single packet that goes by on the wire. You'll have a socket of some type that you can read this data from.

Unfortunately, the answer to the question varies depending on the platform, but if you Google for, for instance, "windows promiscuous ioctl" you'll probably get somewhere. There's what looks like a decent writeup in Linux Journal[30], as well.

How can I set a custom timeout value for a TCP or UDP socket?

It depends on your system. You might search the net for `SO_RCVTIMEO` and `SO_SNDTIMEO` (for use with **`setsockopt()`**) to see if your system supports such functionality.

The Linux man page suggests using **`alarm()`** or **`setitimer()`** as a substitute.

30. `http://interactive.linuxjournal.com/article/4659`

How can I tell which ports are available to use? Is there a list of "official" port numbers?

Usually this isn't an issue. If you're writing, say, a web server, then it's a good idea to use the well-known port 80 for your software. If you're writing just your own specialized server, then choose a port at random (but greater than 1023) and give it a try.

If the port is already in use, you'll get an "Address already in use" error when you try to `bind()`. Choose another port. (It's a good idea to allow the user of your software to specify an alternate port either with a config file or a command line switch.)

There is a list of official port numbers[31] maintained by the Internet Assigned Numbers Authority (IANA). Just because something (over 1023) is in that list doesn't mean you can't use the port. For instance, Id Software's DOOM uses the same port as "mdqs", whatever that is. All that matters is that no one else *on the same machine* is using that port when you want to use it.

31. `http://www.iana.org/assignments/port-numbers`

8. Man Pages

In the Unix world, there are a lot of manuals. They have little sections that describe individual functions that you have at your disposal.

Of course, **manual** would be too much of a thing to type. I mean, no one in the Unix world, including myself, likes to type that much. Indeed I could go on and on at great length about how much I prefer to be terse but instead I shall be brief and not bore you with long-winded diatribes about how utterly amazingly brief I prefer to be in virtually all circumstances in their entirety.

[Applause]

Thank you. What I am getting at is that these pages are called "man pages" in the Unix world, and I have included my own personal truncated variant here for your reading enjoyment. The thing is, many of these functions are way more general purpose than I'm letting on, but I'm only going to present the parts that are relevant for Internet Sockets Programming.

But wait! That's not all that's wrong with my man pages:

- They are incomplete and only show the basics from the guide.
- There are many more man pages than this in the real world.
- They are different than the ones on your system.
- The header files might be different for certain functions on your system.
- The function parameters might be different for certain functions on your system.

If you want the real information, check your local Unix man pages by typing **man whatever**, where "whatever" is something that you're incredibly interested in, such as "`accept`". (I'm sure Microsoft Visual Studio has something similar in their help section. But "man" is better because it is one byte more concise than "help". Unix wins again!)

So, if these are so flawed, why even include them at all in the Guide? Well, there are a few reasons, but the best are that (a) these versions are geared specifically toward network programming and are easier to digest than the real ones, and (b) these versions contain examples!

Oh! And speaking of the examples, I don't tend to put in all the error checking because it really increases the length of the code. But you should absolutely do error checking pretty much any time you make any of the system calls unless you're totally 100% sure it's not going to fail, and you should probably do it even then!

8.1. accept()

Accept an incoming connection on a listening socket

Prototypes

```
#include <sys/types.h>
#include <sys/socket.h>

int accept(int s, struct sockaddr *addr, socklen_t *addrlen);
```

Description

Once you've gone through the trouble of getting a SOCK_STREAM socket and setting it up for incoming connections with **listen()**, then you call **accept()** to actually get yourself a new socket descriptor to use for subsequent communication with the newly connected client.

The old socket that you are using for listening is still there, and will be used for further **accept()** calls as they come in.

s	The **listen()**ing socket descriptor.
addr	This is filled in with the address of the site that's connecting to you.
addrlen	This is filled in with the **sizeof()** the structure returned in the *addr* parameter. You can safely ignore it if you assume you're getting a struct sockaddr_in back, which you know you are, because that's the type you passed in for *addr*.

accept() will normally block, and you can use **select()** to peek on the listening socket descriptor ahead of time to see if it's "ready to read". If so, then there's a new connection waiting to be **accept()**ed! Yay! Alternatively, you could set the O_NONBLOCK flag on the listening socket using **fcntl()**, and then it will never block, choosing instead to return -1 with *errno* set to EWOULDBLOCK.

The socket descriptor returned by **accept()** is a bona fide socket descriptor, open and connected to the remote host. You have to **close()** it when you're done with it.

Return Value

accept() returns the newly connected socket descriptor, or -1 on error, with *errno* set appropriately.

Example

```
int s, s2;
struct sockaddr_in myaddr, remoteaddr;
socklen_t remoteaddr_len;

myaddr.sin_family = AF_INET;
myaddr.sin_port = htons(3490); // clients connect to this port
myaddr.sin_addr.s_addr = INADDR_ANY; // autoselect IP address

s = socket(PF_INET, SOCK_STREAM, 0);
bind(s, (struct sockaddr*)myaddr, sizeof myaddr);

listen(s, 10); // set s up to be a server (listening) socket

for(;;) {
    s2 = accept(s, &remoteaddr, &remoteaddr_len);

    // now you can send() and recv() with the
    // connected client via socket s2
```

```
}
```

See Also

socket(), **listen()**, `struct sockaddr_in`

8.2. bind()

Associate a socket with an IP address and port number

Prototypes

```
#include <sys/types.h>
#include <sys/socket.h>

int bind(int sockfd, struct sockaddr *my_addr, socklen_t addrlen);
```

Description

When a remote machine wants to connect to your server program, it needs two pieces of information: the IP address and the port number. The **bind()** call allows you to do just that.

First, you call **socket()** to get a socket descriptor, and then you load up a `struct sockaddr_in` with the IP address and port number information, and then you pass both of those into **bind()**, and the IP address and port are magically (using actual magic) bound to the socket!

If you don't know your IP address, or you know you only have one IP address on the machine, or you don't care which of the machine's IP addresses is used, you can simply set the `s_addr` field in your `struct sockaddr_in` to `INADDR_ANY` and it will fill in the IP address for you.

Lastly, the *addrlen* parameter should be set to `sizeof my_addr`.

Return Value

Returns zero on success, or `-1` on error (and **errno** will be set accordingly.)

Example

```
struct sockaddr_in myaddr;
int s;

myaddr.sin_family = AF_INET;
myaddr.sin_port = htons(3490);

// you can specify an IP address:
inet_aton("63.161.169.137", &myaddr.sin_addr.s_addr);

// or you can let it automatically select one:
myaddr.sin_addr.s_addr = INADDR_ANY;

s = socket(PF_INET, SOCK_STREAM, 0);
bind(s, (struct sockaddr*)myaddr, sizeof myaddr);
```

See Also

socket(), `struct sockaddr_in`, `struct in_addr`

8.3. connect()

Connect a socket to a server

Prototypes

```
#include <sys/types.h>
#include <sys/socket.h>

int connect(int sockfd, const struct sockaddr *serv_addr,
            socklen_t addrlen);
```

Description

Once you've built a socket descriptor with the **socket()** call, you can **connect()** that socket to a remote server using the well-named **connect()** system call. All you need to do is pass it the socket descriptor and the address of the server you're interested in getting to know better. (Oh, and the length of the address, which is commonly passed to functions like this.)

If you haven't yet called **bind()** on the socket descriptor, it is automatically bound to your IP address and a random local port. This is usually just fine with you, since you really don't care what your local port is; you only care what the remote port is so you can put it in the *serv_addr* parameter. You *can* call **bind()** if you really want your client socket to be on a specific IP address and port, but this is pretty rare.

Once the socket is **connect()**ed, you're free to **send()** and **recv()** data on it to your heart's content.

Special note: if you **connect()** a SOCK_DGRAM UDP socket to a remote host, you can use **send()** and **recv()** as well as **sendto()** and **recvfrom()**. If you want.

Return Value

Returns zero on success, or -1 on error (and **errno** will be set accordingly.)

Example

```
int s;
struct sockaddr_in serv_addr;

// pretend the server is at 63.161.169.137 listening on port 80:

myaddr.sin_family = AF_INET;
myaddr.sin_port = htons(80);
inet_aton("63.161.169.137", &myaddr.sin_addr.s_addr);

s = socket(PF_INET, SOCK_STREAM, 0);
connect(s, (struct sockaddr*)myaddr, sizeof myaddr);

// now we're ready to send() and recv()
```

See Also

socket(), **bind()**

8.4. close()

Close a socket descriptor

Prototypes

```
#include <unistd.h>

int close(int s);
```

Description

After you've finished using the socket for whatever demented scheme you have concocted and you don't want to **send()** or **recv()** or, indeed, do *anything else* at all with the socket, you can **close()** it, and it'll be freed up, never to be used again.

The remote side can tell if this happens one of two ways. One: if the remote side calls **recv()**, it will return `0`. Two: if the remote side calls **send()**, it'll receive a signal `SIGPIPE` and send() will return `-1` and *errno* will be set to `EPIPE`.

Windows users: the function you need to use is called **closesocket()**, not **close()**. If you try to use **close()** on a socket descriptor, it's possible Windows will get angry... And you wouldn't like it when it's angry.

Return Value

Returns zero on success, or `-1` on error (and **errno** will be set accordingly.)

Example

```
s = socket(PF_INET, SOCK_DGRAM, 0);
.
.
.
// a whole lotta stuff...*BRRRONNNN!*
.
.
.
close(s);  // not much to it, really.
```

See Also

socket(), **shutdown()**

8.5. gethostname()

Returns the name of the system

Prototypes

```
#include <sys/unistd.h>

int gethostname(char *name, size_t len);
```

Description

Your system has a name. They all do. This is a slightly more Unixy thing than the rest of the networky stuff we've been talking about, but it still has its uses.

For instance, you can get your host name, and then call **gethostbyname()** to find out your IP address.

The parameter *name* should point to a buffer that will hold the host name, and *len* is the size of that buffer in bytes. **gethostname()** won't overwrite the end of the buffer (it might return an error, or it might just stop writing), and it will NUL-terminate the string if there's room for it in the buffer.

Return Value

Returns zero on success, or -1 on error (and **errno** will be set accordingly.)

Example

```
char hostname[128];

gethostname(hostname, sizeof hostname);
printf("My hostname: %s\n", hostname);
```

See Also

gethostbyname()

8.6. gethostbyname(), gethostbyaddr()

Get an IP address for a hostname, or vice-versa

Prototypes

```
#include <sys/socket.h>
#include <netdb.h>

struct hostent *gethostbyname(const char *name);
struct hostent *gethostbyaddr(const char *addr, int len, int type);
```

Description

These functions map back and forth between host names and IP addresses. After all, you want an IP address to pass to **connect()**, right? But no one wants to remember an IP address. So you let your users type in things like "www.yahoo.com" instead of "66.94.230.35".

gethostbyname() takes a string like "www.yahoo.com", and returns a `struct hostent` which contains tons of information, including the IP address. (Other information is the official host name, a list of aliases, the address type, the length of the addresses, and the list of addresses—it's a general-purpose structure that's pretty easy to use for our specific purposes once you see how.)

gethostbyaddr() takes a `struct in_addr` and brings you up a corresponding host name (if there is one), so it's sort of the reverse of **gethostbyname()**. As for parameters, even though *addr* is a `char*`, you actually want to pass in a pointer to a `struct in_addr`. *len* should be `sizeof(struct in_addr)`, and *type* should be `AF_INET`.

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

*char *h_name*	The real canonical host name.
*char **h_aliases*	A list of aliases that can be accessed with arrays—the last element is `NULL`
int h_addrtype	The result's address type, which really should be `AF_INET` for our purposes..
int length	The length of the addresses in bytes, which is 4 for IP (version 4) addresses.
*char **h_addr_list*	A list of IP addresses for this host. Although this is a `char**`, it's really an array of `struct in_addr*`s in disguise. The last array element is `NULL`.
h_addr	A commonly defined alias for *h_addr_list[0]*. If you just want any old IP address for this host (yeah, they can have more than one) just use this field.

Return Value

Returns a pointer to a resultant `struct hostent` or success, or `NULL` on error.

Instead of the normal **perror()** and all that stuff you'd normally use for error reporting, these functions have parallel results in the variable *h_errno*, which can be printed using the functions **herror()** or **hstrerror()**. These work just like the classic *errno*, **perror()**, and **strerror()** functions you're used to.

Example

```
int i;
struct hostent *he;
struct in_addr **addr_list;
struct in_addr addr;

// get the addresses of www.yahoo.com:

he = gethostbyname("www.yahoo.com");
if (he == NULL) { // do some error checking
    herror("gethostbyname"); // herror(), NOT perror()
    exit(1);
}

// print information about this host:
printf("Official name is: %s\n", he->h_name);
printf("IP address: %s\n", inet_ntoa(*(struct in_addr*)he->h_addr));
printf("All addresses: ");
addr_list = (struct in_addr **)he->h_addr_list;
for(i = 0; addr_list[i] != NULL; i++) {
    printf("%s ", inet_ntoa(*addr_list[i]));
}
printf("\n");

// get the host name of 66.94.230.32:

inet_aton("66.94.230.32", &addr);
he = gethostbyaddr(&addr, sizeof addr, AF_INET);

printf("Host name: %s\n", he->h_name);
```

See Also

gethostname(), *errno*, **perror()**, **strerror()**, `struct in_addr`

8.7. getpeername()

Return address info about the remote side of the connection

Prototypes

```
#include <sys/socket.h>

int getpeername(int s, struct sockaddr *addr, socklen_t *len);
```

Description

Once you have either **accept()**ed a remote connection, or **connect()**ed to a server, you now have what is known as a *peer*. Your peer is simply the computer you're connected to, identified by an IP address and a port. So...

getpeername() simply returns a `struct sockaddr_in` filled with information about the machine you're connected to.

Why is it called a "name"? Well, there are a lot of different kinds of sockets, not just Internet Sockets like we're using in this guide, and so "name" was a nice generic term that covered all cases. In our case, though, the peer's "name" is it's IP address and port.

Although the function returns the size of the resultant address in *len*, you must preload *len* with the size of *addr*.

Return Value

Returns zero on success, or `-1` on error (and **errno** will be set accordingly.)

Example

```
int s;
struct sockaddr_in server, addr;
socklen_t len;

// make a socket
s = socket(PF_INET, SOCK_STREAM, 0);

// connect to a server
server.sin_family = AF_INET;
inet_aton("63.161.169.137", &server.sin_addr);
server.sin_port = htons(80);

connect(s, (struct sockaddr*)&server, sizeof server);

// get the peer name
// we know we just connected to 63.161.169.137:80, so this should print:
//    Peer IP address: 63.161.169.137
//    Peer port      : 80

len = sizeof addr;
getpeername(s, (struct sockaddr*)&addr, &len);
printf("Peer IP address: %s\n", inet_ntoa(addr.sin_addr));
printf("Peer port      : %d\n", ntohs(addr.sin_port));
```

See Also

gethostname(), **gethostbyname()**, **gethostbyaddr()**

8.8. *errno*

Holds the error code for the last system call

Prototypes

```
#include <errno.h>

int errno;
```

Description

This is the variable that holds error information for a lot of system calls. If you'll recall, things like **`socket()`** and **`listen()`** return `-1` on error, and they set the exact value of *`errno`* to let you know specifically which error occurred.

The header file *`errno.h`* lists a bunch of constant symbolic names for errors, such as `EADDRINUSE`, `EPIPE`, `ECONNREFUSED`, etc. Your local man pages will tell you what codes can be returned as an error, and you can use these at run time to handle different errors in different ways.

Or, more commonly, you can call **`perror()`** or **`strerror()`** to get a human-readable version of the error.

Return Value

The value of the variable is the latest error to have transpired, which might be the code for "success" if the last action succeeded.

Example

```
s = socket(PF_INET, SOCK_STREAM, 0);
if (s == -1) {
    perror("socket"); // or use strerror()
}

tryagain:
if (select(n, &readfds, NULL, NULL) == -1) {
    // an error has occurred!!

    // if we were only interrupted, just restart the select() call:
    if (errno == EINTR) goto tryagain;  // AAAA!  goto!!!

    // otherwise it's a more serious error:
    perror("select");
    exit(1);
}
```

See Also

`perror()`, **`strerror()`**

8.9. fcntl()

Control socket descriptors

Prototypes

```
#include <sys/unistd.h>
#include <sys/fcntl.h>

int fcntl(int s, int cmd, long arg);
```

Description

This function is typically used to do file locking and other file-oriented stuff, but it also has a couple socket-related functions that you might see or use from time to time.

Parameter *s* is the socket descriptor you wish to operate on, *cmd* should be set to F_SETFL, and *arg* can be one of the following commands. (Like I said, there's more to **fcntl()** than I'm letting on here, but I'm trying to stay socket-oriented.)

O_NONBLOCK	Set the socket to be non-blocking. See the section on blocking for more details.
O_ASYNC	Set the socket to do asynchronous I/O. When data is ready to be **recv()**'d on the socket, the signal SIGIO will be raised. This is rare to see, and beyond the scope of the guide. And I think it's only available on certain systems.

Return Value

Returns zero on success, or -1 on error (and **errno** will be set accordingly.)

Different uses of the **fcntl()** actually have different return values, but I haven't covered them here because they're not socket-related. See your local **fcntl()** man page for more information.

Example

```
int s = socket(PF_INET, SOCK_STREAM, 0);

fcntl(s, F_SETFL, O_NONBLOCK);  // set to non-blocking
fcntl(s, F_SETFL, O_ASYNC);     // set to asynchronous I/O
```

See Also

Blocking, **send()**

8.10. htons(), htonl(), ntohs(), ntohl()

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

Prototypes

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

uint32_t htonl(uint32_t hostlong);
uint16_t htons(uint16_t hostshort);
uint32_t ntohl(uint32_t netlong);
uint16_t ntohs(uint16_t netshort);
```

Description

Just to make you really unhappy, different computers use different byte orderings internally for their multibyte integers (i.e. any integer that's larger than a `char`.) The upshot of this is that if you **`send()`** a two-byte `short int` from an Intel box to a Mac (before they became Intel boxes, too, I mean), what one computer thinks is the number `1`, the other will think is the number `256`, and vice-versa.

The way to get around this problem is for everyone to put aside their differences and agree that Motorola and IBM had it right, and Intel did it the weird way, and so we all convert our byte orderings to "big-endian" before sending them out. Since Intel is a "little-endian" machine, it's far more politically correct to call our preferred byte ordering "Network Byte Order". So these functions convert from your native byte order to network byte order and back again.

(This means on Intel these functions swap all the bytes around, and on PowerPC they do nothing because the bytes are already in Network Byte Order. But you should always use them in your code anyway, since someone might want to build it on an Intel machine and still have things work properly.)

Note that the types involved are 32-bit (4 byte, probably `int`) and 16-bit (2 byte, very likely `short`) numbers. 64-bit machines might have a **`htonll()`** for 64-bit `int`s, but I've not seen it. You'll just have to write your own.

Anyway, the way these functions work is that you first decide if you're converting *from* host (your machine's) byte order or from network byte order. If "host", the the first letter of the function you're going to call is "h". Otherwise it's "n" for "network". The middle of the function name is always "to" because you're converting from one "to" another, and the penultimate letter shows what you're converting *to*. The last letter is the size of the data, "s" for short, or "l" for long. Thus:

`htons()`	**h**ost **to** **n**etwork **s**hort
`htonl()`	**h**ost **to** **n**etwork **l**ong
`ntohs()`	**n**etwork **to** **h**ost **s**hort
`ntohl()`	**n**etwork **to** **h**ost **l**ong

Return Value

Each function returns the converted value.

Example

```
uint32_t some_long = 10;
uint16_t some_short = 20;

uint32_t network_byte_order;
```

```
// convert and send
network_byte_order = htonl(some_long);
send(s, &network_byte_order, sizeof(uint32_t), 0);

some_short == ntohs(htons(some_short)); // this expression is true
```

8.11. inet_ntoa(), inet_aton()

Convert IP addresses from a dots-and-number string to a `struct in_addr` and back

Prototypes

```
#include <sys/socket.h>
#include <netinet/in.h>
#include <arpa/inet.h>

char *inet_ntoa(struct in_addr in);
int inet_aton(const char *cp, struct in_addr *inp);
in_addr_t inet_addr(const char *cp);
```

Description

All of these functions convert from a `struct in_addr` (part of your `struct sockaddr_in`, most likely) to a string in dots-and-numbers format (e.g. "192.168.5.10") and vice-versa. If you have an IP address passed on the command line or something, this is the easiest way to get a `struct in_addr` to **`connect()`** to, or whatever. If you need more power, try some of the DNS functions like **`gethostbyname()`** or attempt a *coup d'État* in your local country.

The function **`inet_ntoa()`** converts a network address in a `struct in_addr` to a dots-and-numbers format string. The "n" in "ntoa" stands for network, and the "a" stands for ASCII for historical reasons (so it's "Network To ASCII"—the "toa" suffix has an analogous friend in the C library called **`atoi()`** which converts an ASCII string to an integer.)

The function **`inet_aton()`** is the opposite, converting from a dots-and-numbers string into a `in_addr_t` (which is the type of the field `s_addr` in your `struct in_addr`.)

Finally, the function **`inet_addr()`** is an older function that does basically the same thing as **`inet_aton()`**. It's theoretically deprecated, but you'll see it a lot and the police won't come get you if you use it.

Return Value

`inet_aton()` returns non-zero if the address is a valid one, and it returns zero if the address is invalid.

`inet_ntoa()` returns the dots-and-numbers string in a static buffer that is overwritten with each call to the function.

`inet_addr()` returns the address as an `in_addr_t`, or `-1` if there's an error. (That is the same result as if you tried to convert the string "255.255.255.255", which is a valid IP address. This is why **`inet_aton()`** is better.)

Example

```
struct sockaddr_in antelope;
char *some_addr;

inet_aton("10.0.0.1", &antelope.sin_addr); // store IP in antelope

some_addr = inet_ntoa(antelope.sin_addr); // return the IP
printf("%s\n", some_addr); // prints "10.0.0.1"

// and this call is the same as the inet_aton() call, above:
antelope.sin_addr.s_addr = inet_addr("10.0.0.1");
```

See Also

`gethostbyname()`, **`gethostbyaddr()`**

8.12. listen()

Tell a socket to listen for incoming connections

Prototypes

```
#include <sys/socket.h>

int listen(int s, int backlog);
```

Description

You can take your socket descriptor (made with the **socket()** system call) and tell it to listen for incoming connections. This is what differentiates the servers from the clients, guys.

The *backlog* parameter can mean a couple different things depending on the system you on, but loosely it is how many pending connections you can have before the kernel starts rejecting new ones. So as the new connections come in, you should be quick to **accept()** them so that the backlog doesn't fill. Try setting it to 10 or so, and if your clients start getting "Connection refused" under heavy load, set it higher.

Before calling **listen()**, your server should call **bind()** to attach itself to a specific port number. That port number (on the server's IP address) will be the one that clients connect to.

Return Value

Returns zero on success, or `-1` on error (and **errno** will be set accordingly.)

Example

```
int s;
struct sockaddr_in myaddr;

myaddr.sin_family = AF_INET;
myaddr.sin_port = htons(3490); // clients connect to this port
myaddr.sin_addr.s_addr = INADDR_ANY; // autoselect IP address

s = socket(PF_INET, SOCK_STREAM, 0);
bind(s, (struct sockaddr*)myaddr, sizeof myaddr);

listen(s, 10); // set s up to be a server (listening) socket

// then have an accept() loop down here somewhere
```

See Also

accept(), **bind()**, **socket()**

8.13. perror(), strerror()

Print an error as a human-readable string

Prototypes

```
#include <stdio.h>
#include <string.h>   // for strerror()

void perror(const char *s);
char *strerror(int errnum);
```

Description

Since so many functions return -1 on error and set the value of the variable *errno* to be some number, it would sure be nice if you could easily print that in a form that made sense to you.

Mercifully, **perror()** does that. If you want more description to be printed before the error, you can point the parameter *s* to it (or you can leave *s* as NULL and nothing additional will be printed.)

In a nutshell, this function takes *errno* values, like ECONNRESET, and prints them nicely, like "Connection reset by peer."

The function **strerror()** is very similar to **perror()**, except it returns a pointer to the error message string for a given value (you usually pass in the variable *errno*.)

Return Value

strerror() returns a pointer to the error message string.

Example

```
int s;

s = socket(PF_INET, SOCK_STREAM, 0);

if (s == -1) { // some error has occurred
    // prints "socket error: " + the error message:
    perror("socket error");
}

// similarly:
if (listen(s, 10) == -1) {
    // this prints "an error: " + the error message from errno:
    printf("an error: %s\n", strerror(errno));
}
```

See Also

errno

8.14. poll()

Test for events on multiple sockets simultaneously

Prototypes

```
#include <sys/poll.h>

int poll(struct pollfd *ufds, unsigned int nfds, int timeout);
```

Description

This function is very similar to **select()** in that they both watch sets of file descriptors for events, such as incoming data ready to **recv()**, socket ready to **send()** data to, out-of-band data ready to **recv()**, errors, etc.

The basic idea is that you pass an array of *nfds* `struct pollfd`s in *ufds*, along with a timeout in milliseconds (1000 milliseconds in a second.) The *timeout* can be negative if you want to wait forever. If no event happens on any of the socket descriptors by the timeout, **poll()** will return.

Each element in the array of `struct pollfd`s represents one socket descriptor, and contains the following fields:

```
struct pollfd {
    int fd;         // the socket descriptor
    short events;   // bitmap of events we're interested in
    short revents;  // when poll() returns, bitmap of events that occurred
};
```

Before calling **poll()**, load *fd* with the socket descriptor (if you set *fd* to a negative number, this `struct pollfd` is ignored and its *revents* field is set to zero) and then construct the *events* field by bitwise-ORing the following macros:

`POLLIN`	Alert me when data is ready to **recv()** on this socket.
`POLLOUT`	Alert me when I can **send()** data to this socket without blocking.
`POLLPRI`	Alert me when out-of-band data is ready to **recv()** on this socket.

Once the **poll()** call returns, the *revents* field will be constructed as a bitwise-OR of the above fields, telling you which descriptors actually have had that event occur. Additionally, these other fields might be present:

`POLLERR`	An error has occurred on this socket.
`POLLHUP`	The remote side of the connection hung up.
`POLLNVAL`	Something was wrong with the socket descriptor *fd*—maybe it's uninitialized?

Return Value

Returns the number of elements in the *ufds* array that have had event occur on them; this can be zero if the timeout occurred. Also returns `-1` on error (and **errno** will be set accordingly.)

Example

```
int s1, s2;
int rv;
char buf1[256], buf2[256];
struct pollfd ufds[2];
```

```
s1 = socket(PF_INET, SOCK_STREAM, 0);
s2 = socket(PF_INET, SOCK_STREAM, 0);

// pretend we've connected both to a server at this point
//connect(s1, ...)...
//connect(s2, ...)...

// set up the array of file descriptors.
//
// in this example, we want to know when there's normal or out-of-band
// data ready to be recv()'d...

ufds[0].fd = s1;
ufds[0].events = POLLIN | POLLPRI; // check for normal or out-of-band

ufds[1] = s2;
ufds[1].events = POLLIN; // check for just normal data

// wait for events on the sockets, 3.5 second timeout
rv = poll(ufds, 2, 3500);

if (rv == -1) {
    perror("poll"); // error occurred in poll()
} else if (rv == 0) {
    printf("Timeout occurred!  No data after 3.5 seconds.\n");
} else {
    // check for events on s1:
    if (ufds[0].revents & POLLIN) {
        recv(s1, buf1, sizeof buf1, 0); // receive normal data
    }
    if (ufds[0].revents & POLLPRI) {
        recv(s1, buf1, sizeof buf1, MSG_OOB); // out-of-band data
    }

    // check for events on s2:
    if (ufds[1].revents & POLLIN) {
        recv(s1, buf2, sizeof buf2, 0);
    }
}
```

See Also

`select()`

8.15. recv(), recvfrom()

Receive data on a socket

Prototypes

```
#include <sys/types.h>
#include <sys/socket.h>

ssize_t recv(int s, void *buf, size_t len, int flags);
ssize_t recvfrom(int s, void *buf, size_t len, int flags,
                 struct sockaddr *from, socklen_t *fromlen);
```

Description

Once you have a socket up and connected, you can read incoming data from the remote side using the **recv()** (for TCP SOCK_STREAM sockets) and **recvfrom()** (for UDP SOCK_DGRAM sockets).

Both functions take the socket descriptor *s*, a pointer to the buffer *buf*, the size (in bytes) of the buffer *len*, and a set of *flags* that control how the functions work.

Additionally, the **recvfrom()** takes a struct sockaddr*, *from* that will tell you where the data came from, and will fill in *fromlen* with the size of struct sockaddr. (You must also initialize *fromlen* to be the size of *from* or struct sockaddr.)

So what wondrous flags can you pass into this function? Here are some of them, but you should check your local man pages for more information and what is actually supported on your system. You bitwise-or these together, or just set *flags* to 0 if you want it to be a regular vanilla **recv()**.

MSG_OOB	Receive Out of Band data. This is how to get data that has been sent to you with the MSG_OOB flag in **send()**. As the receiving side, you will have had signal SIGURG raised telling you there is urgent data. In your handler for that signal, you could call **recv()** with this MSG_OOB flag.
MSG_PEEK	If you want to call **recv()** "just for pretend", you can call it with this flag. This will tell you what's waiting in the buffer for when you call **recv()** "for real" (i.e. *without* the MSG_PEEK flag. It's like a sneak preview into the next **recv()** call.
MSG_WAITALL	Tell **recv()** to not return until all the data you specified in the *len* parameter. It will ignore your wishes in extreme circumstances, however, like if a signal interrupts the call or if some error occurs or if the remote side closes the connection, etc. Don't be mad with it.

When you call **recv()**, it will block until there is some data to read. If you want to not block, set the socket to non-blocking or check with **select()** or **poll()** to see if there is incoming data before calling **recv()** or **recvfrom()**.

Return Value

Returns the number of bytes actually received (which might be less than you requested in the *len* parameter), or -1 on error (and **errno** will be set accordingly.)

If the remote side has closed the connection, **recv()** will return 0. This is the normal method for determining if the remote side has closed the connection. Normality is good, rebel!

Example

```
int s1, s2;
int byte_count, fromlen;
struct sockaddr_in addr;
char buf[512];

// show example with a TCP stream socket first
s1 = socket(PF_INET, SOCK_STREAM, 0);

// info about the server
addr.sin_family = AF_INET;
addr.sin_port = htons(3490);
inet_aton("10.9.8.7", &addr.sin_addr);

connect(s1, &addr, sizeof addr); // connect to server

// all right!  now that we're connected, we can receive some data!
byte_count = recv(s1, buf, sizeof buf, 0);
printf("recv()'d %d bytes of data in buf\n", byte_count);

// now demo for UDP datagram sockets:
s2 = socket(PF_INET, SOCK_DGRAM, 0);

fromlen = sizeof addr;
byte_count = recvfrom(s2, buf, sizeof buf, 0, &addr, &fromlen);
printf("recv()'d %d bytes of data in buf\n", byte_count);
printf("from IP address %s\n", inet_ntoa(addr.sin_addr));
```

See Also

`send()`, **`sendto()`**, **`select()`**, **`poll()`**, Blocking

8.16. `select()`

Check if sockets descriptors are ready to read/write

Prototypes

```
#include <sys/select.h>

int select(int n, fd_set *readfds, fd_set *writefds, fd_set *exceptfds,
           struct timeval *timeout);

FD_SET(int fd, fd_set *set);
FD_CLR(int fd, fd_set *set);
FD_ISSET(int fd, fd_set *set);
FD_ZERO(fd_set *set);
```

Description

The **`select()`** function gives you a way to simultaneously check multiple sockets to see if they have data waiting to be **`recv()`**d, or if you can **`send()`** data to them without blocking, or if some exception has occurred.

You populate your sets of socket descriptors using the macros, like **`FD_SET()`**, above. Once you have the set, you pass it into the function as one of the following parameters: *`readfds`* if you want to know when any of the sockets in the set is ready to **`recv()`** data, *`writefds`* if any of the sockets is ready to **`send()`** data to, and/or *`exceptfds`* if you need to know when an exception (error) occurs on any of the sockets. Any or all of these parameters can be `NULL` if you're not interested in those types of events. After **`select()`** returns, the values in the sets will be changed to show which are ready for reading or writing, and which have exceptions.

The first parameter, *`n`* is the highest-numbered socket descriptor (they're just `int`s, remember?) plus one.

Lastly, the `struct timeval`, *`timeout`*, at the end—this lets you tell **`select()`** how long to check these sets for. It'll return after the timeout, or when an event occurs, whichever is first. The `struct timeval` has two fields: *`tv_sec`* is the number of seconds, to which is added *`tv_usec`*, the number of microseconds (1,000,000 microseconds in a second.)

The helper macros do the following:

`FD_SET(int fd, fd_set *set);`	Add *`fd`* to the *`set`*.
`FD_CLR(int fd, fd_set *set);`	Remove *`fd`* from the *`set`*.
`FD_ISSET(int fd, fd_set *set);`	Return true if *`fd`* is in the *`set`*.
`FD_ZERO(fd_set *set);`	Clear all entries from the *`set`*.

Return Value

Returns the number of descriptors in the set on success, `0` if the timeout was reached, or `-1` on error (and **`errno`** will be set accordingly.) Also, the sets are modified to show which sockets are ready.

Example

```
int s1, s2, n;
fd_set readfds;
struct timeval tv;
char buf1[256], buf2[256];

s1 = socket(PF_INET, SOCK_STREAM, 0);
```

```
s2 = socket(PF_INET, SOCK_STREAM, 0);

// pretend we've connected both to a server at this point
//connect(s1, ...)...
//connect(s2, ...)...

// clear the set ahead of time
FD_ZERO(&readfds);

// add our descriptors to the set
FD_SET(s1, &readfds);
FD_SET(s2, &readfds);

// since we got s2 second, it's the "greater", so we use that for
// the n param in select()
n = s2 + 1;

// wait until either socket has data ready to be recv()d (timeout 10.5 secs)
tv.tv_sec = 10;
tv.tv_usec = 500000;
rv = select(n, &readfds, NULL, NULL, &tv);

if (rv == -1) {
    perror("select"); // error occurred in select()
} else if (rv == 0) {
    printf("Timeout occurred!  No data after 10.5 seconds.\n");
} else {
    // one or both of the descriptors have data
    if (FD_ISSET(s1, &readfds)) {
        recv(s1, buf1, sizeof buf1, 0);
    }
    if (FD_ISSET(s2, &readfds)) {
        recv(s1, buf2, sizeof buf2, 0);
    }
}
```

See Also

`poll()`

8.17. setsockopt(), getsockopt()

Set various options for a socket

Prototypes

```
#include <sys/types.h>
#include <sys/socket.h>

int getsockopt(int s, int level, int optname, void *optval,
               socklen_t *optlen);
int setsockopt(int s, int level, int optname, const void *optval,
               socklen_t optlen);
```

Description

Sockets are fairly configurable beasts. In fact, they are so configurable, I'm not even going to cover it all here. It's probably system-dependent anyway. But I will talk about the basics.

Obviously, these functions get and set certain options on a socket. On a Linux box, all the socket information is in the man page for socket in section 7. (Type: "**man 7 socket**" to get all these goodies.)

As for parameters, *s* is the socket you're talking about, level should be set to `SOL_SOCKET`. Then you set the *optname* to the name you're interested in. Again, see your man page for all the options, but here are some of the most fun ones:

`SO_BINDTODEVICE`	Bind this socket to a symbolic device name like `eth0` instead of using **`bind()`** to bind it to an IP address. Type the command **ifconfig** under Unix to see the device names.
`SO_REUSEADDR`	Allows other sockets to **`bind()`** to this port, unless there is an active listening socket bound to the port already. This enables you to get around those "Address already in use" error messages when you try to restart your server after a crash.
`SO_BROADCAST`	Allows UDP datagram (`SOCK_DGRAM`) sockets to send and receive packets sent to and from the broadcast address. Does nothing—*NOTHING!!*—to TCP stream sockets! Hahaha!

As for the parameter *optval*, it's usually a pointer to an `int` indicating the value in question. For booleans, zero is false, and non-zero is true. And that's an absolute fact, unless it's different on your system. If there is no parameter to be passed, *optval* can be `NULL`.

The final parameter, *optlen*, is filled out for you by **`getsockopt()`** and you have to specify it for **`getsockopt()`**, where it will probably be `sizeof(int)`.

Warning: on some systems (notably Sun and Windows), the option can be a `char` instead of an `int`, and is set to, for example, a character value of `'1'` instead of an `int` value of `1`. Again, check your own man pages for more info with "**man setsockopt**" and "**man 7 socket**"!

Return Value

Returns zero on success, or `-1` on error (and **`errno`** will be set accordingly.)

Example

```
int optval;
int optlen;
char *optval2;

// set SO_REUSEADDR on a socket to true (1):
optval = 1;
```

```
setsockopt(s1, SOL_SOCKET, SO_REUSEADDR, &optval, sizeof optval);

// bind a socket to a device name (might not work on all systems):
optval2 = "eth1"; // 4 bytes long, so 4, below:
setsockopt(s2, SOL_SOCKET, SO_BINDTODEVICE, optval2, 4);

// see if the SO_BROADCAST flag is set:
getsockopt(s3, SOL_SOCKET, SO_BROADCAST, &optval, &optlen);
if (optval != 0) {
    print("SO_BROADCAST enabled on s3!\n");
}
```

See Also

fcntl()

8.18. send(), sendto()

Send data out over a socket

Prototypes

```
#include <sys/types.h>
#include <sys/socket.h>

ssize_t send(int s, const void *buf, size_t len, int flags);
ssize_t sendto(int s, const void *buf, size_t len,
               int flags, const struct sockaddr *to,
               socklen_t tolen);
```

Description

These functions send data to a socket. Generally speaking, **send()** is used for TCP SOCK_STREAM connected sockets, and **sendto()** is used for UDP SOCK_DGRAM unconnected datagram sockets. With the unconnected sockets, you must specify the destination of a packet each time you send one, and that's why the last parameters of **sendto()** define where the packet is going.

With both **send()** and **sendto()**, the parameter *s* is the socket, *buf* is a pointer to the data you want to send, *len* is the number of bytes you want to send, and *flags* allows you to specify more information about how the data is to be sent. Set *flags* to zero if you want it to be "normal" data. Here are some of the commonly used flags, but check your local **send()** man pages for more details:

MSG_OOB	Send as "out of band" data. TCP supports this, and it's a way to tell the receiving system that this data has a higher priority than the normal data. The receiver will receive the signal SIGURG and it can then receive this data without first receiving all the rest of the normal data in the queue.
MSG_DONTROUTE	Don't send this data over a router, just keep it local.
MSG_DONTWAIT	If **send()** would block because outbound traffic is clogged, have it return EAGAIN. This is like a "enable non-blocking just for this send." See the section on blocking for more details.
MSG_NOSIGNAL	If you **send()** to a remote host which is no longer **recv()**ing, you'll typically get the signal SIGPIPE. Adding this flag prevents that signal from being raised.

Return Value

Returns the number of bytes actually sent, or -1 on error (and **errno** will be set accordingly.) Note that the number of bytes actually sent might be less than the number you asked it to send! See the section on handling partial **send()**s for a helper function to get around this.

Also, if the socket has been closed by either side, the process calling **send()** will get the signal SIGPIPE. (Unless **send()** was called with the MSG_NOSIGNAL flag.)

Example

```
int spatula_count = 3490;
char *secret_message = "The Cheese is in The Toaster";

int stream_socket, dgram_socket;
```

```
struct sockaddr_in dest;
int temp;

// first with TCP stream sockets:
stream_socket = socket(PF_INET, SOCK_STREAM, 0);
.
.
.
// convert to network byte order
temp = htonl(spatula_count);
// send data normally:
send(stream_socket, &temp, sizeof temp, 0);

// send secret message out of band:
send(stream_socket, secret_message, strlen(secret_message)+1, MSG_OOB);

// now with UDP datagram sockets:
dgram_socket = socket(PF_INET, SOCK_DGRAM, 0);
.
.
.
// build destination
dest.sin_family = AF_INET;
inet_aton("10.0.0.1", &dest.sin_addr);
dest.sin_port = htons(2223);

// send secret message normally:
sendto(dgram_socket, secret_message, strlen(secret_message)+1, 0,
       (struct sockaddr*)&dest, sizeof dest);
```

See Also

recv(), **recvfrom()**

8.19. shutdown()

Stop further sends and receives on a socket

Prototypes

```
#include <sys/socket.h>

int shutdown(int s, int how);
```

Description

That's it! I've had it! No more **send()**s are allowed on this socket, but I still want to **recv()** data on it! Or vice-versa! How can I do this?

When you **close()** a socket descriptor, it closes both sides of the socket for reading and writing, and frees the socket descriptor. If you just want to close one side or the other, you can use this **shutdown()** call.

As for parameters, *s* is obviously the socket you want to perform this action on, and what action that is can be specified with the *how* parameter. How can be SHUT_RD to prevent further **recv()**s, SHUT_WR to prohibit further **send()**s, or SHUT_RDWR to do both.

Note that **shutdown()** doesn't free up the socket descriptor, so you still have to eventually **close()** the socket even if it has been fully shut down.

This is a rarely used system call.

Return Value

Returns zero on success, or -1 on error (and **errno** will be set accordingly.)

Example

```
int s = socket(PF_INET, SOCK_STREAM, 0);

// ...do some send()s and stuff in here...

// and now that we're done, don't allow any more sends()s:
shutdown(s, SHUT_RD);
```

See Also

close()

8.20. socket()

Allocate a socket descriptor

Prototypes

```
#include <sys/types.h>
#include <sys/socket.h>

int socket(int domain, int type, int protocol);
```

Description

Returns a new socket descriptor that you can use to do sockety things with. This is generally the first call in the whopping process of writing a socket program, and you can use the result for subsequent calls to **listen()**, bind(), accept(), or a variety of other functions.

domain	*domain* describes what kind of socket you're interested in. This can, believe me, be a wide variety of things, but since this is a socket guide, it's going to be PF_INET for you. And, correspondingly, when you load up your struct sockaddr_in to use with this socket, you're going to set the sin_family field to AF_INET (Also of interest is PF_INET6 if you're going to be doing IPv6 stuff. If you don't know what that is, don't worry about it...yet.)
type	Also, the *type* parameter can be a number of things, but you'll probably be setting it to either SOCK_STREAM for reliable TCP sockets (**send()**, **recv()**) or SOCK_DGRAM for unreliable fast UDP sockets (**sendto()**, **recvfrom()**.) (Another interesting socket type is SOCK_RAW which can be used to construct packets by hand. It's pretty cool.)
protocol	Finally, the *protocol* parameter tells which protocol to use with a certain socket type. Like I've already said, for instance, SOCK_STREAM uses TCP. Fortunately for you, when using SOCK_STREAM or SOCK_DGRAM, you can just set the protocol to 0, and it'll use the proper protocol automatically. Otherwise, you can use **getprotobyname()** to look up the proper protocol number.

Return Value

The new socket descriptor to be used in subsequent calls, or -1 on error (and **errno** will be set accordingly.)

Example

```
int s1, s2;

s1 = socket(PF_INET, SOCK_STREAM, 0);
s2 = socket(PF_INET, SOCK_DGRAM, 0);

if (s1 == -1) {
    perror("socket");
}
```

See Also

accept(), **bind()**, **listen()**

8.21. struct sockaddr_in, struct in_addr

Structures for handling internet addresses

Prototypes

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

struct sockaddr_in {
    short            sin_family;   // e.g. AF_INET
    unsigned short   sin_port;     // e.g. htons(3490)
    struct in_addr   sin_addr;     // see struct in_addr, below
    char             sin_zero[8];  // zero this if you want to
};

struct in_addr {
    unsigned long s_addr;  // load with inet_aton()
};
```

Description

These are the basic structures for all syscalls and functions that deal with internet addresses. In memory, the `struct sockaddr_in` is the same size as `struct sockaddr`, and you can freely cast the pointer of one type to the other without any harm, except the possible end of the universe.

Just kidding on that end-of-the-universe thing...if the universe does end when you cast a `struct sockaddr_in*` to a `struct sockaddr*`, I promise you it's pure coincidence and you shouldn't even worry about it.

So, with that in mind, remember that whenever a function says it takes a `struct sockaddr*` you can cast your `struct sockaddr_in*` to that type with ease and safety.

There's also this `sin_zero` field which some people claim must be set to zero. Other people don't claim anything about it (the Linux documentation doesn't even mention it at all), and setting it to zero doesn't seem to be actually necessary. So, if you feel like it, set it to zero using **`memset()`**.

Now, that `struct in_addr` is a weird beast on different systems. Sometimes it's a crazy `union` with all kinds of `#define`s and other nonsense. But what you should do is only use the *`s_addr`* field in this structure, because many systems only implement that one.

With IPv4 (what basically everyone in 2005 still uses), the `struct s_addr` is a 4-byte number that represents one digit in an IP address per byte. (You won't ever see an IP address with a number in it greater than 255.)

Example

```
struct sockaddr_in myaddr;
int s;

myaddr.sin_family = AF_INET;
myaddr.sin_port = htons(3490);
inet_aton("10.0.0.1", &myaddr.sin_addr);

s = socket(PF_INET, SOCK_STREAM, 0);
bind(s, (struct sockaddr*)&myaddr, sizeof myaddr);
```

See Also

`accept()`, **`bind()`**, **`connect()`**, **`inet_aton()`**, **`inet_ntoa()`**

9. More References

You've come this far, and now you're screaming for more! Where else can you go to learn more about all this stuff?

9.1. Books

For old-school actual hold-it-in-your-hand pulp paper books, try some of the following excellent books. I used to be an affiliate with a very popular internet bookseller, but their new customer tracking system is incompatible with a print document. As such, I get no more kickbacks. If you feel compassion for my plight, paypal a donation to `beej@beej.us`. `:-)`

Unix Network Programming, volumes 1-2 by W. Richard Stevens. Published by Prentice Hall. ISBNs for volumes 1-2: 0131411551[32], 0130810819[33].

Internetworking with TCP/IP, volumes I-III by Douglas E. Comer and David L. Stevens. Published by Prentice Hall. ISBNs for volumes I, II, and III: 0131876716[34], 0130319961[35], 0130320714[36].

TCP/IP Illustrated, volumes 1-3 by W. Richard Stevens and Gary R. Wright. Published by Addison Wesley. ISBNs for volumes 1, 2, and 3 (and a 3-volume set): 0201633469[37], 020163354X[38], 0201634953[39], (0201776316[40]).

TCP/IP Network Administration by Craig Hunt. Published by O'Reilly & Associates, Inc. ISBN 0596002971[41].

Advanced Programming in the UNIX Environment by W. Richard Stevens. Published by Addison Wesley. ISBN 0201433079[42].

9.2. Web References

On the web:

BSD Sockets: A Quick And Dirty Primer[43] (Unix system programming info, too!)

The Unix Socket FAQ[44]

Intro to TCP/IP[45]

TCP/IP FAQ[46]

The Winsock FAQ[47]

And here are some relevant Wikipedia pages:

32. `http://beej.us/guide/url/unixnet1`
33. `http://beej.us/guide/url/unixnet2`
34. `http://beej.us/guide/url/intertcp1`
35. `http://beej.us/guide/url/intertcp2`
36. `http://beej.us/guide/url/intertcp3`
37. `http://beej.us/guide/url/tcpi1`
38. `http://beej.us/guide/url/tcpi2`
39. `http://beej.us/guide/url/tcpi3`
40. `http://beej.us/guide/url/tcpi123`
41. `http://beej.us/guide/url/tcpna`
42. `http://beej.us/guide/url/advunix`
43. `http://www.frostbytes.com/jimf/papers/sockets/sockets.html`
44. `http://www.developerweb.net/forum/forumdisplay.php?f=70`
45. `http://pclt.cis.yale.edu/pclt/COMM/TCPIP.HTM`
46. `http://www.faqs.org/faqs/internet/tcp-ip/tcp-ip-faq/part1/`
47. `http://tangentsoft.net/wskfaq/`

Berkeley Sockets[48]

Internet Protocol (IP)[49]

Transmission Control Protocol (TCP)[50]

User Datagram Protocol (UDP)[51]

Client-Server[52]

Serialization[53] (packing and unpacking data)

9.3. RFCs

RFCs[54]—the real dirt:

RFC 768[55]—The User Datagram Protocol (UDP)

RFC 791[56]—The Internet Protocol (IP)

RFC 793[57]—The Transmission Control Protocol (TCP)

RFC 854[58]—The Telnet Protocol

RFC 951[59]—The Bootstrap Protocol (BOOTP)

RFC 1350[60]—The Trivial File Transfer Protocol (TFTP)

RFC 4506[61]—External Data Representation Standard (XDR)

The IETF has a nice online tool for searching and browsing RFCs[62].

48. http://en.wikipedia.org/wiki/Berkeley_sockets
49. http://en.wikipedia.org/wiki/Internet_Protocol
50. http://en.wikipedia.org/wiki/Transmission_Control_Protocol
51. http://en.wikipedia.org/wiki/User_Datagram_Protocol
52. http://en.wikipedia.org/wiki/Client-server
53. http://en.wikipedia.org/wiki/Serialization
54. http://www.rfc-editor.org/
55. http://tools.ietf.org/html/rfc768
56. http://tools.ietf.org/html/rfc791
57. http://tools.ietf.org/html/rfc793
58. http://tools.ietf.org/html/rfc854
59. http://tools.ietf.org/html/rfc951
60. http://tools.ietf.org/html/rfc1350
61. http://tools.ietf.org/html/rfc4506
62. http://tools.ietf.org/rfc/

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