Socket

CIS 340 System Programming

Haodong Wang

New IPC Ideas

- IPC: inter-process communication
- Until now, we did the communication through:
  - File system: file descriptors, read()/write() and pipes
  - Total reliable byte stream between producer and consumer
- New ideas:
  - We want to create a generalization of the pipe construct for network-based I/O
  - That means we still want file descriptors and read()/write() calls to work
  - We need to take some extra features into consideration:
    - Network Protocol Stacks
    - Network Naming Conventions
    - Requirements of Protocol-Specific Message Passing
  - The BSD and UNIX solution is the socket() call. Most concisely, it can be described as a communication endpoint.
  - The call returns a file descriptor.
  - int socket(int domain, int type, int protocol);

Communication Domain

- This basically specifies a protocol stack.
- Some systems contain a richer set of communication domains than others
  - AF_UNIX or AF_LOCAL: The UNIX IPC domain, local to a single machine
  - AF_INET: The Internet domain, global in scope
  - AF_INET6: The Internet domain, using IPv6
- Once a domain is specified, we know how to associate a name with the socket
- As well as knowing the semantics of supported IPC mechanisms

Unix Domain Sockets

- Let's start with the simpler (but less interesting) case of the AF_UNIX communication domain
- The header le <sys/un.h> denes addresses

```
#define UNIX_PATH_MAX 108

struct sockaddr_un {
  unsigned short sun_family;   /* AF_UNIX */
  char sun_path[UNIX_PATH_MAX]; /* Pathname */
};
```

- Some examples of Unix domain sockets can be found under the /dev directory

Types of Sockets in Unix Domain

- We'll be looking at two types of sockets available in Unix
  - SOCK_DGRAM provides datagram communication semantics
  - Only promises best-effort delivery
  - Unix may discard datagrams in times of buffer congestion
  - Connectionless!
- 2nd type
  - SOCK_STREAM implements virtual circuit communication semantics
  - Reliable FIFO point-to-point communications
  - Appears as a byte stream to applications
  - This is actually how some later UNIX systems implement pipes!
- Socket type should be chosen according to the needs of the application, and should be programmed in accordance with well-specified delivery semantics of chosen type.

Operations on Sockets

- Binding a name to a socket:

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

- Sending datagram on a socket (asynchronous):

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

- Receiving datagram from a socket (synchronous, blocking):

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


Server I

```
#include <errno.h>
#include <strings.h>
#include <stdio.h>
#include <unistd.h>
#include <sys/socket.h>
#include <sys/un.h>

main() {
  short p_len;
  int socket_fd, cc, h_len, fsize, namelen;
  void printsun();
  struct sockaddr_un s_un, from;
  size_t addrlength;

  struct {
    char head;
    u_long body;
    char tail;
  } msg;

  socket_fd = socket (AF_UNIX, SOCK_DGRAM, 0);

  s_un.sun_family = AF_UNIX;
```


Server II

```
  strcpy(s_un.sun_path, "udgram");
  addrlength = sizeof(s_un.sun_family) + sizeof(s_un.sun_path);
  unlink("udgram");

  bind(socket_fd, (struct sockaddr *)&s_un, addrlength);

  for(;;) {
    fsize = sizeof(from);
    cc = recvfrom(socket_fd, &msg, sizeof(msg), 0,
      (struct sockaddr *)&from, &fsize);
    printsun(&from, "unix_rdgram:␣", "Packet␣from");
    printf("Got␣data␣::%c%ld%c\n", msg.head,msg.body,msg.tail);
    fflush(stdout);
  }
}

void printsun(Sun, s1, s2)
struct sockaddr_un *Sun; char *s1, *s2;
{
  printf("%s␣%s\n",s1,s2);
  printf("␣␣␣␣␣␣family␣<%d>␣addr␣<%s>\n",
    Sun->sun_family, Sun->sun_path);
}
```

Client I

```
#include <errno.h>
#include <strings.h>
#include <stdio.h>
#include <unistd.h>
#include <sys/socket.h>
#include <sys/un.h>

main() {
  int socket_fd, cc;
  //long getpid();
  struct sockaddr_un dest;

  struct {
    char head;
    u_long body;
    char tail;
  } msgbuf;

  socket_fd = socket (AF_UNIX, SOCK_DGRAM, 0);
  dest.sun_family = AF_UNIX;
  strcpy(dest.sun_path, "udgram");

  msgbuf.head = '<';
```


Client II

```
  msgbuf.body = (u_long) getpid();
  msgbuf.tail = '>';

  cc = sendto(socket_fd, &msgbuf, sizeof(msgbuf),0,
    (struct sockaddr *)&dest,sizeof(dest));
}
```


Sockets and the Internet (IPv4)

- AF_INET communication domain
- SOCK_DGRAM - Same as before! UDP/IP
- SOCK_STREAM - Same as before! TCP/IP
- We need a way to associate names with sockets to be able to do network I/O through a socket file descriptor

Sockets and the Internet (IPv4)

- The header le <netinet/in.h> denes a 32-bit for an Internet host.
- This actually identies a specic network interface on a specific system on the Internet.
- It's represented by a 32 bit unsigned number

```
struct in_addr {
  __u32 s_addr;
}
```

- The addresses are usually represented by dotted decimal notation.

Representing the Address in C

- In header file <netinet/in.h>

```
#define __SOCK_SIZE__ 16 /* sizeof(struct sockaddr) */

struct sockaddr_in {
  short int sin_family; /* Address family */
  unsigned short int sin_port; /* Port number */
  struct in_addr sin_addr; /* Internet address */
  /* Pad to size of `struct sockaddr'. */
  unsigned char __pad[__SOCK_SIZE__ - sizeof(short int) -
  sizeof(unsigned short int) - sizeof(struct in_addr)];
};
```

- Declare and/or allocate instance of struct sockaddr_in whenever you need to specify a full address on the Internet
- A port is an Internet communication endpoint associated with an application. (host,port) defines an Internet address.
- Ports in range [0,1023] reserved for root; others available to ordinary users. (See RFC 1700)

Usual Ports for Services

- FTP uses 20 and 21
- SSH uses 22
- Telnet uses 23
- HTTP uses 80, commonly
- HTTPS uses 443
- Check /etc/services to see what "well-known" ports are

Translating Host Names into IP Address(es)

- Library function to map symbolic host name into IP address(es):

```
#include <netdb.h>

struct hostent *gethostbyname(const char *name);

void herror(const char *s);
```

- The hostent data structure:

```
struct hostent {
    char  *h_name;            /* official name of host */
    char **h_aliases;         /* alias list */
    int    h_addrtype;        /* host address type */
    int    h_length;          /* length of address */
    char **h_addr_list;       /* list of addresses */
}
#define h_addr h_addr_list[0] /* for backward compatibility */
```


Translating Host Names into IP Address(es)

- If we have a dotted decimal string and we want to convert it into an address we can use, the above function is useful.
- I Also see man inet for more functions!

getaddrs.c Example

```
#include <netdb.h>
#include <stdio.h>
#include <stdlib.h>
#include <sys/socket.h>
#include <arpa/inet.h>
#include <netinet/in.h>
main(argc,argv)
int argc; char **argv;
{
  struct hostent *entry; char **next;
  struct in_addr address, **addrptr;
  entry = gethostbyname(argv[1]);
  if (!entry) { herror("lookup error"); exit(1); }
  printf("Official name -> %s\n", entry->h_name);
  if (entry->h_aliases[0]) {
    printf("Aliases -> \n");
    for (next = entry->h_aliases; *next; next++)
      printf(" %s\n", *next);
  }
  printf("IP Addresses:\n");
  for (addrptr=(struct in_addr **) entry->h_addr_list;
    *addrptr; addrptr++)
    printf(" %s\n", inet_ntoa(**addrptr));
}
```


Get Symbolic Name from IP Address

- There's also an inverse function (we know IP address, want symbolic name)

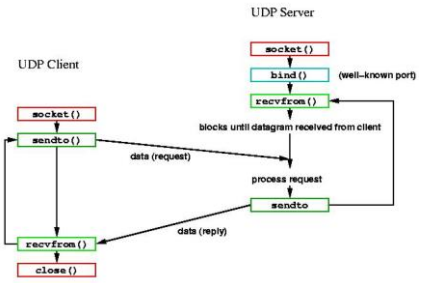
```
#include <netdb.h>

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


gethost.c Example

```
#include <netdb.h>
#include <stdio.h>
#include <stdlib.h>
#include <sys/socket.h>
#include <arpa/inet.h>
#include <netinet/in.h>
main(argc,argv)
int argc; char **argv;
{
  struct hostent *entry; char **next;
  struct in_addr address, **addrptr;
  inet_aton(argv[1], &address);
  entry = gethostbyaddr((char *)&address, sizeof(address),
    AF_INET);
  if (!entry) { herror("lookup error"); exit(1); }
  printf("Official name -> %s\n", entry->h_name);
  if (entry->h_aliases[0]) {
    printf("Aliases -> \n");
    for (next = entry->h_aliases; *next; next++)
      printf(" %s\n", *next);
  }
  printf("IP Addresses:\n");
  for (addrptr=(struct in_addr **) entry->h_addr_list;
    *addrptr; addrptr++)
    printf(" %s\n", inet_ntoa(**addrptr));
}
```


Communication Architecture



recv_upd.c: UDP/IP Server I

```
#include <netdb.h>
#include <stdio.h>
#include <stdlib.h>
#include <sys/socket.h>
#include <arpa/inet.h>
#include <netinet/in.h>
#include <strings.h>
void printsin(s_in, s1, s2)
struct sockaddr_in *s_in; char *s1, *s2;
{
  printf ("Program: %s\n%s ", s1, s2);
  printf ("(%d,%d)\n", s_in->sin_addr.s_addr, s_in->sin_port);
}

main()
{
  short p_len;
  int socket_fd, cc, h_len, fsize, namelen;
  struct sockaddr_in s_in, from;
  struct { char head; u_long body; char tail;} msg;

  socket_fd = socket (AF_INET, SOCK_DGRAM, 0);
  /* You must do this just in case */
```


recv_upd.c: UDP/IP Server II

```
  bzero((char *) &s_in, sizeof(s_in));

  s_in.sin_family = (short)AF_INET;
  s_in.sin_addr.s_addr = htonl(INADDR_ANY); /* WILDCARD */
  s_in.sin_port = htons((u_short)0x3333);
  printsin( &s_in, "RECV_UDP", "Local socket is:");
  fflush(stdout);
  bind(socket_fd, (struct sockaddr *)&s_in, sizeof(s_in));
  for(;;) {
    fsize = sizeof(from);
    cc = recvfrom(socket_fd, &msg, sizeof(msg), 0,
            (struct sockaddr *)&from,&fsize);
    printsin( &from, "recv_udp: ", "Packet from:");
    printf("Got data ::%c%ld%c\n",msg.head,
      ntohl(msg.body),msg.tail);
    fflush(stdout);
  }
}
```


send_upd.c: UDP/IP Client I

```
#include <netdb.h>
#include <stdio.h>
#include <stdlib.h>
#include <sys/socket.h>
#include <arpa/inet.h>
#include <netinet/in.h>
#include <strings.h>
main(argc,argv)
int argc; char **argv;
{
  int socket_fd;
  struct sockaddr_in dest;
  struct hostent *hostptr;
  struct { char head; u_long body; char tail; } msgbuf;
  socket_fd = socket (AF_INET, SOCK_DGRAM, 0);
  /* You must do this just in case */
  bzero((char *) &dest, sizeof(dest));

  hostptr = gethostbyname(argv[1]);
  dest.sin_family = (short) AF_INET;
  bcopy(hostptr->h_addr, (char *)&dest.sin_addr,
    hostptr->h_length);
  dest.sin_port = htons((u_short)0x3333);
```


send_upd.c: UDP/IP Client II

```
  msgbuf.head = '<';
  msgbuf.body = htonl(getpid()); /* IMPORTANT! */
  msgbuf.tail = '>';
  sendto(socket_fd,&msgbuf,sizeof(msgbuf),0,
    (struct sockaddr *)&dest, sizeof(dest));
}
```

Similarities and Differences

- Note that there are striking similarities between Unix datagram programs and Internet datagram programs
- We do need to do extra work for Internet programs
- Socket creation parameters are trivially different
- Naming conventions are significantly different
- The underlying implementation is completely different! But hidden from the programmers
- Practical note: You can always test and develop network programs on "localhost" (127.0.0.1). The implementation should be smart enough to NOT send the packets over the network (instead just pass it from output buffer to input buffer)