Application Programming Interfaces

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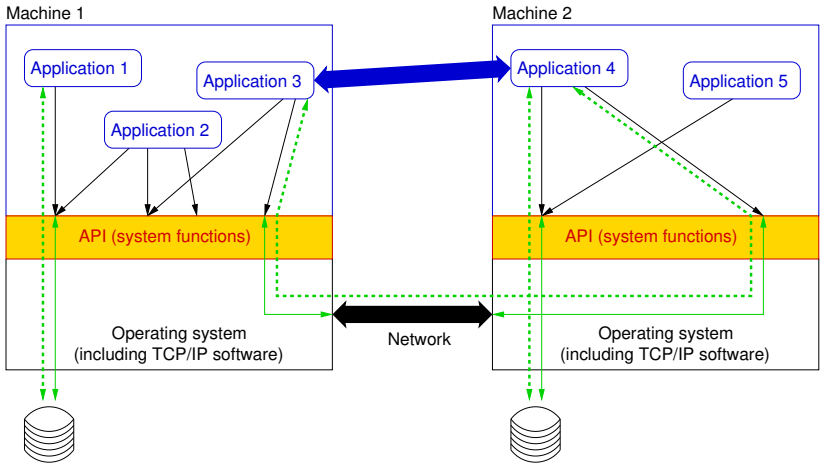
System calls



System calls (cont'd)

- Where do we find API descriptions?
  - In Section 2 of the manual pages
  - Section 3 is dedicated to library functions, which are wrappers over APIs (implemented using calls to the respective API)
  - Examples:
    `man -S2 open` (often `man 2 open` will also work)
    `man -S3 printf` (or `man 3 printf`)
- Some interesting (for us) APIs:
  - Process management (`fork` and company — already seen)
  - File I/O
  - Terminal I/O (`cin`, `cout` / `scanf`, `printf`) – library functions, not API!
  - The TCP/IP implementation (Berkeley sockets)

File I/O

Operation	Meaning
`open`	prepares a file for I/O operations returns a file descriptor (`int`) used by all the other operations
`close`	terminates the use of a previously opened file/device
`read`	obtain data from a file/device
`write`	write data to a file/device
`lseek`	move to some position in the file/device (not applicable to all devices)

- For example,

```
char result[256];
int file = open("echo",O_RDONLY);
if (file == -1)
  return 1;
read(file,result,255);
close(file);
```

File I/O (cont'd)

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

int main (int argc, char** argv) {
  int file = open(argv[1],O_WRONLY|O_CREAT|O_APPEND,S_IRUSR|S_IWUSR);
  int i = 0; char prefix[12]; char message[256] = "something";
  if (file == -1)
    return 1;
  while (true) {
    i++;
    printf("Message: ");
    fgets(message,255,stdin);
    if (message[strlen(message)-1] == '\n')
      message[strlen(message)-1] == '\0';
    if (strlen(message) == 0)
      break;
    snprintf(prefix,12,"%d: ",i);
    write(file,prefix,strlen(prefix));
    write(file,message,strlen(message));
    write(file,"\n",1);
  }
  close(file);
}
```


Text files

```
int readline(int fd, char* buf_str, size_t max) {
  size_t i;
  for (i = 0; i < max; i++) {
    char  tmp;
    int what = read(fd,&tmp,1);
    if (what == 0 || tmp == '\n') {
      buf_str[i] = '\0';
      return i;
    }
    buf_str[i] = tmp;
  }
  buf_str[i] = '\0';
  return i;
}
```

```
int dbf = open("myfile",O_RDONLY);
if (dbf == -1) {
  perror("myfile");
  exit(1);
}
char message[256];
int nc = readline(dbf,message,255);
```

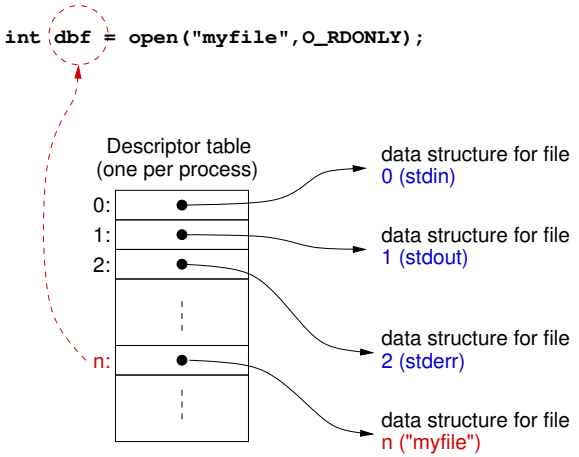

Text files (cont'd)

```
const int recv_nodata = -2;

int readline(const int fd, char* buf, const size_t max) {
    size_t i;
    int begin = 1;

    for (i = 0; i < max; i++) {
        char tmp;
        int what = read(fd,&tmp,1);
        if (what == -1) return -1;
        if (begin) {
            if (what == 0)
                return recv_nodata;
            begin = 0;
        }
        if (what == 0 || tmp == '\n') {
            buf[i] = '\0';
            return i;
        }
        buf[i] = tmp;
    }
    buf[i] = '\0';
    return i;
}
```


File descriptors

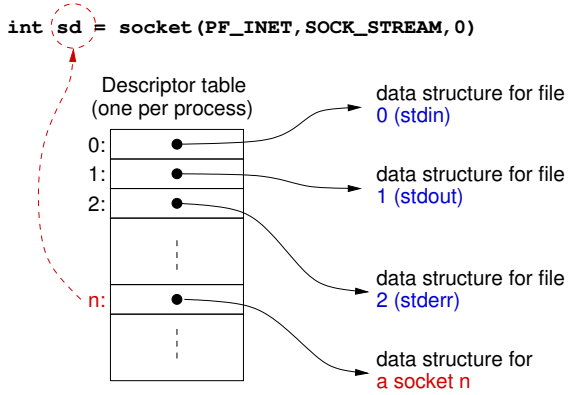


The TCP/IP API

- TCP/IP is a loosely specified protocol
- In other words, the TCP/IP standard does not specify the API, only the functionality
- A TCP/IP interface must support the following operations:
  - Allocate resources for communication
  - Specify communication endpoints
  - Initiate a connection (client) or wait for connection (server)
  - Send and receive data
  - Identify data arrival
  - Generate urgent data and handle incoming urgent data
  - Terminate a connection, handle connection termination, abort communication
  - Handle error conditions
  - Release resources
- We use one (by far the most popular) TCP/IP implementation called Berkeley sockets

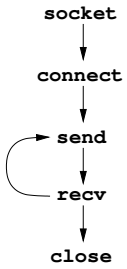
Berkeley sockets

- Recall that an application that wants to access a file uses `open`
  - Further recall that `open` returns a file descriptor
- An application that wanto to communicate creates a socket using `socket`
  - `socket` also returns a descriptor

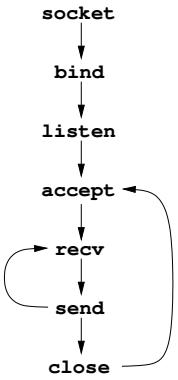


What to do with sockets

- We have a socket, what do we do with it?
- We can convince it to be either passive (for servers) or active (for clients).



Active socket
(client)



Passive socket
(server)

The socket API

Who	Call	Meaning
Both	`socket`	Creates a socket, returns a descriptor
Client	`connect`	Connects to a remote server (client)
Server	`bind`	Associates (“binds”) the socket to a local IP address and a port number
	`listen`	Place the socket into passive mode (also sets the length of the queue)
	`accept`	Accept the next incoming connection (server)
Both	`send`	Send data (can also use `write`)
	`recv`	Receive data (can also use `read`)
	`close`	Terminate communication and destroys the descriptor

- Necessary headers:

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

Specifying an address

- In principle, there exist address families to hold different type of addresses
- In practice, TCP/IP uses one family of addresses, called `AF_INET`
- An address (within an address family) should contain at least the address of some machine and a port number
- The TCP/IP API includes C structures for address endpoints:

```
struct sockaddr_in {
  ...
  sa_family_t        sin_family; /* Address family, AF_INET for us */
  unsigned short int sin_port;   /* Port number                    */
  struct in_addr     sin_addr;   /* IP address                     */
  ...
};

struct in_addr {
  unsigned int s_addr;   /* 32 bits, i.e., 4 bytes */
};
```


Finding an address

- Usually, a server address is given as a machine name or an IP address in dotted decimal notation:

  `cs.ubishops.ca` or `207.162.99.35`

- No matter how the server is specified (as dotted address or name), we have to obtain the actual IP address
- `gethostbyname` does the job no matter how the server is specified and puts the result in the following 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;         /* Address from name server           */
#define h_addr  h_addr_list[0] /* Address, for backward compatibility */
};
```


Finding an address (cont'd)

- Actually, `h_addr_list` is an array that contains the bytes of a network address
- They are given in network byte order (aka big endian, "big end first"), i.e., exactly in the right order to be put in a `sockaddr_in` structure

```
#include <stdio.h>
#include <netdb.h>

extern int h_errno;

int main (int argc, char** argv) {
  struct hostent* host_info = gethostbyname(argv[1]);
  if (host_info != NULL) {
    printf("%s is ", argv[1]);
    for (int i = 0; i < host_info -> h_length; i++)
      printf("%d.", (unsigned char)((host_info -> h_addr)[i]));
    printf("\n");
  }
  else
    printf("Host lookup error %d: %s\n", h_errno, hstrerror(h_errno));
}
```


Finding a well-known port

- If you know the name of a standard service, you can find the port number associated to that service using `getservbyname` which puts the result in the following structure:

```
struct servent {
  char *s_name;      /* Official service name. */
  char **s_aliases;  /* Alias list.            */
  int s_port;        /* Port number.           */
  char *s_proto;     /* Protocol to use.       */
};
```

- For example:

```
struct servent* service = getservbyname("ftp","tcp");
if (service != NULL) {
    printf("%s\n%d\n%s\n",
           service -> s_name,
           service -> s_port,
           service -> s_proto);
}
```

```
< godel:slides/code > ./a.out
ftp
21
tcp
```