INTER-PROCESS COMMUNICATION

UNIX Programming 2014 Fall by Euiseong Seo

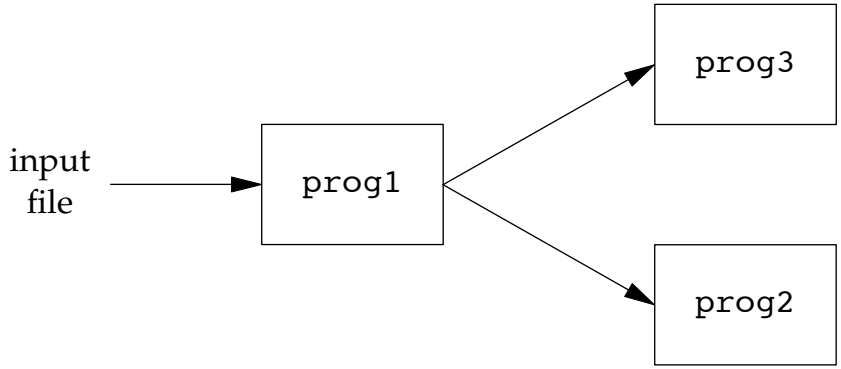
Named Pipes

- Anonymous pipes can be used only between related processes
- Processes not from the same ancestor sometimes need to communicate with each other
- FIFO
  - A type of files (`S_ISFIFO` macro tests against `st_mode`)
  - Usually called named pipes
- Multiple readers/writers are allowed

Uses for FIFOs

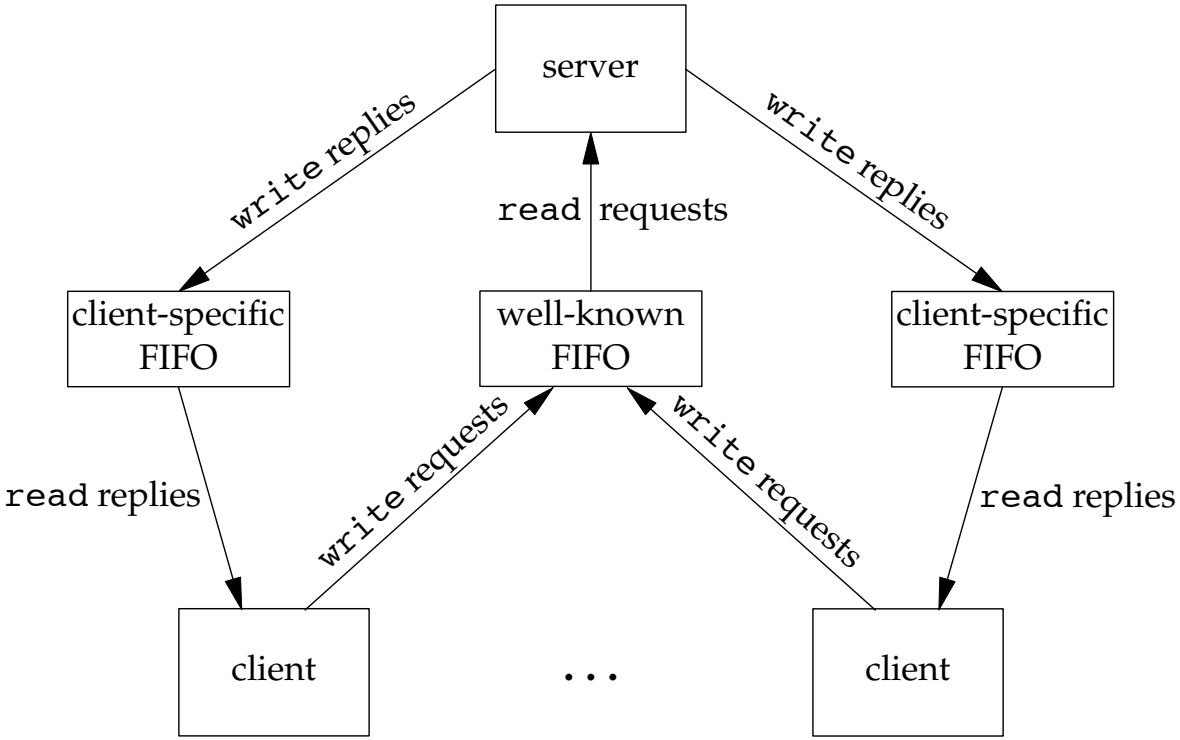
- Used by shell commands to pass data from one shell pipeline to another without creating temporary files
- Used as rendezvous points in client-server applications to pass data between clients and servers

Duplicate Output Streams with FIFOs




```
mkfifo fifo1
prog3 < fifo1 &
prog1 < infile | tee fifo1 | prog2
```

Client-Server Communication using FIFOs



Creating a FIFO

- Prototype

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

int mkfifo(const char *pathname, mode_t mode);
```

Accessing a FIFO

- Like a normal file access, a process opens a FIFO for read, write or read/write accesses
- open() for read-only blocks until some other process opens FIFO for writing
- open() for write-only blocks until some other process opens FIFO for reading
- open() for read-only with O_NONBLOCK returns immediately
- open() for write-only with O_NONBLOCK returns -1 if no process has FIFO open for reading

Close and Delete a FIFO

- Close a FIFO with close() when you no longer use it
- Delete a FIFO with unlink()

System V IPC (XSI IPC)

- Message queues, semaphores and shared memory
- Message queues
  - A linked list of messages stored within kernel
- Semaphore
  - A counter for sharing data object for multiple processes
- Shared memory
  - A memory region that can be shared by multiple processes

Key and Identifier

- All IPC objects are stored in kernel memory
- They are referred to by IPC object *identifier*

```
euiseong@accept:~/Temp$ ipcs

------ Shared Memory Segments --------
key        shmid      owner      perms      bytes      nattch     status

------ Semaphore Arrays --------
key        semid      owner      perms      nsems

------ Message Queues --------
key        msqid      owner      perms      used-bytes   messages
0x000004d2 32768      euiseong   666        2304         8
```

- ID is a unique large number assigned by kernel when you create an IPC structure with a key
- Server and client rendezvous with key, not with ID
- Kernel will translate a given key to corresponding ID

Message Queue

- Data structures

```
struct msqid_ds {
    struct ipc_perm msg_perm;
    msgqnum_t   msg_qnum; // # of messages on queue
    msglen_t    msg_qbytes; // max # of bytes on queue
    pid_t   msg_lspid; // pid of last msgsnd()
    pid_t   msg_lrpid; // pid of last msgrcv()
    time_t  msg_stime; // last-msgsnd() time
    time_t  msg_rtime; // last-msgrcv() time
    time_t  msg_ctime; // last-change time
};

struct ipc_perm {
    uid_t   uid; // owner's EUID
    gid_t   gid; // owner's EGID
    uid_t   cuid; // creator's EUID
    gid_t   cgid; // creator's EGID
    mode_t  mode; // access mode
};
```

Creating a Message Queue

- Prototype

```
#include <sys/types.h>
#include <sys/ipc.h>
#include <sys/msg.h>

int msgget(key_t key, int msgflg);
```

- msgget() returns a non-negative queue ID
- msgflg can be a combination of flags
  - IPC_CREAT
  - IPC_EXCL

Controlling a Message Queue

- Prototype

```
#include <sys/types.h>
#include <sys/ipc.h>
#include <sys/msg.h>

int msgctl(int msqid, int cmd, struct msqid_ds *buf);
```

- cmd can be one of the followings
  - IPC_STAT
  - IPC_SET
  - IPC_RMID

Sending and Receiving via Queue

- Prototype

```
#include <sys/types.h>
#include <sys/ipc.h>
#include <sys/msg.h>

int msgsnd(int msqid, const void *msgp, size_t msgsz, int msgflg);

ssize_t msgrcv(int msqid, void *msgp, size_t msgsz, long msgtyp,int msgflg);
```

- Data structure

```
struct msgbuf {
    long mtype;       /* message type, must be > 0 */
    char mtext[1024];    /* message data */
};
```

Sending and Receiving via Queue

- msgtyp can be one of followings
  - 0: first message in queue
  - >0: first message in queue of type msgtyp unless MSG_EXCEPT in msgflg
  - <0: first message in queue with lowest type less than or equal to absolute value of msgtyp

IPC-Related Commands

- ipcs
  - Provide information on IPC facilities
- ipcrm
  - Remove a message queue, semaphore set or shared memory
  - Users can select an IPC facility to remove with its key or ID

Example - Producer

```
struct msgbuf
{
    long msgtype;
    char mtext[256];
    int  seq;
};

int main()
{
    time_t curtime;
    key_t key_id;
    int i;
    struct msgbuf sendbuf;

    key_id = msgget(2014,IPC_CREAT|0666);
    if (key_id == -1)
       {perror("msgget error : ");
        exit(0);}
```

```
 memset(sendbuf.mtext, 0x0, 256);
    sendbuf.seq = 0;
    for(i = 0;i<100;i++) {
        sendbuf.seq = i;
        if (i % 2 == 0)
            sendbuf.msgtype = 2;
        else
            sendbuf.msgtype = 1;
        time(&curtime);
        strcpy(sendbuf.mtext,
ctime(&curtime));
        if (msgsnd(key_id, (void
*)&sendbuf, sizeof(struct msgbuf),
IPC_NOWAIT)<
            0)
        {perror("msgsnd error : ");
exit(0);}
        sleep(1);
    }
}
```

Example - Consumer

```
struct msgbuf
{
    long msgtype;
    char mtext[256];
    int  seq;
};

int main(int argc, char **argv)
{
    key_t key_id;
    struct msgbuf recvbuf;
    int msgtype;

    if(argc >= 2 &&
    strcmp(argv[1],"2")==0)
        msgtype = 2;
    else
        msgtype = 1;
```

```
 key_id = msgget(2014, IPC_CREAT|0666);
    if (key_id < 0)
    { perror("msgget error : ");
      exit(0);}
    while(1)
    {
        if(msgrcv(1024, (void *)&recvbuf,
sizeof(struct msgbuf), msgtype, 0) == -1)
        { perror("msgrcv"); exit(0);}

printf("%d\t%s\n", recvbuf.seq,
recvbuf.mtext);
    }
    exit(0);
}
```

Semaphore

- Procedure to obtain a shared resource
  1. Test semaphore that controls resource
  2. If value of semaphore is positive, process can use resource by decrementing semaphore by 1
  3. If value of semaphore is 0, sleep and wait till it becomes 1
- Process increases semaphore value by 1 after it is done with shared resource
- Initial value of semaphore determines how many processes can concurrently access shared resource
- Semaphore operation is atomic (non-interruptible)

Creating Semaphores

- Prototype

```
#include <sys/types.h>
#include <sys/ipc.h>
#include <sys/sem.h>

int semget(key_t key, int nsems, int semflg);
```

- Similar to message queue operations
- This creates or obtains an array of semaphores
- Number of semaphores is nsems

Controlling Semaphores

- Prototype

```
#include <sys/types.h>
#include <sys/ipc.h>
#include <sys/sem.h>

int semctl(int semid, int semnum, int cmd, ...);
```

- You can do followings with semctl()
  - Read a semaphore member value
  - Remove a semaphore array
  - Read permission or owner information
  - And so on…

Semaphore Operations

- Prototype

```
#include <sys/types.h>
#include <sys/ipc.h>
#include <sys/sem.h>

int semop(int semid, struct sembuf *sops, unsigned nsops);

struct sembuf {
    unsigned short sem_num; // member index
    short sem_op; // negative, 0 or positive
    short sem_flg; // IPC_NOWAIT, SEM_UNDO
};
```

- semop() blocks when sem_op is negative, sem_num-th semaphore is smaller than sem_op and sem_flg is not IPC_NOWAIT
- Otherwise sem_op will be added to sem_num-th semaphore and return

Shared Memory

- Multiple process can map the same contents in their address space by using mmap() to the same file
- IPC shared memory provide shared memory area that can be mapped into processes' address space
- IPC shared memory does not use an actual file as its medium

Creating a Shared Memory Region

- Prototype

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

int shmget(key_t key, size_t size, int shmflg);
```

- size-byte memory space will be created in kernel

Control, Mapping and Unmapping of SHM

- Prototype

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

int shmctl(int shmid, int cmd, struct shmid_ds *buf);
void *shmat(int shmid, const void *shmaddr, int shmflg);
int shmdt(const void *shmaddr);
```

- shmat() maps shimid into shmaddr
  - For portability, let shmaddr be 0
    - Kernel will choose appropriate address
  - Returns actual mapped address, which will be used by shmdt() to unmap

Example - Producer

```
int main()
{
    time_t curtime;
    key_t key_id;
    int semid, shmid;
    union semun newcmd;
    int i;
    void *shmaddr;
    char strbuffer[256];
    struct sembuf oparr;
    semid = semget(2015, 1, IPC_CREAT|0666);
    newcmd.val = 1;
    semctl(semid, 0, SETVAL, newcmd);
    shmid=shmget(2016, 256,IPC_CREAT|0666);
    shmaddr=shmat(shmid, 0, 0);
    memset(shmaddr, 0x0, 256);
    oparr.sem_num = 0;
    oparr.sem_flg = 0;
    for(i = 0;i<100;i++) {
        time(&curtime);
      sprintf(strbuffer,"%d:%s",i,ctime(&curtime));
        oparr.sem_op = -1;
        semop(semid, &oparr, 1);
        strcpy(shmaddr, strbuffer);
        oparr.sem_op = 1;
        semop(semid, &oparr, 1);
        sleep(1);
    }
}
```

Example - Consumer

```c
int main()
{
    time_t curtime;
    key_t key_id;
    int semid, shmid;
    union semun newcmd;
    int i;
    void *shmaddr;
    char strbuffer[256];
    struct sembuf oparr;

    semid = semget(2015, 1, IPC_CREAT|0666);
    newcmd.val = 1;
    semctl(semid, 0, SETVAL, newcmd);
    shmid = shmget(2016, 256, IPC_CREAT|0666);
    shmaddr=shmat(shmid, 0, 0);
    while(1) {
        oparr.sem_num = 0;
        oparr.sem_op = -1;
        oparr.sem_flg = 0;
        semop(semid, &oparr, 1);
        if(*(int *)shmaddr == 0) {
            oparr.sem_op = 1;
            semop(semid, &oparr, 1);
        } else {
            printf("%s", (char *)shmaddr);
            memset(shmaddr, 0x0, 256);
            oparr.sem_op = 1;
            semop(semid, &oparr, 1);
        }
    }
}
```