

# Unix Shared Memory

# What is Shared Memory?

- ❑ The parent and child processes are run in *separate* address spaces.
- ❑ A *shared memory segment* is a piece of memory that can be allocated and attached to an address space. Thus, processes that have this memory segment attached will have access to it.
- ❑ But, *race conditions can occur!*

# Procedure for Using Shared Memory

- ❑ Find a *key*. Unix uses this key for identifying shared memory segments.
- ❑ Use `shmget()` to allocate a shared memory.
- ❑ Use `shmat()` to attach a shared memory to an address space.
- ❑ Use `shmdt()` to detach a shared memory from an address space.
- ❑ Use `shmctl()` to deallocate a shared memory.

## Keys: 1/2

- ❑ To use shared memory, include the following:

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

- ❑ A key is a value of type `key_t`. There are three ways to generate a key:

- ❖ Do it yourself
- ❖ Use function `ftok()`
- ❖ Ask the system to provide a private key.

## Keys: 2/2

- ❑ Do it yourself: use

```
key_t      SomeKey;  
SomeKey = 1234;
```

- ❑ Use `ftok()` to generate one for you:

```
key_t = ftok(char *path, int ID);
```

- ❖ `path` is a path name (e.g., `"/"`)

- ❖ `ID` is an integer (e.g., `'a'`)

- ❖ Function `ftok()` returns a key of type `key_t`:

```
SomeKey = ftok("/" , 'x');
```

- ❑ Keys are *global* entities. If other processes know your key, they can access your shared memory.

- ❑ Ask the system to provide a private key using `IPC_PRIVATE`.

# Asking for a Shared Memory: 1/4

## ❑ Include the following:

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

## ❑ Use `shmget()` to request a shared memory:

```
shm_id = shmget(
    key_t key,      /* identity key */
    int size,       /* memory size */
    int flag);      /* creation or use */
```

## ❑ `shmget()` returns a shared memory ID.

## ❑ The flag, for our purpose, is either `0666` (rw) or `IPC_CREAT` | `0666`. Yes, `IPC_CREAT`.

## Asking for a Shared Memory: 2/4

- ❑ The following creates a shared memory of size `struct Data` with a private key `IPC_PRIVATE`. This is a creation (`IPC_CREAT`) and permits read and write (`0666`).

```
struct Data { int a; double b; char x; };  
int          ShmID;
```

```
ShmID = shmget(  
    IPC_PRIVATE,    /* private key */  
    sizeof(struct Data), /* size */  
    IPC_CREAT | 0666); /* cr & rw */
```

## Asking for a Shared Memory: 3/4

- ❑ The following creates a shared memory with a key based on the current directory:

```
struct Data { int a; double b; char x;};  
int      ShmID;  
key_t    Key;  
  
Key = ftok("./", 'h');  
ShmID = shmget(  
    Key,          /* a key */  
    sizeof(struct Data),  
    IPC_CREAT | 0666);
```



## Asking for a Shared Memory: 4/4

- ❑ When asking for a shared memory, the process that creates it uses `IPC_CREAT` | `0666` and the process that accesses a created one uses `0666`.
- ❑ If the return value is negative (Unix convention), the request was unsuccessful, and no shared memory is allocated.
- ❑ *Create a shared memory before its use!*

# After the Execution of `shmget()`

Process 1

Process 2

```
shmget(..., IPC_CREAT | 0666);
```



The diagram illustrates the state of shared memory after the execution of `shmget()`. It shows two processes, Process 1 and Process 2, each represented by a yellow box with a blue border. Process 1 contains the code `shmget(..., IPC_CREAT | 0666);`. A red dashed arrow points from the `IPC_CREAT` flag in this code to a green box labeled "shared memory" located below the space between the two processes. Process 2 is empty.

shared memory

*Shared memory is allocated; but, is not part of the address space*

# Attaching a Shared Memory: 1/3

- ❑ Use `shmat()` to attach an existing shared memory to an address space:

```
shm_ptr = shmat(  
    int  shm_id, /* ID from shmget() */  
    char *ptr,   /* use NULL here    */  
    int  flag); /* use 0 here        */
```

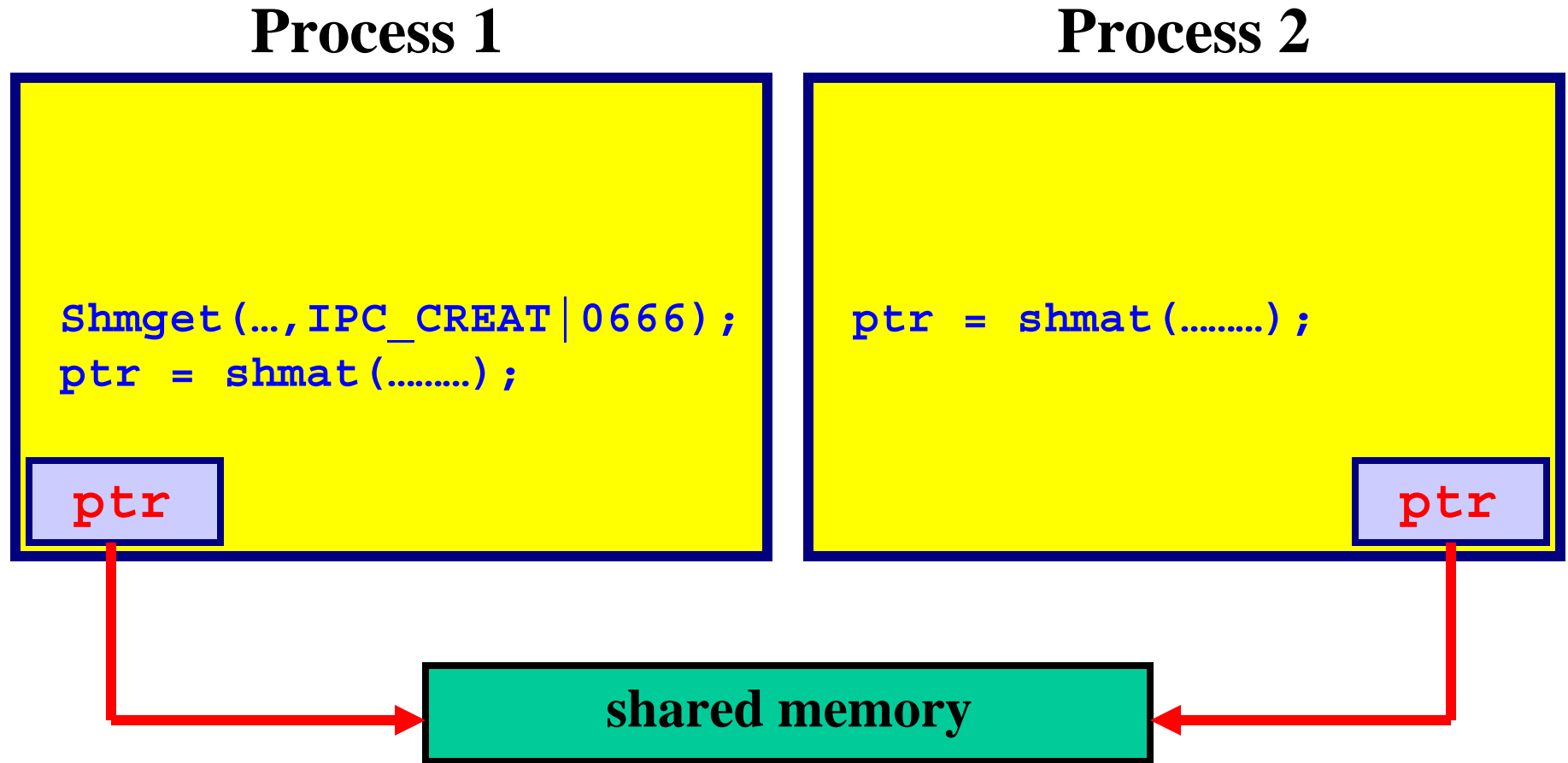
- ❑ `shm_id` is the shared memory ID returned by `shmget()`.
- ❑ Use `NULL` and `0` for the second and third arguments, respectively.
- ❑ `shmat()` returns a `void` pointer to the memory. If unsuccessful, it returns a negative integer.

## Attaching a Shared Memory: 2/3

```
struct Data { int a; double b; char x;};
int      ShmID;
key_t    Key;
struct Data *p;

Key = ftok("./", 'h');
ShmID = shmget(Key, sizeof(struct Data),
               IPC_CREAT | 0666);
p = (struct Data *) shmat(ShmID, NULL, 0);
if ((int) p < 0) {
    printf("shmat() failed\n"); exit(1);
}
p->a = 1; p->b = 5.0; p->c = '.';
```

# Attaching a Shared Memory: 3/3



*Now processes can access the shared memory*

# Detaching/Removing Shared Memory

- ❑ To detach a shared memory, use

`shmdt (shm_ptr) ;`

`shm_ptr` is the pointer returned by `shmat ()`.

- ❑ After a shared memory is detached, it is still there. You can re-attach and use it again.

- ❑ To remove a shared memory, use

`shmctl (shm_ID, IPC_RMID, NULL) ;`

`shm_ID` is the shared memory ID returned by `shmget ()`. After a shared memory is removed, it no longer exists.

# Communicating with a Child: 1/2

```
void main(int argc, char *argv[])
{
    int    ShmID, *ShmPTR, status;
    pid_t  pid;

    ShmID = shmget(IPC_PRIVATE, 4*sizeof(int), IPC_CREAT | 0666);
    ShmPTR = (int *) shmat(ShmID, NULL, 0);
    ShmPTR[0] = atoi(argv[0]);  ShmPTR[1] = atoi(argv[1]);
    ShmPTR[2] = atoi(argv[2]);  ShmPTR[2] = atoi(argv[3]);
    if ((pid = fork()) == 0) {
        Child(ShmPTR);
        exit(0);
    }
    wait(&status);
    shmdt((void *) ShmPTR);  shmctl(ShmID, IPC_RMID, NULL);
    exit(0);
}
```

# Communicating with a Child: 2/2

```
void Child(int SharedMem[])
{
    printf("%d %d %d %d\n", SharedMem[0],
           SharedMem[1], SharedMem[2], SharedMem[3]);
}
```

❑ *Why are `shmget()` and `shmat()` unnecessary in the child process?*



# Communicating Among Separate Processes: 1/5

- Define the structure of a shared memory segment as follows:

```
#define NOT_READY (-1)
#define FILLED (0)
#define TAKEN (1)

struct Memory {
    int status;
    int data[4];
};
```

# Communicating Among Separate Processes: 2/5

## The “Server”

*Prepare for a shared memory*



```
void main(int argc, char *argv[])
{
    key_t          ShmKEY;
    int            ShmID, i;
    struct Memory  *ShmPTR;
```

```
    ShmKEY = ftok("./", 'x');
    ShmID = shmget(ShmKEY, sizeof(struct Memory),
                  IPC_CREAT | 0666);
    ShmPTR = (struct Memory *) shmat(ShmID, NULL, 0);
```

# Communicating Among Separate Processes: 3/5

*shared memory not ready*

```
ShmPTR->status = NOT_READY;
```

*filling in data*

```
for (i = 0; i < 4; i++)  
    ShmPTR->data[i] = atoi(argv[i]);
```

```
ShmPTR->status = FILLED;  
while (ShmPTR->status != TAKEN)  
    sleep(1); /* sleep for 1 second */
```

```
shmdt((void *) ShmPTR);  
shmctl(ShmID, IPC_RMID, NULL);  
exit(0);
```

```
}
```

*detach and remove shared memory*

*wait until the data is taken*

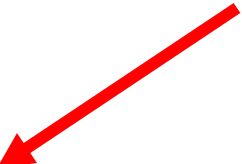
# Communicating Among Separate Processes: 4/5

The “Client”

```
void main(void)
{
    key_t      ShmKEY;
    int        ShmID;
    struct Memory *ShmPTR;

    ShmKEY=ftok(".", 'x');
    ShmID = shmget(ShmKEY, sizeof(struct Memory), 0666);
    ShmPTR = (struct Memory *) shmat(ShmID, NULL, 0);
    while (ShmPTR->status != FILLED)
        ;
    printf("%d %d %d %d\n", ShmPTR->data[0],
        ShmPTR->data[1], ShmPTR->data[2], ShmPTR->data[3]);
    ShmPTR->status = TAKEN;
    shmdt((void *) ShmPTR);
    exit(0);
}
```

*prepare for shared memory*



# Communicating Among Separate Processes: 5/5

- ❑ The “server” must run first to *prepare* a shared memory.
- ❑ Try run the server in one window, and run the client in another a little later.
- ❑ Or, run the server as a background process. Then, run the client in the foreground:

```
server 1 3 5 7 &  
client
```

- ❑ This version uses **busy waiting**.
- ❑ *One may use Unix semaphores for mutual exclusion.*

## Important Notes

- ❑ If you did not remove your shared memory segments (*e.g.*, program crashes before the execution of `shmctl()`), they will be in the system forever. This will degrade the system performance.
- ❑ Use the `ipcs` command to check if you have shared memory segments left in the system.
- ❑ Use the `ipcrm` command to remove your shared memory segments.