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:**

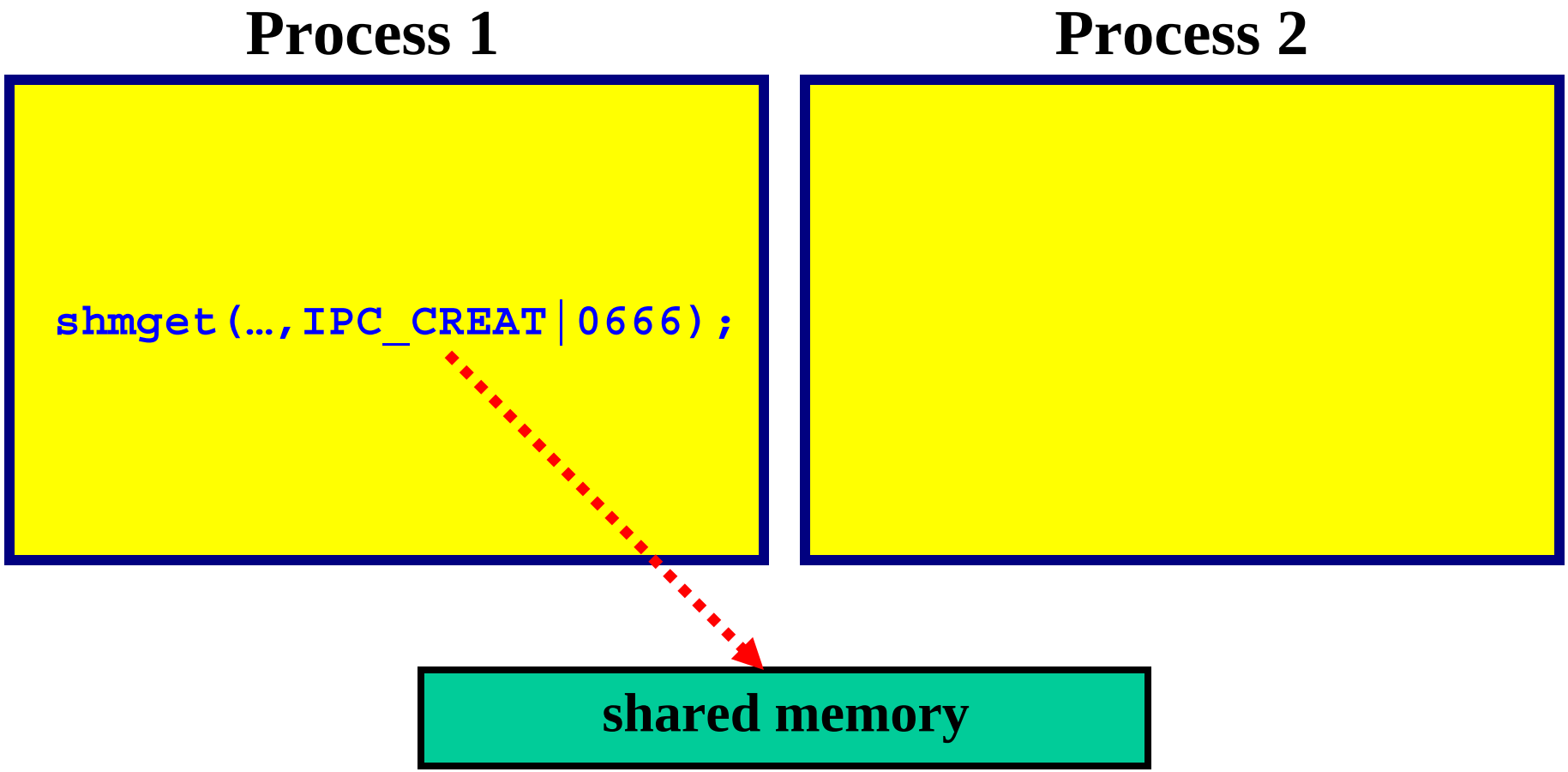
```
struct Data { int a; double b; char x;};
int    ShmID;
key_t  Key;

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()`



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       */
```

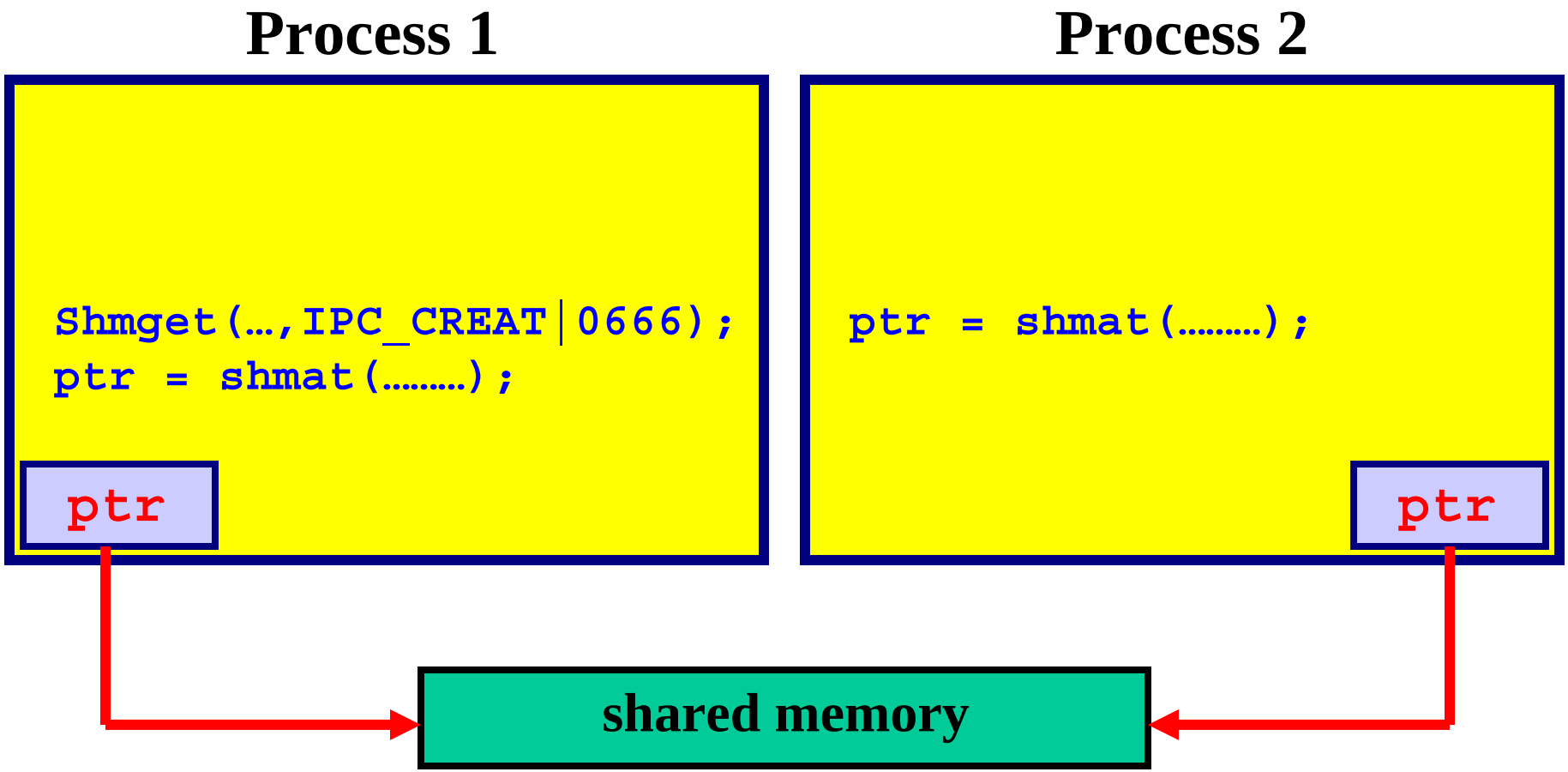
- `shm_id` is the shared memory ID returned by `shmget()`.
- Use `NULL` and `0` for the second and third arguments, respectively.
- `shmat()` returns a `void` pointer to the memory. If unsuccessful, it returns a negative integer.

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:**

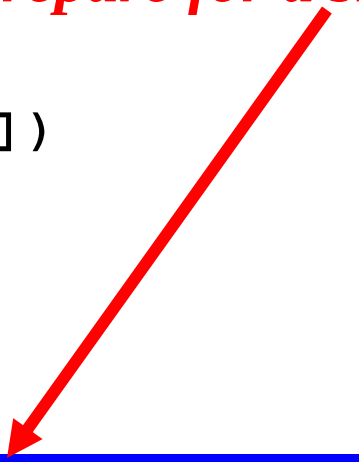
```
#define  NOT_READY   (-1)
#define  FILLED      (0)
#define  TAKEN       (1)

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);
}
```

wait until the data is taken

detach and remove shared memory

Communicating Among Separate Processes: 4/5

The "Client"

prepare for shared memory

```
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);
}
```

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.**