DM510: Processes

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Disclaimer

These slides contain (modified) content and media from the official Operating System Concepts slides: https://www.os-book.com/OS10/slide-dir/index.html

Today's lecture

- Chapter 3 of course book

Process Basics

Processes and programs

- **Program:** executable file, typically stored on hard disk (passive)
- **Process:** An active instance of a program currently in execution
- There may be multiple processes that all come from the same program
- A process can have multiple **threads** of execution

Processes and programs

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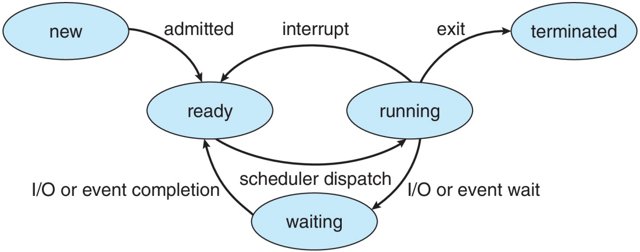
! We defer the discussion of threads to next lecture and consider here only single-threaded processes

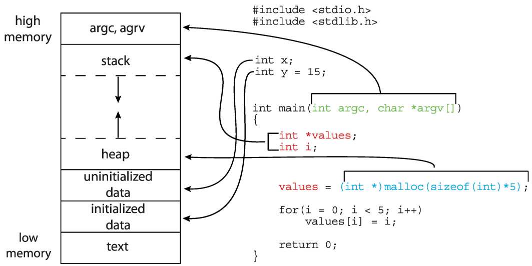
States of a process

Possible states

- **New:** just created, but not executing, yet
- **Running:** currently being executed on CPU
- **Waiting:** cannot execute until certain event occurs
- **Ready:** can be executed, but is currently not
- **Terminated:** process has ended



Data of a process



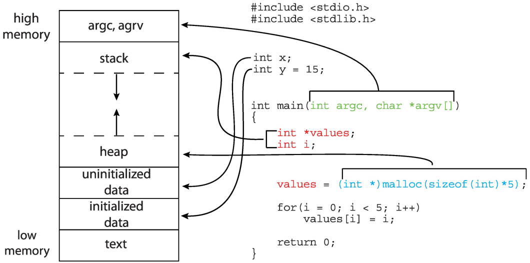
```
#include <stdio.h>
#include <stdlib.h>

int x;
int y = 15;

int main(int argc, char *argv[])
{
    int *values;
    int i;

    values = (int *)malloc(sizeof(int)*5);

    for(i = 0; i < 5; i++)
        values[i] = i;

    return 0;
}
```

Memory layout of C program

Internal data of a process (context)

- Current value of CPU **registers** including program counter
- The program code/instructions, called **text section**
- **Stack:** function parameters, local variables, return addresses
- **Data section:** global variables
- **Heap:** dynamically allocated memory

Data of a process



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Memory layout of C program

Internal data of a process (context)

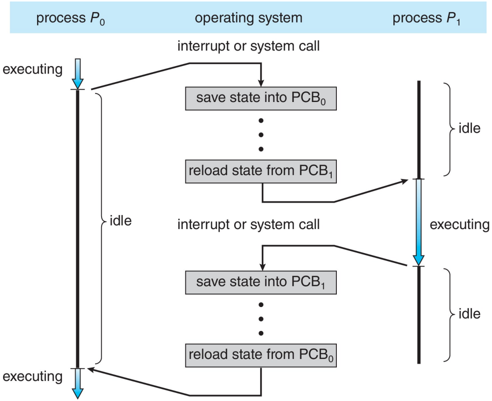
- registers
- text section
- stack
- data section
- heap

Additional data maintained by kernel (process control block)

- **Process status**
- **Scheduling information:** e.g. priority
- **Accounting information:** elapsed time, CPU time used, etc.
- **I/O status information:** devices allocated to process, open files, etc.

Context switch

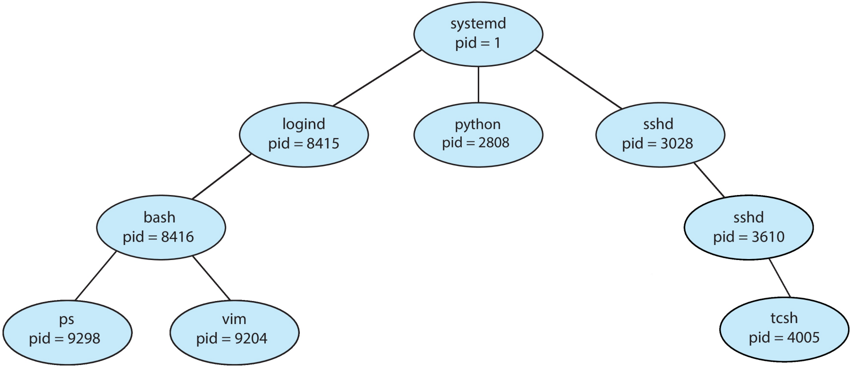
- When kernel preempts a process, it must save its context to be able to restore it later
- Many **context switches** can impact a system's overall performance
- Some architectures have hardware support like multiple register sets



Process Creation and Termination

Process tree

- A process can create other processes through system calls
- This leads to a parent-child relationship among processes



Fork system call

- In Unix systems, the `fork()` system call is used to create a new process
- It creates an exact copy of the caller, including context (data section, heap, stack, etc.)
- Only difference is value returned by `fork()` will be different: zero for child process, process id of child for the parent process
- Often system call to `exec()` (loader) follows immediately after forking

fork in C

```c
int main() {
  pid_t pid;
  pid = fork();
  if (pid < 0) {
    fprintf(stderr, "error");
  }
  else if (pid == 0) {
    printf("child-process");
  }
  else {
    printf("parent-process");
    wait(NULL)
    printf("child-terminated");
  }
  return 0;
}
```

Termination

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- Parent can terminate child using `abort()` system call

Reasons for aborting a process

- Task performed by process is no longer needed
- Kernel needs to reclaim resources
- Sometimes child process is not allowed to continue when parent terminates

Cooperation and Communication

Cooperation

- Some processes work independently, other cooperate regarding their tasks
- Cooperation requires means of **communication** provided by the kernel

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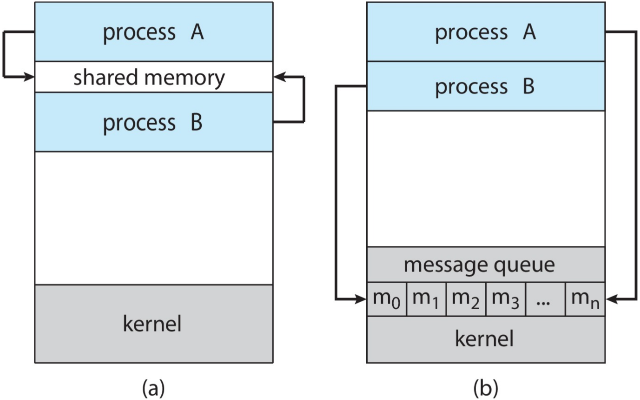
Example: Chrome Browser

An extreme example of cooperation is Google's Chrome web browser

- Separate renderer process for each tab + main process + plug-in processes
- **More secure** by restricting priveledges of websites
- **More reliable** since single malfunctioning websites does not crash entire browser

Communication models

Two main variants of communication: (a) **shared memory** and (b) **message passing**



Producer-consumer with shared memory

The following example has one process produce items and the other consume them. Both processes have access to the following data:

```
#define BUFLEN 10
item buffer[BUFLEN];
int in = 0;
int out = 0;
```

Producer

```
while (true) {
  item next_produced = produce();
  while (((in + 1) % BUFLEN) == out)
    ; /* busy waiting */
  buffer[in] = next_produced;
  in = (in + 1) % BUFLEN;
}
```

Consumer

```
while (true) {
  while (in == out)
    ; /* busy waiting */
  item next_consumed = buffer[out];
  out = (out + 1) % BUFLEN;
  consume(next_consumed);
}
```

Race condition in shared memory

Without appropriate measures (**future lecture**), preemption can lead to errors.

Consider two producers running the previous code simultaneously:

$$\begin{aligned} \texttt{in} &= 0 \\ \texttt{out} &= 0 \\ \texttt{buffer[0]} &= \text{uninitialized} \\ \texttt{buffer[1]} &= \text{uninitialized} \end{aligned}$$

Producer A

- `buffer[in] = itemA;`
- `in = (in + 1) % BUFLEN;`
-
-

Producer B

- `buffer[in] = itemB;`
- `in = (in + 1) % BUFLEN;`
-
-

Race condition in shared memory

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Consider two producers running the previous code simultaneously:

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`out` = 0
`buffer[0]` = itemA
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- `buffer[in] = itemA;`
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Consider two producers running the previous code simultaneously:

`in` = 0
`out` = 0
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`buffer[1]` = uninitialized

Producer A

- `buffer[in] = itemA;`
-
- `in = (in + 1) % BUFLEN;`
-

Producer B

-
- `buffer[in] = itemB;`
- `in = (in + 1) % BUFLEN;`
-

Race condition in shared memory

Without appropriate measures (**future lecture**), preemption can lead to errors.

Consider two producers running the previous code simultaneously:

`in` = 1
`out` = 0
`buffer[0]` = itemB
`buffer[1]` = uninitialized

Producer A

- `buffer[in] = itemA;`
-
-
- `in = (in + 1) % BUFLEN;`

Producer B

-
- `buffer[in] = itemB;`
- `in = (in + 1) % BUFLEN;`
-

Race condition in shared memory

Without appropriate measures (**future lecture**), preemption can lead to errors.

Consider two producers running the previous code simultaneously:

`in` = 2
`out` = 0
`buffer[0]` = itemB
`buffer[1]` = uninitialized

Producer A

- `buffer[in] = itemA;`
-
-
- `in = (in + 1) % BUFLEN;`

Producer B

-
- `buffer[in] = itemB;`
- `in = (in + 1) % BUFLEN;`
-

Race condition in shared memory

Without appropriate measures (**future lecture**), preemption can lead to errors.

Consider two producers running the previous code simultaneously:

`in` = 2
`out` = 0
`buffer[0]` = itemB
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Producer A

- `buffer[in] = itemA;`
-
-
- `in = (in + 1) % BUFLEN;`

Producer B

-
- `buffer[in] = itemB;`
- `in = (in + 1) % BUFLEN;`
-

Only specific instructions are guaranteed to be executed **atomically** (not preempted).

Even within a single line the code can be preempted

Message passing

kernel provides system calls `send(link, message)` and `receive(link, &message)`

Design decisions

- fixed length or variable length messages
- unidirectional or bidirectional
- means of establishing link:
    - By process id (direct communication)
    - Parent process creates link, which child can access (e.g. ordinary pipes)
    - Via ports or file system (e.g. named pipes)
- synchronous (send/receive blocks until other process calls counterpart) or asynchronous (continue immediately)
- buffering: zero capacity, bounded capacity, unbounded capacity

Message passing

kernel provides system calls `send(link, message)` and `receive(link, &message)`

Design decisions

Producer-consumer with message passing:

Producer

```
while (true) {
  item next_produced = produce();
  send(link, next_produced);
}
```

Consumer

```
while (true) {
  item next_consumed;
  receive(link, &next_consumed);
  consume(next_consumed);
}
```

Other forms of communication

- TCP/IP connection using sockets
- Remote procedure calls and local procedure calls

We will defer discussion to the networks lecture