# Lecture 2

## Processes, threads, scheduling

# Abstractions: what is a process?

- Process definitions:
  1. an *instance of a running program*, or
  2. a process is *the context associated with a program in execution.*
- The context represents state information:
  - program variables/values, stored in the user space;
  - management information such as process ID, priority, owner, current directory, open file descriptors, etc. stored in the kernel space.
- A process performs a task of the job. There are user processes and OS processes.

# I. Process structure

- The process consists of the executable (instructions), its data, stack, other buffer memory and administrative (management, part of the context) information.

- The administrative information is mostly stored in the kernel space.

- The process has a lifecycle: the process is switching from one state to another as a consequence of kernel decisions following specific events.

# Administration: process context

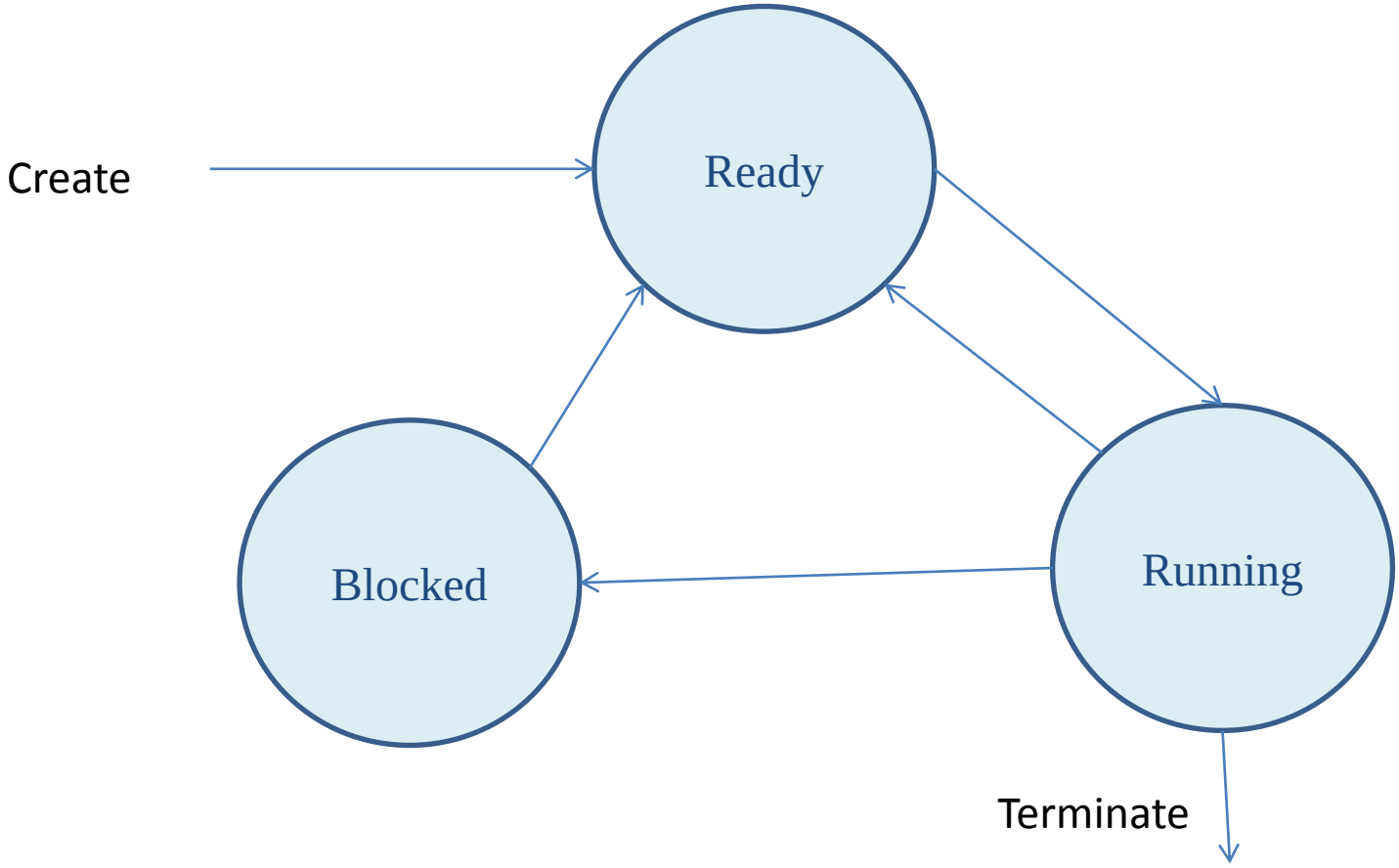
- Process ID: unique integer value
- Parent process ID
- Real user ID: the id of the user who started this process
- Effective user ID: user whose rights are carried (normally the same as above)
- Current directory: the start directory for looking up relative pathnames
- File descriptor table: table with data about all input/output streams opened by the process. It is indexed by an integer value called file descriptor.
- The environment: list of strings VARIABLE = VALUE used to customize the behaviour of certain programs.

- Code area
- Data area
- Stack
- Heap
- Priority
- Signal disposition: masks indicating which signals are awaiting delivery, which are blocked.
- Umask: mask value used to ensure that specified access permissions are not granted when this process creates a file

# Process management

- Create: the internal representation of the process is created; initial resources are allocated; initialize the program that is to run the process.
- Terminate: release all resources; possibly inform other processes of the end of this one.
- Change program: the process replaces the code it is executing (by calling exec).
- Block: wait an event, e.g., the completion of an I/O operation.
- Awaken process: after sleeping, the process can run again.
- Switch process: process context switching.
- Schedule process: takes control of the CPU.
- Set process parameters: e.g., priority.
- Get process parameters: e.g., CPU time so far

# Basic process states



# Create a child process

- A process can create a child process, identical to it, for example, by calling fork() – Unix function. As the kernel creates a copy of the caller, two processes will return from this call.
- The parent and the child will continue to execute asynchronously, competing for CPU time shares.
- Generally, users want the child to compute something different from the parent. The fork() returns the child ID to the parent, while it returns 0 to the child itself. For this reason, fork() is placed inside an *if test.*
- Example:

```
int i;
if (fork()) { /* must be the parent */
        for (i=0; i<1000; i++)
                printf("\t\t\tParent %d\n", i);
        }
        else { /* must be the child */
                for (i=0; i<1000; i++)
                        printf("Child %d\n", i);
        }
```

- Question: in what order will the two strings be printed ?

# Process genealogy

- All processes are descendents of the init process, whose PID is 1.
- The kernel starts init in the last step of the boot process.
- The init process, in turn, reads the system init-scripts and executes more programs, eventually completing the boot process.

- Every process in the system has exactly one parent.
- Likewise, every process has zero or more children.
- Processes that are all direct children of the same parent are called siblings.

# II. Thread

- A thread is known as a lightweight process; within a process we can have one (process ≡ thread) or more threads.
- All threads share the process context, including code.

- The context private to each thread is represented by the registers file and stack, the priority and own id.

- When a process starts execution, a single thread is executed, which begins executing the main() function of the program. It will continue so until new threads are created:

```
thread_create(char *stack, int stack_size, void (*func)(), void
    *arg);
```

- Generally the thread switch within the process is handled by the thread library, without calling the kernel. It is very fast as the thread context is minimum.
- Thread *affinity* (or process affinity) describes on which core the thread (or process) is allowed to run.
- For example, in Java, it’s the task of the JVM’s optimizer to ensure, that *objects affine to one thread* are placed close to each other in memory to fit into one core’s cache, but place objects affine to different threads not too close to each other to avoid that they share a cache line – avoid collision.
- The system represents affinity with a bitmask called a processor affinity mask.

- Comment: *thread affinity* forces a thread to run on a specific subset of cores and should generally be avoided, because it can interfere with the scheduler's ability to schedule threads effectively across cores.

# Advantages/disadvantages

- Threads provide concurrency in a program. This can be exploited by multi-core computers.
- Concurrency corresponds to many programs internal structure.

- If a thread changes directory, all threads in the process see the new current directory.
- If a thread closes a file descriptor, it will be closed in all threads.
- If a thread calls exit(), the whole process, including all its threads, will terminate.
- If a thread is more time consuming than others, all other threads will starve of CPU time.

# III. Purpose of scheduling

- Historically, the CPU was allocated to one process until its completion – known as batch processing. Then, the CPU was time-shared by multiple processes ready to execute.
- As CPU is time-shared, processes compete for the next available time slice.

- The scheduler is the kernel process that implements an algorithm that decides which process gets the CPU next.

- The scheduling process needs to be fair to all processes.
- Processes ready to execute are organized in a queue from where the scheduler selects the next one to run.
- A process takes control of the CPU by having its state restored, after the state of the previous process is saved.

# Scheduling strategies: first-come first-served / round-robin

- FCFS is the simplest algorithm: processes are getting CPU control in their order in the ready-to-execute queue.
- One possibility is to have the control of the CPU until the process finishes - non-preemptive execution. This may lead to starvation of other processes.
- Therefore, the best solution is to time-share the CPU.
- If a process is not finished during its time slice, it will be returned at the end of the queue.

- Other possibilities to be switched from the running state are:
  - an I/O operation that will put the process in the blocked queue;
  - it suspends itself until a certain event occurs;
  - a higher priority process requires control.

# Example: shortest process first

- If the CPU is not time-shared, the order in which processes are scheduled is important.
- Processes can be ordered according to their execution time.
- If processes get control in the increasing value of their execution time, the average turnaround time is better than in the random order.
- The *turnaround time* is the time consumed from the moment the process is ready for execution until its completion.

- Example: 3 processes, a(40), b(60), c(20); Tat: average turnaround time

Ta = 40, Tb = 100, Tc = 120  Tat = (Ta + Tb + Tc)/3 = 260/3

In increasing value of execution time:

Tc = 20, Ta = 60, Tb = 120,  Tat =200/3

# Conclusions

- Processes and threads are the main execution abstractions managed by the kernel.
- The thread switch is much faster than the process switch.
- The scheduler is the kernel process that decides which process will take control of the CPU in the next time slice.