Project: Process and Resource Manager

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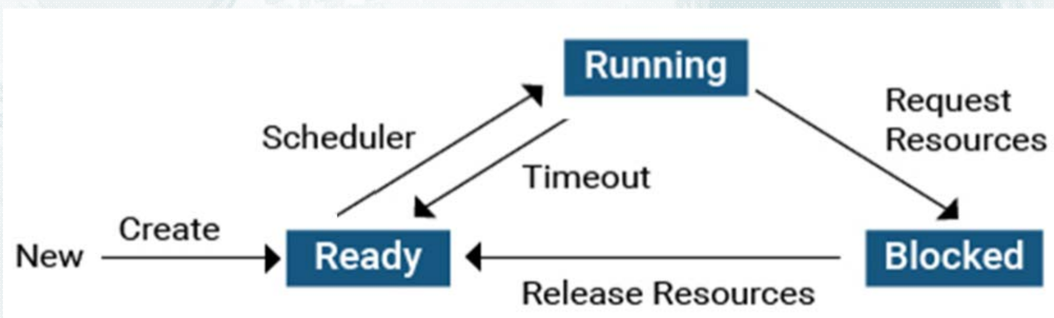
Project Overview

- **Basic Manager** supports
  - data structures to represent and manage processes and resources
  - operations invoked by processes to:
    - create and destroy processes
    - request and release resources
  - timeout function to mimic preemptive scheduling
- Presentation shell allows testing without actual processes and hardware
- **Extended manager**
  - resources can have multiple identical units
  - processes have different priorities and are scheduled accordingly

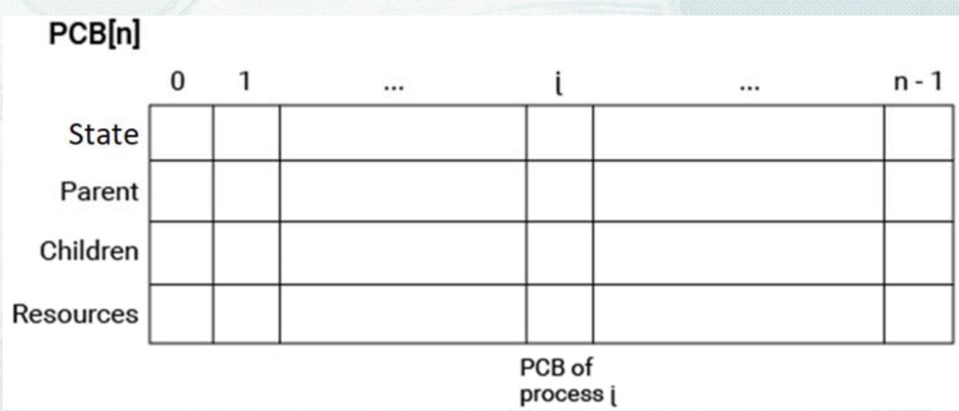
2.1 Process States

- A process can be in one of three states: **ready, running, blocked**
- Possible state transitions:

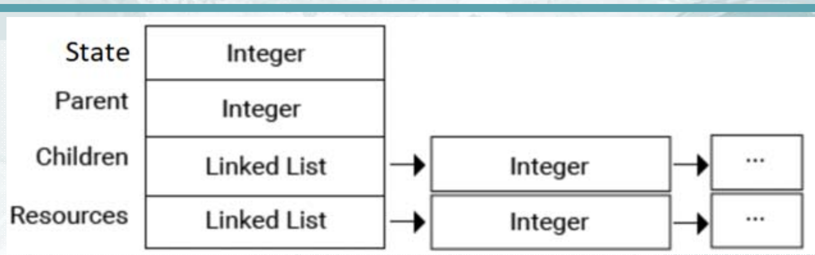


2.2 Representation of Processes

- Each process is represented by a **process control block (PCB)**
- PCBs are organized as a fixed-size array, PCB[n]
- Each process is uniquely identified by the PCB index



PCB[i] in basic manager version



- **State**: *running* state can be implicit: head of ready list
  - *ready* and *blocked* are implemented explicitly: integer or binary (1 and 0)
- **Parent**: index of process that created process i
- **Children**: linked list of processes that process i has created
  - each element contains index of child process
- **Resources**: linked list of resources that process i is currently holding
  - each element contains the index of a resource

Lists of processes

- Manager maintains all PCBs on one of several lists:
  - **blocked** processes: kept on **waiting lists** associated with resources
  - **ready** processes: kept on a **Ready List (RL)**
- Basic manager version:
  - all processes have the **same priority**
  - RL is organized as a **single linked list** of PCB indices
- At system **initialization**:
  - process 0 is created automatically and becomes the first running process
  - all other processes are created and destroyed at run time

Process creation

Currently running process, i, can create a new child process, j, using the function:

create()
  allocate new PCB[j]
  state = ready
  insert j into list of children of i
  parent = i
  children = NULL
  resources = NULL
  insert j into RL
  display: "process j created"

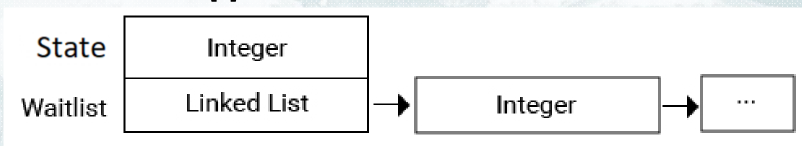
Process destruction

- Currently running process, i, can destroy a child process, j, or itself (i = j)
- The function also recursively destroys all of j's descendants
  - reason for destroying entire subtree: avoid orphan processes

destroy(j)
  for all k in children of j destroy(k)
  remove j from parent's list of children
  remove j from RL or waiting list
  release all resources of j
  free PCB of j
  display: "n processes destroyed"

2.4 Representation of Resources

- System supports a fixed set of resources created at system initialization
- Any process may request, acquire, and later release a resource
- When a resource is unavailable, the requesting process becomes blocked
- Each resource is represented by a **resource control block (RCB)**
- RCBs are organized as a fixed-size array, RCB[m], analogous to PCBs
- Each resource RCB[r] has the form:



- State: free or allocated (1 and 0)
- Waitlist: linked list of processes blocked on the resource

Requesting a resource

Currently running process, i, may request any of the resources, r, at any time:

```
request(r)
    if state of r is free
        state of r = allocated
        insert r into list of resources of process i
        display: “resource r allocated”
    else
        state of i = blocked
        move i from RL to waitlist of r
        display: “process i blocked”
        scheduler()
```

Releasing a resource

Currently running process, i, may release any of the resources, r, it is holding:

```
release(r)
    remove r from resources list of process i
    if waitlist of r is empty
        state of r = free
    else
        move process j from the head of waitlist of r to RL
        state of j = ready
        insert r into resources list of process j
    display: "resource r released"
```

2.6 Time-Sharing

- Basic manager version: all processes have the **same priority**
  - RL is a single linked list of PCBs accessed in FIFO order
  - process at the head of the RL is the currently running process
- System mimics **preemptive scheduling** by a function timeout()

```
timeout()
    move process i from head of RL to end of RL
    scheduler()
```

- New process, j, now at the head of the RL becomes the running process
- Repeatedly invoking timeout mimics time-sharing

Scheduler

- Scheduler performs **context switch** from currently running process i to a new process j
- Scheduler is called whenever:
  - process i blocks on a resource and is removed from RL
  - timeout function moves the process to the end of the RL
- In a real system, context switch:
  - saves CPU state of running process i
  - loads CPU state of a new process j
- In this project we do not have physical CPU to save and restore registers
  - scheduler only displays which process is currently running
  - user terminal begins to play the role of currently running process

```
scheduler()
    find process i currently at the head of RL
    display: "process i running"
```

2.7 System Initialization

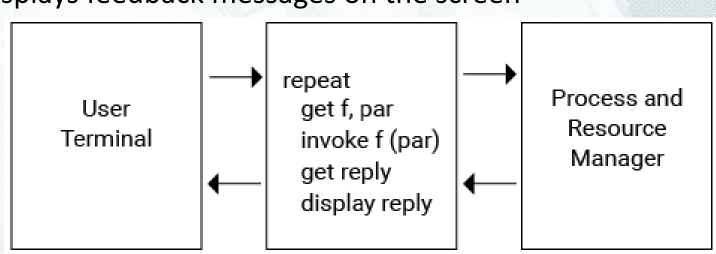
- When system starts, create data structures PCB[n], RCB[m], RL
- In addition to the functions create, destroy, request, release, timeout: implement *init()* function:
  - all PCB entries are initialized to free except PCB[0]
  - PCB[0] is a running process with no parent, no children, and no resources
  - all RCB entries are initialized to free
  - RL contains process 0
- *init* allows continuous testing of the system without having to repeatedly terminate and restart the program

Error Handling

- Functions must implement checks to detect **illegal/unexpected operations**
- Examples:
  - Creating more than n processes
  - Destroying a process that is not a child of the current process
  - Requesting a nonexistent resource
  - Requesting a resource the process is already holding
  - Releasing a resource the process is not holding
  - Process 0 should be prevented from requesting any resource to avoid deadlock where no process is on the RL
- In each case, the corresponding function should display “error” (e.g. -1)

3. The Presentation Shell

- We do not have access to CPU, hardware interrupts, or executable process code
- **Presentation shell:** allows testing and demonstration of manager
  - repeatedly accepts commands from user terminal
  - invokes corresponding manager function
  - displays feedback messages on the screen



- user terminal represents the currently running process
- user terminal also represents the hardware: timeout function is an interrupt

Shell syntax

Shell command	Function
cr	create()
de <i>	destroy(i)
rq <r>	request(r)
rl <r>	release(r)
to	timeout()
in	init()

Example of shell session

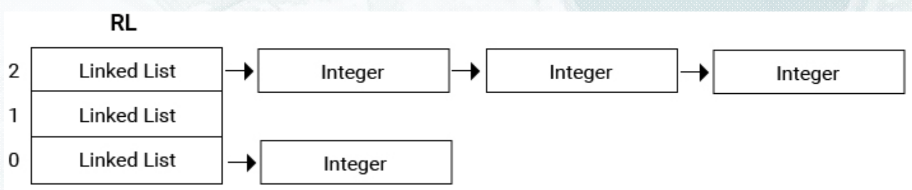
…
* process 5 running
> cr
* process 6 created
> rq 3
* resource 3 allocated
> to
* process 6 running
> rq 3
* process 6 blocked
* process 5 running

> de 6
* 1 process destroyed
> rl 2
* error
> in
* process 0 running
…

Exact output format will be specified on course page

4.1 Multilevel Scheduling

- Each process has a fixed **priority**, represented by a positive integer
- RL is extended to segregate processes into FIFO lists according to priorities
- Each list element contains PCB index of the corresponding process
- For this project, RL has 3 priority levels
- **Example**:



- Initially:
  - lowest level, 0, contains 1 process (process 0)
  - priority levels 1 and 2 are empty

Extensions to basic manager

- **PCBs**:
  - new field, ***priority***, is included in each PCB: 0, 1, or 2
- **Functions:**
  - ***create*** function must accept priority value, p, as an argument: *create(p)*
    - p is stored in the priority field of the new PCB
    - process is entered at the corresponding level in RL
  - some functions must call ***scheduler*** at the end:
    - ***create****:* context switch if new process has higher priority than current
    - ***release****:* context switch if *release* unblocks a higher-priority process
    - ***delete****:* context switch if a deleted process releases a resource on which a higher-level process is blocked

Extensions to basic manager (cont)

scheduler()
find highest priority ready process j
display: "process j running"

- j: head of highest-priority non-empty list (RL)
- real scheduler may perform context switch
- implicit in our case:
  - if currently running process is still the head of the highest-priority list: no context switch
  - if any function has changed the head of that list: context switch

- **Shell:**
  - cr command must accept priority value: cr p
  - additional error checks to deal with priority, e.g., priority > 3 or < 0

4.2. Multiunit Resources

- Each resource is extended to have multiple identical units
- Thus each RCB represents a *class* of resources
- For this project assume 4 resources:
  - Resources 0 and 1 have 1 unit each
  - Resource 2 has 2 units
  - Resource 3 has 3 units

Extensions to basic manager

- **RCBs:**
  - new field, ***inventory***, indicates initial number of units (1, 2, or 3)
  - ***state***: integer counter, to keep track of how many units are still available
  - ***waitlist:*** each element contains process index and number of units requested
- **Functions:**
  - ***request****:* accept resource index and number of requested units: *request(r, k)*
    - check whether a sufficient number of units is available
    - partial allocation of units should not be supported
  - ***release****:* accept resource index and number of released units: *release(r, k)*
    - executes a loop to unblock zero, one, or more processes from waitlist
    - example: releasing 2 units of resource 3 could enable 0, 1, or 2 processes

Extensions to basic manager (cont)

- **Shell:**
  - commands rq and rl must accept resource index and number of units: "rq r k" and "rl r k"
  - error checks:
    - number of units requested + number already held ≤ initial inventory
      - prevent blocking a process forever
    - number of units released ≤ number of units currently held

5. Summary of Specific Tasks

- Design and implement the **extended** version of the manager:
  - PCB, RCB, and RL data structures
  - functions *create(), destroy(), request(), release(), timeout(), scheduler(), init()*
- Design and implement the shell
- Instantiate manager to include the following at start-up:
  - A process descriptor array PCB[16]
  - A resource descriptor array RCB[4] with multiunit resources
  - A ready list RL with 3 priority levels (0, 1, 2)
- Test the manager using a variety of command sequences to explore all aspects

Example 1

Command	Running
in	0
cr 1	1
cr 1	1
rq 0 1	1
to	2
rq 1 1	2
rq 0 1	1
rq 1 1	0
de 1	0
to	0