

## Implementation of Memory Module of Operating System

Our memory management module implements a **paging** scheme with fixed-size frames, supporting dynamic allocation, non contiguity and FIFO-based replacement when memory is exhausted. It simulates process arrivals and departures, and tracking internal fragmentation.

### Total Memory (KB) and Page Size (KB)

The user inputs the total main memory and the page size. From these, the number of frames is computed as

$num\_frames = page\_size / total\_memory$ .

### Process Parameters

- Arrival time
- Total size in KB
- Duration (execution time).

```
typedef struct {
    int pid;
    int arrival_time;
    int size;
    int num_pages;
    int duration;
    int departure_time;
    int allocated_count;
    int allocated_frames[MAX_FRAMES];
} Process;
```

Up to 100 processes are supported. For each process:

**PID** is assigned sequentially.

**Number of Pages** =  $\lceil size / page\_size \rceil$

**Internal Fragmentation** per process is computed as the unused portion of the last page

### Frames :

```
typedef struct {
    int pid;
    int page_number;
    int next_free;
} Frame;
```

### Memory Management Technique:

We generate arrival and departure events for each process, sort them using **Quick Sort Algorithm**, and then step through in chronological order.

On arrival, we allocate as many free frames as the process needs; if we run out, we repeatedly dequeue from the FIFO queue, count an eviction, and reassign that frame. We record each allocated frame in the process's table and enqueue it for future replacement.

On a **departure**, we walk through the process's allocated frames, clear their metadata, push them back onto the free list, and remove them from the FIFO queue implicitly by marking them free.

### Paging Type:

Fixed-size paging with frame allocation in main memory; there is no backing store evicted pages are simply discarded

### Replacement:

When no free frames remain, the oldest allocated frame is evicted. This simulates the FIFO page replacement algorithm.

### Internal Fragmentation Tracking:

We accumulate the unused bytes in the last page of each process to report total internal fragmentation at the end of the simulation.

### Data structures

Structure	Purpose	Time Complexity
Frame frames[]	Array of all physical frames	O(1) access
Free-list (int free_list_head)	Singly-linked list of free frames via next_free field	push/pop: O(1)
FIFO Queue (queue[])	Circular buffer of recently-allocated frames for replacement	enqueue/dequeue: O(1) amortized

Process procs[]	Array storing per-process metadata	O(1) access
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**Processes.txt**

```
Log: Show Apex Log Analysis
1  0 32 2
2  0 12 4
3  3 11 3
4  3 12 4
5  5 6 2
6  5 10 5
7  9 13 3
8  9 7 2
9  8 3 1
10 9 4 4
```

**Output Snapshots**  
(Attached)

```
• laiba@laiba-Lenovo-V14-G3-IAP:~/OS-CEP/code$ ./memoryAllocModule
Enter total memory (KB): 32
Enter page size (KB): 4
```

```
=====
TIME 0 Process Arrival
=====
```

```
→ P1 needs 8 pages
```

```
Process 1 fully allocated.
```

```
[000]:P1 Pg0 [001]:P1 Pg1 [002]:P1 Pg2 [003]:P1 Pg3
[004]:P1 Pg4 [005]:P1 Pg5 [006]:P1 Pg6 [007]:P1 Pg7
```

```
=====
TIME 0 Process Arrival
=====
```

```
→ P2 needs 3 pages
```

```
Evicting frame 000 (P1 Pg0)
Evicting frame 001 (P1 Pg1)
Evicting frame 002 (P1 Pg2)
```

```
Process 2 fully allocated.
```

```
[000]:P2 Pg0 [001]:P2 Pg1 [002]:P2 Pg2 [003]:P1 Pg3
[004]:P1 Pg4 [005]:P1 Pg5 [006]:P1 Pg6 [007]:P1 Pg7
```

```
=====
TIME 2 Process Termination
=====
```

```
→ Freeing 8 pages of P1
```

```
[000]:P2 Pg0 [001]:P2 Pg1 [002]:P2 Pg2 [003]: Free
[004]: Free [005]: Free [006]: Free [007]: Free
```

```
=====
TIME 3 Process Arrival
=====
```

```
→ P3 needs 3 pages
```

```
Process 3 fully allocated.
```

```
[000]:P2 Pg0 [001]:P2 Pg1 [002]:P2 Pg2 [003]: Free
[004]: Free [005]:P3 Pg2 [006]:P3 Pg1 [007]:P3 Pg0
```

```
=====
TIME 3 Process Arrival
=====
```

```
→ P4 needs 3 pages
```

```
Evicting frame 007 (P3 Pg0)
```

```
Process 4 fully allocated.
```

```
[000]:P2 Pg0 [001]:P2 Pg1 [002]:P2 Pg2 [003]:P4 Pg1
[004]:P4 Pg0 [005]:P3 Pg2 [006]:P3 Pg1 [007]:P4 Pg2
```

```
=====
TIME 4 Process Termination
=====
```

```
→ Freeing 3 pages of P2
```

[000]: Free [001]: Free [002]: Free [003]:P4 Pg1  
[004]:P4 Pg0 [005]:P3 Pg2 [006]:P3 Pg1 [007]:P4 Pg2

=====

**TIME 5 Process Arrival**

=====

→ P5 needs 2 pages

Process 5 fully allocated.

[000]: Free [001]:P5 Pg1 [002]:P5 Pg0 [003]:P4 Pg1  
[004]:P4 Pg0 [005]:P3 Pg2 [006]:P3 Pg1 [007]:P4 Pg2

=====

**TIME 5 Process Arrival**

=====

→ P6 needs 3 pages

Evicting frame 006 (P3 Pg1)  
Evicting frame 005 (P3 Pg2)

Process 6 fully allocated.

[000]:P6 Pg0 [001]:P5 Pg1 [002]:P5 Pg0 [003]:P4 Pg1  
[004]:P4 Pg0 [005]:P6 Pg2 [006]:P6 Pg1 [007]:P4 Pg2

=====

**TIME 6 Process Termination**

=====

→ Freeing 3 pages of P3

[000]:P6 Pg0 [001]:P5 Pg1 [002]:P5 Pg0 [003]:P4 Pg1  
[004]:P4 Pg0 [005]:P6 Pg2 [006]:P6 Pg1 [007]:P4 Pg2

=====

**TIME 7 Process Termination**

=====

→ Freeing 3 pages of P4

[000]:P6 Pg0 [001]:P5 Pg1 [002]:P5 Pg0 [003]: Free  
[004]: Free [005]:P6 Pg2 [006]:P6 Pg1 [007]: Free

=====

**TIME 7 Process Termination**

=====

→ Freeing 2 pages of P5

[000]:P6 Pg0 [001]: Free [002]: Free [003]: Free  
[004]: Free [005]:P6 Pg2 [006]:P6 Pg1 [007]: Free

=====

**TIME 8 Process Arrival**

=====

→ P9 needs 1 pages

Process 9 fully allocated.

[000]:P6 Pg0 [001]:P9 Pg0 [002]: Free [003]: Free  
[004]: Free [005]:P6 Pg2 [006]:P6 Pg1 [007]: Free

=====

Process 9 fully allocated.

[000]:P6 Pg0 [001]:P9 Pg0 [002]: Free [003]: Free  
[004]: Free [005]:P6 Pg2 [006]:P6 Pg1 [007]: Free

=====

TIME 9 Process Termination

=====

→ Freeing 1 pages of P9

[000]:P6 Pg0 [001]: Free [002]: Free [003]: Free  
[004]: Free [005]:P6 Pg2 [006]:P6 Pg1 [007]: Free

=====

TIME 9 Process Arrival

=====

→ P7 needs 4 pages

Process 7 fully allocated.

[000]:P6 Pg0 [001]:P7 Pg0 [002]:P7 Pg1 [003]:P7 Pg3  
[004]: Free [005]:P6 Pg2 [006]:P6 Pg1 [007]:P7 Pg2

=====

TIME 9 Process Arrival

=====

→ P8 needs 2 pages

Evicting frame 001 (P7 Pg0)

Process 8 fully allocated.

[000]:P6 Pg0 [001]:P8 Pg1 [002]:P7 Pg1 [003]:P7 Pg3  
[004]:P8 Pg0 [005]:P6 Pg2 [006]:P6 Pg1 [007]:P7 Pg2

=====

TIME 9 Process Arrival

=====

→ P10 needs 1 pages

Evicting frame 001 (P8 Pg1)

Process 10 fully allocated.

[000]:P6 Pg0 [001]:P10 Pg0 [002]:P7 Pg1 [003]:P7 Pg3  
[004]:P8 Pg0 [005]:P6 Pg2 [006]:P6 Pg1 [007]:P7 Pg2

=====

TIME 10 Process Termination

=====

→ Freeing 3 pages of P6

[000]: Free [001]:P10 Pg0 [002]:P7 Pg1 [003]:P7 Pg3  
[004]:P8 Pg0 [005]: Free [006]: Free [007]:P7 Pg2

=====

TIME 11 Process Termination

=====

→ Freeing 2 pages of P8

[000]: Free [001]:P10 Pg0 [002]:P7 Pg1 [003]:P7 Pg3  
[004]: Free [005]: Free [006]: Free [007]:P7 Pg2

```
[000]: Free [001]:P10 Pg0 [002]:P7 Pg1 [003]:P7 Pg3  
[004]: Free [005]: Free [006]: Free [007]:P7 Pg2
```

```
=====
```

**TIME 12 Process Termination**

```
=====
```

→ Freeing 4 pages of P7

```
[000]: Free [001]:P10 Pg0 [002]: Free [003]: Free  
[004]: Free [005]: Free [006]: Free [007]: Free
```

```
=====
```

**TIME 13 Process Termination**

```
=====
```

→ Freeing 1 pages of P10

```
[000]: Free [001]: Free [002]: Free [003]: Free  
[004]: Free [005]: Free [006]: Free [007]: Free
```

```
=====
```

Total allocations: 22  
Total evictions: 8  
Total processes handled: 10  
Total internal fragmentation: 10 KB  
Average frames per process: 2.20

```
=====
```

o laiba@laiba-Lenovo-V14-G3-IAP:~/OS-CEP/code\$ █