R

بسم الله الرحمن الرحیم

سیستم عامل

جلسه شانزدهم – الگوریتم‌های جایگزینی صفحه (۱)

جلسه‌ی گذشته

مدیریت حافظه – حافظه‌ی مجازی

Virtual Memory

- **Virtual memory** – separation of user logical memory from physical memory
  - *Only part of the program needs to be in memory for execution*
  - *Logical address space can therefore be much larger than physical address space*
  - *Allows address spaces to be shared by several processes*
  - *Allows for more efficient process creation*
  - *More programs running concurrently*
  - *Less I/O needed to load or swap processes*

Page Sharing in Fork System Call

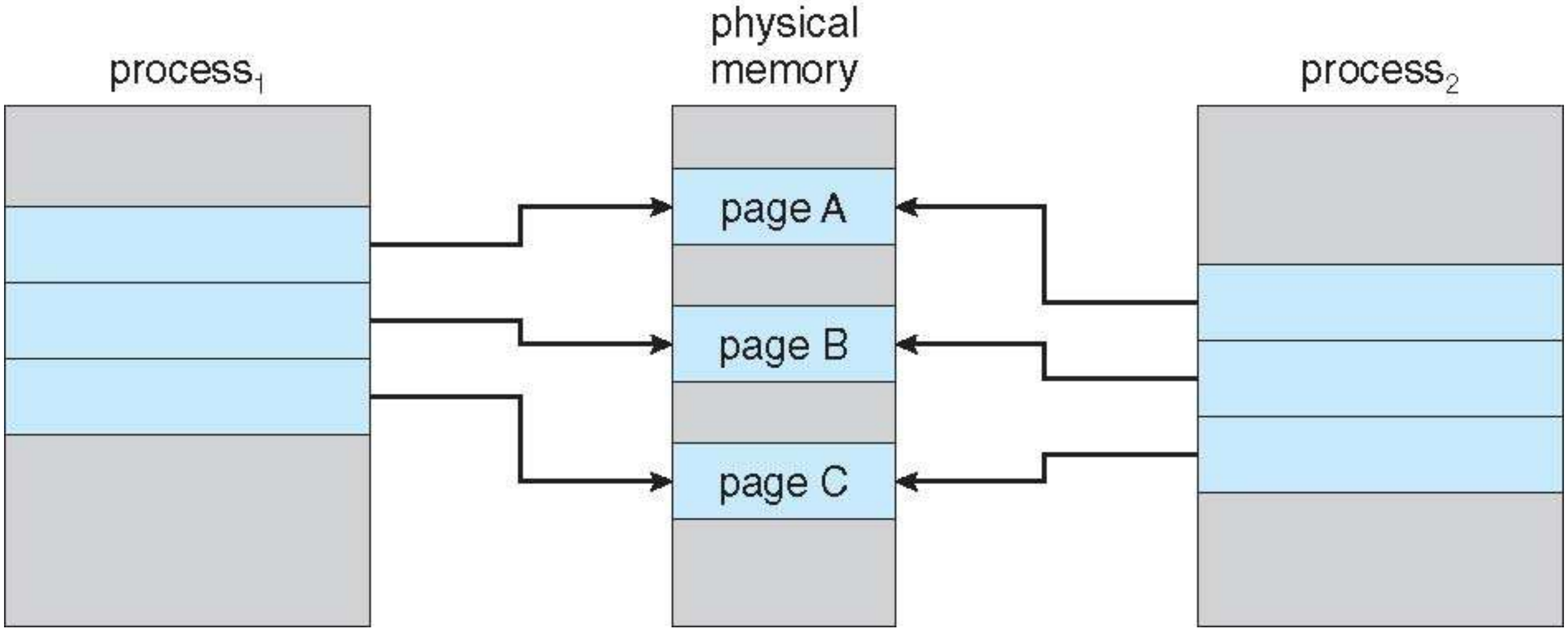
- Normal usage: copy the parent’s virtual address space and immediately do an “Exec” system call
  - *Exec overwrites the calling address space with the contents of an executable file (ie a new program)*
- Desired Semantics:
  - *Pages are copied, not shared*
- Observations
  - *Copying every page in an address space is expensive!*
  - *Processes can’t notice the difference between copying and sharing unless pages are modified!*

Copy-on-Write Page Sharing

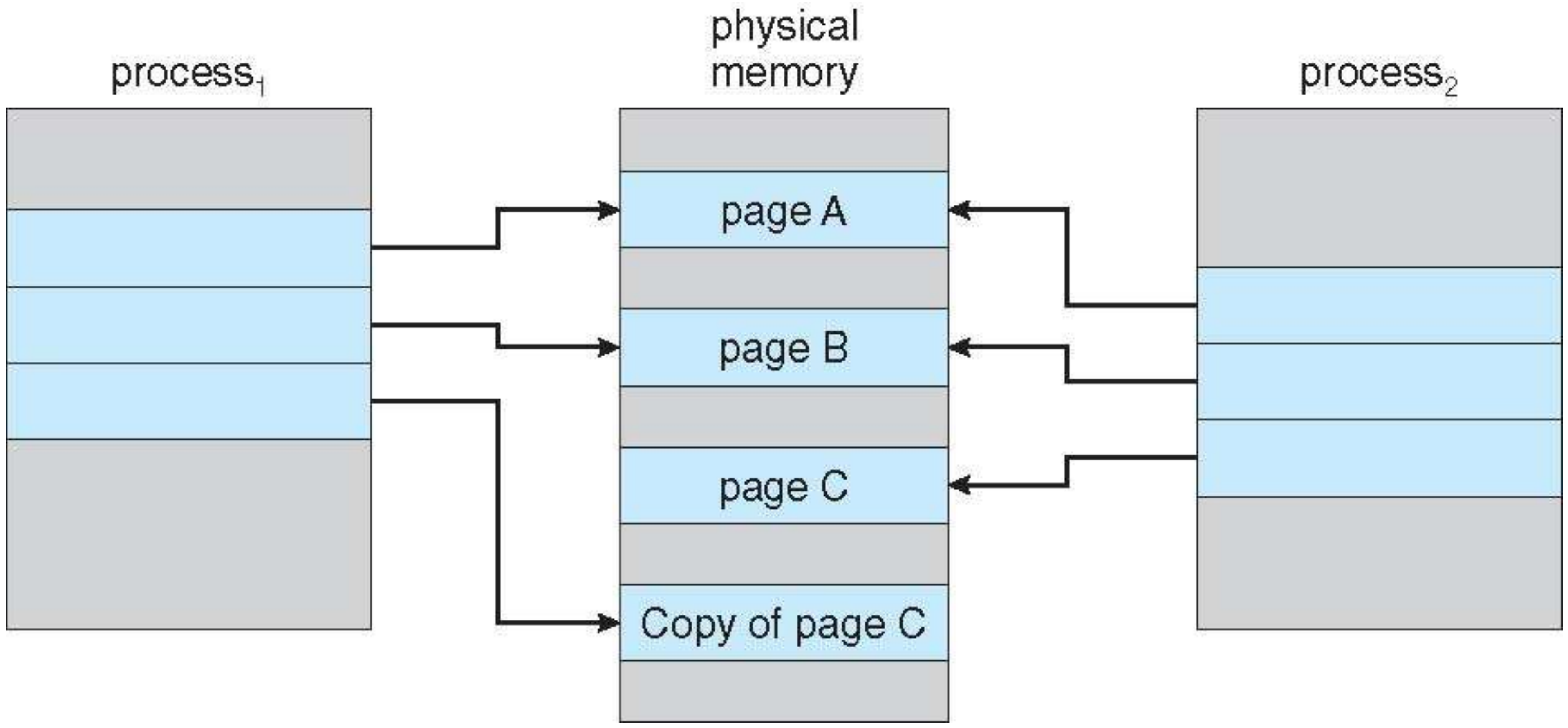
- Initialize new page table, but point entries to existing page frames of parent, i.e. share pages
- Temporarily mark all pages "read-only"
- Continue to share all pages until a protection fault occurs
- Protection fault (copy-on-write fault):
  - *Is this page really read only or is it writable but temporarily protected for copy-on-write?*
  - *If it is writable, copy the page, ~~mark both copies writable~~, resume execution as if no fault occurred*

فقط copy مخصوص پردازه‌ای که تلاش کرده بنویسه writable می‌شود.
همچنین سیستم عامل در یک داده‌ساختار مجزا خارج از page table اطلاعات مختص به page sharing را نگه می‌دارد،
در این داده‌ساختار یک شمارنده که هر صفحه‌ی اشتراک گذاشته‌شده، متعلق به چند پردازه است نیز وجود دارد و اگر
این عدد ۱ بود، صفحه را کپی نمی‌کند.

Before Process 1 Modifies Page C



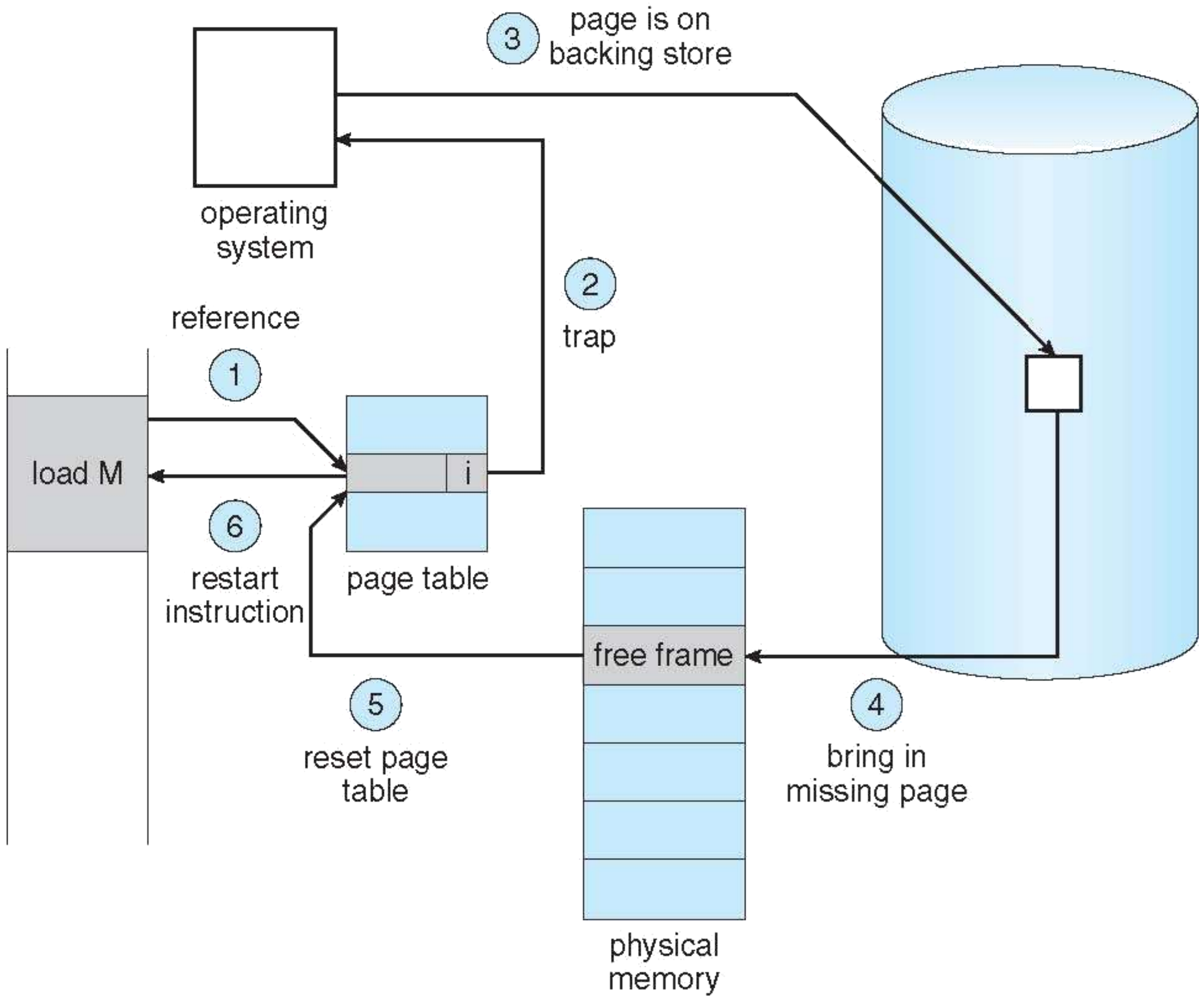
After Process 1 Modifies Page C



Virtual Memory Implementation

- When is the kernel involved?
  - *Process creation*
  - *Process is scheduled to run*
  - *A fault occurs*
  - *Process termination*

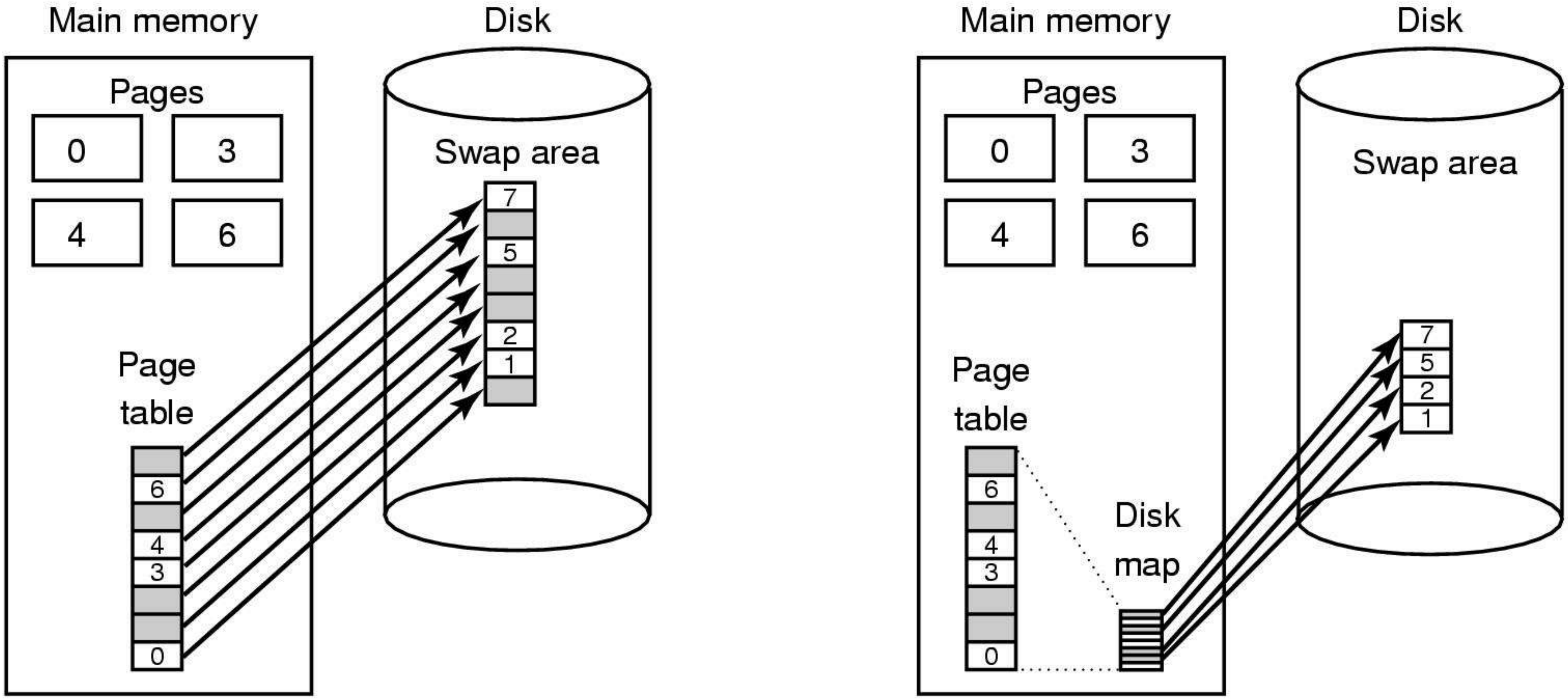
Handling a Page Fault



Managing the Swap Area on Disk

- ***Approach #1:***
- A process starts up
  - *Assume it has N pages in its virtual address space*
- A region of the swap area is set aside for the pages
- There are N pages in the swap region
- The pages are kept in order
- For each process, we need to know:
  - *Disk address of page 0*
  - *Number of pages in address space*
- Each page is either...
  - *In a memory frame*
  - *Stored on disk*

Approach #2



(a) (b)

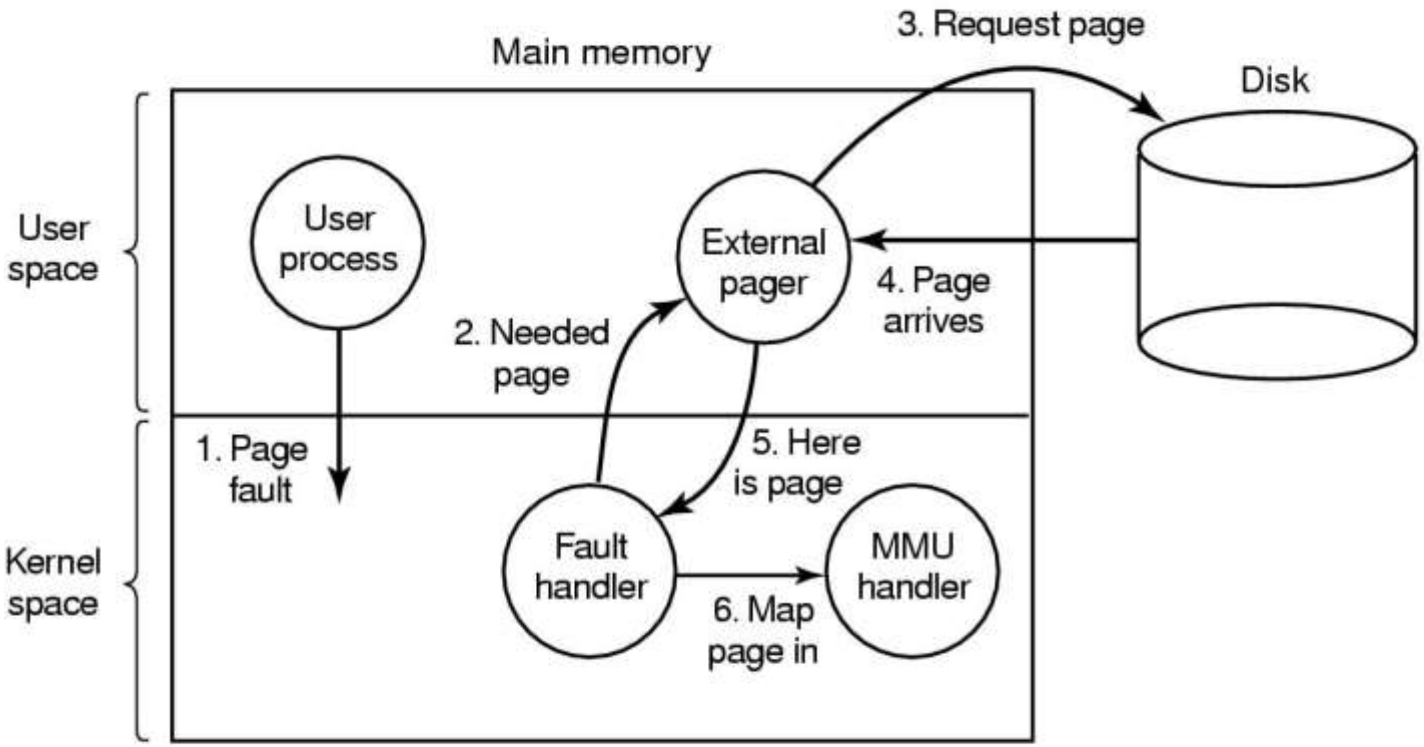
Approach #3

- Swap to a file
  - *Each process has its own swap file*
  - *File system manages disk layout of files*

Approach #4

- Swap to an external pager process (object)
- A user-level external pager determines policy
  - *Which page to evict*
  - *When to perform disk I/O*
  - *How to manage the swap file*
- When the OS needs to read in or write out a page it sends a message to the external pager
  - *Which may even reside on a different machine*

Approach #4


3. Request page
Main memory
Disk
User space
User process
External pager
4. Page arrives
2. Needed page
1. Page fault
5. Here is page
Kernel space
Fault handler
MMU handler
6. Map page in

Mechanism vs Policy

- Kernel contains
  - *Code to interact with the MMU*
    - This code tends to be *machine dependent*
    - *Mechanism*
  - *Code to handle page faults*
    - This code tends to be *machine independent* and may embody generic operating system policies
    - Policy

جلسه‌ی جدید

Page replacement algorithms

کارایی صفحەبندی

Paging Performance

- Paging works best if there are plenty of free frames
- If all pages are full of dirty pages…
  - *we must perform 2 disk operations for each page fault*
  - *This doubles page fault latency*
- It can be a good idea to periodically write out dirty pages in order to speed up page fault handling delay

Paging Daemon

- Paging daemon
  - *A kernel process*
  - *Wakes up periodically*
  - *Counts the number of free page frames*
  - *If too few, run the page replacement algorithm...*
    - Select a page & write it to disk
    - Mark the page as clean
  - *If this page is needed later... then it is still there*
  - *If an empty frame is needed then this page is evicted*

جایگزینی صفحه

Page Replacement

- Assume a normal page table (e.g., BLITZ)
- User-program is executing
- A *PageInvalidFault* occurs!
  - *The page needed is not in memory*
- Select some frame and remove the page in it
  - *If it has been modified, it must be written back to disk*
    - the "dirty" bit in its page table entry tells us if this is necessary
- Figure out which page was needed from the faulting addr
- Read the needed page into this frame
- Restart the interrupted process by retrying the same instruction

Page Replacement Algorithms

- Which frame to replace?
- *Algorithms?*
  - *ورودی: لیست صفحه‌هایی که در حافظه هستند.*
  - *خروجی: کدام صفحه را از حافظه خارج کنیم*
  - *هدف: کاهش تعداد page faultها*

الگوریتمی با کمینه تعداد PAGE FAULT!

The optimal page replacement algorithm

- **Idea:** Given all the data, how to find the optimal page replacement?

Time		0	1	2	3	4	5	6	7	8	9	10
Requests			c	a	d	b	e	b	a	b	c	d
Page	0	a										
Frames	1	b										
	2	c										
	3	d										
Page faults												

The optimal page replacement algorithm

- **Idea:** Given all the data, how to find the optimal page replacement?

Time		0	1	2	3	4	5	6	7	8	9	10
Requests			c	a	d	b	e	b	a	b	c	d
Page	0	a	a	a	a	a						
Frames	1	b	b	b	b	b						
	2	c	c	c	c	c						
	3	d	d	d	d	d						
Page faults							X					

The optimal page replacement algorithm

- **Idea:** Given all the data, how to find the optimal page replacement?
- **Longest Forward Distance (LFD):** Select the page that will not be needed for the longest time

LFD

- Replace the page that will not be needed for the longest
- Example:

Time		0	1	2	3	4	5	6	7	8	9	10
Requests			c	a	d	b	e	b	a	b	c	d
Page Frames	0	a	a	a	a	a						
	1	b	b	b	b	b						
	2	c	c	c	c	c						
	3	d	d	d	d	d						
Page faults							X					

LFD

- Replace the page that will not be needed for the longest
- Example:

Time		0	1	2	3	4	5	6	7	8	9	10
Requests			c	a	d	b	e	b	a	b	c	d
Page	0	a	a	a	a	a	a	a	a	a	a	
Frames	1	b	b	b	b	b	b	b	b	b	b	
	2	c	c	c	c	c	c	c	c	c	c	
	3	d	d	d	d	d	e	e	e	e	e	
Page faults							X				X	

Is LFD Optimal?

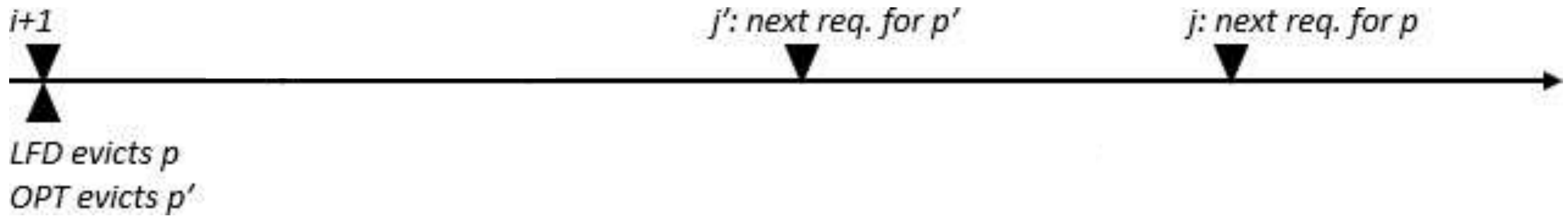
- Try to prove by contradiction…

Is LFD Optimal?

- **OPT:** Optimum with longest prefix equal to LFD
  - *First non-equal poistion: i+1*
- Case 1) i+1 is not a page fault.
  - *Is it possible?*
- Case 2) i+1 is page fault
  - *LFD evicts p*
  - *OPT evicts p’*

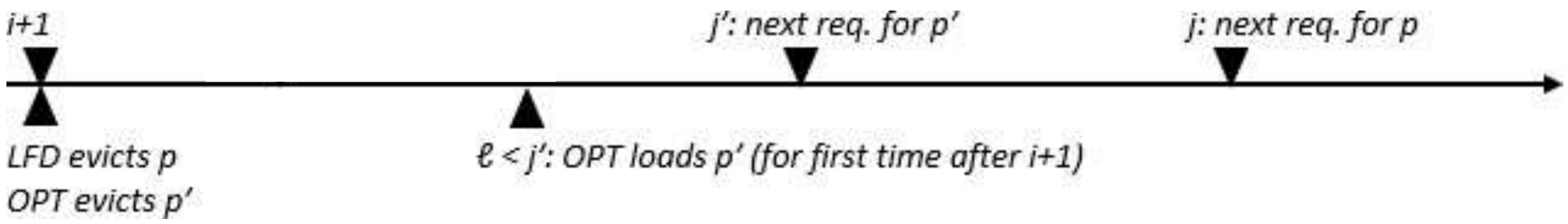
Is LFD Optimal?

- **OPT:** Optimum with longest prefix equal to LFD
  - *First non-equal poistion: i+1*
- Case 2) i+1 is page fault
  - *LFD evicts p*
  - *OPT evicts p'*



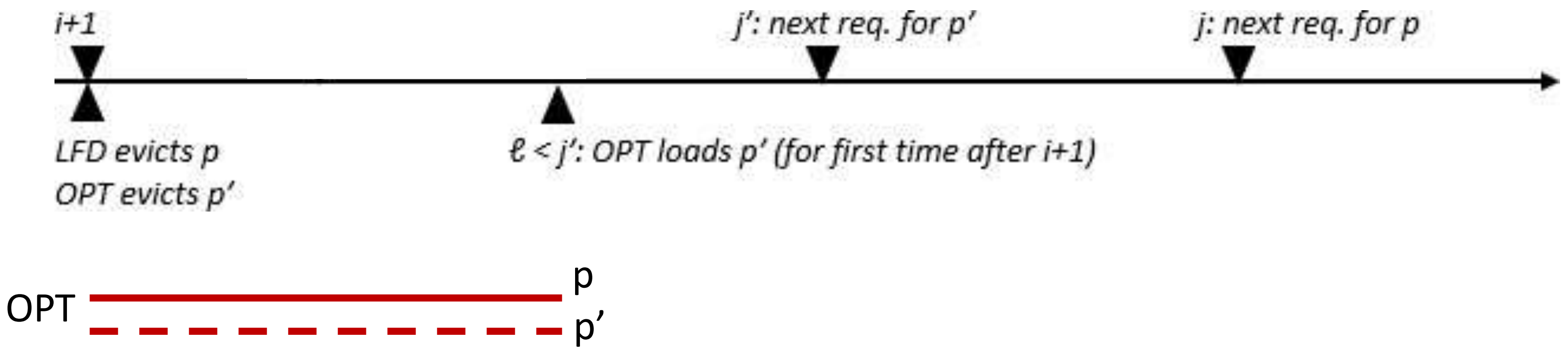
Is LFD Optimal?

- Proof (by contradiction):
  - **OPT**: Optimum with longest prefix equal to LFD Case
  - 2) i+1 is page fault
    - Case 2-A) OPT keeps p until l
    - Case 2-B) OPT evicts p at l' < l



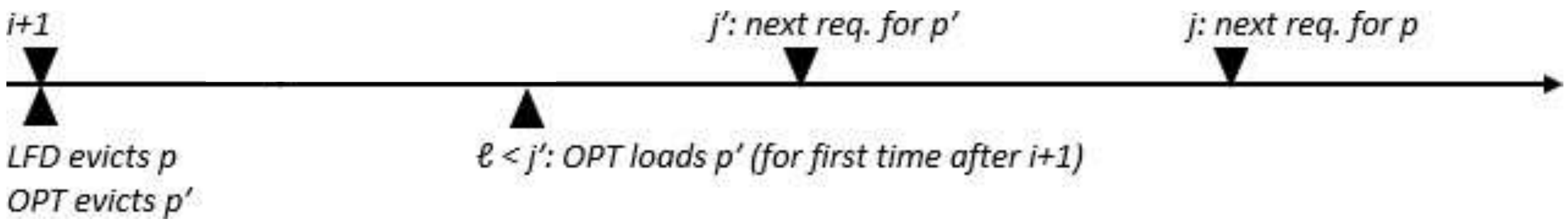
Is LFD Optimal?

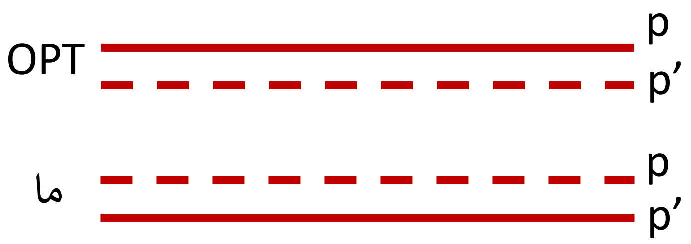
- Proof (by contradiction):
  - **OPT**: Optimum with longest prefix equal to LFD Case
  - 2) i+1 is page fault
    - Case 2-A) OPT keeps p until l
    - Case 2-B) OPT evicts p at l’ < l



Is LFD Optimal?

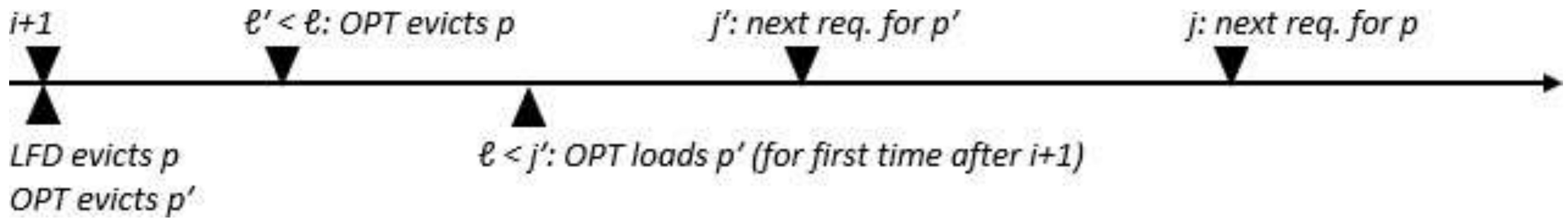
- Proof (by contradiction):
  - **OPT**: Optimum with longest prefix equal to LFD Case
  - 2) i+1 is page fault
    - Case 2-A) OPT keeps p until l
    - Case 2-B) OPT evicts p at l’ < l





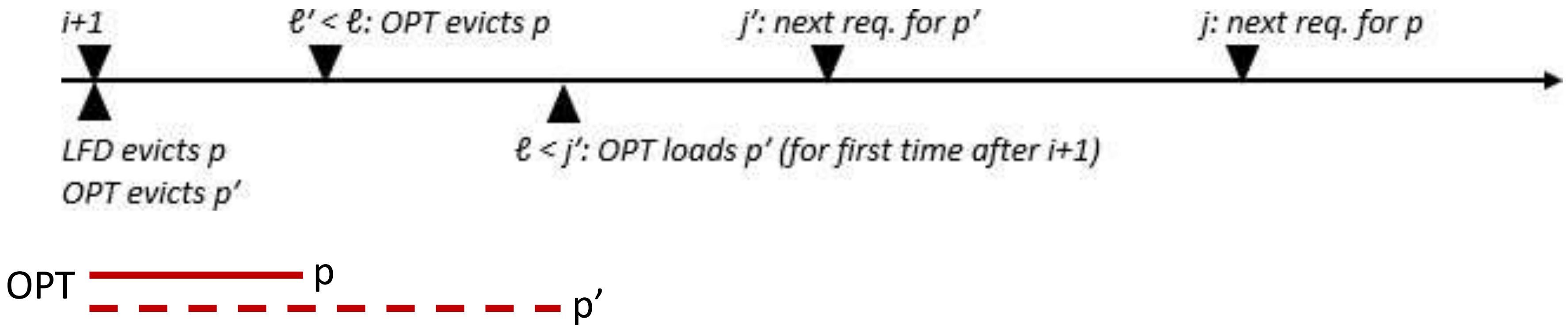
Is LFD Optimal?

- Proof (by contradiction):
  - **OPT**: Optimum with longest prefix equal to LFD Case
  - 2) i+1 is page fault
    - Case 2-A) OPT keeps p until l
    - Case 2-B) OPT evicts p at l’ < l



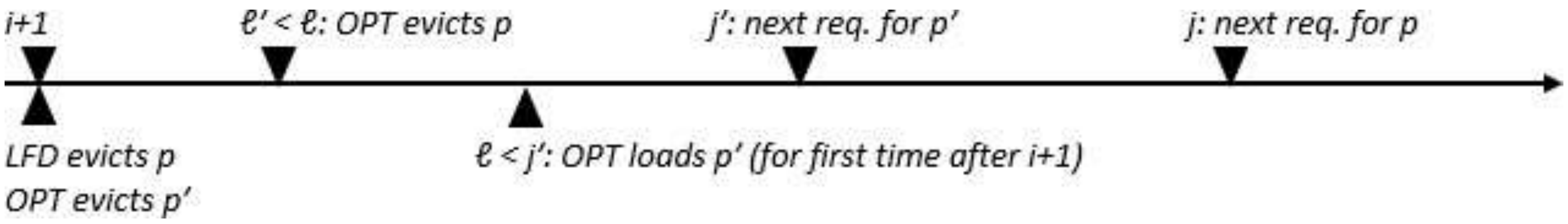
Is LFD Optimal?

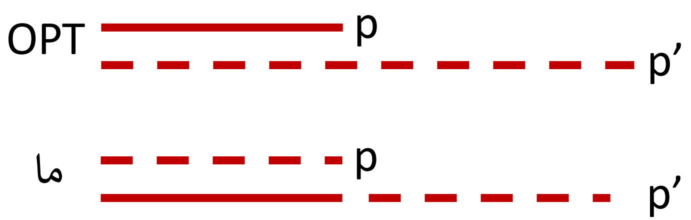
- Proof (by contradiction):
  - **OPT**: Optimum with longest prefix equal to LFD Case
  - 2) i+1 is page fault
    - Case 2-A) OPT keeps p until l
    - Case 2-B) OPT evicts p at l’ < l



Is LFD Optimal?

- Proof (by contradiction):
  - **OPT**: Optimum with longest prefix equal to LFD Case
  - 2) i+1 is page fault
    - Case 2-A) OPT keeps p until l
    - Case 2-B) OPT evicts p at l’ < l





LFD = OPT

Optimal Page Replacement

- Idea:
  - *Select the page that will not be needed for the longest time*
- Problem:
  - *Can't know the future of a program*
  - *Can't know when a given page will be needed next*
  - *The optimal algorithm is unrealizable*

Optimal Page Replacement

- However:
  - *We can use it as a control case for simulation studies*
    - Run the program once
    - Generate a log of all memory references
    - Do we need all of them?
    - Use the log to simulate various page replacement algorithms
    - Can compare others to “optimal” algorithm