CS 4410
Operating Systems

Page Replacement (1)

Summer 2016

Cornell University

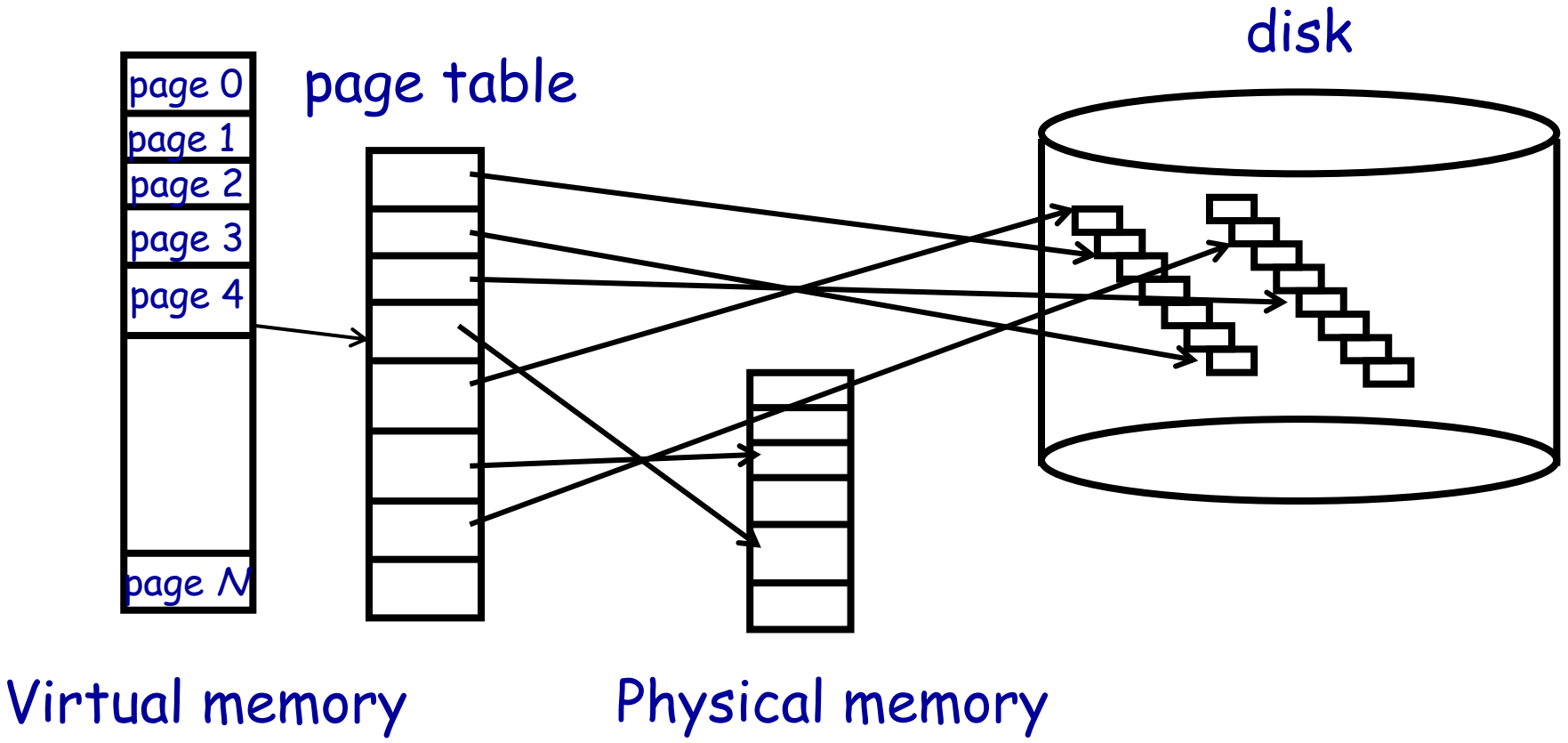
Today

- Page replacement algorithms

Virtual Memory

- Each process has the illusion of a large contiguous address space.
- However, physical memory might be much smaller than the sum of the memory request of the ready processes.
- How do we give this illusion to multiple processes?
  - With Virtual Memory, some frames may reside in disk.

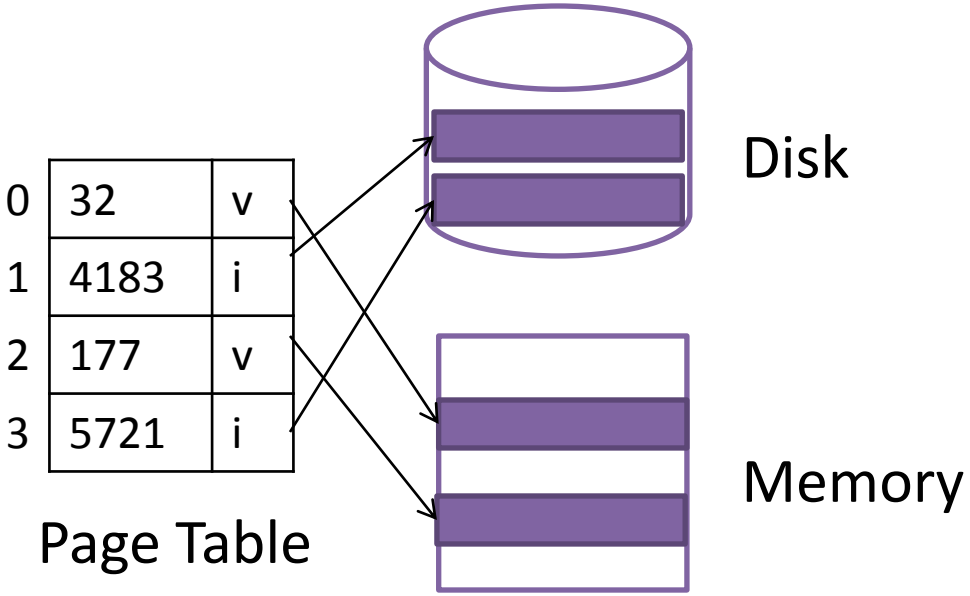
Virtual Memory



Valid bit

Extend page table entry with a valid bit :

- If page in memory, the valid bit is set to *v*, otherwise, the valid bit is set to *i.*
- If page is in memory, translation works as before.
- If page is not in memory, translation causes a **page fault.**

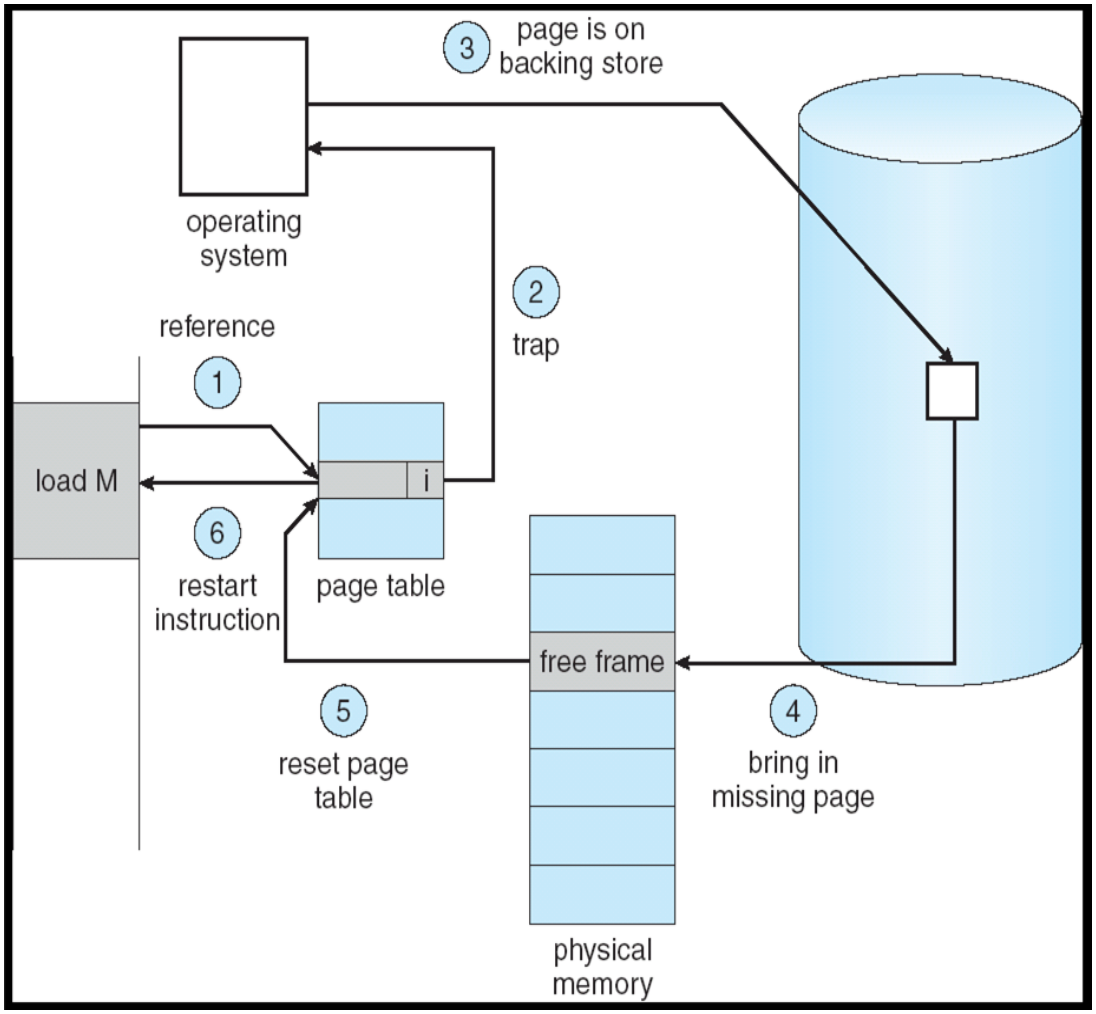


Page Fault

On a page fault:

- OS finds a **free frame**, or evicts one from memory.
- Issues disk request to **fetch data** for page.
- **Block** current process, **context switch** to new process .
- When disk completes, set **valid bit to *v***, and current process in ready queue.

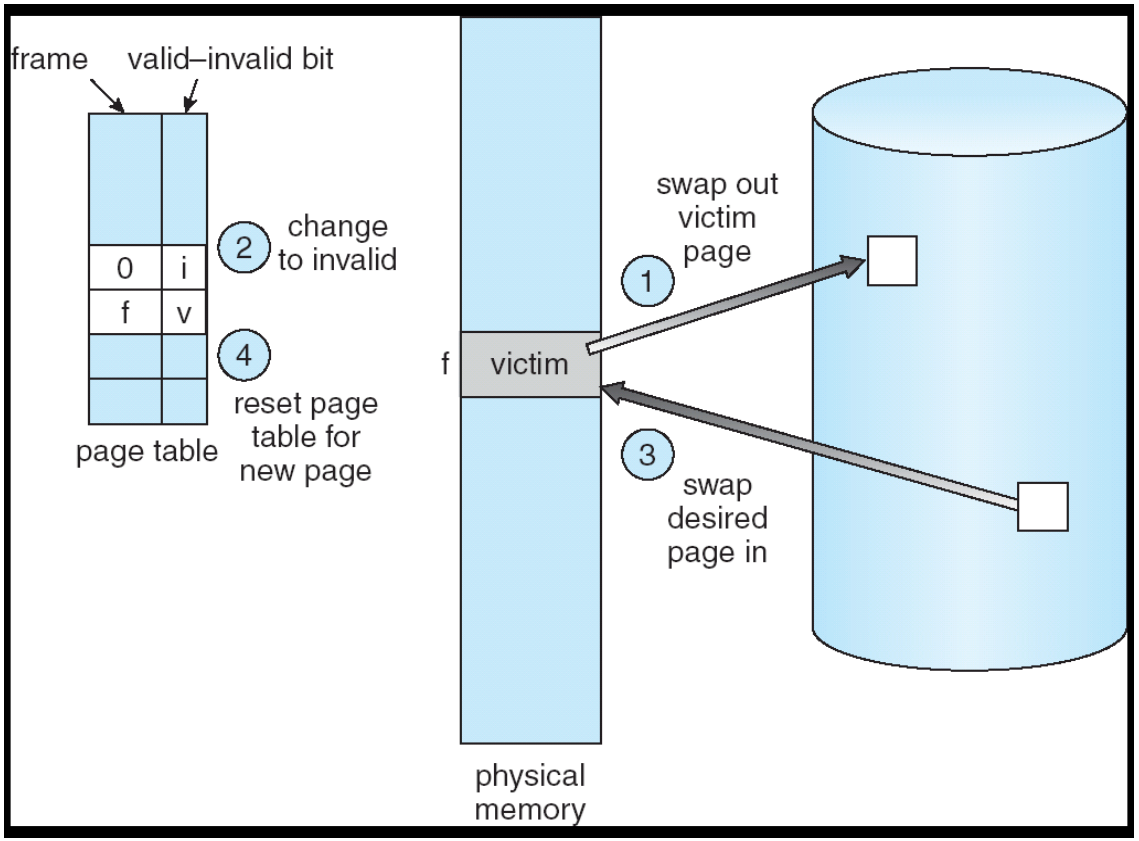
Page Fault


3
page is on
backing store
operating
system
2
trap
reference
1
load M
i
6
restart
instruction
page table
free frame
5
reset page
table
4
bring in
missing page
physical
memory

Page Replacement

- When a process has used up all frames it is allowed to use, OS must select a page to eject from memory to allow new page.
- The page to eject is selected using a Page Replacement Algorithm.

Page Replacement



Dirty Bits

- Use **dirty bit** to reduce **overhead of page transfers**.
- Only modified pages are written to disk.
- Non-modified pages can always be brought back from the original source.
  - Program code segments are rarely modified, can bring pages back from the program image stored on disk

Page Replacement Algorithms

- **FIFO**: the page brought it earliest is evicted
- **OPT**: evict page that will not be used for longest period of time
- **LRU**: evict page that has not been used the longest
- **MRU**: evict the most recently used page
- **LFU**: evict least frequently used page

FIFO

- A FIFO queue holds all pages in memory.
- The OS replaces the page at the head of the queue.
- A newly brought page is placed at the tail of the queue.

FIFO

- Reference string: 1, 2, 3, 4, 1, 2, 5, 1, 2, 3, 4, 5
- 3 frames (3 pages can be in memory at a time **per process**):

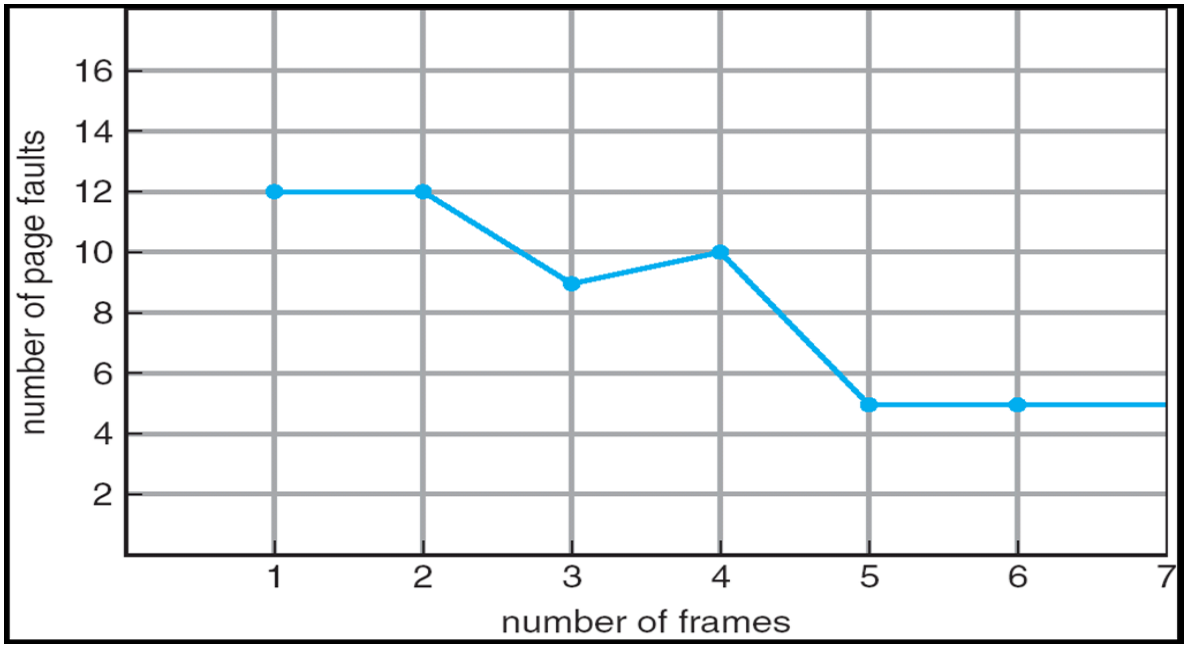
1	4	5	
2	1	3	9 page faults
3	2	4	

- 4 frames:

1	5	4	
2	1	5	10 page faults
3	2		
4	3		

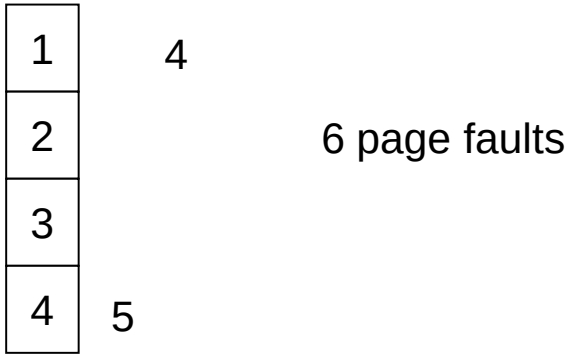
- Belady's Anomaly: sometimes, more frames → more page faults

Belady's Anomaly



Optimal Algorithm

- Replace page that will not be used for longest period of time.
- 4 frames example
- 1, 2, 3, 4, 1, 2, 5, 1, 2, 3, 4, 5



- Used for measuring how well an algorithm performs.

OPT Approximation

- In real life, we do not have access to the future page request stream of a program.
- So we need to make a best guess for which pages will not be used for the longest time.

Today

- Page replacement algorithms

Coming up…

- Next lecture: more page replacement algorithms
- HW3 is due on Monday
- Next in-class exam on Wednesday