

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD

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Lecture-28 By Vivek Dubey

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COMPUTER SCIENCE AND ENGINEERING

CS403PC

COMPUTER SCIENCE AND ENGINEERING (ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING)

CS403PC

BHARAT INSTITUTE OF ENGINEERING AND TECHNOLOGY

Scheme of Operating System

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S. No.	Course Code	Course Title	L	T	P	Credits
3	CS403PC	Operating Systems	3	0	0	3
6	CS406PC	Operating Systems Lab	0	0	3	1.5

UNIT-4: Memory Management and Virtual Memory



- **Logical versus Physical Address Space**
- **Swapping Memory,**
- **Contiguous Allocation,**
- **Paging,**
- **Segmentation,**
 - Segmentation with Paging,
 - Demand Paging,
 - Page Replacement,
 - Page Replacement Algorithms.

Concept of Paging - 1

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- There are **two different** types of computer memory;
 - Primary Memory and Secondary Memory
- **Primary storage data**
 - **is temporary** and **is frequently accessed** by applications or other hardware systems.
 - **is typically stored in random access memory (RAM)** for fast retrieval.
- **Secondary storage**
 - is where data in a computer is **kept for longer periods of time.**
 - is typically **slower than primary.**
 - example of secondary memory could be a **Solid-State Drive (SDD)**

Concept of Paging - 1

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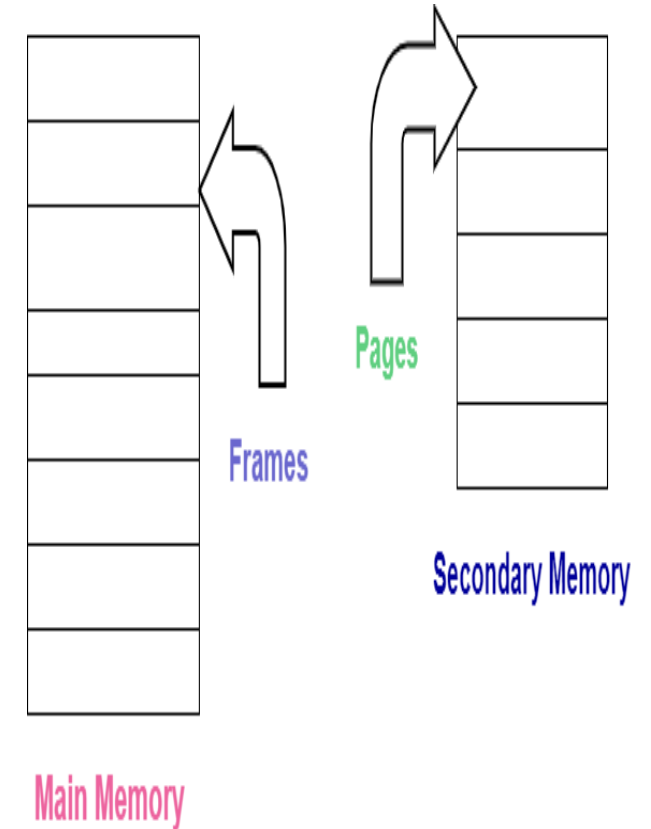


- **Paging is a function of memory management**
 - *where a computer will **store and retrieve data** from a device's secondary storage to the primary storage.*
- **Memory management** *is a fundamental aspect of any computing device, and paging specifically is important to the implementation of virtual memory.*
- **Virtual memory** is a **memory management technique**
 - *where secondary memory can be used as if it were a part of the main memory.*
- **Paging acts as an important part of virtual memory,**
 - *as it allows programs in secondary storage to exceed the available size of the physical storage.*

How paging works *a concept*



- In a memory management system that takes advantage of paging, the OS reads data from secondary storage in blocks called pages, *all of which have identical size.*
- The physical region of memory (Main Memory) containing a single page is called a frame.
- When paging is used, a frame does not have to comprise a single physically contiguous region in secondary storage.
- This paging approach offers an advantage over earlier memory management methods, because it facilitates more efficient and faster use of storage.

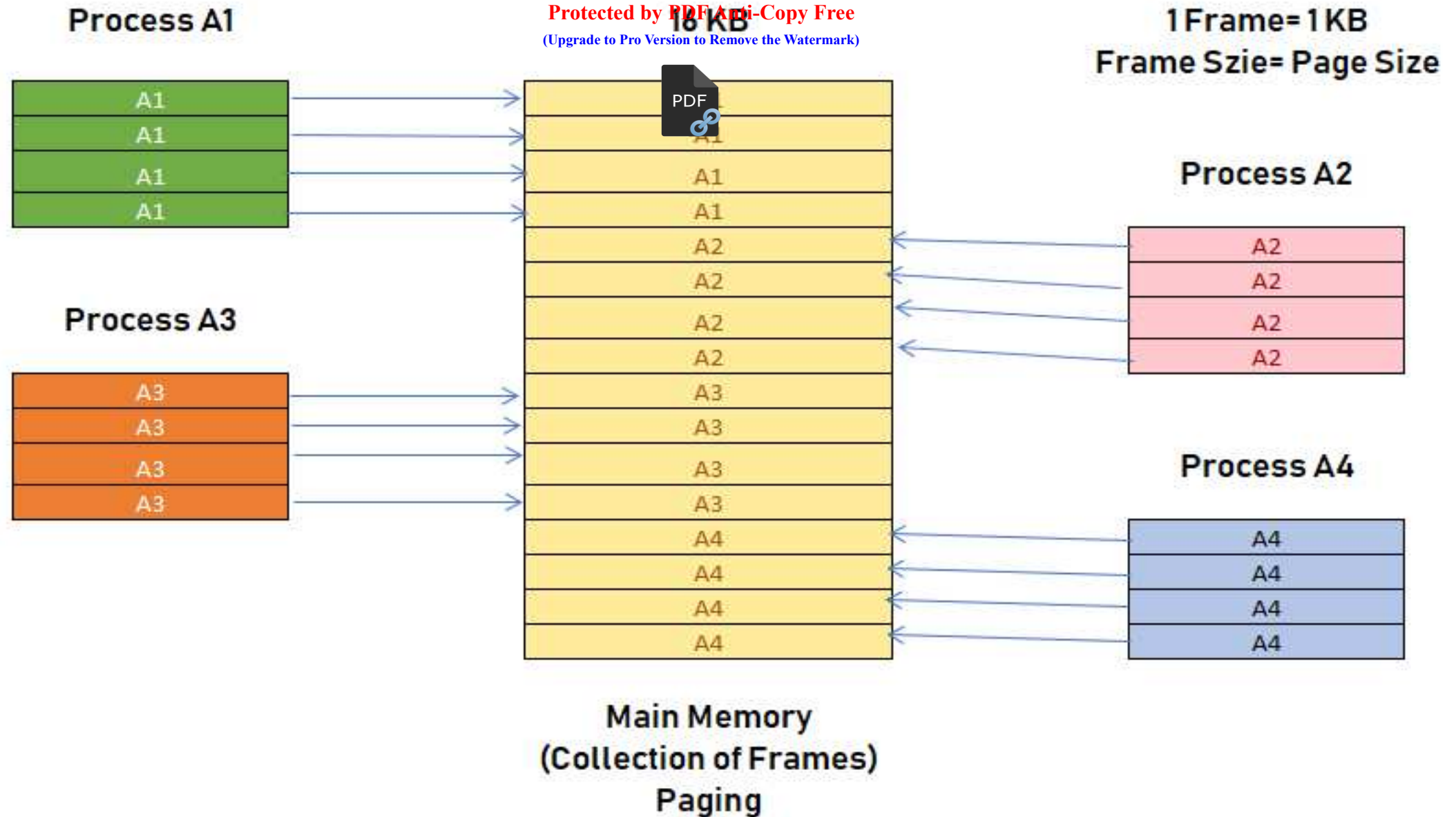


Example of Paging in OS

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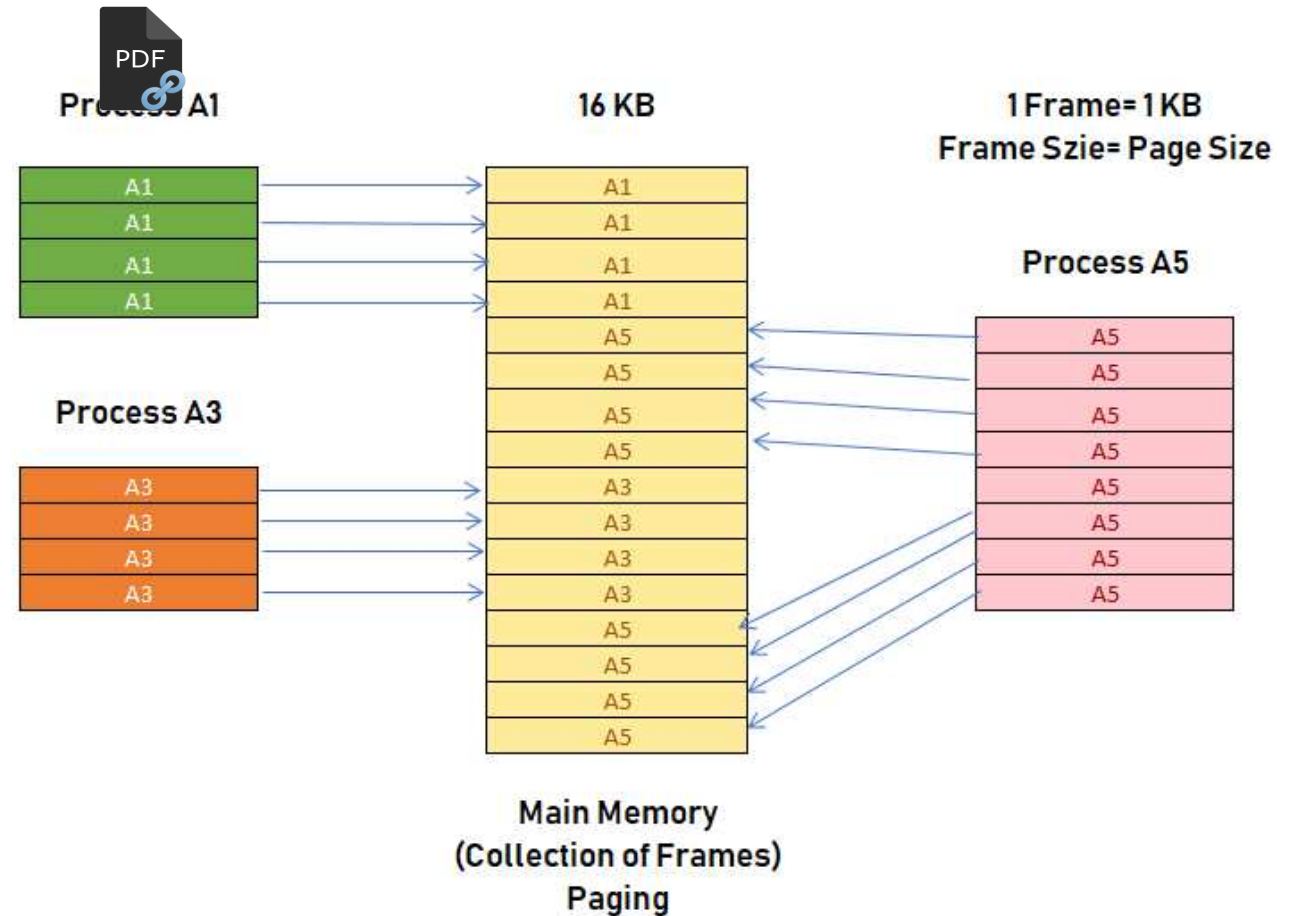


- For example, if the main memory size is 16 KB and Frame size is 1 KB. Here, the main memory will be divided into the collection of 16 frames of 1 KB each.
- There are 4 separate processes in the system that is A1, A2, A3, and A4 of 4 KB each. Here, all the processes are divided into pages of 1 KB each so that operating system can store one page in one frame.
- At the beginning of the process, all the frames remain empty so that all the pages of the processes will get stored in a contiguous way.



- In this example, now A2 and A4 are moved to the waiting state after some time.
- Therefore, eight frames become empty, and so other pages can be loaded in that empty blocks.
- The process A5 of size 8 pages (8 KB) are waiting in the ready queue.

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Advantages and Disadvantages of Paging



Advantages of Paging

- Easy to use memory management algorithm
- No need for external Fragmentation
- Swapping is easy between equal-sized pages and page frames.

Disadvantages of Paging

- May cause Internal fragmentation.
- Page tables consume additional memory.
- Multi-level paging may lead to memory reference overhead.

Technical Concept of Paging - 1



- Paging permits the **physical address space** of a process to be **non-contiguous**.
 - *is a **fixed-size partitioning scheme**.*
 - *in the Paging technique, the secondary memory and main memory are divided into equal fixed-size partitions.*
- Paging solves the **problem of fitting memory chunks of varying sizes** onto the backing store and this problem is suffered by many memory management schemes.
- Paging helps to **avoid external fragmentation** and the **need for compaction**.

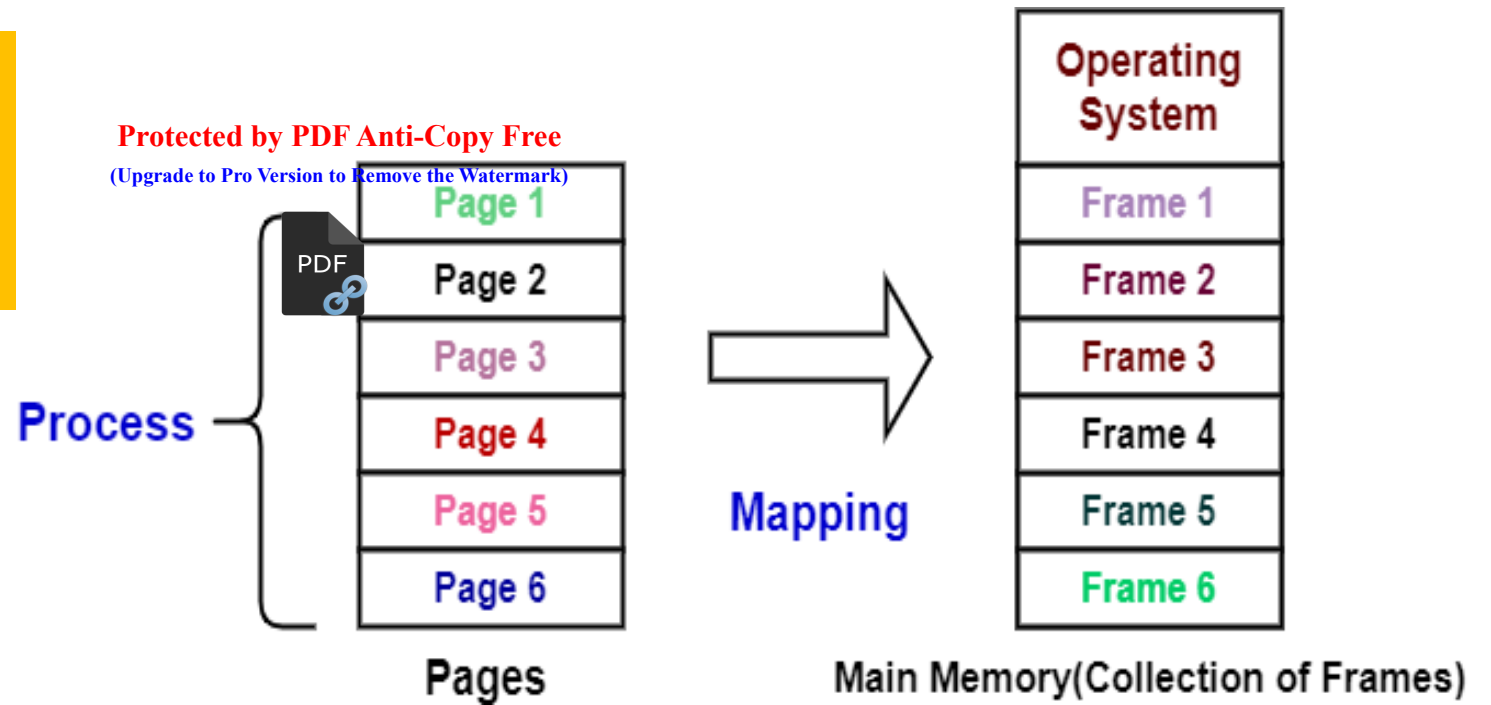
Technical Concept of Paging - 2

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- **The paging technique**
 - *divides the physical memory(main memory)* into fixed-size blocks that are known as **Frames** and
 - *also divide the logical memory(secondary memory)* into blocks of the same size that are known as **Pages**.
- **This paging technique** keeps the track of all the free frames.
 - The Frame has the same size as that of a Page.
 - A frame is basically a place where a (logical) page can be (physically) placed.

Technical Concept of Paging - 3



- Each process is mainly divided into parts where the size of each part is the same as the page size.
- There is a possibility that the size of the last part may be less than the page size.
- Pages of a process are brought into the main memory only when there is a requirement otherwise they reside in the secondary storage.
- One page of a process is mainly stored in one of the frames of the memory. Also, the pages can be stored at different locations of the memory but always the main priority is to find contiguous frames.

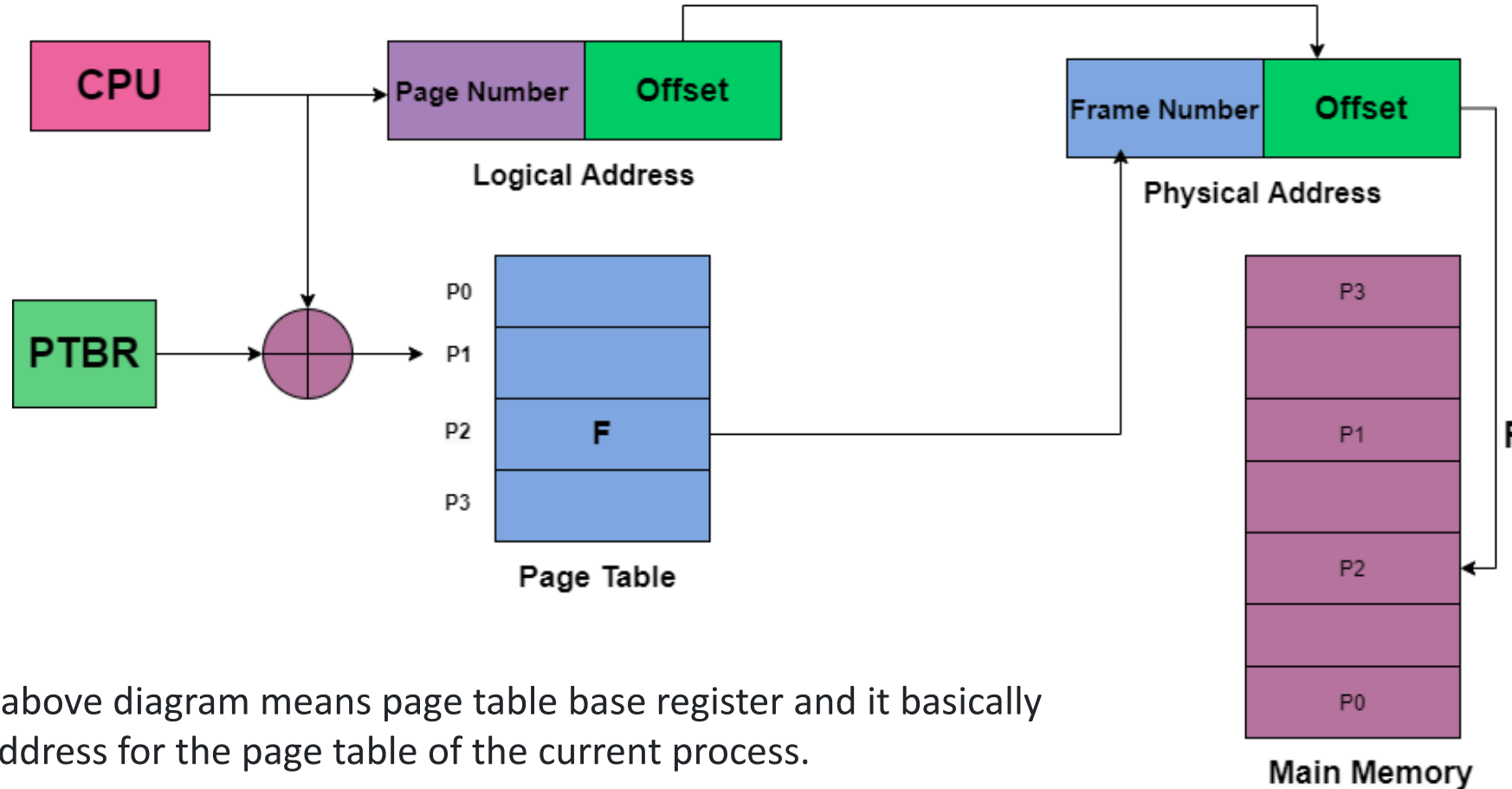
Technical Concept of Paging - 4

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- **Important points to be noted:**
 - The CPU always generates a logical address.
 - In order to access the main memory always a physical address is needed.
- The **logical address generated by CPU** always consists of two parts:
 - Page Number(p)
 - Page Offset (d)
- where,
 - **Page Number** is used to specify the specific page of the process from which the CPU wants to read the data and it is also used as an index to the page table.
 - **and Page offset** is mainly used to specify the specific word on the page that the CPU wants to read.

Translation of the Logical address into the Physical address



The **PTBR** in the above diagram means page table base register and it basically holds the base address for the page table of the current process.

Technical Concept of Paging - 5

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- The Page table mainly **contains the base address of each page** in the Physical memory. The base address is then combined with the page offset in order to define the **physical memory address** which is then sent to the memory unit.
- Thus, page table mainly provides the corresponding frame number (base address of the frame) where that page is stored in the main memory.
- The **frame number** is combined with the **page offset** and forms the **required physical address**.
- So, **The physical address consists of two parts:**
 1. Page offset(d)
 2. Frame Number(f)
- where,
 - The **Frame number** is used to indicate the specific frame where the required page is stored.
 - and **Page Offset** indicates the specific word that has to be read from that page.

Limitation in Paging in OS

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- A big challenge with paging is that if the logical address space is large, then the page table may take up a lot of space in main memory.
- For a process with a large logical address space, a lot of its page table entries are invalid as a lot of the logical address space goes unused.
- **Segmented Paging**
 - A solution to the problem is to use segmentation along with paging to reduce the size of page table. Traditionally, a program is divided into four segments, namely code segment, data segment, stack segment and heap segment.

Segmented Paging in OS

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- The size of the page table can be reduced by creating a page table for each segment. To accomplish this hardware support is required. The address provided by CPU will now be partitioned into segment no., page no. and offset.

31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0

Seg No	Page No	Offset
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Segmented Paging Techniques

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- The memory management unit (MMU) will use the segment table which will contain the address of page table(base) and limit. The page table will point to the page frames of the segments in main memory.

CODE
DATA
STACK
HEAP

Base of PT	Limit
512	64
4096	32
2048	2048
12288	1024

Segment Table

Page No
10
21
:

Page Table of Segment 0

Page No
19
52

Page Table of Segment 1

Page No
102
67
:
:

Page Table of Segment 2

Page No
96
37
:
:

Page Table of Segment 3

Advantages and Disadvantages Segmented Paging

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Advantages of Segmented Paging

1. The page table size is reduced as pages are present only for data of segments, hence reducing the memory requirements.
2. Gives a programmers view along with the advantages of paging.
3. Reduces external fragmentation in comparison with segmentation.
4. Since the entire segment need not be swapped out, the swapping out into virtual memory becomes easier .

Disadvantages of Segmented Paging

1. Internal fragmentation still exists in pages.
2. Extra hardware is required
3. Translation becomes more sequential increasing the memory access time.
4. External fragmentation occurs because of varying sizes of page tables and varying sizes of segment tables in today's systems.

Paged Segmentation in OS

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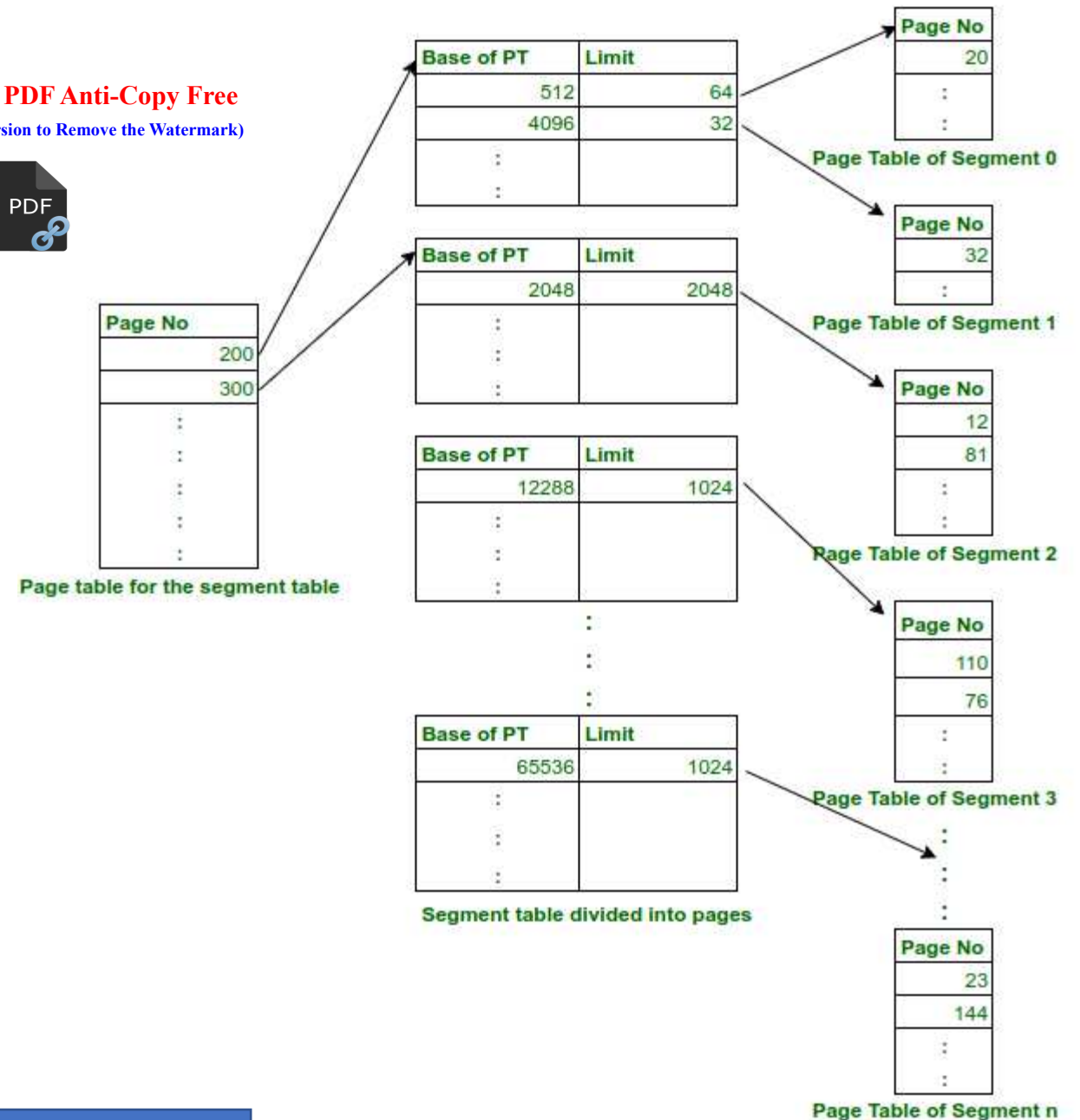
- In segmented paging, not every process has the same number of segments and the segment tables can be large in size which will cause external fragmentation due to the varying segment table sizes. To solve this problem, we use **paged segmentation** which requires the segment table to be paged. The logical address generated by the CPU will now consist of page no #1, segment no, page no #2 and offset.

Paged Segmentation Technique

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The page table even with segmented paging can have a lot of invalid pages. Instead of using multi level paging along with segmented paging, the problem of larger page table can be solved by directly applying multi level paging instead of segmented paging.



Advantages and Disadvantages of Paged Segmentation

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- **Advantages of Paged Segmentation**

1. No external fragmentation
2. Reduced memory requirements as no. of pages limited to segment size.
3. Page table size is smaller just like segmented paging,
4. Similar to segmented paging, the entire segment need not be swapped out.

- **Disadvantages of Paged Segmentation**

1. Internal fragmentation remains a problem.
2. Hardware is complexer than segmented paging.
3. Extra level of paging at first stage adds to the delay in memory access.