University Of Diyala
College Of Engineering
Computer Engineering Department

COMPUTER ARCHITECTURE II

PART 4: VIRTUAL MEMORY

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Second stage

2022-2023

FROM THE PREVIOUS LECTURE

OPTIMIZATIONS OF CACHE PERFORMANCE

1- Small and Simple First-Level Caches to Reduce Hit Time and Power

2- Way Prediction to Reduce Hit Time

3- Pipelined Cache Access to Increase Bandwidth

4- Non-blocking Caches to Increase Cache Bandwidth

5- Multi-banked Caches to Increase Cache Bandwidth

6- Critical Word First and Early Restart to Reduce Miss Penalty

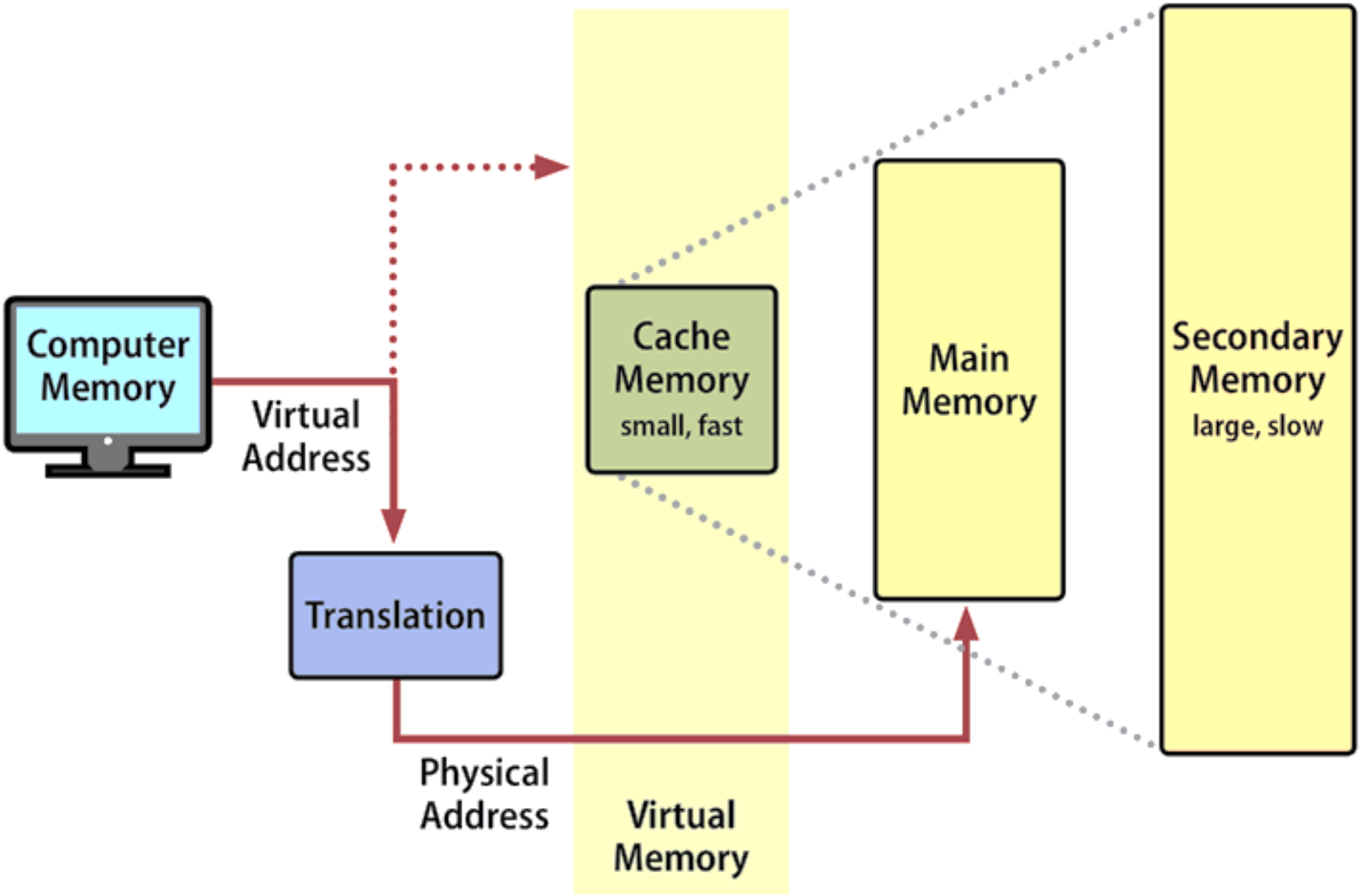
7- Merging Write Buffer to Reduce Miss Penalty

8- Complier Optimizations to Reduce Miss Rate

9- Hardware Prefetching of Instructions and Data to Reduce Miss Penalty or Miss Rate

10- Compiler-Controlled Prefetching to Reduce Miss Penalty or Miss Rate

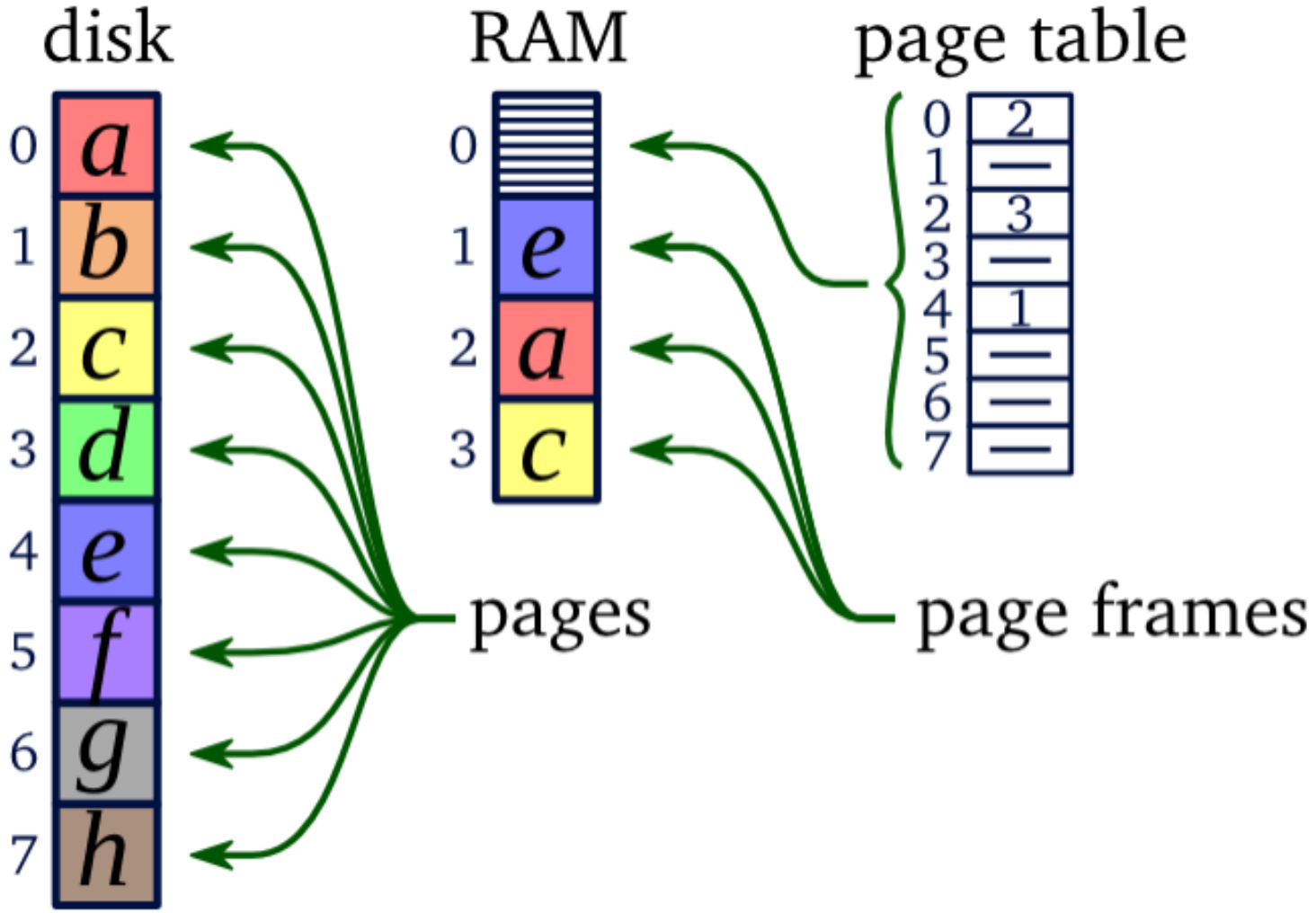
VIRTUAL MEMORY



VIRTUAL MEMORY

- **Virtual memory** is a memory management capability done by operating system (OS) using (hardware and software) to allow a computer to use physical memory shortages temporarily for transferring data from main memory to disk storage.
- A system using virtual memory uses a section of the hard drive to emulate RAM.
- Processes can be protected from one another by having their own page tables.

VIRTUAL MEMORY



ADDRESS TRANSLATION

Virtual addresses to Physical addresses

- Virtual addresses are generated by the CPU.
- Physical addresses used by main memory.
- Between the CPU and main memory there's a piece of hardware called the Memory Management Unit **(MMU)**. It's job is to translate virtual addresses to physical addresses.
- The **MMU** hardware translates virtual addresses to physical addresses using a simple table lookup. This table is called the **page map or page table.**

ADDRESS TRANSLATION

Page map or Page table

- **a bit (valid bit)** to specify weather the page is loaded into memory or not.
- **several bits (location bits)** to specify which page frame in main memory contains the page.
- **a bit (dirty bit)** to specify whether the page in memory has been updated or not. This bit is useful at the time of removing the page from memory to decide whether to store it back to disk if dirty bit is 1.
- **a bit (referenced bit)** that is set by the CPU sets when the page is accessed. This bit could be used to decide which page frame should be removed to make room for a needed page.

TRANSLATION LOOK-ASIDE BUFFER (TLB)

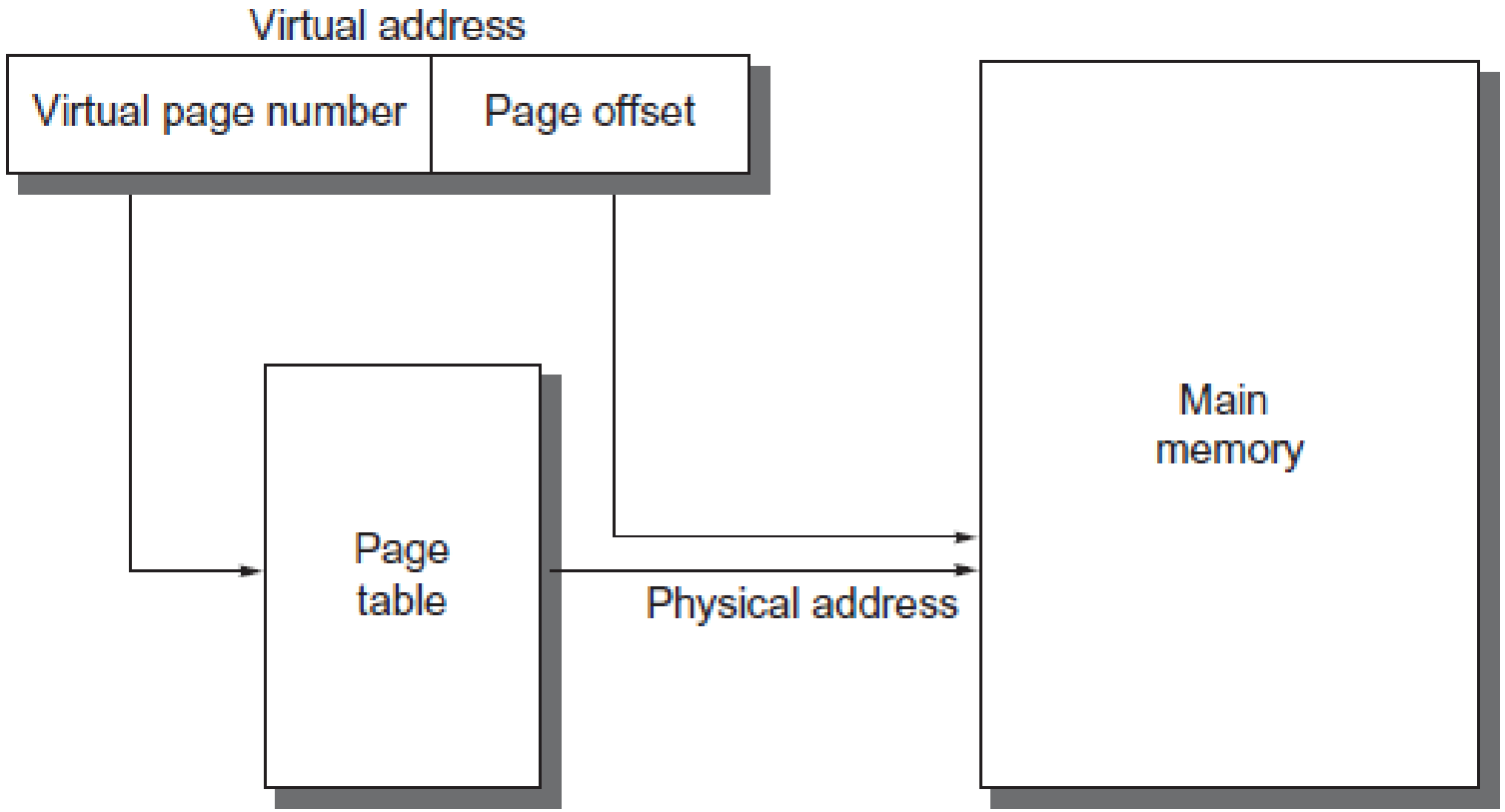


Figure B.23 The mapping of a virtual address to a physical address via a page table.

VIRTUAL MEMORY

Similarity in concept of Virtual memory and Cache memory

- **Cache memory:**
  - **Program** in main memory is broken up into **fixed-size cache blocks.**
  - Fast program is the one uses most of the blocks in the cache (few cache misses).
- **Virtual memory:**
  - **Program** on disk is broken up into **fixed-size memory pages (swap files)**.
  - Fast program is the one uses most of the pages in main memory (few page faults).

VIRTUAL MEMORY

Differences between virtual memory and cache memory

- **General description:**
  - **Cache memory** is a small high-speed memory usually Static RAM (SRAM) that contains the most recently accessed pieces of main memory.
  - **Virtual memory** can be described as the amount of physical hard drive space used to store additional memory that the RAM is unable to store.
- **Function:**
  - **Cache memory** increases the accessing speed of CPU.
  - **Virtual memory** increases the capacity of the main memory i.e increases the degree of multiprogramming.

- **Management:**
  - Cache memory is managed by the hardware.
  - Virtual memory is managed by the operating system (OS).
- **Mapping:**
  - No mapping structures are required in a cache memory.
  - Virtual memory requires mapping structures to map virtual address to physical address.
- **Advantage/Disadvantage:**
  - Cache memory lessens the amount of time to access data.
  - Virtual memory slows down the computer as it takes a lot of energy and time to access data from the hard drive to be used.

❑ Size:

- The size of cache memory is smaller (less) than that of virtual memory.
- Cache blocks are smaller than memory pages.

❑ Memory Unit:

- Cache memory can be described as a memory unit.
- Virtual memory it cannot be described as a memory unit, it’s a technique.