KARNAVATI UNIVERSITY

Operating Systems

Course Code: **71203002004**

Introduction to Memory Organization

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Memory Management in Operating System

Memory is a part of the computer that stores data, instructions, and information either temporarily (RAM) or permanently (storage).

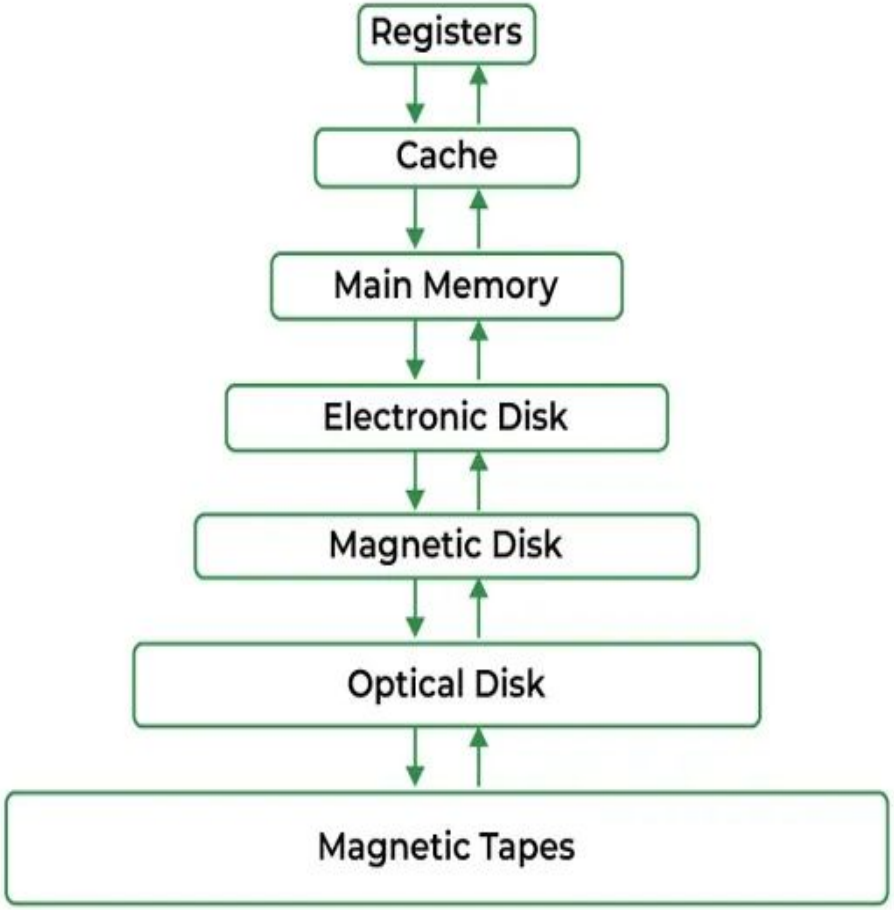
- It is divided into small units called **bytes/words**, each with a unique address.

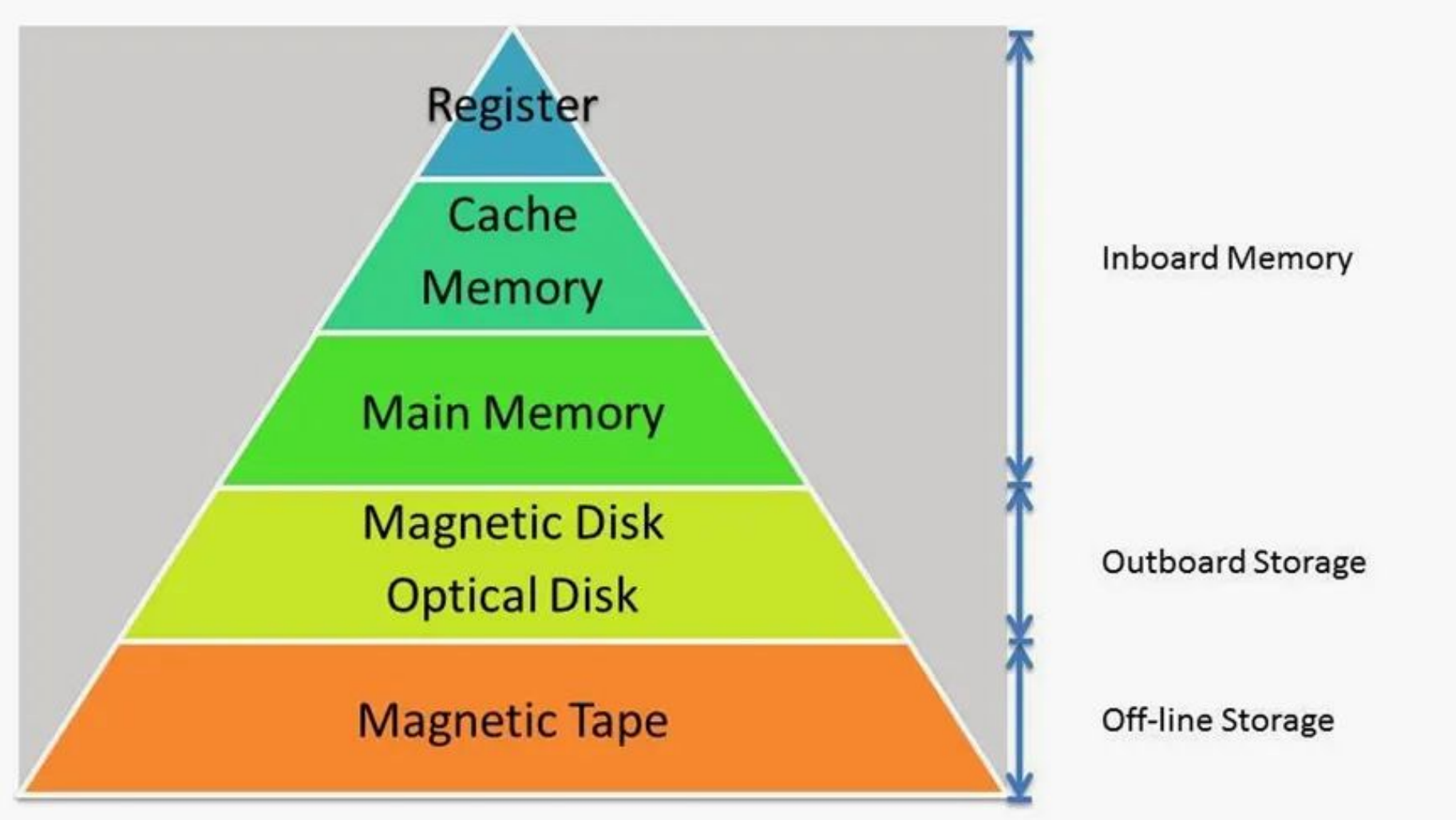
- Memory stores both the input data and the program instructions needed by the CPU.

- It works closely with the CPU to give fast access to the data being used.

Memory Management in Operating System

Memory Management is the proce by which the operating system efficiently uses memory. It decides how memory is **allocated** (given to processes) and **deallocated** (freed after use). This ensures smooth performance and stability, especiall when multiple programs run togeth




Register
Cache Memory
Main Memory
Magnetic Disk
Optical Disk
Magnetic Tape
Inboard Memory
Outboard Storage
Off-line Storage

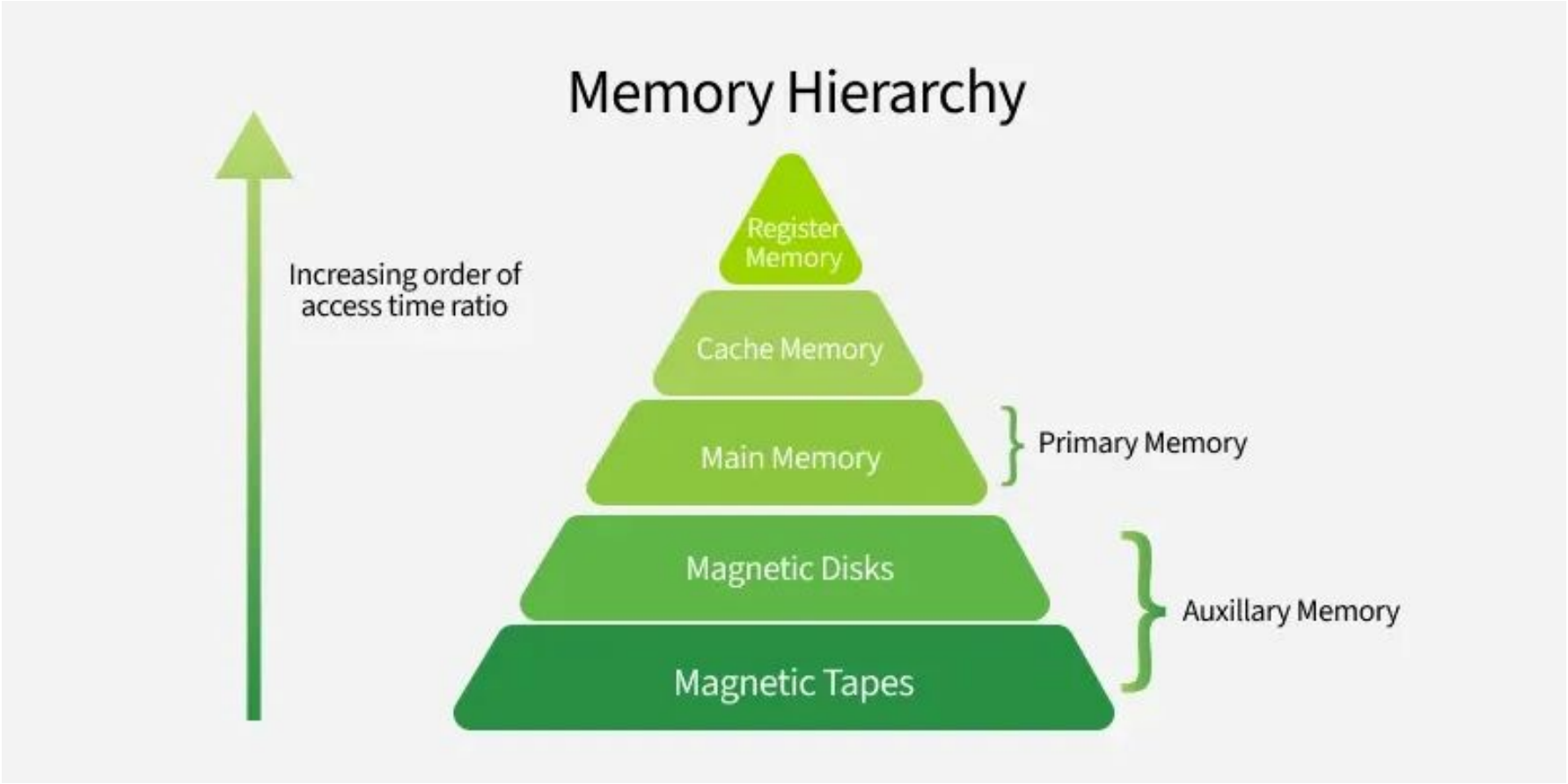
Why Memory Management is Needed?

1. To allocate and free memory for processes.
2. To keep track of which parts of memory are in use.
3. To reduce **fragmentation** (wasted memory space).
4. To make the best use of main memory.
5. To maintain data accuracy while processes run.

Memory Organization in Computer Architecture

Memory organization decides how data is stored and accessed in a computer.

- Fast but small memory (like cache and registers) is used by the CPU for quick access.
- Large but slow memory (like hard drives) stores data for the long term.
- The memory hierarchy ensures a balance between **speed** and **capacity**.


Memory Hierarchy
Increasing order of access time ratio
Register Memory
Cache Memory
Main Memory
Primary Memory
Magnetic Disks
Auxillary Memory
Magnetic Tapes

Types of Memory in a Computer System

1. Auxiliary Memory (Non-Volatile, Secondary Storage)

- Used for **long-term storage** and backup.
- Not directly accessed by CPU (needs I/O operations).
- Examples:
  - **HDD (Hard Disk Drive):** Large, permanent storage but slower.
  - **SSD (Solid State Drive):** Faster than HDD, no moving parts.
  - **Optical Discs & USB Drives:** Portable storage, less used today.

Types of Memory in a Computer System

2. Main Memory (Volatile, Primary Storage)

- Communicates directly with the CPU.
- Mostly **RAM** and **ROM**.

RAM (Random Access Memory): Temporary storage used while the computer is running.

- **DRAM (Dynamic RAM):** Slower, cheaper.
- **SRAM (Static RAM):** Faster, but costly.

ROM (Read-Only Memory): Permanent storage, cannot be easily changed.

- Stores the **bootable program** (to start the OS).
- Types: PROM, EPROM, EEPROM.

Types of Memory in a Computer System

3. Cache Memory

- Very fast memory between CPU and RAM.
- Stores **frequently used data** so CPU can access it faster.

4. Registers

- Smallest and **fastest memory** inside the CPU.
- Stores data and instructions currently being executed.

5. Tertiary & Offline Memory

- **Tertiary:** Used for backups and archiving (e.g., magnetic tapes).
- **Offline:** Not directly accessible (e.g., external hard drives, DVDs).

Based on Storage Time

- **Volatile Memory:** Data is lost when power is off (e.g., RAM).
- **Non-Volatile Memory:** Data stays even without power (e.g., ROM, HDD, SSD).

How Memory Works

- **Program Load:** Programs move from storage (HDD/SSD) → RAM → Cache → CPU.
- **Data Access:** CPU first checks **Registers** → **Cache** → **RAM** → Storage (in that order).
- **Swapping & Virtual Memory:** If RAM is full, OS moves data between RAM and storage (paging).

Requirements of Memory Management System

Memory Distribution

- Allocate memory to processes as needed.
- Use memory efficiently to reduce **fragmentation** (wasted space).

Memory Security

- Prevent one process from accessing or changing another process's memory.

Deallocating Memory

- Free memory when a process is finished.
- Return unused memory back to the system.

Requirements of Memory Management System

Memory Sharing

- Allow processes to share memory safely when needed.

Virtual Memory

- Give programs the illusion of having more memory than physically available.
- Done by moving data between **RAM** and **hard disk**.

Avoiding Fragmentation

- Ensure memory is allocated in a way that reduces wasted space and improves speed.

Requirements of Memory Management System

Memory Mapping

- Map files directly to memory for faster read/write operations.

Handling Memory Leaks

- Detect and prevent situations where a process holds memory it no longer needs.

Ways to Organize Memory in a Computer System

1. RAM (Random Access Memory)

- Temporary memory used while programs are running.
- Volatile → data is lost when power is off.
- Can read/write data in any order.

2. ROM (Read-Only Memory)

- Permanent memory (non-volatile).
- Stores boot instructions (OS startup).
- Data can only be read, not written.

Ways to Organize Memory in a Computer System

3. Cache Memory

- Very fast, small memory between CPU and RAM.
- Stores frequently used data & instructions.
- Works on **locality of reference** (recently/frequently used data is likely needed again).

Cache Performance Terms:

- **Cache Hit** → data found in cache (fast).
- **Cache Miss** → data not in cache (slower, fetched from RAM).
- **Hit Ratio** = Hits / (Hits + Misses).

Ways to Organize Memory in a Computer System

Cache Mapping Techniques:

1. **Direct Mapping:** Each memory block maps to one fixed cache location.
2. **Set-Associative Mapping:** Each block can go to a specific set of cache lines.
3. **Fully Associative Mapping:** Any block can go to any cache line (flexible, but costly).

Ways to Organize Memory in a Computer System

4. Virtual Memory

- Lets programs use more memory than physically available.
- Achieved by swapping between **RAM** and **disk storage**.

5. Flash Memory

- Non-volatile, used in **USB drives, memory cards, SSDs**.

Ways to Organize Memory in a Computer System

6. Magnetic Disks

- Non-volatile, used for **mass storage** (HDDs).
- Slower than RAM/Cache.

7. Registers

- Ultra-fast, small memory **inside the CPU**.
- Holds data currently being processed.

Applications of Memory Organization

- **Program Execution** – load programs from disk → RAM → CPU.
- **Data Storage** – efficient data access in databases & files.
- **Virtual Memory** – run bigger programs on small systems.
- **Cache Memory** – reduce access time for frequent data.
- **OS Management** – OS controls allocation, caching, swapping.

Advantages of Memory Organization

- Efficient use of memory resources.
- Faster data access (cache & virtual memory).
- Simplified program execution (pipelining).
- Improved reliability (error correction codes).
- Compatible with different memory types (RAM, ROM, Flash, HDD).

Disadvantages of Memory Organization

- **Complexity** – advanced techniques are hard to design/manage.
- **Cost** – cache & ECC memory increase hardware cost.
- **Overhead** – virtual memory adds extra processing.
- **Compatibility Issues** – not all memory types work in all systems.
- **Security Risks** – virtual memory can leak sensitive info.

DISCUSSION & REVISION

1. Which memory is the fastest?
2. Which memory is non-volatile and stores boot instructions?
3. Which memory temporarily stores frequently used data for CPU?
4. Which memory technique allows using more memory than physically available?
5. Which memory is used in USB drives and SSDs?
6. Which storage device uses magnetic surfaces to store data?
7. What do we call data found in cache?
8. Which memory loses data when power is off?

REFERENCES

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