## **🖥️ Communication with I/O Devices**

The CPU interacts with devices like keyboards, mice, printers, displays, network cards, and storage through **I/O subsystems**.

## **📦 Main I/O Communication Methods**

### **🔹 1. Programmed I/O**

* **CPU is in control** and actively checks the I/O device (polling).
* Steps:  
  1. CPU sends a command to the device.
  2. CPU waits and **keeps checking** if the device is ready.
  3. Once ready, data is transferred.
* **Drawback**: CPU is **blocked** and wastes time waiting.

✅ **Simple** ❌ **Inefficient**, especially for slow devices

### **🔹 2. Interrupt-Driven I/O**

* I/O device **interrupts the CPU** when it’s ready.
* Steps:  
  1. CPU sends a request and **continues other tasks**.
  2. When the I/O device is ready, it sends an **interrupt signal**.
  3. CPU stops what it’s doing, handles the interrupt (via an ISR), then resumes.

✅ **Efficient** ❌ Needs interrupt handling logic

### **🔹 3. Direct Memory Access (DMA)**

* Used for **high-speed data transfer** (e.g., disks, network).
* A **DMA controller** transfers data **directly between memory and I/O device** without CPU intervention.
* CPU only initializes the DMA transfer and is **free during the transfer**.

✅ **Best performance** ❌ Requires dedicated DMA hardware

## **🔄 Data Transfer Modes**

| **Mode** | **Who controls transfer** | **CPU Free?** | **Speed** | **Best For** |
| --- | --- | --- | --- | --- |
| Programmed I/O | CPU | ❌ | Slow | Simple devices |
| Interrupt-Driven I/O | Device via interrupt | ✅ | Medium | Keyboard, Mouse |
| DMA | DMA Controller | ✅✅ | Fast | Disk, Network, Audio |

## **🛠️ I/O Mapped vs Memory-Mapped I/O**

### **🧩 Memory-Mapped I/O:**

* I/O devices have addresses **in the same space as RAM**.
* CPU uses **normal instructions** to access devices (e.g., MOV, LOAD, STORE).

### **🎮 I/O-Mapped I/O:**

* Separate address space for I/O devices.
* Uses **special I/O instructions** (e.g., IN, OUT).

## **🧠 Summary**

* CPU communicates with I/O devices via **I/O interfaces/controllers**.
* Modes:  
  + **Programmed I/O** (polling)
  + **Interrupt-driven I/O**
  + **DMA**
* Can use **memory-mapped** or **I/O-mapped** addressing.