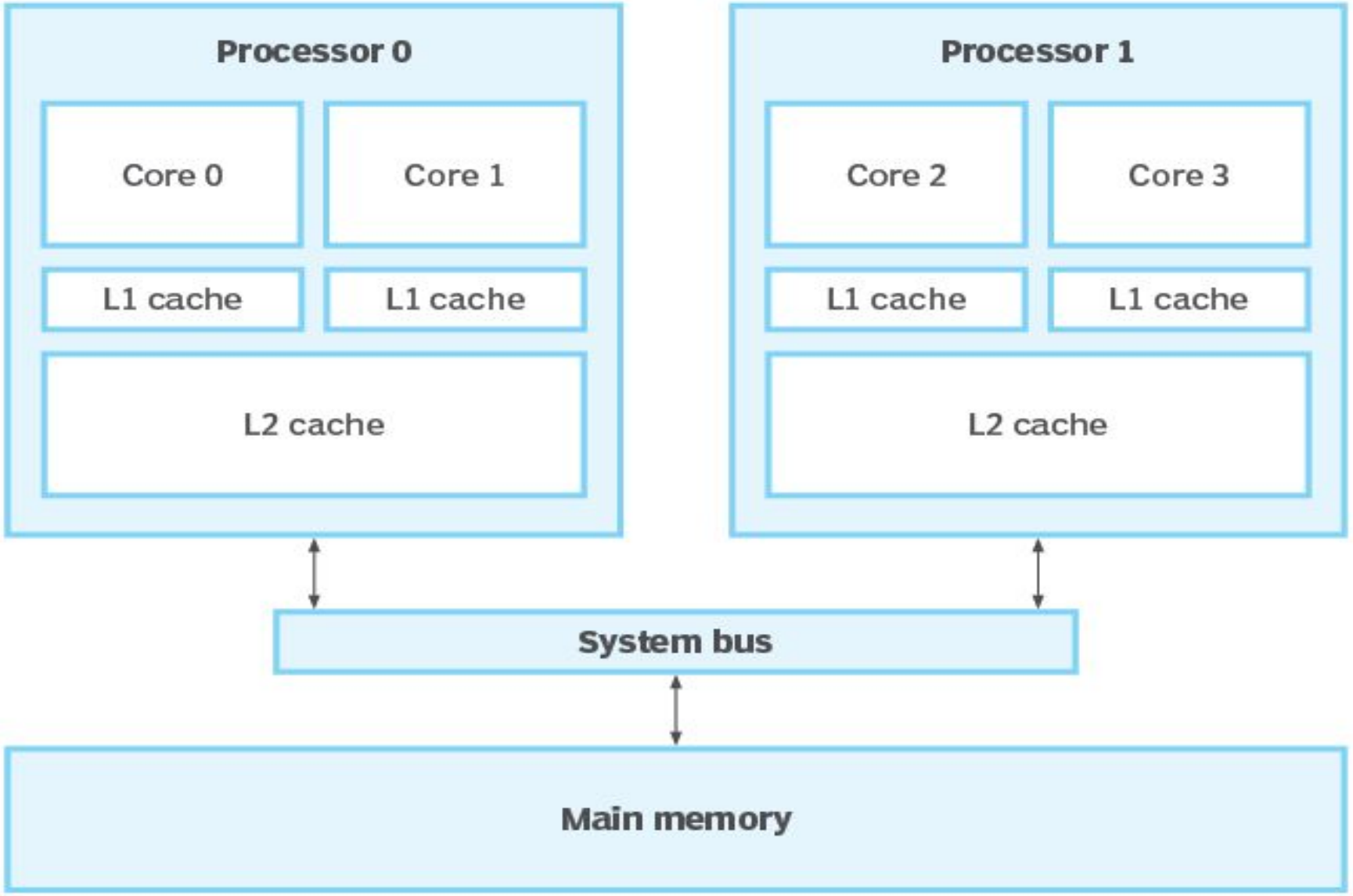
Multi-Core Processors

- **Multi-Core Processors** is a **single computing unit** that consists of two or more independent **processing units (cores)**.
- Each core functions as a **separate CPU**, allowing the processor to perform multiple tasks simultaneously, improving performance and efficiency.
- **Core processor** (or simply **core**) is the **processing unit** within a **CPU (Central Processing Unit)** that executes instructions.
- A processor may have **one core (single-core)** or **multiple cores (multi-core)** to perform multiple tasks simultaneously

Multi-Core Processors Architecture



Architecture of Multi-Core Processors

A **multi-core processor** integrates multiple cores onto a single **integrated circuit (IC)**. The architecture consists of:

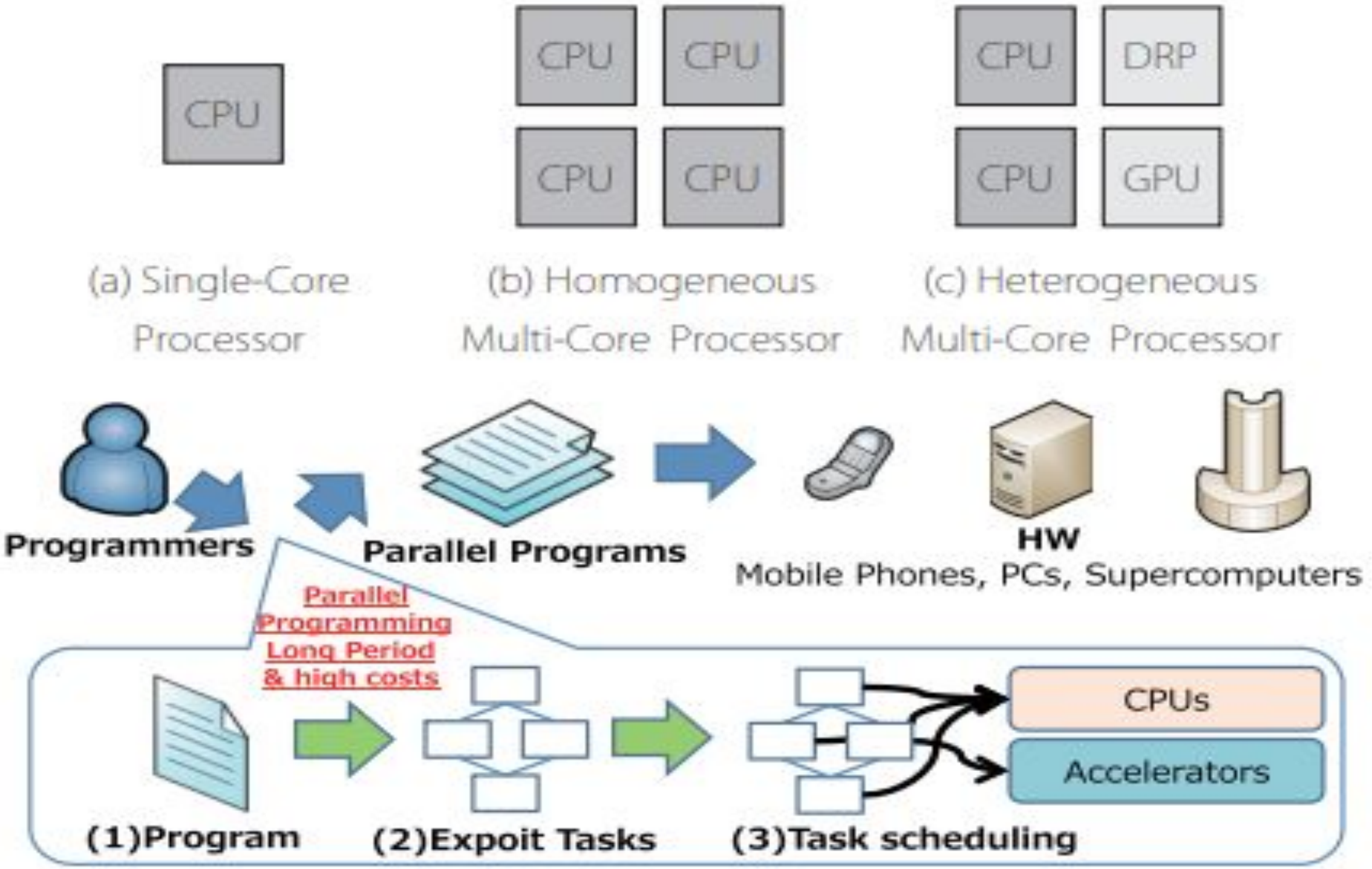
- **Multiple Cores**: Independent processing units executing instructions in parallel.
- **Cache Memory**: Shared or dedicated cache (L1, L2, L3) to enhance data access speed.
- **Memory Controller**: Manages access to system memory (RAM).
- **Interconnects**: Enables communication between cores (e.g., ring, mesh, or bus interconnect).
- **I/O Interfaces**: Handles communication with peripherals.

Advantages of Multi-Core Processors

✅ **Increased Performance**: Enables parallel execution of tasks, improving processing speed.
✅ **Energy Efficiency**: Multiple cores can execute tasks at lower clock speeds, reducing power consumption.
✅ **Better Multitasking**: Handles multiple applications without slowing down the system.
✅ **Enhanced Scalability**: Modern software is optimized for multi-threading, improving responsiveness.
✅ **Reduced Heat Generation**: Lower clock speeds per core result in less heat compared to single-core processors.

Types of Multi-Core Architectures

Architecture	Description	Example
Homogeneous Multi-Core	All cores are identical in structure and capability.	Intel Core i7, AMD Ryzen 9
Heterogeneous Multi-Core	Cores have different capabilities, optimized for specific tasks.	ARM big.LITTLE, Apple M-series
Symmetric Multi-Core (SMP)	All cores share equal access to memory and resources.	Intel Xeon, AMD EPYC
Asymmetric Multi-Core (AMP)	Cores have different roles and access privileges.	Specialized DSP & GPU cores



dynamically reconfigurable processors(DRP) and graphic processing unit(GPU)

Example: Speedup Factor in Multi-Core Processors

- The **speedup factor** measures how much faster a multi-core processor executes a task compared to a single-core processor. It is calculated using the formula:

$$S(N) = \frac{T_1}{T_N}$$

- T_1 = Execution time on a **single core**
- T_N = Execution time on **N cores**

Example

Scenario:

A computational task takes **100 seconds** to execute on a **single-core processor**. When executed on a **quad-core processor (4 cores)**, the execution time reduces to **30 seconds**.

Step 1: Assign Given Values

- $T_1 = 100$ seconds (single-core execution time)
- $T_4 = 30$ seconds (execution time on 4 cores)

Step 2: Compute Speedup Factor

$$S(4) = \frac{T_1}{T_4} = \frac{100}{30}$$

$$S(4) = 3.33$$

✅ **Final Answer:** The **quad-core processor achieves a speedup of 3.33×** compared to the single-

Interpretation of Results

1. **Ideal Speedup:** If the task was perfectly parallelized, the expected speedup for **4 cores** would be **4×**, but in reality, due to **synchronization overhead and non-parallelizable portions**, the speedup is often **less than the number of cores.**
2. **Efficiency Calculation:**
   - **Efficiency =** $\frac{S(N)}{N} = \frac{3.33}{4} = 0.83$ **(or 83% efficiency)**
   - **This means the multi-core execution is 83% efficient.**

Applications of Multi-Core Processors

- **High-Performance Computing (HPC)** – Used in supercomputers for scientific simulations.
- **Artificial Intelligence & Machine Learning** – Accelerates deep learning model training.
- **Gaming** – Enhances real-time rendering and physics computations.
- **Mobile Devices** – Efficient power management for extended battery life.
- **Cloud Computing & Data Centers** – Supports virtualization and parallel processing.