COMPUTER ARCHITECTURE

KASITI BRIAN WAKUKHAH

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INRODUCTION

- Over the past 65 years, computer technology has seen rapid advancements in performance and memory. Architectural innovations and the development of integrated circuits have been key contributors to this enhanced performance.
- The advent of Reduced Instruction Set Computer (RISC) architecture has simplified instruction execution by employing techniques such as instruction-level parallelism (ILP) and caching, which have significantly boosted overall computer performance.
- Intel's adoption of RISC principles has established the company as a prominent leader in the microprocessor manufacturing industry.
- During the 1980s to the 2000s, the emergence of various classes of computers, including PCs, tablets, and smartphones, was fueled by the advent of "super-processors," marking a significant leap from previous decades. The ARM architecture, in particular, became widely adopted in mobile phones.

INTRODUCTION (cont…)

- Software has evolved significantly over time, progressing from assembly languages to low-level languages like C and C++, then to higher-level programming languages such as Java and C#, and finally to scripting languages like JavaScript.
- The traditional model of locally installed applications has been largely replaced by Software as a Service (SaaS).
- New parallelism models have emerged, including Data-Level Parallelism, Thread-Level Parallelism, and Request-Level Parallelism, leading to a shift away from reliance on Instruction-Level Parallelism (ILP).
- Performance improvements have driven the transition from single-core to multi-core processors, which represent the future of computing.

Classes of Computers

- The evolution of computer technology has given rise to distinct computer markets, each characterized by unique features, requirements, and technologies. These markets include:

1. Personal Mobile Devices
2. Desktop Computing
3. Servers
4. Cluster/Warehouse-Scale Computers
5. Embedded Computers

Personal Mobile Devices (PMD)

- Performance needs are optimized for web and multimedia applications.

- Key factors include energy efficiency (long battery life), real-time processing, and high cost.

- Relies on flash memory for storage instead of hard drives.

- Examples: Smartphones, wearables, and tablets.

Desktop Computing

- Laptops now dominate the computer technology market due to their portability and performance.

- New higher-performance microprocessors are introduced here before expanding to other markets.
- Examples : Laptops, desktops and workstations

Servers

- Designed for minimal downtime to prevent revenue loss in case of system failure.
- Key factors include continuous availability (24/7 uptime), scalability, and high throughput when communicating with client-side applications.
- Examples: Enterprise servers, cloud backends, and web hosting services.

Cluster/Warehouse-Scale Computers

- Emphasize scalability over computation speed, utilizing redundant low-cost hardware with software-based fault handling.
- Key factors include scalability, fault tolerance, and cost-efficient operations.
- Examples: Google, Amazon, and Facebook/Meta data centers.

Embedded Computers

- Found in everyday appliances and industrial systems such as microwaves, networking switches, printers, and more.

- Key factors include low cost, efficiency, and application-specific functionality.

- Unlike Personal Mobile Devices (PMDs), they cannot run third-party apps and are designed for specific tasks.

Classes of Parallelism and Parallel architecture

Types of Parallelism

- **Data-Level Parallelism (DLP)** – Operates on multiple data items simultaneously.
- **Task-Level Parallelism (TLP)** – Involves multiple independent tasks executing in parallel.
- **Ways Hardware Exploits Parallelism:**
- **Instruction-Level Parallelism (ILP)** – Uses techniques like pipelining and speculative execution for modest levels of DLP.
- **Vector Architectures & GPUs** – Apply a single instruction to multiple data elements simultaneously (high DLP).
- **Thread-Level Parallelism (TLP)** – Uses multiple threads that interact closely to exploit DLP or TLP.
- **Request-Level Parallelism (RLP)** – Handles independent tasks with minimal interaction

Defining Computer Architecture

- The key components of computer design are Instruction Set Architecture(ISA), Microarchitecture and hardware implementation.

They key aspects to Instruction Set Architecture include :

1. Class of ISA
2. Memory Addressing
3. Addressing mode
4. Operand Types & sizes
5. Operations
6. Control Flow
7. Instruction Encoding

Trends in Technology

Several key hardware technologies are evolving hence shaping the modern computing designs.They include :

- Integrated Circuit Logic Technology
- DRAM technology
- Flash Memory
- Magnetic Disks

Networking Technology Performance Trends include :

- Bandwidth throughput has improved
- Microprocessors and networks have significant gain with bandwidth over latency
- Memory and disk storage prioritize but still have bandwidth advances

Trends in Power and Energy in Integrated Circuits

Power and Energy Considerations :

- Ensuring power supply systems can handle peak power demands
- Sustained Power Consumption
- Energy efficiency. Energy per task is more reliable than power consumption

Techniques for Power efficiency

- Clock gating
- Overclocking
- Dynamic Voltage-Frequency scaling
- Designing for Typical Cases

Trends in Cost

Factors Influencing Cost:

1. Time, Volume, and Commoditization

   - Learning Curve:Costs decrease over time as production processes improve, exemplified by the drop in prices of computer technology gadgets from the 1980s to the 2020s.

   - Higher Production Volume: Increased production volume lowers costs by enhancing efficiency.

   - Commoditization: Commodities like flash memory and CPUs increase competition, which prevents monopolies and reduces costs.

2. Cost of Integrated Circuits

   - Manufacturing Process:Cost is influenced by factors such as wafer price, yield, and defects per unit area.

   - Die Size: Larger die sizes significantly impact cost, as they reduce the number of usable chips per wafer, thereby increasing the cost per chip.

   - Formula:

Cost per die=Cost of waferDies per wafer×Die yield\text{Cost per die} = \frac{\text{Cost of wafer}}{\text{Dies per wafer} \times \text{Die yield}}

Trending cost (cont..)

3. Key Areas for Designers

- The primary factor under a designer's control that influences cost is the die area.

- Larger dies increase cost exponentially due to higher defect probability and lower yield.

- Additional steps, such as testing, packaging, and final validation, also contribute to overall costs.