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A Fundamental Turn toward **Concurrency in Software**

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How to measure the CPU Performance?

Microprocessor performance depends on two main factors

- **Internal clock speed** — determines how fast a CPU completes the number of the logical and arithmetic operations
- **Number of transistors** — determines how many different types of operations a CPU can perform simultaneously

2 Passenger

Nissan 350z

7 Passenger !!!

Audi Q7

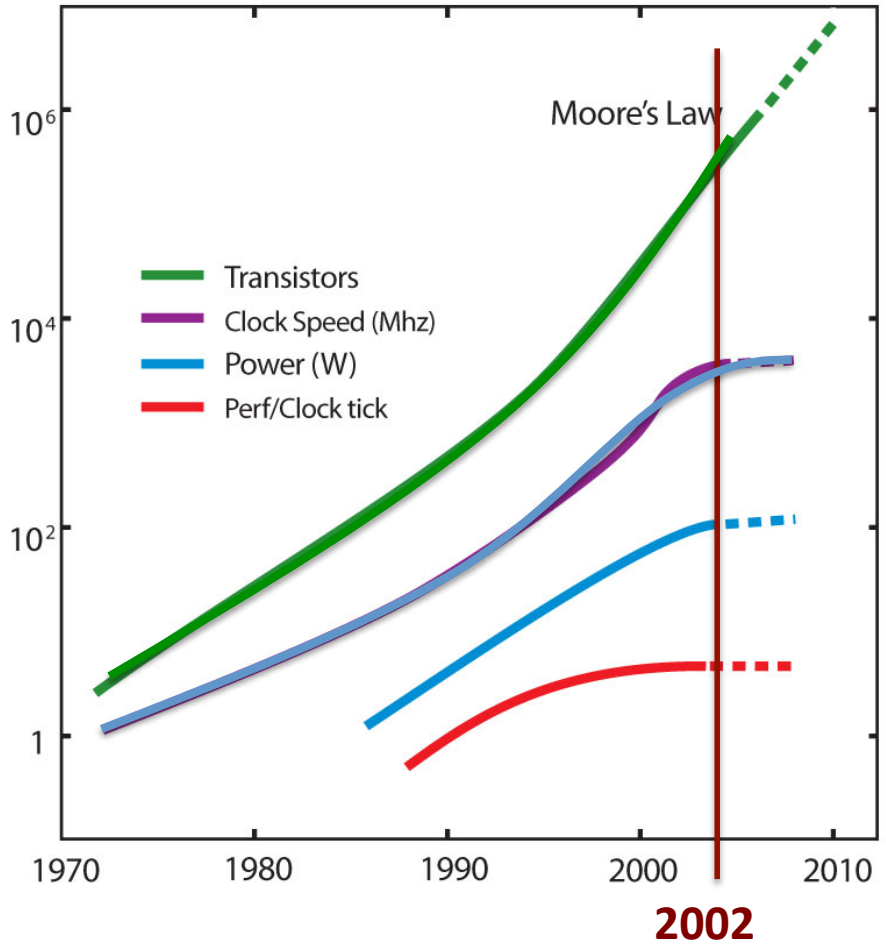
Performance = Clock speed x Number of instructions per cycle

Is there any Performance Problem with **CPU Evolution**?

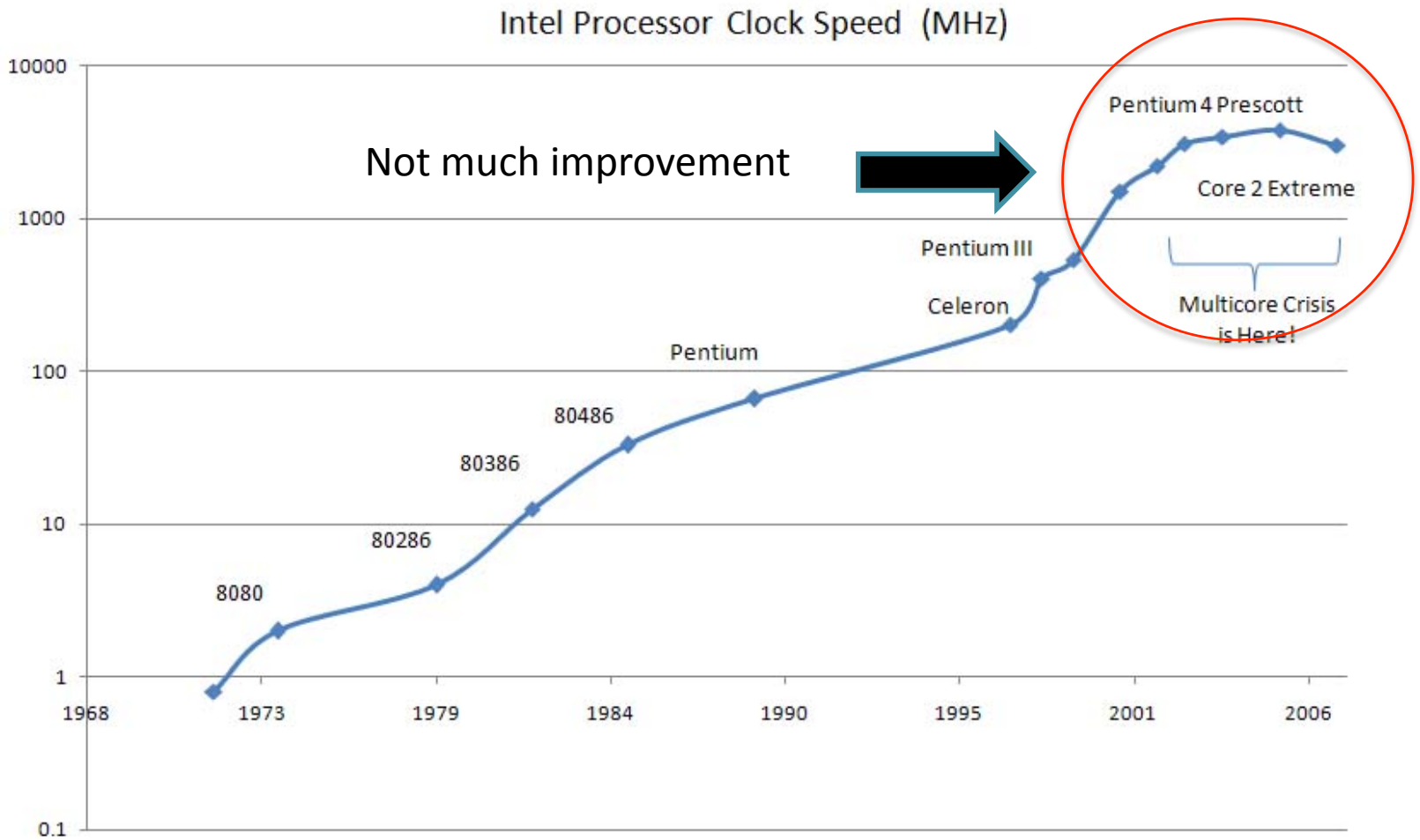
PERFORMANCE PROBLEM?

Transistors are still shrinking, and the number per microprocessor is still growing. However, the performance measured in arithmetic operations per second has flattened out since 2002

"The biggest reason for the leveling off is **the heat dissipation problem**," says Ken Koch, one of the leaders of the Roadrunner project. It would be like running a car at high speed with no water in the radiator.

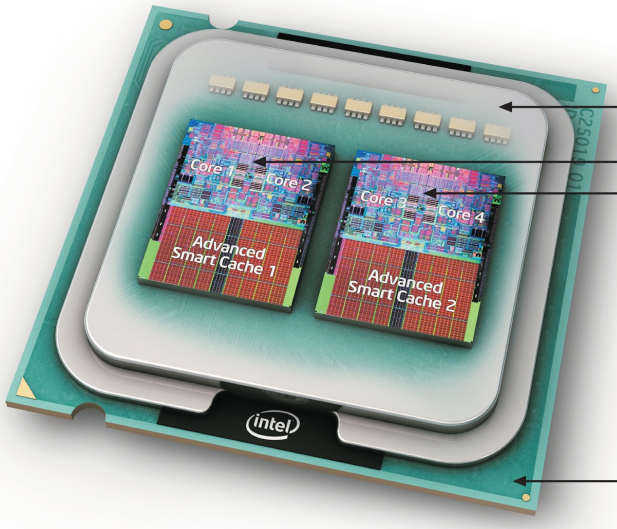


Faster Clock Speed Development **Halts**?



Why we need Multi-Core?

- Difficult to make single-core clock frequencies even higher
- Deeply pipelined circuits
  - heat problems
  - difficult design and verification
  - server farms need expensive air-conditioning

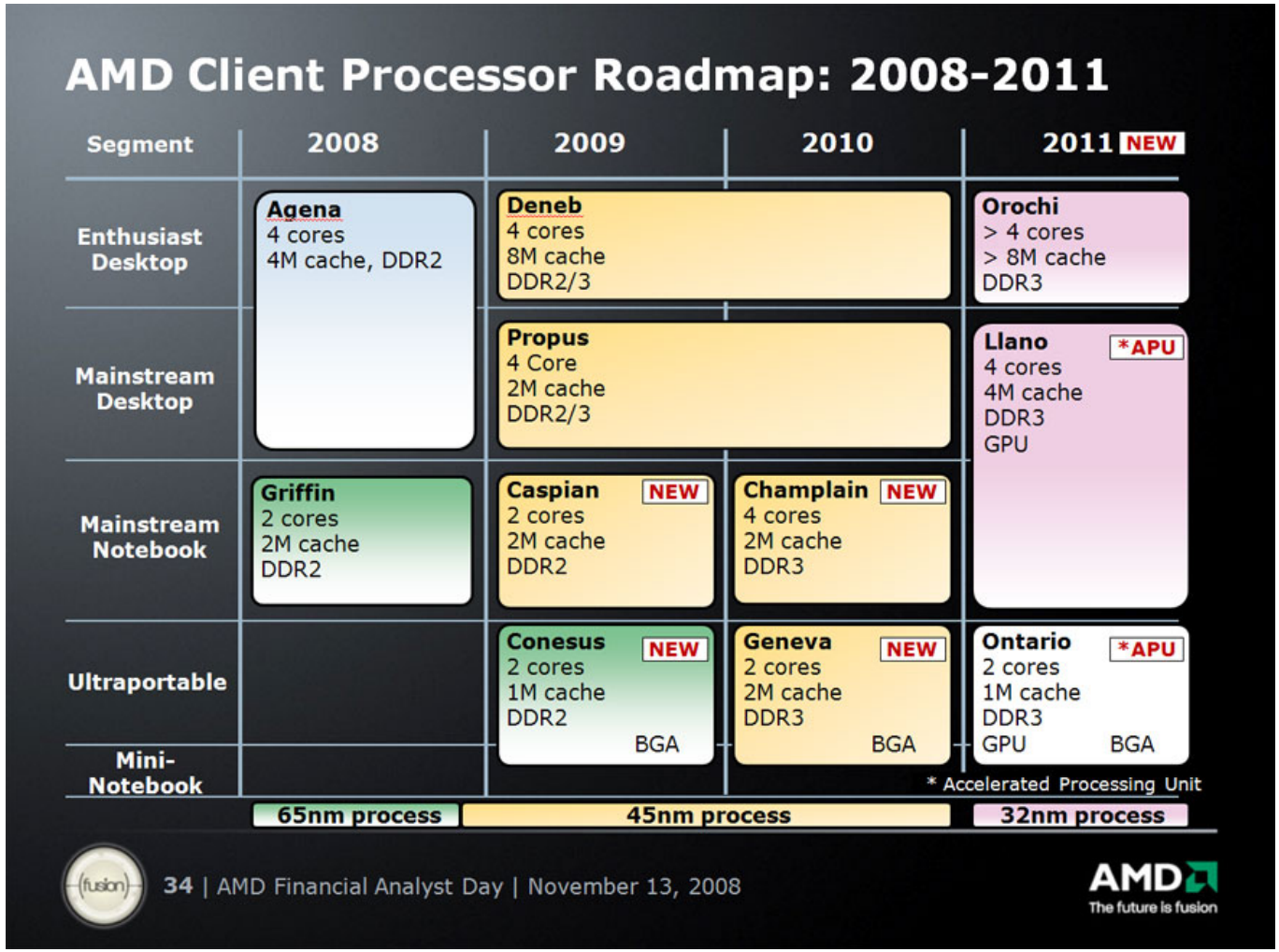


Integrated Heat Spreader (IHS): The integrated metal heat spreader spreads heat from the silicon chips and protects them. The IHS acts as contact for the heatsink and provides more surface area leading to better cooling.

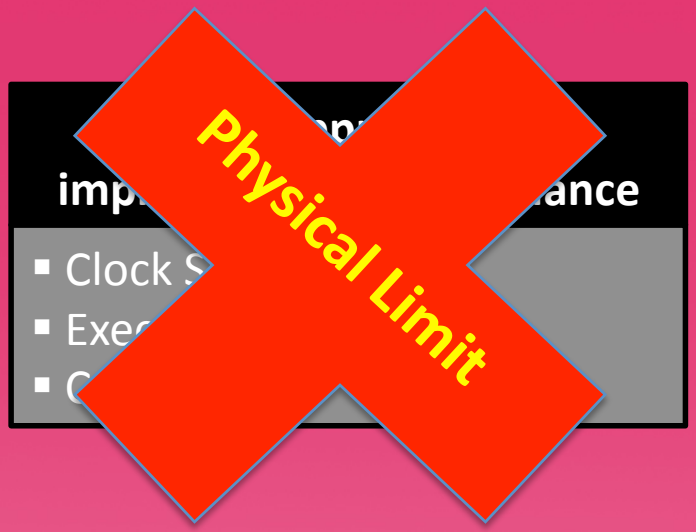
Silicon chips (dies): The two dies inside the Intel® Core™ 2 Extreme quad-core processor are 143 mm² in size and utilize a whopping 291 million transistors each. The four cores are based on the Intel® Core™ Microarchitecture with innovative features like Wide Dynamic Execution, Advanced Digital Media Boost, Smart Memory Access and Intelligent Power Capability. The Advanced Smart Caches have 4 MByte capacity each.

Substrate: The dies are mounted directly to the substrate which facilitates the contact to the motherboard and chipset of the PC via 775 contacts and electrical connections.

Multi-Core Trend



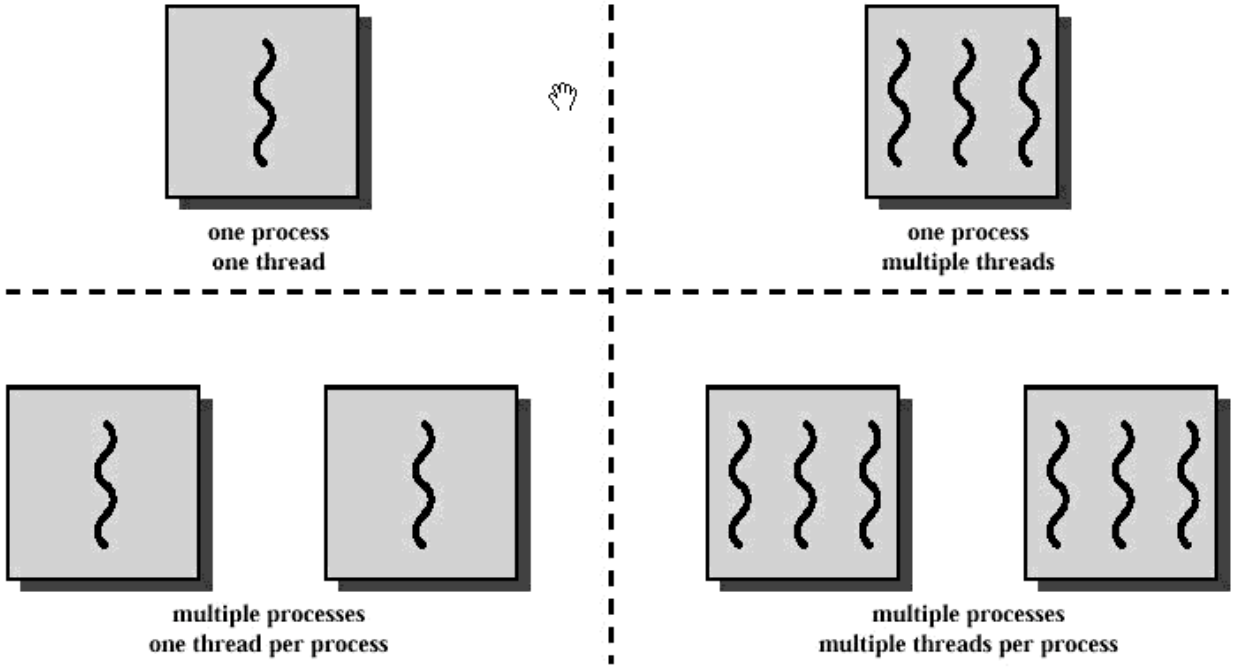
Possible approaches to gain higher processing performance



Near-future approaches for improving CPU performance

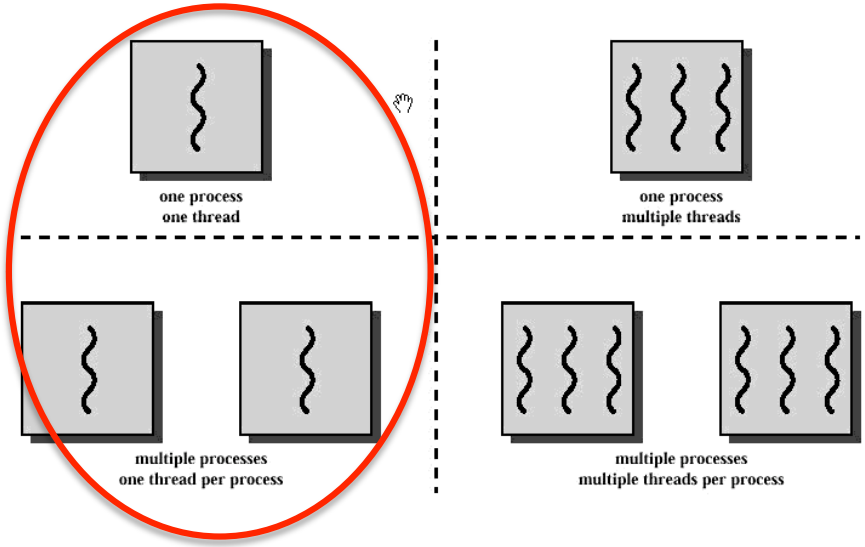
- Hyper Threading
- Multi-Core
- Cache

A variety of models for threads and processes



Single Threading – when the OS does not recognize the concept of thread (DOS, Unix)
Multi Threading – when the OS supports multiple threads of execution within a single process (Solaris)

Unfortunately, the existing applications cannot take much benefits



Single-Thread Applications

Near-future approaches for improving CPU performance

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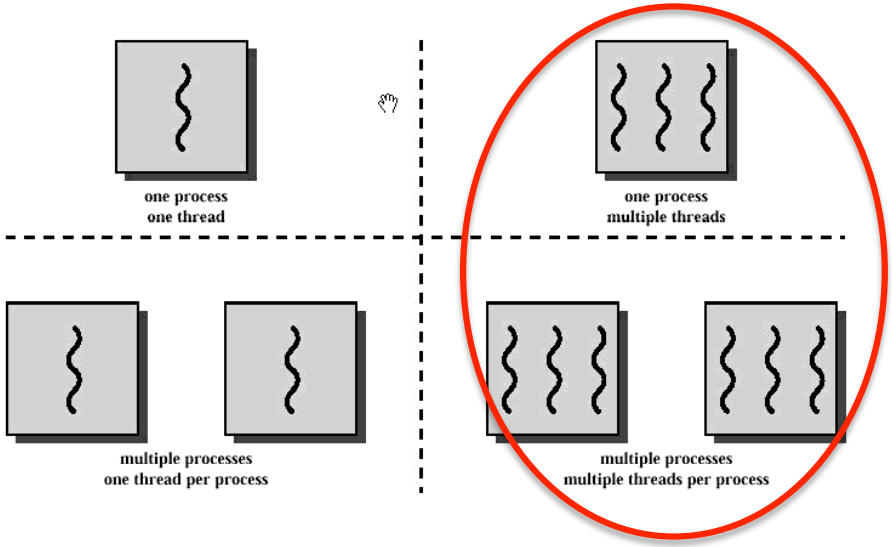
Not Many Benefits Gained

Programming Paradigm Shift !!!



MULTI-Thread Applications
(Concurrent Programming)

Near-future approaches for improving CPU performance

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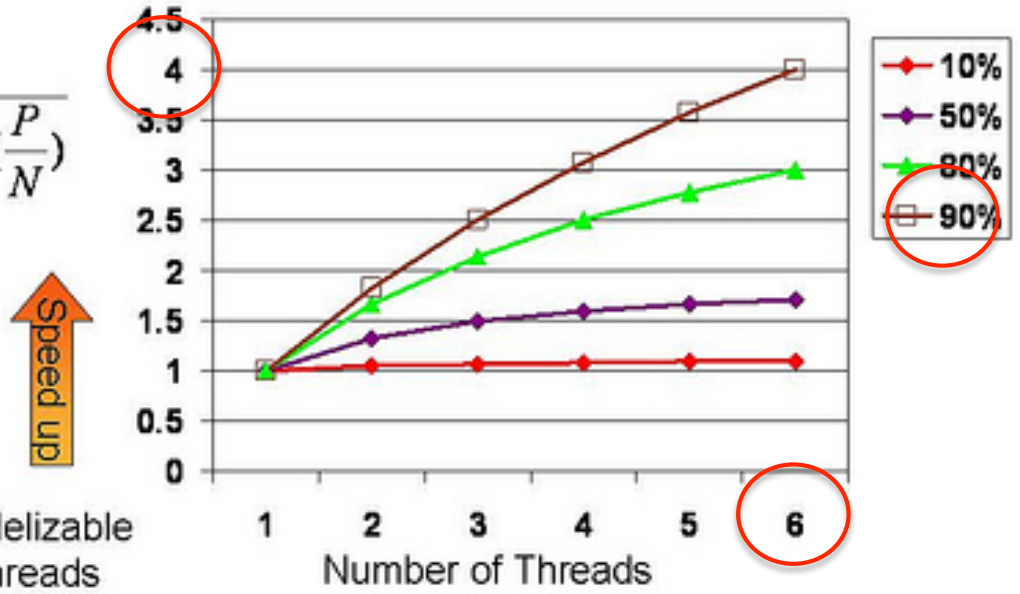
Full Benefits
For CPU Performance

Parallelism and Improvement

Amdahl's Law

"Maximum expected improvement to an overall system when only part of the system is parallelized."

$$\frac{1}{(1-P)+(\frac{P}{N})}$$



P = % parallelizable
N = # of threads

Conclusion

- **Applications will be concurrent** to fully utilize the CPU throughput
- Existing applications are likely **to become CPU-bound**
- **Application efficiency and performance optimization** is more important
- Programming languages and systems **will deal with concurrency**
  - Java 5
  - C++