
Slide Set #20:
Advanced Pipelining, Multiprocessors,
and El Grande Finale
Chapter 7

1

Multiple Issue Processors

- Key metric: CPI → IPC
- Key questions:
 1. What set of instructions can be issued together?
 2. Who decides which instructions to issue together?
 - Static multiple issue
 - Dynamic multiple issue

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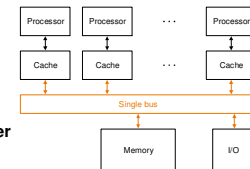
Exploiting More ILP

- ILP = _____
(parallelism within a single program)
- How can we exploit more ILP?
 1. _____
(Split execution into many stages)
 2. _____
(Start executing more than one instruction each cycle)

2

Multi-processing in SOME form... (chapter 7)

1. Multi-processors – multiple CPUs in a system
2. Multi-core – multiple CPUs on a single chip
3. Clusters – machines on a network working together



Idea: create powerful computers by connecting many smaller ones

good news: works for timesharing (better than supercomputer)

bad news: its really hard to write good concurrent programs
many commercial failures

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Who? When? Why?

- “For over a decade prophets have voiced the contention that the organization of a single computer has reached its limits and that truly significant advances can be made only by interconnection of a multiplicity of computers in such a manner as to permit cooperative solution.... Demonstration is made of the continued validity of the single processor approach...”
- “...it appears that the long-term direction will be to use increased silicon to build multiple processors on a single chip.”

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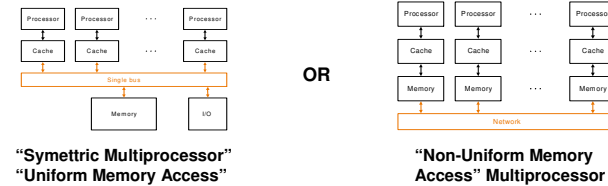
Multiprocessor/core: How do processors COORDINATE?

- synchronization
- built-in send / receive primitives
- operating system protocols

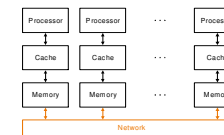
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Multiprocessor/core: How do processors SHARE data?

1. Shared variables in memory



2. Send explicit messages between processors



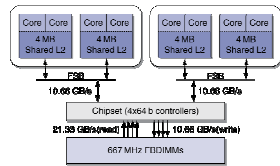
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Flynn’s Taxonomy of multiprocessors(1966)

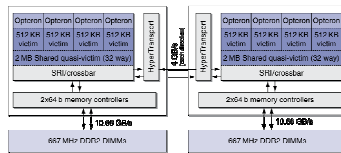
1. Single instruction stream, single data stream
2. Single instruction stream, multiple data streams
3. Multiple instruction streams, single data stream
4. Multiple instruction streams, multiple data streams

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Example Multi-Core Systems (part 1)



2 x quad-core
Intel Xeon e5345
(Clovertown)



2 x quad-core
AMD Opteron X4 2356
(Barcelona)

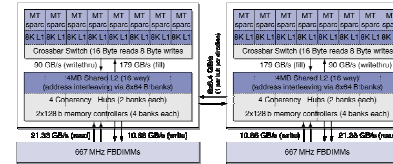
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Clusters

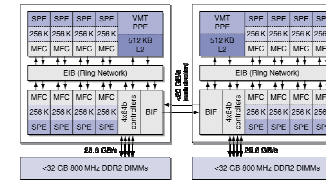
- Constructed from whole computers
- Independent, scalable networks
- Strengths:
 - Many applications amenable to loosely coupled machines
 - Exploit local area networks
 - Cost effective / Easy to expand
- Weaknesses:
 - Administration costs not necessarily lower
 - Connected using I/O bus
- Highly available due to separation of memories
- Approach taken by Google etc.

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Example Multi-Core Systems (part 2)



2 x oct-core
Sun UltraSPARC
T2 5140 (Niagara 2)



2 x oct-core
IBM Cell QS20

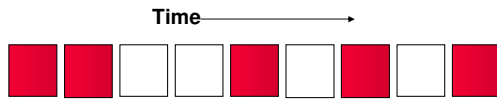
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A Whirlwind tour of Chip Multiprocessors and Multithreading

Slides from Joel Emer's talk at
Microprocessor Forum

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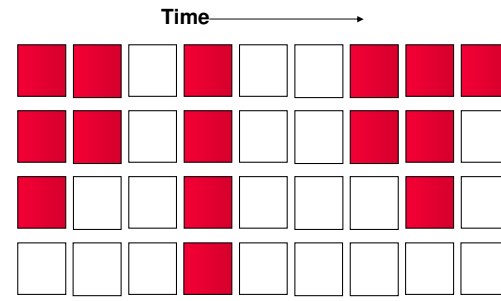
Instruction Issue



Reduced function unit utilization due to....

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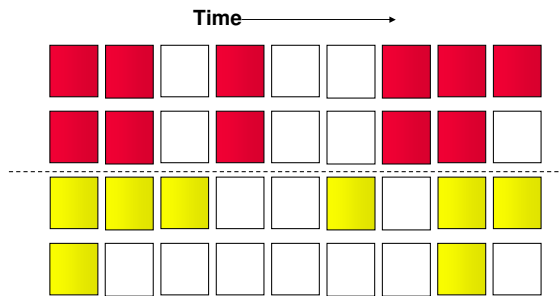
Superscalar Issue



Superscalar leads to more performance, but lower utilization

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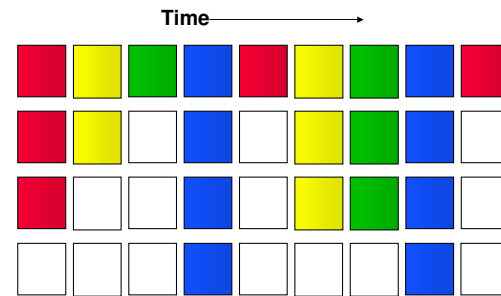
Chip Multiprocessor



Limited utilization when only running one thread

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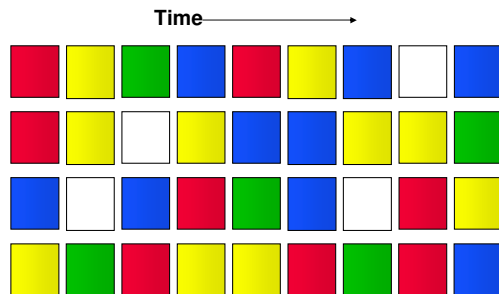
Fine Grained Multithreading



Intra-thread dependencies still limit performance

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Simultaneous Multithreading



Maximum utilization of function units by independent operations

Concluding Remarks

- **Goal: higher performance by using multiple processors / cores**
- **Difficulties**
 - Developing parallel software
 - Devising appropriate architectures
- **Many reasons for optimism**
 - Changing software and application environment
 - Chip-level multiprocessors with lower latency, higher bandwidth interconnect
- **An ongoing challenge!**