Outline

- Tomorrow: ACMP
  - Recent: cell, power, Niagara, Larrabee
  - Early: cm³, HEP, Cosmic Cube
  - Examples

- Memory Consistency
- Cache Coherence
- Interconnect
- Tightly coupled vs. loosely coupled
  - Multi-core (one thread spans an engine, multiple engines)

- Metrical (speedup, efficiency, redundancy)
- Amdahl's Law
- Granularity

Some basics
Granularity of Concurrency
Amdahl's Law

Speed-up as a function of the parallelizability (c) of the application

Speed-up of an application as we add more and more processors (p)

Graphs showing speed-up with varying numbers of processors and different parallelizability values.
\[ T_1(A) = \frac{T(A)}{T_0} \]

\[ 5_0 = \frac{T_1}{T_1} = \frac{\alpha T_1 + (1-\alpha) T_1}{T_0} \]

**Table**

<table>
<thead>
<tr>
<th>State</th>
<th>Time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>XYZ 1</td>
<td>15</td>
</tr>
<tr>
<td>XYZ 2</td>
<td>30</td>
</tr>
<tr>
<td>XYZ 3</td>
<td>33</td>
</tr>
</tbody>
</table>

**One Hour**

\[ 50 \rightarrow 50 \]

\[ \begin{array}{ccc}
15 & 30 & 45 \\
2 & 30 & 33 \\
0 & 30 & 30 \\
\end{array} \]
\[ T_P = \alpha \frac{T_1}{\rho} + \frac{(1-\alpha)T_1}{1} \]

\[ S_P = \frac{T_1}{T_P} = \frac{T_1}{\alpha \frac{T_1}{\rho} + (1-\alpha)T_1} \]

\[ S_P = \frac{1}{\alpha \frac{T_1}{\rho} + (1-\alpha)} \]
Redundancy:  [

Utilization:  \[ 1 = \frac{1}{s} \]

Efficiency:  \[ \frac{1.8}{3.5} \]

Speed-up:  \[ \frac{4}{5} \]

Metrics

\[ \overline{18} \]
Programmer's job is tougher

Easier for the hardware

Message passing

Loosely-coupled (i.e., "Multi-computer Network")

Memory contention

Hardware has to worry about cache coherence,

Easier for the software

Each processor capable of doing work on its own

Shared memory

Tightly-coupled (i.e., "Multi-processor")

Tightly-coupled vs. Loosely-coupled
Interconnection networks
- Cost
- Latency
- Contention

Cache Coherency
- Snoopy
- Directory

Memory Consistency
- Sequential Consistency and Mutual Exclusion
Network

Cost
\( O(n) \)
\( O(n^2) \)

Category
\( O(1) \)
\( O(1) \)

Contention
BAD

\( O \)
\( I_B \)

\( \Omega \) Network
Duncan Lawrie
TRAC
BANYAN TREE

IB

\( O((\log n)^2) \)
\( O(\log n) \)
\( O((\log n)^2) \)
\( O(n) \)

\( \Theta \) Net
MOSIT
\[ A \rightarrow 001 \]
\[ D \rightarrow 010 \]

Latency

\[ \frac{n \times \log_k n \times k^2}{k} \]

Cost

\[ 64 \]

\[ n \rightarrow n^2 \]