Operational Analysis of Processor Speed Scaling

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Parallelism and Performance

“Parallel architectures... introduce many new optimization parameters, and so far, no successful autotuners for parallel [applications] exist.”

The Landscape of Parallel Computing Research: A Berkeley View
Motivation

- Server applications will increasingly run on multi-processor machines
  - Not multi-core but many-core (i.e., hundreds of cores)
  - Datacenter-on-chip

- Performance questions
  - Will my application's performance improve with more cores? Frequency scaling? Cache structure?
Performance Models

Models should be

1. Applicable to many applications and architectures
2. Easy to calibrate
3. Instructional; enhance understanding of parallel systems

Architecture parameters
- e.g., # cores, per-core speed

\[ f(X) = P \]

Performance metric e.g.,
- response and execution time, throughput

<table>
<thead>
<tr>
<th># cores</th>
<th>speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>9sec</td>
<td>6sec</td>
</tr>
<tr>
<td>12sec</td>
<td>6sec</td>
</tr>
<tr>
<td>20sec</td>
<td>15sec</td>
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Operational Laws

- Performance model parameters reflect only measurable quantities
  - Verified by measurements
  - Robust, easy to understand, accessible for administrators

- Well-known operational laws
  - Utilization Law – bottleneck/throughput analysis
  - Little's Law – queuing theory
Revisit Operational Analysis

- **Measurable quantities**
  - Request arrivals and departures
  - Concept of busy time, response time, and throughput
  - Properties of the parallel architecture

- **New approaches for operational analysis**
  - Novel analysis of the *occupancy curve*
Occupancy Curve

- Plot of the number of requests in the system versus time
- Horizontal line equal to the number of processors separates requests being serviced from those queued
  - Operational: request arrivals, departures, and number of processors can be measured directly
Processor Speed Scaling

- Processor power can be adjusted by changing parameters or migrating applications
  - May correspond to raw frequencies because of caching

- How does speed scaling affect performance?
  - Deterministic scheduling: Scheduling decisions are based on the set of runnable jobs, their static properties, the amount of remaining service for each job
  - Arrival rate monotonicity: If arrival times of all jobs are multiplied by a constant, aggregate queuing does not increase
Speed Scaling Law

If all processors get a speedup factor of \( f \), then aggregate queuing will decrease by at least a factor of \( \frac{f}{f - 1} \).

- **Derivation step 1:** Increase processor speed by \( f \), decrease request arrival times by \( \frac{1}{f} \)
  - Aggregate queuing delay scales down by \( \frac{1}{f} \)
  - Rescale x-axis of occupancy curve
- **Derivation step 2:** Increase request arrival times by \( f \)
  - No queuing increase
- **Operational law that is useful for server management**
Takeaway

- Revisit operational laws for future parallel processor architectures
  1. Identified an operational law for server systems that bounds the effect of processor speed scaling

- Ongoing work
  - [MASCOTS 08] Operational laws for capacity planning
  - [USENIX 08] Cross-platform performance model for processor selection and online server management