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

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

$$f(X) = P$$

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

speed \ # cores			
	9sec	6sec	3sec
	12sec	6sec	4sec
	20sec	15sec	9sec

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

Operational Laws

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

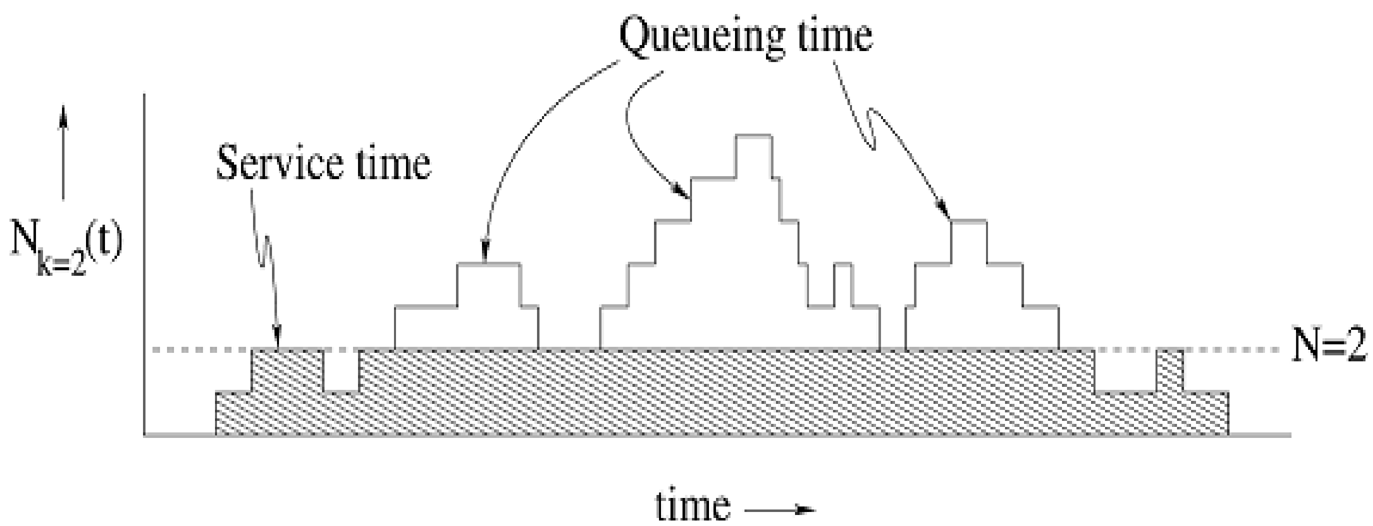
- Well-known operational laws
  - Utilization Law – bottleneck/throughput analysis
  - Little's Law – queuing theory

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 `(f -1)/f`.

- Derivation step 1: Increase processor speed by `f`, decrease request arrival times by `1/f`
  - Aggregate queuing delay scales down by `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