BigHouse: A Simulation Infrastructure for DataCenter Systems

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Outline

• Introduction to Simulation
• BigHouse Simulator
• Case Studies
• Evaluation
• Conclusion & Our Simulator
Datacenter Research is Challenging

- Tools only evaluate a single component
  - Processor, caches, DRAM, disks, etc…
- Evaluating an entire server is difficult
  - Requires coordination of many slow tools
  - Models far too much detail
Requirements for Datacenter Simulation

- Handle scope of data center problems
  - E.g., Performance, power, thermal, reliability
  - Goal: General modeling infrastructure
- Publicly distributable
  - Goal: Does not rely on proprietary binaries
- Needs to simulate 1 to 10,000 servers
  - Goal: Scalable to clusters of machines
The BigHouse Simulator

- Framework for simulating data center systems
  - Discrete-event simulation statistical rigor
  - Easily extensible to new domains
- Claim: Queuing theory is correct abstraction
  - Simulate at the granularity of requests/tasks
    (i.e., request enters/exits a server)
  - Represent workloads as statistical distributions
  - Stochastic approach allows parallelization
BigHouse Overview

Stochastic queuing simulation methodology:
1. Workload characterization
2. System modeling
3. Statistically---rigorous discrete---event simulation

Characterization

Simulation

Offline Benchmarking
Log
Online Instrumentation

System

System Model
(e.g., power-performance)

Workload Model
(e.g., arrival/service dists)

Iterate to convergence

Power, Response Time, etc.
BigHouse Features

BigHouse provides:
• Base objects for modeling (extend with object-oriented programming)
• Statistical probes to instrument object metrics (per-task)
• Statistically-rigorous sampling of outputs parallel histogram approx.
• Automatic parallelization across cores/machines

User provides:
• Model to represent new behavior (e.g., Markov chain to modulate queue)
• New workload distributions (or reuse existing workload suite)
Workload Characterization

- May need to capture more complicated effect (e.g., correlation)
- Similar to statistical simulation
System Modeling

Observations of system model fed to statistical probes
Statistics Sub--System

Automatically determines simulation convergence

Power Model

Server Power

150W

Statistics Manager

Probes
Sojourn Time
Server Power

10ms

Sojourn Time

Warm
Converged

...
Case Study 1: Google Web Search
Web Search Model

CPU and Memory performance modulate service rate
Simulation accurately predicts saturation points. Average error of 9.2% (relative processor slowdown).
Better use of power infrastructure = large gains
– Throttle power DVFS during infrequent spikes
– Power Capping ---~40% more servers
Dynamic Voltage and Frequency Scaling
Power Capping Model

Power Models
\[ P_{\text{Server}} = f(U_{\text{server}}, f_{\text{cpu}}) \]
\[ P_{\text{Rack}} = \sum P_{\text{server}}[i] \]

Performance Models
\[ \text{Service\_rate} = f(f_{\text{cpu}}) \]
\[ \text{Latency} = f(f_{\text{cpu}}) + \text{Queuing} \]

Power Management Policy
Set \( f_{\text{cpu}} \) s.t. \( P_{\text{server}} \propto U_{\text{server}} \)

CPU and Memory performance modulate service rate
Our Simulator - Architecture
Conclusion

• BigHouse: Simulation tool for data center systems
  – Turnaround of hours rather than days
  – Statistically rigorous
  – Parallelizable

• Community engagement
  – Workload repository
  – New system models
  – Validation at scale
*THANK YOU*
Q?