Black-Box Performance Control for High-Volume Non-Interactive Systems

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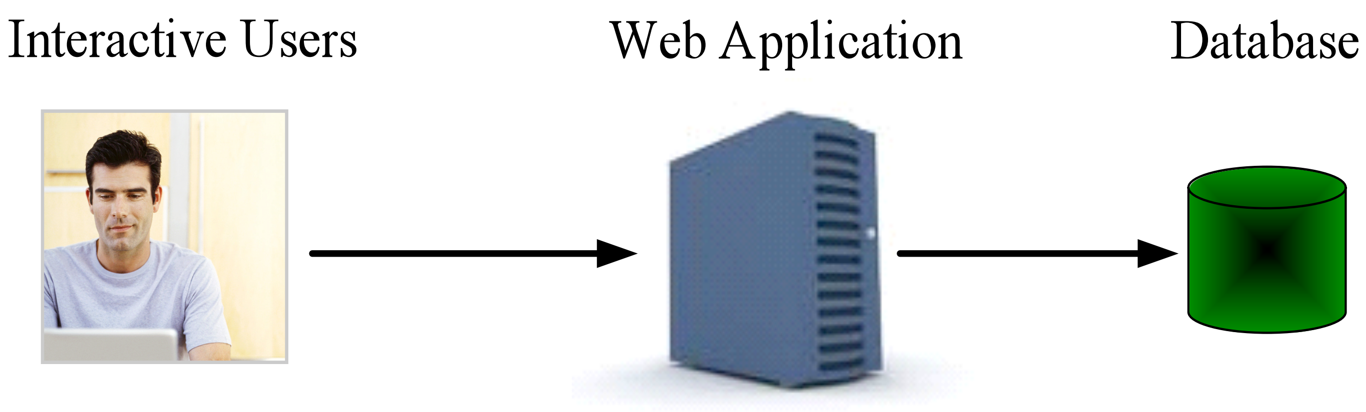
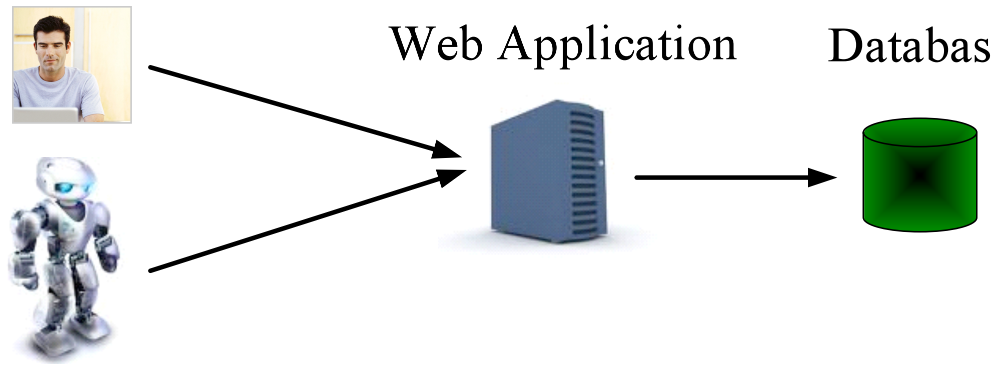
Response Time Driven Performance Control for Interactive Web Applications



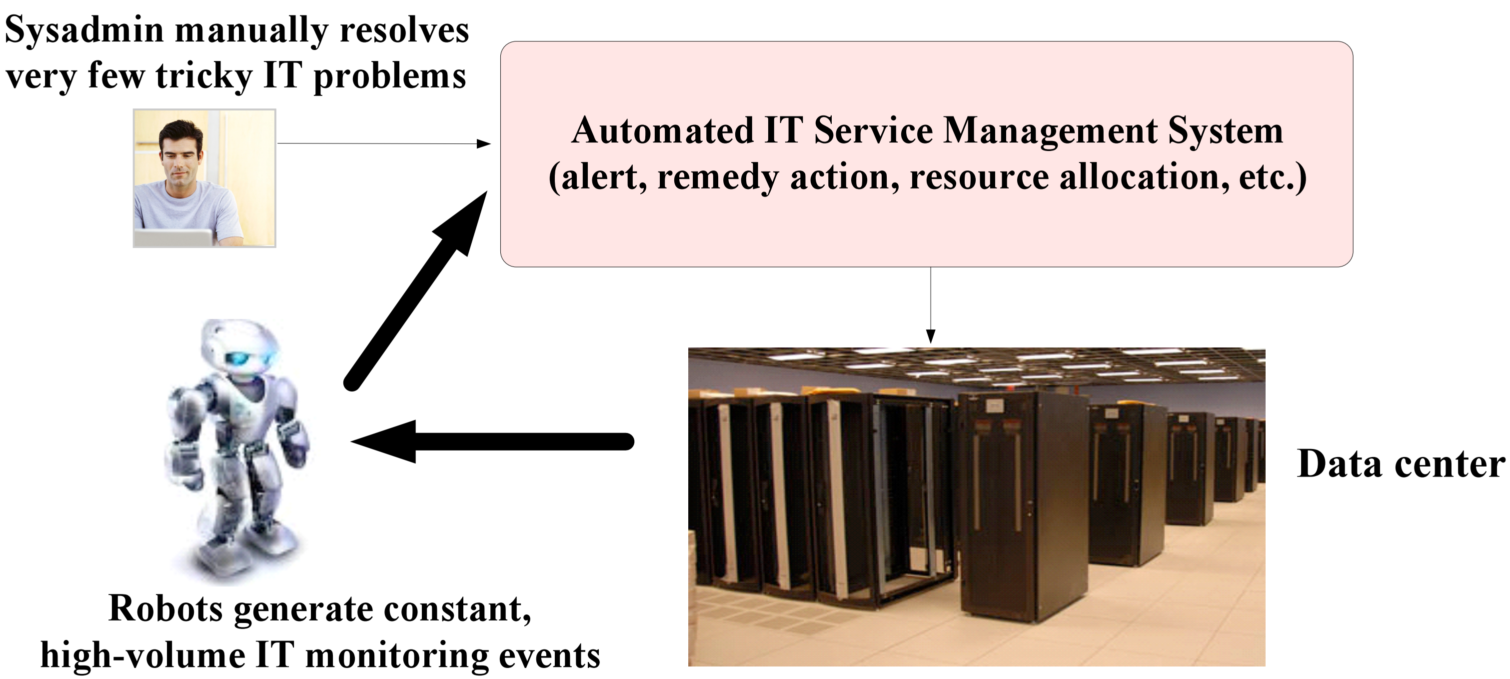
- Interactive users are sensitive to sub-second response time
- Naturally, performance control is driven by response time
  - E.g, stop admitting new requests if response time exceeds a threshold
  - Well studied area: admission control, service differentiation, etc.

But there are Robots that Impact Perf Control



- Many Web services also provide APIs to explicitly work with robots
  - Twitter API Traffic was 10x of its Web traffic
- Some applications work with interactive users during daytime, and then are driven by robot tools at nights to perform heavy-duty analytics
- How robots impact performance control
  - They often have tons of work to do and hence are throughput centric
  - They may not require sub-second response time, e.g., crawler and analytics

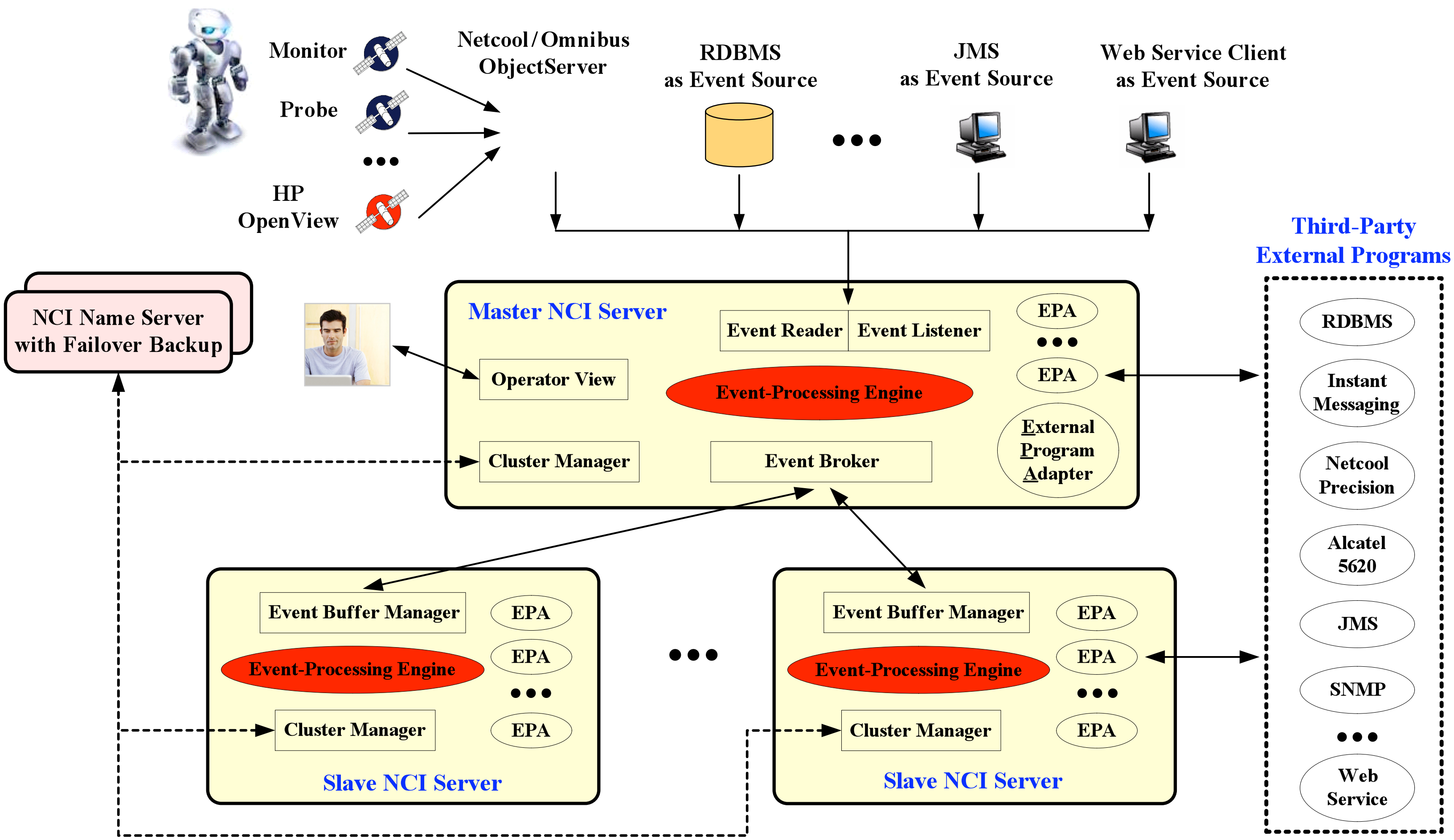
IT Monitoring and Mgmt: a World where Robots Rule



- Before an IT service mgmt system (ITSM) can manage a data center, it must manage itself well
  - Withstand event flash crowd triggered by, e.g., router failure
  - Achieve high event-processing throughput by driving up resource utilization
  - Avoid resource saturation as sysadmins may want to do manual investigation

Simplified View of IBM Tivoli Netcool/Impact

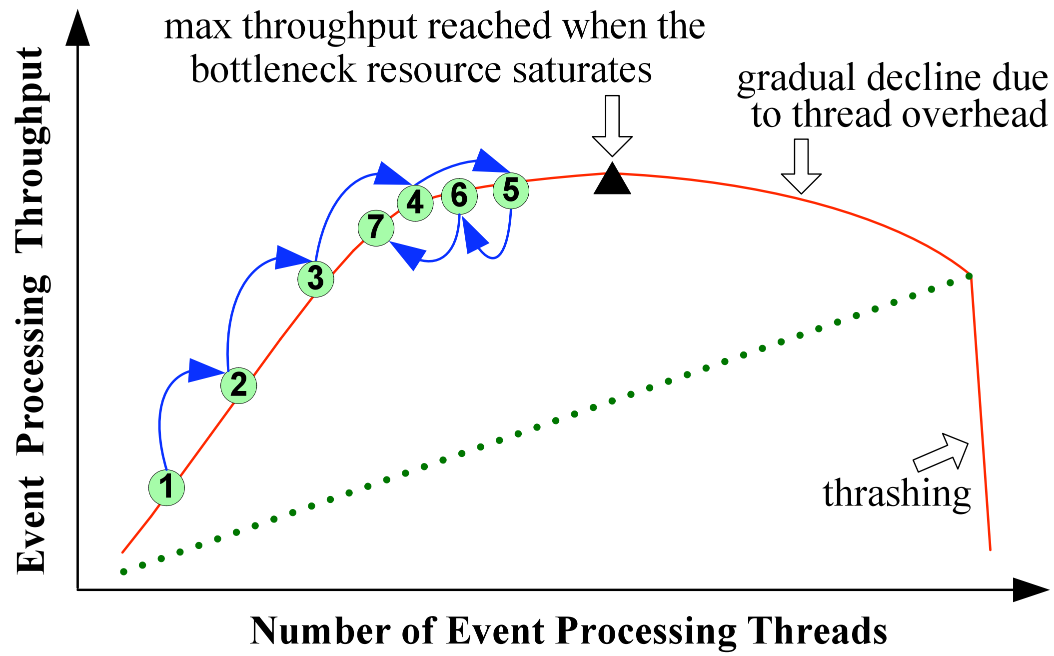
- It provides a reusable framework for integrating all kinds of siloed monitoring and mgmt tools
- It is built atop a J2EE engine but cannot use response-time driven performance control



Why Perf Control is Difficult in Netcool/Impact

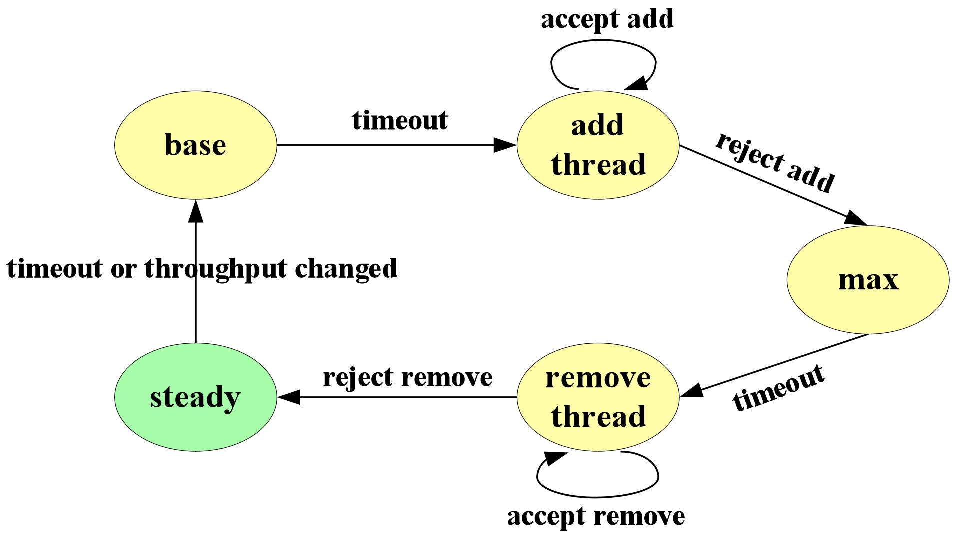
- Work with third-party software provided by many vendors
- We cannot greedily maximize performance without considering congestion
- Bottleneck can be anything anywhere: CPU, disk, memory, network, etc.
- Bottleneck depends on how users write their code atop Netcool/Impact
- Not a simple static topology like web->app->DB
- No simple perf indicator like packet loss or response time violation

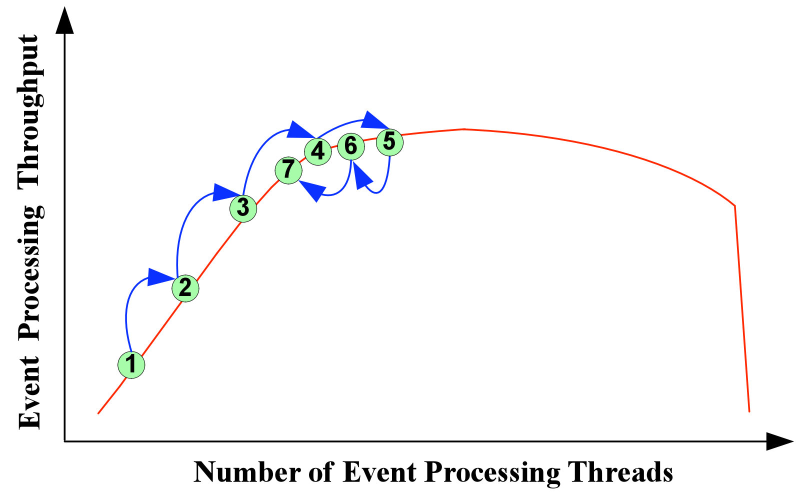
Black-Box Approach: Throughput-guided Concurrency Control (TCC)



- Why not simply use TCP to maximize throughput
  - We deal with general distributed systems rather than just network
  - No packet loss as performance indicator
  - Unlike router, a general server’s service time is not a constant

Simplified State-Transition Diagram for Thread Tuning





- base state: reduce threads by w%
- add-thread state: repeatedly add threads so long as every p% increase in threads improves throughput by q% or more
- remove-thread state: repeatedly remove threads by r% each time so long as throughput does not decrease significantly

Conditions for Friendly Resource Sharing

- Repeatedly add threads so long as every p% increase in threads improves throughput by q% or more

$$q > \frac{p(p+1)}{p+2}$$

e.g., double threads (p=100%) and then see thruput increases by q=1%. This is no good.

- Reduce threads by w% at the beginning of exploration

$$w \geq 1 - (\frac{p}{q} - 1)^2$$

The base state must be sufficiently low so that it will end up with less threads if resource is saturated

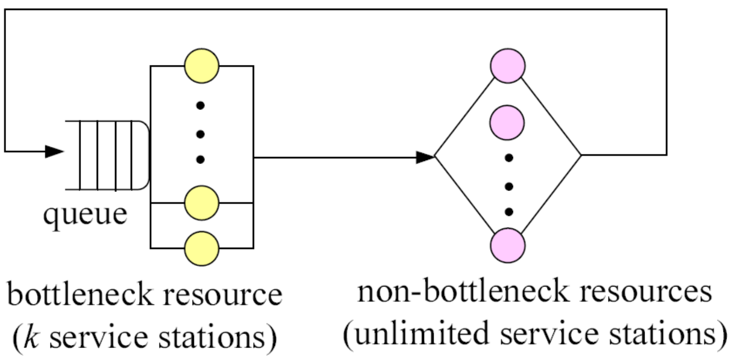
Conditions for Friendly Resource Sharing

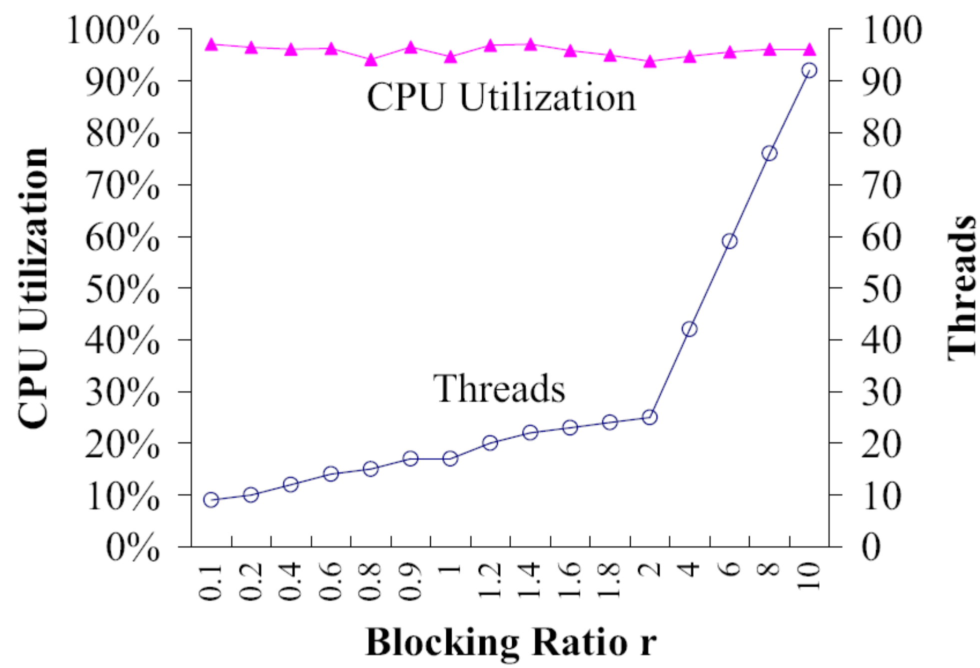
$$q \quad > \quad \frac{p(p+1)}{p+2} \qquad\qquad w \quad \geq \quad 1-(\frac{p}{q}-1)^2$$

- If there is an uncontrolled competing program, NCI shares 44–49% of the bottleneck resource
- Two instances of NCI share bottleneck resources in a friendly manner
- However, three or more instances of NCI need coordination from the master

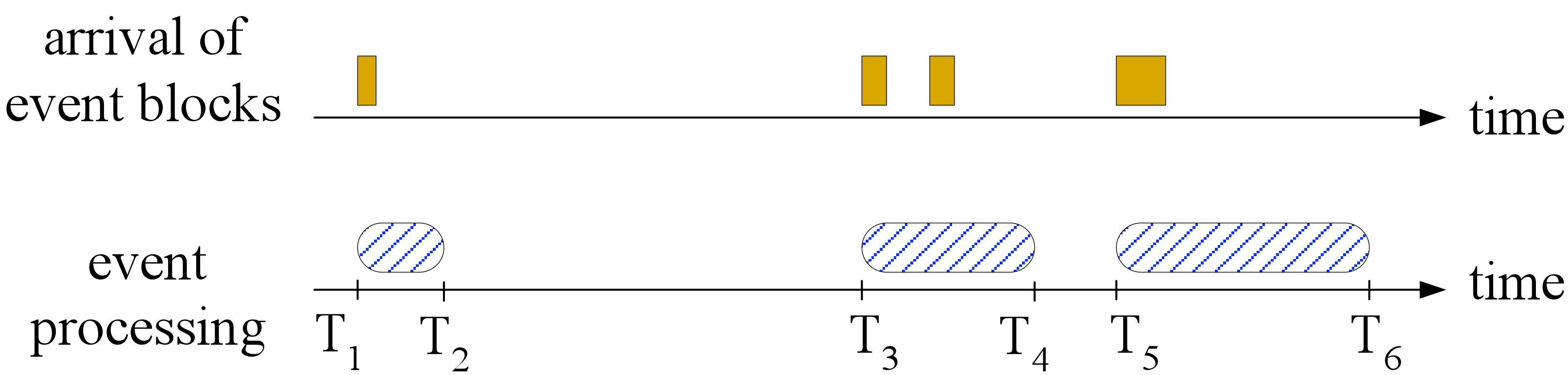
Drive up Resource Utilization to Achieve High Throughput

- TCC is friendly but also sufficiently aggressive to drive up resource utilization





Throughput Measurement 1: Exclude Idle Time from Throughput Calculation



$$\text{Throughput} = \frac{n}{T_6 - T_1}$$

$$\text{Throughput} = \frac{n}{(T_2 - T_1) + (T_4 - T_3) + (T_6 - T_5)}$$

Throughput Measurement 2: Minimize Measurement Samples

- Minimize the number of measurement samples while ensuring a high probability of making correct decisions

Problem formulation

Minimize $n = n_1 + n_2$

Subject to

$$\sigma_y^2 = \frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2} \leq \left\{ \frac{\max(H - \mu_y,\ \mu_y - L)}{Z_{1-\alpha}} \right\}^2 \quad (18)$$

$$n_1, n_2 > 0 \quad (19)$$

Solution

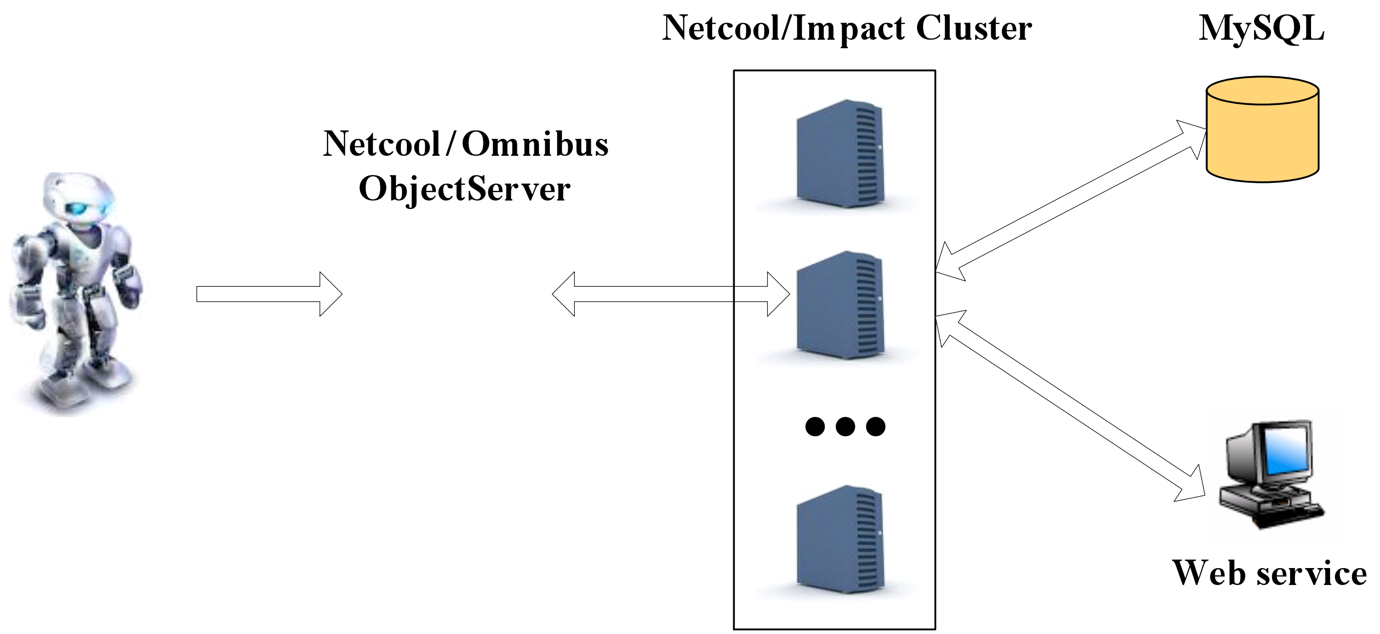
$$\widehat{n}_1 = \sigma_1(\sigma_1 + \sigma_2) \left\{ \frac{Z_{1-\alpha}}{\max(H - \mu_y,\ \mu_y - L)} \right\}^2$$

$$\widehat{n}_2 = \sigma_2(\sigma_1 + \sigma_2) \left\{ \frac{Z_{1-\alpha}}{\max(H - \mu_y,\ \mu_y - L)} \right\}^2$$

Throughput Measurement 3: Exclude Outliers from Throughput Calculation

- Extreme activities such as Java garbage collection introduce large variance
  - Sometimes GC can take as long as 20 seconds
- There are many known methods to handle outliers
- We found that simply dropping 1% of the largest samples works well
- This is simple but critical

Experimental Setup



- In some experiments, we introduce extra network delay
- In some experiments, we control service time of the Web service and Netcool/Impact user scripts

Scalability of NCI Cluster

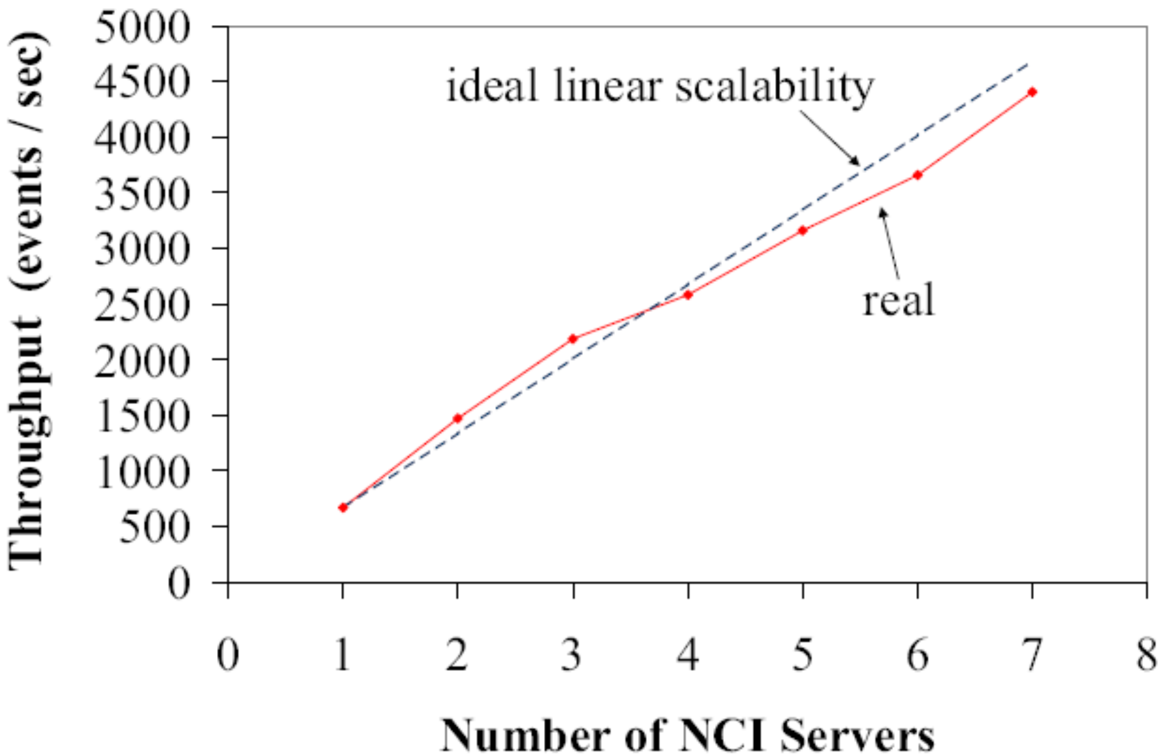
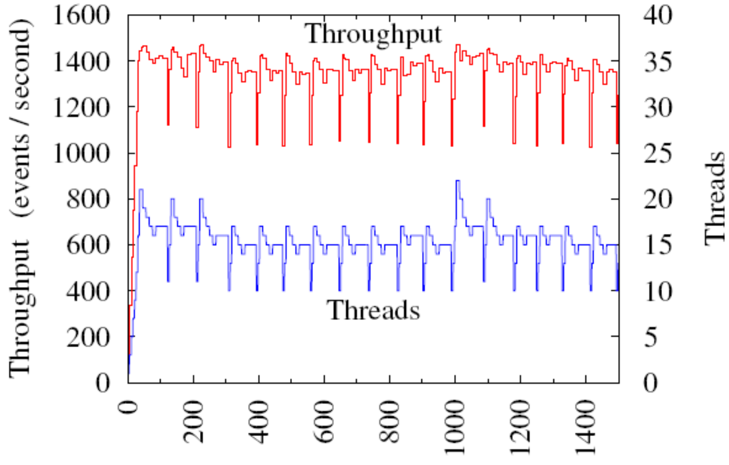
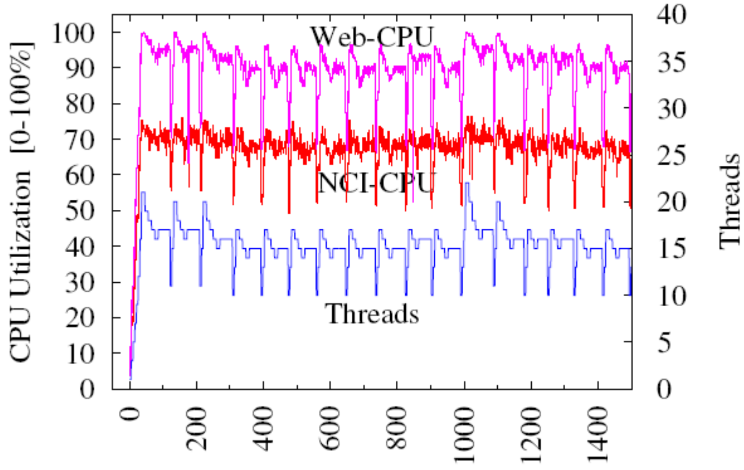


Figure 7: Scalability of NCI.

CPU as the Bottleneck Resource



(b) Throughput



(a) CPU Utilization

Recover from Memory Thrashing

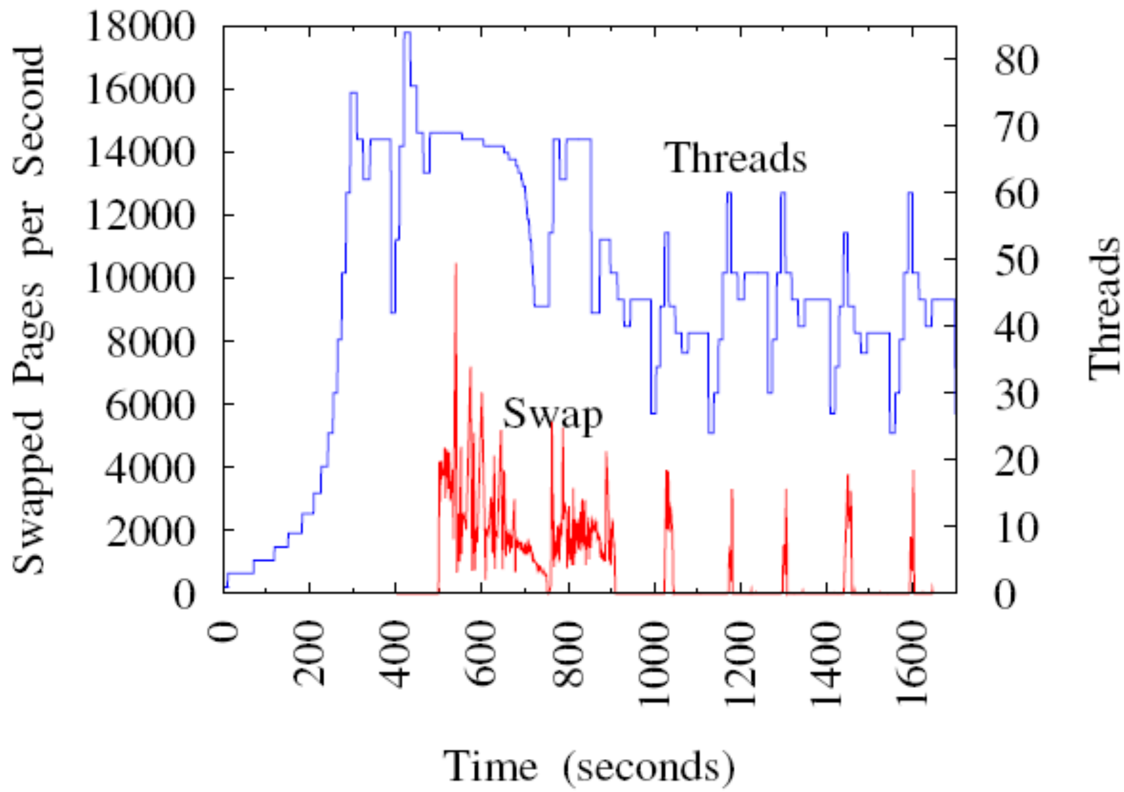


Figure 9: Memory bottleneck and memory thrashing.

Disk as the Bottleneck

Reducing threads actually improves disk performance

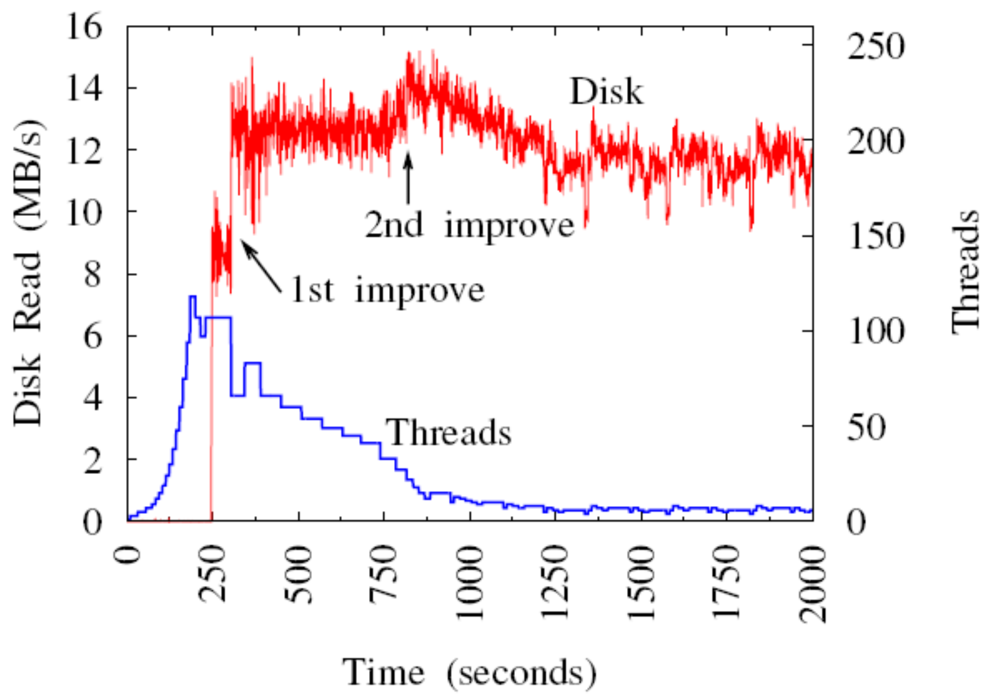


Figure 10: The Web machine's disk is the bottleneck. Removing threads actually improves disk throughput.

Work with an Uncontrolled Competing Program

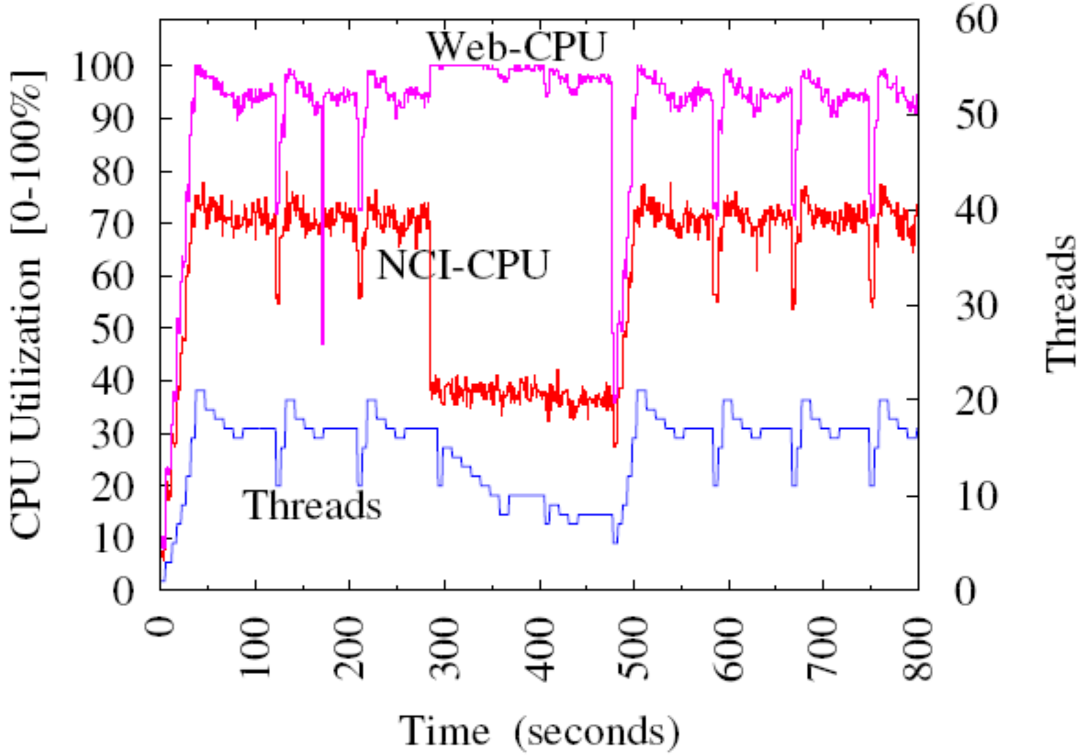


Figure 12: An external program competes for the bottleneck resource, which is the Web machine's CPU.

Related Work

- Greedy parameter search
  - Too greedy without considering resource contention
- TCP-style congestion control, e.g., TCP Vegas
  - Assume minimum RTT is the mean service time
  - In DB, min response time is the best-case cache hit service time. It cannot be used to estimate the congestion-free baseline throughput.
- Control theory
  - Not sufficiently black-box
  - Need to monitor resource utilization if applied to Netcool/Impact
- Queueing theory
  - Assume a known static topology and a known bottleneck

Future Work

- Is it possible to get “TCP-friendly” for general distributed systems?
  - Currently three or more instances of NCI need coordination in order to be friendly to each other
- Can we estimate the utilization of Google’s internal servers by observing changes in query response time?
  - This is possible for restricted queuing models
  - What’s the most general model for which this is still doable?

Take Home Message

- We need to revisit performance control for systems that handle workloads generated by software tools (robots)
  - Mixed human/robot worklaod (Twitter fits here)
  - Mostly robot workload (Netcool/Impact fits here)
  - Robot-only workload (Hardoop fits here)