Framework for Consolidated Workload Adaptive Management

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Agenda

- Virtualization technologies,
- Model of Adaptive Systems,
- Simple algorithms for adaptive management of workloads,
- Solaris 10 Containers,
- Architecture of framework for adaptive management of Solaris containers,
- Practical aspects of using simple policies for management of workloads within Solaris 10 environment.

Consolidation through Virtualization

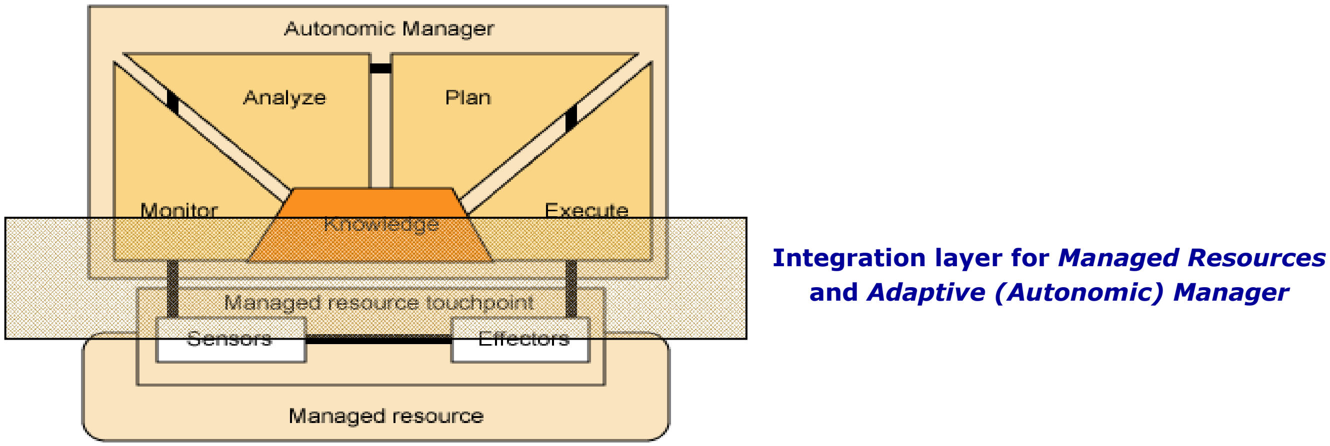
The big challenge for consolidating multiple applications into a single physical server is to provide mechanisms of control over the resources (CPU, memory portions or network bandwidth).

- ***Container based*** - there is only one underlying operating system kernel, which the containers enhance by providing distinct borders offering increased isolation between groups of processes (*OpenVZ, Solaris Containers*),
- ***Paravirtualization –*** provides a virtual machine and access to the native hardware, and thereby lets users run many instances of different OS's (*VMWare, XEN*).

Efficiency and correctness of the control strategy depends on many parameters, all of which must be very carefully identified.

To automate such a task some adaptation techniques should be used e.g. *Control Theory, Fuzzy Logic, Decision Trees*.

Adaptive System Model



Horn, P. Autonomic Computing: IBM's Perspective on the State of Information Technology, October 15, 2001

Our effort was to design and implement a framework which integrates variety of resources and exposes them through well known interface to adaptive manager.

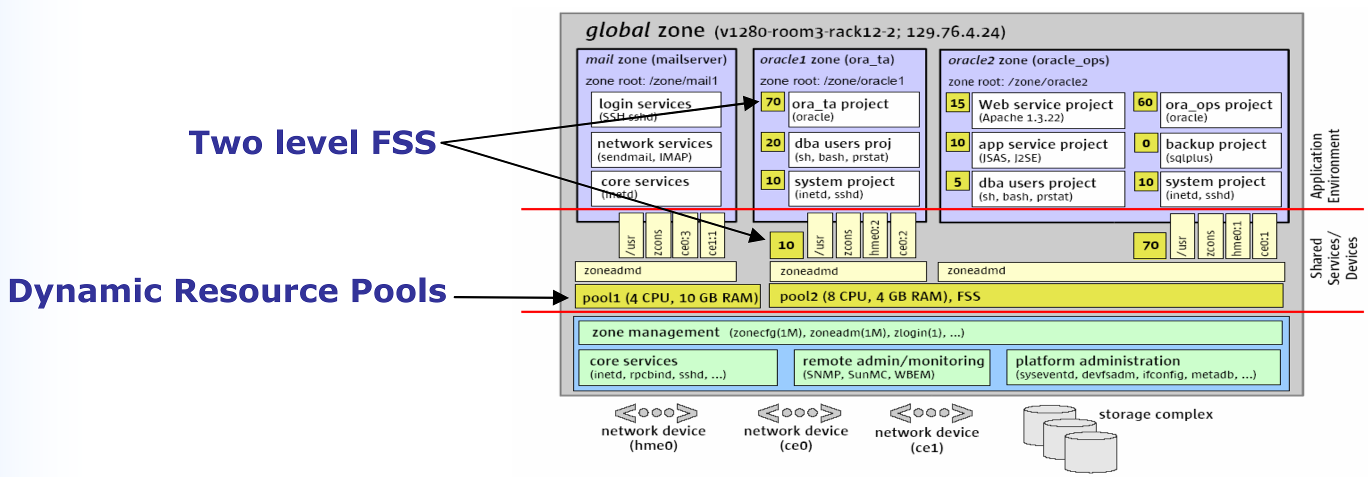
Solaris 10 Containers

Rich virtualization and resource management facilities:

- Two level *Fair Share Scheduler* (*Zones, Projects*),
- *Dynamic Resource Pools.*

CPU entitlement of workload $E_w = S_w / \Sigma_i^N S_i$ (1)

S_w – shares assigned to workload W, S_i – shares assigned to active workload i={1,..,N}



Source: „Consolidating Applications with Solaris Containers", Sun Microsystems Technical Whitepaper, November 2004

Workload controller implementation Case study

- Open-loop AM workload manager, exploiting the FSS model, after transformation of equation (1):

$$S^t_w = (U_w * \sum N^w_{i \neq s} S_i * A^t_i) / (1 - U_w), \text{ where } \mathbf{U_w} \text{ is a target CPU usage} \quad (2)$$

Number of active workload is changing at time t according to activity state vector $A_t = [A_t^1, \ldots, A_t^{Nw}]$, where $A_t^i = 0$ if W_i is not active and $A_t^i = 1$ if W_i is active, $i = \{1,\ldots,Nw\}$

- Closed-loop AM workload manager, which directly tunes Containers' or Projects' resource shares to achieve desired CPU allocation to the workload.

Proportional regulator

$$S_w^{t+1} = S_w^t + K_p * e(t), \text{ where } e(t) = U_w^t - U_w \quad (3)$$

Proportional-Integral regulator

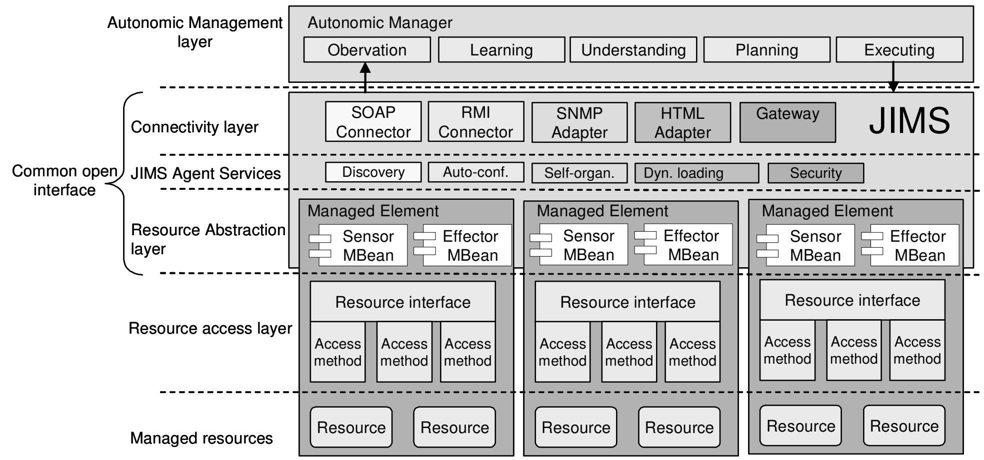
$$S_w^{t+1} = S_w^t + K_p * e(t) + K_i \sum_i^t e(t) \quad (4)$$

K_p and K_i coefficients are calculated using analysis of step response method

- Computer systems are *non-linear* (linear in some interval), *response delay* thus hybrid controllers using some rules should be used.

Adaptive Management of Virtualized Resources with JIMS

- Control loop consists of four basic steps: *Monitor, Analyze, Plan, Execute* which exploit knowledge collected during system activity,
- It requires exposition of virtualized resources using *Managed Element* interface which represents computer resources instrumented with sensors and effectors,
- It's designed as a extension of JIMS (Java Infrastructure Monitoring System) platform implemented as a set of JMX MBeans,
- Each container have separate instances of *Effector* and *Sensor* MBeans exposed using JMX connectors (RMI, SOAP) making available them to a decision subsystem.



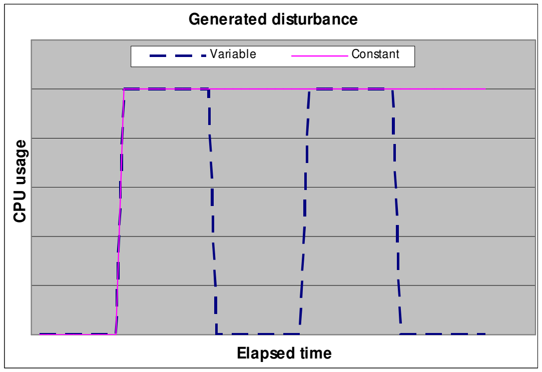
Solaris 10 Management Case study

Implementation based on hybrid controller

- P/PI algorithms,
- Jacobson algorithm

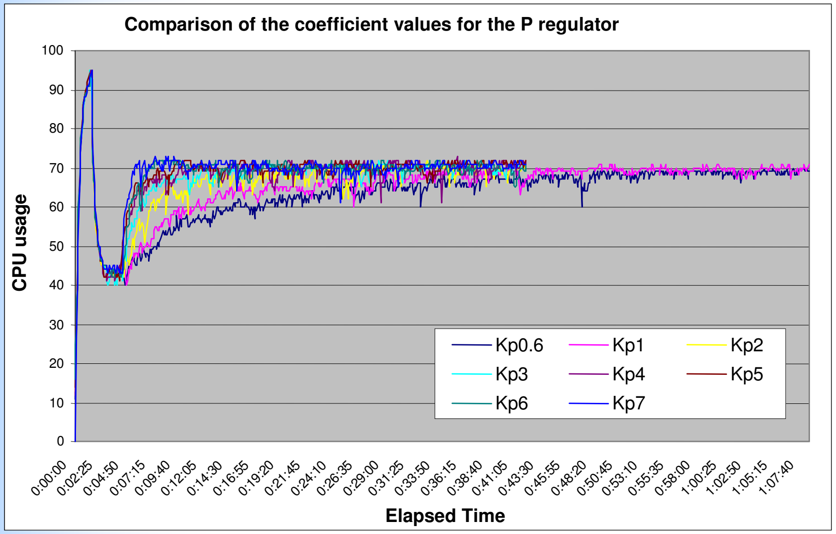
$$Uest_t = coef * U_{t-1} + (1-coef)*U_t$$

- Rules (irregular thread monitoring scheduling, CPU bound workloads)



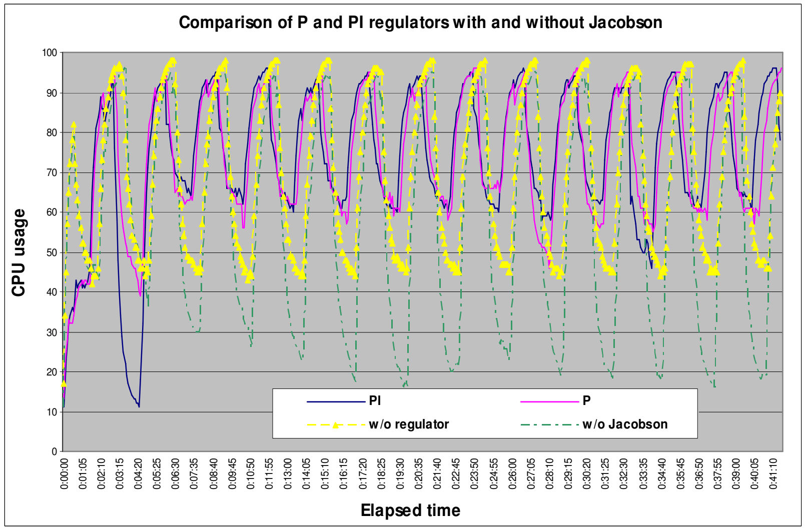
Target CPU usage U_w = 70%

Constant disturbance



Best results for K_p=7

Variable disturbance



Integral of squared error: P (102271), PI (100413)
Jacobson coefficient: 0.4

Summary

- Primary contribution of our work is a implementation of framework based on JMX technology for adaptive management of virtualized resources,
- Implemented framework was verified for a simple control policy,
- It opens a very wide area of research for control strategy selection which might use heuristic rules or fuzzy logic.