Increasing Cloud Power Efficiency through Consolidation Techniques

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Agenda

1. Cloud Computing Architecture
2. Server Consolidation
3. IBM Cloud Software Stack
4. Power Efficient Management Infrastructure
5. Experimental Results
6. Conclusions and Ongoing Work
What is Cloud computing

“The architecture and terminology of Cloud computing is as clearly and precisely defined as, well, a cloud.”

Fonte: www.openCloudmanifesto.org
Cloud Computing architectures

- Large-scale data centers offering virtualized resources in a reliable and scalable manner
- Computational resources, paid on an on demand and pay-per-use basis, to third-party service providers that do not want to build a private IT infrastructure

Main issues

- High economical expenditures for the Cloud owner
- Power required by IT resources and cooling system → Energy-related costs account for the 12% of data center economical expenditures
- IT infrastructures responsible for the 2% of the global carbon dioxide

Need of novel solutions to dynamically reconfigure the Cloud infrastructure, so to reduce the total power consumption
Virtualization Technologies

- Provisioning of many Virtual Machines (VMs) through resource sharing
- Enablers of live migration

Server Consolidation

- Concentrate the workload to efficiently use physical hosts
- Greedy consolidation strategies can affect VMs performance
- Execute VMs on as few physical machines as possible, while ensuring Service Level Agreements (SLAs)
- For instance, two physical servers, one VM each, both underutilized → both VMs in the same physical server to switch one server off
IBM Cloud Software Stack

- Extensively based on pre-existing IBM Tivoli Technologies
- Main components
  - Xen Virtual Machine Monitor
  - IBM Tivoli Provisioning Manager (TPM)
  - IBM Tivoli Monitoring Manager (TMM)
  - IBM System Directors (SD)
Xen

- **Paravirtualization approach**
- Different domains: **Dom0** for **administration**, **domX** for **guest VMs**
- Each domain has its own configuration in terms of virtual CPUs, network interfaces, disk space, hostname, etc.

IBM Cloud exploits **Xen VMs live migration**

- Pre-copy approach
- Migration almost completely transparent to final users
- Domain filesystem available at the destination server through **Network File Systems**

*Live migration through Xen command* `xm migrate --live`
IBM Tivoli

TPM
- Automates IT resources provisioning
- Exploits the concepts of provisioning workflows as a set of configuration operations arranged in a particular order
- TPM allows to dynamically allocate resources to applications based on number of requests and/or priority

TMM
- Monitors physical hosts and VMs to detect and react to either faults or saturations
- Adopts a client-agent-server architecture
- Monitoring agents, called Tivoli Enterprise Monitoring Agents (TEMAs), collect monitoring data and send them to a Tivoli Enterprise Monitoring Server (TEMS)
- Tivoli Enterprise Portal Client (TEPC) for the final presentation
IBM System Directors

IBM System Directors (SD)

- Automates processes to proactively manage systems, such as preventive maintenance, capacity planning, diagnostic monitoring, etc.
- Allows the gathering of power consumption indicators

Active Energy Manager (AEM)

- Included in SD
- Enables the gathering of power consumption indicators
- Allows the introduction of power capping to limit the maximum server power consumption by dynamically scaling CPUs frequency and voltage

The Cloud administrator exploits TMM and SD-AEM to identify unnecessary physical servers. If needed, he can decide to consolidate VMs to turn off not required physical servers.
Data center power consumption is inherently related with the processing power, and largely depends on powered-on physical hosts.

**Power efficiency**

- $CP(x) = \text{computational power}$, $P(x) = \text{consumed power}$
- Data center A is more power efficient than a data center B if either
  - $CP(A) > CP(B)$ and $P(A) = P(B)$, or
  - $CP(A) = CP(B)$ and $P(A) < P(B)$

**VMs dynamic allocation**

- Dynamic VMs consolidation to reduce the power consumption
- Dynamic power capping and time-dependant VMs workloads can make the current allocation unfeasible
- For instance, in peak hours, we allocate additional VMs due to many requests. During night hours, VMs should be consolidated, so that the data center can switch off underutilized physical servers
Management Infrastructure for Cloud Power Efficiency

1. Gathers both load and power consumption indicators from servers and network elements
2. Decides if a better VMs allocation exists under multiple constraints, such as CPU, memory, SLAs, etc.
3. Reconfigures the data center at run-time if a better VMs allocation exists

We focus on infrastructure monitoring aspects
- SD-AEM collects power consumption data from hardware
- TMM gathers load indicators from hosts and VMs
- Two separate tools → We need a proper plug-in to exchange data among them
- The obtained monitoring infrastructure allows the provisioning of both load and power consumption indicators to VMs allocation managers
Experimental Results

IBM Cloud testbed

- 6 x IBM BladeCenter H21 with 2 CPUs Intel Xeon 2.666 MHz Core Duo and 4 GB RAM
- Xen VM with 1 VCPU and 512 MB RAM
- Power capping limits the maximum server power consumption to 213 W
- Results of a one hour-long test to see the variations of the power consumption within this time window

Two Workload Types

- Raw VCPU computation – Computation-bound, no communications, and no interaction with users
- Apache HTTP server provider – Simple Web page requests, useful to test how the VM reacts under concurrent access to the network cards
Raw VCPU Computation

Compare the number of cycles-per-second the Java program performs with VCPU load in \{20\%, 40\%, 60\%, 80\%, 99\%\}

- Consolidation from 1 VM/1 host to 5 VMs/1 host
- Power consumption depends on VCPU load and server consolidation
- Performance almost stable up to 3 VMs. For VCPU loads > 40\%, performance decreases when we consolidate more than 3 VMs
- Consolidation power saving are remarkable
- If the performance degradation is the difference between the number of cycles, with 5 consolidated VMs, we have energy saving of 75\% and 20\% performance degradation
Apache HTTP Server Provider

Compare the **requests-per-second** processed by the server

- Traffic generator ab, 5000000 reqs/test, concurrency in \{1, 10, 20, 50, 100\}
- VCPU usage of each VM is always below 45%
- **Average number of requests/sec** degrades **almost linearly** when concurrent services > 1. Difference due to **network communications** (increased hypervisor overhead)

- Number of requests/sec for each host increases, while power consumption almost stable: **saturation point in 4 VMs on the same host**
- Each VM processes fewer requests, but parallelism leads to a higher number of processed requests: **power required to process one HTTP request reduces**

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Server consolidation
- Convenient in terms of power savings
- Lead to performance degradation when the number of consolidated VMs is higher than a service-specific threshold

Thumb rules for energy-efficient deployment in the Cloud
- VMs with a raw VCPU computation less than 80% → up to 4 VMs in one host without remarkable performance degradations
- VMs with an Apache HTTP server → performance degrades even for low consolidation degree
- Service provider SLAs have to be considered
  - VMs migration is a network-bound process, and can negatively affect Cloud services that perform network communications
  - Dynamic server consolidation affects VM performance due to both physical resource sharing and hypervisor overhead
Conclusions

- **VMs migration** for the sake of server consolidation extremely feasible to increase Cloud power efficiency
- **Performance degradations** differ for different services executed into the VM

Ongoing Work

- Automatic VMs live migration
- **Identification of service profiles** to better estimate the side-effects of VMs consolidation
  - Preemptively avoid configurations that would not respect SLAs
  - Drive VM allocation algorithm to speed-up the decision process
The fog has gone...

... and clouds are disclosed into the sky!

Thanks for your attention!
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Is there any question?