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Infrastructure Monitoring of Compute Cloud

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Abstract—*In the present scenario, cloud services like SaaS, PaaS and IaaS are of importance in all real time applications. Cloud based IT services are the need of the hour and are being widely used in areas related to education, health, business, knowledge management etc. Applications that are critical to the industry require real time response and should function smoothly. Clouds implement services in manner that makes them available anywhere, anytime and are scalable in nature. Monitoring of cloud functioning is required to measure the correct and efficient functioning of these cloud services. In our paper, we highlight the need for monitoring cloud infrastructure, associated services and parameters that require monitoring in a compute cloud. We present the categories under which the infrastructure within a compute cloud can be monitored.*

1. INTRODUCTION

Information technology (IT) comprises of hardware, software and telecommunication networks that are used for management of information. In today's dynamic global environment using IT to manage business processes has become the key to success for managers and business organizations. IT plays a vital role in providing efficient and effective management services to the users and thus helps in improving the quality of business processes.

Cloud computing is an emerging IT trend that enables business organizations to implement their processes on a cloud and users can access these with the help of internet services. Putting data and processes on the cloud enables the users to access these from anywhere just with the availability of internet services. Market reach to the customers increases with applications running on the cloud. Instead of traditional licensing models and in house data centers, cloud provides the "pay-as-you-go" facility to the users. In place of purchasing and maintaining the infrastructure, organizations hire the required infrastructure from compute clouds, utilize it till the time required and then return it back to the cloud providers. This also caters to the varying requirements of the organizations as they can hire resources as per their changing requirements.

Infrastructural requirements of an organization or end user can be in the form of compute, storage and network. Consumers can rent resources like servers, storage, networking technology and data center space from IaaS clouds instead of purchasing them and installing them in their own data centers. IaaS based clouds provide an efficient and scalable environment for fulfilling these requirements through resource virtualization. Within an IaaS based cloud, compute services are used to provide processing power as a resource to the consumers. Using Virtual Machines (VM) in an organization is a cost effective way of managing fluctuating system workloads within an organization. Users can provision VMs as per their requirements and use them as and when required. Management of these VMs like running and suspending them are the responsibilities of the cloud.

Using cloud for infrastructure requirements reduces over provisioning of IT resources, improves IT capabilities, reduces cost, improves scalability and availability of resources to the organizations without owning the infrastructure.

To ensure reliability, integrity, availability and security of services accessed from cloud, continuous monitoring of the associated infrastructure is required. Infrastructure hired by organizations in the form of VMs from compute clouds should be monitored consistently to provide efficient and reliable compute services to the users.

IaaS cloud services are provided by various open source and private providers. Consumers can use these platforms to implement their own clouds. Open source platforms give the advantage of flexibility to the consumer where they customize the cloud as per their specific needs. Some widely used open source IaaS cloud platforms are OpenStack[15], CloudStack[16] and Eucalyptus[17].

In this paper, section 2 explains the need for infrastructure monitoring, Section 3 describes components of infrastructure monitoring. Section 4 illustrates the case study . Section 5 gives the related work and Section 6 states the conclusions.

2. NEED FOR INFRASTRUCTURE MONITORING

With real time applications being run on the cloud these days, monitoring of cloud and its infrastructure is becoming an important aspect. Infrastructure performance monitoring also gives information regarding the support for applications hosted in that environment, response time of the applications when they work in a virtual environment, infrastructure response time, change in the performance of the system when new infrastructure is added to or removed from the system. Performance of the applications installed on this infrastructure is also affected by the status of the infrastructure and hence monitoring of infrastructure is necessary.

The provider and consumer, both benefit from this. Management of cloud infrastructure becomes convenient for provider when complete monitoring information is available. Also in case of consumers, monitoring provides performance indicators regarding infrastructure, platforms and applications. SLA monitoring with respect to resource availability, scalability, delay in service, etc. provides the consumers with information on QoS offered by the cloud and overall performance of the system. Monitoring also plays a vital role in certifying SLA compliance when cloud audits are performed [12].

Any organization after transferring its processes onto the cloud require monitoring to ensure smooth functioning of business processes and for improving performance. To guarantee the performance required by the applications and services, estimated workloads need to be measured, capacity of the infrastructure resources (CPU, memory, disk, network) needed is to be measured. Real time monitoring gives better information than static monitoring. Fast changing network conditions, varying resources [9] also affect the performance of business processes and need to be monitored constantly. Monitoring the perceived performance is required so that corrective measures can be taken when required. QoS and QoP are important in case of public critical processes. when hosting services for public agencies, strict security measures are to be followed by the provider and can be audited by consistent monitoring. Outages, slow response time and security issues are some critical aspects that need to be monitored. Infrastructure of data centers where clouds are implemented need to be monitored to handle troubleshooting and other management actions [3]. Comprehensive and reliable monitoring measures are required to locate the problems when they arise and to identify of the cause of failure if it is at the provider end or is caused by the applications.

The idea of measured services highlighted by NIST [18] that allows consumers to pay for the services as per their usage, type of service used and the price model adopted also requires monitoring. Data generated by monitoring in form of metrics at different levels of granularity provides the users with a conformation on what they are paying for to the providers.

3. INFRASTRUCTURE MONITORING

The complexity of cloud operations is increasing with the ever growing demand for compute services. In this scenario, accurate and fine grained monitoring activities are required to efficiently operate the platform and manage their increasing complexity [6]. Efficient monitoring of the system helps in determining the health of the system and is of benefit to both the consumers and the providers [1, 8, 13]. Performance of the system, degree of resource utilization can be measured using monitoring. Monitoring facilitates the providers to watch for problems that can arise in the system by keeping a track of the status of all the processes running within a system. Also, existing and arising trends in the system regarding resource utilization can also be revealed by monitoring. Making informed decisions based on resource usage trends can prevent potential bottlenecks that can arise in a system. Features like scalability, failure detection, live migration and high availability can be implemented efficiently if complete information about the system status and its resources is available.

Process monitoring, resource alerting, intelligent alerting and trending are some aspects of monitoring that enable providers and consumers to keep themselves updated about the system. Monitoring also enables the consumers to verify if the service level targets have been met by the provider or not. Also the consumer can track their resource usage trends and verify if they are being charged by the provider for the same.

In our paper, we present the areas that need to be monitored in case of cloud infrastructure. The main areas covered under infrastructure monitoring include physical resources, virtual resources and their performance. Based on our analysis of three standard open source IaaS cloud platforms namely OpenStack, CloudStack and Eucalyptus, we say that infrastructure monitoring of the compute infrastructure of an IaaS cloud should be carried out under the following four main aspects:

- *Compute infrastructure* for listing all monitoring attributes associated compute offerings.
- *Compute infrastructure utilization* for assessing resource usage.
- *Background processes* to keep track of all the processes running in the background.
- *OS processes* to track usage of CPU, memory and network.

Monitoring data should be collected under the above four headers and can be utilized to provide all the required information about the system.

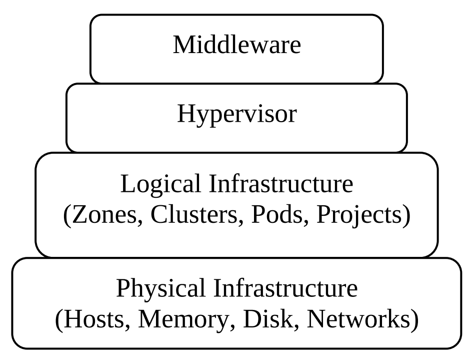

Fig. 1: Computer Infrastructure.

The following subsections explain these four headers in detail:

4. COMPUTE INFRASTRUCTURE

Compute infrastructure of a cloud consists of resources that be virtualized and provisioned to users. For efficient resource provisioning, accurate information of existing physical and logical resources on the system is required. Using infrastructure monitoring, this information can be gathered and utilized for understanding the actual status of the system. Detailed knowledge about the system enables the administrators to provide smooth services to the users.

Every cloud follows a pattern in which it is designed. The architecture might be hierarchical or flat. But the standard components of the infrastructure in every cloud remain similar.

At the root level, exists the physical infrastructure which comprises of the hardware like servers and memory. Above this resides the hypervisor that enables virtualization of these hardware resources. Some clouds use middleware to interact with the hypervisor as middleware provides the API support required by the cloud to interact with the hypervisor. In some cases, instead of middleware, the cloud has its own plug-in to interact with the hypervisor. Above the middleware reside the logical components in which the infrastructure can be partitioned. These components can exist in a hierarchical manner and may divide the physical infrastructure on various basis like, similar hypervisors and geographical distributions. Multiple levels of logical divisions can exist based on the cloud architecture. In OpenStack these divisions comprise of cells, availability zones and host aggregates. In CloudStack, the divisions are in the form of zones, pods, clusters and domains and in Eucalyptus there are availability zones and nodes. In case of compute infrastructure monitoring, the aim is to identify the parameters associated with the infrastructure and monitor the desired ones.

The physical infrastructure can be categorized as physical servers on which VMs are provisioned and storage in the form of disk and memory. The amount of available physical resources in the system need to be monitored. The number of hosts, their ids, size of memory etc. are all monitored to keep an information regarding the state of the system. The VMs existing on physical servers (hosts) also need to be monitored for the resources associated with them and for the number of VMs of different sizes that can be provisioned on the available servers. Data about the type of hypervisors, its state, hardware resources associated with it, the zone to which it belongs are all the parameters that should be monitored with respect to the hypervisor. The number of zones available in a cloud, capacity of each zone, their ids and names along with the number of hosts and instances associated with them is also maintained. All these parameters when monitored give a description of the physical state of the system and enable appropriate provisioning of resources to users. Fig. 1 shows the general infrastructure division of a compute cloud.

5. COMPUTE INFRASTRUCTURE USAGE

Infrastructure associated with compute services also needs to be monitored for its usage. The current resources available with a host, the amount of free and used memory, available and utilized disk space, number of VMs currently running on a host, size of running VMs, the status of resources within zones etc., all need to be monitored. This data gives an accurate information about the current state of the system. An analysis of this data provides the current usage trends within the system. Information about the resources that are free and that are running at threshold levels can also be gathered from this data. Service providers can analyze and decide on what resources are to be scaled up and down in the system based on the consumption.

6. BACKGROUND PROCESSES

Background processes are the processes that are associated with components providing compute services and run at the backend to facilitate smooth functioning of services. These might include processes like scheduling, SLA management, policy management, quota management, service orchestration, VM management etc.. Monitoring of these processes and associated parameters give information regarding the smooth functioning of the system. Information regarding if a process is running correctly implies that associated component is functioning in desired manner. Background processes also involve overheads and their monitoring indicates the effect of these processes on the system.

7. OS PROCESSES

CPU, memory and network related processes come under the category of OS processes. Parameters associated with these processes and their values should be monitored consistently. CPU, memory and network are used at every level of the compute infrastructure and should be measured at each level. Total available resources, maximum usage and current usage of these resources should be monitored to understand the current state of the system.

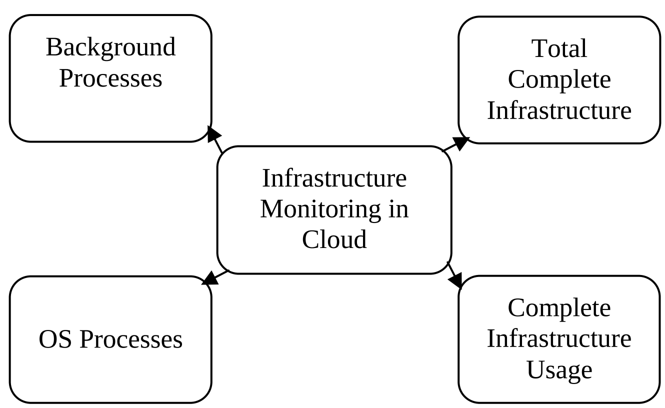

Fig. 2: Computers Infrastructure Monitoring.

The above four categories of infrastructure monitoring provide a comprehensive data about the system resources, current state of the system and the associated processes at every level in the system. Fig. 2 depicts the infrastructure monitoring components diagrammatically. Monitoring compute infrastructure information at this fine grained level presents the accurate status of the system to the administrators and hence enables them to provision services in an efficient manner to the users and also improve the system performance.

8. CASE STUDY

In the previous section, we present the four main categories under which infrastructure of a cloud should be monitored. OpenStack, CloudStack and Eucalyptus are three popular open source IaaS cloud platforms that are used by organizations. Monitoring services within these clouds are available to keep track of the system status and performance. Also, open source monitoring tools are available that can be integrated with these clouds to provide better monitoring services to the consumers and providers. Some of the popular open source monitoring tools used are Nagios[22], Zenoss Zenpack[19], CollectD[21] and Zabbix[20]. In this section we present a short description of OpenStack, CloudStack and Eucalyptus and the four monitoring tools. We then give an analysis of when these tools are applied on the clouds with respect to the infrastructure monitoring categories identified by us.

OpenStack [15] is an open source IaaS cloud platform that is popularly used by organizations for implementing compute services. Resources in the form of compute, storage and networking are controlled by OpenStack through a datacenter. OpenStack framework provides efficient and real time management of available resources in a flexible manner. It also implements features like high availability, automated provisioning, load balancing and scalability.

CloudStack [16] is an open source, open standards, multi-tenant cloud orchestration platform. It is scalable, flexible, secure and hypervisor agnostic. Compute and storage resources are provisioned to the users in form of service offerings. A service offering is a set of virtual resources, like, CPU, memory and disk. The system administrator can define different type of offerings as per the user requirements. A compute service offering includes guest CPU, guest RAM, guest networking type (virtual or direct) and tags on the root disk [14]. Along with the resources, a service offering also involves features related to resource metering, usage and charges for usage. A user can select from the available offerings while creating a virtual machine (VM). Once provisioned, CloudStack enables users with virtual machine management services that include starting, stopping, restarting and destroying virtual machines. Management of associated resources, like, CPU, network and storage and their utilization is also a part of VM management. Using virtual machines in an organization is a cost effective mechanism for management of fluctuating system workloads.

Eucalyptus [17] follows a simple design to implement IaaS functionality. It has a modular and distributed design which can scale easily and optimize performance in various different setups. It is hypervisor agnostic and can be implemented on a limited number of resources. On demand provisioning and self service configuration of compute resources is provided to the consumers. It follows a hierarchical structure in which there exists a cloud controller, and multiple cluster controllers and node controllers. All VM provisioning and management requests are made via the cloud controller. It provides features like scalability and live migration.

Zenoss ZenPack [19] is an open source monitoring software that provides monitoring support from the perspective of the service provider. Zenoss allows system administrators to monitor some of the important aspects of cloud like availability, inventory, configuration, performance, and events related to the system. The main components monitored are hosts, hypervisors, services, instances, flavors, images, servers and software. OS process utilization is also monitored within ZenPack. The key metrics provided by zenoss are for CPU and memory tracking. These metrics are provided within Zenoss at all the levels of granularity. Alerts regarding low and high thresholds of the resources are also available.

Zabbix [20] is an open source monitoring software that provides proactive monitoring of the infrastructure. It works with the aim of monitoring everything inside the network. Number of hosts and users, network traffic, memory usage and CPU utilization are some of the parameters monitored by Zabbix.

Collectd[21] is a monitoring tool that provides an agent based monitoring approach. An agent is deployed on each host that needs to be monitored. Information to be monitored by the CollectD is collected in form of system metrics. Current system performance, future system loads, available and resources being used currently can be measured using CollectD. Information to be monitored is collected in form of system metrics relating to memory, CPU, secondary storage etc. and can be used to measure the current status of system.

Nagios[22] is a popular open source cloud monitoring software. It monitors usage of available resources like CPU, memory, etc. Cloud capacity including memory,

storage, private and public ip's is also monitored. Information regarding state and status of VM's is monitored. Checks for usage of various resources like memory, CPU, network and disk usage within a VM are also carried out.

We now give some of the findings obtained when we applied these monitoring tools on the mentioned clouds with respect to the infrastructure monitoring categories defined by us.

We applied Zenoss Zenpack, Zabbix and CollectD on OpenStack. Our findings were as follows:

- Zenoss ZenPack mainly performs process monitoring. OS processes, like, CPU, memory and network are monitored. Most of the background processes are also monitored by Zenoss. Compute usage parameters like, resources on a host, state of a VM, resources being utilized by a VM are measured. Zenoss also provides statistics about the number and id of hosts and tenants available in the system.

- Zabbix collects monitoring information about the states and status of the infrastructure resources like hosts, tenants and VM's. Complete monitoring of OS process utilization for CPU, memory and network usage is carried out in Zabbix. There is no support for monitoring of background processes.
- CollectD gathers detailed information about the compute infrastructure resources like, hosts, hypervisors, tenants and VM's. Background processes except policy enforcement and OS processes are not monitored by CollectD.

In case of Eucalyptus, we consider Nagios, Ganglia and CloudWatch. Some observations based on our case study are as follows:

- Nagios provides monitoring specific to current status of clusters and nodes. It keeps a check of the services and the CPU utilization on these.
- Ganglia [23] for Eucalyptus performs VM level monitoring. VM details, current status and resource utilization statistics are maintained by Ganglia.
- CloudWatch, the inbuilt monitoring tool in Eucalyptus provides monitoring at diverse levels. Compute infrastructure monitoring is provided only at the instance level. CloudWatch also monitors services like auto scaling instances, load balancing and elastic block storage volumes.

In case of CloudStack, we apply Zenoss Zenpack, CollectD and Nagios. Our study indicates that the major aspect of monitoring covered by all the three monitoring software is of compute infrastructure and its usage. Monitoring support for background processes is not there in these software. Zenoss Zenpack provides the maximum monitoring support for OS processes. Some attributes like status of total resources, resources currently in use, available resources and metrics about resources at different levels of granularity are monitored by all the software.

On the basis of the above case study, we can suggest that all the tools analyzed above offer monitoring support for some specific part of infrastructural monitoring component. Currently available tools do not cover the desired monitoring functionality in an exhaustive manner. Monitoring of processes supporting compute services is scarcely carried out in any of the tools. There is a need for tools that can provide comprehensive monitoring of resources and services at the infrastructure level. At design time of new monitoring tools or up gradation of the existing ones, the categories of infrastructure monitoring defined by us can be referred by the tool developers. This categorization of infrastructure monitoring requirements reduces the task of identifying requirements at different user levels.

9. RELATED WORK

Numerous frameworks for monitoring the cloud infrastructure have been proposed. Most of the frameworks focus on a specific aspect of monitoring. Rodrigues et al. [7] propose architecture that focuses on evaluating Scalability, Accuracy, and Adaptability in cloud monitoring systems based on local filters. Marquezan et al. [2] in their paper address the issue of taking monitoring data based management decisions by proposing a 3-D monitoring model for analyzing cloud monitoring information . Andreolini et al. [11] present a monitoring architecture for managing issues like scalability and persistence in service delivery. The architecture aims to obtain high scalability. Enhanced infrastructure performance on the basis of max-min algorithm approach is proposed by Alam et al. [10] Multiple monitoring based approaches for improving on services like SLA's, privacy violation issues, increasing scalability, accuracy have also been proposed [4,5,14].

10. CONCLUSION

Infrastructure monitoring is an area in cloud that is currently being explored. Monitoring provides information required for measuring system performance, application performance, SLA management etc. Also in case of real time business processes, monitoring QoS and QoP parameters, response time and outages is required. Detailed monitoring of infrastructure under the categories of compute infrastructure, compute infrastructure usage, background processes and OS processes provide the consumers with a categorical information that enables them in taking informed decisions about the system.

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