9. Enterprise cloud computing ecosystem and roadmap (4 hours)

- **9.1. Public cloud providers**
- **9.2. Cloud management platforms and tools**
- **9.3. Tools for building private clouds**
- **9.4. Future of enterprise cloud computing**

PUBLIC CLOUD PROVIDERS

The major public cloud service providers are: Amazon EC2, Google App Engine and Microsoft Azure.

An infrastructure as a service (IaaS) cloud (such as Amazon EC2):

- offers self-service infrastructure (both compute and storage) provisioning built on an underlying large-scale data center based on virtualization.
- Dynamic monitoring and load balancing services are the latest addition to the Amazon cloud, i.e. CloudWatch, Auto Scaling and Elastic Load Balancing.

Platform as a service (PaaS) clouds, such as Google App Engine and Microsoft Azure, :

- Offer a software development and deployment platform while hiding much of the underlying virtualization and dynamic resource management layers.

The common feature of these offerings is the ability of users to pay only for the resources they actually consume, at a very fine granularity. From a business perspective this is the essence of classifying any offering as a public cloud service.

CLOUD MANAGEMENT PLATFORMS AND TOOLS:

- Configuring and managing a small set of servers on an IaaS cloud can be accomplished easily using an IaaS offering's own infrastructure self-service APIs and tools.
- Managing a larger and more complex deployment requires more tools support and automation, just as it does within an enterprise data center.
- Cloud management platforms such as ***3tera, RightScale, Kaavo, EnStratus and Ylastic provide web-based graphical tools to configure and manage complex configurations of servers deployed in the cloud.*** Some of these tools work only with Amazon EC2, while others, such as RightScale, enable management of multi-cloud deployments; for example, spanning Amazon EC2 and GoGrid.
- In addition to graphical self-service infrastructure management, some cloud management tools also offer dynamic monitoring and load balancing. These capabilities were crucial in the initial stages of IaaS before Amazon EC2 itself introduced Elastic Load Balancing, CloudWatch and Auto Scaling.
- Some cloud management tools, such as 3tera, Appistry or ServiceMesh can also be deployed within the enterprise and used to manage a combination of local and public cloud infrastructure.
- 'Application virtualization' technology from rPath or AppZero makes deployment of an enterprise application tasks simpler and also optimizes the application images in size. Such tools also promise to enable portability of application images across different clouds and private data centers
- There is another emerging trend related to infrastructure management: Hosted technical software for email security and virus scanning, such as MessageLabs (recently acquired by Symantec). We foresee that even more technical software, such as middleware for managing web services, workflows, or identity, moving to hosted models.

TOOLS FOR BUILDING PRIVATE CLOUDS

IaaS using Eucalyptus

- Eucalyptus is an open source framework (developed at the University of California, Santa Barbara) that implements infrastructure as a service (IaaS) on a collection of server clusters.
- Eucalyptus Systems is a commercial offering based on this open source project, targeted at enterprises interested in building private clouds.
- The design of Eucalyptus also provides insights into the issues that need to be handled while creating an IaaS cloud, and serves as a platform for research in this emerging area.
- Eucalyptus implements external APIs identical to Amazon EC2, it also provides clues as to the possible internal architectures of such public clouds. For the same reason, Eucalyptus deployments can also be controlled by cloud management tools, such as RightScale.

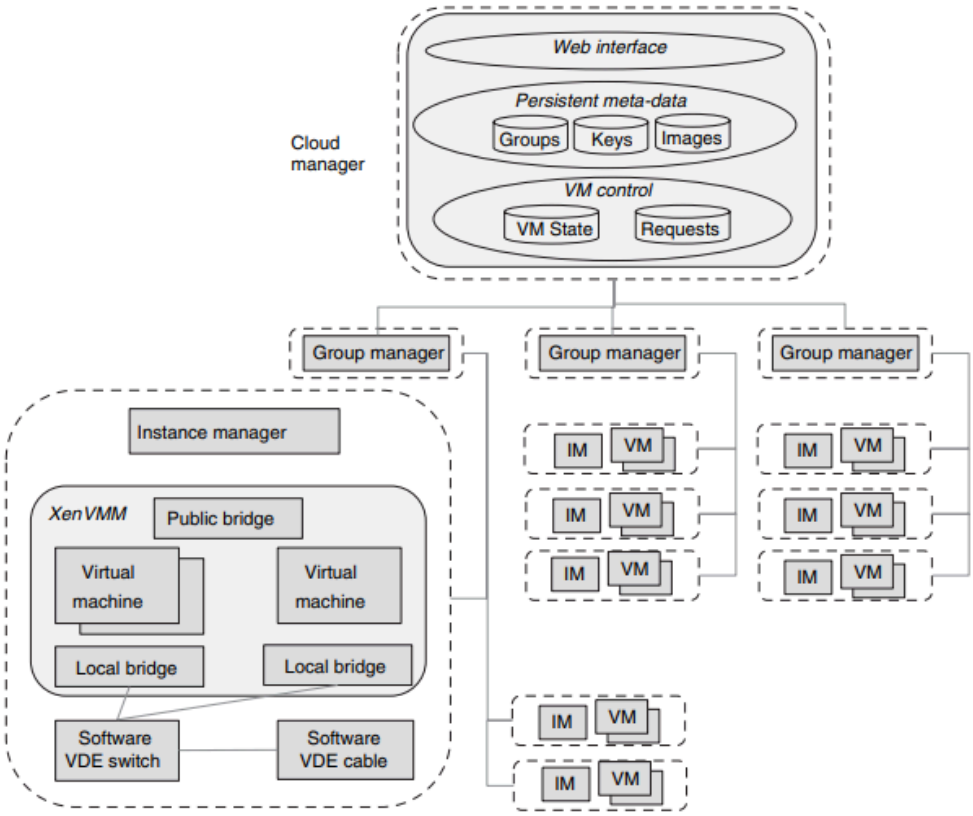

FIGURE 17.2. Eucalyptus IaaS framework

Above figure illustrates the Eucalyptus architecture.

- Eucalyptus can run on a collection of one or more server clusters. Servers within each cluster are connected via a fast local Ethernet, while clusters can be connected to each other via possibly slower networks, such as private wide area networks or even the internet.
- Each server node runs the Xen hypervisor on which user virtual machines are provisioned on demand.
- Each cluster node also runs a Eucalyptus Instance Manager (IM) process on the XenLinux host operating system (provisioned automatically when Xen boots).
- One node in each cluster runs a Eucalyptus group manager (GM) process, and a single cloud manager (CM) process server is responsible for overall control of the Eucalyptus cloud, i.e. all clusters. The group managers and cloud manager run natively on specially designated servers rather than as virtual machines.
- The cloud manager provides a web interface, including REST APIs identical to that of Amazon EC2, using which users can request for virtual servers and monitor their status. The cloud manager also maintains persistent meta-data describing the cloud, such as groups, their addresses, access keys given to users to connect to their assigned servers, as well as virtual machine images using which user virtual servers ma be provisioned. The cloud manager is responsible for controlling the entire cloud, and therefore also needs to track the dynamic state of all virtual machines in the cloud, the load, performance and utilizations of each cluster, as well as the status of all user requests.
- Each instance manager on a cluster node is responsible for provisioning virtual machines as requested by its group manager, as well as communicating the status of the node, i.e. resource utilization and available capacity, to its group manager on request. Each group manager in turn monitors the status of its entire cluster and

communicates that back to the cloud manager on request. The group manager also makes intra-cluster scheduling decisions in response to the requests it receives from the cloud manager.

PaaS on IaaS: AppScale

The AppScale open source project (also developed at the University of California, Santa Barbara) mimics the GAE platform through distributed deployment of the GAE development web-server on a cluster of virtual machines. Using AppScale, a GAE-like PaaS environment can be implemented in a scalable manner on an IaaS platform, such as EC2 or Eucalyptus.

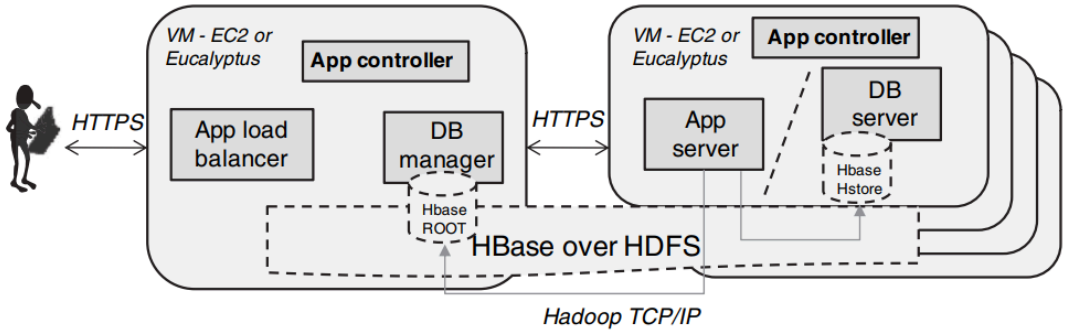

FIGURE 17.3. AppScale PaaS on IaaS architecture

Future of enterprise cloud computing

It has been well elucidated in the popular book The Big Switch, the evolution of industrial use of electricity from private generating plants to a public electricity grid can serve as an illuminating analogy for the possible evolution of enterprise IT and cloud computing. In such an analogy, privately run enterprise data centers are analogous to private electric plants whereas the public electricity grid illustrates a possible model towards which the public

the clouds of today may evolve.
As another analogy, let us consider data communications: In the initial days of digital networks, corporations owned their own data communication lines. Today all data communication lines are owned by operators who lease them out, not only to end-users, but also to each other. The physical resource (bandwidth) has become a commodity, and it is only in the mix of value added services where higher profits are to be made.
In the Forrester report it is mentioned that 80% of future computing experiences will be accomplished by light computing modes (in other words: smartphones, displays, browser-based laptops, etc.), while 20% will still require heavy compute resources for graphics, AI, and other workloads.

According to report some future trends are:

- Increased application access (Mobile apps)
- Moving away from traditional desktops
- Unified endpoint management
- Services partner focusing on employee experience
- AI for decision making

Some future trends in cloud are;

- Commoditization of the data center
- Inter-operating Virtualized Data Centers
- Convergence of private and public clouds
- Generalized ‘cloud’ services