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Devising a Cloud Based Architecture for IT Implementation in Power Distribution Utilities

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Abstract—*Cloud Computing is a virtualized computing power and storage delivered via platform-independent infrastructures of abstracted hardware and software. Cloud computing is based on many already existing technologies such as the internet, grid computing, virtualization and web services. It is a recent technology, which is adopted by many industries world wide. However, Power Distribution Companies, especially in India, are yet to adopt the same on a significant scale. Information Technology (IT) has been contributing in a major way in the power distribution sector, especially in the areas of business process automation, revenue and commercial management, distribution system automation, consumer relationship management (CRM) and AT&C loss reduction. However, all the above programmes are based on a computing model wherein the infrastructure, applications as well as the platform are managed by the utility company itself. The power distribution companies are already suffering heavy losses due to low tariffs, old networks, outdated equipments and a lack of political will. Under these circumstances, any recurring extra burden due to above mentioned costs will negate the benefits gained through IT reforms. Cloud computing due to its pay-as-you-go model is an appropriate alternative computing model for the Power Distribution Companies which can continue providing all the necessary functionalities while keeping the recurring maintenance and upgradation costs as well as efforts to a minimum. All the three service models of cloud computing namely Infrastructure as a service (IaaS), Platform as a service (PaaS) and Software as a service (SaaS) are more or less unexplored in respect of power distribution companies. However, the most vulnerable area of recurring expenditure is infrastructure (Servers, Storage and Memory) required for primary business process Metering, Billing and Collection (MBC) of any Power Distribution Company. Infrastructure requirements against MBC increase continuously with rapid growth of consumer base. Keeping this fact in mind, in this thesis work, a suitable hybrid cloud based IaaS architecture for implementing the Metering, Billing and Collection (MBC) business process has been proposed for Power Distribution Companies. The proposed architecture is supposed to take care of growing infrastructure related requirements in respect of MBC business process in an effective and economical manner.*

Broad Academic Area of Work: Cloud Computing

Keywords*: Cloud Computing, Power Distribution Company, MBC, Architecture, IaaS, Hybrid, Virtualization.*

1. INTRODUCTION

Background

Cloud computing is a modern technology that is a conglomeration of developments in cluster computing, grid computing, virtualization and web technologies. Cloud computing engulfs infrastructure, platforms as well as applications development and use. Cloud computing has three service models-Infrastructure as a service (IaaS), Platform as a service (PaaS) and Software as a service (SaaS). Cloud Computing is characterized by on-demand deployment of virtual, flexible, highly scalable resources with a pay per use/ Pay as you go charging model.

The primary functions of a power distribution company is to distribute electrical power to its consumers, maintain the distribution lines and sub-stations, take periodic meter readings of its consumers (automated meter reading or manual), prepare bills against the consumers and collect revenue against the same as well as take penal action in case of non payment of revenue bills or any other malpractices as defined by the law of the land. In order to make the above business process modern and efficient, it is imperative that the same is implemented through IT applications. The primary business process of a Power Distribution Company is Metering, Billing and Collection (MBC). Various infrastructures like servers, storage and network are required for MBC implementation depending upon the architecture chosen. A general observation has been that the infrastructure requirements increase periodically due to exponential increase in the consumer base. This thesis work was started to devise suitable cloud based IaaS architecture for effective and economical implementation of the MBC business process

Objectives

The primary objective of the project is to devise appropriate cloud based architecture to the management of the Power Distribution Companies in order to achieve the following milestones:

1. To minimize recurring capital expenditure on IT infrastructure required for implementation of Metering, Billing and Collection (MBC) business process.
2. To enable consumers as well as power distribution company's officials to seamlessly access MBC application based services on demand.
3. To provide flexibility and agility to the power distribution company's management in respect of management of application and related infrastructures.
4. To minimize the maintenance overhead on the part of the power distribution Company.
5. The goal of this thesis work is to outline cloud computing based IaaS architecture design towards a complete solution for power distribution utilities in general.

2. REQUIREMENT GATHERING AND OVERALL SYSTEM STUDY

Requirement Gathering

Requirement was collected and analyzed by interacting with various stakeholders of the MBC business process such as Deputy General Managers of Electrical circles, Assistant General Managers of Electrical Divisions, Assistant General Managers of Industrial Revenue Collection Areas, Sub-Divisional Engineers of Electrical Sub-Divisions, Sub-Managers (Revenue) of Electrical Sub-Divisions, Junior Managers of Electrical Sub-Divisions, Deputy Accounts Officers of Electrical Sub-Divisions, Bill Clerks/Meter Readers of Electrical Sub-Divisions and so on. The MBC business process involves the following activities-

- Meter readings of the energy meters, installed in consumers' premises, are collected periodically by meter readers of the concerned electrical Sub-Divisions. In case of HT consumers (consumers having connected load higher than a stipulated value), meter readings are captured and stored in the central database server through the M-DAS system. If the M-DAS system fails to transfer the meter readings of any consumer meter to the central server, the readings are collected by the Junior Managers of the concerned Industrial Revenue Collection Area
- The M-DAS system involves modems which are fitted to the HT Consumers' energy meters. Meter data is captured by these modems and sent to the M-DAS database server of the central data center through GPRS/GSM connectivity. M-DAS data is viewed and managed through an application hosted in the M-DAS server
- In electrical Sub-Divisions, meter readings collected by meter readers are then entered into the system through the MBC application by the bill clerks of the concerned Sub-Divisions. In case of meter readings of HT consumers collected through M-DAS system, meter reading data is made available to the MBC database through an automated scheduling process. In case of meter readings of HT consumers collected manually by the Junior Managers of the Industrial Revenue Collection Areas, the same are entered into the billing database through the MBC application by the concerned officers.
- Subsequent to the above step, billing and invoicing is done through the MBC application by the concerned electrical Sub-Divisions/Industrial Revenue Collection Areas.
- Payments against the revenue bills generated by the MBC application are collected by the cashiers of the concerned electrical Sub-Divisions/Industrial Revenue Collection Areas through the MBC application.
- In case of any malpractices committed by any consumer, penal bills are generated through the MBC application and served to the concerned consumers by the concerned electrical Sub-Divisions/Industrial Revenue Collection Areas. Payment against the same is collected by the cashiers of the concerned electrical Sub-Divisions/Industrial Revenue Collection Areas through the MBC application.
- The new service connection process, load enhancement/reduction, name/address change, voluntary service disconnection, meter replacement process, defaulter notice generation, temporary and permanent service line disconnection are done by the concerned electrical Sub-Divisions through the MBC application.

Monitoring of the above activities is done by the higher offices through the MBC and M-DAS applications.

Overall System study

The MBC Application Server, MBC Database Server, M-DAS Application Server, M-DAS Database server, SAN storage is located inside the centralized data center set up by the utility. All offices i.e. Head Office, Zone, Circle, Division, Industrial Revenue Collection Areas as well as the Sub-Divisions are connected by a MPLS/VPN cloud so that applications and data can be accessed by the end users. User access is controlled by the Identity and access management servers (RADIUS). Standard security measures are put in place at the centralized datacenter.

3. EXISTING CLOUD COMPUTING

After having gone through the cloud computing technology adopted by various energy utilities, it is realized that utilities around the world are using the different deployment models as suited to their needs. When it comes to the service model, both SaaS and IaaS are used. As most of the Power Distribution utilities are already having their own datacenter with dedicated resources for dedicated applications and owing to the sensitive nature of the applications used as well as various regulatory constraints, the service model IaaS will be best suited for the Power Distribution Companies. IaaS will enable redistribution of resources and security concerns can be better handled in case of a private/hybrid cloud.

4. ARCHITECTURE DESIGN

Workflow of MBC Process of Power Distribution Companies

Most of the power distribution utilities have either set up or in the process of setting up their own data centers for managing various business processes through IT implementation. In India, under R-APDRP scheme, all state power distribution utilities are in the process of setting up centralized data centers. The workflow of the MBC process, managed through these data centers, is described below-

1. The servers and SAN storage are housed in the centralized data center and are interconnected by gigabyte LAN.
2. The remote end user connects with the data center through MPLS/VPN.
3. The Identity and Access Management server validates the end user's credentials and rights of access.
4. If the validation is successful, then the user can access applications through the respective application servers (MBC and M-DAS application servers). The application servers, in turn, use the respective database servers (MBC and M-DAS database servers). The data storage and retrieval is accomplished through SAN storage.

Choice of appropriate IaaS deployment model

Considering the fact that Power Distribution Companies have set up their own data centers, mostly without enabling any virtualization technologies, among the three different cloud deployment models i.e. public, private and hybrid cloud, hybrid model will be the appropriate choice. The reasons are given below-

1. Private cloud will guarantee data security. It will also ensure data scaling, but only up to a certain limit. With exponential increase in the number of consumers, the existing resources will soon turn out to be insufficient leading to computing deadlocks. There will be no other alternative but to augment resources leading to huge investments on the part of the utilities. We may choose to plan for sufficient resources while initially building the private cloud. But this too will involve huge investment which is impractical for most of the power distribution companies already reeling under heavy losses.
2. Public cloud will involve expenditure based on use. However, if we adopt a public cloud, the existing data center infrastructure will be largely wasted. Moreover in public cloud-
   a) Data is hosted off site, which may be an issue while storing consumer data due to privacy reasons.
   b) Systems are hosted off site, so control and security can be an issue.
   c) In public clouds, we rent the infrastructure fully. So long term costs may turn out to be high if data traffic is extensive.
3. In this context, the advantages of hybrid cloud can be summarized as follows-

a) By intermixing private and public cloud infrastructures, companies will be able to leverage the best of what both have to offer. The hybrid model allows businesses to rely on the cost-effective public cloud for non-critical operations and on the private cloud for critical, particularly sensitive operations.

b) Enhanced agility is an important feature of hybrid clouds. Hybrid cloud has emerged as a new, less disruptive, powerful economical way of delivering IT services than the traditional hardware-bound, premise-bound model.

c) Instead of having to replace the legacy technology, a hybrid cloud model allows companies to bridge the gap between old and new systems. Moreover, with this type of model, companies can enjoy seamless scaling by allocating resources for immediate requirements at a much lower cost instead of investing on new local IT infrastructure

The appropriate Hybrid Model

Hybrid cloud architecture is proposed here for managing the infrastructure part related to the MBC (Metering, Billing and Collection) operations of a power distribution Company. It is assumed that the existing data center of the utility is not set up as a private cloud i.e. little virtualization is done in terms of the infrastructure present. So, in order to build a hybrid cloud, we will first have to build a private cloud with the existing infrastructure. We have two options to build a hybrid cloud from a private cloud-

Completely separate private and public cloud loads: We segregate the applications/servers/storages, depending upon load balancing concerns, regulatory restrictions, control feature requirements and security policies. One part is handled exclusively by the private cloud and the other is handled by the public cloud.

Use Cloud bursting: Cloud bursting is a process in which the load of the same application/module is shifted from private cloud to public cloud depending upon a threshold load at the servers of the private cloud. If the threshold is crossed, then the load is shifted to public cloud and it is shifted back to the local data center when the local load is below the threshold.

In order to choose the appropriate type in the instant case, we need to analyse the required infrastructure in the instant case. We have primarily the following loads-

1) MBC Application
2) M-DAS Application
3) MBC Database
4) M-DAS Database
5) Backup and Storage (SAN)
6) Identity and access management server

In order to segregate this load to completely separate the public and private part, we will have to rent high bandwidth from the public cloud provider. The reason is that the architecture is dependent upon constant traffic among different components. The MBC and M-DAS applications will be constantly accessing the respective database servers which in turn will be accessing the SAN storage for update and retrievals. If any of these components is kept exclusively in the public cloud, then high bandwidth will be constantly needed for communication with other components within the private data center. This will surely result in high costs due to constant use of rented bandwidth from public cloud providers over and above the local bandwidth provider like BSNL in India. Moreover, the regulatory principles may forbid us to move some of the loads to public clouds due to security concerns.

On the other hand, if we use cloud bursting, then we transfer some of the load to public cloud only in the event of a demand spike. Then also, we will have to rent bandwidth from the public cloud service provider, but the duration will be less due to the shifting of the load back to the local data center once the demand reduces below the predefined threshold value. Consequently, the financial implication will be significantly lower. Moreover, we can choose not to scale out the sensitive applications/data in accordance with regulatory guidelines. The challenge will be to sync the applications in both public and private sites as well as data replication in case storage is scaled out to public cloud provider.

As our primary objective is to provide seamless MBC operation with significant cost reduction, a mixture of both the hybrid cloud models are explored in the instant case.

The Final Architecture

In consideration of the above facts, the following architecture is proposed for implementation of the MBC business process of Power Distribution Companies-

1. The end user will connect through MPLS/VPN connectivity to the data center of the utility. The end user may be employee posted at a Sub-Division/Division/Circle/Zone/Head-Office.
2. In the data center of the utility, a private cloud is established with the available resources. Any hypervisor, which supports full virtualization like VMware Workstation, VMware Server (formerly GSX Server), VirtualBox, Win4BSD, Win4Lin Pro may be used for achieving Application, Storage and Memory virtualization. A virtual infrastructure manager like Eucalyptus, OpenNebula will be used for managing the Virtual Machines. Resource selection, resource preparation, VM creation, VM migration, VM termination etc. can be performed with the virtual infrastructure manager. An integrated load balancer/scheduler will also be used along with the virtual infrastructure manager, the choice of which will depend upon the virtual infrastructure manager used.
3. VMs will be provisioned (created, migrated, terminated as and when needed) for MBC Application, MBC Database, M-DAS Application, M-DAS Database and Identity Management & Access Management applications. These VMs will be mapped to the pool of physical servers available through the hypervisor.
4. The scheduler/load balancer will keep on monitoring the load on the VMs as well as the physical hosts. During demand spikes, the virtual infrastructure manager will shift the load of MBC Application/M-DAS Application/MBC Database Server/M-DAS Database server to the public cloud depending upon the actual load on the physical hosts as shown by the integrated load balancer/scheduler. Once the load on the physical servers falls below the threshold set, then the load of MBC Application/M-DAS Application/MBC Database Server/M-DAS Database server will be shifted back to the servers of the data center.
5. Storage is already virtualized using SAN storage. However, the backup storage will be done in the public cloud.
6. SLAs with public cloud service providers should be deterministic ones.
7. Proper security features are to be included so that loss of control, trust issues and multi tenancy concerns are taken care of. If necessary, these concerns must be handled while preparing the SLA with the public cloud service provider.

5. BUILDING A PROTOTYPE, TESTING AND RESULTS

Our architecture involves the following IAAS components-

1. A hypervisor.
2. A virtual infrastructure manager
3. Virtual Machines

4. Load Balancer
5. Cloud Bursting to public cloud

A prototype for the architecture in hand was decided to be built using the following products-

1. Open nebula VirtualBox sandbox:
2. Oracle VM VirtualBox.
3. In this prototype we created two types of virtual machines. One was ttyLinux whose image is pre built along with OpenNebula VirtualBox SandBox. The second type of VM was Windows XP.
4. Storage load balancing is in built in OpenNebula VirtualBox SandBox.
5. Due to necessary financial involvement for using services of a public cloud, we have not implemented cloud bursting/use of public cloud services.

The above prototype was tested and found to be working perfectly. The ttyLinux VMs as well as the Windows XP VM was instantiated on the same host. The VMs could communicate with each other. The networking mode was NAT (Network Address Translation). Users were able to access the VMs and files within the VMs. The cloud bursting part/hybrid cloud part could not be tested due to non availability of EC2 and S3 accounts owing to financial involvement requirements.

The prototype, thus, was able to implement the proposed architecture sans the public cloud interface component.

6. CONCLUSION

The proposed architecture provides a viable alternative to Power Distribution Companies in respect of setting up their IT infrastructure. This architecture will enable Power utilities to use virtualization for efficient management of available IT resources like server, storage and memory. Consequently, maintenance and upgradation cost will go down as underutilized resources will be used during demand spikes. Also, if during peak demand periods the internal infrastructure is unable to cope up with the enhanced load, then the excess load can be handled by a public cloud. Thus public cloud is used only during certain high demand phases and not continuously. Moreover, there is no need to procure new infrastructure for handling demand spikes. Hence cost incurred by the Power utilities will be minimal

The prototype is implemented successfully. It shows how the proposed architecture can be accomplished.

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List of abbreviations used

IaaS:	Infrastructure as a Service
PaaS:	Platform as a Service
SaaS:	Software as a Service
MBC:	Metering Billing Collection
MDAS:	Meter Data Acquisition System
MPLS:	Multi Protocol Label Switching
VPN:	Virtual Private Network
VM:	Virtual Machine
QEMU:	Quick Emulator
EC2:	Elastic Compute Cloud
S3:	Simple Storage Service
SAN:	Storage Area Network