# Toward the Design and Implementation of the Hosted Private Cloud

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***Abstract*—In recent years, cloud computing products and services are widely used by enterprises, companies and individuals in their daily tasks. Among different cloud computing models, private cloud is more appropriate for small and medium business (SMB) from the perspectives of security, control and reliability. However, the complexity of deployment, configuration and management of cloud computing infrastructure causes additional efforts and costs, especially because SMBs usually do not have enough IT resources. Therefore, the hosted private cloud model is developed to achieve higher usability by masking the complexities from users, and keep the advantages of private cloud at the same time. In this paper, based on previous virtualization solution, the design and the implementation of hosted private cloud are introduced.**

***Keywords–Cloud Computing; Private Cloud; Hosted Private Cloud.***

## I. INTRODUCTION

Cloud computing has attracted considerable attention in recent years. As the related technologies grow and mature, cloud computing products and services are widely used by enterprises, companies and individuals in their daily tasks [1]. Public cloud services, such as Amazon AWS [2], Microsoft Azure [3], Google Cloud Platform [4] and so on, provide comprehensive computing, storage and network resources through Internet. On the other hand, hybrid cloud is the composition of multiple clouds, that achieves heterogeneous resource consolidation and keeps the benefits brought by individual clouds [5]. Finally, companies or organizations can build and manage their own private cloud to deliver necessary infrastructure, platform and application services internally. For SMBs, private cloud model is more appropriate from the perspectives of security, control and reliability [6]. However, the complexity of deployment, configuration and management of cloud computing infrastructure causes additional efforts and costs, especially because SMBs usually do not have enough IT resources (e.g., hardware, software and engineers). Therefore, the model of hosted private cloud is developed to achieve higher usability by masking the construction and management complexities from users and keep the advantages of private cloud at the same time.

Fig. 1 depicts the context diagram of the hosted private cloud. There are several actors, including Cloud Infrastructure Administrator, Hosted Private Cloud Administrator, Private Cloud Owner/User and Service Consumer, which are stated as the following.

- **Cloud Infrastructure Administrator**: Cloud Infrastructure Administrator is responsible for the construction, configuration, management and maintenance of physical hardware and environment. Computation resources, storage resources, networking, energy, security and so on are included. Different scale of cloud infrastructure is constructed and configured for further usage. Based on particular requirements and conditions, the administrator helps to add, configure, remove, monitor and maintain the components inside cloud infrastructure.

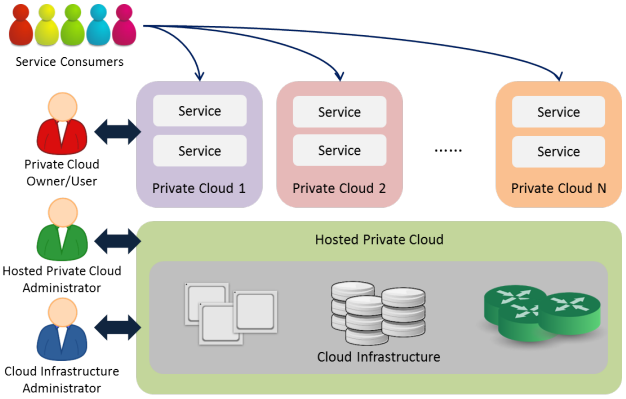


Figure 1. Context diagram of the hosted private cloud.

- **Hosted Private Cloud Administrator**: Hosted Private Cloud Administrator is responsible for the management of hosted private cloud built by underlying cloud infrastructure. Through the functionalities provided by hosted private cloud, the administrator can manage, monitor and allocate corresponding resources for multiple private cloud environments. Based on the monitoring information and the requirements from Private Cloud Owner/User, resources for private cloud environment can be managed and adjusted by Hosted Private Cloud Administrator. In addition, the administrator might configure security policies (e.g., network connectivity and isolation), backup and restore mechanism, failover plan and so on for better service quality of the hosted private cloud.
- **Private Cloud Owner/User**: When the hosted private cloud is built, Private Cloud Owner/User can register and request private cloud environment. Hosted Private Cloud Administrator evaluates the request from Private Cloud Owner/User and constructs corresponding

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private cloud environment if the underlying resources are sufficient. Once the environment is built, Private Cloud Owner/User can manage and monitor the private cloud environment, and create corresponding environment (e.g., virtual machines, storage and networking) for services and applications. Another usage scenario for Private Cloud Owner/User is to provide service and application (e.g., disk images) directly for Hosted Private Cloud Administrator without creating private cloud environment from scratch. This facilitates the service and application deployment and eases the burden of construction of private cloud environment from Private Cloud Owner/User.

- **Service Consumers**: Service consumers are the end users who use the services built on private cloud environment.

In this paper, the design and the implementation of hosted private cloud are introduced. The hosted private cloud is modified and extended from previous virtualization solution, Cloud Appliance Kernel Environment (CAKE) [7][8]. It provides different tenants (Private Cloud Owner/User) with isolated resources to support their tasks and efficient management mechanisms for Hosted Private Cloud Administrator and Private Cloud Owner/User. Current deployment of the hosted private cloud is also described in this paper for further functional and performance evaluation [9].

The remainder of this paper is organized as follows. Section II reviews related studies. Section III introduces the virtualization solution, CAKE. Section IV describes the architecture of the hosted private cloud and Section V presents the deployment for functional and quality evaluation. Finally, Section VI presents conclusion and future works.

## II. Related Work

Moghaddam et al. [10] surveyed different architecture, models, deployment types, key technologies and characteristics of cloud computing. According to their survey, the "virtual private cloud" offered by public cloud service providers achieved both flexibility of public clouds and reliability of private clouds. Resources can be shared by different subscribers and the private cloud can be accessed through secure communication channel. Cardellini and Iannucci [11] presented an architecture for a reliable, scalable, flexible and modular private cloud. Authors also implemented a case study to evaluate the proposed private cloud architecture by Linux Terminal Server Project (LTSP). Mangal et al. [12] integrated private cloud and public cloud for more efficient resource utilization. Based on specific load conditions, the virtualization instances will be migrated to public cloud or back to the private cloud accordingly. Shtern et al. [13] designed a reference architecture (AERIE), which can create virtual private cloud on top of public clouds. The issues of security and data protection were considered and mitigated through the proposed design. In addition to academic studies, several commercial products or services of "managed private cloud" and "virtual private cloud" are available [14][15][16].

To sum up, the model of hosted private cloud achieves both flexibility and reliability and has attracted attentions of software companies, service providers and consumers. Unlike the consideration of complex or hybrid architecture and the provision of large scale cloud environment, the design of the hosted private cloud in this paper tries to build private environments for consumers like SMBs efficiently. Furthermore, the simplicity and manageability are also considered in the design for cloud infrastructure providers and hosted private cloud providers.

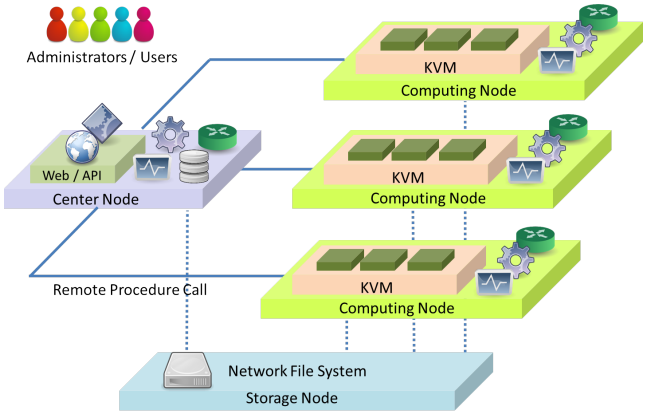


Figure 2. Overview of the CAKE architecture.

## III. Cloud Appliance Kernel Environment

CAKE, developed by Institute for Information Industry, is a server virtualization management solution based on Kernel-based Virtual Machine (KVM) [17]. It supports lifecycle management of virtual machines, and provides user friendly management console for administrators and users. CAKE is designed as an appliance based on commodity hardware. Thus, users can purchase or use existing hardware without any modification and install CAKE to build and manage private cloud efficiently. Based on different usage requirements, CAKE can be deployed as a single node service or multi-node cluster for virtualization capacity or high availability. As shown in Fig. 2, there are three major components in CAKE, including Center Node, Computing Node and Storage Node.

- **Center Node**: The major functionality of Center Node is to manage the virtualization environment built by all the Computing Nodes in the CAKE cluster. In addition, Center Node provides user management, network configuration, storage management, API service, backup and restore, and monitoring mechanisms. Users and administrators can login to Center Node to use and manage the virtualization environment through web interface.
- **Computing Node**: The Computing Node is the physical environment for virtual machines. It receives requests (as the form of remote procedure call) from Center Node and performs corresponding management tasks on virtual machines based on KVM through libvirt [18], including creation, deletion, boot, shutdown, configuration, migration and so on. Computing Nodes can be added to or removed from CAKE cluster dynamically based on resource requirements.
- **Storage Node**: The Storage Node is responsible for the preservation of images, templates, snapshots, and virtual disks of virtual machines. Currently, Network

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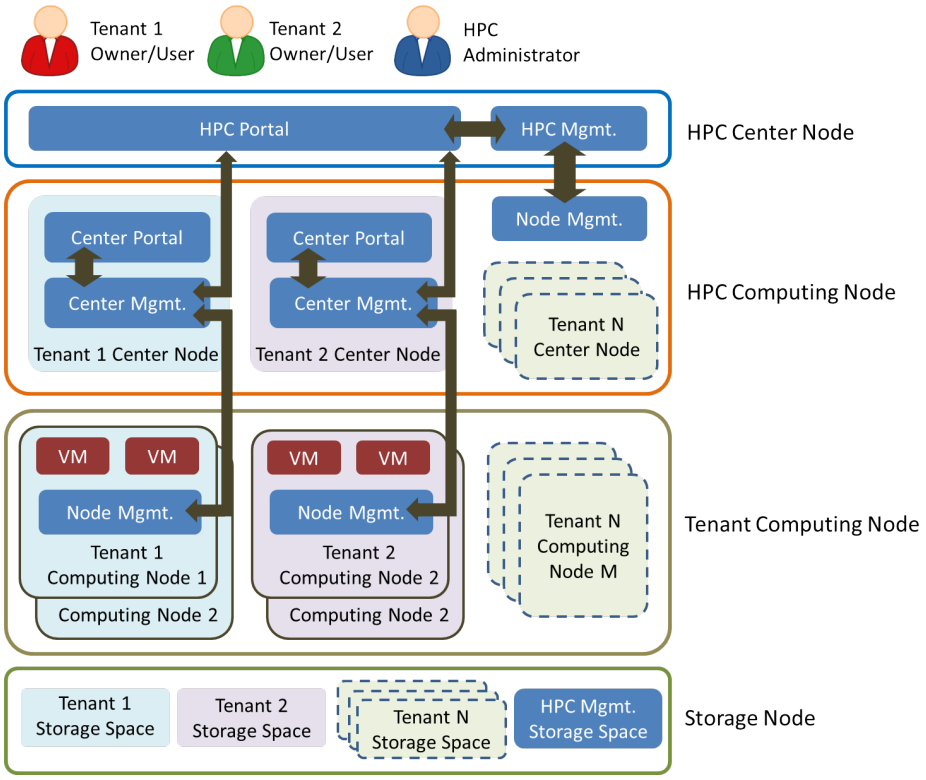


Figure 3. Architecture of the hosted private cloud.

File System (NFS) [19] is used in CAKE for simplicity and reliability. Center node and the computing nodes in CAKE cluster mount the NFS for all the operations in the virtualization environment.

## IV. Architecture of Hosted Private Cloud

The operation model of CAKE is suitable for one specific organization, company or SMB. In other words, the multi-tenancy is not taken into consideration in the original design. Therefore, the design and implementation should be extended and modified to fulfill the requirements of hosted private cloud. Meanwhile, the original design and the operation model of CAKE can be leveraged to simplify the architecture design of hosted private cloud, and decrease the implementation effort. Fig. 3 shows the architecture of the hosted private cloud based on CAKE. The major modification is to add a higher layer for the management and monitoring of the overall hosted private cloud, which is achieved by one specific set of CAKE cluster. The specific CAKE cluster manages multiple virtualized CAKE centers, which are connected by particular CAKE clusters to construct multiple private cloud environments. Components of the hosted private cloud include Hosted Private Cloud (HPC) Center Node, Hosted Private Cloud (HPC) Computing Node, Tenant Center Node, Tenant Computing Node and Storage Node.

- **HPC Center Node**: The major functionality of HPC Center Node is to manage the overall hosted private cloud environment. As shown in Fig. 3, through HPC management module, HPC Center Node requests HPC Computing Node to perform the construction, configuration and management tasks on Tenant Center Nodes. It also provides web interface (HPC Portal) for HPC administrator to manage HPC cluster and tenants in the hosted private cloud environment. HPC administrators can add, delete, configure and monitor tenants and underlying resources accordingly. In addition, tenant owners and users can login with corresponding tenant identification to manage their private cloud environments. Monitoring data gathered by Tenant Center Nodes will be sent back to HPC Center Node for summarized information of the whole hosted private cloud environment. Finally, multiple HPC Center Nodes can be built and federated for the concern of high availability [20].

- **HPC Computing Node**: HPC Computing Node is the physical environment only for Tenant Center Node (virtualized CAKE Center). One HPC Computing Node can support the running of several Tenant Center Nodes. Based on the amount of managed tenants, HPC Computing Node can be added or removed by HPC administrator accordingly. In order to achieve high availability, HPC Center Node will detect the status of HPC Computing Node periodically. If HPC Computing Node is down for unknown reasons, HPC Center Node will trigger the migration task to move Tenant Center Node from failure HPC Computing Node to another. On the other hand, HPC administrator can perform migration manually due to maintenance requirements.

- **Tenant Center Node**: Tenant Center Node is virtualized CAKE Center and deployed on HPC Computing

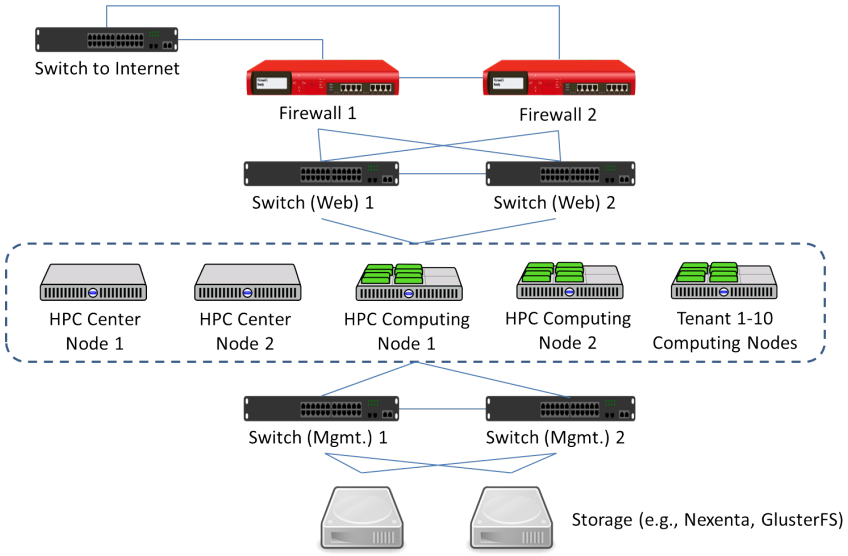


Figure 4. Deployment of the hosted private cloud.

Node. Similar to the operation model of CAKE, it helps to manage dedicated private cloud environment built by Tenant Computing Nodes. If new tenant should be built, HPC administrator can create Tenant Center Node from image template efficiently and associate allocated Tenant Computing Nodes.

- **Tenant Computing Node**: Tenant Computing Node is the physical environment for virtual machines operated by specific tenants. Similarly, it receives requests from particular Tenant Center Node and performs corresponding control and management tasks on virtual machines. Tenant Computing Node can be added to or removed from specific tenant based on requirements. If multiple Tenant Computing Nodes are deployed, the availability of virtual machines can be improved through the periodical check and migration request from Tenant Center Node.
- **Storage Node**: Multi-tenancy (e.g., access management and data isolation) should be taken into consideration in the hosted private cloud. Corresponding storage spaces should be configured and managed for different tenants. In addition, performance, scalability and availability are also important issues due to large amounts of usages simultaneously and continuously. Software-defined storage (e.g., Nexenta [21] and GlusterFS [22]) can be appropriate solutions for hosted private cloud.

## V. Deployment

Currently, the deployment of the hosted private cloud is performed in one cabinet for functional and performance evaluation. Fig. 4 depicts the organization of hardware, networking and HPC nodes. The physical server used in the deployment is 2U 4-Node server. Two HPC Center Nodes and two HPC Computing Nodes are used in current deployment, which can be allocated in one physical 2U 4-Node server. With the above configuration, availability can be achieved to tackle possible failure situations. On the other hand, five 2U 4-Node servers are allocated for tenants. Each tenant uses two nodes in one physical server for fundamental virtualization capacity and availability. The hosted private cloud is anticipated to support ten tenants. Therefore, it is expected to provide 16 virtual machines for each tenant, and totally 160 virtual machines for the current setting of hosted private cloud in one cabinet. Based on further resource or operation requirements, physical servers can be added and configured to Tenant Computing Nodes for tenants. Nexenta and GlusterFS are deployed and evaluated in the hosted private cloud individually. Both storage systems can be configured to support the data access and space management of multiple tenants. In addition, Nexenta and GlusterFS provide failover mechanism for high availability requirement. Finally, virtual LAN (VLAN) and secure sockets layer virtual private network (SSL-VPN) can be created and configured through firewall and switch to enhance security and isolation of tenants in hosted private cloud. On the other hand, in order to achieve high availability of the whole environment, firewall and switch are federated and deployed with failover capability.

## VI. Conclusion

In this paper, the design and the implementation of hosted private cloud are introduced. Based on previous virtualization solution (CAKE), the hosted private cloud is extended and modified to provide different tenants with isolated resources to support their tasks, and efficient management mechanism for administrators. Besides, it leverages the original design and operation model of CAKE that simplifies the architecture design of hosted private cloud and decreases the implementation effort. For future works, test cases based on real world usage scenarios will be designed and deployed for functional evaluation. In addition, different deployment scale of the hosted private cloud (e.g., from one cabinet to multiple cabinets) should be examined. Finally, the performance, reliability and availability will be evaluated for actual service delivery in future works.

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