PRIVATE CLOUD COMPUTING

IN A GOVERNMENT ENTERPRISE

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STATEMENT OF NON-PLAGIARISM

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Rasha Al-hameedi
Date: 16th August 2012
ABSTRACT

The cloud computing technology has gained traction over the past years as a client server network architecture. Its premise is the reshaping of the data center traffic flows by introducing segregation between owning and using a network, which is a paradigm shift in architecting and maintaining network frameworks. Cloud computing relies on the virtualization of the physical infrastructure and then builds different management layers for services, monitoring and operations.

Recognizing the added business value that cloud computing has to present, the government sector has ventured into adopting it into its organization and reaping the full range of the benefits it offers. This report details the implementation of a private cloud in such a government enterprise and focuses on the relevance of cloud computing to the enterprise, considerations for its adoption as opposed to the other available technologies and the architecture transformation based on the requirement analysis.

The project proposes an implementation plan aligned with the business goals and objectives to transform the client server based network into a private cloud based on a service oriented approach while addressing the security, scalability and reliability aspects. The objective of this implementation is to improve the average server utilization, reduce total cost expenditure, increase the level of automation and reduce administration overhead.
ACKNOWLEDGEMENT

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1 INTRODUCTION

Client server network framework is the model by which most datacenters deliver services to their users. This framework has transformed by great lengths since its inception in the late 80’s until it has evolved into cloud computing.

There are many views of how cloud computing is defined. One of the comprehensive and simplistic is the one provided by U.S. National Institute of Standards and Technology (NIST) (1). It states that the cloud is a pool of configurable computing resources that can be easily provisioned through an on-demand network access. Other definitions that are industry specific such as the government is found in Gartner (2). It states that cloud computing is a computing style which is elastic and scalable in nature and allows the delivery of IT-capabilities as a service to an organization’s local data center or an external one. The below figure shows how cloud computing interacts with other technologies(3).

![Figure 1: Cloud Computing](image)

Upgrading the client server network framework into a cloud computing datacenter for a government organization is the main objective of this project. ITSP (alias) is the organization selected to implement this project as they showed interest in transforming their datacenter to be more competently managed. Using the private cloud computing technology ITSP will be able to
better the data center and computing resources service request management as it completely supports the organization’s business requirements.

Prior to concluding that private cloud computing should be the adopted enterprise solution, a series of exercises such as researching, identifying business and technical requirements, comprehensive requirement and gap analysis were conducted all of which are discussed in detail in this paper.

Although cloud offering is quite appealing and brings forth the promise of addressing the major challenges with data center management with all of its resources, there are still significant hurdles to cross. Special consideration must be taken when dealing with legacy and rigid applications. Furthermore, no matter the computing power added, if the application is database bound then this approach will not resolve its scalability issues. Such considerations and additional infrastructure modifications required for ITSP to be cloud compatible is also detailed in this paper.

1.1 OBJECTIVES & GOALS

The aim of this project is to leverage the internal expenditure of a government enterprise by using the available computing resources to complement their overall performance driven strategic goals through implementing a cloud computing platform. The following sections will provide a detailed account of how the analysis, implementation and evaluation for building a private cloud computing platform in the government enterprise are achieved.

Any government entity has as one of its top ranking strategic objectives, the maintenance of performance and business continuity in a cost effective manner. The following is a list of the main objectives of the private cloud implementation that is aligned with ITSP’s strategic goals:

- Introduce a new client server model, private cloud computing, while investing in the existing infrastructure to its fullest potential.
- Identifying the necessary components for the private cloud that matches the organization’s business and technical requirements.
- Achieve more performance without over spending to keep in line with reducing IT expenditures in hardware purchases.
• Maximize on access authorization for non-IT staff without comprising security.
• Pushing beyond current limitations of the infrastructure through virtualization and hardware abstraction.

1.2 PROJECT SCOPE

The ITSP organization suffers of an imbalance between the quality, performance of services and the data center constraints. The IT management is usually under constant pressure to cater for the constantly changing needs of the business applications which at times, if unwielded, tends to tax the underlying architecture greatly. These rising challenges were met with strong responses from the IT staff by introducing significant advancements such as service oriented architecture, service management and virtualization. However, these changes still have not completely eliminated the performance and hardware management challenges being faced.

The adoption of the cloud services concept into the organization for the enhancement of its IT services would extend the current infrastructure since virtualization is one of its key features. Cloud computing has the ability to resolve cost issues effectively as well as any discrepancy between business needs and the capability of the data center to deliver. In summary, cloud computing is a platform that transforms data centers to be economically service oriented with a distributed manageability through the use of virtualization (4).

The cloud is a service management platform and uses a service-oriented architecture approach to design cloud service portfolios. This means that services in the cloud are loosely coupled to provide modular design where integration and migration of services are flexible (5).

The high level implementation scope of the cloud is highlighted below:

1. **Private cloud:** will comprise of the abstracted computing resources from the hardware fabric and will be used by the organization to provide computing power to users independent of each other. The cloud will enable management of both the hardware and virtual layers. The cloud service delivery model used will be infrastructure as a service.
2. **Migrate existing infrastructure:** moving the physical hosts and virtual servers into the private cloud based on specific business and security needs.

3. **End to end management of services:** automation of request management, of service delivery, of monitoring and reporting and self-service interfaces for users.

There will be dedicated connections between all the private clouds and traffic routed through firewalls and routers for regulatory and security purposes.

## 2 LITERATURE REVIEW

### 2.1 NETWORKING BASCIS

Client-Server architecture framework was the model used since the beginning of the computing days before the 1980’s. Data and programs were retained in large mainframes and users were connected to these servers through computer terminals. These terminals had minimal capabilities and were only used for connection purposes. Access was given to users based on the discretion of the IT administrators who were acting as the custodians of these servers. The client-server model in its infancy did not have a lot power, was not user-centric and was not a user-enabling environment and since access could only be given to one user at time, this resulted in huge bottle-necks. This type of connection is usually referred to as a master-slave relationship as the control is centralized with the servers (6). Figure 2 (7) below demonstrates a typical client-server model.

![Figure 2: Client-Server Model](image-url)
In later years peer-to-peer computing (P2P) was developed and was driven by the need to connect computers to each other. This network architecture proposed that each computer possessed similar capabilities and responsibilities. In this type of connection where control was decentralized, each computer acts as a server and client as since resources and services were directly exchanged between them thus control was decentralized. One of the prominent implementations of P2P computing is the Internet which initially dubbed as ARPAnet when it was used across a few sites in the United States. P2P is best exemplified by the Usenet network which was conceived in 1979 (8). A depiction of a P2P computing model is shown in figure 3 below.

A subset of the P2P model followed in 1973 and was named distributed computing. This model targeted the provision of more computer power by using the idle machines across the network or Internet. The idea was achieved by tapping the unused computer resources by installing software that run processing activities on the said computer when it is in an idle state. A practical application of this model was achieved in 1988 in the Digital Equipment Corporation (DEC) System Research Center (6).

![Figure 3: P2P Computing](image)

![Figure 4: Client-Server Technology Timeline](image)
The next in the client-server evolution was the ability for multiple users to collaborate simultaneously on the same computer based project. This was what shaped cloud computing to what it is today. Group collaboration was possible by using the Internet as a cloud to house the projects being worked on (9). Figure 4 (10) illustrates the timeline progress of the client-server technology.

2.2 CLOUD HISTORY

Cloud computing with documents and services took flight when search companies like Google started development with large farms of servers. This started to extend to encompass web-based applications and gave birth to Internet-based collaboration which in essence is cloud computing. Soon after, on the software front, cloud-based applications were being developed. The concept of cloud computing has gained prominence by 2007 to a bona-fide computing technology to be relied on an enterprise level (6, 11). Cloud computing is one of the main contributors in the industrialization of computing (4, 12).

2.2.1 CLOUD COMPUTING CONCEPT

In today’s business age there is a strong alignment forged between business and technology in such a way that it has become increasingly challenging to mention one without the other. Traditional data centers might be the absolute fit for business needs but other considerations might compel companies to search for more affordable and modular alternatives. One of these options are presented through cloud computing.

Cloud Computing is a business and economic model for maintaining data centers due to the agility it offers on both theses counts (4). This agility is manifested in its automation of how the end user can request additional resources and how the administrators can manage the provisioning of these resources. The traditional data center setup poses challenges as the organization expands in terms of space, budget, time and energy needs.

Although the concept of cloud computing is not new, its current methods of implementation have revolutionized client-server frameworks on the following levels:
• Provider and Customer viewpoints
• Business and economic models
• Technical underpinnings

The concept of cloud computing revolves around the fact that all computing related activities are delivered based on a service oriented architecture. The services range all the way from the infrastructure layer through the application layer and reaching to the collaboration level.

The business drive for the shift toward offering computing services through cloud computing is illustrated through figure 5 (13) and explained below:

ADVANTAGES (14)

1. *Elasticity & Scalability*: Although organizations have grown into the practice of capacity planning to ensure that required hardware and software resources are accounted for, accurate predictions on how the client will be using the services are not possible.

2. *Self-service provisioning and automation*: Acquiring the necessary resources is no longer an arduous process as it is automated and self-managed from the end user and IT administrator sides respectively

3. *Capital expenditures*: Instead of investing in large purchases of hardware to appease the need of medium sized applications, cloud services offers computing resources on predefined storage spaces. This enables organizations to buy exactly what fits their needs without the need for overprovision especially with budget constraints. Moreover, if the organization finds it suitable to transform all its computing services to be cloud based then administration, maintenance and support expenses are greatly reduced which translates to a greater return on investments (ROI).

4. *Business agility*: The cloud model allows for great modularity as adding hardware has never been easier. Business relocation or expansion can happen with great ease as the IT services are hosted elsewhere and are adaptable to changes in the market.
DISADVANTAGES (14)

1. **Security**: In public clouds the user is unaware of the exact location of the data which may be of great concern to organizations especially if the information stored is highly sensitive.

2. **Internet Connection**: Relying on network connections is very risky for businesses that require high availability and business continuity.

3. 

4. **Dependency**: Users do not have the data stored with them and have to rely on internet connections to access it.

5. **Risk**: With cloud computing remote servers are controlled by the cloud provider in terms of compliance and hardware.

![Image](image_url)

**Figure 5**: Cloud Computing Benefits (+) & Drawbacks (-)
2.2.2 CLOUD TYPES

Cloud Computing is offered in three main methods:

1. **Public Clouds**: Applications and computers are located and hosted on the Internet. The user does not know where the data is stored as it is distributed and does not own the infrastructure (15).

2. **Private Clouds**: Cloud is run and owned by the organization. This form offers more security and does not rely on the Internet connection for bandwidth (15).

3. **Hybrid Cloud**: A balanced combination of public and private clouds. Computing power and application are split between the clouds based on security, availability and business continuity requirements. The hybrid cloud comes in many setups. One of its implementations is the cloud gateway which is a technology that provides a link between the organization’s private cloud and other public clouds through the use of cloud APIs. It enables data management and migration across the different cloud architectures (15). It helps in the federation of internal and external resources and pooling their combined computing power to leverage the business. It is offered as one of the hybrid cloud computing options. They are located between a private and public cloud where it translated between protocols and through policy engines enables data migration into and out of public cloud storage (16).

CLOUD COMPONENTS & SERVICES

The cloud itself is a collection of networks, hardware components, service layers and the interface that allows the control of the delivery of computing resources. This kind of architecture allows companies to handle computing services as a pool of resources instead of environments that requires management. The cloud computing platform begins with the decoupling of the physical implementations (hardware) from computing resources (software) through virtualization.
The cloud ecosystem main participants comprise of the following:

1. **End user**: Users of the cloud services
2. **Business Management**: Those responsible for the overall working of the cloud services
3. **Cloud Service Providers**: Responsible for dispensing the IT assets and their maintenance

**CLOUD MODELS**

Service in cloud computing refers to packaged tasks that are automated and can be delivered to clients as per their need. There are three cloud services delivery models to select from. These are detailed below. It is vital to have an understanding of the underpinnings of each model as it will dictate the choice of which type of cloud services to adopt and what blend of delivery model should be employed. One of the leading examples of this model is Amazon EX.

1. **Software delivery as a service (SaaS)**: Focuses on providing storage and computing resources to be used to deliver customized business applications. This was one of the first models that were offered by cloud service where business application were hosted by the providers and was delivered to the client as a service. This model operates in two modes, Simple multi-tenancy and Fine grain multi-tenancy.

2. **Platform delivery as a service (PaaS)**: Provides development environments to be used by IT organizations to create cloud ready-business applications. It is viewed as an evolution to web hosting. The benefit of this model lies in the fact that all development related activities including the infrastructure is handled and managed by the cloud.

3. **Infrastructure as a service (IaaS)**: Provides purpose built business applications. The customer rents the infrastructure and is charged on a usage basis.
HOW THE CLOUD WORKS

The cloud is a large scale of network inter-connected servers that combine their collective resources to generate large computing power. Figure 6 (4) shows the basic components in a cloud computing architecture which are explained in the points below:

- **Cloud Architecture**: the main component in the cloud platform is intelligent management to connect the computers and arbitrate the assigning of the resources to users. As seen Fig 7 the user’s main interaction is with the user interface. The user request is passed through the system management which is responsible for locating the right resource. It then calls the system’s appropriate resources through the provisioning service. Once the web application is launched the cloud’s monitoring functions track the usage on order for the computing resources are appropriately portioned and assigned to the respective user (6).

- **Cloud Services**: These are services that are web based applications offered through the cloud. The application or services is hosted in the cloud and the users use it through the Internet. The web browser accesses the application and a session is launched on the user’s computer as a desktop application but the application and operational documents remain within the cloud. The advantage of such a setup is lies in the fact that the application and data remain independent of the user’s computer and they can be accessed from any location through the Internet with multiple users collaborating on the same document in real time and are not machine-centric.

- **Cloud Storage**: the first usage of cloud primarily started with data storage. The cloud storage works by storing the data in many third-party servers as oppose to within the servers in the organization as per the typical way of networked data storage. From a user’s perspective the data is stored in a virtual server with a dedicate name but actually is distributed across many servers and may differ as time progresses.

From a financial aspect it is cheaper to use virtual resources instead of dedicated servers. As for security data duplication occurs across all the machines that the data is stored on in the cloud.
CLOUD & VIRTUALIZATION

Although virtualization has its own niche in the IT industry, cloud computing has managed to use this technology and take it to the next level within its own implementation. Virtualization can be applied to a wide range of areas when it comes to data center manageability such as networks, hardware, storage, operating systems and applications. Some of the virtualizations features that make it apt for the cloud computing platform are:

1. **Partitioning:** Multiple operating systems and applications are supported on a single physical system.

2. **Isolation:** Virtual machines and physical systems are segregated even the data us not shared between the virtual containers.

3. **Encapsulation:** Virtual machines can be stored as a single file and separated from applications.

![Cloud Basic Architecture](image)
2.2.3 PRIVATE CLOUD COMPUTING

PRIVATE CLOUDS

Private clouds are a means to achieve the cloud benefits on an internal basis. It is the best choice when the main concern of an organization is privacy and security and when large investments have already been made to leverage the current infrastructure. A healthy mix of both private and public clouds could also be a viable option. Private clouds can be offered as virtualized environments residing within the company or a dedicated private space within the cloud vendor data center (17).

PRIVATE CLOUD CHARACTERISTICS

Private cloud computing, virtual private cloud and private data center refers to the same concept of building an internal IT system that contains virtualized storage, servers and firewalls. The main contrast between public and private clouds is that in the latter the client has complete control of the service management. The two types of clouds are analogous to the Internet and Intranet respectively.

The below points are the hallmark characteristics that distinguish private cloud computing:

- More Security as the location is known and thus more control of all details concerning data management.
- Independence from relying on the Internet especially with large amounts of data and systems that have a low tolerance for down time.
- Virtualized infrastructure with special software that allows IT administrators to handle the infrastructure as a centralized computing resource.
- Automated tasks and ability to monitor resource provisioning.
3 CURRENT ORGANIZATION ASSESSMENT

Based on the organization’s request, it will be referred to using the alias ITSP throughout the report to ensure that its identity is kept anonymous. ITSP will stand for Information Technology Strategic Planning. The following sections details ITSP’s infrastructure from a network, physical and virtual aspects to ensure that it will be able to support the new technology being introduced. Understanding how the organization currently stands will greatly contribute to the features that will be used from the private cloud and how it will be configured. Moreover it will help in evaluating how the current structure is aligned with the business requirements and whether it is compatible with the solution proposed.

ITSP is one of the many enterprises embracing the new initiative of moving towards an e-government by transforming the way they manage and run their business while still being cost-effective and efficient using the latest leading edge technologies. It primarily deals with designing and validating business solutions for other affiliated entities. It is responsible for researching leading edge technologies to leverage its business needs as well as that of other entities. ITSP has two types of clients; one being its internal business units and the other are the externally affiliated entities.

3.1 ITSP’s INFRASTRUCTURE

The data center is hosted in the ITSP premises and it holds all the servers of ITSP and its clients. The clients serviced by ITSP are also from the government sector and they are as follows:

- SECC: A security company the provides security consulting services for the military industry
- CONSTCO: A construction company for building military sites and government entities
- FINCO: A financial consulting company that offers its service for the military and government sectors
ITSP’s IT department provides services to both types of clients. If a server is to be provisioned or an application is required for a certain business line then they would be responsible for providing it. ITSP houses different servers for the three clients and its own. These are distributed as shown below:

- 200 servers: 50 of which are ITSP’s own servers, 32 are SECC’s, 65 are CONSTCO’s and 53 are FINCO’s.
- The servers of each client are distributed across the three environments; development, quality and production
- Most servers are virtualized using Windows 2008 Hyper-V 2008 R2
- There are 1000 employees in ITSP of which 100 are from the IT department

LOGICAL VLAN TYPES

As mentioned above, there are three major environments for the organization based on the nature of the business. Each environment has its own VLANS. The infrastructure of ITSP is composed of 9 VLANS, where each VLAN is specific to what environment it will be serving.

The below is an illustration of the network segregation across these VLANS (18):

- Clustered firewalls
- Production VLAN: used by all employees in ITSP and external clients to gain access to all deployed applications.
- Staging/Quality VLAN: used by the application owners from each client in coordination with the ITSP IT service delivery team for testing applications before being deployed to the production VLAN.
- Development VLAN: used by the R&D and DEV team at ITSP for fulfilling and testing client requests and is isolated from the remaining VLANs for security purposes.
Figure 7: Physical Server Network

a) **PRODUCTION VLAN** (18)

- VLAN0005: Active Directory, DNS, Mail, File, Database and Web application servers
- VLAN0002-VLAN0004: Web servers and for public access

Figure 8: Production Physical Network
b) **STAGING/QUALITY** (18)
- VLAN0008: Active Directory, DNS, Mail, File, Database and Web application servers
- VLAN0006-VLAN0007: Web servers and for public access

![Figure 9: Staging Physical Network](image)


c) **DEVELOPMENT** (18)

1. VLAN0009: Active Directory, DNS, Mail, File, Database and Web application servers

![Figure 10: Development Physical Network](image)
3.1.1 INFRASTRUCTURE DESIGN

VIRTUAL LAYER

Virtualization is achieved across the storage and server platforms. Storage virtualization is done by pooling many physical network storage devices as single one and controlled through a single console. Server virtualization is done by pooling infrastructure resources as a single computing power. A virtual machine is a complete computing software environment that abstracts hardware resources of the physical machine this results in multiple of these virtual machines to run on a single physical server. Each virtual machine supports its own operating system and has its own logical instance of the server’s resources.

The virtual infrastructure is built using the Microsoft technology Hyper-V 2008 R2 and Virtual Machine Manager 2008 which assumes the role of the orchestrator between the services it offers on application level and infrastructure level. Microsoft centralized management platform for virtualization is Microsoft System Center Virtual machine manager. It is responsible for configuring, provisioning, managing and monitoring the data center’s virtual machines.

Figure 11: Virtual Infrastructure
Figure 11(19) illustrates the virtual infrastructure design and components and each is explained in the below points:

**VMM COMPONENTS**

- **Virtual Machine Manager Server 2008**: Core component which controls the interaction and communication between other components.
- **VMM library server**: Maintains the VMM library which includes a resource catalog, configurations, operating system profiles and hardware profiles.
- **Virtual Machine Manager Agent**: Manages the virtual machines on the physical hosts and enables their communication with the VMM server.
- **VMM Administration Console**: Manages and monitors hosts and the library servers through web based console or through the use of windows power shell.

**MANAGED HOST LAYER**

Server virtualization is achieved through virtualizing the server workloads. Microsoft Hyper-V acts as the hypervisor and is part of Windows Server 2008 R2. It allows the running of multiple virtual machines on a single physical computer. Hyper-V server, Microsoft’s server virtualization solution is possible through the hypervisor virtualization platform. It is responsible for the isolating the execution environments between the virtual machines and is offered in different flavors. The one used in the ITSP organization is Type1 shown in figure 12 (20). It runs directly on the physical hardware. The virtual machines are then positioned on top of the hypervisor. On top of the Hyper Visor are two types of partitions:

- **Parent partition**: The controlling partition which contains the virtualization stack and owns the hardware devices and is responsible for managing the resources for the child partitions.
- **Child partition**: The guest operating system which is created by the parent partition.

![Hyper-V Architecture](image)

**Figure 12: Hyper-V Architecture**

### 3.1.2 PHYSICAL DESIGN

**PHYSICAL DIAGRAM**

The below diagram (21) is a representation of all the infrastructure components. It includes:

- **Storage Layer**: Made up of SAN and NAS boxes and used across the entire data center.

- **Network Layer**: Made up of three VLANs as discussed above.

- **Physical Layer**: The application and database servers on which the Virtual layer abstracts its computing power.

- **Virtual Infrastructure**: constitutes of the virtual servers and the administration layer.
3.2 ITSP’s PHYSICAL SECURITY

The existing infrastructure of the ITSP enterprise is a virtualized environment. The data center is housed within the IT department where access is restricted to authorized individuals only through fingerprint and special access swipe systems. The server room is under camera surveillance (22).

3.2.1 LOCATION: DATA CENTER, IT DEPT

- The location of server room is strategically placed in the farthest corner of the IT department away from human traffic, offices and windows to ensure limited accessibility.
- The floor in the data center is a raised false floor where the network cables run beneath along with the cooling systems. In case of a failure in any of the cooling system or if the temperature rises to above 2 degrees an alarm is sounded.
• The data center houses most of the network components and is under video surveillance. It is triggered through motion detection technology. This monitors any attempts of unauthorized entries or actions of a malicious intent nature.

• Access to the room is only allowed through special access cards provided to a select group of IT administrators. There are two doors that requires access card authentication. The identity of the individual is logged electronically. The doors are double glazed and crack proof.

3.2.2 NETWORK: LAN, ENVIRONEMENTS

• The network has many VLANs where each is subdivided into subnet and each is dedicated to cater to specific services thereby isolating access levels and critical environments. This helps in segregating access to systems based on the business nature and the security level it requires.

• The development environment is located in a private network with no access to the other networks. The user testing and production environment are placed in separate VLANs where traffic and access between them is governed by ports and firewalls. This infrastructure setup is designed to ensure that the users will have access only to systems that they require for their daily job functions.

3.2.3 SYSTEM ACCESS (USERS: USERNAMES, PASSWORD, RIGHTS)

• The users range from internal users within the organization (network administrators, operation administrators, developers, designers and end users) and external users from other affiliated governmental entities.

• User Account management is managed by the Active Directory to ensure account and access control across the organization

• Network access to users is governed through leveled access control (on network, system, file and application level access)

• No one IT administrator has full system rights. Access to servers is restricted to domain administrators and selected group of IT administrators.
Server hosting critical systems is configured to deny access to all requests except for those that are included on the granted access list.

4 ORGANIZATION REQUIREMENTS

Identifying business and technical requirements is a crucial success factor in implementing the solution. Without mapping the proposed solution to the business need and challenges, the project would not have fulfilled its objectives. It is also important to collect requirements from the concerned individuals referred to as the stakeholders. They may have a positive or negative impact on the solution efficacy within the organization and must have their concerns addressed and considered during analysis and design phases.

4.1 STAKEHOLDER MEMBERS

Scheduled meeting and brainstorming sessions to understand the current standing of the organization were held. Key players in the success of this project are outlined below and a kick off meeting was held to ensure a common understanding of expectations and deliverables. Below are the roles and responsibilities of those involved in the implementation of the project:

<table>
<thead>
<tr>
<th>STAKEHOLDER</th>
<th>ROLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEO</td>
<td>Project Sponsor</td>
</tr>
<tr>
<td>CIO</td>
<td>Project Supervisor and provide business requirements</td>
</tr>
<tr>
<td>IT department (Infrastructure, service delivery and administrator teams)</td>
<td>Provide technical requirements and will be involved in testing and evaluation processes</td>
</tr>
<tr>
<td>Application owners</td>
<td>Provide technical requirements and will be involved in testing and evaluation processes</td>
</tr>
<tr>
<td>Departmental Heads</td>
<td>Approvals &amp; Decision Making</td>
</tr>
</tbody>
</table>

Table 1: Stakeholder Registry
The management level focuses more on concerns such as security and expenses. Annual reports received on expenditures indicate that an incline in hardware purchases which is not reflected with a better application performance.

The IT department and application owners have mainly technical concerns with service management and data center management as that constitutes the pain areas in the organization. The next sections detail the challenges, business and technical collected from the identified stakeholders.

4.2 BUSINESS & TECHNICAL CHALLENGES

Based on the annual strategic review of the business and IT alignment it was noted that the IT department is lagging in providing the expected service level provided for both internal and external clients. This was discovered to be mainly due to the following reasons:

- The distributed nature of the organizations deems it necessary to invest on network bandwidth and hardware computing power. Such investment tends to grow enormously due to over-provisioning and improper planning.
- Unable to keep up with provisioning of servers as it is time consuming due to the lack of well-defined procedures
- Unable to keep up with requests from both internal and external clients in regards to technical assistance or facilitating computing resources due to lack of defined procedures for managing services
- The communication between the different teams within the IT department is not smooth thus unable to manage the life cycle of computing resources in an efficient manner
- Lack of clear visibility into the virtual and physical layers in the datacenter resulted in a decrease in performance of mission critical applications
- Provisioning of host servers is not based on mapping the server specification to the needs of the applications that it will be hosting
- Delays in service and resource provisioning have stressed relations between ITSP IT department and its internal and external clients.
Lack of monitoring of infrastructure all the way up to applications in an efficient manner causes the IT department to be in reactive instead of proactive mode.

On interviewing the IT department they communicated that the requests for computing resources they receive are not prioritized and usually is expected to be delivered urgently. It was evident at this stage that an improved and efficient means of managing the infrastructure and service life-cycle management is needed to be introduced.

End users constantly face performance issues with applications and delays in getting their requests serviced by the IT department.

Application owner are responsible for testing, deploying and upgrading applications for client. They face issues with response times of the IT department to provision necessary computing resources for projects and applications.

IT department is unable to efficiently manage the data center infrastructure due to lack of proper monitoring and operational system in place. In addition they are unable to keep up with incoming requests due to lack of proper procedures and are unable to keep up with resource lifecycle management. The different teams in IT are also not communicating efficiently which leads to duplication in efforts and mismanagement of tasks.

4.3 BUSINESS REQUIREMENTS

The ITSP organization is currently looking for a solution that offers a better way of managing its infrastructure and automating service requests. Hardware maintenance increases without gaining much on return of investment (ROI). This kind of overhead drains investments without gaining much on business or technical aspects. As ITSP services many clients, security and resource segregation is also a concern. Each client has its own demands and services that fluctuate based on the market and the ITSP IT department needs an efficient way of managing their requests and providing the needed computing resources to maintain their applications.

- **Data Center management**: Proper management of hardware is essential in maintaining a stable environment for the applications to function. Investments in hardware resources should not be higher than the benefit is provides.
• **Application management**: A hardware fabric that possesses strong computing power is necessary to keep up with application demands. Application deployment and upgrades must be more dynamic and flexible.

• **Security**: Serving more than one client who shares the same infrastructure causes security concerns for data storage. Each client requires that their applications are hosted in separate servers than other clients in order to maintain data privacy and confidentiality.

• **Budgetary management**: Funding and investments must be reciprocated with high return of investments. That can be achieved with maximizing on existing infrastructure with adequate management and resource provisioning to meet the all clients demands.

### 4.4 TECHNICAL REQUIREMENTS

In order to address the technical challenges and needs for the ITSP organization, the private cloud must be able to provide a robust solution to manage infrastructure resources and help in providing these resources in an automated manner. Identifying the exact business and technical needs would be the driving force behind designing, implementing and configuring the private cloud. The stakeholders expressed their desire to test drive the system in an environment similar to that of the production to validate and confirm that the private cloud would be able to be extended across the entire data center. This is achieved through the implementation of a proof of concept of the private cloud for the quality VLAN as it is closest to the production in terms of hardware and network configuration. Using the QC VLAN the issues faced in the production environment by the users will be simulated. As this VLAN is used by the application owners for application testing and quality verification purposes, they would represent the end users in the production environment. Below are the specifications of the QC VLAN:

• This VLAN is currently used by the three clients.

• Each Client has their application owners test their application in coordination with IT service delivery team for deployment and upgrade purposes.

• For the POC purposes there will be two applications selected from each client. Since most applications are clustered this will amount to 2 physical hosts for each client where
one node will be the active node in the cluster and the other node is the passive one for failover purposes.

- The network configuration for the QC private clouds will use existing QC VLAN configurations.

Based on the above the private cloud must satisfy the technical needs as described below:

**Hardware abstraction**

The infrastructure layer should be segregated logically from the virtualized layer to ease management of the data center. This will enable the IT staff to focus on the hardware layer and the authorized users to manage the abstracted virtual layer as private clouds. Physical hosts for each client must be independent so that any failure in one client’s application will not affect the other. Furthermore, computing resource demands for any of the clients should not lead to a business impact on the other clients.

**Service management**

Ability to have a method for the IT to manage the incoming requests from the clients and classify them according to priority and urgency. In addition, the possibility of automating responses of recurring requests.

**Provisioning resources**

There must be a way in which the users can obtain computing resources when needed in an automated way without the need to wait for the IT department to respond back as delays in responding to requests have strained relations between the clients and the ITSP IT department.

**Monitoring**

Monitoring the infrastructure performance should not be a reactive activity. Alerts, notifications and remedies should be a scheduled and automated process and can be shared between the IT and clients. This will help alleviate some of the workload off the IT and keeps the clients in control and aware of their own environments.
**Application deployment and maintenance**

With frequently changing business requirements and the need to test them before release, the enterprise requires the availability of testing environments that need only be maintained for a brief amount of time without worrying about the resources and administration that it requires. This means an automated way to deploy applications and related releases without the need to manually prepare the hardware and virtual requirements every time.

**Application performance**

Performance of the application depends on the availability of adequate computing resources. These resources should dynamically react to application needs without the need to manually provision hardware. If an application should experience an increase in the workload then it should be detected and additional resources should automatically be assigned.

**Access and Authorization**

The cloud should cater for both the IT staff and clients. For the IT, it should provide an interface and management tool to maintain the hardware layer and help with its abstraction to a virtual layer. This layer should be accessible to authorized users who are the application owners in this case and allow them a range of operational actions that would assist them in deploying and maintaining applications. The cloud should provide access on role-based basis to the user.

5 **REQUIREMENT ANALYSIS**

A complete and comprehensive understanding of the business requirements is essential in realizing the success of the solution. The requirement analysis ensures this as well as tackling compatibility, security and any other considerations and constraints. On meeting the stakeholders to collect both business and technical requirements, expectations had to be tempered to match current potential and requirements. It was agreed on that the main drive for introducing the cloud computing platform into the enterprise as the proposed solution is to alleviate most of the user experience issues especially in performance, access and development areas. The analysis phase started with understanding the business process of the ITSP IT department services to its clients. Following that was how the solution will address the identified requirements and finally defining...
the scope of the proposed solution. The fulfillment of both functional and non-functional requirements will be evaluated during the implementation and testing phase.

5.1 THE BUSINESS PROCESS

The nature of the organization’s business is centered on providing IT services to its business units and vetting new enterprise solution for the different government affiliated entities. The following diagram shows the process for providing IT services to internal and external client by the ITSP organization.
solution and then hands it over to the application owners whether they are located in ITSP or the other affiliated entities. During the deployment lifecycle the IT teams provide the following services:

- Infrastructure Team: provision of hardware resources when required.
- Service Delivery Team: front-line support for clients.
- Administrators: monitor daily tasks and monitor system health.

The business need can range from a request for providing a new server to facilitating an enterprise solution for a particular business line. The ITSP clients due to their line of business, may require expanding their infrastructure to handle increase in workloads or require new applications to service their business needs.

### 5.2 NON-FUNCTIONAL REQUIREMENT ANALYSIS

Based on the analysis of the above business requirements, the following are the reasoning behind the business choice of the proposed solution:

- Testing environments for developers especially when development is made using different computing technologies with no compatibility issues
- Assessing new line of business applications before purchasing with ease and flexibility
- Transitioning legacy and unsupported applications to new ones incrementally after the appropriate testing and quality measures have been fully conducted.
- Provide clients with control of their own application environments without being completely dependent on the IT department

The identification of a company’s suitability for the adoption of cloud computing will be decided primarily based on the amount of the Return on Investment (ROI). Below is the cost comparison between the cost for the traditional data center and the expected cloud services costs.
TRADITIONAL COSTS

Below are the typical costs incurred for the upkeep of a traditional data center:

1. Legacy applications that are no longer supported in the market.
2. Mission critical application that are only used by a selected audience in the organization.
3. Maintaining different applications with varying workloads depending on their usage. Workload refers to independent services or code collections to be execute (8).
4. The majority of the cost in maintaining a data center is centered between infrastructure arrangements and software licensing, heating and air conditioning.

CLOUD SERVICES COSTS

Based on the Microsoft paper (23) the below are the estimates for three cost factors for a cloud based data center:

1. Power distribution and cooling is 20 percent of total operating costs
2. Computing costs are 48 percent of total operating costs
3. Labor costs are 6 percent of total operating costs

COST BREAKDOWN

To ensure that the benefit of the cloud platform implementation is tangible and can be realized, a cost analysis of what the cloud can add in terms of expenditure reduction was conducted (24):

1. Cloud migration costs
2. Cloud start-up costs
3. Cloud implementation and deployment
4. Fortifying cloud security through security patches, antivirus and firewalls
<table>
<thead>
<tr>
<th>IT BUDGET</th>
<th>NO CLOUD/$Million</th>
<th>WITH CLOUD/$Million</th>
</tr>
</thead>
<tbody>
<tr>
<td>Server Infrastructure</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>Storage Infrastructure</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Network Infrastructure</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Backup</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Operation</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Maintenance</td>
<td>6</td>
<td>4.5</td>
</tr>
<tr>
<td>Client Infra</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Support Facilities</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>Application Software</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>52</strong></td>
<td><strong>35.5</strong></td>
</tr>
</tbody>
</table>

**Table 2: Cost Breakdown**

The findings were conclusive in that financial benefits will be gained and thus justifies the strategic decision to transform the data center to a cloud computing platform.

### 5.3 FUNCTIONAL REQUIREMENT ANALYSIS

Based on the technical requirements discussed above the analysis covers the cloud usage profile which is basically the expectations for the private cloud, infrastructure restructuring required and how the technical needs are met through private cloud features that will be implemented.

**CLOUD USAGE PROFILE**

The following points summarize the profile for how and where the private cloud will be used in the organization:

- Private cloud computing is most appropriate for adoption at this point as it extends the virtualization layer to encompass end to end management of the datacenter starting from the hardware layer all the way to automating and managing the data center services
• It will be used to provide hardware and logical separation for the different client’s mission critical applications thus maintaining data privacy without the fear of being legally liable for any security breaches that may threaten the organization

• It is well suited for monitoring operational activities and reporting for both IT staff and cloud users.

• **Scope of the cloud architecture**
  
  a. Comprehensive framework for the server-side, client-side and intermediary infrastructure (25)
  
  b. Cloud computing infrastructure (CCI) must provide features that cover security, compliance and monitoring

• **Security**
  
  a. Clients have different clouds
  
  b. Monitoring activities of the private cloud data transmission
  
  c. All applications to be hosted on the private cloud will have their respective databases in the private cloud to ensure privacy and security compliance

• **User access**
  
  a. The end user is able to access the application within the private clouds
  
  b. Application owners are able to use self-provisioning within the private cloud for development work and testing purposes
  
  c. Users do not need to be aware of the back-end business architecture

• **Private Cloud Choice:** after careful scrutiny of the organizations strategy and business requirements it was unanimously decided that the data center should be transformed into a private cloud. The private cloud will be residing within the company and will house mission critical applications and will enable user’s access on a role-based basis. The choice behind choosing Microsoft as the private cloud service provider is that most of the organization’s current platform are centered on Microsoft products and is one of the
largest contracts of the enterprise. This means that licensing costs are greatly reduced and other related costs like support and maintenance are already part of the main contract.

- **Virtualization:** Since the enterprise’s data center is virtualized using Microsoft products it would seem as an appropriate choice to extend its capabilities through cloud computing using the same vendor and make use of the high level management capabilities in areas like self-service, fault tolerance and resource scheduling.

- **Product Compatibility:** compatibility issue will not be a major issue as both the virtualization technology and private clouds will be of the same product line.

**INFRASTRUCTURE ANALYSIS**

As the solution introduced is software based in nature and only requires the addition of a few physical machines to host the cloud software components the changes to both the network and infrastructure levels are as follows:

1. The cloud software requires the addition of 3 physical host servers in which 6 virtual machines will be created to house the cloud software
2. The physical servers used by the cloud software will be using the same switch that the production Active Directory and DNS uses
3. As there are three clients there will be three private cloud; each cloud for a client
4. The physical machines of the selected application from the QC VLAN for the POC will be part of the private cloud and will be configured using the QC VLAN network configuration
5. The virtual machines in the selected servers will be rearranged to ensure that the application requirements is matched to the appropriate serves specifications
6. Integration between the cloud and the active directory and the selected QC VLAN servers is achieved through software connectors and management packs.
7. Existing virtualization software already in use, Virtual Machine Manager 2008 will be upgraded to 2012 as it is now part of the cloud components.
TECHNICAL REQUIREMENT ANALYSIS

Infrastructure Management: the hardware fabric management is segregated from the service level through using System Center 2012 virtual machine manager (VMM). This administrative interface allows the infrastructure team to manage capacity allocations and operate hardware configuration with ease.

Service management: requests will be automated through self-service portals and customizable workflows which will be used by the application owners. The interface tracks and displays the request status for the clients and IT staff to view. This feature is made available in System Center 2012 service manager self-service portal and service catalog modules.

Application deployment and upgrade: service and virtual machine templates will be used to automate the creation of virtual servers and deploying or upgrading machines within the physical host servers using VMM 2012.

Monitoring: events and incidents trigger a remedy workflow that does not require human intervention using the Operations Manager 2012 component.

Performance: availability and scalability will be dynamic as computing resources are added to application platforms as and when required. Hardware or virtual failures are managed through server redundancy and fault tolerance.

Security: the hardware fabric is allocated separately through domain fault tolerance and virtual machines of each client is located in different physical servers.

Coordination: The different IT teams are dedicated and focused in different service levels; Infrastructure team focuses on hardware fabric using the virtual machine manager, the service delivery team focuses on supporting the application owners using the orchestrator and service manager and finally the IT administrator focus on monitoring and reporting using the operations manager.
5.4 CONSIDERATIONS

Below is a list of points to consider when designing and implementing the solution for the ITSP organization:

- **Organizational challenges** by resistance in adopting the private by the IT administrator staff as this will incur investment in their learning curve and will be accountable for new tasks. It will also introduce significant changes to the service management processes.

- **Government and industry regulations** regarding data privacy in terms of storage and access in clouds as this will take precedence over most other requirements. There are many governance domains that address strategic and policy issues in the cloud computing environment.

- **Hardware and software dependencies** of services. As in many organizations, most applications in the data center share the infrastructure and data. So, when migrating applications, data or storage into the cloud it should be taken into account that they should support technical independence. Prior to any migration an inventory of all systems and applications should be prepared where all interdependencies must be outlined from a hardware, platform, software perspectives and be removed accordingly to create containers of functionality that migrate with ease during the transition to the cloud this includes firewall, intrusion detection systems, virtual private network and secure connections.

- **Impact analysis** on migrating data center capabilities or applications to the cloud in relation to the overall business.

- **Governance** is crucial to ensure a data center with a modular approach and service oriented architecture. Implementation of cloud standards through using information and tools recommended by the Cloud Security Alliance (CSA) and the US National Institute of standards and technology (NIST) which address the cloud security and compliance models against the cloud architecture model.

- **Workloads**, that is, services or code to be executed must be dynamic in nature. This will allow well-defined interfaces between the functionality containers without dependencies.
Developers will be able to link services with ease to be used in different combinations by different applications.

- **Security Plan** must be put in place to ensure that appropriate measures are taken for data encryption, detection and forensics programs, user authorization and identification. Security risk assessment must be conducted end to end.

### 5.5 RISK ASSESSMENT

One of the critical planning exercises during the planning phase is Risk Management. It is considered to be one of the critical exercises in project planning as it enables the project manager to predict potential issues that might pose a threat to the success of the project. It is an established fact that each project will have risks and this is where risk planning (identifying and mitigating risks) plays an effective role in preventing any possible derailment in the event that they might occur. The below table outlines the identified risks where IM stands for impact and RV stands for risk value (Refer to Appendix C for MACS Risk Assessment form):

<table>
<thead>
<tr>
<th>#</th>
<th>IDENTIFIED RISK</th>
<th>IM</th>
<th>RV</th>
<th>PRIORITY</th>
<th>RISK MITIGATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>Incomplete Quality Testing</td>
<td>5</td>
<td>2</td>
<td>10</td>
<td>Agreeing and adhering to the test scenarios</td>
</tr>
<tr>
<td>R2</td>
<td>Scope Creep</td>
<td>9</td>
<td>5</td>
<td>45</td>
<td>Exhaustive requirement gathering from all stakeholders</td>
</tr>
<tr>
<td>R3</td>
<td>Lack of Training</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>Ensure that all users attend the scheduled training session and enforce the train the trainer concept</td>
</tr>
<tr>
<td>R4</td>
<td>Hardware Failure</td>
<td>7</td>
<td>4</td>
<td>28</td>
<td>During the network design, the resulting hardware specifications must be carefully considered</td>
</tr>
<tr>
<td>R5</td>
<td>Security</td>
<td>9</td>
<td>5</td>
<td>45</td>
<td>Encryption protocols, audit controls, policies and procedures, SLAs</td>
</tr>
</tbody>
</table>

Table 3: Identified risks
5.6 PROFESSIONAL, LEGAL & ETHICAL ISSUES

As cloud computing comes in different service models and span different architectures thus require high vigilance on security, manageability, governance and compliance.

**Professional:** To ensure effective and compliant implementation of the private cloud the following aspects must be taken into consideration and be, focused as success criteria to evaluate the success of the project:

1. Decision making during planning and implementation must be primarily based on the governmental organization needs, restrictions and limitations
2. Logical and Physical network designs of the current infrastructure must be communicated through management the necessary approvals have been provided
3. Adopting a standard that is compatible with the cloud computing product being used in order to ensure cloud interoperability and facilitate vendor independence
4. The proposed design for the new infrastructure overhaul will reflect business needs communicated by the customer and allow for scalability in case of future grows and high availability by introducing hardware redundancy

**Legal:** The risk that entails the implementation of new technology in the organization must be properly planned under the risk management plan and a strategic approach to mitigate the following identified risks(4):

1. Appropriate measure to ensure that accessibility to sensitive data is not compromised by adopting an Identity Management solution and Encryption approach to ensure data integrity
2. Availability and performance must adhere to the stipulation reflected in the service level agreement
3. Abiding by the compliance and governance policies set forth by the client based on the UAE governmental standards.
**Ethical:**

1. Conduct auditing exercises at the end of the project implementation to ensure that the client requirements were met especially from a security perspective.

2. Data management will be the responsibility of authorized administrators and will follow the necessary protocol in managing data and conforming to the chain of command when escalating issues that might arise in the course of their administrative duties.

3. Upon the client’s request, anonymity is required due to security reasons an alias is used instead.

4. A consent form was signed stating that all information shared in the project should remain confidential and a penalty clause was included in case of confidentiality breach should occur.

**Social:** Awareness and Training sessions will be conducted to maintain a common understanding with the client and all other identified stakeholders.

### 6 PROPOSED SOLUTION

The private cloud poses as the best fit solution as it has addressed the identified business needs discussed in the analysis phase and will be adopted as an enterprise solution for the datacenter. A proof of concept will be conducted first to ensure the feasibility of the solution and whether it will be adequate to be extended to the entire data center.

As most of the complaints arise from the application owners the quality VLAN is selected for the pilot implementation to be converted to a private cloud. Since the quality VLAN is very similar to that of the production VLAN it makes it the best fit for the proof of concept implementation of the private cloud.

Selected servers in the quality VLAN will be part of the private cloud and since most of these servers are already virtualized then what needs to be done is build the cloud layer on top of it. The scope if this pilot implementation will include:
The private cloud will be a small scale implementation that will cater for specific clients of approximately 200 users.

The application owners of the clients SECC, COSNTCO and FINCO along with the ITSP IT department will be using this private cloud as they are the ones experiencing the most challenges and mission critical applications.

They will be able to use the private cloud designed to deploy their applications to production readily and use the self-service portal to provision the services when required.

Introduction of the ability for users to self-service capabilities through a user interface. Provisioning of IT resources upon request in an automated manner. Application owners are able to deploy their applications rapidly and monitored in an efficient way.

The below diagram depicts the framework for introducing private cloud computing into the data center as per the business requirements:

Figure 14: Private Cloud Conceptual Solution
The layers illustrated in figure 14 are what constitute the layers of the private cloud architecture to be built in the organization (26):

- **The Infrastructure layer:** is in fact the Hyper-V virtualization layer that abstracts the physical systems, data and applications. This virtualization layer is what supports the automation and management capabilities of the cloud infrastructure and distinguishes it from a mere virtualized LAN. It is considered to be the bedrock of the cloud platform and which has already been implemented completely in the organization save for the application virtualization and legacy systems. These will be addressed in the private cloud implementation. The consequent layers assist in the development of complex workflows and task automation (27). The following is a brief description of each layers function in the cloud and that would be incorporated in the design.

- **Automation layer:** targets the automation of operational tasks, such as virtual machine backup/restore and maintenance activities

- **Management layer:** responsible for the management and monitoring all components and their respective dependencies.

- **Orchestration layer:** responsible for managing end-to–end business processes through the use of workflows.

- **Service Management layer:** responsible for the automation of best practices to create built-in IT process

- **Self Service layer:** aids authorized users to request and managed cloud services through a web based interface.
Figure 15: ITSP Clients’ Private Clouds

Figure 15 shows the overall solution which includes the private cloud for the three clients. The following points are a summary of the features and benefits that the private cloud will introduce:

- Virtualization enhancements to the existing infrastructure by virtualizing selected application and applying IaaS cloud computing model to it using Microsoft Application virtualization and cloud computing technologies.

- Internal private cloud using existing hardware to deliver infrastructure as a service. This platform will be dedicated to users within the organization’s intranet. All databases will be hosted in this environment.

- Self-service for users through the Microsoft App Controller.

- Complete end-to-end monitoring and management on all clouds using Microsoft System Center 2012.
• Pooled resources from a storage, network are turned to abstracted units that are dynamically provisioned.

• The underlying infrastructure (servers, network and storage) are resources in the private cloud which can be delegated to a group or individual users with specific usage quotas. Within the cloud the users can create virtual machines and deploy applications by using service and virtual templates.

7 GAP ANALYSIS

This type of analysis provides an account of the differences between the existing organization’s infrastructure and the proposed solution and what needs to be introduced to fill the gap. As the analysis of the business requirements have produced the outcome that the private cloud provides the best fit solution, the gap analysis starts with conducting a cloud readiness assessment. This basically assesses how the organization will need to be ready to be compatible with the private cloud as an enterprise.

An assessment of the current readiness status was done through interviews and readiness assessment forms and tools. The criteria employed in most of the readiness forms and interviews with the responsible parties were based on the following categories:

• **Strategy**: business and IT alignment.

• **Process**: process automation towards business agility.

• **Architecture**: current capability of data center.

• **Technology**: design and deploy of current technologies.

• **People & Governance**: roles and skills required to sustain the cloud, accountability framework, stakeholder collaboration policies.

Some of the questions in the interview were:

• Data Center foot print threshold level?

• What percentage of the current infrastructure is virtualized?
• Level of sponsorship for the cloud computing initiative?
• Business value measurement of the cloud to the enterprise?

For a complete list of the questions, refer to Appendix A: Readiness Assessment Form

The outcome of the readiness exercise is summarized below:

a. The data center is completely virtualized save for the legacy and unsupported applications. The application selected to be moved to the cloud were assessed based on the following points and table (3) shows the business impact of each:

   i. Network capability and bandwidth allocation
   ii. Whether independent architecture for each application or a consistent one exists
   iii. Do applications use common business services or are self-contained one
   iv. Workload management

<table>
<thead>
<tr>
<th>SOFTWARE</th>
<th>CLIENT</th>
<th>USE</th>
<th>BUSINESS IMPACT</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECM (SharePoint)</td>
<td>SECC</td>
<td>The enterprise content management solution</td>
<td>MEDIUM</td>
</tr>
<tr>
<td>HRMS</td>
<td>SECC</td>
<td>In-house built human resource management system</td>
<td>HIGH</td>
</tr>
<tr>
<td>Finance</td>
<td>FINCO</td>
<td>In-house built finance system</td>
<td>HIGH</td>
</tr>
<tr>
<td>SAP-BW</td>
<td>CONSTCO</td>
<td>Business operation automation enterprise solution</td>
<td>HIGH</td>
</tr>
<tr>
<td>TFS</td>
<td>CONSTCO</td>
<td>Team Foundation service for software development lifecycle management</td>
<td>MEDIUM</td>
</tr>
<tr>
<td>ERP</td>
<td>FINCO</td>
<td>Enterprise resource planning system</td>
<td>HIGH</td>
</tr>
</tbody>
</table>

Table 4: Business Impact of Selected Applications
b. The cloud software requires the addition of physical host servers.

c. Certain modification is required for the QC VLAN physical servers to be hosted in the private cloud.

The following are the main points that highlight the steps to bridge the difference between the current data center and the desired version based on the conducted gap analysis:

- The current virtualization software will be upgraded from 2008 to 2012 to be compatible with the cloud software System Center 2012

- The physical infrastructure has been completely virtualized and this needs to be extended to the applications as well. In order to do so certain virtual machines will need to be reallocated to different physical hosts to maximize on the servers’ specifications.

- Since most of the technology in the organization is geared toward the Microsoft technology then the internal private cloud will be a Microsoft virtual private cloud and resides within the enterprise’s own data center. It will host all application and business process that are deemed secure and contains sensitive intellectual property.

- Defined deployment procedures of the selected applications so that the service and virtual machine templates can be designed and implemented as they will be the basis for automating application deployment, release and updates.

- The private clouds will be in Infrastructure as a Service (IaaS) delivery mode thus any physical host to be migrated must be both clustered and virtualized.

8 SOLUTION DESIGN

The design phase is about structuring how the solution will be implemented logically and physically and will illustrate how the software components introduced will address the business needs. As outlined in the gap analysis phase, a pilot implementation will be implemented using the QC VLAN to validate the proposed solution feasibility and contribution in resolving the
challenges faced by the ITSP organization. The next sections will explain the logical flow starting with preparing the infrastructure and making it into building blocks for the private cloud.

8.1 SOLUTION DESCRIPTION

The main idea behind the solution is to architecturally provide infrastructure as a service to clients and deploy it as a private cloud. Infrastructure as a service is abstracting the physical layer in such a way that the clients can interact and request what they need of computing resource without the knowledge of what hardware components that lie behind. A private cloud is a deployment model that ensures that the IT has complete control of the infrastructure while allowing users to use automated services from it.

The approach to designing the solution will follow these steps:

- Identify the architecture components to build the private cloud model
- The logical design of how the private cloud will be built
- The physical design and hardware specifications of the private cloud infrastructure

![Figure 16: Delivering IT as a Service](image-url)
The design will tackle the issue of the host’s waste of computing resources by creating resource pools with homogenous specification mapped to the application and services that it will be hosting which will result in efficient provisioning. In cases like upgrades and capacity increase all the hardware in each scale unit is identical therefore there will be no decrease in performance or downtime.

The services that the solution will offer are:

- Provisioning virtual machines by application owners
- Ability to define resource templates for applications
- Monitor and manage end to end the service life-cycle
- Self-service web portal for clients to create their and automate their requests

The user roles that the solution will offer for interaction with the cloud are:

- **Application Owners**: managing the guests in the cloud of a specific host group.
- **Infrastructure team**: members from the IT department responsible for the infrastructure and own the fabric resources.
- **IT administrators**: delegated members that monitor and manage operation activities of the cloud.

### 8.2 ARCHITECTURE MODEL

In order to achieve the ideal design it must address the actual business needs of ITSP that has been identified. Thus using the aid of the private cloud reference developed by the private cloud community, the platform will be designed for ITSP. This model helps in identifying how the business and technology will be blended to offer a solution that is both leveraged by software automation but also based on service management best practices. The latter two areas are specifically what ITSP is lacking in.
As most of the servers in the data-center are already virtualized using Microsoft virtualization technology, most of the effort will be in implementing the cloud layers on top of the virtual layer and Microsoft recommended that the private cloud platform should be implemented using System Center 2012 and Windows Server 2008 R2.

Window 2008 R2 SP1 is equipped with the virtualization technology named Hyper-V; it will act as the operating system for the private cloud components and the host hypervisor for the virtual machines and it also acts as the foundation of the private cloud infrastructure. System Center 2012 will be used as the management toolset to manage the private cloud to deliver the IT as a service to the ITSP clients.

Each layer in the cloud has many capabilities and the corresponding modules in System Center 2012 will provide them to satisfy the business needs. For the purpose of this pilot implementation only those capabilities in each layer that directly address the immediate business needs will be built and configured. They are as follows:

- **Hardware layer**: made up of storage, network, compute and data center facility each of these components come with their own management interfaces and can interact with higher level of architectures through APIs
- **Virtualization layer**: through windows 2008 R2 the virtualization is achieved and virtual machines and network with VLANs can be used as well as shared cluster volumes and virtual disks.
- **Automation layer**: provides the capability to have the higher-levels management and orchestration layer to interact with the physical and virtual lower-layers
- **Management layer**: provides the capability of automating tasks into processes and operation activities.
- **Orchestration layer**: binds the products, technologies and processes to create end to end workflows to automate complicated tasks.
- **Self-service and admin interface**: removes the barriers between user’s need for IT resources and the delivery of those resources through providing a self-service interface.
The table below summarizes the components of the private cloud that will cater to the identified business needs and who will benefit from it.

<table>
<thead>
<tr>
<th>BUSINESS NEED</th>
<th>CLOUD LAYER</th>
<th>SYSTEM CENTER 2012 COMPONENTS</th>
<th>USED BY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self service</td>
<td>App Controller</td>
<td>App controller, service manager, orchestrator, VMM</td>
<td>End users to put in their requests</td>
</tr>
<tr>
<td>Server provisioning</td>
<td>Service Delivery</td>
<td>Service manager, orchestrator, VMM</td>
<td>Application owners to create service templates and Service Delivery team to define business specifications</td>
</tr>
<tr>
<td>Automate IT services</td>
<td>Service Operation</td>
<td>Service Manager, Orchestrator</td>
<td>Operation team to automate request execution</td>
</tr>
<tr>
<td>Performance Monitoring</td>
<td>Management</td>
<td>Service manager, orchestrator, VMM</td>
<td>IT administrator to create monitoring dashboard and reports</td>
</tr>
<tr>
<td>Capacity management</td>
<td>Management</td>
<td>Service manager, orchestrator, VMM</td>
<td>IT administrators to manage available hardware resources</td>
</tr>
<tr>
<td>Infrastructure management</td>
<td>Infrastructure, Management</td>
<td>Service Manager, Orchestrator, Operation manager</td>
<td>IT administrators</td>
</tr>
<tr>
<td>IT teams communication</td>
<td>Service Delivery, Service Operation</td>
<td>Orchestrator, Service Manager</td>
<td>Service Delivery team will define business specifications and the Operation team will automate them</td>
</tr>
</tbody>
</table>

Table 5: Requirements and Cloud Components Mapping
8.3 LOGICAL DESIGN

Once the architectural components were identified the next step is to design the logical flow of how the design will be implemented as shown in figure 17.

First, the infrastructure will be prepared and defined through the following steps:

- The physical resources are managed together as a scale unit which is a set of servers, of network or storage capacity. It’s the measurement of the required hardware to be added into the data center.
- These scale-units will then be grouped into logical resource pools comprising of servers, network and storage and in turn will be abstracted into virtual machines using the hypervisor.
- Using the Virtual Machine manager, the data center fabric is then created based on abstraction of these virtual machines and network switches which is where resources will
be managed and provisioned and are called host groups. This design ensures the logical and physical separation of the management platform from the VM hosting platform. The host group is structured and grouped based on the physical site location that ITSP provides service to and the resource allocation based on the applications hosted. Using this structure each client will have their separate set of hosts independently and thus eliminates the existing security concerns of sharing host servers.

Secondly, the configuration and definition of infrastructure services by:

- Using the service manager the services will be defined in the service catalog and broken into classes based on their priority and hardware resource requirements.
- The corresponding workload pattern will then be created which then translates to VM templates which includes configuration such as amount of CPU and storage.

Thirdly, will be bringing the fabric and services together through:

- The workload for each service using the appropriate fabric will be configured in the Orchestrator.
- VM templates are then prepared in the virtual machine manager and enabled as a self-service through the app controller.
- The tasks in System Center 2012 will wizard controlled or configurable through graphically modeled processes.

Lastly, will be to add the servers into the host groups to be able to create the private cloud:

- Add host servers to host group in VMM
- Create self-service user roles in VMM
- Create VMM library
- Create the private cloud from the host groups
Creating the private cloud in this manner will enable the back-end administrators who will essentially be the service providers to control the metal provisioning by creating the fabric through the VMM. The application owners (clients) request access to the virtual machines by running the service templates wizard made available through the App Controller.

### 8.4 PHYSICAL DESIGN

The network design shown below represents how the current infrastructure will be transformed to be added into the private cloud. As mentioned the allocation of virtual machines in the host servers are not compatible and will be rearranged using the virtual machine manager. The network configuration of the current QC VLAN will be used to create the equivalent VLAN for each client in the cloud.

Figure 18 shows three logical networks created to separate the development, quality and production environments. The figure also details the selected application servers for the QC VLAN that will be the scope of the pilot implementation. The virtual machines in each host server are shown as well and it should be noted that these will be relocated to be aligned with the application needs. The existing hardware environment in the QC VLAN is as shown in the table below. Each server hosts different virtual machines as is indicated in the physical design for different types of application which creates a mismatch of resource allocation and wastage.
The table below shows the hardware profile of the current infrastructure:

<table>
<thead>
<tr>
<th>HARDWARE</th>
<th>DESCRIPTION</th>
<th>SPECIFICATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storage</td>
<td>Server type 1</td>
<td>EMC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VNX-5300</td>
</tr>
<tr>
<td>Physical Servers</td>
<td>Server type 2</td>
<td>CPU RAM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Node 1 and 2</td>
</tr>
<tr>
<td></td>
<td>Server type 3</td>
<td>CPU RAM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Node 3 and 5</td>
</tr>
<tr>
<td>Switches</td>
<td>Network switches (Uses 3 ports from each of the 3 main switches to constitute the VLAN)</td>
<td>Barcode FX-1234</td>
</tr>
</tbody>
</table>

Table 6: Infrastructure Hardware Profile
There are 6 hyper-v nodes that host the virtual machines of the selected four applications. Currently the virtual machines are housed as follows:

<table>
<thead>
<tr>
<th>Server Type</th>
<th>Virtual Machines Allocation</th>
<th>Node</th>
</tr>
</thead>
<tbody>
<tr>
<td>SharePoint servers</td>
<td>2 web front end(4 v)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 app server(2 v)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 SQL server (2 v)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 web front end (4v)</td>
<td>Node3 (Hyper-v 17)</td>
</tr>
<tr>
<td></td>
<td>1 app server (2v)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 SQL server (2v)</td>
<td>Node2 (Hyper-v 16)</td>
</tr>
<tr>
<td>ERP servers</td>
<td>2 app server(4v)</td>
<td>Node1 (Hyper-v 15)</td>
</tr>
<tr>
<td></td>
<td>2 SQL server(4v)</td>
<td></td>
</tr>
<tr>
<td>SAP servers</td>
<td>2 app server(2v)</td>
<td>Node4 (Hyper-v 18)</td>
</tr>
<tr>
<td></td>
<td>2 SQL server(2v)</td>
<td>Node6 (Hyper-v 20)</td>
</tr>
<tr>
<td>HRMS servers</td>
<td>2 app server(2v)</td>
<td>Node5 (Hyper-v 19)</td>
</tr>
<tr>
<td></td>
<td>2 SQL server (2v)</td>
<td></td>
</tr>
<tr>
<td>FINANCE servers</td>
<td>2 app server (2v)</td>
<td>Node5 (Hyper-v 19)</td>
</tr>
<tr>
<td></td>
<td>2 SQL server (2v)</td>
<td></td>
</tr>
<tr>
<td>TFS servers</td>
<td>2 app server (2v)</td>
<td>Node1 (Hyper-v 15)</td>
</tr>
<tr>
<td></td>
<td>2 SQL server (2v)</td>
<td>Node6 (Hyper-v 20)</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>40 Virtual CPU</strong></td>
<td></td>
</tr>
</tbody>
</table>

**Table 7: Current Virtual Machines Allocation**

The storage technology used is the EMC VNX5300 due to its virtual provisioning and reduplication capabilities. It is also compatible with System Center 2012 Operation Manager component. The next step is to detail the design specification as well as the infrastructure level changes that will be introduced.
8.5 **DESIGN SPECIFICATIONS**

In this stage the logical resource pools and host groups configuration definition for the private cloud will be prepared. As the pilot implementation will encompass the migration of selected applications from the QC environment into the newly created private cloud, below is a tabular representation of those applications and its respective end-users:

<table>
<thead>
<tr>
<th>SharePoint 2010</th>
<th>Application Owners</th>
<th>SECC</th>
</tr>
</thead>
<tbody>
<tr>
<td>HRMS</td>
<td>Application Owners</td>
<td>SECC</td>
</tr>
<tr>
<td><strong>Team Foundation Services</strong></td>
<td>Application Owners</td>
<td>CONSTCO</td>
</tr>
<tr>
<td>SAP</td>
<td>Application Owners</td>
<td>CONSTCO</td>
</tr>
<tr>
<td><strong>ERP, Finance</strong></td>
<td>Application Owners</td>
<td>FINCO</td>
</tr>
</tbody>
</table>

**Table 8: Selected Applications**

The Quality VLAN hosts all the servers that will be used for staging and quality testing purposes and is identical to the production environment. Although VMs are separated from their host through the hypervisor all the quality servers of all clients are placed on the same logical network which is a security concern. All these servers are virtualized, clustered and highly-available. The problem with managing these servers whether virtual machines or physical servers is due to the sheer size of them and the fact that the host servers on which the VMs are hosted on might not be the best fit. There are a number of applications hosted in the QC VLAN; only a number of them will be part of the pilot implementation to illustrate how the cloud can benefit the organization on an enterprise level. Since there are 3 clients using the QC VLAN, thus there will be 3 private clouds. Each cloud will be using the network configuration of the QC VLAN. The client might be on the same virtual network but are segregated at the hardware and virtual level. Each cloud will contain several host groups based on application that each client works with.

The QC VLAN will be migrated in to the cloud in two main stages; one being in the design phase and the other in the implementation phase as shown below:
STAGE 1 (Design phase):

1. Identify the additional servers for the private cloud
2. Restructure the infrastructure by logically placing the servers into logical resource pools
3. Prepare the configuration settings for the hardware fabric and private cloud

STAGE 2 (Implementation phase):

4. Install and Configure the System Center 2012 components
5. Configure the hardware fabric to be used by the clouds
6. Build the private cloud for each QC VLAN of each client

The table below indicates the number of additional servers for the private cloud software components that will be needed.

<table>
<thead>
<tr>
<th>ADDITIONAL SERVERS</th>
<th>#</th>
<th>HARDWARE SPECIFICATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Center Virtual Machine Manager</td>
<td>2 virtual CPU</td>
<td>4 GB memory, 80 GB disk size</td>
</tr>
<tr>
<td>System Center Operations Manager</td>
<td>2 virtual CPU</td>
<td>4 GB memory, 60 GB disk size</td>
</tr>
<tr>
<td>System Center Data Protection Manager</td>
<td>2 virtual CPU</td>
<td>2 GB memory, 40 GB disk size</td>
</tr>
<tr>
<td>System Center Orchestrator</td>
<td>2 virtual CPU</td>
<td>4 GB memory, 60 GB disk size</td>
</tr>
<tr>
<td>System Center Service Manager</td>
<td>2 virtual CPU</td>
<td>4 GB memory, 60 GB disk size</td>
</tr>
<tr>
<td>System Center App Controller</td>
<td>2 virtual CPU</td>
<td>2 GB memory, 40 GB disk size</td>
</tr>
</tbody>
</table>

Table 9: Private Cloud Hardware Specifications
The restructuring of the infrastructure required in order to be added in to the private cloud comprises of:

- Creating logical resource pool groupings of the resources for each client based on the application used.
- Map the resource pools into host groups for each client which will be used to create the private cloud for each client.

### 8.5.1 CREATING THE RESOURCE POOLS

There are two major issues with the current distribution of the virtual machines:

- All the virtual servers are hosted in the same physical server which is a large fault tolerance as when the physical server goes down all virtual machines stop working as well thus the server redundancy made available is not effective
- Based on the hardware specifications of the nodes it is evident that the applications are not hosted in the appropriate physical host

With the new logical arrangement of the hardware as shown in the below table, provisioning requests will be spread across the resource pool and this is ensured by the resource pool definition and physical infrastructure mapping.

![Figure 19: Logical Resource Pools](image)
### Resource Pool Configuration

<table>
<thead>
<tr>
<th>Resource Pool 1</th>
<th>SharePoint servers</th>
<th>Server type 1</th>
<th>Node 1 and 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resource Pool 2</td>
<td>ERP servers</td>
<td>Server type 2</td>
<td>Node 3 and 5</td>
</tr>
<tr>
<td>Resource Pool 3</td>
<td>SAP servers</td>
<td>Server type 3</td>
<td>Node 4 and 6</td>
</tr>
<tr>
<td>Resource Pool 4</td>
<td>HRMS servers</td>
<td>Server type 1</td>
<td>Node 1 and 2</td>
</tr>
<tr>
<td>Resource Pool 5</td>
<td>Finance servers</td>
<td>Server type 3</td>
<td>Node 3 and 5</td>
</tr>
<tr>
<td>Resource Pool 6</td>
<td>TFS servers</td>
<td>Server type 3</td>
<td>Node 4 and 6</td>
</tr>
</tbody>
</table>

**Table 10: Resource Pool Configuration**

8.5.2 **HOST GROUP CONFIGURATION**

Once the virtual nodes have been rearranged the hardware fabric is ready to be configured based on the following settings:

<table>
<thead>
<tr>
<th>RESOURCES</th>
<th>NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Host group</td>
<td></td>
</tr>
<tr>
<td>• SECC</td>
<td>o QC VLAN</td>
</tr>
<tr>
<td></td>
<td>SharePoint_x</td>
</tr>
<tr>
<td></td>
<td>HRMS_x</td>
</tr>
<tr>
<td>• CONSTCO</td>
<td>o QC VLAN</td>
</tr>
<tr>
<td></td>
<td>TFS_y</td>
</tr>
<tr>
<td></td>
<td>SAP_y</td>
</tr>
<tr>
<td>• FINCO</td>
<td>o QC VLAN</td>
</tr>
<tr>
<td></td>
<td>ERP_z</td>
</tr>
<tr>
<td></td>
<td>Finance_z</td>
</tr>
<tr>
<td>Logical Network</td>
<td></td>
</tr>
<tr>
<td>• Corporate: internal network for internal application and database servers</td>
<td></td>
</tr>
<tr>
<td>• Internet: public network for web servers</td>
<td></td>
</tr>
<tr>
<td>Network classification</td>
<td></td>
</tr>
<tr>
<td>• Backend (divided into four separate VLANS, one</td>
<td></td>
</tr>
</tbody>
</table>
of which is the QC VLAN)

- Backend-QC: 150.140.100.0/24 on VLAN 3

### Table 11: Host Groups’ Configuration

<table>
<thead>
<tr>
<th>IP address Pool (Backend-QC pool)</th>
<th>Will be dedicated as the QC VLAN for all users</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storage Classification</td>
<td></td>
</tr>
<tr>
<td>- Gold: storage pool for high performance and I/O intensive operations. (SSD, solid state drives)</td>
<td></td>
</tr>
<tr>
<td>- Silver: SCSI storage disks (RAID 5)</td>
<td></td>
</tr>
</tbody>
</table>

Once the host group containers have been configured it is ready to receive the existing hyper-v hosts in the QC VLAN. During the implementation phase the existing host servers will be migrated to the appropriate host groups. The virtual machines will automatically be recognized by the virtual machine manager and will then be manually relocated to its appropriate host group using the resource pool table shown above.

The next step in building the private cloud would be to create a self-service user role and then add the users that would be able to use the self-service portal in this role. Actions that the self-service is allowed to perform will also be assigned to ensure the least privilege rule is applied. The user will be allowed to perform the following actions:

- Deploy
- Author
- Start/stop/shutdown
- Pause and resume
- Store
- Local administrator
- Remote connection
8.5.3 PRIVATE CLOUD CONFIGURATION

The QC VLAN private cloud is ready to be built at this stage from the host groups using the below specifications.

<table>
<thead>
<tr>
<th>PRIVATE CLOUD</th>
<th>RESOURCES</th>
</tr>
</thead>
</table>
| SECC Client (cloud created from host groups) | • Host groups: SP, HRMS  
• Logical Network: Back-End  
• Storage classification: Gold and Silver  
• Capability Profile: Hyper-V |
| CONSTCO Client (cloud created from host groups) | • Host groups: TFS, SAP  
• Logical Network: Back-End  
• Storage classification: Gold and Silver  
• Capability Profile: Hyper-V |
| FINCO Client (cloud created from host groups) | • Host groups: ERP, Finance  
• Logical Network: Back-End  
• Storage classification: Gold and Silver  
• Capability Profile: Hyper-V |

Table 12: Private Cloud Configuration

9 IMPLEMENTATION

This stage will comprise of implementing the solution based on the logical and physical design and the configuration based on the design specifications. In this section of the report is a detailed account of how the POC private cloud was implemented for the ITSP organization. The IT department helped in preparing the hardware and OS configuration of the private cloud and finally testing it after its complete implementation and provided their acceptance forms along with the application owners.
1. **Preparing the System Center 2012 virtual machines**

   The implementation begins with installing the operating system Windows 2008 R2 on each virtual server of the System Center 2012 virtual machines and each will be configured to connect to the organization’s internal network. This was accomplished with the help of the IT department.

2. **Installing the System Center 2012 components**

   Since the base infrastructure is in place the components will be linked together based on the following:
   - First the software components will be installed using the unified installer which is a utility provided by Microsoft to ease the installation process for the System Center 2012 into their respective servers as stated in the physical design. The below figures is a snapshot of the component selection window during the unified installer execution where the server names of each of the System Center components are named.

   ![System Centre 2012 Installation Wizard](image)

   **Figure 20: System Centre 2012 Installation Wizard**
• Once all the information during the installation step is entered the below summary report was generated.

Figure 21: System Center 2012 wizard completion

3. Connecting the System Center 2012 together

• The software components of System Center 2012 interact with each other as shown in the figure below. The orchestrator and service manager are located in the middle of the interaction as they are both responsible for automating the workflow of services. The orchestrator will integrate with the VMM, Operations manager, Active directory and data protection manager to be able to automate the services that each of these software’s provide. The service manager will integrate with the operation manager to enable the reporting services. The service manager connects to VMM, Operations manager and Active Directory to maintain the
configuration management database that is required to keep track of all the items housed in the private cloud.

**Figure 22: System Center 2012 Component Interconnections**

- The connection between the components as shown above starts with the installation of the four integration packs for the Orchestrator. To install the integration packs they will have to be registered, deployed and then configured.

- To register any of the integration packs the following steps were followed:
  - Open System Center 2012 Orchestration Deployment Manager
  - Right click the Integration packs on the left menu
  - Select register IP with Orchestration Management Server
  - Select the desired the integration pack (VMM, Operations manager, Data Protection manager, Service Manager)
• The details of the addition of the VMM integration pack is shown in the figure below.

Figure 23: VMM Integration Pack installation

• The below figure shows the completion of registering all the integration packs

Figure 24: Integration Packs Installation Wizard Completion
Following the registration of the integration packs is their deployment.

![Integration Packs Deployment Wizard](image1)

**Figure 25: Integration Packs Deployment Wizard**

Following the deployment of the integration packs is their configuration. The below figure shows the configuration details for the VMM integration packs.

![VMM Integration Pack Configuration](image2)

**Figure 26: VMM Integration Pack Configuration**
The below are the configuration details of the other integration packs

- **Connection Name: Operation Manager Connection**
  - Server Name: opsmgr.ITSP.dir
  - Domain: ITSP
  - Username: administrator
  - Password: ******

- **Connection Name: Service Manager Connection**
  - Server Name: servicemgr.ITSP.dir
  - Domain: ITSP
  - Username: administrator
  - Password: ******

- **Connection Name: DPM Connection**
  - Server Name: dpm.ITSP.dir
  - Domain: ITSP
  - Username: administrator
  - Password: ******
  - Port: 5001

Once the orchestrator connections have been setup the next step is to setup the service manager component. It is responsible for creating the organizational processes and automating the response to maintain the private cloud. Setting up the service manager is through configuring its connectors to the Active Directory, Operations Manager, Virtual Machine Manager and Orchestrator. Lastly would be registering the data warehouse connector to establish reporting services.

The objects to select when prompted from the Active Directory include computers, users and groups. These objects will be imported into the Service Manager and will aid in maintaining the configuration database of the private cloud to be able to link all the items during creating a workflow.
• The Operation manager connector when installed will aid the Service Manager to:
  o Generate incidents from the Operation Manager alerts
  o Define templates for incoming alerts
  o Set alert polling frequency

• The alerts that will be imported from Operation manager is selected to be only the critical ones and to be polled every 1 minute. It is saved as a template called Operation Manager Incidents Template.

• The below figure shows the configuration details of the Operation manager Connector.

![Image: Operation Manager Connector Configuration Wizard](image)

**Figure 27: Operation Manager Connector Configuration Wizard**

• The next connector in line is the Operation Manager CI connector that aids the Service Manager to select which configuration items from the Operation Manager to import. The configuration items can be imported through installing the desired management packs. The below figure shows the management packs that were selected during the installation.
Figure 28: Operation Manager CI Connector Management Packs Installation

- The next connector is that of the Virtual Machine Manager which lets the Service Manager imports items such as clouds, service templates, VIP templates and storage classifications as shown below.

Figure 29: VMM Connector Configuration Wizard
• The next connector is the Orchestrator which helps the Service manager to import run books, i.e. service workflows created in the orchestrator. The synchronization folder from which all the run books of the Orchestrator will be imported is specified as well as the Orchestrator management server URL to be able to enable any hyperlinks within the run books as shown below.

![Orchestrator Connector Configuration Wizard](image)

**Figure 30: Orchestrator Connector Configuration Wizard**

• The last configuration in the Service Manager setup is to enable the reporting services through registering the Data Warehouse Connector which provide the ability to run reports and use other data warehouse functionality.

• This installation will first register the service manager in the data warehouse and then load the management packs to be able to deploy an run the reports in the service manager. The below figure shows the successful connection to the Data warehouse server.
A new service account named **DW_ServiceManagerMG SecureReference** is used as the credentials to connect from the service manager to the Data warehouse server and will be automatically be given server admin privileges once the configuration is complete.

Once the registration is complete the management packs to deploy the report will be scheduled as jobs to run. There are five jobs that are affiliated to the report deployment and they are:

- Extract_<Service Manager management group name>
- Extract_<data warehouse management group name>
- Load.Common
- Transform.Common
- MPSyncJob
The final step in connecting the system center 2012 components is connecting the Virtual Machine Manager to the Operations Manager to enable the monitoring of the virtual machine’s and related services health and availability as well as the VMM management server its library, database and self-service portal. The administrator can also view the virtualized environment diagrammatically through the Operation manager console.

The below figure shows the configuration details of the connection to the Operation Manager to enable monitoring.

![Image of Operation Manager Configuration Wizard]

**Figure 32: Operation Manager Configuration Wizard**

4. **Configuring the private cloud infrastructure**

   - Once all the System center components were installed and configure the infrastructure configuration takes place as per the details described in the design phase. The stage in the preparation of the private cloud will include the following:
     
     i. Creating the host groups
     
     ii. Creating the logical network
     
     iii. Creating the storage classifications
• The host groups will group the virtual machine hosts based on which client will be using it, thus based on the application distribution among the client shown in figure (34) there will be four host groups created.

• To create the host group the following was done:
  o Opened the VMM console
  o Clicked on VM and services on the left menu
  o Selected on All Hosts and then create Host Group

• The below figure shows the tree structure for the three hosts.

![Host Groups Folder Structure]

**Figure 33: Host Groups Folder Structure**

• The next step is to configure each host group based on the type of resources it selecting properties. The below figure shows the application host group properties window.
Below are the configurations for each of the properties on left menu

- Placement Rules

- Host Reserves (the resources dedicated for host machine to operate)
  - CPU: 5%
  - Memory: 500MB
  - Disk I/O: 0 IOPS
  - Disk Space: 2%
  - Network I/O: 1%

- Dynamic Optimization: this is to be used if the host machines are in a cluster since this is not the case in QC but in production the values are left to default.

- Network: IP pools are selected as the network type which will be configured in the next steps.
- Storage: The Gold storage level is selected as that is required by the application.
- PRO Configuration: default values.
- Custom Properties: no custom properties are required at this stage.

- The next step is defining the logical networks. The host servers that will be migrated into the host groups will have their logical network imported so in this step the logical network that will be created will be for the servers that need internet access.

- Below are the steps that were followed to create the logical network:
  - Opened the VMM console
  - Clicked on Fabric on the left menu
  - Selected logical network

- The name given for this logical network is Internet-Network. The IP range set for this network is 155.100.1.0/24 and will be used by the three main host groups in case any of the application owners deploy servers that need internet access.

- Following the creation of the logical network for Internet access is the creation of the IP pool for that network. Below are the steps that were followed to create the IP Pool:
  - Opened the VMM console
  - Clicked on Fabric on the left menu
  - Selected logical network and then create IP pool
Below are the configuration details for the IP Pool properties.

- Network site:
  - logical network selected will be the one named Internet-Network
  - IP subnet is the 155.100.1.0/24

- VIP And Reserved IPs:
  - starting IP address: 155.100.1.10
  - ending IP address: 155.100.1.30
  - reserved IP for load balancer: 155.100.1.25

- Gateway: 155.100.1.1

- DNS: 155.130.1.1

A VIP template is a virtual IP template created for application owners to use in case they need to deploy application servers that need load balancers. Below are the configuration details used for the VIP template:

- Template Name: ITSP VIP Template

- Type: the type of template that best fits the environment
  - Manufacturer: Microsoft
  - Model: Microsoft Load Balancing (NLB)

- Protocol: TCP is selected to the protocol to create the NLB VIP template.

The last step in configuring the infrastructure for the private cloud is the storage configuration. The storage that is used by ITSP is EMC-VX5342 which is SMI-S which means that it can be automatically discovered by the virtual machine manager.
5. **Building the private cloud**

   - This stage comprises of the following steps:
     
     i. Adding the existing host servers from the QC VLAN
     
     ii. Relocating the virtual machines

   - Creating the three clouds for the three clients

   - When the existing servers are added the networking and storage configuration are automatically imported. To add a host server the following steps were followed:
     
     o Opened the VMM console
     
     o Clicked on Fabric on the left menu
     
     o Selected the Add resource option

   - The below figure shows the Add Resource window

![Add Resource window](image)

**Figure 35: Adding Physical Host Wizard**
The below are the configuration details for the above operation:

- Credentials: this is the account used to discover the host machines and install the VMM agent on them.

- Discovery Scope: the names of the machines which are to be added and they are HyperV-15, HyperV-16, HyperV-17, HyperV-18, HyperV-19 and HyperV-20

- Host Settings: this is where the host servers will be mapped to their host groups
  - SharePoint Host group: Hyper-V
  - HRMS Host group: Hyper-V
  - SAP Host group: Hyper-V
  - TFS Host group: Hyper-V
  - Finance Host group: Hyper-V
  - ERP Host group: Hyper-V

The following step was to relocate the virtual machines to the appropriate servers as shown in table (9) in the design section. This is achieved by:

- Opening the VMM console
- Selecting the VMs from the ribbon menu on top
- Right click the desired the VM to relocate and select quick migration from the pop-up menu
- The new host for the VM is then defined and the disk location to save the virtual hard disk files

Finally as all the infrastructure components have been completely configured and the virtual machine are up and running the final step is associate the host groups to their respective clouds. As stated in table 9 in the design section the host groups
will be distributed among three clouds for each of the three clients.

- To start creating the cloud for any of the clients the following steps were executed:
  - Opened the VMM console
  - Clicked on the Create Cloud option on the ribbon menu on top
- The below figure shows the create cloud window with the properties to be configured

![Figure 36: Private Cloud Creation Wizard](image)

- The entered configuration details for the creating the cloud for SECC, y and z:
  - SECC
    - Resources: the host group for SECC will be HRMS and SP
    - Logical Networks: the logical network attached to the host group will be automatically selected
- Load Balancers: the one created for this host group is automatically selected
- VIP Profiles: the one created for this host group is automatically selected
- Storage: for the is private cloud the gold storage classification is selected
- Library: the physical path where backup copies of the virtual machines will be placed. The path given is on a shared drive on the RMC storage server
- Capacity: the capacity is distributes as below
  - Virtual CPUS: 10
  - Memory: 4GB
  - Storage: 300GB
  - Virtual Machines: 5
- Capability profiles: since all the hosts are using windows 2008 hyper-V is selected as the profile
  - CONSTCO
  - FINCO

- After the three clouds have been built and contain the appropriate application host servers the following step is to enable the self-service role in each cloud in order for the application owners as it is the key aspect to enable provisioning resources through the app controller. To enable the self-service role for the SECC private cloud. A user role is created and the application owners from this client are added. Next is to allocate the quota of resources that the members of the group are allowed to use and the permissible actions that they can perform with the resources in the cloud. This group is then associated with the SECC cloud. This same process is applied to the CONSTCO and FINCO.
In order for the provisioning and cloud operational activities to be automated, templates of virtual machines and services must be created. The main difference between a VM template and a service template is that the later deploy machines and related service together and all services are linked to the service templates they were created from. Service templates contain the definition for creating machine, their connectivity, and application definition. It is mainly beneficial for deploying applications and upgrading machines. Creating a both templates is done through using the VMM where the VM template is created first. A service template is then created for the HRMS application using the service template designer shown in the figure below:

**HRMS SERVICE TEMPLATE**

![HRMS Service Template Design](image)

**Figure 37: HRMS Application Service Template Design**
Tier 1 will be the application tier which contains the virtual machine and virtual IP address templates, Windows 2008 OS image and a web deploy package that is part of the application package.

Tier 2 will be the business logic and contains the VM template and the script and msi files to install the application code.

Tier 3 is the database tier and contains the VM template, the SQL server and SQL profile installation packs.

The final step in having the cloud ready for use is to create services within the service catalog. The self-service portal in the service manager will be used by the application owners to request services that require a workflow to be executed or is complicated in nature. The App controller self-service portal is reserved for performing simple and defined actions to the private cloud. The service manager service catalog lists all services the IT department is offering to its clients as shown below.

Figure 38: Service Catalog for IT Department
The IT administrator can classify custom services as and when required through creation wizards in the service manager. When a user selects a service from the data center cloud category a request form is displayed to enter the necessary information to automate the fulfillment of the selected request by triggering the required system level automation activities. The request form for any service is dynamically created and based on the needs submitted automatically triggers workflow automation or is routed to the appropriate group for action or approval. Users can track their requests and view its status through the self-service portal itself as indicated in the figure.

Figure 39: Service Request Form for Resource Provisioning
10 TESTING AND EVALUATION

Testing is one of the important processes in any form of implementation as it serves as a success factor for the project and helps to identify design and/or implementation flaws. The testing methodology adopted focuses on testing the services that the private cloud is offering to ensure that the business challenges have indeed been addressed. The testing cycle used is composed of the following:

- The objectives that the testing process should achieve
- Testing requirements necessary to perform the test scenarios
- Test scenarios which will be conducted with the coordination of the IT department and application owners.
- Test results which will give an indication on whether the solution is to be released on an enterprise level along with test closure in the form of system check feedback forms and is part of the hand-off process.
- Evaluation and recommendation

10.1 TESTING OBJECTIVES

The testing process objectives are to verify and validate the business needs and are summarized as below:

1. Verification of the fulfillment of the business needs by testing the functionalities that the private cloud introduced.
2. Validation will address whether the solution meets the user’s expectations in terms of application performance and the amount of time it takes to service a request.
3. Test whether the solution is user-friendly and technically capable of managing the data center infrastructure.
10.2 TESTING REQUIREMENTS

When performing the test process the following are the software, hardware requirements and considerations used:

a. Test scripts which are programing code procedures that replicate the user actions. They are generated using Windows PowerShell 2.0.

b. Test suites which are a collection of test cases of the service quality the solution is offering through detail instructions to be executed by the concerned tester to check the correctness of the system configuration against the expected outcome.

c. Solution Hardware
   - Application physical and virtual servers
   - Network
   - Storage

d. Solution Software
   - Selected applications for the pilot implementation
   - System Center 2012 components

e. Testers from the ITSP IT department and application owners from the three clients who are the users in this case.

10.3 TESTING SCENARIOS & RESULTS

The testing scenario covers a range of end-user and IT staff test cases that reflect the functional and non-functional business needs. They are as follows:

1. Functional Testing: testing the solution against the business requirements
   a. Cloud creation by an IT administrator
   b. Creation of virtual machine by application owner
   c. Application deployment by application owner
d. Creating workflows

e. Creating service template

f. Update deployed application

g. Monitoring

2. **Non-functional Testing**: testing the solution against the client’s business expectations

   a. Performance testing

   b. User friendly environment

   c. Stress test

   d. Security

   e. Hardware failure

### 10.3.1 FUNCTIONAL TESTING

The functional testing is performed using a test cloud similar to the private cloud built in the implementation phase. The testers will use it to conduct their tests based on the defined test scenarios above. The following test case scenarios were conducted based on the requirements communicated by the client and represents end to end testing of the services that the private cloud should offer.

a. **Administrator creating a cloud**

   This test ensures that the cloud configuration was done correctly by creating a test cloud. The IT administrator who in this case is also the VMM administrator will use the VMM console to create the cloud and make it available for the application users to use. The service template encapsulates what is required to deploy and run a new application instance. The table below shows the test results.
### Test Case: Administrator creating cloud

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Function Description</th>
<th>Method</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ensuring that the VMM configuration are correct</td>
<td>Administrator create test cloud with physical resources, storage and network</td>
<td>Cloud creation wizard</td>
<td>Successful</td>
</tr>
<tr>
<td></td>
<td>Administrator enables self-service role and quotas</td>
<td>Cloud creation wizard</td>
<td>Successful</td>
</tr>
<tr>
<td></td>
<td>Administrator create VM images and VM templates</td>
<td>VM Resources wizard</td>
<td>Successful</td>
</tr>
<tr>
<td></td>
<td>Application owner create service templates for an application</td>
<td>Service Designer</td>
<td>Successful</td>
</tr>
</tbody>
</table>

**Table 13: Administrator Creating Cloud**

b. **Application owner creating a virtual machine in the cloud**

This test aims to test infrastructure resource provisioning that will be used by the application owners. They will access the service by logging into the App controller portal and select the test cloud and by selecting a VM image or VM template. The VMM will then automatically create the VM in the cloud and verify that it satisfies all constraints.
### Test Case

**Application owner a virtual machine in the test cloud**

<table>
<thead>
<tr>
<th><strong>Purpose</strong></th>
<th>Ability of the users to use the clouds they were assigned to provision their resources when required</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tools used</strong></td>
<td><strong>Function Description</strong></td>
</tr>
<tr>
<td><strong>App Controller</strong></td>
<td>Display services available to the assigned test cloud</td>
</tr>
<tr>
<td><strong>App Controller</strong></td>
<td>Application owner submits request to provision resources by creates VM in the cloud</td>
</tr>
<tr>
<td><strong>VMM</strong></td>
<td>Automatically creates VM according to VM template that was save in VMM library</td>
</tr>
</tbody>
</table>

**Table 14: Application Owner a Virtual Machine in the Test Cloud**

c. **Application owner deploying an application**

This test case is to verify that the application owners can deploy applications in an automated fashion. This is required in cases when a production deployment is needed once the application testing has been completed. The application owner will log in to the app controller to submit a request to deploy a new application into the test cloud using the service template already built. The VMM will execute the request by creating the virtual machine and the application instance in the test cloud. During the creation process the VMM will check constraints like allowed quota available capabilities of the test cloud.
<table>
<thead>
<tr>
<th>Test Case</th>
<th>Application owner deploys application new instance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Purpose</strong></td>
<td>Ability of application owner to deploy applications from scratch using templates and the process is completely automated</td>
</tr>
<tr>
<td><strong>Tools used</strong></td>
<td>Function Description</td>
</tr>
<tr>
<td>App Controller</td>
<td>Display services available to the assigned test cloud</td>
</tr>
<tr>
<td>App Controller</td>
<td>Application owner submits request to create a new application</td>
</tr>
<tr>
<td>VMM</td>
<td>Automatically creates VM and application new instance based on saved service template saved in the VMM library</td>
</tr>
</tbody>
</table>

Table 15: Application Owner Deploy Application New Instance

d. **Updating deployed application by service delivery team**

It is challenging to keep with updating the infrastructure software without it resulting in business downtime. The solution offers the infrastructure administrator with the ability to execute such tasks through an automated process and this case is what has been tested. The administrator creates a VM image imported with the new patch applied to the OS using the VMM console. This VM images is then imported in to the VMM library which marks automatically all the outdated VM images, VM templates and service templates and sends a notification to the app controller to inform the application owners. Once approved by the application owner to ensure that the changes will not affect the application running the VMM will install the new VM image.
Table 16: Infrastructure Team Updating OS on all Machines

e. **Creating workflows**

This test verifies how the cloud uses workflows to resolve the strained relations between the clients and IT department due to lack of procedures to handle service requests. The application owner will use the service manager self-service portal which contains all configuration management databases that holds all configuration and management related information of the private clouds. The portal lists all the services available as a service catalog and the application owner will select the service template for the HRMS virtual machine creation. This initiates a workflow that will send a notification to the HR department manager that his approval is required. Once approved the service manager portal will contact the orchestrator to execute the run book which includes communication with the VMM to create the virtual machine and the HRMS application instance.
### Test Case
Creating approval process workflow for VM creation

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Tools used</th>
<th>Function Description</th>
<th>Method</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test the automation of workflow and the configuration between the</td>
<td>Service manager self-service portal</td>
<td>Display service catalog available for user</td>
<td>Self-service portal</td>
<td>Successful</td>
</tr>
<tr>
<td>System center 2012 components</td>
<td></td>
<td>and initiates workflow</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Orchestrator</td>
<td>Executes run book that interacts with</td>
<td>Automated</td>
<td>Successful</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Microsoft and non-Microsoft tools</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>VMM</td>
<td>Automatically creates VM according HRMS service templates stored in VMM library</td>
<td>Automated</td>
<td>Successful</td>
</tr>
</tbody>
</table>

**Table 17: Creating Approval Process Workflow for VM Creation**

f. **Monitoring**

The ability of the solution to monitor, detect and remedy issues using an automated process is what has been tested. The HRMS application is stressed by allowing a number of users to use it. This increase in workload and decrease in performance is detected by the operations manager agent installed on the VMs. The agents will generate an alert and the operation manager will send an incident to the service manager which will in turn notify the service delivery team. It will then use the orchestrator to execute the run book that will add another virtual machine to the web tier of the HRMS application by coordinating with VMM to use the HRMS service template.
### Table 18: Automatic Monitoring, Detection and Remedy of Issues

<table>
<thead>
<tr>
<th>Test Case</th>
<th>Function Description</th>
<th>Method</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Purpose</strong></td>
<td>Test the automation of workflow and the configuration between the System center 2012 components</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Tools used</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operation Manager agent</td>
<td>Detects performance decrease and send alert</td>
<td>Automated</td>
<td>Successful</td>
</tr>
<tr>
<td>Operation manager console</td>
<td>Records incident into database and sends to service manager</td>
<td>Automated</td>
<td>Successful</td>
</tr>
<tr>
<td>Service manager</td>
<td>Notifies service delivery team and initiates remedy workflow using the orchestrator</td>
<td>Automated</td>
<td>Successful</td>
</tr>
<tr>
<td>VMM</td>
<td>Creates the new VM machine in the test HRMS web tier using the service template</td>
<td>Automated</td>
<td>Successful</td>
</tr>
</tbody>
</table>

#### 10.3.2 NON-FUNCTIONAL TESTING

For the majority of the non-functional testing SharePoint 2010 application is used as the test application. An instance of it is created in the test cloud to generate the test results. This type of test entails many tasks which should be performed automatically to reduce monotony and errors. Visual Studio is capable of automating the test runs consistently.

a. **Performance**

Performance depends on the how the hardware is managed to support client computing resource demands when using their applications. Performance testing is conducted to check the capability of the private cloud to provide better application performance for the users by managing the hardware fabric efficiently. The test was conducted on the servers as they host the application and on the switches from a network ability perspective.
b. **Hyper-V Hosts**

The server’s performance test was conducted using the workload generator to simulate end user workload for the different applications simultaneously and the application performance was monitored. The test ran for duration of 8 hours to simulate a working day normal hours. The performance counters monitored was on each of the hyper-v host machines. The counters measure the percentage of the processing time in the guest code, the hypervisor code and in both. This was used to measure the total processor utilization of all the virtual machines in the host against the target threshold. Based on the result the utilization of resources remained in a healthy state with sufficient space for a virtual machine failover and previous performance issues faced by the application owners when testing their application are no longer a problem as the private cloud dynamically adds resources if the application consumption reaches a predefined threshold.

<table>
<thead>
<tr>
<th>Performance Counter</th>
<th>Target</th>
<th>Node 1</th>
<th>Node 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hyper-V logical processor% Guest Run Time</td>
<td>60%</td>
<td>30.87%</td>
<td>35.34%</td>
</tr>
<tr>
<td>Hyper-V logical processor% Hypervisor Run Time</td>
<td>10%</td>
<td>3.9%</td>
<td>5.6%</td>
</tr>
<tr>
<td>Hyper-V logical processor% Total run Time</td>
<td>70%</td>
<td>34.77%</td>
<td>40.94%</td>
</tr>
</tbody>
</table>

*Table 19: Hyper-V Performance Test Results*

f. **Switches**

As the network’s capability is as important as the server’s capability in terms of its ability to control data traffic flow through congestion and high network utilization it was also monitored for its performance with the same workload generated for the Hyper-V hosts. Below is a table showing the results of the switch performance test.
The Brocade FCX switches flow control capabilities feature stops sending data for brief time durations when the network utilization increases; meanwhile the switch handles the congestion and resumes full performance during peak workloads.

<table>
<thead>
<tr>
<th>Switch</th>
<th>Utilization (memory)</th>
<th>Utilization (ports)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Switch #1</td>
<td>4%</td>
<td>10%</td>
</tr>
<tr>
<td>Switch #2</td>
<td>6%</td>
<td>12%</td>
</tr>
</tbody>
</table>

**Table 20: Hyper-V Performance Test Results**

g. Load & stress test for Virtual Machine

For this test the application owners were asked to execute heavy transactions on all four applications in the private cloud. An instance of each of the applications was created in the test cloud using their respective service templates. For SharePoint the software tool used to generate the client workload was Visual Studio and it ran for 8 hours to simulate working hour’s duration stress loads. This test demonstrates the capability of the private cloud to dynamically handle different levels of computational tasks from different application at the same time.

Some of the SharePoint websites were a bit slow to load but was far better compared to its previous behavior when used heavily. The test was conducted by the application owners to decide on the stress test results by loading the applications and the infrastructure team monitored the performance counter dashboards indicate the processor utilization for the virtual machines running on the host and whether it is in a healthy state and there was sufficient space for VM failover in the operation managers console.
h. **Security**

Users who are given access as self-service roles can use the provision services from the app controller portal or choose workflow enabled services from the service manager service catalogue portal. Application owners were given the self-service role and were only able to view the service to the private clouds they were given permission to.

Hardware resources for each of the private cloud are separated thus no overlapping applications. Unauthorized access and password cracking was also checked. Network is also secure from any down time due to single fault domains arrangement of the infrastructure.

i. **User friendly and self-service features and actions**

Granular control of the actions that the users can perform when given the self-service role to use the private cloud infrastructure services. Both interfaces used to interact with the cloud namely the app controller portal service manager self-service portal are user friendly and have a clear layout that enables the users to navigate to the different features with ease.

j. **Hardware failure**

The failure simulation test was conducted to test the cloud’s capability to handle workload in case of hardware component failure. The failure of one of the SharePoint application hosting servers was selected for this test where the virtual machines in the hosting server will be moved to another host and then powered automatically. The table below shows the status of the physical nodes before and after failure.
### Table 21: Failure Test Results

<table>
<thead>
<tr>
<th>Hyper-V Nodes</th>
<th>Before Node #1 failure</th>
<th>After Node #2 failure</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Node #1</strong></td>
<td>2 WFE_01</td>
<td>2 WFE_01</td>
</tr>
<tr>
<td></td>
<td>1 app server_01</td>
<td>1 app server_01</td>
</tr>
<tr>
<td></td>
<td>1 sql server_01</td>
<td>1 sql server_01</td>
</tr>
<tr>
<td><strong>Node #2</strong></td>
<td>2 WFE_02</td>
<td>Not available</td>
</tr>
<tr>
<td></td>
<td>1 app server_02</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 sql server_02</td>
<td></td>
</tr>
</tbody>
</table>

### 10.3.3 USER ACCEPTANCE

Finally after the function and non-functional testing were completed, feedback forms were distributed to both the IT department and application owners as a testimony of their views on the private cloud as an enterprise solution. The first feedback form was on the cloud performance filled by both the IT admins and application owners.

<table>
<thead>
<tr>
<th>Questions</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance of the applications during peak working hours</td>
<td>As an application user we did not face any performance issues especially with mission critical applications. Multiple applications were used at the same time with no prominent usage issues on the contrary the performance has increased significantly based on past experience</td>
</tr>
<tr>
<td><strong>Did any application suffer slow performance during the test</strong></td>
<td>Compared to the other application SharePoint was a bit slower which can be due to the fact that it naturally consumes a large portion of the server resources even without the client load</td>
</tr>
<tr>
<td><strong>How did the performance increase compared to past experience</strong></td>
<td>There has been a significant increase in the applications and system responsiveness in general in comparison to how it was before the private cloud. Incident requests to the IT has significantly decreased as the cloud dynamically manages workload increase or network congestion</td>
</tr>
<tr>
<td><strong>As a user, do you feel that the cloud has added value to the performance</strong></td>
<td>The private cloud enabled us the users to have more control on the resources we need for testing and business use by provisioning computing resources through self-service interfaces as well as design templates of how our applications should be built automatically</td>
</tr>
<tr>
<td><strong>As an IT administrator how do you see that the cloud has added business value</strong></td>
<td>From an infrastructure management perspective the private cloud has dramatically shifted the reactive mode the team was constantly in and is now proactive; IT introduced tools and practices for service management and offering the infrastructure as a service for the users to interface with directly.</td>
</tr>
</tbody>
</table>

**Table 22: User Acceptance Form for Performance**

The second feedback form was filled by the IT administrator and application owners in regards to the overall private cloud services and how it resolved the business challenges.
### Private cloud services

<table>
<thead>
<tr>
<th>Questions</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>App controller self-service portal</strong></td>
<td>Have a self-service portal to submit in requests and automate their execution for computing resources instead of contacting the IT department for support was the best choice in this solution. There are no more delays in provisioning resources for applications and projects due to IT personnel shortage or backlog as the process is now automated and initiated by the application owner.</td>
</tr>
<tr>
<td><strong>Service Manager self-service portal</strong></td>
<td>Complex requests that require workflows and integration with third party application can also be requested, designed and executed automatically through this interface. This has greatly benefited the application owner community as we can now focus on testing and validating applications for the production environment without being delayed with operational activities.</td>
</tr>
<tr>
<td><strong>Operation Monitoring</strong></td>
<td>Monitoring dashboards are available on the self-service portal for each user to monitor the performance of his/her list of virtual machines. Should any issue arise an alert is automatically raised and will either be resolved automatically or will be escalated to the IT team for follow-up. The entire process is dynamic and required no human intervention</td>
</tr>
<tr>
<td><strong>VM templates</strong></td>
<td>Building virtual machines are no longer done from scratch. Users can select from a list of preconfigured templates of how the virtual machine will function when requesting computing resources in the portal. This significantly eases the process of having the necessary hardware ready for application consumption.</td>
</tr>
<tr>
<td><strong>Service Templates</strong></td>
<td>Not only can virtual machines use templates but so can applications. We used the service designer to design template of how applications should be deployed along with their respective configuration, settings and connections then used to deploy applications automatically with minimal human intervention</td>
</tr>
</tbody>
</table>

Table 23: User Acceptance Form for Private Cloud Services
The final feedback form was a rating of the private cloud’s capabilities and whether it should be adopted across the organization.

<table>
<thead>
<tr>
<th>Questions</th>
<th>Rating</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did the private cloud enhance the user experience with business application</td>
<td>Yes</td>
<td>Application owner focus on testing business application and no longer delayed with requesting and waiting for computing resources</td>
</tr>
<tr>
<td>How easy was it to adopt the cloud into the organization</td>
<td>User friendly</td>
<td>The migration to the private cloud was possible due to the fact that the organization is already virtualized. Issues were faced when virtual machines had to be rearranged within hosts</td>
</tr>
<tr>
<td>How do you rate the performance in comparison to before the cloud</td>
<td>Better</td>
<td>Application’s performance has greatly increased as the cloud dynamically manages allocation of resources based on the workload of the application</td>
</tr>
<tr>
<td>How did the cloud improve the interaction between the application owners and IT</td>
<td>Better</td>
<td>The private cloud introduced a layering approach as the IT focuses on managing the infrastructure layer and an service layer for the users to use to initiate and automate requests</td>
</tr>
<tr>
<td>Coordination between the different teams within the IT department</td>
<td>Better</td>
<td>The infrastructure, service delivery and administrators each have their own tools to manage which are already integrated and communicate together</td>
</tr>
</tbody>
</table>
How do you rate the cloud’s ability in improving the performance, service and operation management

<table>
<thead>
<tr>
<th>Question</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>How do you rate the cloud’s ability in improving the performance, service and operation management</td>
<td>Very Good</td>
</tr>
<tr>
<td>Will you support the move of the entire data center to private cloud computing</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Table 24: Private Cloud Rating Form

Below is a graphical representation of the IT department acceptance and that of the application owners.

![IT Acceptance Chart](attachment:image1.png)

Figure 40: IT Acceptance
10.4 TEST RESULTS EVALUATION

The main aim of the testing process was to conclude on whether the private cloud solution is a viable alternative to the traditional methods that the ITSP is using to manage their data center and provide infrastructure services to their clients. The testing included that the functional and non-functional features of the private cloud works well to serve the business needs. The functional testing covered all the services that the private cloud solution is offering to resolve the problems reported by the business and IT side. The QC environment for each client is now a sum of logical and physical parts that can be broken and reassembled as per the business demands.

The non-functional testing addressed service management and service level expectations. Based on the above two main areas the focal user involved in testing both from the IT and business end are satisfied with the private cloud as a solution as it helped them focus on the key areas and offer their service in a managed and efficient way. This was also reflected in the feedback survey taken from different types of testers. They answered positively to most of the questions in the feedback survey based on their hand-on testing in the areas that concerns their line of business. It might be challenging for the application owners to use the new tools to automate their manual work as they need to reach a certain learning curve. The organization
recognizes this drawback and intends to incorporate it as a transition stage when the implementation for the rest of the datacenter starts.

Based on the testing results the private cloud solution helps the application owner deploy applications faster due to demanding project turnovers. It increases business agility between the IT and end-users as they are allowed to service their own requests thus feeling more in control. The architecture is more inclusive now as every facet of the infrastructure such as servers, storage and network is considered as a standardized deployment objects that can be assembled as and when required in minimal time. The private cloud helped in investing considerably in the existing infrastructure and did not require the introduction of major changes in the data center. It focused more on changes to the management areas and logical design. Expenditure costs on purchasing hardware will decrease as the same number of physical machines can host more instance of the applications while maintaining the expected level of support.

The main difference in the private cloud solution is that it offers the network as a service with more interaction from the client side as opposed to trying to manage it only as hardware resources. Due to the hardware abstraction nature of the private cloud the application deployment is decoupled from the server deployment therefore application are deployed faster without the need to rely on physical resources. The new self-service feature introduced by the cloud allows the enterprise to create flexible environments that expand and contract based on the workload and performance requirements. There will be a positive shift in relationships between the ITSP IT department and its clients as they will no longer need to negotiate for resources to deploy their application as the data center is now offered as a self-service proposition.

Below are the points that summarize the main areas that the solution addressed and the business challenges that it resolved based on the testing process:

a. **Scalability**: the infrastructure team no longer is confined to the hardware capacity within the data center as the cloud is scalable based on the workload of the application. If a surge in resource usage is detected by the cloud it will automatically provision computing resources by adding additional computing power or a virtual machine.
b. **Availability**: the hardware resources in each cloud architecturally does not share a fault line with the other components in the hardware pool of the cloud to ensure no bottleneck and hardware failures do not affect more than the application is host

c. **Maintainability**: application deployment is a smooth operation for the application owners as the entire deployment process is automated using the service template built. Service templates design is quite flexible as it includes drag and drop features and wizard enabled processing. Infrastructure hardware and software upgrade do not cause down time as the computing resources are now arranged in upgrade domains.

d. **Security**: each client has its own private cloud with independent resource pools therefore data security concerns are minimized on a virtual and physical level. Access to the self-service is delegated on a role basis through the integration with the Active Directory thus only authorized personnel have access to the infrastructure service. Execution of services is enabled through workflows that require approval process by departmental manager or by IT personnel.

e. **Reliability**: as per the testers feedback the solution offers an easy to user interface both for managing the infrastructure as well as for the self-service portal. Application owners know exactly what service they are allowed to access through using the service catalog. Application performance has increase significantly as the computing resources are automatically provisioned depending on the workload. Failures in the application’s virtual machine automatically trigger a workflow that redirects traffic to its redundant instance. Failure of the physical host will trigger a workflow that relocated the virtual machine to another host on the same resource pool. Since all servers in the resource pool are homogenous relocation of virtual machine between these servers does not compromise the service level.
f. **Serviceability**: The private cloud created two main layers in the data center. The lower layer is the infrastructure, which comprises the cloud fabric. This layer is where the infrastructure team focuses their efforts on without the interruption of clients for provisioning resources. The service delivery team focuses on the second layer, which is the management layer. This layer focuses on managing the fabric, service management, and automating service through self-service portals, workflows, and service templates. This layer also serves as the front-end interface for the client to request and execute services related to provisioning resources. The IT administrators used management layer to monitor the system’s health and take proactive measures like creating remedy templates that resolve performance issues. Communications within the ITSP IT department and its external client have drastically improved as they are now working in a managed and transparent environment that conforms to service management best practices. Below is a diagrammatic representation of how the solution addressed the issues raised:

**Figure 42: Before and After the Private Cloud**
In conclusion the user acceptance form indicates that the solution has been well received by the end users and is the ITSP organization is ready to apply the solution on a larger scale that includes the rest of servers in the QC VLAN and the development and production environments.

11 CONCLUSION

This project’s main objective was to use the cloud computing technology as the new and improved client-server network framework model in the ITSP organization to help in resolving data center management issues. The identified business and technical requirements from the stakeholders centered on having an automated approach to provisioning computing resources to users and segregating the hardware layer between clients. The private cloud computing ensured a complete investment in the existing infrastructure and the virtualization technology used and extended the its functionality to encompass complete hardware abstraction and end to end management of the computing resources. The resources are used as objects to be provisioned, added, removed and isolated within the platform through templates and logical grouping. The introduction of service management through the use of self-service portals and service catalogs also enhanced the end-user experience and gave them more control of their environment.

Using the private cloud computing technology to address the business challenges was adopted based on research, analysis and diagnosis of the solution’s capability and compatibility with organization’s needs and existing infrastructure. The key feature in private clouds is transforming the physical machine’s computing resources to a service that users can request when and as required in an automated fashion and create standard template of these resources for deployment, maintenance and performance purposes. This enabled the IT department to focus on maintaining the data center and allowed users the freedom to obtain, use and manage their own environments in a controlled manner.

The main milestones covered in implementing the solution were requirement gathering and analysis and making educated and informed decisions with the stakeholder’s approval on whether the technology is appropriate, and what is the scope that should be covered and the products that will satisfy the business and technical specifications.
The deployment of the private cloud was based on detailed logical and physical architectural designs to ensure that all considerations and constraints were accounted for. The implementation served as a proof of concept using the quality VLAN due to its environment bearing high similarity to that of the production. It should be noted that the production still has settings for security and network configuration. In addition, it has different types of applications that are in-house developed that may require certain modifications to be cloud compatible. All this must be planned for when executing the solution across the data center.

The evaluation and testing of the implemented private cloud proved that indeed it has delivered on its promise of being the next step in data center management and the organization can begin migrating the rest of the physical host groups into the private cloud.

11.1 RECOMMENDATION AND FUTURE WORK

Cloud computing encompasses end to end transformation of the virtualized data center. Although the main focus of the project will be on the server side, it is part of the organization's road map to invest on the client-side connection devices to incorporate thin clients once the data center has stabilized.

Private cloud can be made of specialized collection of other private cloud where each is focused for instance on a specific technology platform to provide enhanced manageability, focus and control. There can also be an offering of software as a service once the cloud computing platform stabilizes and a proper assessment of in-house applications is conducted and classified based on their respective maturity to be cloud compatible and service oriented. This may lead to further development of these applications to use a common XML and APIs.

The organization can further invest in the private cloud to realize its full potential by introducing an external private cloud in a trusted cloud service provides to deliver infrastructure as a service for external users from home. The purpose of this platform is to provide users access to certain application from outside the organization for flexibility purposes through VPN connections.
REFERENCES


16. Category: 1. In: [online]. [Accessed 4 April 2012]. Available from: http://www.trishburgess.com/2/category/hybrid-cloud/1.html. The purpose of this blog is, as we have done with the public and private clouds in previous blogs, to discuss the pros and cons of the hybrid cloud. In addition, we will present a table that...


23. GREENBERG, Albert, HAMILTON, James, A.MALTZ, David and PATEL, Parveen. The Cost of the Cloud: Research Problems in Data Center Networks. Washington, USA. Microsoft Research, Redmond, [no date].


BIBLIOGRAPHY


APPENDIX A: READINESS ASSESSMENT FORM
APPENDIX B: PROJECT PLAN

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PROJECT NAME: PRIVATE CLOUD COMPUTING
CLIENT NAME: ITSP GOVERNMENT ENTERPRISE
APPENDIX C: MACS Risk Assessment Form

Student: Rasha Al-hameedi
Project Title: Private Cloud Computing in a government enterprise
Supervisor: Mrs. Priya Subashini

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<td>haptic device, etc.</td>
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<td>flashing lights etc.</td>
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