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SYSTEMS ANALYSIS AND DESIGN OF INFORMATION TECHNOLOGY ARCHITECTURES FOR SMALL TO MEDIUM BUSINESSES

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1 ABSTRACT

As more businesses outsource their information technology functions, service providers are beset with many challenges including security, business continuity, performance, agility, cost, etc. Service providers need logical and physical infrastructures that meet today's challenges, but they also need to refresh their technology and look to the future.

This project presents an analysis of a typical information technology service provider for small and medium-size businesses (SMBs) that are considering options for redesigning their infrastructure. The systems analysis includes network and server infrastructure analyses of the current IT infrastructure. An analysis of the benefits and concerns of the current infrastructure is discussed. Three concepts for potential future infrastructure designs are presented, along with their evaluation from the Information Technology Experts. The first concept is to upgrade the current architecture with no architectural changes, the second concept is to design an architecture oriented to Flexibility & Manageability and final concept is to design an architecture oriented to Business Continuity, Security and High Availability.

From interaction with Information Technology (IT) experts, High Availability has been identified as the 4th concept in designing the future IT infrastructures. The prototype architectures are designed at ultimate level of business objectives which helps the SMBs to choose the architecture changes as necessary and lead IT experts to place their current architecture and the direction they are moving in future. Experts showed interests to move away from conventional architectures to cloud based architectures and they seem to be very comfortable in keeping data and services off-premises.

2 ACKNOWLEDGEMENT

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3 INTRODUCTION

3.1 Business summary

There was a common viewpoint that IT infrastructure and hosting servers should be adopted and used by large scale businesses. But in the last decade Small and Medium Businesses embraced this view point by having their own IT infrastructure and hosting the servers for managing their businesses. However, small and medium size businesses cannot always afford to have their own IT workforce hence they outsource the Information Technology services required to run the business to IT service providers. This Capstone Project explains the challenges faced by the small and medium business and IT service providers in having conventional IT Infrastructures. This Capstone project offers proposed solutions to meet these challenges and an evaluation of the solutions from the experts.

3.2 Problem statement

In the growing competitive world, using information technology is one of the common requirements for any business to stay competitive and to expand their business. Small and medium businesses (SMBs) have adopted information technology but they have adopted conventional IT architectures which is limiting their opportunities to grow. The conventional IT architectures offer limited prospects in expanding their businesses and for collaboration with their client base.

Also, with conventional IT infrastructures, SMBs tend to pay more than what they use to run their business loading them with high capital investments because the hardware should be procured to meet ultimate needs and many years of growth. A timely upgrade has never been

possible because of these upfront costs in hardware and software components used in the IT infrastructure. The IT Service providers tend to perform more maintenance to keep the system up and running. Conventional architectures fail to accommodate business objectives like Reliability, Flexibility, Agility, Security, Maintenance, Business Continuity, etc.

3.3 System Analysis summary

For this capstone project, a typical IT architecture for the SMBs has been considered for system analysis. The system analysis includes analyzing Network architecture, Physical architecture of user sites, Physical Server architecture, Server virtualization architecture and different server roles in the current IT architecture. An analysis of each component present in this architecture has been presented which includes network, physical server and virtual machines. The evaluation of this architecture is presented by its Strengths, Weaknesses, Opportunities and Threats.

3.4 Proposal

Considering the system analysis of the current conventional IT infrastructure, this capstone project groups business objectives into 3 groups and designs the 3 IT architecture prototypes focusing on the business objectives for the small and medium businesses.

1. Maintain & Upgrade (MU) architecture with upgrading the current architecture focuses Reliability, Efficiency and Robustness.
2. Flexibility & Manageability (FM) oriented architecture which focuses on Flexibility and Manageability by using the available cloud based solutions.

3. Business continuity, Security & High availability (BSH) oriented architecture which focuses on Security, Business continuity and High availability by hosting and replicating the data and services in different locations.

3.5 Motivation

The main motivation of this capstone project is to benefit SMBs by offering different IT architecture solutions based on their needs and business objective and to help them to grow their business. I worked as an IT Infrastructure and Security Intern for a provider of IT services for SMBs and I desired to gain more knowledge on IT Infrastructure by working on this project and reviewing it from the Information Technology Experts. This has helped me to build my career in Business Analysis and Consulting.

3.6 Benefits of this project

1. Provide practical advice for small and medium businesses.
2. Consideration of multiple Business objectives.
3. Provide insights to SMBs about current technology trends and opportunities.
4. Support SMBs for expansion and future growth.
5. Improve collaboration and communication.
6. Enable Small businesses to maintain a competitive edge with other businesses.

4 Background

Company referred to Information Technology Service Provider for SMBs and Customer is referred to Small and Medium Businesses (SMBs).

4.1 Company background

IT Service Providers (ITSPs) offer end-to-end IT services and are a trusted IT Partner for SMBs. ITSPs offer a wide range of services including and not limited to consulting, design, implementation and IT management covering all areas of technology, server support, network support and CIO/CTO-level services.

ITSPs typically have a strong team of IT Professionals, Engineers, Sales Executives, and Administrators to reach the expectations of its customers. All employees are qualified and certified in their field of expertise.

4.2 Working Relationship

Working as a IT Infrastructure and Security Intern for an ITSP (Summer 2016) has opened a door for me to gain technical knowledge about Servers, Networks, Information Security and more importantly understanding the business needs and domain knowledge in Healthcare, Finance, and Law firms. Since this was my first job in United States, I had an opportunity to work with new people, new issues and challenges associated with it. Every day working here was a learning opportunity as I have been to customer locations I never been before and worked on issues which I never worked before. I gained an attitude of being flexible to changing needs of the organization. I was also participating in all Sales

meetings and calls which helped me to gain soft skills by interacting with experts from different domains.

I have gained some of the skills set mentioned below.

- *ERP Tools*: ConnectWise, Quickbooks.
- *EHR Applications*: MicroMD, Advanta, eClinicalworks.
- *Servers/Virtual Machines*: Server 2008 R2, Server 2012 R2, Hypervisor.
- *Backup tools*: Windows Server Backup, Mozy.
- *Network*: DNS Manager, Cisco Switches, and routers.
- *Database*: SQL Server, MS Access.
- *Security Applications*: Symantec Server, Symantec Cloud.
- *Certifications*: Symantec Sales Expert(Cloud).

4.3 Stakeholders

This section covers participants involved in running ITSP. It is organized as Customers and Partners.

4.3.1 Customers

ITSPs have a wide range of customers including and not limited to Health Care Providers, Lawyer Firms, IRA, CPA Firms, Medium scale manufacturing, Sales, and Charities.

- **Health Care:** Most of the customers are health care providers like Surgery center, Injury rehab centers, dentists, pediatricians. Many healthcare customers use a

different EHR (Electronic Health Record) systems. The Health care providers have a high level of concern for business continuity and Information security.

- **Financial Firms:** Most of the Financial firms are IRA (Individual Retirement Account) and CPA (Certified Public Accountant) firms. Some of the customers handles financial data in billions and their major concern is about the security and high-performance architecture.
- **Charities:** Some of the customers are charity organizations who offers the free counseling services, shelter and education for the teenage kids. These customers require an IT Solution which offers basic record keeping with minimal storage and low cost.

4.3.2 Partners

Partners offer different services which help to run the small business solutions. Some of the major and important providers are:

- **Internet Service Providers** provide FIOS connections, Internet Services and phone services which are cost effective.
- **Application Providers**: Offer applications required to run and manage businesses. Ex: EHR application for practice management and reporting.
- **Network Providers:** For enterprise networking and services.

4.4 History of this architecture

Each SMB has a different IT architecture, the reason for having the different architecture is when SMBs approach IT service providers, it is hard to replace the entire

IT infrastructure due to constraints like cost, user adaptability and compatibility to the software's and services being used to run the day to day business.

However, service providers do some architectural changes by replacing old components from the existing infrastructure to support growing business needs. These architectural changes bring the benefits to the customers by reducing the maintenance time and reliability.

4.5 Problem statements

This section lists the problem statements identified while doing the system analysis of typical IT infrastructure for SMBs. More details on system analysis and problem statements are discussed in section 5.

4.5.1 Aging architecture

One of the major problem an IT service provider faces is outdated architecture being used at SMBs. It might be outdated hardware or the software or services which don't provide reliable support to run the business. This problem should be handled very carefully, before changing any component in an existing architecture, a detailed review of an entire IT architecture must be done. Because, in most of the cases, fixing or replacing a component in an existing architecture will cause more problems to the other components. More details on aged hardware is discussed in the section 4.5.3.

4.5.2 Paradigm shift: New architecture?

Every day there is an invention of new technology. A big room of servers are not being used anymore, the new servers can occupy less in space in a small rack and offers

more memory storage with high performance. When a paradigm shift in a technology leads to a new architecture, it is challenging for solution architects to keep an IT architecture up-to-date with latest technology. New technologies open door to SMBs for wide set of opportunities by offering capabilities for collaboration, limited maintenance with automation, flexible solutions and pricing.

4.5.3 Aging hardware

Aging hardware can occur on an any server, network device or workstation. Any hardware which is older more than 3 years needs attention by IT personnel. As business needs are growing, the data being stored and manipulated will also increase. This hardware will not have enough capacity to process the data. Also, an unexpected breakdown of hardware will affect business continuity and there are some cases where the hardware manufacturer itself has stopped supporting the aged hardware. Some SMBs still use the old workstations with a Windows XP operating system even though Microsoft has stopped supporting windows XP [2].

4.5.4 Maintenance

Inefficient IT architecture leads to difficulty in maintenance and increases the maintenance costs for the customers. In my summer internship at ITSP, some SMBs preferred to invest more on reliable IT infrastructure than spending more on maintenance and in some cases, the maintenance costs are higher than implementation costs because of unreliable infrastructure. An inefficient IT architecture can also cause loss of company reputation. ITPSs aims to provide better service with less maintenance by keeping the company reputation high.

5 Systems Analysis

When a SMBs (customer) approaches an ITSP to design and manage their IT infrastructure, a team consisting of Chief Operational officer, Solution Architect and a Consultant meets the representatives from the potential customer. After briefing the services offered and the quality of services, potential customer will agree to do the analysis of the current system architecture.

Before doing the system analysis for any potential customer, A Non-Disclosure Agreement (NDA) is signed between the SMBs and the ITSP to adhere the information sharing policies [1]. The legal consultants of the company will frame the Non-Disclosure Agreement.

5.1 Current architecture

For the current architecture, I have considered a typical IT architecture for SMBs because most of the SMBs tend to have this architecture or something very similar.

The current architecture has 3 sites (Site A, Site B and Site C) and in two different locations (Location 1 and 2).

1. Site A has a dedicated server room to keep servers and network equipment
2. Site B and Site C are typical user centers where a group of employees work and have access to the IT infrastructure.

The below section describes each architectural diagram in the current architecture.

5.1.1 Network Architecture

Diagram 1 in Appendix-B shows the network architecture diagram for the current architecture. As described in the Section 4.1, the network architecture has 3 sites and two different locations. Site A is the server room to host applications, services and to store the data. Site B and Site C are user centers; the physical architecture of the user center is described in next section 4.1.2.

A network switch in location 1 is used to connect Site A and Site B. The network switch is connected to a firewall; the firewall is connected to the Internet Service Providers (ISPs) router to establish a private connection to location 2. A firewall at location 2 is connected to the ISP router and connected to network switch which is attached to Site C. The network connection between both locations are private and not accessible by external entities.

5.1.2 Physical architecture of User Centers

Diagram 2 in Appendix-B shows the physical architecture of the user sites A and B. A network switch is connected to all devices which requires access to the data and applications. Workstations attached to a local area network are used by the users. A fax machine and multi-functional printer are connected to the network and shared by all the users. Laptops and cell phones are connected via wireless LAN.

5.1.3 Physical Server Architecture

Diagram 3 in Appendix-B shows the physical server architecture of the current architecture which has 3 physical servers which are hosted on premise. These physical servers are used to host the applications and services and are also used to store data, files and backups. The physical servers are connected to a network switch and power supply to supply the power

to the servers. These servers are procured from a vendor through ITSPs. Setting up and installing the physical/virtual servers and its management at small and medium businesses are handled by the ITSP itself and the work is billed to the SMBs.

5.1.4 Server-Virtualization Architecture

Diagram 4 in Appendix B shows the server-virtualization in the current architecture. The 3 physical servers are used to host 8 different virtual machines as shown in the diagram.

The list of virtual servers and their description is written below.

1. ***Application Server:*** The application server is designed to host the applications which are used by the SMBs. A typical application would be used to manage their day-to-day businesses. For ex: The most widely used applications in Healthcare business is Electronic Health/Medical Records (EHR/EMR) software and Practice Management Software. The basic functions of these applications are Scheduling, Billing, Medical records, e-Prescription, Claims management, etc.
2. ***Database Server:*** The Database server is designed to host the databases which are used for the SMBs. The database server may be SQL server, MySQL server or other databases.
3. ***Domain Controller Server (DC):*** The Domain controller server hosts the active directory domain services which manage user accounts for the employees who work at SMBs. This enables the employees to use resources from the different work sites/location by logging in to the domain network.
4. ***Virtual Domain Controller (VDC):*** The Virtual Domain controller is replication (clone) of the Domain controller to avoid problems which causes downtime in the whole

infrastructure. This allows better use of the resources by isolating the box from other services. It is very important to keep the time synchronization in DC as well as VDC [5].

5. ***File Server:*** The File server provides shared access to all the users which acts as the central management of all files. Each user has been provided their own storage space to keep files, and there is shared storage space to keep common files. However, the user cannot access each other files due to security reasons (only the users with administrative privilege to the file server can access all the information in the file server). This server needs more security since the raw files can be accessed and viewed easily.
6. ***Data Backup:*** This server is designed to store the backup of the data which is present in File server and as well as the user's data who handles the confidential or financial information. All the servers have Windows Server backup running in each of them. The third party backup solutions has been used to perform the online backup and local back up of the data.
7. ***Email Server:*** The Email server is also referred as the exchange server, which is designed to host the Email Exchange Server. For ex: Microsoft Exchange server has been used to set up email accounts for the users. Exchange server is coordinated with Active directory to create the new user accounts.

5.1.5 Server Roles

Diagram 5 in Appendix-B shows the server roles and services running in each virtual machine. A single virtual machine is used to perform multiple tasks by hosting more than one service. The primary domain controller (PDC) is also used to host the primary Active Directory (ADS) Services and primary Domain Naming Server (DNS). In the same way, a virtual domain controller has been used to host the secondary Active Directory Serviced, Domain Naming Server, and secondary domain services. Hosting a virtual machine for serving multipurpose without any isolation can cause downtime issues. Because, if one service needs a reboot, IT personnel has to reboot the other services forcefully or fixing an issue in one service would cause an issue in another service.

5.2 Advantages and Disadvantages

This section covers the advantages and disadvantages for the current IT architecture. Though, the current IT infrastructure meets the basic IT requirements of SMBs, there are some drawbacks of hosting all services onsite.

5.2.1 Advantages

- Meets the current needs of the SMBs.
- IT Infrastructure is designed solely designed for specific SMB.
- Comfortable of owning data with Trust.
- Having control over the IT Infrastructure.
- Easy to communicate with IT Services team (Less communication downtime).
- Increased user satisfaction since user preferences are considered.

- Easy to make changes to the system.
- Helps to develop the skill sets inside the business.

5.2.2 Disadvantages

- High capital investments/upfront costs for the installation.
- Paying for more than what being used by taking risks in ROI.
- Not flexible enough for changing business needs.
- Low proper resource utilization
- High maintenance costs.
- Lack of policies and standard being applied and used.
- Lack of disaster recovery plan.
- Less Secured: Vulnerable to security threats.
- Not having redundant power backups and other components might limit the availability.

6 Proposal

After the system analysis of the current IT architecture (in Section 4), there were some problems identified in the current design and business model. The Information Technology resources play a major role in keeping the business competitive enough in current market. The SMBs do not grow if the current technology being used is not to current industry standards and doesn't meet metrics like security, manageability, and flexibility for the growing business needs.

The below are problems identified in the current design and need attention:

- ***Paying more than what being used:*** The current architecture shows that all the services are hosted on-premises and cost of the hardware being paid upfront by the customer itself which shows that customer has paid more than what being used for the resources. Hardware must be purchased to handle peak loads, plus account for several years of growth.
- ***No proper business continuity plan:*** In case of disaster, there is no proper plan for recovering the data. All the data and its backup are stored only on premises. In case of power failure, power backups in house cannot supply power to the hardware beyond 2 hours. This would affect the business with more system downtime.
- ***Security Concerns:*** The current policies, procedures and standards in the IT architecture shows that it is vulnerable to security threats. Some of the missing requirements to keep the information secured are:
    - *Agents to monitor the clients and suspicious activity.*

- *Not enough physical security to the servers.*
- *No regular Intrusion detection and monitoring activity.*
- *Employees uses remote access instead of VPNs.*

Recently, there were two ransomware attacks to the workstations which had a static IP for the remote access.

- ***Offers less flexibility and scalability:*** The current architecture offers less flexibility and scalability for the changing needs of businesses. The SMBs has to invest more if they have to upgrade the hardware and other software components by purchasing more than used.

In order to address the problems stated above and provide solutions, this project designed prototype architecture options which suitable for the SMBs. This project involves evaluating metrics which are considered while designing the IT architecture and performing methods described below in my capstone project.

1. Designing three prototypical architecture with different perspectives: Considering the current architecture and business model, this project designed three architecture options which suits the business model. The project identified the architecture solutions which meets most required metrics with additional capabilities which helps the businesses to adapt and grow in the current market. These architectures are mutually inclusive but the level the metrics might vary in each.
2. Documenting each architecture: After designing the architecture options, this project will document each of them with a set of diagrams which shows the overall architecture, server architecture and logical architecture.

3. Evaluating each architecture: An evaluation of each architecture with the established metrics and an analysis of advantages and disadvantages of each architecture is presented.
4. Reviews: A review and recommendation of each architecture from IT experts is presented in this project.

6.1 Maintain and Upgrade (MU) Architecture

MU Architecture is designed to maintain and upgrade the current hardware, storage, services, procedures with no architectural change. Upgrading the hardware refers to replacing the servers, workstations and network components. A storage upgrade will be adding memory for the current storage if required. Upgrading services refers to updating software applications and introducing new applications which improves the efficiency in the business model. Upgrading the current architecture with redundant hardware components will add less downtime with more reliability.

6.2 Flexibility and Manageability (FM) Architecture

FM Architecture is designed to meet the changing needs of the SMBs and focuses more on the Flexibility, Scalability, and Agility. Current industry trends recommend using cloud services by hosting some of the services in the cloud. This architecture offers a solution with extreme level of flexibility and manageability for the SMBs. By switching some of the services to collaborative environments using cloud services, Architecture B achieves elasticity to upscale or downscale the business requirements when needed. This

architecture also gives the ability to move the services quickly and offers solutions with no capital investment on the hardware and software licenses.

6.3 Business Continuity, Security and High Availability (BSH) Architecture

BSH Architecture is designed to meet highly reliable and secured solution for the SMBs, the architecture offers a solution with extreme level of Business Continuity, Security and High Availability. This architecture provides a solution which is highly available with a more reliable infrastructure and enables the SMBs to function even after a disaster. This solution also intends to use private environments, to provide more security and privacy to the data and services.

6.4 Deliverables

This section covers the list of deliverables which are submitted by the end of the capstone defense.

The below are list of deliverables from this project:

1. Three IT architecture designs at high level.
2. Set of diagrams which represent the above three architectures. (An actual technical specification cannot be presented).
3. A benefits and challenges of each architecture will be presented
4. Expert commentary: a review from the Wilmington IT experts about the architecture designs.
5. Document into final report (The final report and calculations will be based on the data available in public sources).

The following will not be delivered from this project:

1. Implementation of any of these architectures.
2. Actual technical specifications of these architecture.
3. Any sensitive data related to any entity (Individual, Group or business) is removed.

6.5 Project Plan and Schedule

6.5.1 Hour estimates

Deliverables	**Estimated Hours**
1. Three IT architecture designs at high level.	*45*
2. Set of diagrams which represent the above three architectures.	24
3. A SWOT analysis of each architecture	12
4. Expert commentary: a review from the Wilmington IT experts	20
5. Document into final report	60
Total Hours	**161**

6.5.2 Project Timeline

Month	Feb		March				April			
Week	*Week 1*	*Week 2*	*Week 3*	*Week 4*	*Week 5*	*Week 6*	*Week 7*	*Week 8*	*Week 9*	*Week 10*
Deliverables										
Deliverable 1										
Deliverable 2										
Deliverable 3										
Deliverable 4										
Deliverable 5										
Deliverable 6									**Defence**	

7 Proposed Architectures

7.1 Proposed Architecture : Maintain and Upgrade

Maintain & Upgrade (MU) architecture is designed to upgrade the old components in the current legacy architecture. Architecture A is not intended to alter the entire IT architecture; however, it upgrades the current IT infrastructure. Some of the components used in the current infrastructure are old, not efficient and don't support the future needs of the SMB. In order to increase the performance, robustness and resource utilization, the old components need to upgrade.

Hardware components that are no longer supported by the manufacturer itself could cause more downtime for the business. *Ex*: A network switch which is 10-years-old and not supported by its manufacturer could cause problems simultaneously by breaking network connections to the users. In my experience, the whole network for the site was down and users were not able to connect to servers, we had troubleshot all possible ways as per the guidelines. The network was down for 4 hours, the network was up and running with several hard reboots of the network switch itself. Over time, the old hardware components reduce the performance and productivity of its users, often fails, needs more maintenance, reduces the efficiency, and uses more resources. Out of warranty hardware causes unexpected downtime and has a direct impact on the businesses and revenue [9]. To address these problems for SMBs, architecture A is designed.

Below is the list of diagrams attached to represent the Architecture A and shows the changes to the current architecture.

- ***Diagram 6*** *in Appendix-C:* shows the overall network architecture and there are no major changes to the network architecture except replacing the old switch which will discussed later in this section.
- ***Diagram 7*** *in Appendix-C*: shows the physical architecture of the user centre B with no changes to the current architecture.
- ***Diagram 8*** *in Appendix-C*: shows the physical server architecture of the server room. Old hardware components (Physical server 1, Network switch and Power Supply (UPS)) have been replaced with the new components.
- ***Diagram 9*** *in Appendix-C*: shows the server architecture, multipurpose virtual machines in each physical server has been moved to single-purpose virtual machines. Fax server has been removed from the physical server to accommodate resources for other priority services.
- ***Diagram 10*** *in Appendix-C*: shows the server roles in the Architecture A. New virtual machines are designed to host only one service in each virtual machine which provides the isolation between the services.

Some of the hardware and component changes for the Architecture A is listed below.

1. ***Replacing the old Network switch attached to the Server room and User site A.***

   Since all the data is stored in server room and applications are hosted on premises, it is required to have a reliable network connection. Replacing an old switch with a modern switch will provide a reliable connection to the users and improves the robustness in the network. Several factors should be considered while choosing the

new switch like speed, number of ports and interfaces etc. [10]. The old network switch which provides LAN connection to server room and user centre A will be replaced with an advanced network switch. Refer *Diagram 6* - Overall network architecture, *Diagram 8*- Physical server architecture and *Diagram – 9* Virtualization architecture.

2. ***Replacing the Physical Server 1 (old server).***

The current old physical server (Server 1) which is no longer supported by the manufacturer and often broke contribute towards the aging IT infrastructure. The old server needs repeated maintenance which costs more to the SMB and doesn't support the evolving needs of business. To meet these requirements, an old physical server is replaced with a new physical server [11]. *Diagram 8*- Physical server architecture shows the new architecture with new physical server.

3. ***Moving the Fax server.***

The users and customers rarely use the Fax server. Instead of having a dedicated virtual machine for the fax server, it can be moved to any workstation which does the same function. A PC can be configured as the fax server and free up the resources dedicated for the fax server on a virtual machine. Fax server virtual machine has been removed from the current server virtualization architecture. *Refer Diagram – 9 Virtualization architecture.*

4. ***Replacing the old Power supply (UPS).***

An Uninterruptible Power Supply (UPS) is required for any server room which supplies power to the physical servers and other network components. The UPS not only backs

up the Power, it also manages the stable voltage level which is being supplied to hardware components. To provide efficient power supply to the hardware components, the old UPS is replaced by a new UPS. *Refer Diagram 8 - Physical server architecture*.

5. ***Replacing server operating system for all the servers.***

   Reconfiguring the virtual machines which are running on old server operating system to advanced or the latest server operating system. Updating the server operating system will allow the support of a wide variety of opportunities, minimizes maintenance, maximizes efficiency, and ensures security and compliance. There are some constraints before upgrading server operating system, the new operating system should meet the specifications of existing software hosted on the server. If the SMB would like to upgrade the existing software then there is an additional cost for purchasing new licenses. Updating the servers to latest server operating system would save the power utilization by saving 2% of the power costs annually. [12]

6. ***Moving multipurpose VM's to single purpose VM's.***

   In the current server-virtualization architecture, the virtual machines are configured for multiple purposes and two or more services are being hosted on the same virtual machine without isolation between the services. Services like Active Directory Services, Domain Naming Server(DNS) and Mail exchange server is hosted on the same virtual machine. In Architecture A, virtual machines will have configured to host only one service by keeping isolation between these services.

- In the current server architecture, the primary domain controller virtual machine is used to host the Active Directory Services (ADS) and Domain Name Server (DNS) without any isolation between these two services. (*Refer Diagram 5 – Server Roles from the current legacy architecture*).
- Architecture provides the isolation between the different services by hosting it in different virtual machine. Primary Domain Controller has solely used to host the primary Active Directory Services (ADS) and a new virtual machine Primary Domain Name Server (DNS) has been used to host the primary Domain Naming services. *Refer Diagram 10 – Server roles of Architecture A.*
- Same way, the Secondary domain controller has been used to host the Secondary Virtual Domain Controller, Secondary Domain Name Server, and Secondary Mail exchange server. *Refer Diagram 5 – Server roles of current architecture*.
- To isolate these services, three virtual machines have been designed to host these services independently. Two new virtual machines Secondary Mail server and Secondary DNS, have been created to host the Secondary Mail exchange server and secondary DNS Manager respectively. Secondary Mail exchange server has been moved to physical server 3 for balancing the load on servers. *Refer Diagram 10–Server roles of MU architecture.*

7.1.1 Benefits

❖ ***Improves Reliability:***

An infrastructure upgrade will provide a preventive solution to reliability issues and reduces a system failures. It helps to achieve less downtime and improves the overall reliability of the system.

- ***Improves Performance:***

  As infrastructure upgrade with more modern hardware components makes best use of the resources in terms of memory, CPU, and power. The upgraded IT infrastructure can handle the resources efficiently and improves the overall server performance.

- ***Increases Productivity:***

  By providing higher availability of the system with less downtime and system failures, an upgrade will improve the overall productivity of the system as well as productivity of the SMB. An upgrade in hardware and software components reduces the maintenance efforts of IT personnel and reduces maintenance costs.

- ***Control over the IT infrastructure:***

  This architecture enables SMBs to have more control on their IT infrastructure because most of the components in the infrastructure are owned by the SMB itself and not been accessible to other entities.

- ***Accessible without WAN:***

  In case of the WAN outage, the data and services can still be accessible from the on premises.

- ***Improves Security:***

  The advanced hardware and software components used in the upgrade will have recent firmware and patches which helps to prevent the potential security risks.

7.1.2 Caveats, Challenges, and Concerns

- ***Business continuity plans***

  MU Architecture provides limited business continuity protection. All the data, services and data backups are stored on premises. In case of a disaster and data loss, there are no data recovery options available.

- ***Implementation: Migration of services***

  Implementation will be challenging for IT Personnel. A clear execution plan must be prepared for changing the hardware and software components and moving the services to the new virtual machines.

- ***Limited collaboration:***

  Though this architecture let SMBs to have more control their IT infrastructure but don't support accessing the data out of premises which limits the SMBs capability for collaboration. If the ERP systems hosted on premises and made not accessible outside of the premises, then the customers of SMBs cannot access the data if required.

- ***Buy more hardware components than required:***

  MU Architecture implementation will have high upfront expenses for SMBs and results in buying more than what is required because hardware components should be purchased to meet ultimate needs of business and to support future growth. High upfront investments will leave the burden to small businesses, and the hardware purchased must be replaced in future.

7.2 Proposed Architecture: Flexibility and Manageability

Flexibility and Manageability (FM) architecture is designed to meet the above requirements by offering an IT architecture which is mainly focused on Flexible, Manageability, Agility for SMBs. The current architecture is not flexible enough to meet the changing needs of SMBs. Unlike big enterprises, SMBs often expand their business with increasing number of customers, SMBs may move to a different location or establish a new site and it is difficult to move the data and services to the new site since the data and services are hosted within the private network of the primary location. The current architecture doesn't offer a collaborative environment by limiting access to data and services for its users. Ex: Employees cannot access the data when they want to work from home. The current architecture requires more maintenance which creates burden for a IT personnel.

Since a major concern was where the data and services are hosted, architecture B intends to move the data and services to the collaborative environments which allow users to access the data outside of the premises and opens the ability to scale. By switching some of the services to collaborative environments using cloud services Architecture B achieves the elasticity to upscale or downscale as business requirements change. This architecture has ability to move the services quickly. Cloud based services need little upfront investment on the hardware and software licenses. This architecture also offers advanced level of services to the SMBs with time to time upgrades and less maintenance.

Below is the list of the diagrams attached which represents the architecture B.

Diagram 11 represents the overall network architecture. Data and some of the services are switched to the cloud.

Diagram 12 shows the physical architecture of the user centre which remains the same as the current architecture.

Diagram 13 shows the physical server architecture. Two physical servers have been removed from the current architecture and by keeping the latest physical server. Application, services, Data, Files, and backups has been moved to the public cloud. More details on services and data being to public cloud will be discussed in next diagram.

Diagram 14 and Diagram 15 shows the server-virtualization architecture. As the current architecture doesn't meet needs like Flexibility, Elasticity, and Agility. Architecture B aims to meet these requirements by offering a different solution than a traditional solution by choosing the solutions from Appendix A. The below section discusses the servers being moved to the collaborative environments like cloud.

Architecture B utilises only one physical server which is used to host the below virtual machines/services. These virtual machines are used to host the Active Directory Services(ADS) and Domain Name Server (DNS). Some of the cloud solutions offers the Active Directory Services however, they are not standard active directory solutions which are used by all other cloud service providers. It is difficult to integrate the active directory from one cloud service provider to another provider if SMBs are using the solutions from different service provider. Hence Active Directory service along with DNS are hosted on premises.

- *Primary Domain Controller* is a virtual machine which is used to host the Primary Active Directory Services.
- *Primary Domain Name Server* is a virtual machine which is used to host the Primary Domain Name Server.
- *Secondary Domain Controller* is a virtual machine which is used to host the Virtual Active Directory Services.
- *Secondary Domain Name Server* is a virtual machine which is used to host the Virtual DNS.

Remaining services are hosted in the public cloud by using solutions available in the current market. The public cloud is the shared space used by the public, which offers the best in class solution with limited upfront costs to the small and medium business. Figure 14 shows the services from the cloud are connected to private network of SMB through an Internet Service Provider (ISP). SMBs and other consumers using the public cloud utilize same resources. Some providers share the actual location of the data with SMBs while others do not that information. However, the cloud service provider solely manages the data and services. Below are the services which are hosted on public cloud.

- ***Application Server***

  SMBs don't have applications which are developed in-house, rather they will be bought from third party application vendors. Now, most of the application vendors offers Software-as-a-Service(SaaS) cloud solutions, they do charge their customer based on the number of users. SMB can increase the customer base by requesting the application provider to add more users ex: Salesforce CRM application. These applications can be

accessed anywhere using the internet which offers flexibility to the customers and elasticity for the business needs of SMBs.

- ***Database Server***

In most of the cases, the application itself has a database. There are some scenarios where the business wants to have a backup or replication of the database for which this database server can be used. By hosting the database server on the cloud, the SMB gets accessibility from anywhere, easy elasticity of the database whenever needed, and easy migration the server when needed supports the SMBs. Ex: AWS SQL Server and Azure database server.

- ***File Server***

The File server will be migrated to an online solution which offers a flexible file system and provides access to the user everywhere using the internet. File services on cloud services are highly scalable, which can be scaled up or scaled down when required. A file server can be any available solution in the current market. Ex: Dropbox and Microsoft OneDrive. [13]

- ***Email Server***

The Email exchange server will be replaced by a Software-as-a-Service (SaaS) solution, the pricing for the email server will be per user charge with pay-as-you-use model. The size of the email profiles can be expanded if needed. As with other services, Email can be accessed anywhere using the internet. The cloud email solutions offer extended support by protecting from spam and suspicious incoming email. Ex: Microsoft office 365, office 365 business premium offers complete solution for the Email with

connected Active Directory, Microsoft office applications and complete access to OneDrive. [13]

- ***Data backups & Recovery***

The current backup & recovery solution on markets offers flexible and durable storage for the data archiving. The Backup and recovery process is managed by the service provider and minimizes maintenance time & cost on premises. Some of the cloud solutions like AWS will pay attention to customer preferences for archiving the data and store in a specific location. [14]

7.2.1 Benefits and Opportunities

- ***Flexibility and Scalability***

  Cloud solutions offer the flexibility to fulfill the changing needs of SMBs. A cloud solution which is on public cloud enables the SMB to scale up and down the requirements when needed. SMB are also billed as per the usage. With the cloud solution, it is easier shrink or expand the database, file system and services like email, etc.

- ***Agility***

  Data and services which are hosted on the cloud enables the SMBs to move services quickly and makes data accessible from any location. This gives SMBs an ability to switch locations and services as required.

- ***Increased employee's productivity:***

By allowing the user to access data from anywhere using the internet, employees at SMBs will be productive by working remotely when needed. The cloud platform also provides the collaborative environment which enables the employees to collaborate and work with visibility of the work progress.

- ***Low Maintenance:***

  Since the public cloud services are hosted and managed by the cloud provider itself, SMBs will not have to worry about maintenance of servers and hardware components.

7.2.2 Caveats, Challenges, and Concerns

- ***Trust***

  A major concern for SMB owners is lack of trust on cloud service providers. They don't know where the data is being stored and shared with other consumers on the public cloud. The SMBs will not have complete visibility over their data which is being stored in the public cloud, and large cloud service providers influence the potential customers with case studies of success stories from existing customers which creates the trust between SMBs and provider.

- ***Limited Control***

  The data and services hosted on the public cloud and community cloud are controlled by the cloud service providers, by disabling the SMBs control over their data and services. However, they do so and ensure that control has not given to any other customer which are sharing the public cloud.

- ***Need of high bandwidth***

Since all the data and services are hosted in public cloud, whenever the users access the data from the user centres, it requires strong bandwidth to access the data over the internet from the public cloud. In case of lower bandwidth, users face issues and slowness in accessing the data. Higher bandwidth usage charges are billed to SMBs.

- ***Unspecified downtime***

  Sine the SMBs doesn't have control over the cloud solutions, they are affected by abrupt in services due to unspecified downtime. Ex: for some technical issue if the Microsoft Email 365 service is not available, the users cannot access their emails.

- ***Security risks***

  The cloud service offers high-level data protection to its customer's data and ensures all the policies in place to secure the data. Since sharing the login details (social engineering attacks) causes the most recent security risks, it is required to train the users to protect confidential information and to share best practices to secure the SMBs data.

7.3 Proposed Architecture C: Business Continuity, Security & High availability (BSH)

This architecture is designed for SMBs by mainly focusing on Security, Business Continuity and High Availability. The current architecture does not provide enough security to Data and has limited business continuity abilities. The current infrastructure is vulnerable to security threats with no active monitoring of the overall system. With all data in one location, it is harder to have business continuity after a loss of data in case of disaster. The current Infrastructure makes small businesses non-functional at the times of disaster or after the disaster. The SMBs can achieve

this by having the disaster recovery plans while designing their IT infrastructure by storing the data in different location and being able to access to them without interruption. [15]

The BSH oriented architecture is intended to store the data in different locations. This architecture adopted private cloud solutions by keeping the data and other services on private virtual machines without sharing the resources unlike on public cloud. Based on the counterparts in Cloud insights by Infor [28], the cloud-based infrastructure solutions provide more protection to data and offers less disruptive services compared to on-premise infrastructure.

The below diagrams attached and below sections provides the description of security based architecture.

Diagram 16 represents the overall network architecture. As the diagram shows, data and application has been stored in the different region by enabling the business continuity option.

Diagram 17 represents the user centre architecture with no changes.

Diagram 18 shows the physical server architecture. Two physical servers have been removed from the current architecture and a latest physical server is kept. Application, services, Data, Files, and backups have been moved to different regions on the private cloud. Private cloud is referred to as a data centre or a cloud platform which offers the private hosted environment without sharing the resources with other users. For Ex: Azure and AWS offers the virtual private cloud solutions [16] [17] while cloud partners like iWeb offers hosted environments in a data centre. [18]

Diagram 19 & 20 shows the server virtualization of architecture C. The physical server on the premises is used to host the primary and secondary active directory services along with DNS. The Private cloud/data centre on Region 1 is used to host the Application Server, Database Server, File Server, and Mail Exchange Server. The Private Cloud/Datacenter on Region 2 (Different location than Region 1 and on premises) is used to host the replication of the all the servers from the Region 1.

(The private cloud and Data centre are referred as same in this report)

The BSH architecture has few limitations, if the server hosted on the private cloud, the resources should be subscribed to meet peak loads of the business needs. Unlike in MU architecture, the purchasing additional resources are not required in BSH architecture, because SMB can manage the resources by having an ability to upscale the resources as required and also an ability to downscale the resources if SMB does not require more resources than needed. These private cloud environments offer 365/7/24 monitoring, offers high availability (up to 5 nines of uptime) and ensures data is not being compromised by external entities. The private cloud platform offers the highly reliable private connection (virtual) to the data by monitoring the inbound and outbound network traffic using advanced firewalls.

Benefits and Opportunities

- ***High Availability***

  This architecture provides the high availability of the services since most of the private cloud platforms are designed to provide hybrid and high level of

service availability. Some of the private cloud providers assures five 9s availability (99.999%) with 5-6 minutes of downtime per year. [19]

- ***Information Assurance***

  This architecture provides higher information assurance by protecting data from information threats. Some of the information threats cannot be handled on own by small and medium business when data is hosted on premises. However, the private cloud or data centre offers protection against these information threats [20]. With this architecture, SMBs can host their data and applications on high-class infrastructure with less upfront expenses.

- ***Ability to gain control over the server***

  Unlike FM architecture, this architecture allows SMBs to have some level control or full control (depending on the private cloud provider or data center) on their servers. The SMBs has ability to set the downtime if required for maintenance since the resources are not shared with any other businesses.

- ***Business Continuity***

  This architecture provides the business continuity plans and keeps the businesses running even after the disaster. Because data and services are replicated in different locations, the business can continue to be functional in case of disaster and loss. [21]

7.3.1 Caveats, Challenges, and Concerns

- ***Higher Costs***

Even if this architecture provides better quality infrastructure than other proposed infrastructures, for the better quality; SMBs should pay more costs. Having private virtual machines on the data centre and having the private virtual network would costs same as having the data and applications hosted on premises. However, the small and business not owning these machines for lifetime, the payments should be made monthly or annually which gives them an opportunity to upgrade whenever needed. [22]

- ***SMBs lose some control over architecture:***

  Though hosting dedicated servers on the private cloud or data center gives the ability control them, the SMBs still not gain complete control over their infrastructure.

- ***Complexity***

  This architecture might lead to complexity while deploying and connecting different virtual machines and deploying the virtual private network. The cloud providers provide the required for the deployment and integration. However, the complexity comes from custom architecture which varies from business to business. [23]

7.4 Cost

This section indicates the cost estimates for all the proposed architectures. The cost is divided into Fixed Cost (FC), Variable Cost (VC) and Total Cost of Ownership. Since the cost estimates for any architecture are not accurate unless it is designed for any small and medium

business customer. Hence, the costs represented as Low, Medium, and High indicators. This section also states the what is included in each of the costs ex: setup costs, subscription costs, etc.

***Table** 1 Cost Indicator for Maintain & Upgrade Architecture.*

Cost Indication for M&U IT Architecture			
Cost	Fixed Cost (FC)	Variable Cost (VC)	Total Cost of Ownership (TCO)
Indication	High	Medium	High
What is Included?	Hardware Costs • New Server • New Firewalls • New Switches • Other miscellaneous components Installation Costs (setup and configuration) • Network • Physical Server • Virtual Machines Licensing Costs • Business applications • Server Operating systems • Software Licenses • Warranties	Maintenance costs Internet subscription Power Space System Failure costs Annual Subscription costs (if any)	FC + VC

Table 1 shows the cost indication for M&U architecture. Fixed Cost for this architecture is indicated as *High* which includes one-time expenses like buying new server and network components and their installation costs. The variable expenses indicated as *Medium* includes regular maintenance costs and other usage costs for Internet and power etc. The Total cost ownership (TCO) would be *high* since the Fixed Cost are high and variable expenses add to it. [24]

***Table** 2 Cost Indicator for Flexibility & Manageability oriented architecture*

Cost Indication for F&M Oriented Architecture			
Cost	Fixed Cost (FC)	Variable Cost (VC)	Total Cost of Ownership (TCO)
Indication	Low	Medium	Medium
What is Included?	Installation Costs (setup and configuration)	Maintenance costs Support/service costs Internet subscription • Network Bandwidth Costs Subscription costs • Email • File Server • Data Backups. • DNS • Active Directory Services	FC + VC

Table 2 shows the cost indication for F&M oriented architecture. This architecture intends to use available cloud solutions which makes Fixed cost for this architecture to Low. Most of the solutions will be pay as you go which means customers will be billed as per the usage and not charged for any licenses. SMBs will only be charged for subscriptions which makes variable expenses as medium [25]. Overall the total cost ownership will be medium with low fixed cost and medium variable cost.

***Table** 3 Cost Indicator for Business Continuity, Security and High Availability Architecture*

Cost Indication for BSH Oriented Architecture			
Cost	Fixed Cost (FC)	Variable Cost (VC)	Total Cost of Ownership (TCO)
Indication	Medium	High	High

What is Included?	Hardware Costs • New Firewalls • New Switches • Other miscellaneous components Installation Costs (setup and configuration) • Network • Private Network on cloud (Express Route/Direct Link)	Maintenance costs (IT Labor) Internet subscription • Network Bandwidth Costs Subscription costs • Network Bandwidth (Inbound and Outbound) • Data Center Space • Storage • CPU • Power and Cooling • Software • Server Costs (Server-OS and licenses)	FC + VC

Table 3 shows the cost indication for BSH oriented architecture. This architecture uses third party service provider (private cloud/data centre) to host the applications and to store the data. This architecture has medium fixed costs with some of the installation costs and high subscription costs which adds up variable expenses and makes Total cost of ownership to high. The components included in the table is referred from AWS TCO calculator report. [26]

Table 4 Cost summary for architecture designs

	Fixed Cost (FC)	**Variable Cost (VC)**	**Total Cost Ownership (TCO)**
Maintain & Upgrade (MU)	*High*	*Medium*	*High*
Flexible & Manageable (FM)	*Low*	*Medium*	*Medium*
Business Continuity, Security & High Availability. (BSH)	*Medium*	*High*	*High*

Table 4 shows cost summaries for the proposed architecture designs. The MU architecture has High FC because SMBs must buy the hardware components upfront and must buy more than what they needed to accommodate ultimate business needs and future growth, MU has Medium VC which cover costs of Maintenance, Power, and other subscription costs and has Higher TCO because of higher FC and maintenance costs.

Whereas FM architecture has Low FC with limited upfront costs for installation and user training, Medium VC which covers all monthly subscription costs for cloud solutions and Medium TCO because of limited fixed costs and medium variable costs. Whereas BSH architecture has Medium FC for installation costs, expertise cost, etc. has Higher VC which covers the data center maintenance costs and monthly costs for all usage (server, CPU, memory, storage, bandwidth, etc.) and very higher TCO because highly variable cost.

Overall, BSH architecture has very high costs compared to other two architectures because hosting dedicated servers and network on data center or private cloud costs more and private cloud providers bill each usage costs to SMBs. [26] MU architecture has higher cost compared to FM architecture because of higher fixed costs and monthly variable cost added to it. The FM architecture is cost effective since there are no considerable fixed costs and variable costs are depended on business requirements and adopts pay-as-you-use model where variable costs can be varied according to usage.

7.5 Experts Reviews

As discussed in the section 5, the proposed architectures were discussed and evaluated by Information Technology Experts. I had a chance to interact with 3 local IT experts for one hour each. A few open-ended questions are asked to these experts and all 4 architectures including the current architecture has been presented and discussed with the experts. The open-ended questions are in Appendix-F.

7.5.1 Expert 1 Interview

The first expert I had meeting with is *Albert Steed, the Chief Information Officer of Velocity Solutions, Inc*. The meeting was challenging and helpful in resolving the single point failures in the architecture designs. Albert Steed is referred as Expert 1 in later sections. The meeting notes are attached in the *Appendix-G.*

Below are the suggestions from the Expert 1 for proposed architectures.

1. Suggested to have VPN connections instead of the leased lines to connect between the two locations which would lower the cost.

2. Suggested to have the names for all three proposed architectures and

3. Suggested to move some of the virtual machines in server-oriented architecture to different physical servers.

4. Suggested to use the solutions from the same cloud solution provider which makes easier for VPN which adds the security to the data over internet.
5. Suggested to move Secondary Active Directory services (ADS) and Domain Naming Server (DNS) to the cloud.
6. Suggested to have the secondary Internet Service Provider (ISP) for high availability. (BSH oriented architecture)
7. Suggested to replicate the virtual machines from region 1 to region 2 (BSH oriented architecture)

7.5.2 Expert 2 Interview

The second expert I had a meeting with is *Parker Moran, the Infrastructure Manager at UNC*. The meeting was helpful and found different ways of hosting the physical servers. *Parker Moran* is referred as Expert 2 in later sections. The meeting notes are attached in the *Appendix-H*

Below are the suggestions from the Expert 2 for proposed architectures.

1. Suggested to change colour for the components being upgraded in server-oriented architecture.

2. Having second switch to connect different physical server to add more reliability.
3. Moving the secondary DNS and secondary ADS to cloud or move it to different physical server.
4. Having shared storage structure for all 3 physical servers which helps to move the virtual machines quickly to different physical server then they are hosted.

7.5.3 Expert 3 Interview

The final expert I had a meeting with is *Matt Hernandez, Systems Architect at New Hanover Regional Medical Center, Wilmington*. The meeting was helpful and finding solution for planning the cloud migration and hosting services. *Matt Hernandez* is referred as Expert 3 in later sections. The interview notes are attached in the *Appendix-I*

Below are the suggestions from the Expert 3 for proposed architectures.

1. Suggested to use RISC Networks cloud space for planning, costing and carry out execution of cloud migrations.
2. Having second switch for increasing redundancy in the network.
3. Using VMware Hyper-converged infrastructure for server-virtualization.
4. Differentiating the cloud solutions based on the cloud modules.
5. Trying different VPN options for home and office.
6. Using Cisco network management cloud solutions.

The expert review for the proposed architectures are described in the section 7.1.

8 Conclusion: Closing Thoughts

This capstone project was aimed to analyze and evaluate the IT infrastructure for SMBs from both business and ITSP point of view and propose new infrastructure solutions. After the analysis, the drawbacks of the current architecture have been discussed and highlight problems like SMBs paying for more than what being used when there are high quality solutions available for the same price. The current architecture limits the opportunities for SMBs for the collaboration and limits clients accessing the required data as it is being hosted on-premises. The data and services are being stored and hosted on-premises without any business continuity or disaster recovery plans. To overcome these challenges and this project proposed three architecture designs which is suits the SMBs.

This Project analyzed all the services hosted and components from typical IT infrastructure for SMBs and interacted with some of the IT experts in order to learn what is important for their businesses while hosting the services. Based on this, 3 potential architectures are designed and evaluated from the IT Experts. Initial concept for the architectures were based on the different solutions available, however there was an argument from the advisory committee that this approach is mainstream. The committee suggested to involve the business objectives to design these architecture options. The business objectives are identified and grouped for three architectures as shown in the *Table 5*

***Table** 5 Business Objectives*

	Proposed Architectures		
Business Objectives	**A**	**B**	**C**
	Robustness	Maintenance	Security
	Reliability	Flexibility	Business continuity
	Efficiency	Agility	Privacy

The 3 proposed architectures are designed focusing on these business objectives, however these 3 architecture are not mutually exclusive and they are mutually inclusive. Every architecture has most of the business objectives in them but the level of these adopting these objectives might vary for each architecture.

There was an argument from the Experts that the business objectives for proposed architecture C (BSH oriented architecture) has to be changed to Security, Business Continuity and High Availability. Expert 1 suggested that that Reliability and High availability have the same meaning, but high availability is the business objective used from the service providers these days along with Reliability. Also, there was argument that Privacy cannot be achieved at high level when data is stored third party sites like cloud or data center. The business objectives for the Proposed Architecture C has been revised by adding the High Availability, refer *Table 6*.

***Table** 6 Revised Business Objectives and Proposed Architectures*

	Proposed Architectures		
Business Objectives	**Maintain and Upgrade (MU)**	**Flexibility & Manageability (FM)**	**Business continuity, Security & High availability (BSH)**
	Robustness	Maintenance	Security
	Reliability	Flexibility	Business continuity
	Efficiency	Agility	**High Availability**

The 3 architectures are named based on the architecture solution and suggested by the committee chair and IT experts. Architecture A has been renamed to Maintain and Upgrade (MU) architecture, Architecture B is renamed as Flexibility & Manageability (FM) oriented architecture and Architecture C has been renamed as Business continuity, Security & High availability (BSH) oriented architecture. Before Interacting with IT experts, MU architecture was named as server-oriented architecture, FM architecture was named as service-oriented architecture, BSH architecture was named as security-oriented architecture. The committee highlighted an issue in the architecture names as it could lead to misperceptions, ex: service-oriented architecture may be mispresented as a design style for software design. Hence, the proposed architectures were renamed as labeled in *Table 6.*

Based on the work done for this project, some observations are made and they are discussed in the below sections.

8.1 Proposed architectures and their evaluations.

This section discusses the evaluation and suggested modifications from the IT Experts. Evaluation of each architecture and revised architecture designs are presented.

8.1.1 Maintain and Upgrade architecture

The MU architectures are most adopted by the existing medium size businesses because some customers would not like to change their whole architecture with intention of improving the current architecture and not comfortable moving their infrastructure out of their premises.

The Experts suggested to add another network switch which connects the site A and rest of the network so that if this switch fails the physical servers can be connected to another switch available in the Location 1. This eliminates single point failures for users to have connection to the servers and makes the network more redundant. Refer *Diagram 21* for the revised network design of MU architecture.

One expert suggested to use the new technologies which are used for hosting the servers on site like Hyper converged architecture with VMware and other expert suggested to host using shared data storage structure with Hypervisor. One expert suggested to have VPN's to connect between the different location where as other experts use VPN's as the backup option and not to modify if the leased lines are in place for existing architecture.

Overall the architecture serve it purpose, however still the SMBs end up paying more than what they use. However, with upgrades SMBs will get the benefit of having the reliable infrastructure.

8.1.2 Flexibility & Manageability oriented architecture

The FM oriented architecture is best suit for new businesses and the solutions are readily available to use for small businesses with low upfront cost. One of the Expert mentioned that he used the Microsoft azure cloud solutions for his new gym facility and it cost few hundred dollars. One expert mentioned this architecture works good for the businesses which do not have a location and with no efforts an IT infrastructure can be built with cloud solutions available in the market now. The businesses which are making less revenue and cannot afford high capital investments will benefit from this architecture. One expert mentioned that FM oriented architecture eliminates the regular maintenance from IT Personnel. The same expert mentioned eliminating regular maintenance doesn't mean that it is taking job away from the IT personnel, however IT workforce can concentrate themselves on the work which is value added to the business.

Experts recommended not to keep the secondary active directory services and DNS in the same physical machine because the physical server breakdown would cause losing the data. One expert mentioned that when the exchange server is not hosted on premises and active directory is on premises authentication will come back to the on-premises for verification on every time user logins. Ex: UNCW Exchange server is hosted out of campus and every authentication for exchange server will be verified from the active directory which is hosted on campus. *Diagram 22* shows the secondary active directory service and DNS are moved to the cloud solutions. The experts suggested that these two services can hosted using the virtual machines or using the Microsoft Azure's DNS and Active Directory.

One expert suggested to use the VPN to connect to cloud where as other experts argued that if the business wants to use the multiple cloud solutions using multiple VPNs could be complex. The experts suggested if the VPN has to be used, then it is good to use the all solutions from the same provider. The experts think the overall architecture is good and benefits the growing SMBs by offering flexible solutions however, they showed concerns about the data privacy over the internet.

8.1.3 Business continuity, Security & High availability oriented architecture

The BSH oriented works best for the businesses which requires the business continuity and business which are based on the locations which are affected by disasters often. Experts mentioned that hosting the data and services on the data center or private cloud offers more quality solutions than the services hosted on-premises.

The experts suggested that since the data is hosted offsite and in order to offer high availability it is recommended to have the secondary Internet Service Provider as the backup. The architecture designs with secondary Internet Service Provider (ISP) are attached in the *Appendix –L.* As in the FM oriented architecture, the experts suggested to move the secondary ADS and DNS to the private cloud as new virtual machines. The experts suggested to replicate the data and services over Region 2 instead of having only backups in Region 2 and they added that backups may be taken in each data center or private cloud. By replicating the data and services in different locations will provide the high available and offer the business continuity. All these suggestions are included in the revised architecture Designs, refer *Appendix-L.*

The experts felt that, though this architecture offers the best-in-class services, it would expensive, required same maintenance as the MU architecture and might be complex to handle. They also liked the idea of establishing the direct lines to the data center. Overall, this architecture is good and is needed for the businesses who would like to reach most of the business objectives specified.

8.2 Present and Future

This section discusses the present and future of the solutions provided in this project. It was a very good discussion that lead how the cloud solutions may be a burden for the businesses in the future. The SMBs may be attracted easily to the cloud based solutions because of low upfront costs and the ongoing monthly costs will be based on the usage (CPU, Memory, Bandwidth). However, this cost could go up when data usage grows up when businesses expand and have to use the hybrid infrastructure which is used by many of the large-scale businesses. But, the experts also argued that with price businesses pay for cloud solutions brings more value with timely upgrades which carried out by providers with no extra cost and using advanced technologies which may not affordable for the businesses.

As a part of this project, experts have been asked two questions to learn about which type of architecture (mentioned in this project) are they using for their organization and what would be their preference for future in 3-5 years. Experts was asked to point it on the Venn diagram of three architectures (MU, FM oriented and BSH oriented). Two experts pointed out their current architectures is a hybrid architecture which is mixture of all the architectures specified and for the future, they wanted to move out of traditional server-oriented architecture and use hybrid

architecture of FM oriented and BSH oriented architecture. The other expert mentioned that, their organization using most of services which are hosted on-premises and they are moving slightly towards center of these architectures which uses combination of all the architectures. For more details, Refer the below Diagram 29.

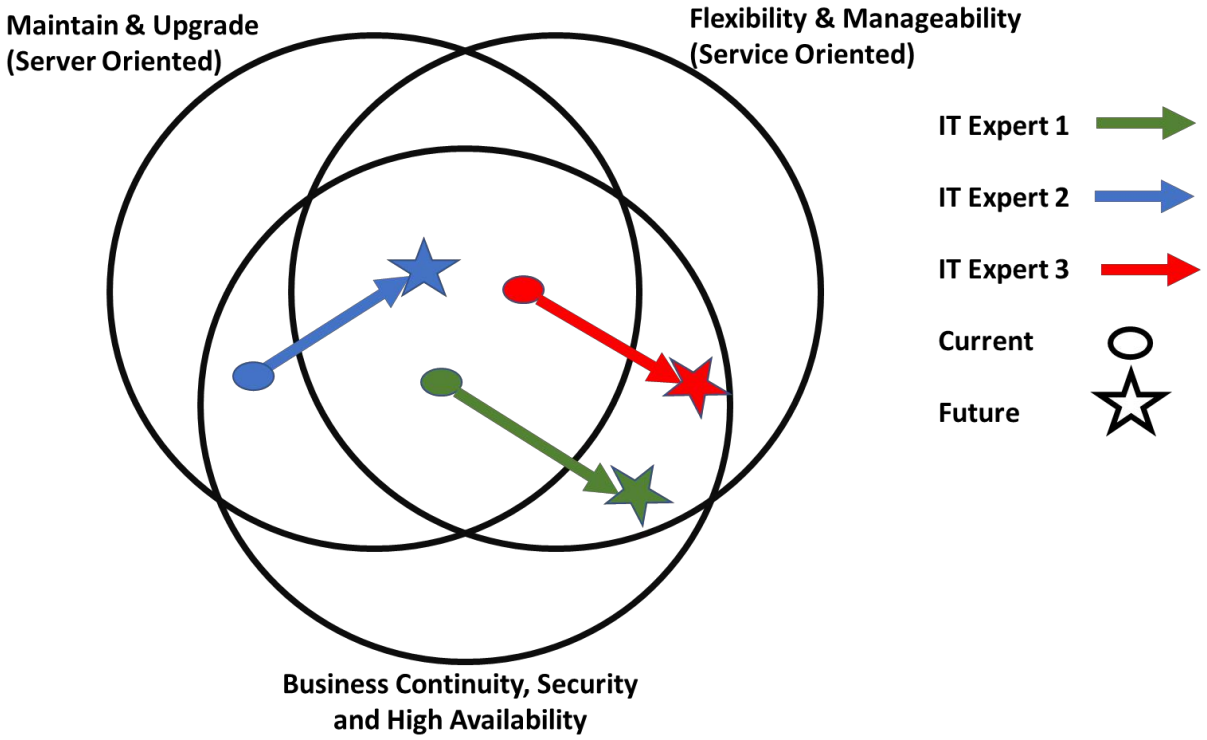

Diagram 29 *Venn Diagram for present and future of IT architectures*

8.3 Learnings and few things that surprised me

Working on this project was truly helpful to me, I am looking for starting my career in Business Analysis or Consulting and having a career goal (in 5-10 years) in Product Management. This project gave me an opportunity in exploring the IT infrastructure fundamentals and in different concepts of looking at it. I am confident that, the knowledge I gain from project would help me in managing the business and different products.

I learned about different methods of hosting the IT services for businesses, advantages and drawbacks about them. I learned how to get the business objectives set in order to grow the business, and this project helped me to understand using different solutions when we have a group of business objectives to meet. I improved my analyzing skills, finding the solutions and different ways of looking at it. I used Microsoft Visio extensively in this project, I understood the different tools available in the Visio and now I have expertise in drawing the architecture designs for the IT Infrastructures.

Along with above skills, I improved my soft skills while working on this project. I learned how to find a right set of mentors when forming the capstone committee which advised me throughout this project and helped me complete this project on timely manner. I learned my mistakes and improved my presentation skills while presenting this project at conference (CONISAR-2016, Las Vegas, NV) and at capstone proposal. I learned planning, preparing and setting up meetings with different IT Experts which also expanded my professional network.

Interacting with different IT experts as of part of this project gave me a wide exposure and learned about different technologies which I haven't worked on before. Below are some of the concepts which I learned from the IT experts and I found it useful in planning and implementing the IT infrastructures.

- Cloud-Managed Network: A network which can be managed on cloud. I always remember presenting on site to resolve any network issues and even at my home. One of the expert mentioned, they are looking replace their switches with CISCO

Meraki switches (offers cloud-managed network by using a SaaS cloud model) which enables them to manage the entire network remotely.

- Hyper Converged Infrastructure: A method of hosting the virtual machines using VMware where virtual machines are treated as nodes. This infrastructure offers more reliability than other hosting methods.
- Cloud Migration tools: An IT consultant wouldn't have to worry about planning cloud migrations and calculating the costs. These tools are used for the migration on-premises infrastructure to the cloud and helps in planning the migrations without any manual intervention. The expert mentioned, they use RISC networks cloud space tool to plan for their cloud migrations.

8.4 Overall Conclusions

This project taken an approach to design prototype architectures at extreme level of defined business objectives which helped to identify architecture changes as necessary as objectives change. However, SMBs can choose a combination of these prototype architecture to meet all business objectives if needed. Some businesses prefer the hybrid architecture which is combination of all these architectures. Designing architectures at extreme level also helped the experts place their current IT architecture and the direction they would like to move in the future.

As discussed in Section 7.3 and Diagram 29 experts are showing trend to move away from the conventional server-oriented architecture to the cloud based or hosted solutions. Servers hosted on premises and server oriented architectures are designed to meet peak

loads over their lifetime which results in added expense, and low utilization. Some experts expressed that conventional architectures often need more maintenance which require manual intervention of IT workforce which reduces the productivity of IT personnel. Rather, by limiting the maintenance, they would like to focus on work which is more value added to their organization. These experts seem to be much more comfortable with having data and services off-premises.

In conclusion, working on this project lead me to discover the 4th dimension of designing the IT architectures i.e. “High Availability” could have been a whole separate architecture. By the recent trends of IT infrastructures and with interaction with IT experts, High availability seems to be most needed business objective these days. Some of the businesses are more critical in nature and they are required to have a system with a High availability. This scenario will be further investigated in future work.

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10 Appendices

APPENDIX A

The *National Institute of Standards and Technology (NIST)* established five essential characteristics of cloud computing that should help you understand the primary differences. They are:

1. ***On-demand self-service:*** once services are established, the customer should be able to provision new users, services, virtual machines, etc. without involving the cloud service provider.

2. ***Broad network access:*** cloud services are typically accessed over the Internet, as opposed to being on an internal network accessible only over private connections.

3. ***Resource pooling:*** there is some degree of shared resources from which services draw as needed.

4. ***Rapid elasticity:*** customers' needs may expand or contract, and the service will expand or contract with those needs.

5. ***Measured service:*** customers are billed based on some measured consumption. That could be licenses, or CPU cycles, or Gigabytes of storage consumed, or number of mailboxes; whatever the thing measured, that is how customers are billed. You pay for what you use.

NIST also has standardized around three types of service models. They are

1. ***Software as a Service (SaaS):*** Applications that could be email, CRM, cloud storage, etc.

2. ***Platform as a Service (PaaS):*** This includes web sites, web applications, etc.

3. ***Infrastructure as a Service (IaaS):*** Typically, virtual machines hosted in the cloud and made available to the customer, who maintains the operating system on up.

Finally, NIST has defined four deployment models. They are

1. **Private cloud:** It's mine, all mine, and not yours. One user exclusively uses the private cloud.

2. ***Community cloud:*** It's yours and mine, but not his, because he isn't one of us. Meaning the cloud is used exclusively by a group of people or a community.

3. **Public cloud:** It's yours, mine, his, and anyone else who is willing to pay for it. Used openly by the public.

4. ***Hybrid cloud***: This part is yours, and that part is mine, and we will connect them together in some way. It's made up of two or more deployment models (private, community and public) within the same organization.

NIST definitions at http://csrc.nist.gov/publications/nistpubs/800-145/SP800-145.pdf.

Reference [6]

Appendix-B

Diagrams for Current Architecture

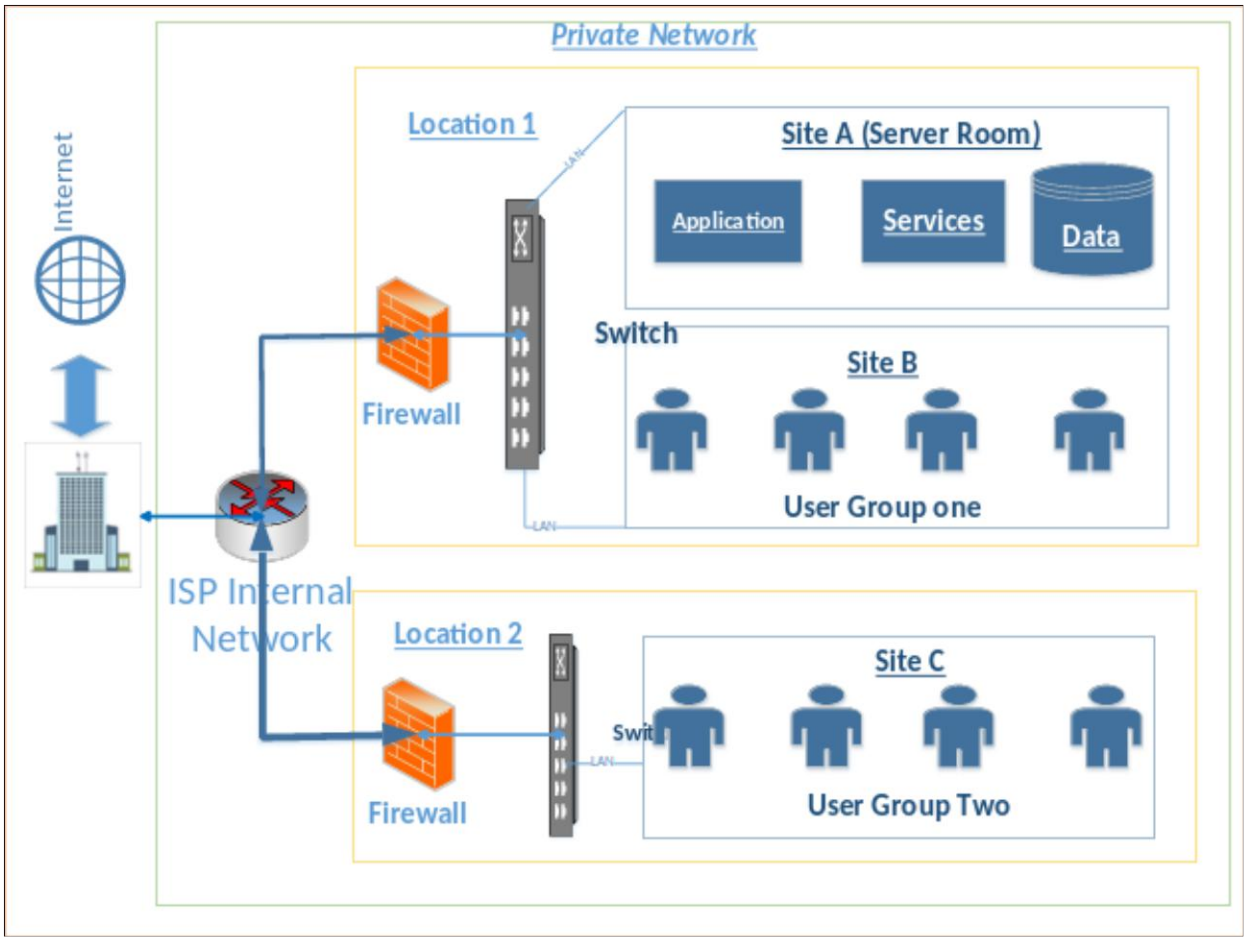


***Diagram** 1 Current Architecture: Network diagram*

***Diagram** 2 Current Architecture: Physical Architecture of User sites*

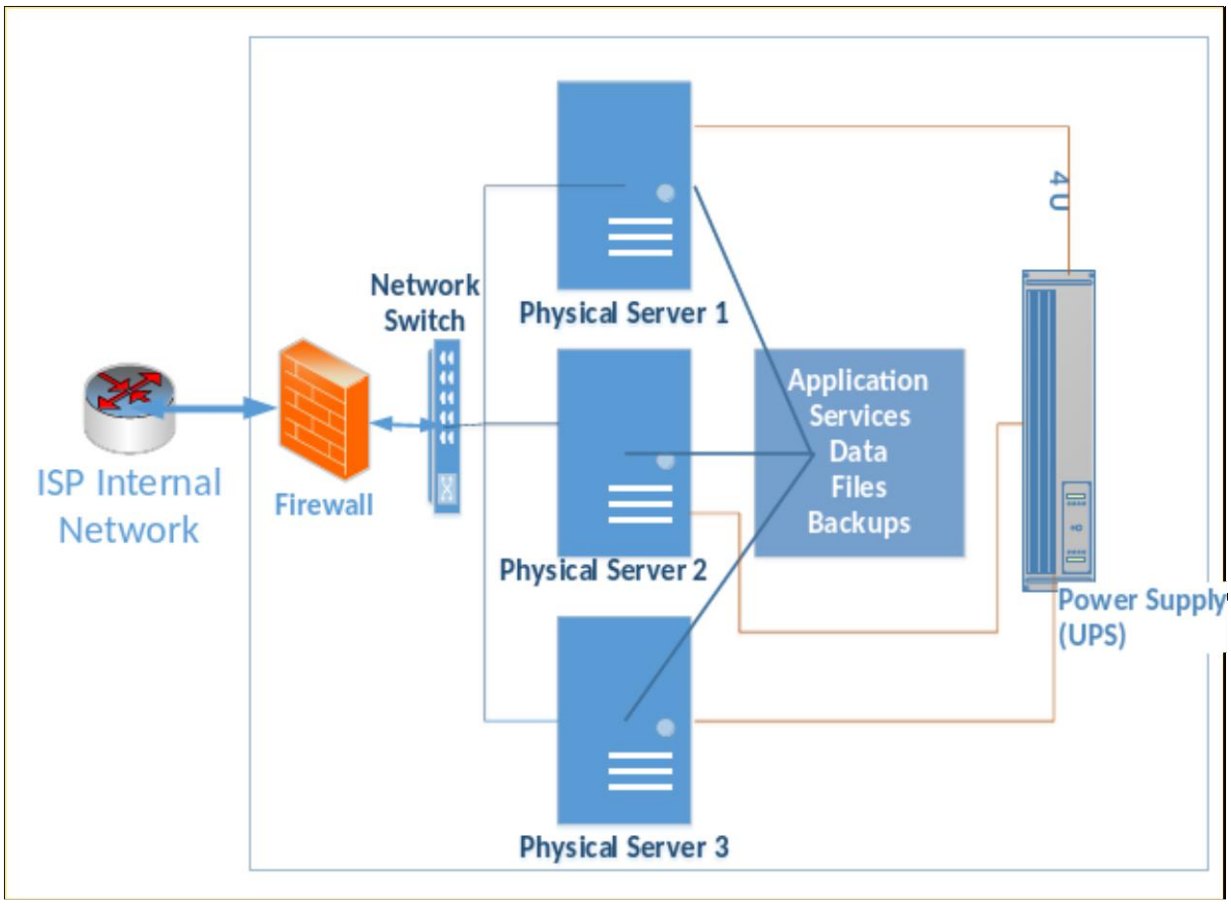


***Diagram** 3 Current Architecture: Physical Server Architecture*

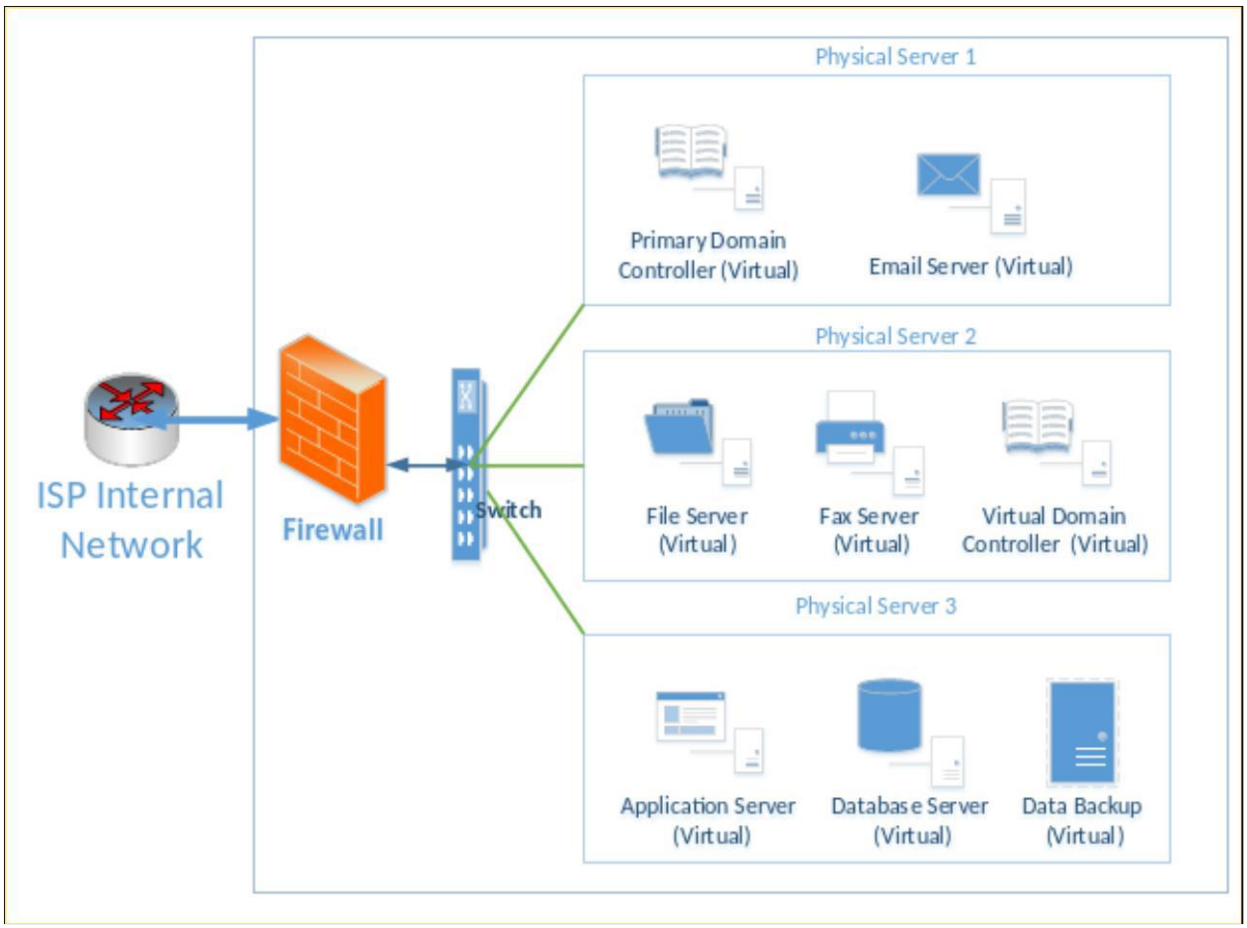


***Diagram** 4 Current Architecture: Server Virtualization Architecture*

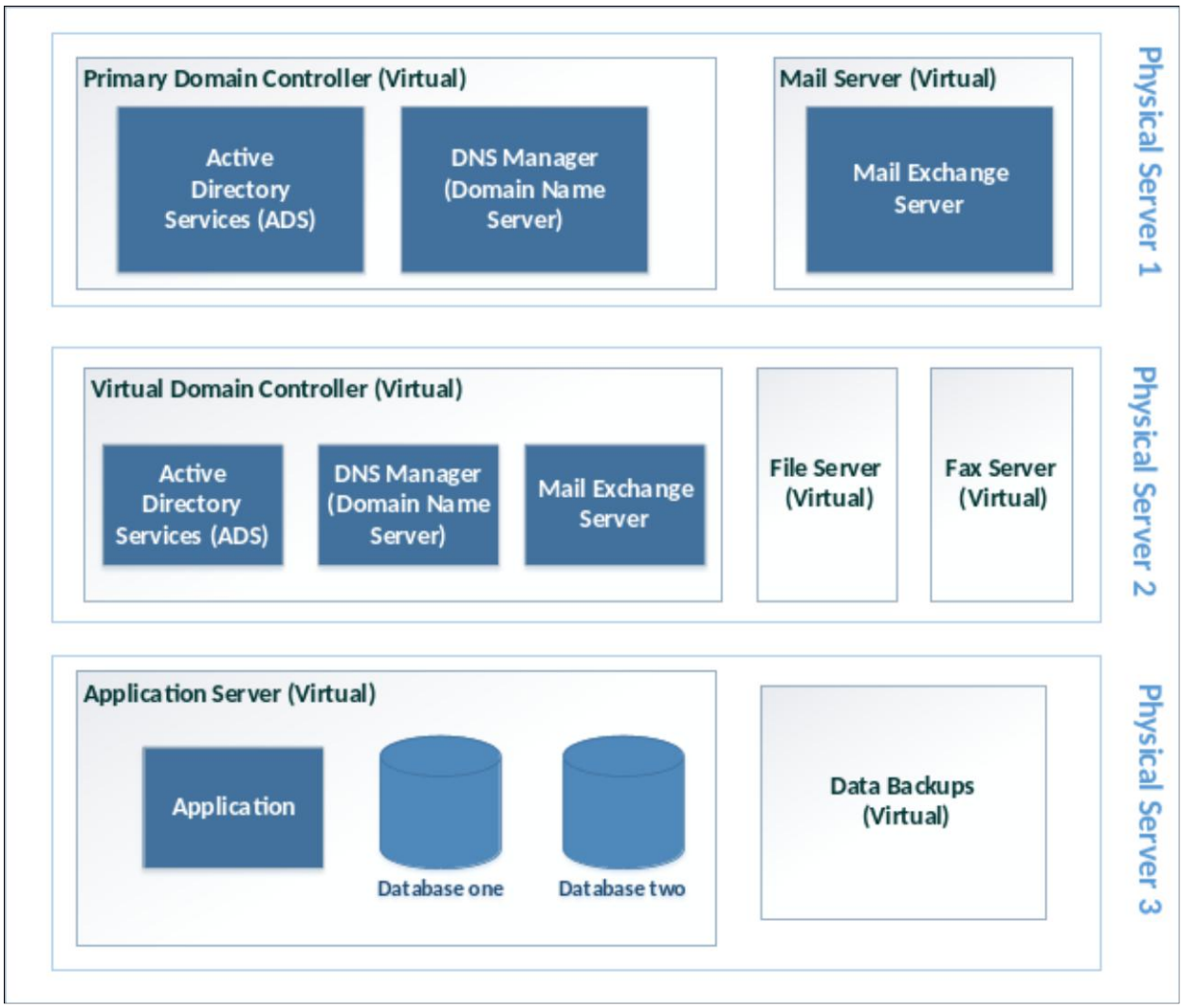


***Diagram** 5 Current Architecture: Server Roles*

Appendix-C

Diagrams for Proposed Architecture A: Maintain & Upgrade Architecture

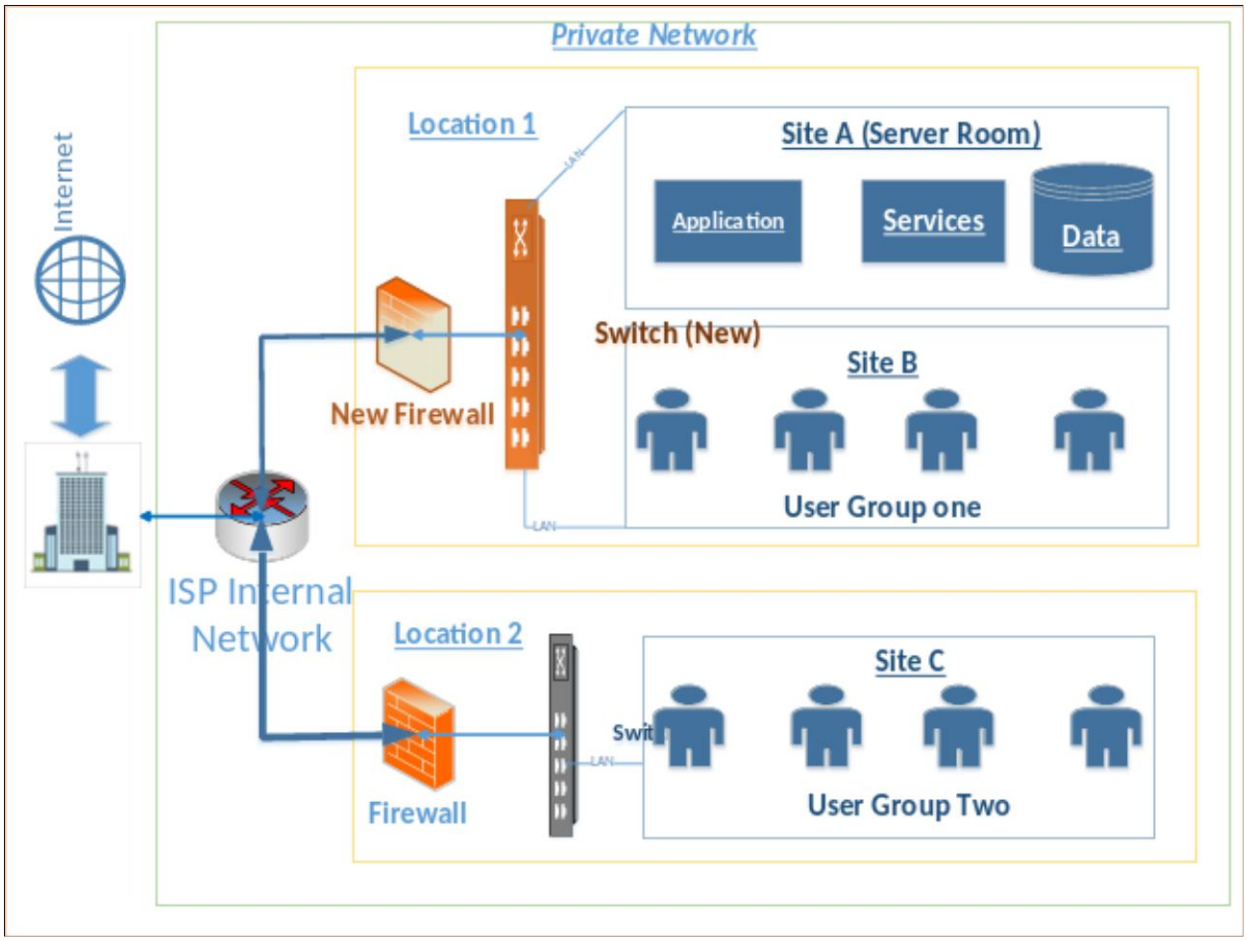


***Diagram** 6 MU Architecture: Network diagram*

***Diagram** 7 MU Architecture: Physical Architecture of User sites*

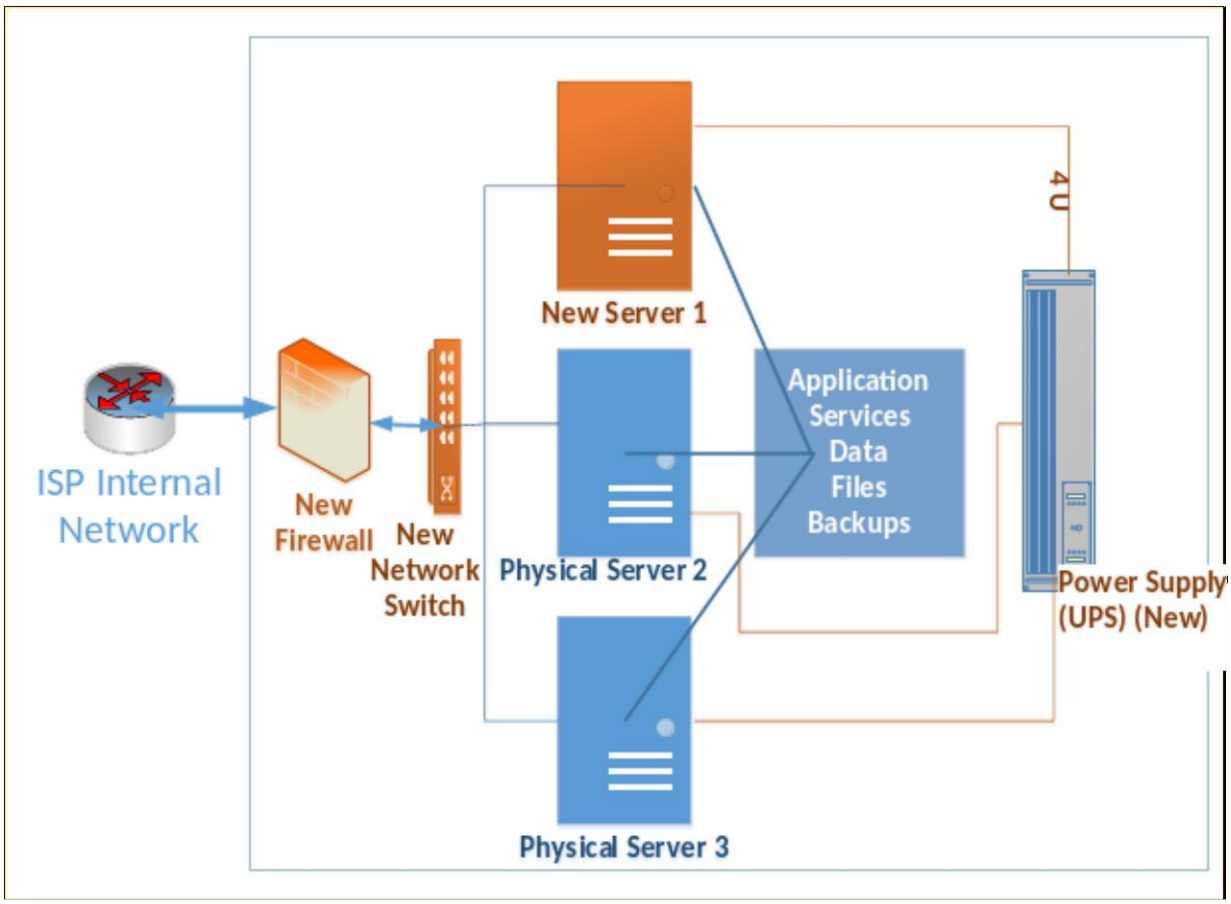


***Diagram** 8 MU Architecture: Physical Server Architecture*

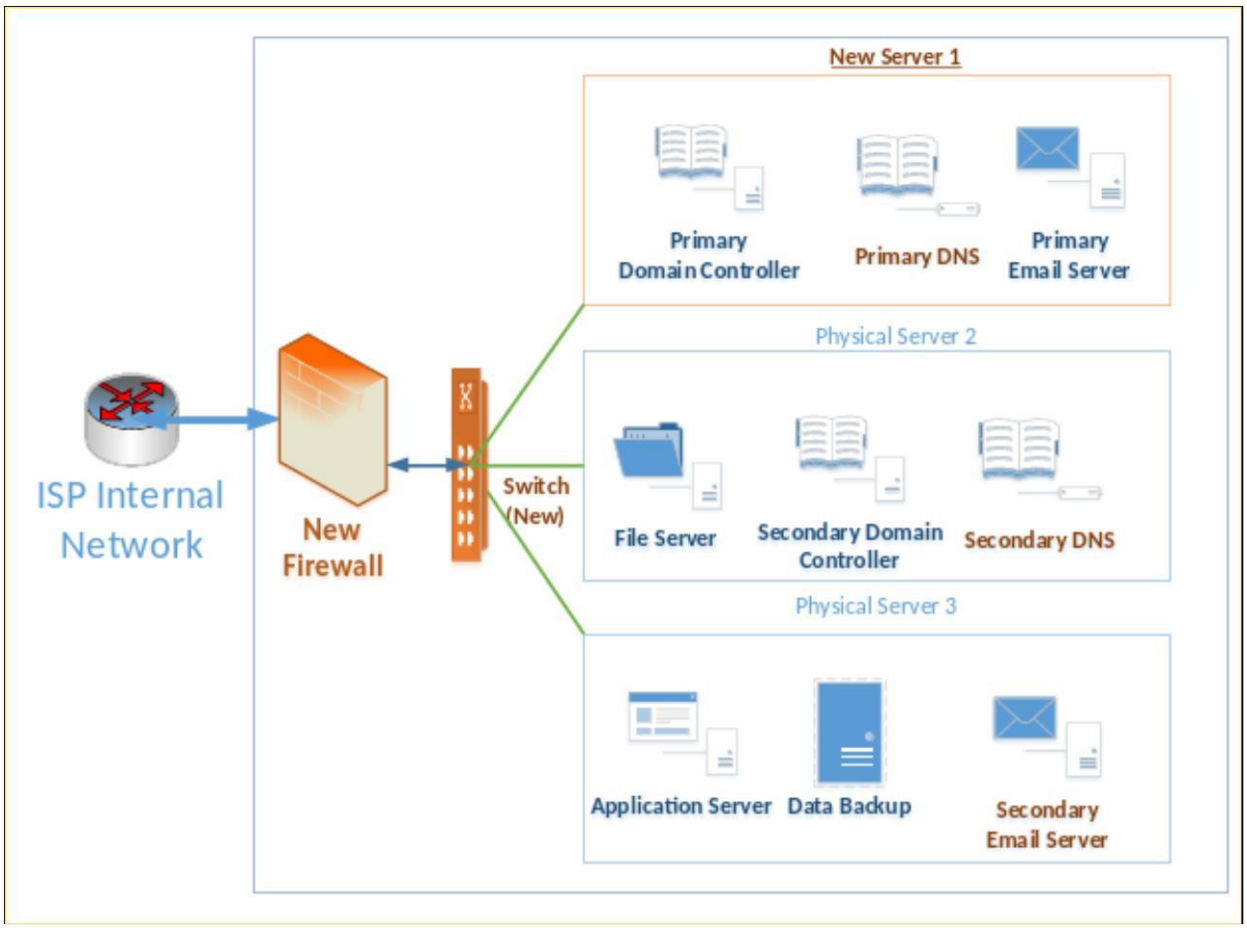


***Diagram** 9 MU Architecture: Server Virtualization Architecture*

***Diagram** 10 MU Architecture: Server Roles*

Appendix-D

Diagrams for Proposed Architecture B: Flexibility & Manageability oriented Architecture

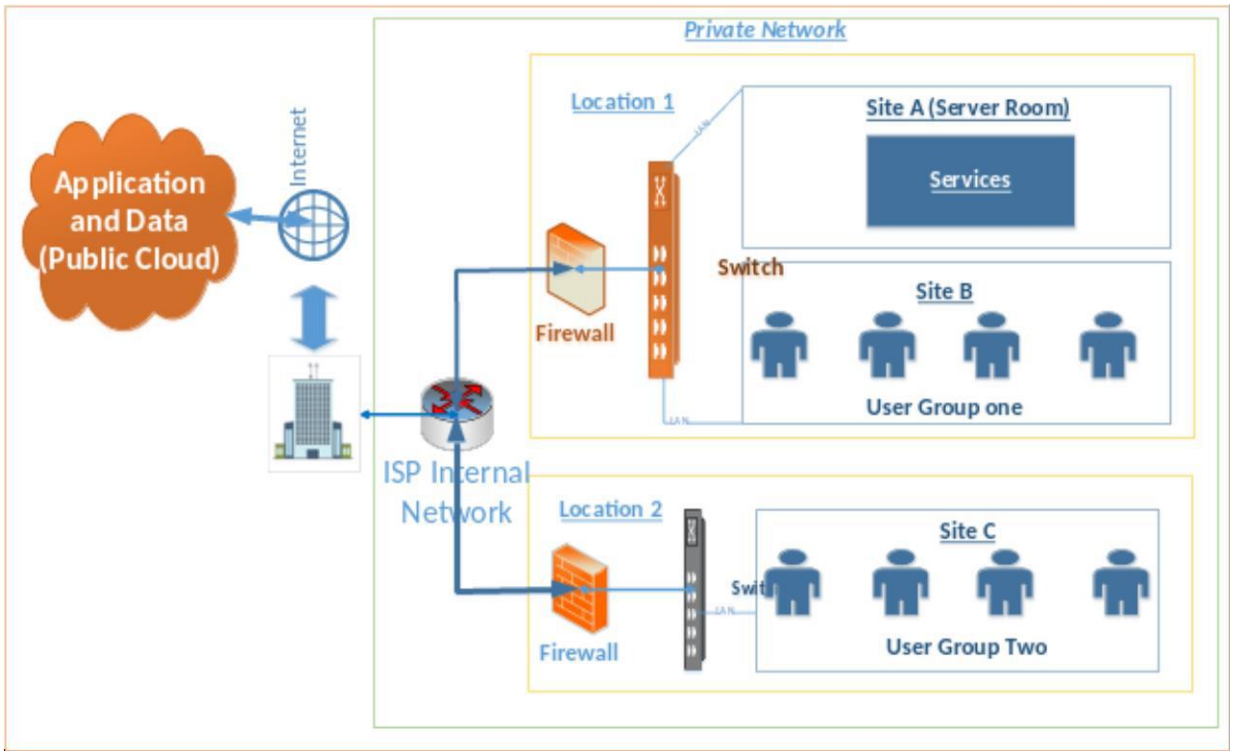


***Diagram** 11 FM oriented Architecture: Network diagram*

***Diagram** 12 FM oriented Architecture: Physical Architecture of User sites*

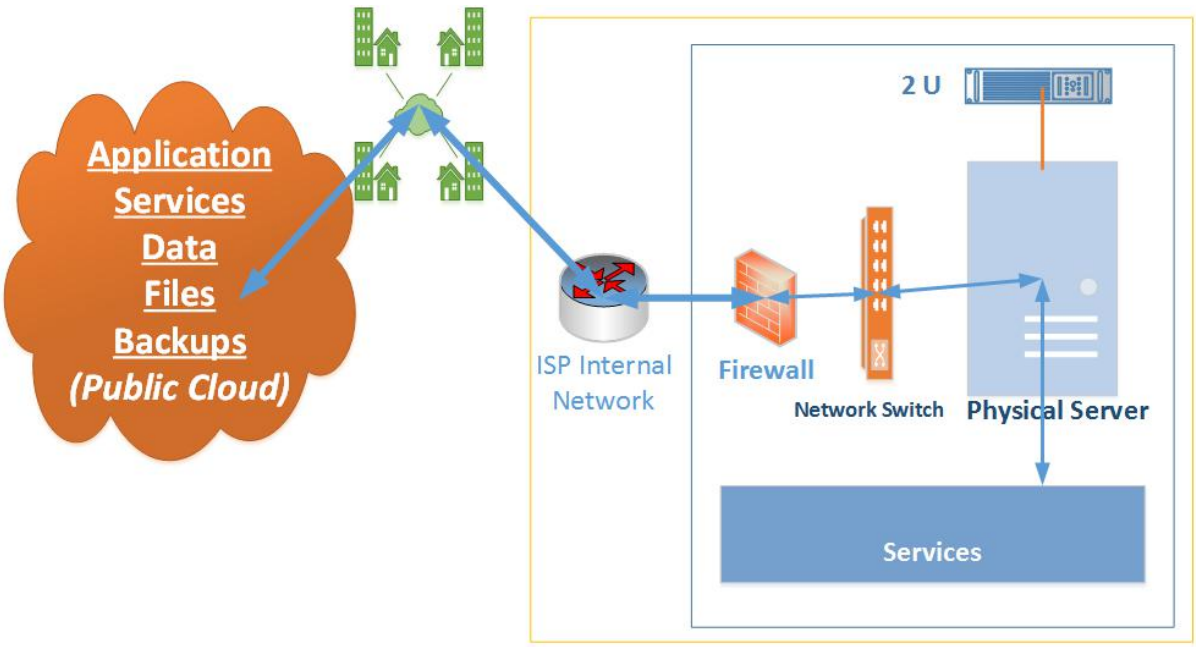


***Diagram** 13 FM oriented Architecture: Physical Server Architecture*

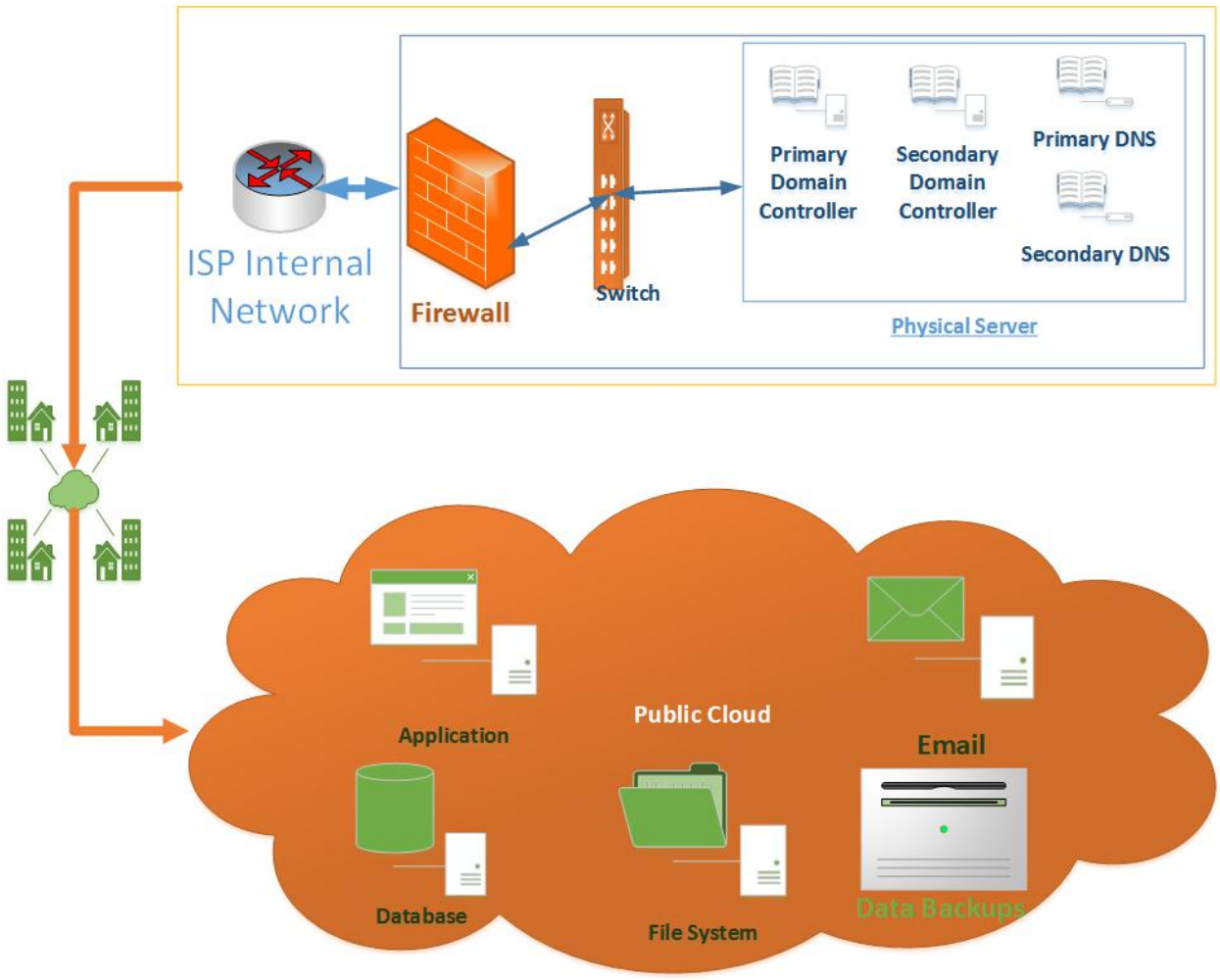


***Diagram** 14 FM oriented Architecture: Server Virtualization Architecture*

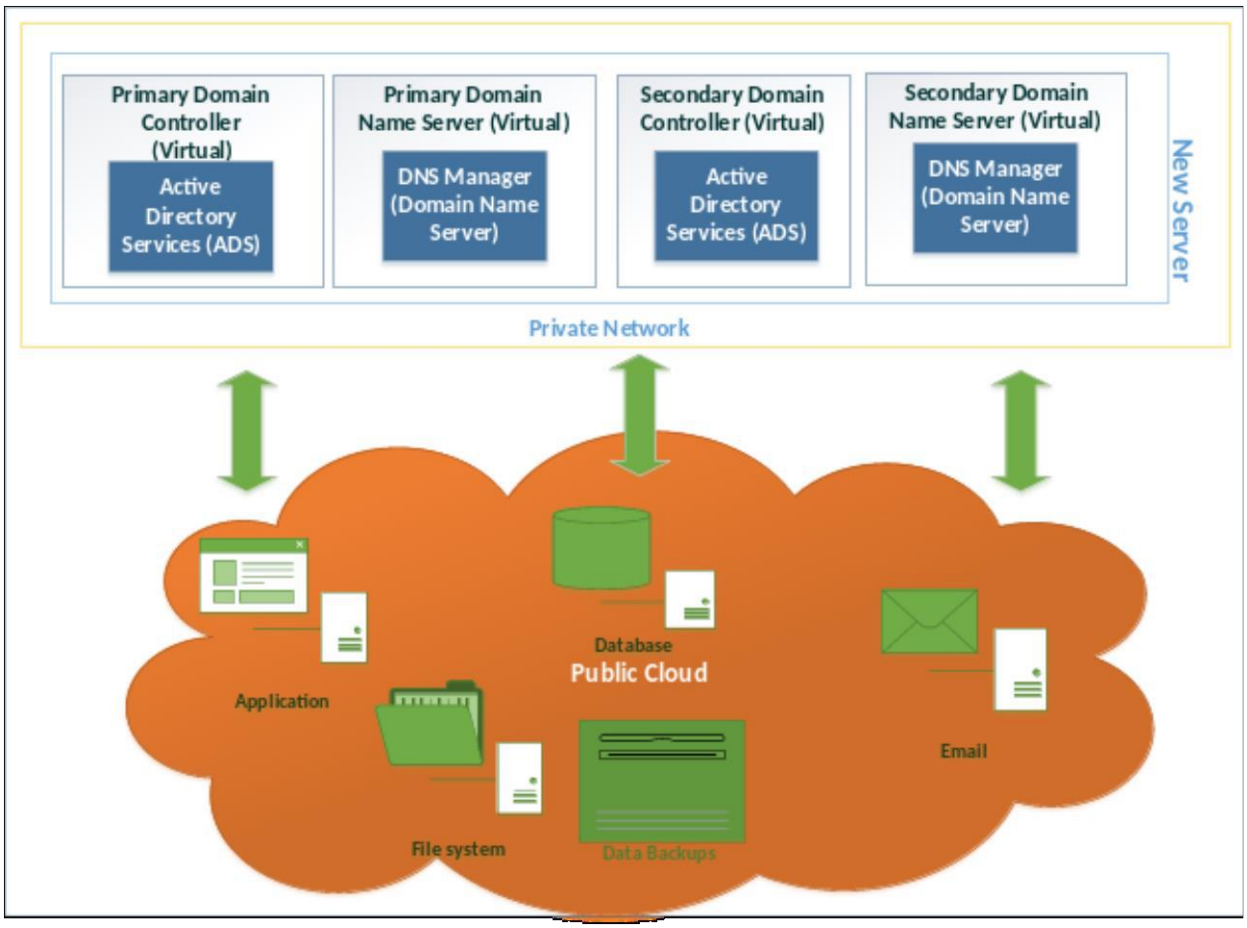


***Diagram** 15 MU Architecture: Server Roles*

Appendix-E

Diagrams for Proposed Architecture C: Business continuity, Security & High availability oriented Architecture

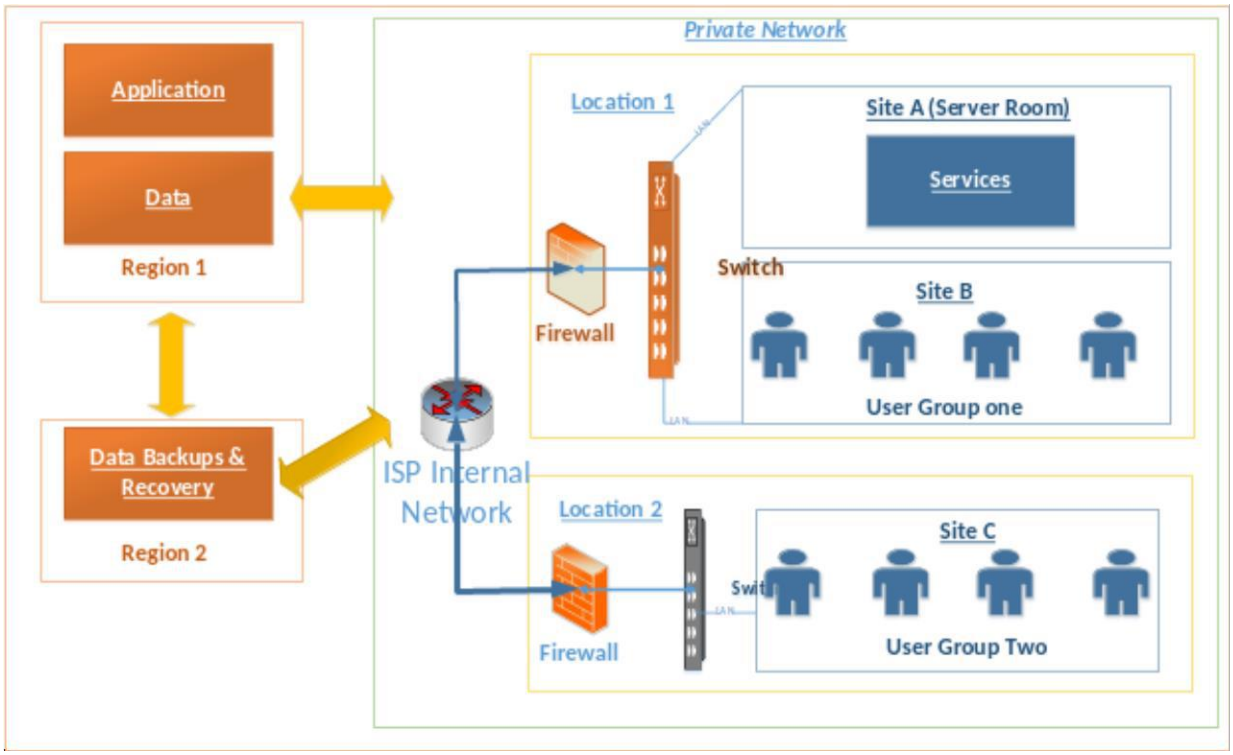


***Diagram** 16 BSH oriented Architecture: Network diagram*

***Diagram** 17 BSH oriented Architecture: Physical Architecture of User sites*

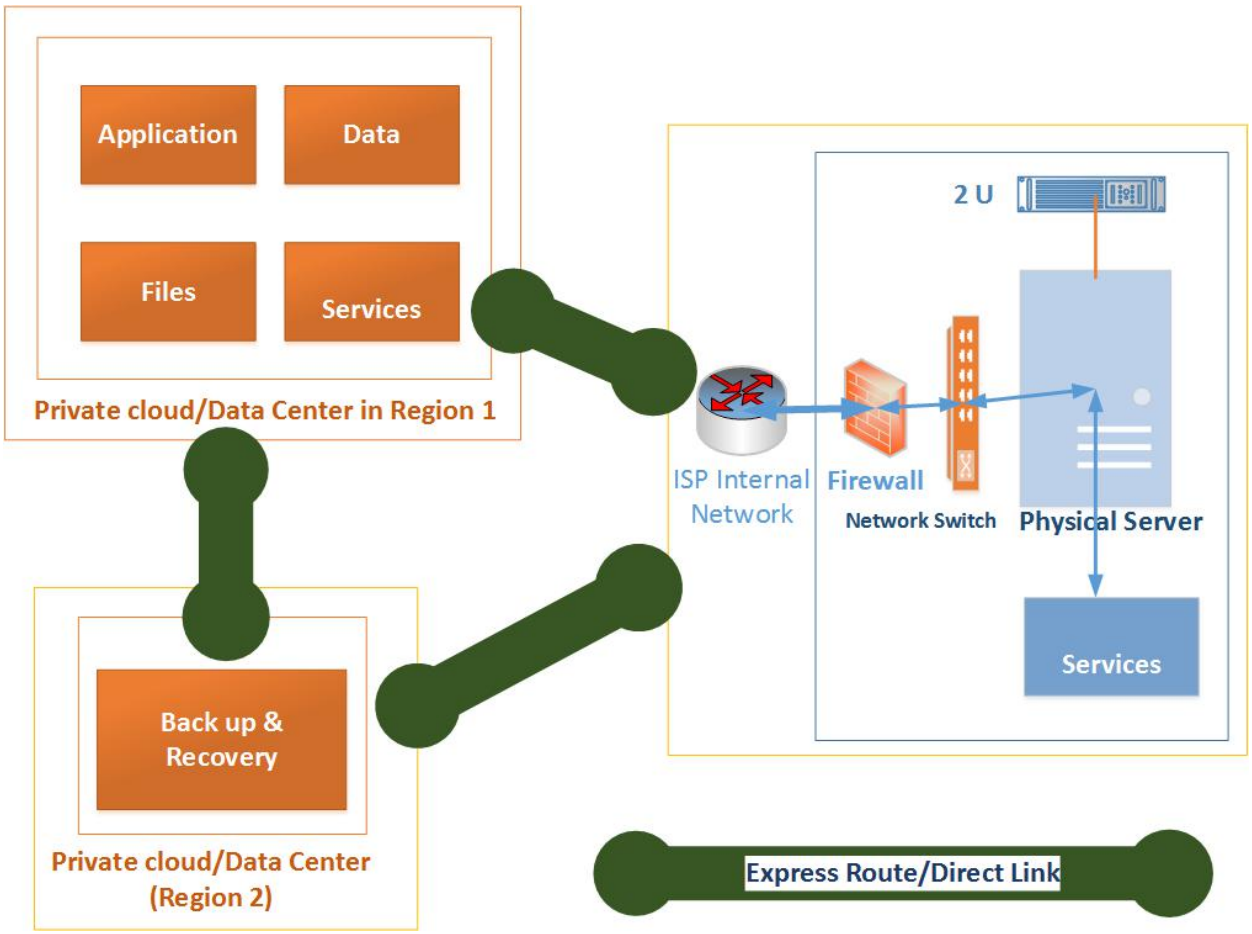


***Diagram** 18 BSH oriented Architecture: Physical Server Architecture*

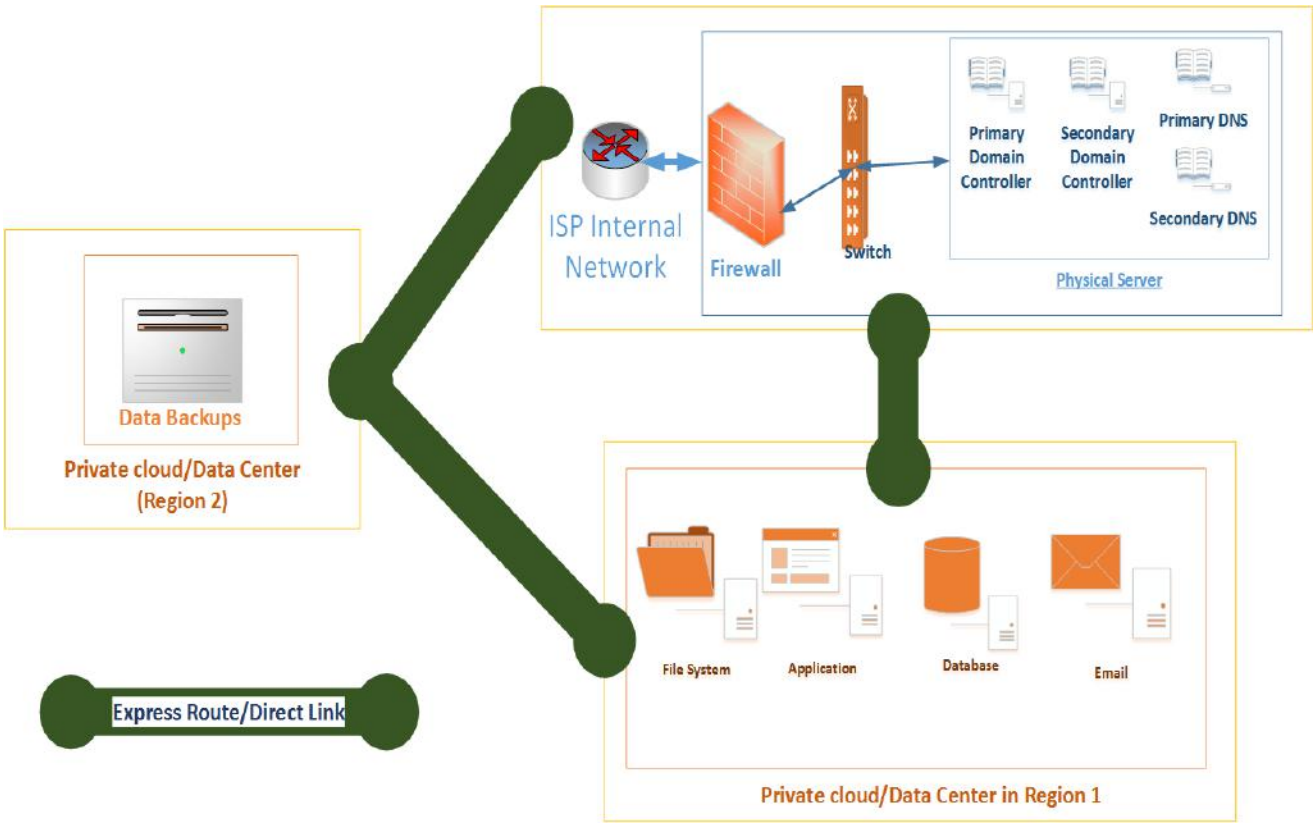


***Diagram** 19 BSH oriented Architecture: Server Virtualization Architecture*

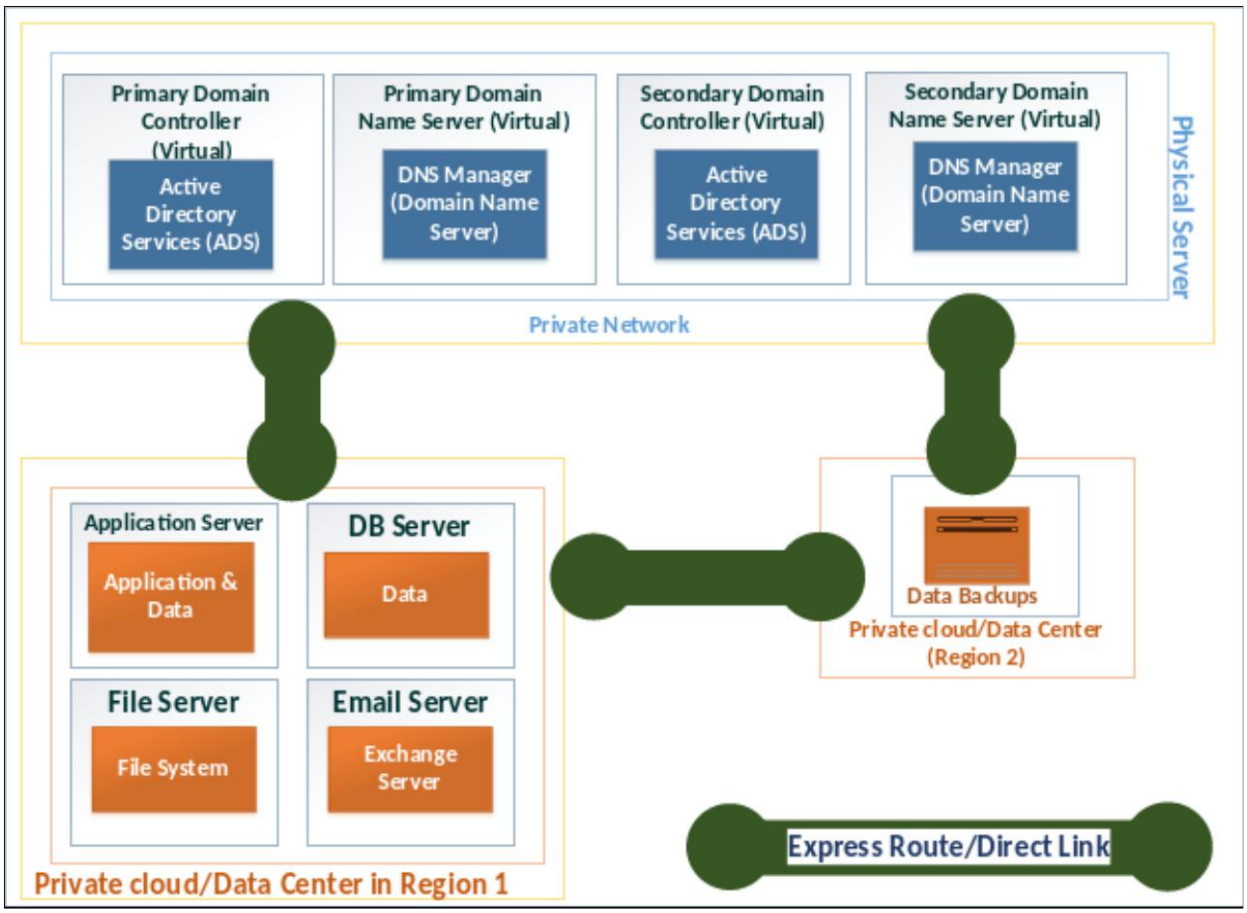


***Diagram** 20 BSH oriented Architecture: Server Roles*

Appendix-F

Expert's Interview Questions

Full Name:

Organization:

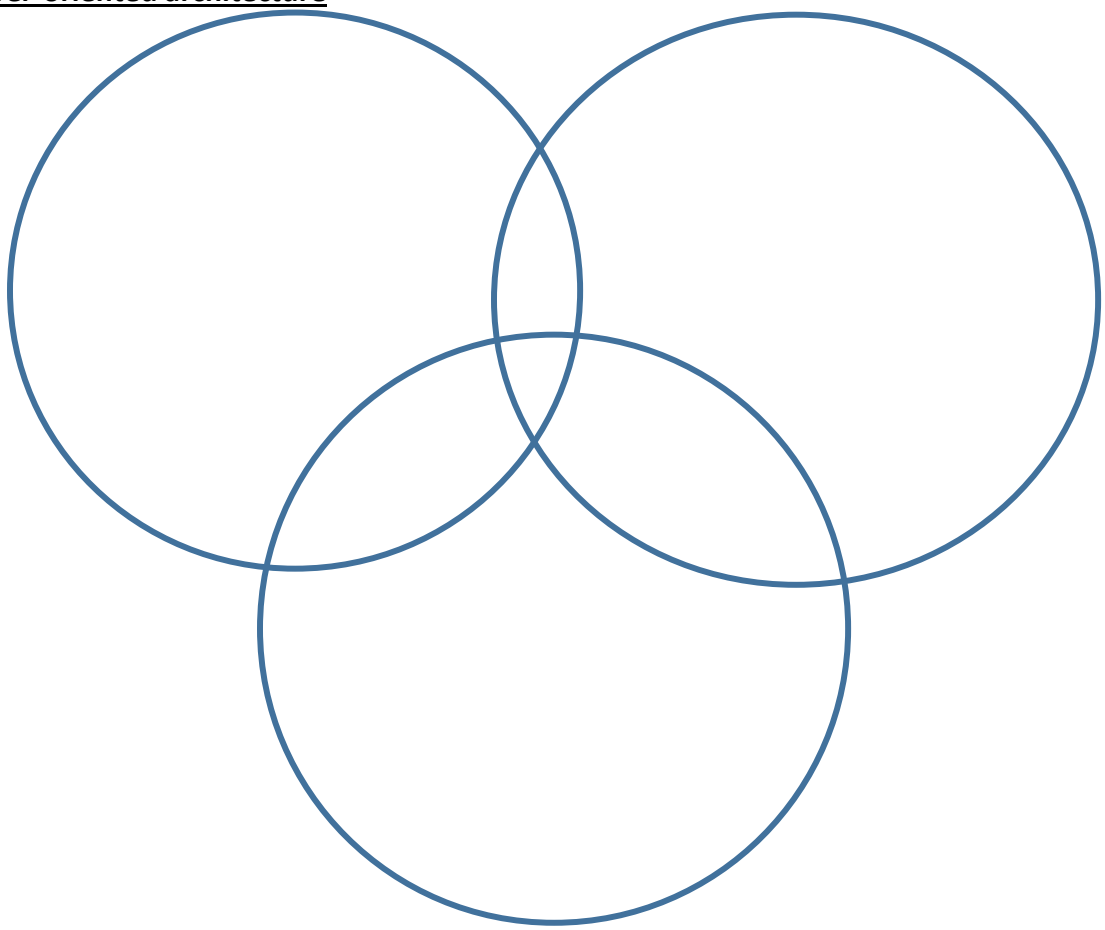
1. Would you like to appear your name in the final project report?
2. Do you provide a permission to audio tape the conversation?
3. The metrics for designing the proposed architectures are taken from previous surveys and they are grouped as below. Are they appropriate for SMBs?

Architecture - A	Architecture - B	Architecture - C
Robustness	Maintenance	Security
Reliability	Flexibility	Privacy
Efficiency	Agility	Business continuity

1. **Where is your organization's architecture fit in the below structure? (Please highlight)**
2. **Where would you like to see your organizations architecture in future (3-5 years)?**

Server-oriented architecture

Service-oriented architecture

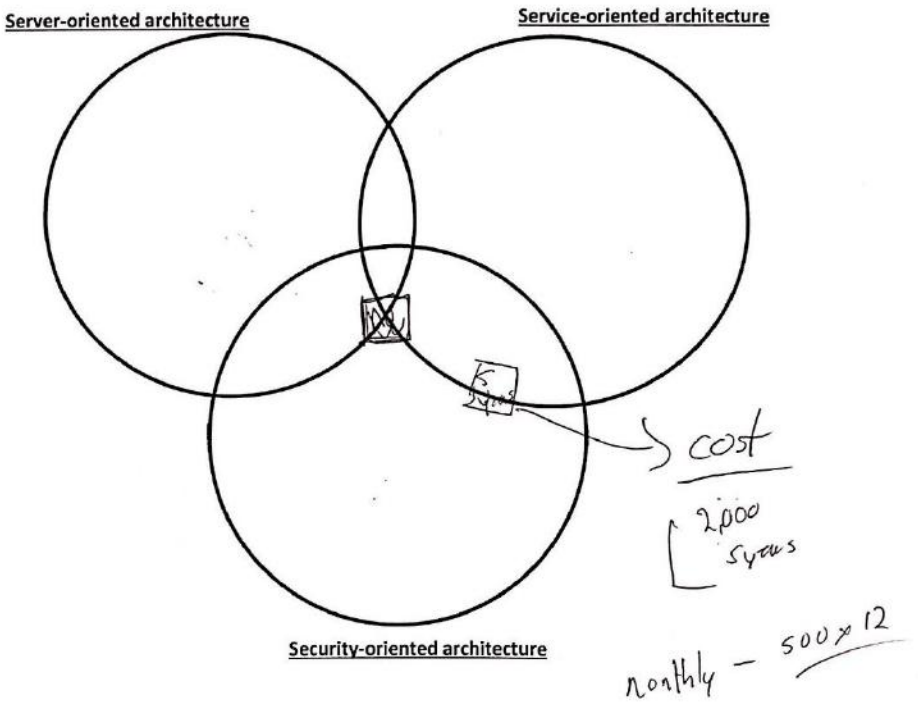


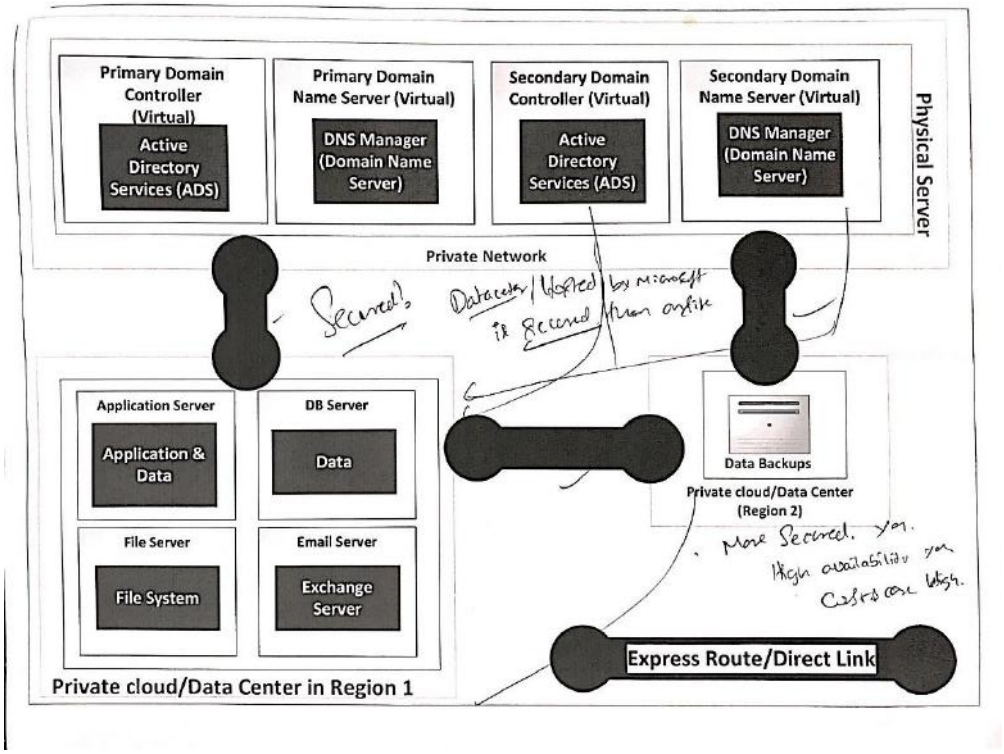
Security-oriented architecture

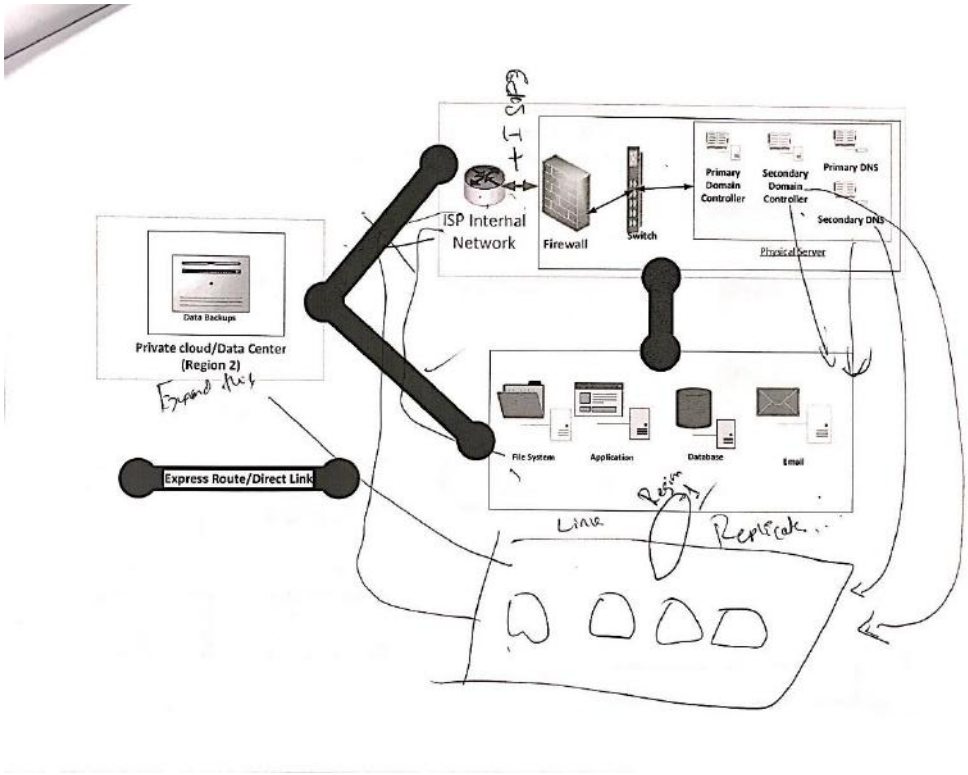
Appendix-G

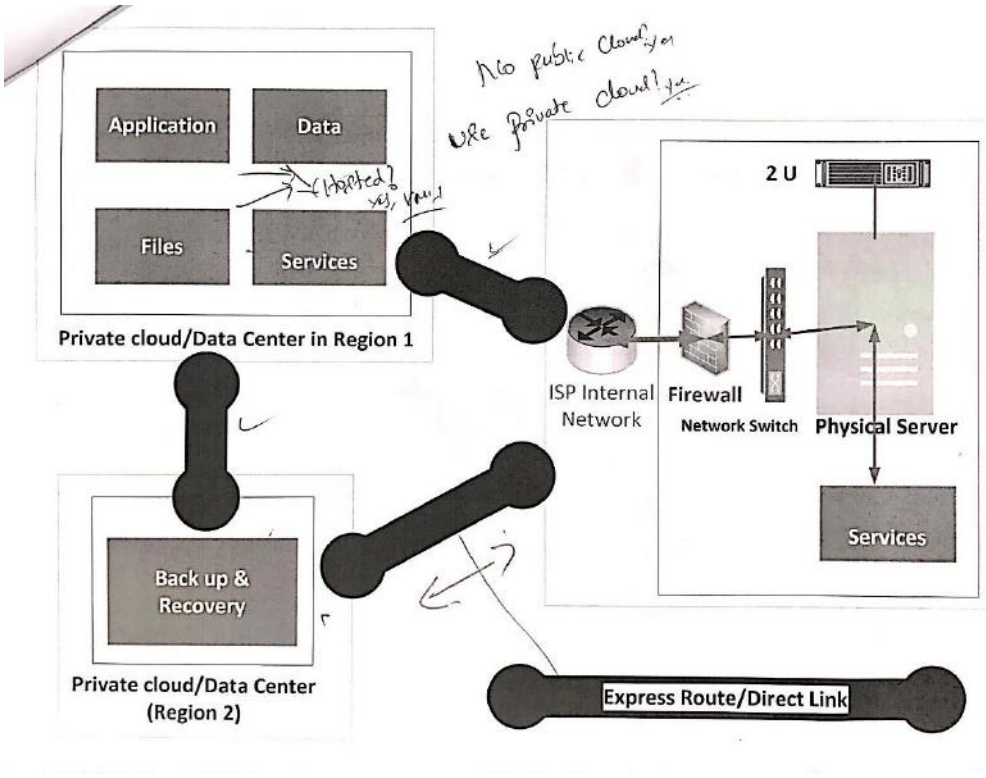
Interview Notes from Expert 1's Meeting

1. **Where is your organization's architecture fit in the below structure? (Please highlight)**
2. **Where would you like to see your organizations architecture in future (3-5 years)?**

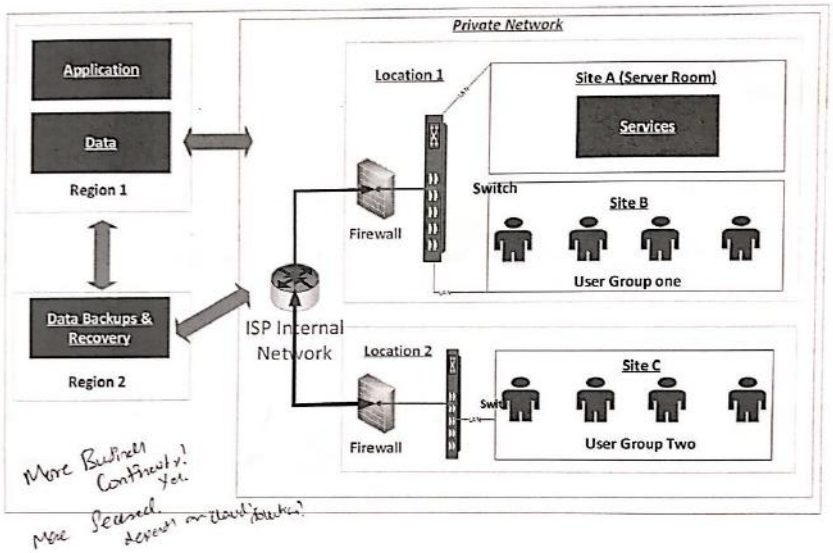


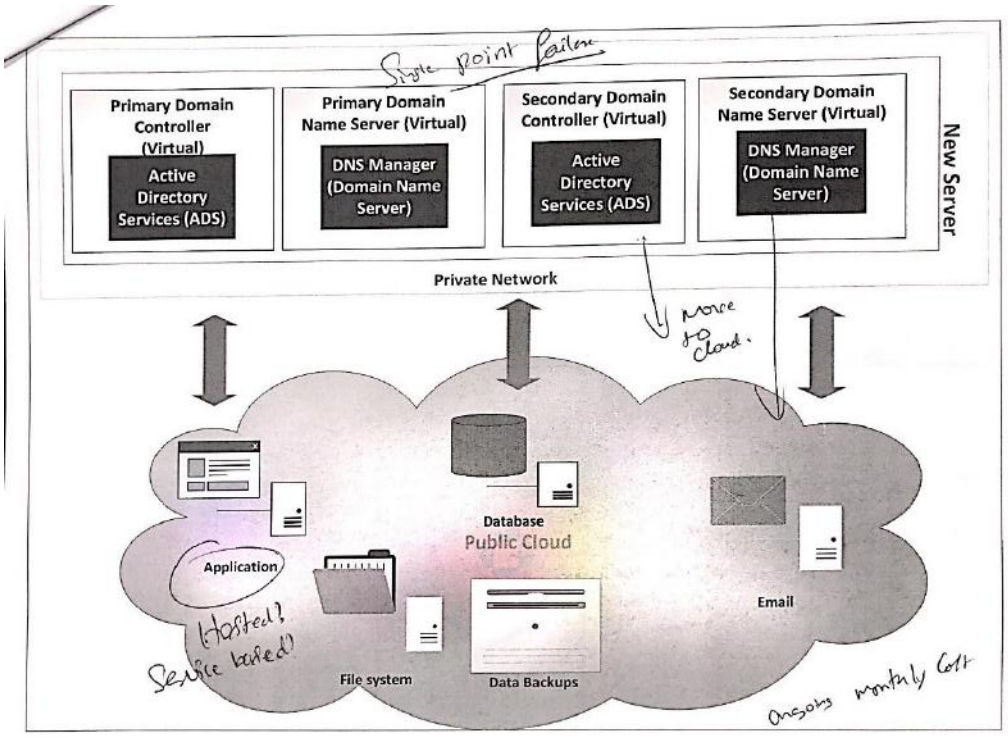

Primary Domain Controller (Virtual)
Active Directory Services (ADS)
Primary Domain Name Server (Virtual)
DNS Manager (Domain Name Server)
Secondary Domain Controller (Virtual)
Active Directory Services (ADS)
Secondary Domain Name Server (Virtual)
DNS Manager (Domain Name Server)
Physical Server
Private Network
Application Server
Application & Data
DB Server
Data
File Server
File System
Email Server
Exchange Server
Private cloud/Data Center in Region 1
Data Backups
Private cloud/Data Center (Region 2)
Express Route/Direct Link

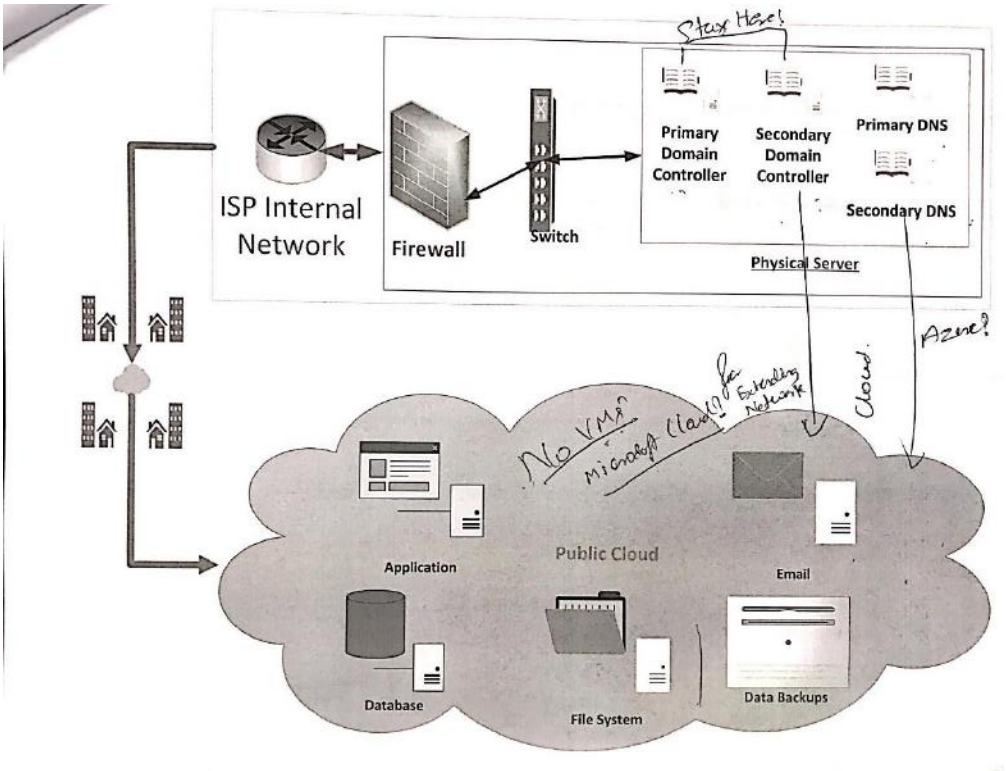

ISP Interhal Network
Firewall
Switch
Primary Domain Controller
Secondary Domain Controller
Primary DNS
Secondary DNS
Physical Server
Data Backups
Private cloud/Data Center (Region 2)
Express Route/Direct Link
File System
Application
Database
Email

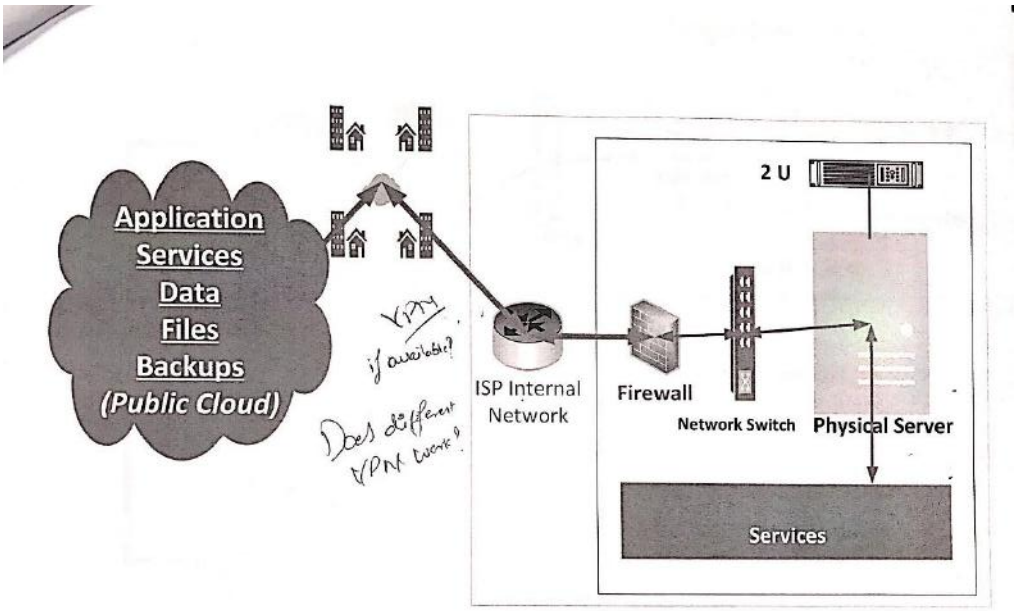


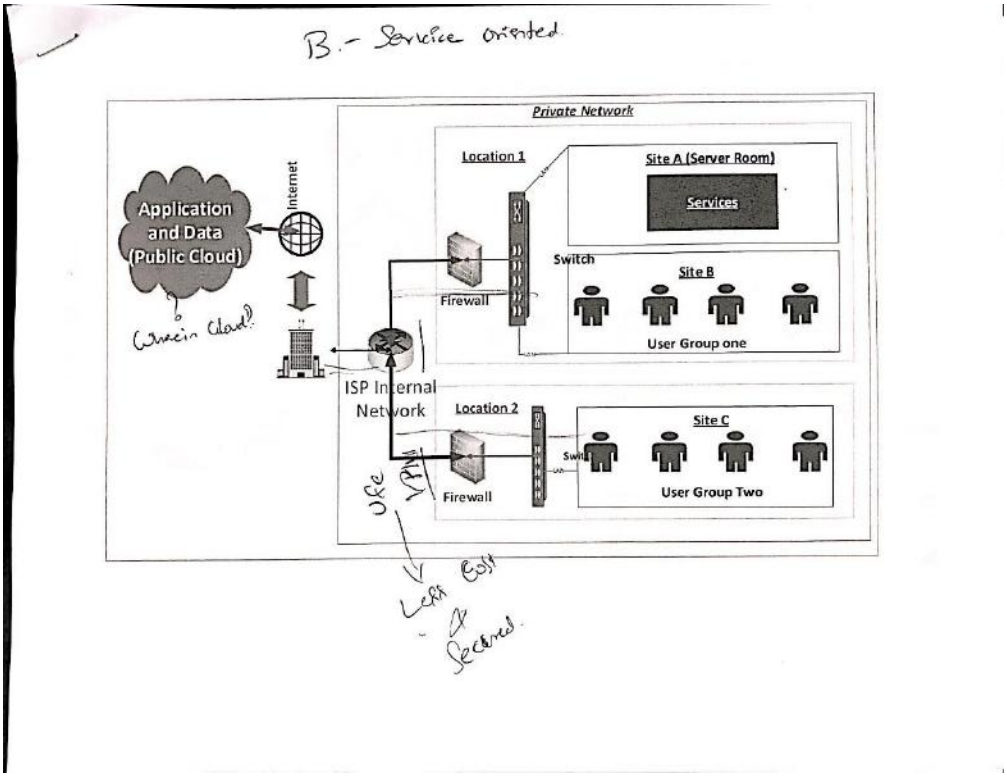
C: Security oriented

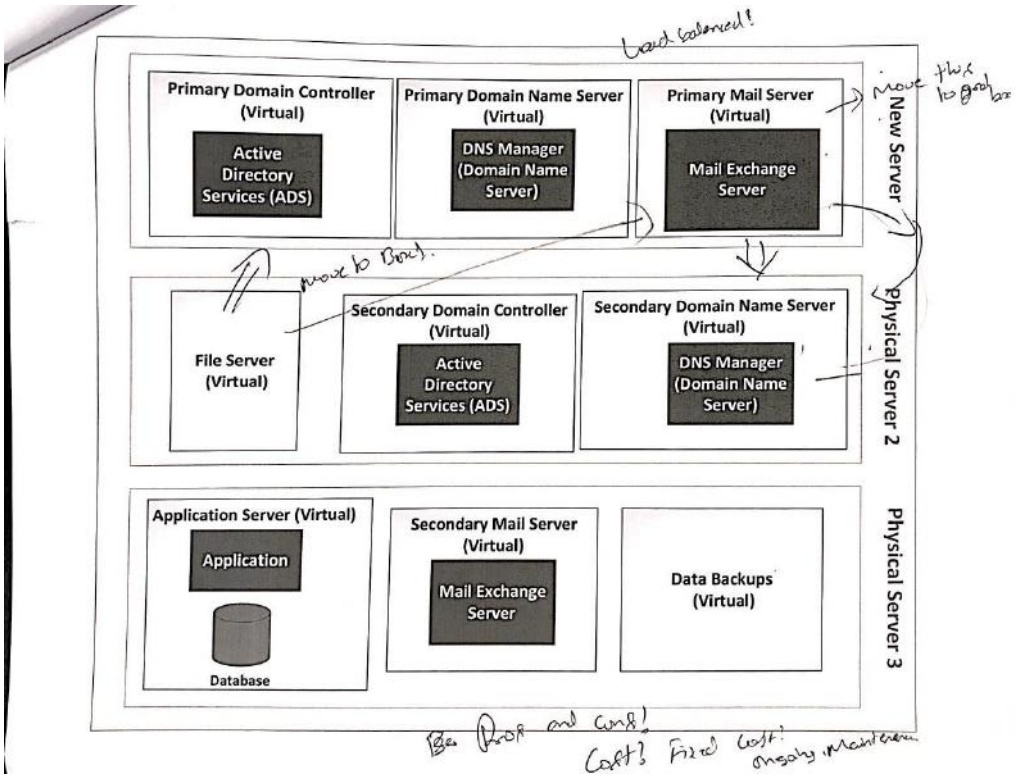


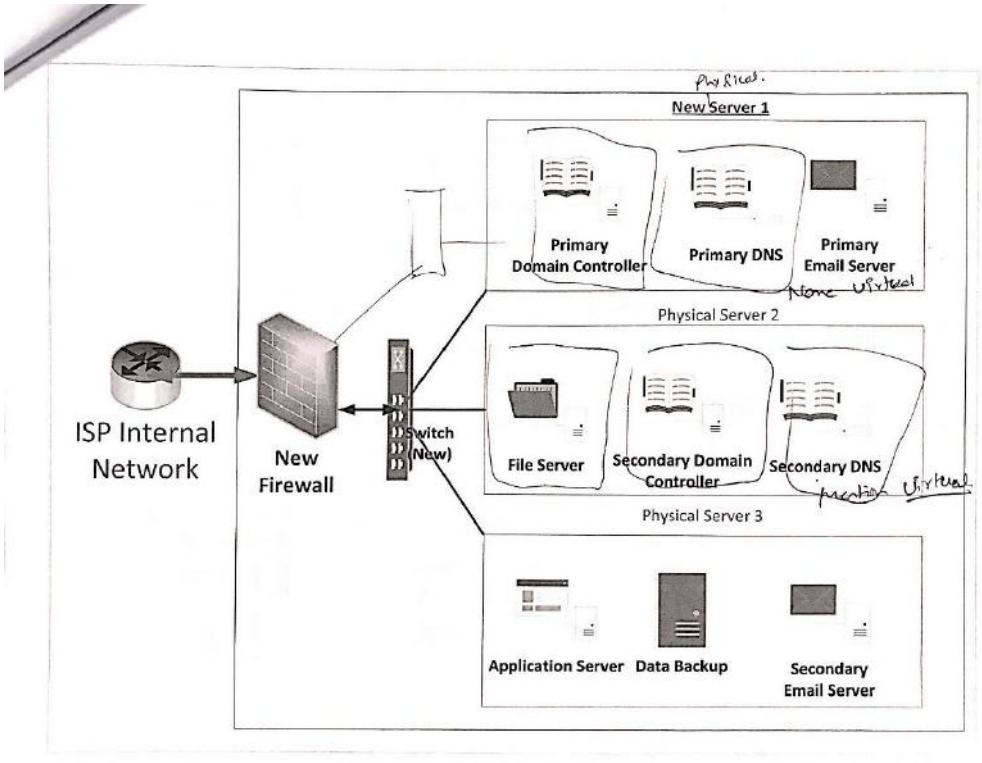

Primary Domain Controller (Virtual)
Active Directory Services (ADS)
Primary Domain Name Server (Virtual)
DNS Manager (Domain Name Server)
Secondary Domain Controller (Virtual)
Active Directory Services (ADS)
Secondary Domain Name Server (Virtual)
DNS Manager (Domain Name Server)
New Server
Private Network
Database
Public Cloud
Application
Email
File system
Data Backups

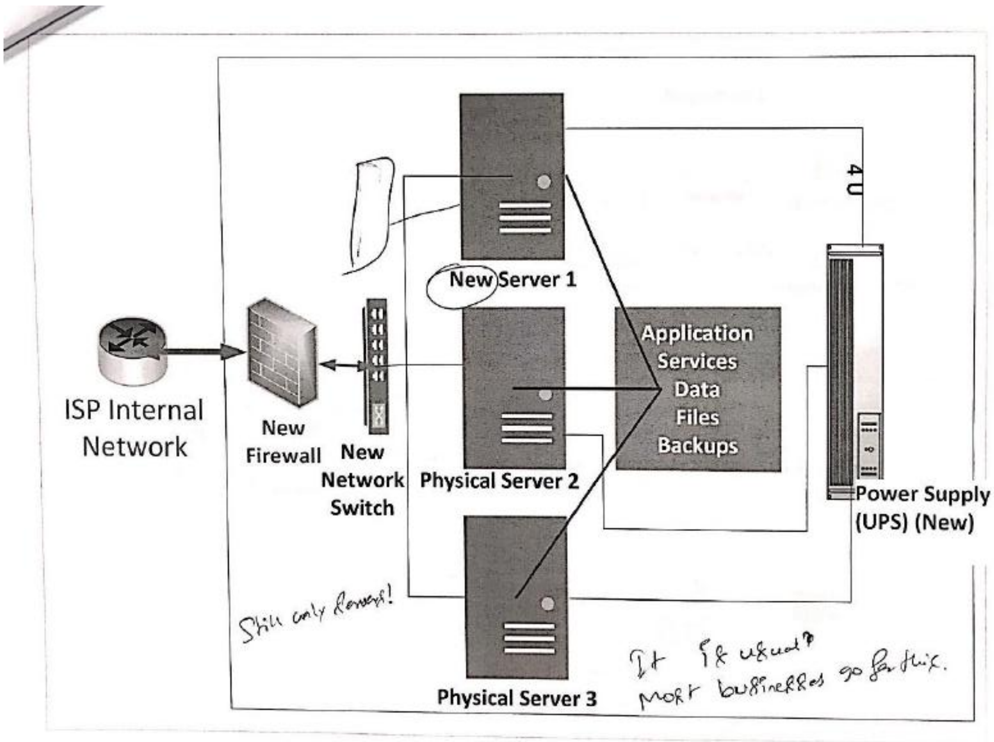

ISP Internal Network
Firewall
Switch
Primary Domain Controller
Secondary Domain Controller
Primary DNS
Secondary DNS
Physical Server
Application
Public Cloud
Email
Database
File System
Data Backups

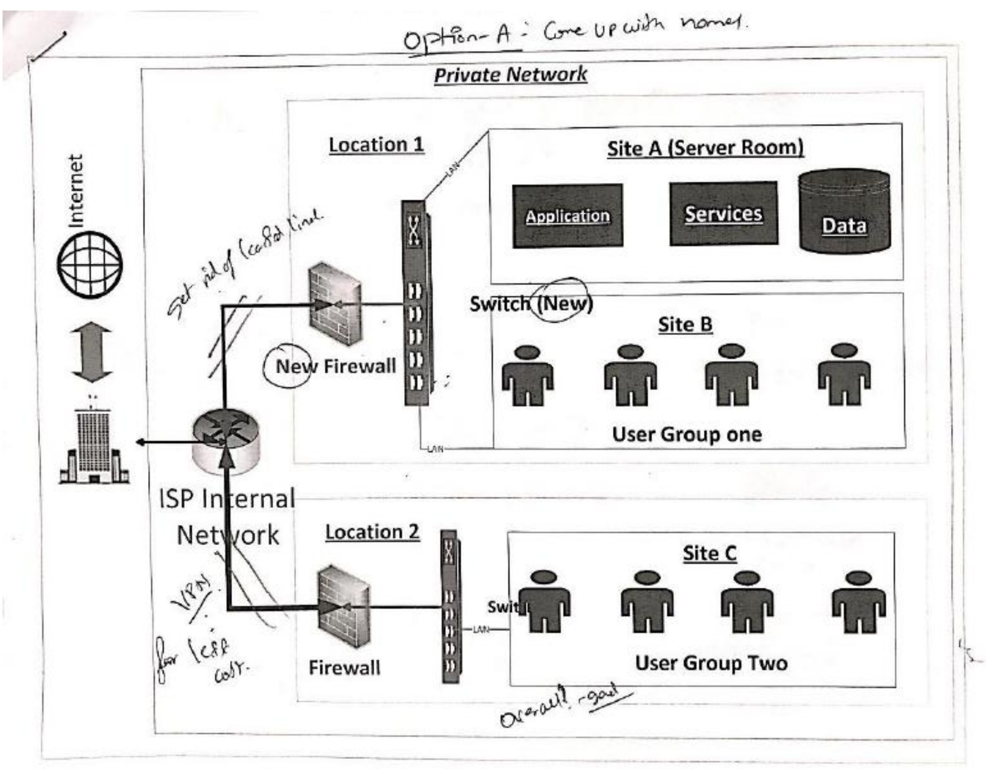

Application
Services
Data
Files
Backups
(Public Cloud)
VPN
if available?
Does different VPN work?
ISP Internal Network
Firewall
2 U
Network Switch
Physical Server
Services


B. - Service oriented
Private Network
Location 1
Site A (Server Room)
Services
Application and Data (Public Cloud)
Internet
Switch
Site B
Firewall
User Group one
ISP Internal Network
Location 2
Site C
Firewall
User Group Two
Use VPN
Less cost
Secured


Primary Domain Controller (Virtual)
Active Directory Services (ADS)
Primary Domain Name Server (Virtual)
DNS Manager (Domain Name Server)
Primary Mail Server (Virtual)
Mail Exchange Server
New Server
File Server (Virtual)
Secondary Domain Controller (Virtual)
Active Directory Services (ADS)
Secondary Domain Name Server (Virtual)
DNS Manager (Domain Name Server)
Physical Server 2
Application Server (Virtual)
Application
Database
Secondary Mail Server (Virtual)
Mail Exchange Server
Data Backups (Virtual)
Physical Server 3


New Server 1
Primary Domain Controller
Primary DNS
Primary Email Server
Physical Server 2
ISP Internal Network
New Firewall
Switch (New)
File Server
Secondary Domain Controller
Secondary DNS
Physical Server 3
Application Server
Data Backup
Secondary Email Server


4 U
New Server 1
ISP Internal Network
New Firewall
New Network Switch
Physical Server 2
Application
Services
Data
Files
Backups
Power Supply (UPS) (New)
Physical Server 3
Still only servers!
It is usual?
Most businesses go for this.


Option-A: Come up with names.
Private Network
Location 1
Site A (Server Room)
Application
Services
Data
Internet
Switch (New)
Site B
New Firewall
User Group one
ISP Internal Network
Location 2
Site C
Firewall
User Group Two
Overall - good

Appendix-H

Interview Notes from Expert 2's Meeting

Expert's Interview Questions

Full Name: Parker Moran

Organization: UNCW

1. Would you like to appear your name in the final project report?

   Yes

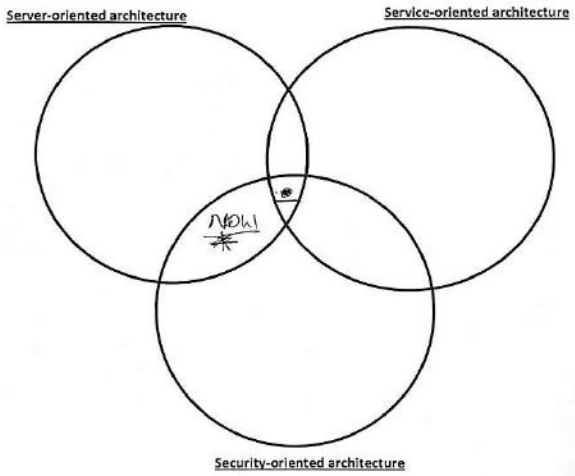
2. Do you provide a permission to audio tape the conversation?

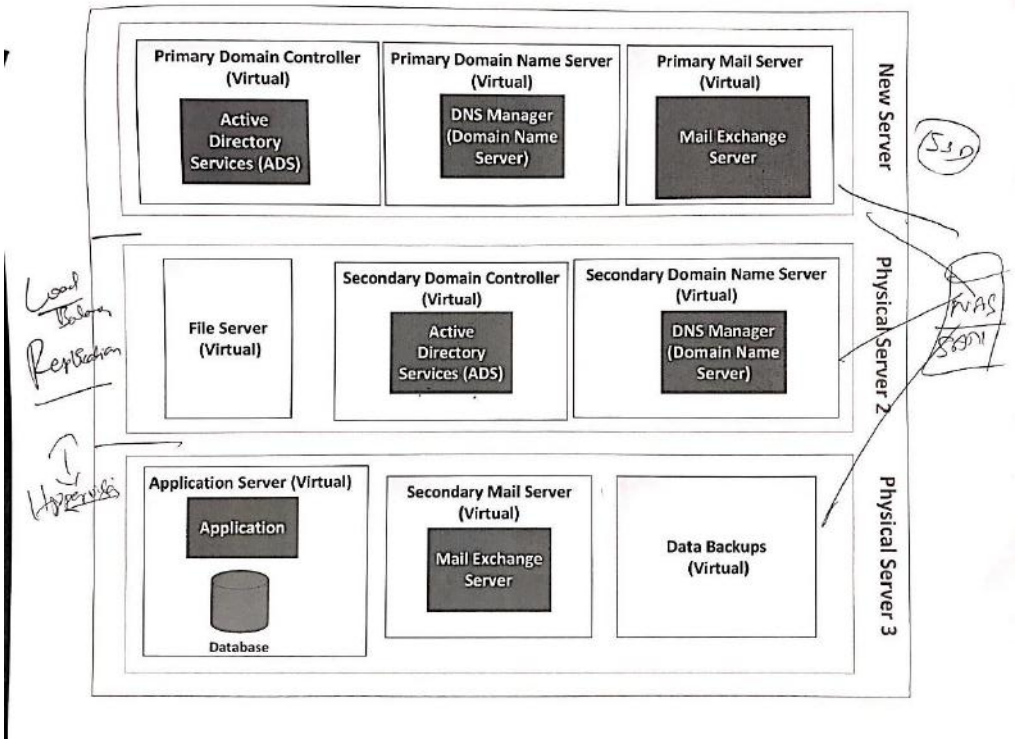
   Yes.

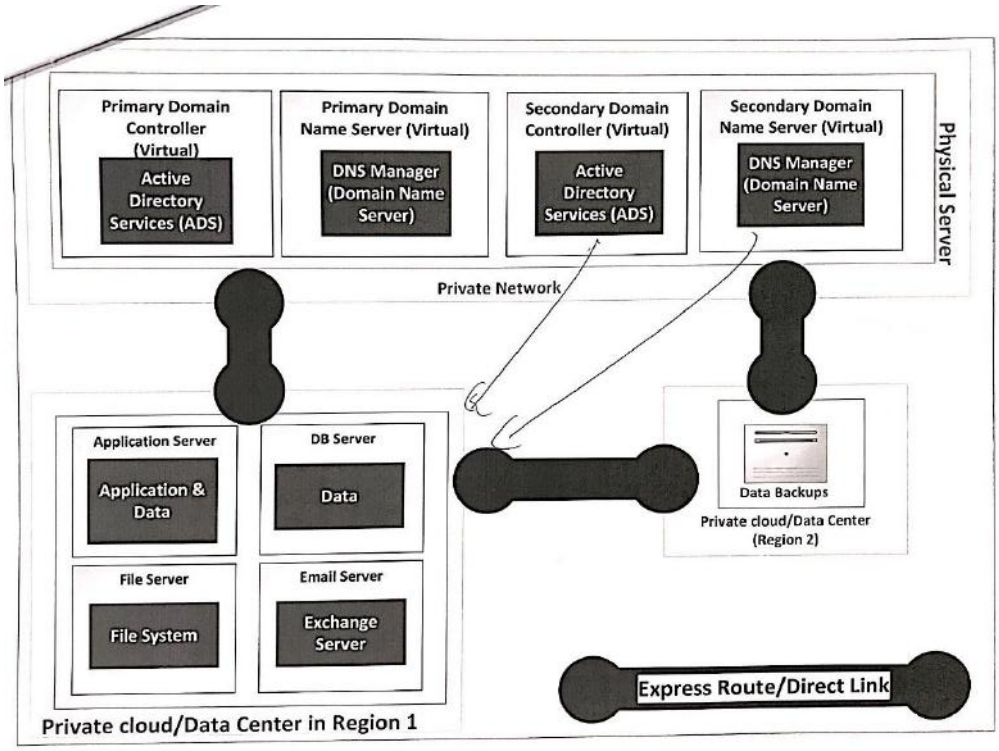
3. The metrics for designing the proposed architectures are taken from previous surveys and they are grouped as below. Are they appropriate for SMB's? Yes

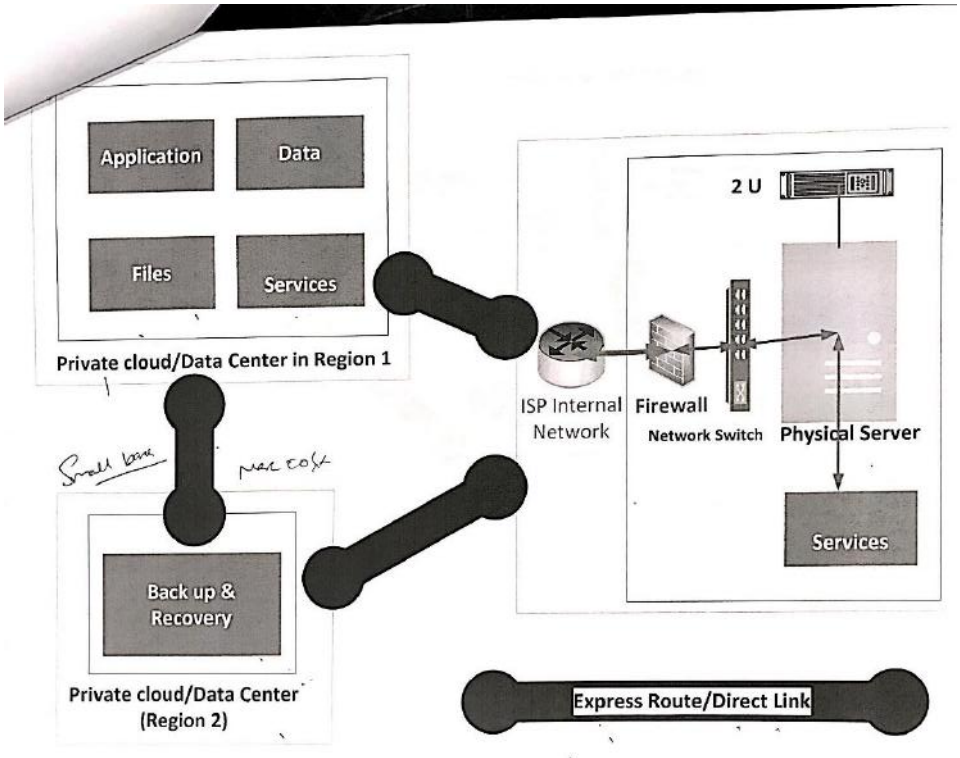
Architecture - A	Architecture - B	Architecture - C
Robustness	Maintenance	Security
Reliability	Flexibility	Privacy
Efficiency	Agility	Business continuity

1. Where is your organization's architecture fit in the below structure? (Please highlight)
2. Where would you like to see your organizations architecture in future (3-5 years)?






Primary Domain Controller (Virtual)
Active Directory Services (ADS)
Primary Domain Name Server (Virtual)
DNS Manager (Domain Name Server)
Secondary Domain Controller (Virtual)
Active Directory Services (ADS)
Secondary Domain Name Server (Virtual)
DNS Manager (Domain Name Server)
Physical Server
Private Network
Application Server
Application & Data
DB Server
Data
File Server
File System
Email Server
Exchange Server
Private cloud/Data Center in Region 1
Data Backups
Private cloud/Data Center (Region 2)
Express Route/Direct Link


Application
Data
Files
Services
Private cloud/Data Center in Region 1
2 U
ISP Internal Network
Firewall
Network Switch
Physical Server
Services
Back up & Recovery
Private cloud/Data Center (Region 2)
Express Route/Direct Link

Proposed Architecture C – Security Oriented architecture

Appendix-I

Interview Notes from Expert 3's Meeting

Expert's Interview Questions

Full Name: Matt Hernandez

Organization: NHRMC

1. Would you like to appear your name in the final project report? - Yes
2. Do you provide a permission to audio tape the conversation? Yes
3. The metrics for designing the proposed architectures are taken from previous surveys and they are grouped as below. Are they appropriate for SMB's?

Architecture - A	Architecture - B	Architecture - C
Robustness	Maintenance	Security
Reliability	Flexibility	Privacy
Efficiency	Agility	Business continuity

Cost

Server

Service

Security

Secured

Simple

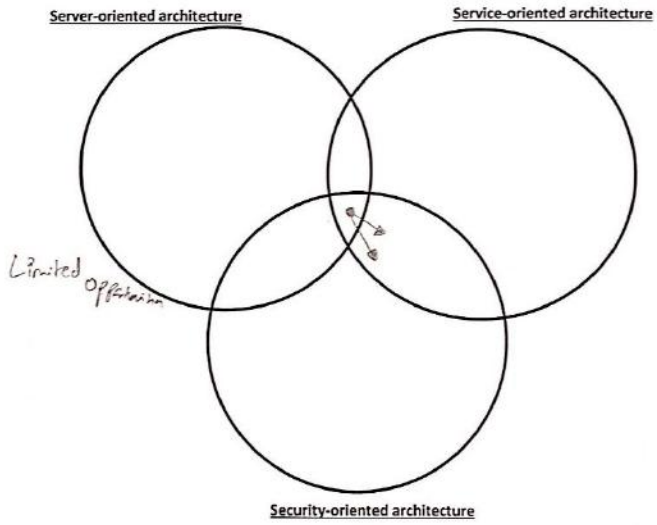
New Business (Extremely Appropriate)

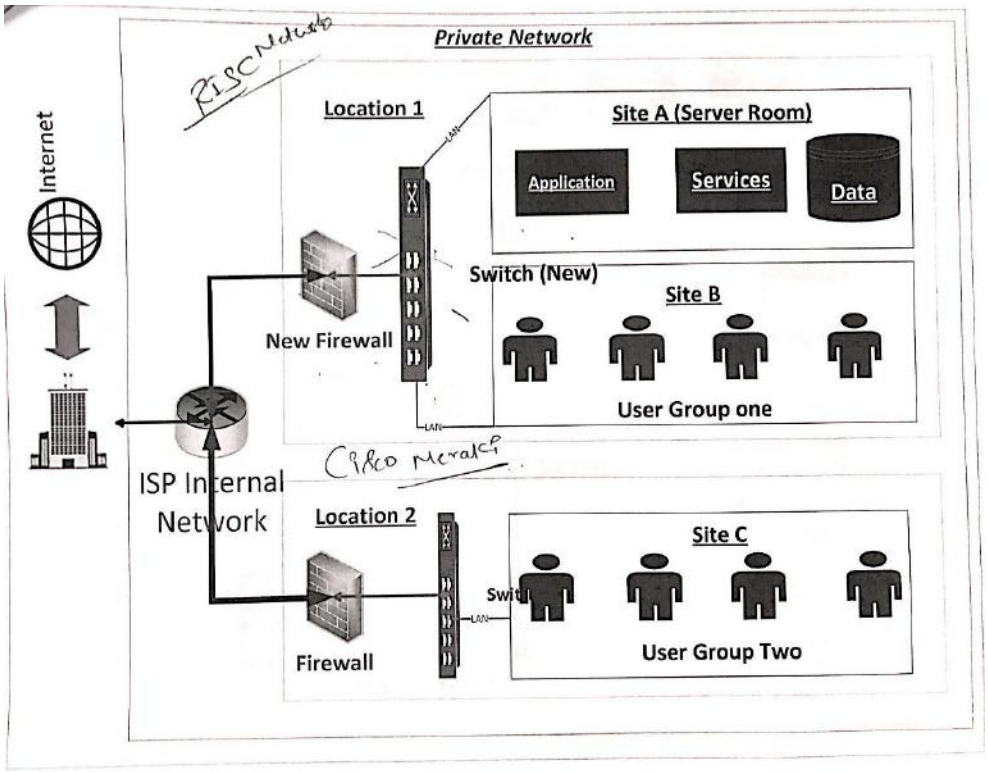
Business value?

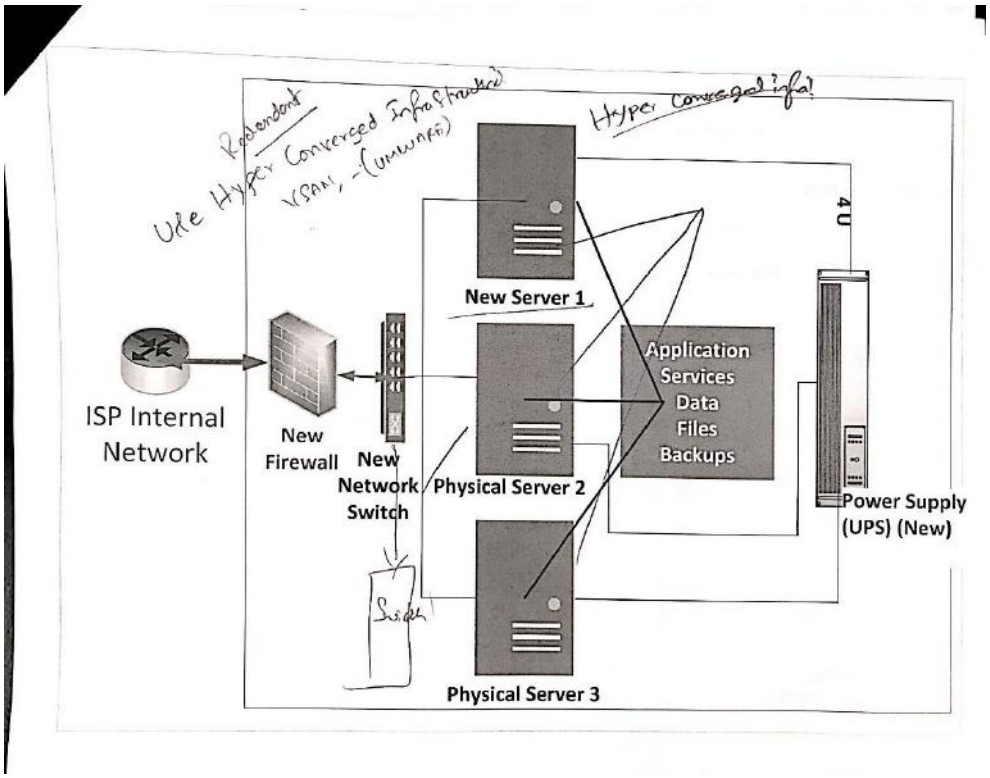
- N:

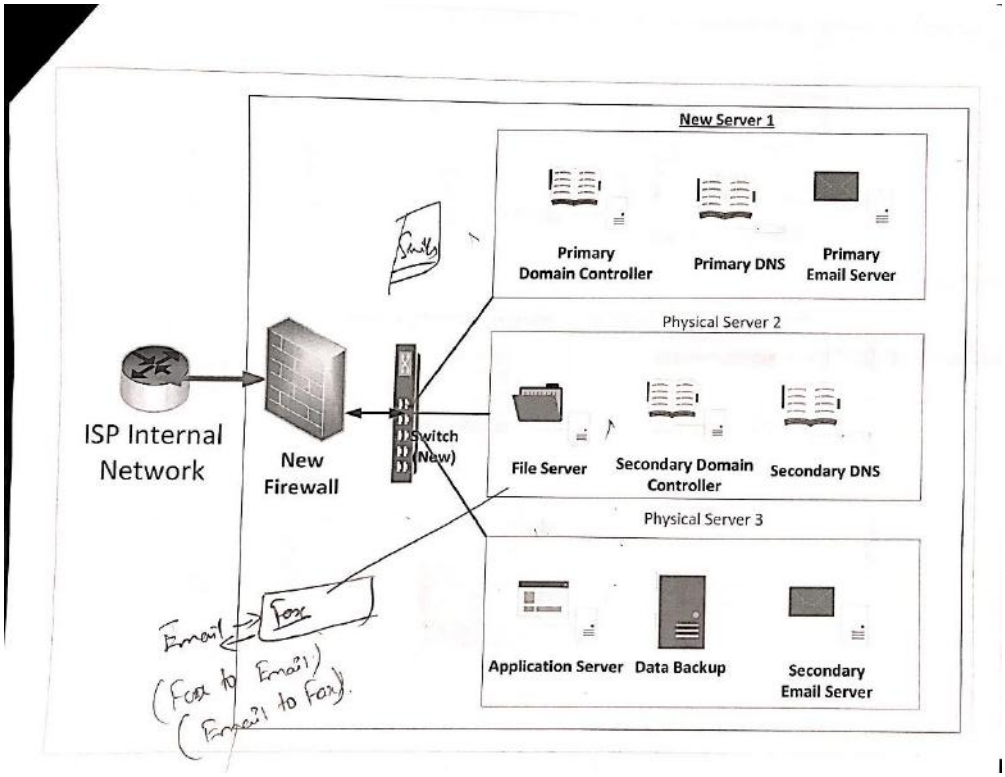
Expensive?

1. **Where is your organization's architecture fit in the below structure? (Please highlight)**
2. **Where would you like to see your organizations architecture in future (3-5 years)?**

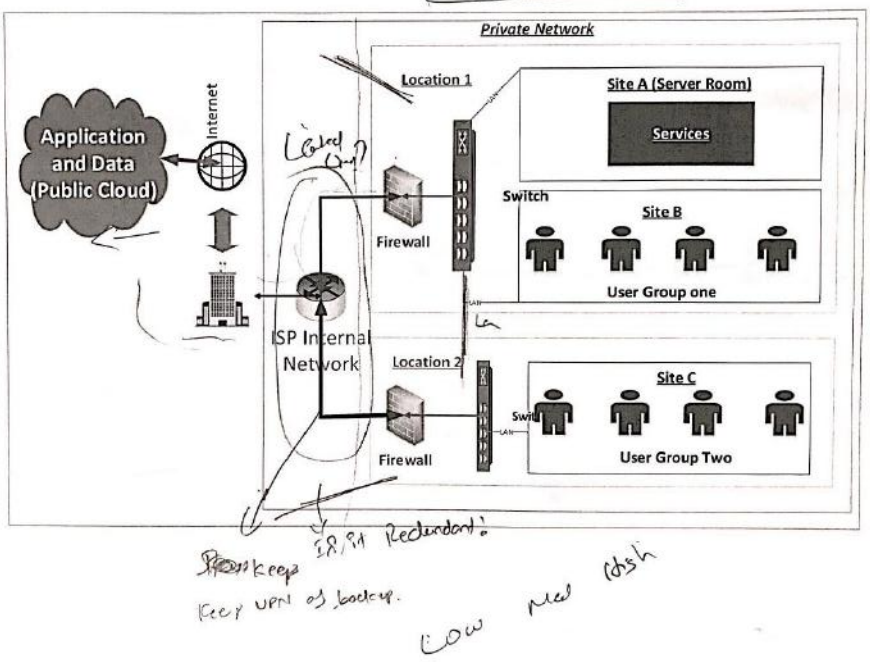


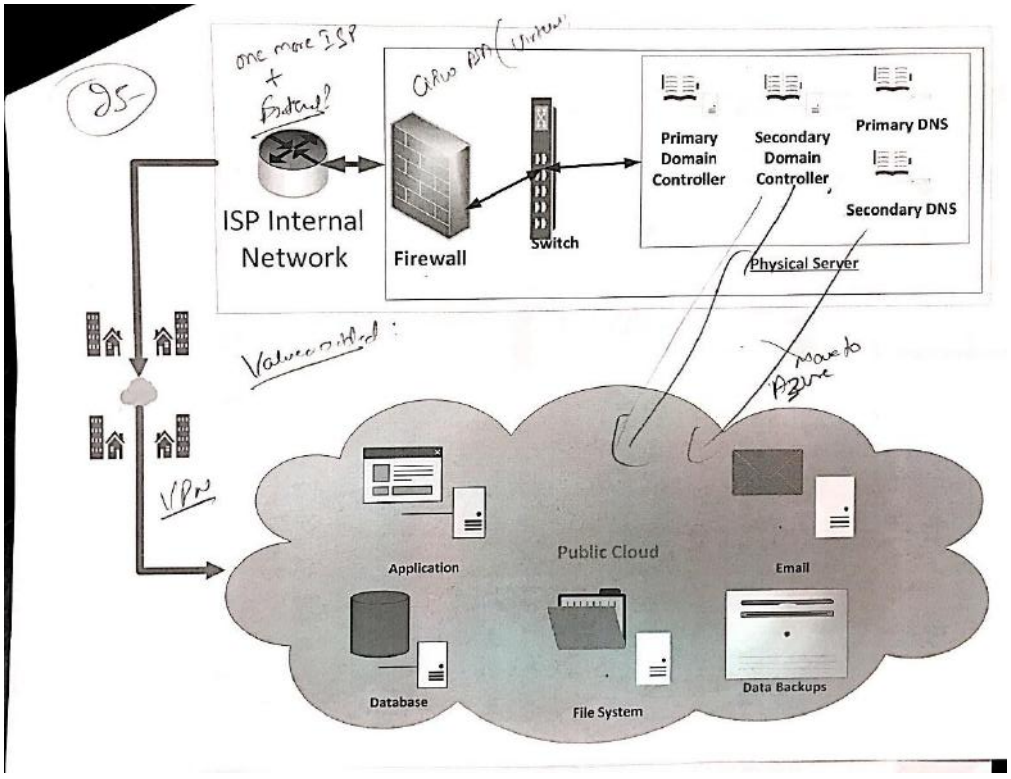


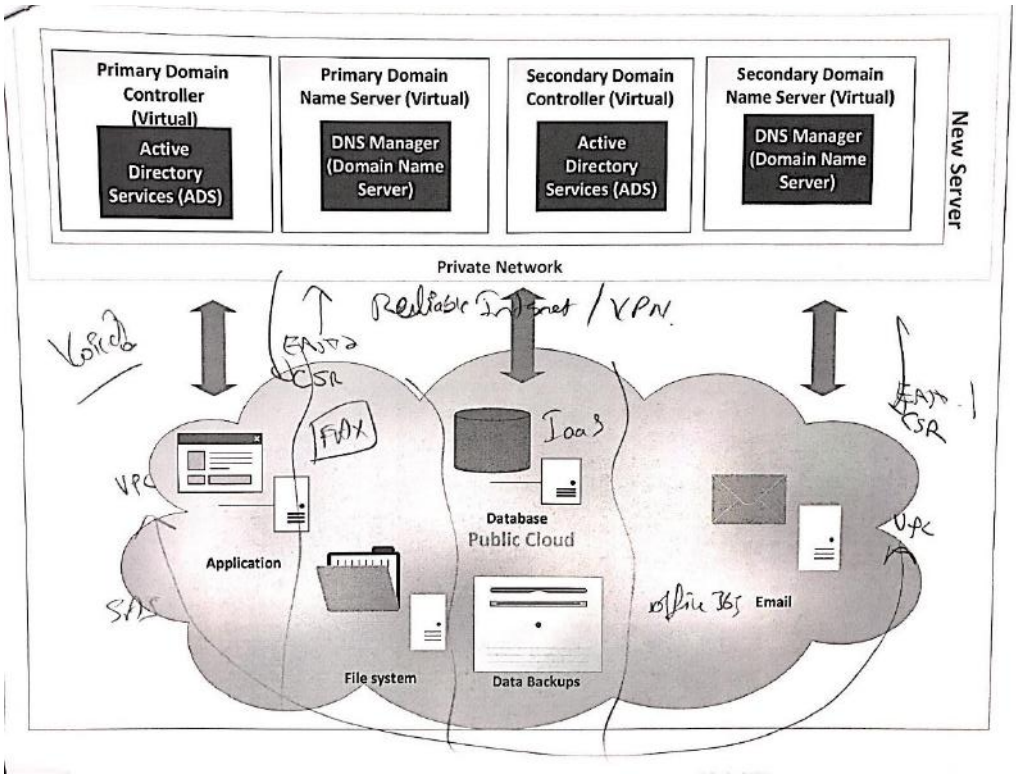

Redundant
Use Hyper Converged Infrastructure
vSAN, -(unknown)
Hyper Converged infra
4U
New Server 1
ISP Internal Network
New Firewall
New Network Switch
Physical Server 2
Application Services Data Files Backups
Power Supply (UPS) (New)
Physical Server 3


New Server 1
Primary Domain Controller
Primary DNS
Primary Email Server
Physical Server 2
File Server
Secondary Domain Controller
Secondary DNS
Physical Server 3
Application Server
Data Backup
Secondary Email Server
ISP Internal Network
New Firewall
Switch (New)
Fax
Email
(Fax to Email)
(Email to Fax).

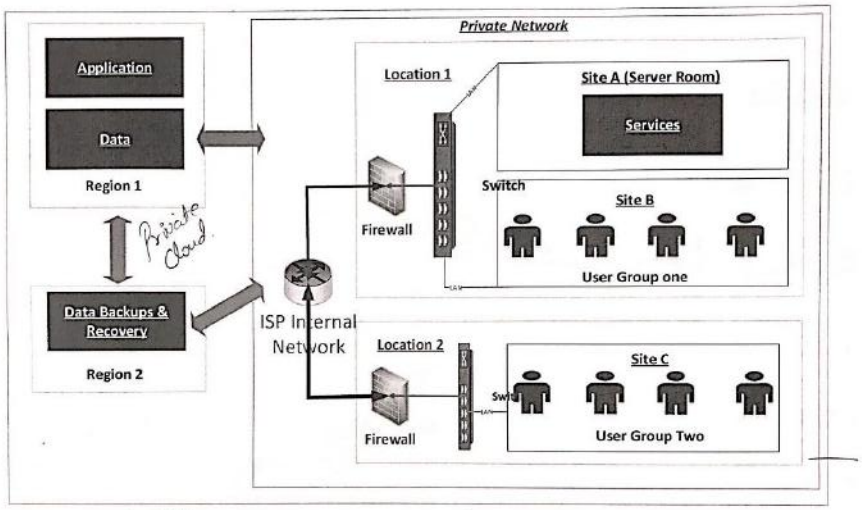
Proposed Architecture B – Service Oriented architecture





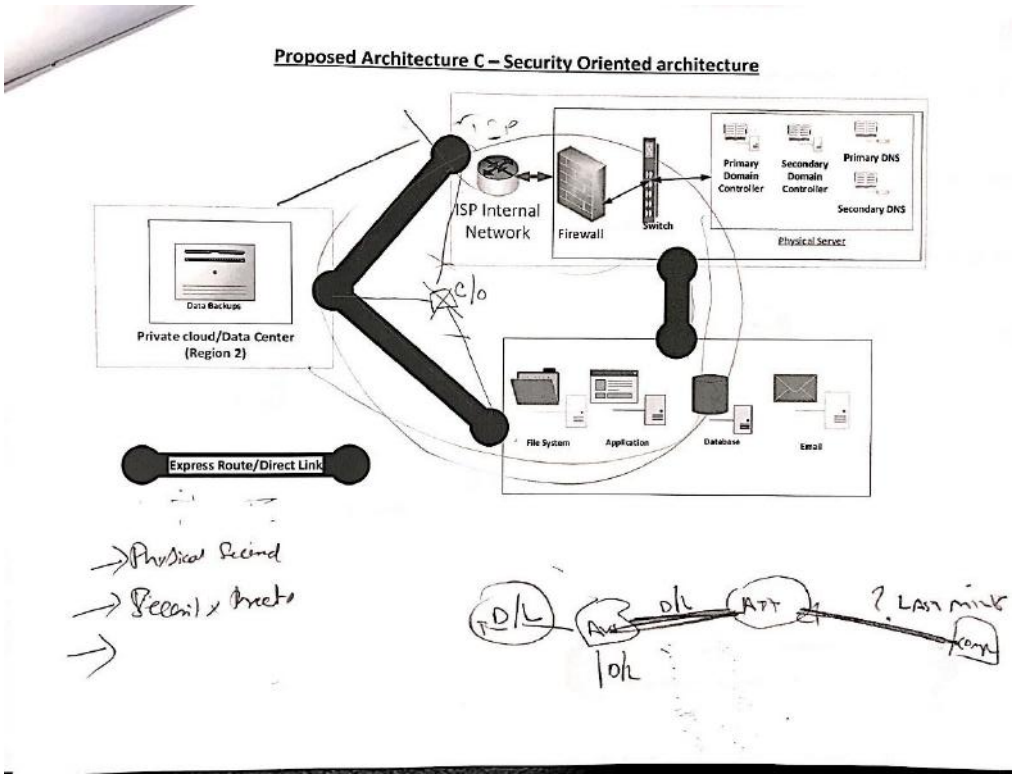


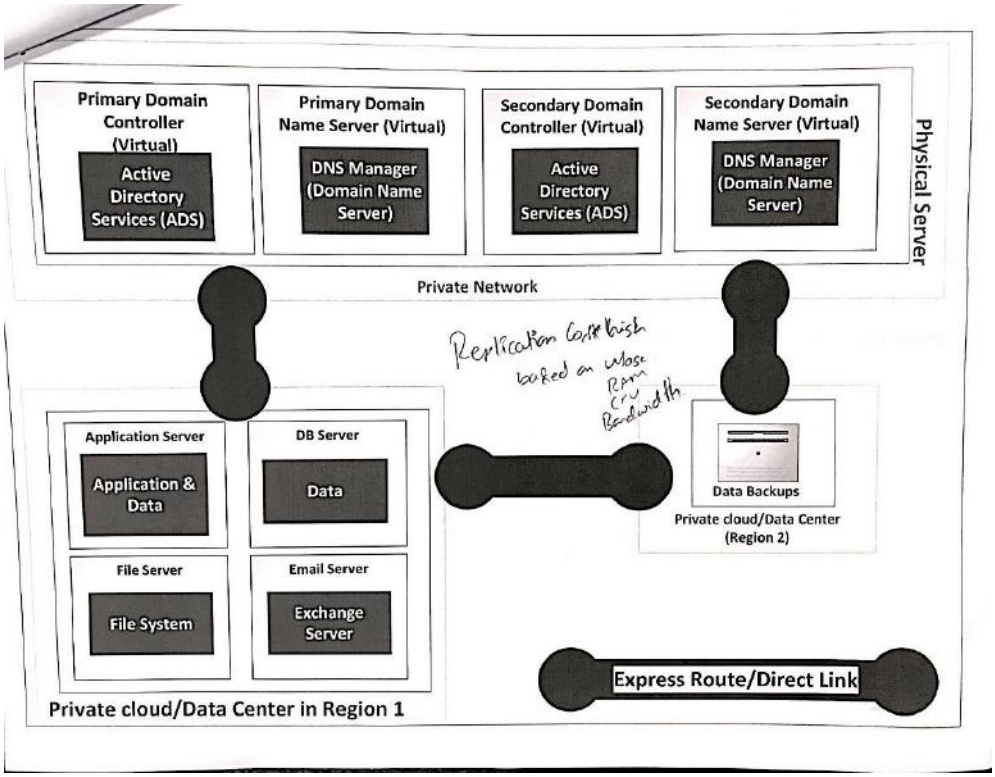
Proposed Architecture C – Security Oriented architecture



Maintenance
Complete
ownership
Business Agreement

Proposed Architecture C – Security Oriented architecture





Appendix-J

Revised Diagrams for Maintain & Upgrade Architecture.

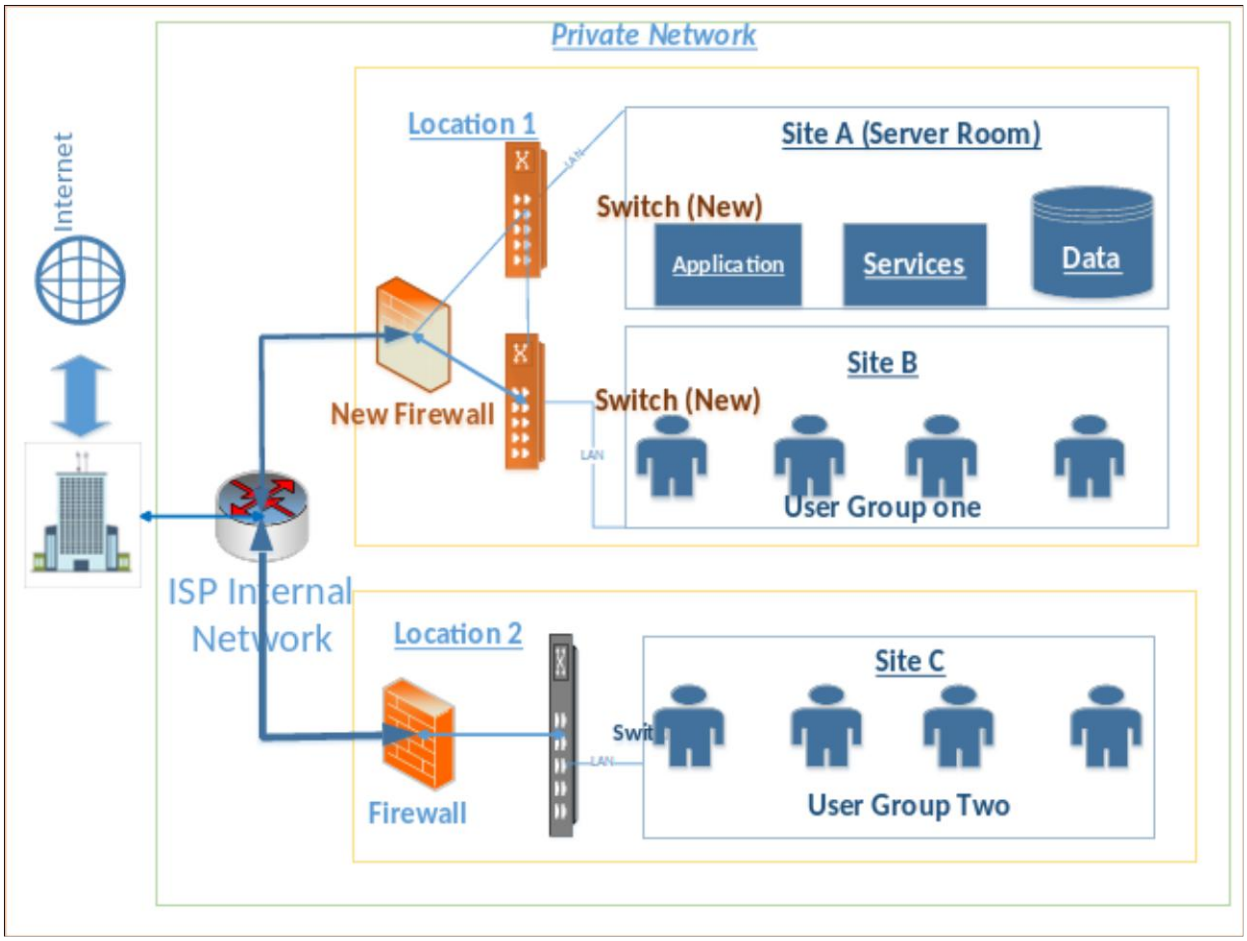


***Diagram** 21 Revised Network Architecture for MU Architecture*

Appendix-K

Revised Diagrams for FM oriented Architecture.

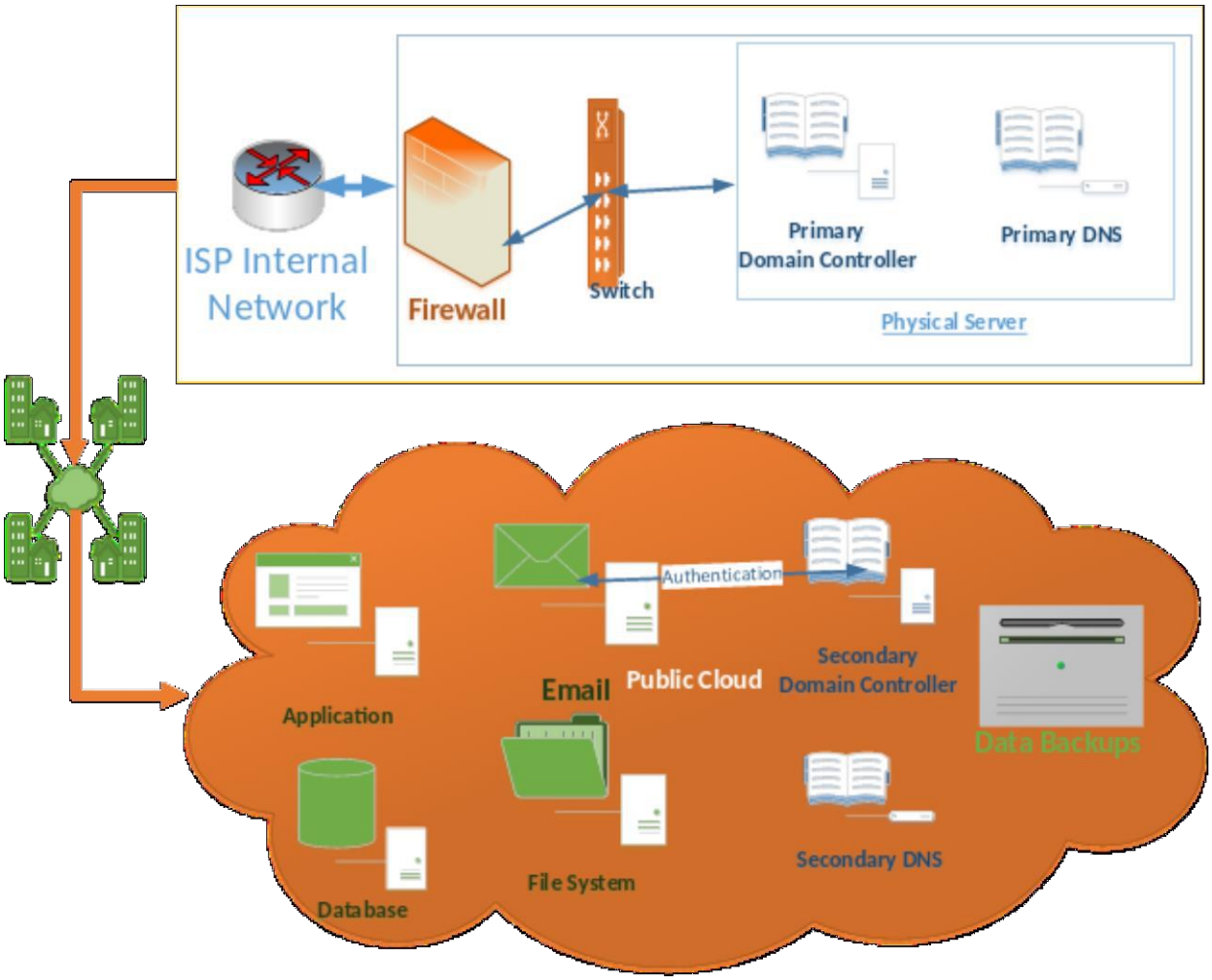


***Diagram** 22 Revised Server-Virtualization Architecture for FM oriented Architecture*

Appendix-L

Revised Diagrams for Business continuity, Security & High availability oriented Architecture.

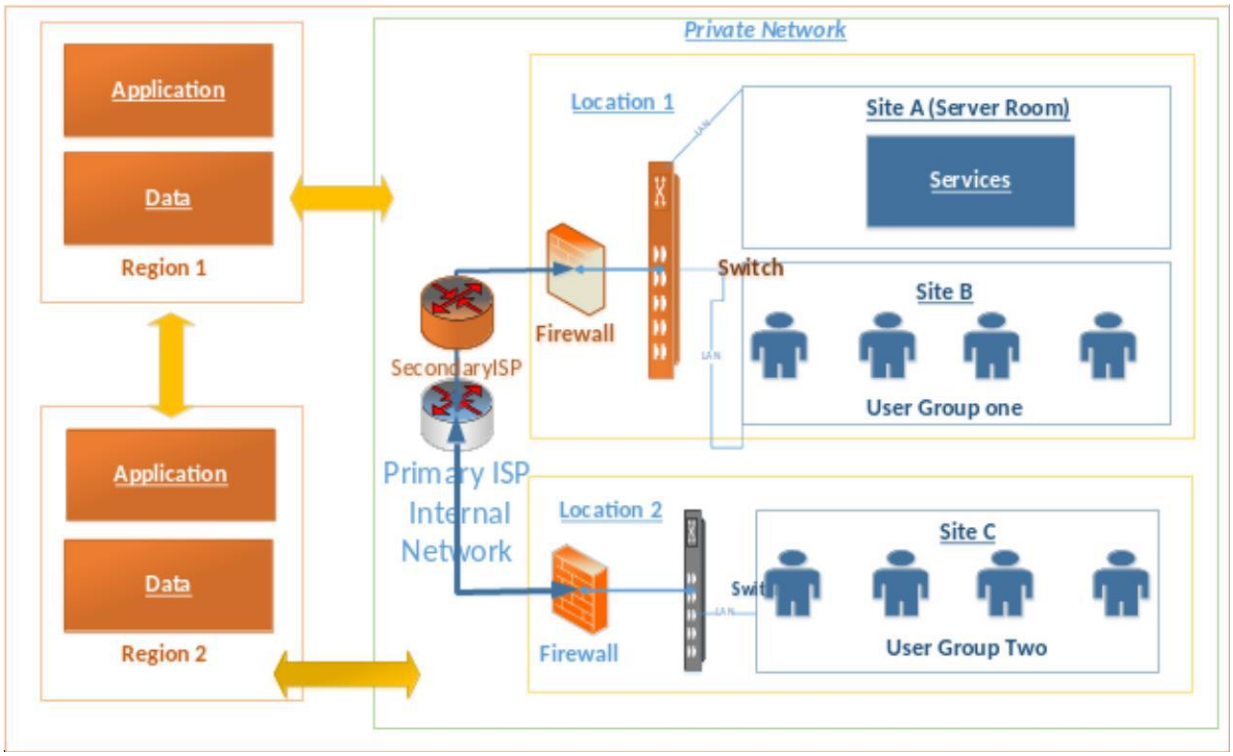


***Diagram** 23 Revised Network Architecture for BSH oriented Architecture*

***Diagram** 24 Revised Physical Architecture for BSH oriented Architecture*

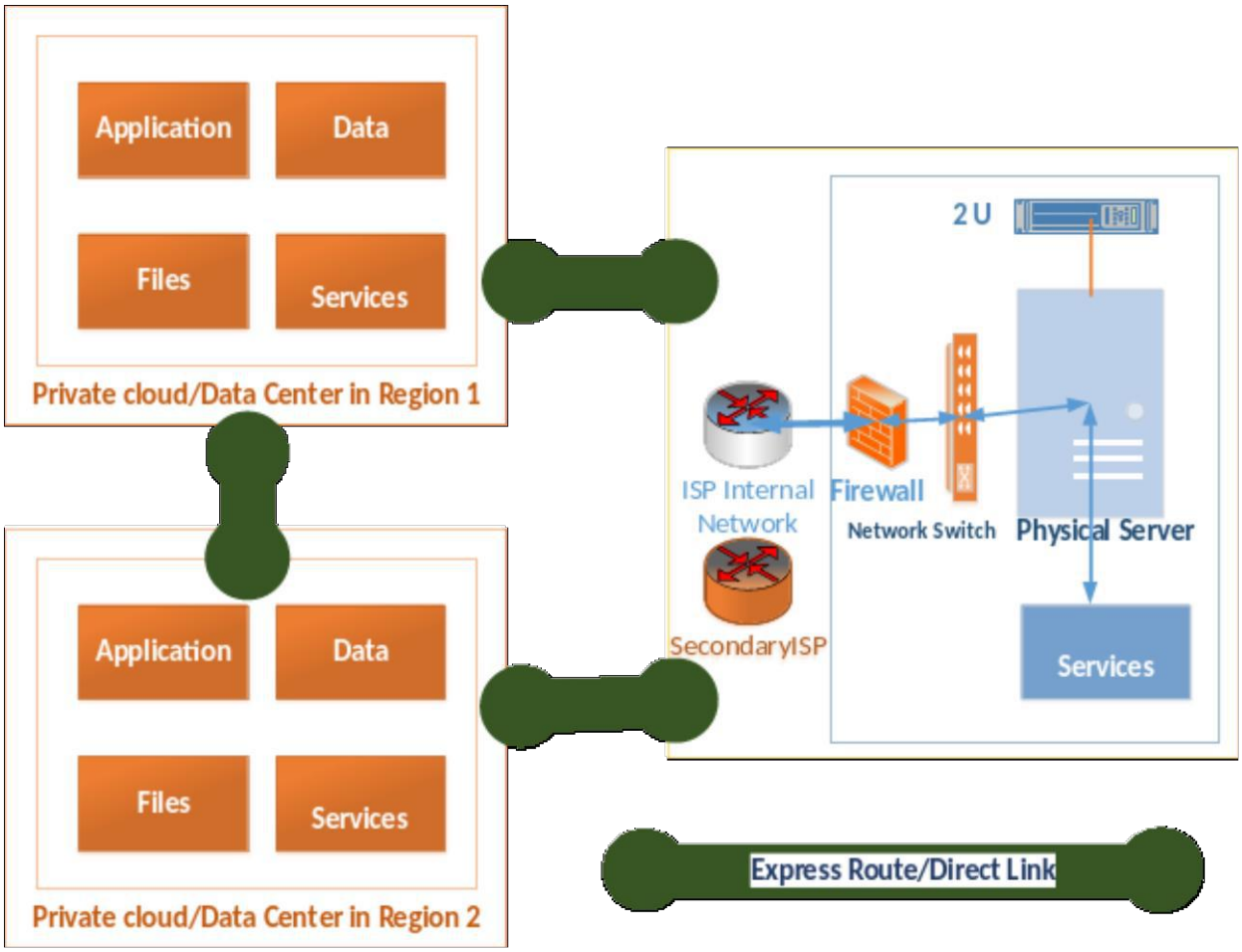


***Diagram** 25 Revised Physical Server Architecture for BSH oriented Architecture*

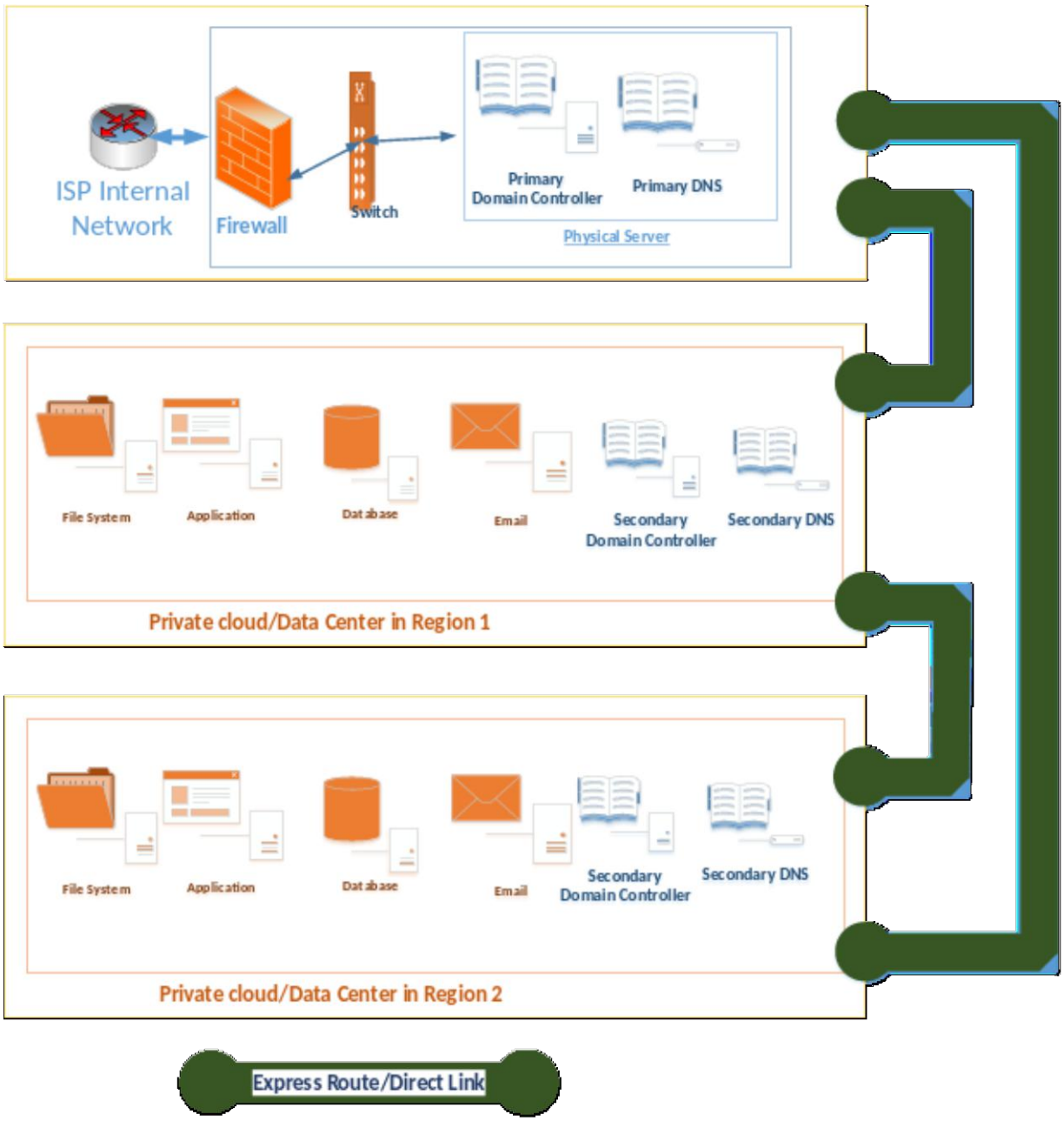


***Diagram** 26 Revised Server-virtualization Architecture for BSH oriented Architecture*

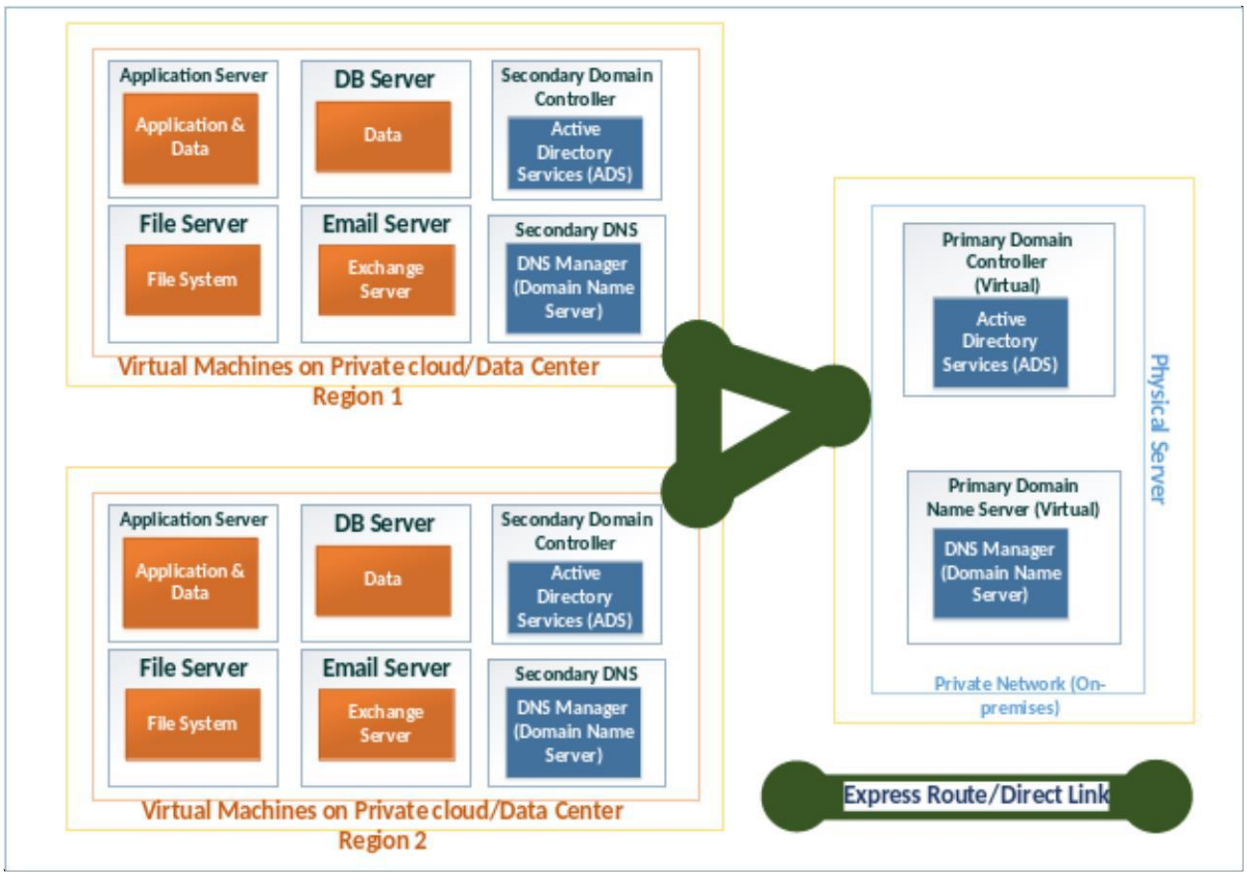


***Diagram** 27 Revised Server Roles for BSH oriented Architecture*