



ADDIS ABABA UNIVERSITY

COLLEGE OF NATURAL AND COMPUTATIONAL SCIENCES

SCHOOL OF INFORMATION SCIENCE

DATA CENTER VIRTUALIZATION FRAMEWORK IN BANKING

SECTOR: THE CASE OF WEGAGEN BANK S.C

BY:

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ADDIS ABABA UNIVERSITY
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A THESIS

ON:

**DATA CENTER VIRTUALIZATION FRAMEWORK IN
BANKING SECTOR: THE CASE OF WEGAGEN BANK S.C**

BY:

GETENET WORKU MEKOYA

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**THE SCHOOL OF INFORMATION SCIENCE OF ADDIS
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REQUIREMENTS FOR THE DEGREE OF MASTER OF
SCIENCE IN INFORMATION SCIENCE**

DECLARATION

I, the undersigned, declare that this thesis is my original work and has not been presented as a partial degree requirement for a degree in any other university and all sources of materials used in the thesis have been duly acknowledged.

GETENET WORKU

The thesis has been submitted for examination with my approval as university advisor.

DEREJE TEFERI (PhD)

June 2017

ADDIS ABABA UNIVERSTY
COLLEGE OF NATURAL SCIENCES
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BY
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DEDICATION

This thesis is dedicated to my beloved father

WORKUMEKOYA

Your spirit is always with me, and my little brother

MICHEAL WORKU

For the inspiration you gave me during my studies.

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TABLE OF CONTENTS

Abstract.....i

List of figures.....ii

List of tables.....iii

List of acronyms.....iv

CHAPTER ONE: INTRODUCTION.....1

1.1 Background1

1.2 Overview of Wegagen bank data center 3

1.3 Statement of the problem..... 4

1.4 Objective of the study.....6

1.4.1 Major Objective.....6

1.4.2 Specific Objectives.....6

1.5 Significance of the Study 6

1.6 Scope and limitation 7

1.7 Organization of Thesis 7

CHAPTER TWO: LITREATURE REVIEW

2.0 Literature Review9

2.1 Data center.....9

2.2 International standards for data center.....10

2.3 Logical layout architecture for data center.....11

2.4 Data center Design parameter.....12

2.4.1 Security.....12

2.4.2 Scalability.....	13
2.4.3. Greener technology.....	13
2.4.4 Low T.C.O.....	13
2.4.5 Intelligent management.....	13
2.5 Modular data center	14
2.6 Components of Data center.....	14
2.6.1 Electric Supply System.....	15
2.6.2 Low Voltage routing.....	16
2.6.3 Raised Floor.....	16
2.6.4 Environmental Control.....	16
2.6.5 Fire Protection.....	17
2.6.6 Security.....	17
2.7 Evolution of Data Center.....	18
2.8 Complexity in Data center.....	20
2.9 Data center Infrastructure management.....	21
2.10 Data center Infrastructure management models.....	22
2.10.1 Gartner Model.....	22
2.10.2 451 Group Model.....	22
2.10.3 Forrester Model.....	23
2.11 Data center management Components.....	24
2.12 Virtualization.....	26
2.13 Generation of Virtualization.....	26

2.14 Virtual Machine Monitor.....	28
2.15 Methods of Virtualization.....	31
2.16 Data center Virtualization.....	33
2.17. ICT and Ethiopian Banking Industry.....	36
2.17.1 Banking overview	36
2.17.2 ICT challenges of Ethiopian banking sector	37
2.18 Challenges and opportunities of Virtualization	38
2.18.1 Virtualization in banking sector... ..	38
2.18.2 Opportunities of virtualization	38
2.18.3 Challenges of Virtualization	39
2.19 Security threats of Virtualization environment	40
2.19.1 Threats of Virtualization environment	41
2.20 Related works	41

CHAPTER THREE: RESEARCH METHODOLOGY

Research design and methodology	46
3.1 Methodology of the study.....	46
3.2 Design science research methodology	47
3.3 Problem identification and selections.....	47
3.4 Define the objective of solution.....	48
3.5 Source of data and data collection method.....	48
3.6 Study population and sampling.....	49
3.7 Methods of data analysis.....	50

3.8 Design and development	50
3.9 Demonstration.....	51
3.10 Evaluation.....	51
3.11 Conceptual framework.....	53
3.12 Procedure.....	53
3.13 Ethical consideration.....	54
 CHAPTER FOUR: DISCUSSION AND INTERPRATION	
4.1 Respondents information.....	55
4.2 What makes data center virtualization attractive.....	56
4.3 Interview interpretation	56
4.4 Performance comparison test.....	60
4.5 Installing and configuring VM machines for high availability.....	61
4.6 Summary of views.....	65
4.7 Functional requirements for the framework.....	65
 CHAPTER FIVE: THE PROPOSED VIRTUALIZTION FRAMEWORK	
5.1 Identifying virtualization type and implementation method.....	66
5.2 Data center virtualization method for Wegagen bank	66
5.3 The proposed virtualization framework	67
5.4 Building the framework	68
5.5 Evaluation of the proposed framework	71
 CHAPTER SIX CONCLUSION AND RECOMMENDATION	
6.1 Conclusion	73

6.2 Recommendation74

LIST OF FIGURES

Figure 2.1 Basic data center diagrams.....	10
Figure 2.2 TIA-942 Logical layouts.....	11
Figure 2.3 Data center evolution phase.....	18
Figure 2.4 Gartner Model	22
Figure2. 5 451 group model.....	23
Figure2. 6 Forrester model.....	23
Figure2. 7 DCM components.....	25
Figure 2.8 Illustration of virtual environment Architecture.....	28
Figure 2.9 Types of Virtualization Architecture.....	29
Figure 2.10 Traditional, bare metal and Hosted Virtualization Architecture.....	30
Figure 2.11 Major types of virtualization.....	31
Figure 2.12 Traditional Architecture.....	34
Figure 2.13 Virtual Architecture.....	34
Figure 2.14 Virtualization of Data Center.....	35
Figure 2.15 Green IT framework using virtualization.....	43
Figure 2.16 vBASE framework.....	45
Figure 3.1 Conceptual framework.....	53
Figure 4.1 Overview of single application server.....	61
Figure 4.2 Configured virtual machines.....	62
Figure 4.3 Overview of Virtualized machine.....	62
Figure 4.4 Overview of virtualized server.....	64
Figure 5.1 Proposed framework.....	69

LIST OF TABLES

Table 3.1 Total population of the study	50
Table 4.1 Biographic information of respondent.....	55

LIST OF ACRONYMS

ANSI	American national standards institute
ATM	Automated teller's machine
BMS	Building management system
CAPEX	Capital Expenditure expense
CIO	Chief Information Officer
DC	Data center
DCIM	Data center infrastructure management
DSRM	Design science research methodology
EATS	Ethiopian automated transfer system
ITSD	Information technology services department
OPEX	Operational expense
TCO	Total cost of ownership
TIA	Telecommunication industry association
VLAN	Virtual local area network
VMM	Virtual machine monitoring
VM	Virtual machine

ABSTRACT

As business and requirements grow, IT infrastructure must become more efficient and agile to meet the outlined strategies, business demands and remain competent. Banks are undertaking massive transformation of their IT infrastructure investments for quality service delivery and improved customer satisfactions. In addition, this technological infrastructure can reduce operational challenges and risks. Virtualizations across data centers is a growing technology for banking sector which provides huge savings in floor space, power and cooling cost and utilization of assets across network, storage devices and servers.

The objective of this research is to explore the current traditional (physical) infrastructure practice and to propose and develop data center virtualization framework that brings a preferred solution for banking sector for quality service delivery in effective, scalable, manageable, and secured manner. Moreover, the study aims to ensure high availability of information technology services for powering banking sectors from technology.

Design science research approach was employed. Data was collected through document analysis and interviewee with ITSD directors, infrastructure and system managers, senior system, database and network administrators and IT experts and the result has been interpreted. The proposed data center virtualization framework was evaluated by experts through demonstrations. Based on the interpretation and findings benefits, of virtualization in relation to high availability, management, scalability and flexibility for Wegagen bank is briefly discussed. The proposed DC virtualization framework will reduce IT infrastructure costs and management complexities and increase service availability and utilization of hardware. Accordingly, when the proposed DC virtualization is implemented, it will have major contribution for the banking sector in Ethiopia.

Key words: Data center, virtualization and Ethiopian banking sector

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

Information technology has become a key player in the economic development of the business world. Organizations today are confronted with rapidly and dynamically changing volatile market. Banking services have been changed and facilitated with the use of information technology for day to day activity in order to provide quality service to their customer with the use of modern day technology. These technologies can facilitate gathering, processing, disseminating, and storing of information in a wide range.

A data center is a special facility conceived to house, manage, and support computing resources that are considered critical for one or more organizations. It provides the capabilities of centralized repositories for storage, management, networking and dissemination of data. A particularly complex structure, a typical data center encompasses special building structures, power backup structures, cooling systems, special-purpose rooms (entrance and telecommunications, for example), equipment cabinets, structured cabling, network devices, storage systems, servers, mainframes, application software, physical security systems, monitoring centers, and many other support systems. All these resources and their interaction are (locally or remotely) managed by specialized personnel [16].

Telecommunication Industry Association (TIA) is accredited by the American National Standards Institute (ANSI) to develop voluntary, consensus-based industry standards for a variety of ICT segments. The Data center requires high availability to run the business. But not all data centers can meet the availability criteria. According to ANSI/TIA-942 standards, data center can be classified to four Rating/Tiers [31].

Rated-1/Tier-1, basic site infrastructure downtime 28.8 hours a year, 99.671% available, data center which has single path for power and cooling distribution, no redundant component.

Rated-2/Tier-2, redundant capacity component site infrastructure downtime 22 hours a year, 99.741% available, a data center which has a single path for power and cooling distribution includes redundant component.

Rated-3/Tier-3 concurrently maintainable site infrastructure downtime 1.6 hours a year, 99.982% available, a data center which has multiple paths for power and cooling distribution path, but with only one active

Rated-4/Tier-4 Fault Tolerant Site Infrastructure downtime 0.8 hours a year 99.995% available, a data center which has multiple path for power and cooling distribution path with all are active.

A Virtualized data Center is a data center where some or all of the hardware (e.g., servers, routers, switches, and links) are virtualized [16]. Typically, a physical hardware is virtualized using software or firmware called hypervisor that divides the equipment into multiple isolated and independent virtual instances. For example, a physical machine (server) is virtualized via a hypervisor that creates virtual machines (VMs) having different capacities (CPU, memory, disk space) and running different operating systems and applications.

The advantage of data center virtualization is that it has a capability of reducing IT investment costs, management complexity, security, efficient utilization of resources, and high availability of banking services. There are many ways to implement data center virtualization in banking sector, such as Network virtualization, Storage virtualization, Server virtualization and desktop virtualization [19]. The current study focuses on desktop/client virtualization.

Network virtualization is the combination of hardware and software network resources, and it combines network functionality into a single virtual network by creating logical virtual networks. It segments the network in to sub-network to increase the performance by minimizing local traffic in the network and improving security by making the internal network structure invisible from the outside.

Storage virtualization is the pooling of physical storage from multiple network storage devices into what appears to be a single storage device that is managed from a central console. Storage virtualization helps the storage administrator to perform the tasks of backup, archiving, and recovery more easily and in less time.

Server virtualization is the masking of server resources, which helps in partitioning the physical server into smaller virtual servers to maximize resources by dividing the physical server into multiple virtual environments. It allows running different operating systems and rebooting independently. It is also used to identify and isolate applications that are unstable. Server

virtualization is mostly used in application and web servers, Server utilization manages complicated details of server resources while increasing utilization rates and maintaining capacity.

Desktop virtualization allows for the creation, modification or deletion of desktop images and separates the desktop environment from the physical computer that is used to access it. It provides more security to the user by providing a guest Operating System image for the desktop environment and it doesn't allow copying or saving of data to a disk other than the server, making desktop virtualization is a more secure option for networking.

1.2 OVERVIEW OF WEGAGEN BANK DATA CENTER

Wegagen bank SC was established on June 11, 1997. Its main data center is located in Addis Ababa. The current data center infrastructure is the traditional one with no virtualization. Wegagen bank has an IT infrastructure that consists of Application Servers, Data base servers, Storage Area Network, Tape and Backup storage. Moreover, it has two (2) sites: One used as the Live Data center while the other is a Disaster recovery site.

Wegagen bank uses banking application and financial system software, which is an integrated software package that constitute modules like deposit accounts (ordinary saving, fixed time deposit, current accounts etc), international banking, credit management, general ledger, treasury operations and others. The bank's data center and networking infrastructure are built to suite the current fully centralized service offering. The data center is configured in a client/server architecture which is mainly equipped with redundant database and application servers.

Equipment's at head office data center include the following.

- Application Servers – HP C7000 Blade Enclosure with 13 Hp BL 460 G7 Blade Servers.
- Database Servers – Four HP DL 580 G7
- Storage Area Network – 2 HP 8/8 Port Enabled SAN Switch
- Storage – Two HP X1800 storage server and Two EVA 4400 Dual Controller Array with Three HP M6412-A Fiber Channel Drive Enclosure
- Tape Backup - HP MSL2024 1 LTO-4 Ultrium1840 FC TP Lib

Equipment's at disaster recovery (DR) site

- Application Servers – HP C7000 Blade Enclosure with Five Hp BL 460 G7 Blade Servers.
- Database Servers – Two HP DL 580 G7
- Storage Area Network – One HP 8/8 Port Enabled SAN Switch
- Storage – One X1800 storage server and One EVA 4400 Dual Controller Array with Two HP M6412-A Fiber Channel Drive Enclosure
- Tape Backup – One HP MSL2024 1 LTO-4 Ultrium1840 FC TP Library
- Networking Infrastructure has 2 x Firewalls + Several Switches and Load Balancers.

1.3. STATEMENT OF THE PROBLEM

Data is the most valuable corporate asset for both tangible and intangible benefits. The real problem that chief information officer (C.I.O) in any organization faces is how to effectively access, store, manipulate, manage and secure data. Mostly, banks built their data center infrastructure traditionally to optimize enterprise business operation process, and this infrastructure should comply with the exponential growth of their data to make high available with maximum performance. This growth of data on daily bases leads the organization to increase their infrastructure in storage, network and processes. To face these challenges banks are spending a huge amount of money on data center infrastructure which is storage, servers, networks cooling and power.

Data center is a core part for many organizations which can provide the place for all core devices, servers and storage and protect them to keep running properly and efficiently. These data centers have direct connection with business partners' and must provide options for connectivity, power, cooling, backup, fire, water and smoking detection and multi-layered security to protect the integrity and high availability of data.

Currently Ethiopian public (both government and private) banking sectors implemented Centralized Online Real-time Exchange (CORE) banking. CORE banking functions include transaction, accounts, loan and payments. Banks make these services available across multiple channels like Automatic Teller Machines (ATMs), internet banking, mobile banking and connect

branches with the help of CORE banking system software. CORE banking basically enables and networks the entire bank's branches to access application from the central data center. Wegagen bank uses OMNI Enterprise Core Banking Solution which has computerized entire business of the bank covering Retail & Corporate offerings including current account and saving account (CASA), Lending, Credit Monitoring & Recovery, Overdrafts, Term Deposits, Remittance, Merchandise Loans, Clearing and Ethiopian Automated Transfer System (EATS). The solution provides interfaces to the local real time gross settlement (RTGS) and Check truncation system (CTS), ECX (Ethiopian Commodity Exchange) interface, Trade Finance Permit approval as per national bank of Ethiopia (NBE).

Wegagen bank is currently running Rated-1/ Tier 1, and yet traditional data center having down time of about 22 hours in a year which is real problem and that affects the daily business activity and its goal. To come up with high availability and to boost its performance this should be upgraded to Rated-3/Tier 3 with a downtime of less than 2 hours a year. The banking industry requires IT to speed up the business growth, which needs flexible, efficient and high level information technology infrastructure. The top priorities in banking industry to maintain the statues using high level technology standards increase its profitability, efficiency of quality services, reducing operational cost and time value. As banks are customer driven and technology dependent, to satisfy end users and stakeholders the banking industry has various challenges in regards to:

1. Operational efficiency
2. Customer satisfaction
3. Flexibility
4. Business continuity with high available service
5. Confidentiality of customer data
6. Reduced risk

The introduction of new technological solution using virtualization, the data centers gives the banking industry to gain a competitive advantage by substantially improving the IT system efficiency with high availability of services and reducing risks associated with the storage, network, process and transfer of information. The data center virtualization infrastructure technology guides the banking services to deliver solution that is high available, flexible, agile,

cost effective, reliable, and that meets requirements set by the government regulations and business environment in a dynamic and competitive market.

To this end the study explores and answers the following research questions:

1. What data center practice is employed in Wegagen bank? And what are the problems that impedes for the implementation of virtualization in data center?
2. How could Data center virtualization be an alternative and preferred solution for Wegagen Bank?
3. Is the current infrastructure is efficient, cost effective and high available for service delivery in Wegagen bank.
4. Could data center virtualization ensure quality of service delivery?

1.4. OBJECTIVE OF THE STUDY

1.4.1 MAJOR OBJECTIVE

The main objective of this study is to propose a virtualized data center framework, which can be implemented in Wegagen bank and can bring a better solution for the use of information technology to deliver efficient, flexible, manageable, secured, and high availability of information technology services for leveraging banking industries from technology.

1.4.2. SPECIFIC OBJECTIVES

- ✓ To assess the current data center practice and infrastructure of Wegagen bank.
- ✓ To review data center and virtualization related literatures to understand different virtualization deployment methods and framework development methods.
- ✓ To identify the current data center infrastructure problem in Wegagen bank.
- ✓ To explore the benefits of virtualized data center in Wegagen bank.
- ✓ To compare the availability, and power effect of traditional data center and the virtualized data center in Wegagen bank
- ✓ To propose virtualized data center framework that can provide efficient service for Wegagen bank.
- ✓ To evaluate the data center virtualized framework.

1.5 SCOPE AND LIMITATION OF THE STUDY

Data center virtualization is deeply rooted in data center installation through technology to provide resource optimization. Mainly, data center virtualization focus in three data center infrastructure areas, which are networking, storage, desktop and servers [19]. The study covers the above mentioned data center infrastructure area and this study cover based on the main data center infrastructure of wegagen bank.

This study doesn't consider the implementation phase of virtualization in the main data center rather the study focuses on examining and assessing the current statues of the infrastructure and proposing the preferred virtualization framework for Wegagen bank. In addition to that this study is only to bring the main data center availability according to the ANSI/TIA-942 standards from Rated-1/Tier-1 to Rated-3/Tier-3 it doesn't include the maximum availability of the standard, which is Rated-4/Tier-4

1.6 SIGNIFICANCY OF THE STUDY

The study allows Wegagen bank to consider additional, more available, cost effective and best way to deploy data center infrastructure for high level customer service and increase system efficiency and facilities. The study would give new directions for Wegagen bank and other banks for their budget allocation in data center infrastructure. Moreover, the studies will also insight the two modes of transformation in modern data center which is information technology transformation and digital transformation. Thus, the proposed virtualized data center framework will help for the implementation of green data center.

1.7 ORGANIZATION OF THESIS

The study will be organized in six sections. The first section introduce by giving an overview of the study. Chapter two covered related literatures on the basic concept of data center and virtualization its evolution, types, deployment models, virtualization challenges and benefits for banking sector; ICT usages in the banking area; and related works done on virtualization frameworks in order to understand how it is implemented or used in banking sectors. Chapter

three describes the research methodology and strategy that aims to identify the potential data center virtualization that could be provided to banking sector. It begins by describing exploratory research approaches. Primary data collection and analysis technique were described as information acquisition method. Procedure and ethical consideration also identified. Chapter four presents the results of the interview described in chapter three. The data collection method utilized was the semi structured interview that provided both control and direction through a list of question under interview. In addition shows an experiment of usage of CPU, Memory, and network performance between the traditional and virtualized while on line application (CORE banking application) runs and evaluation and analysis will be made. In Chapter five, backgrounds of a framework for building the proposed data center virtualization framework for banking sector, the detail elements of the proposed virtualization framework will explain. Finally in chapter six conclusions about the research and suggestions for future research direction were presented.

CHAPTER TWO

LITREATURE REVIEW

In this chapter literatures in relation to the objective of this study are reviewed. It covers data center evolution and its infrastructure, the concept of virtualization and types, tools, and its advantage and challenges.

Information technology innovation is in exponential growth and data center infrastructure became the most important and valuable asset in private, public and governmental organizations. This infrastructure has to become efficient, cost effective, scalable and flexible. Data center infrastructure accommodates various information technologies to make IT operations efficient, to run different organizational applications and mission critical systems based on their activities and business. Organizations are obliged to invest hugely on IT infrastructures mainly storage, servers and network infrastructure, which are switches, routers and cables. This technologies works in integrated way under one facilitated umbrella called data center. Data center infrastructure comprises of power, cooling, rack management lifting, fire suppression and physical security.

2.1 DATA CENTER

The idea of data center has a direct relation with the industry of IT commissioning. Data centers provide the place for all of the core devices, servers and storages and protect them to keep running properly and to provide services for the end users. A data center is a special facility designed to house, manage, and support computing resources that are considered critical for one or more organizations. A particularly complex structure, a typical data center encompasses special building structures, power backup structures, cooling systems, special-purpose rooms (entrance and telecommunications, for example), equipment cabinets, structured cabling, network devices, storage systems, servers, mainframes, application software, physical security systems, monitoring centers, and many other support systems as shown in Fig 2.1. All these resources and their interaction are (locally or remotely) managed by specialized personnel [16].

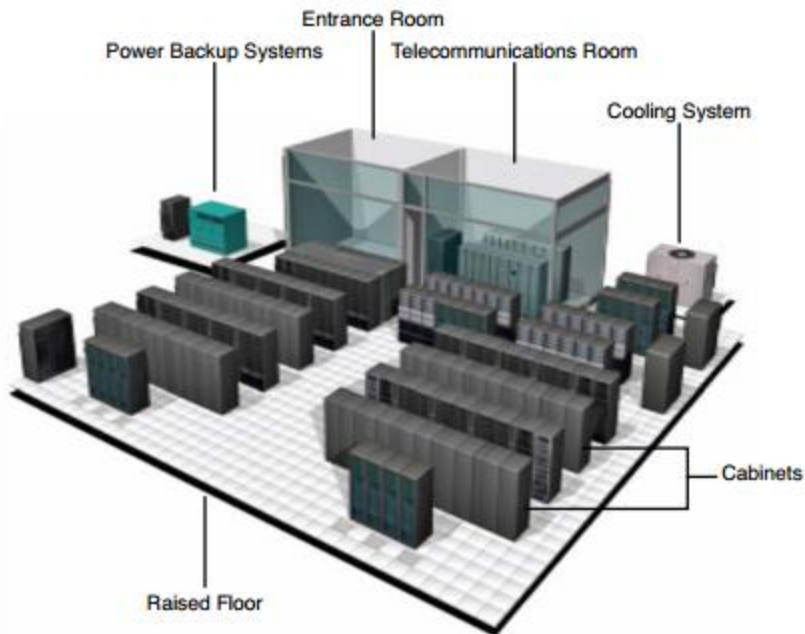


Fig. 2.1 Basic data center diagrams [16]

2.2 INTERNATIONAL STANDARDS FOR DATA CENTER

International standards are important references for data center design. Standard data centers are designed in reference of the following international standards. ANSI/TIA-942-2005 and 2010 are Telecommunications Infrastructure Standard for data centers. A general requirement in data center design has different international standards [31].

1. ANSI/TIA/EIA-568-B.2: commercial building telecommunications cabling standard;
2. ANSI/TIA/EIA-568-B.3 optical fiber cabling components standard,
3. ANSI/TIA-569-B commercial building standard for telecommunications pathways and spaces,
4. ANSI/TIA/EIA-606-A administration standard for commercial telecommunications infrastructure.
5. ANSI/TIA/EIA-J-STD-607, commercial building grounding (Earthling) and bonding requirements for telecommunications
6. ANSI/TIA-758-A, customer-Owned Outside Plant Telecommunications Cabling Standard
IEEE C2-2002,

7. National electrical safety code NFPA70 and 110: National Electrical Code IEEE Std. 1100,
8. Recommended Practice for Powering and grounding electronic equipment IEEE Std. 446,
9. Recommended practice for emergency and standby powers and cooling systems for industrial and commercial applications.

2.3 LOGICAL LAYOUT ARCHITECTURE FOR DATA CENTER

The Logical Layout Architecture for Data center is depicted in Fig 2.2 shows in the context of the TIA/EIA-942 simplified logical data center layout, the top of the rack architecture maps directly to the equipment distribution area (EDA) and the horizontal distribution area (HDA). Figure 2.2 shows a mapping of the logical network architecture to the physical infrastructure.

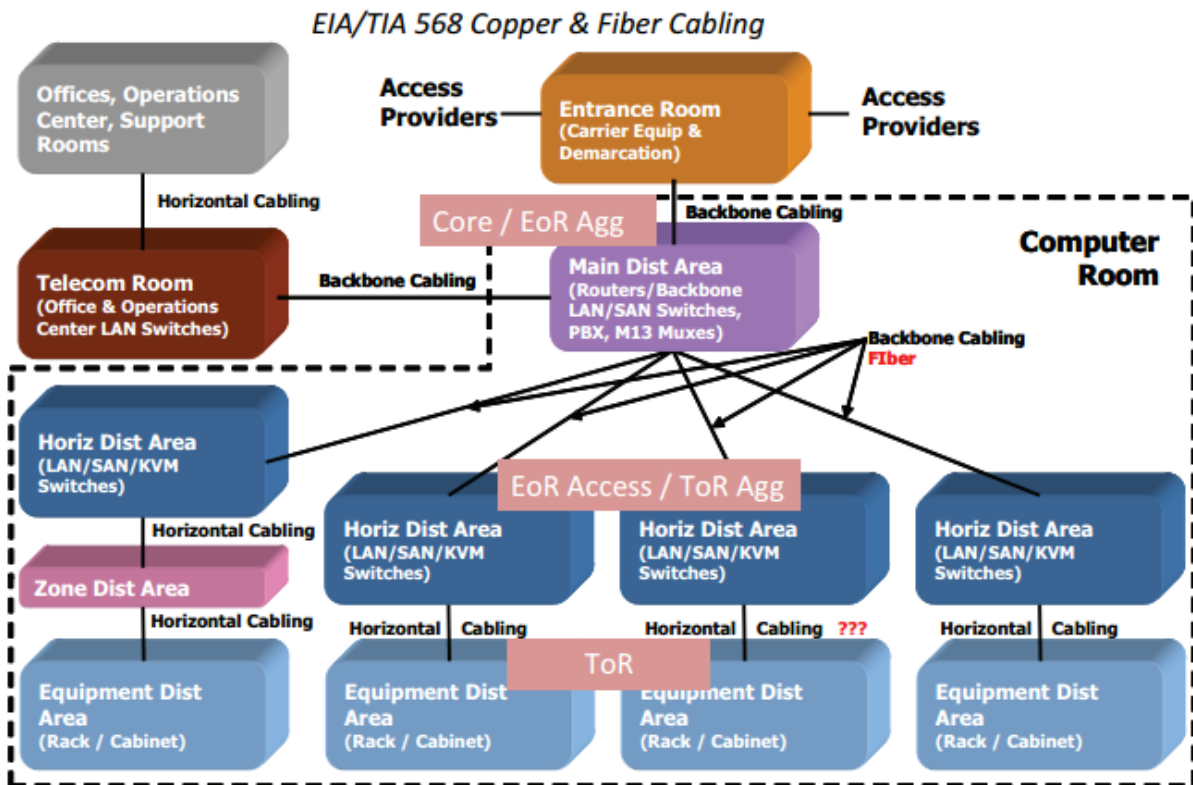


Fig.2.2 TIA-942 Logical layouts [6]

The top of the rack cabling and network architecture in Figure 2.2 optimizes the requirement for horizontal cabling from the server rack by placing the top of the rack aggregation device at the

top of the server rack. Actual placement of the top of the rack device may vary based on customer requirements and seeks to optimize customer requirements for density, cabling, and design methodology. The aggregation of the top of the rack device will be in the HDA based on the specific TIA/EIA reference cabling model deployed. The top of the rack cabling design model follows a logical network layer construct in which the server network connectivity is aggregated at the rack level in the network access layer. The access layer is in turn connected to the network aggregation layer.

2.4 DATA CENTER DESIGN PARAMETERS

Important parameters that are considered during the design phase are related to high availability in data center infrastructure connectivity. Data center requires high availability to run the business. But not all data centers can meet the availability criteria. According to ANSI/TIA-942 standards, datacenter standards can be classified to four tiers

1. Tier1 downtime 28.8 hours a year or Guaranteeing 99.671% availability.
2. Tier 2 downtime 22 hours a year or Guaranteeing 99.741% availability.
3. Tier 3 downtime 1.6 hours a year or Guaranteeing 99.982% availability.
4. Tier 4 downtime 0.8 hours a year or Guaranteeing 99.995% availability.

The main parameter in designing data centers are security, scalability green technology, low total cost of ownership and intelligent management.

2.4.1 SECURITY

Data center infrastructures are on the way of using state-of-the-art technologies to increase efficiency and effectiveness in service delivery. However, these benefits do not come without risks for information being misused, service disrupted or any other attacks interrupting the normal operation of computer based information systems. To handle different threats we can use information security resources like: firewall, and Intrusion Prevention System (IPS) products (to protect the bank network,) and server level content blocking software (to prevent virus, malware, Spam...etc.). Physical security is necessary to be built up for data center protection. It should be able to prevent unauthorized access of peoples to the data center.

2.4.2 SCALABILITY

Datacenter should be flexibly and expandable as business grows. Scalability, the ability of the system to grow either organically or by demand, is both a business and IT objective. From a business perspective, the service must be able to address the needs and demand of the end users who interact with the system. While for IT, the scalability provides the flexibility to be distributed in such a manner that meets the IT requirements or needs at a point in time [3].

2.4.3 GREEN TECHNOLOGY

Saving energy is not only to get greener. The green data center is energy efficient, dense computing eco system where, Software technologies control data growth and shrink capacity demands, managers use service level agreements to manage energy usage, energy efficient computing infrastructure optimizes performance and utilization levels and Physical plant is engineered for maximum energy efficiency [25].

2.4.4 LOW TCO

As energy consumption increasing continually and energy being more and more expensive, power consumption of data center is the biggest part of operation cost. Reducing power consumption is one important consideration during data center design. Through consolidation, virtualization can lead to significant CAPEX and OPEX cost savings and therefore lower TCO at the datacenter. This is reflected by (1) deferred purchase of new servers, (2) smaller datacenter footprint, (3) lower maintenance costs, (4) lower power, ventilation, cooling, rack, and cabling requirements, (5) lower disaster recovery costs, and (6) reduced server deployment costs [10].

2.4.5 INTELLIGENT MANAGEMENT

Data center is an integrated system with several subsystems. Integrated design allows creating highly complex systems from smaller, more manageable building blocks. These smaller units are more easily defined and can be more easily managed. Data center management in today's dynamic environment is complex and requires an integrated answer to numerous challenges. The top priority of data center is to provide continuous, high-quality performance, and to assure the

security of data and equipment. And, this management includes real time monitoring, fault management, power management; record each connectivity's and monitor security.

2.5 MODULAR DATA CENTER

The data center infrastructure has also evolved bringing a new technology as there is a greater than ever need for agility. In creating a more flexible data center solution, organizations are seeing the direct benefits in working with modular designs. A modular data center is an approach that implies a prefabricated module or a method for delivering data centers infrastructure in a modular fashion [17]. A modular solution takes the best ideas for design, reliability and efficiency and packages everything into a prefabricated, repeatable and operationally optimized module.

Now data centers can grow and expand while using efficient modular technologies. A modular solution takes the best ideas for design, reliability, and efficiency and packages everything into a prefabricated, repeatable and operationally optimized module. This translates to a truly agile data center environment which is capable of scale. An approach to data centers design that implies either prefabricated data center module or deployment method for delivering data center infrastructure in a modular, quick and flexible method. A data center product incorporates customized infrastructure to support power or cooling infrastructure, or racks of IT equipment. Containers are built using an ISO (International Standards Organization) intermodal shipping container [17].

2.6 COMPONENTS OF DATA CENTER

The physical facility of data center comprises of different components to deliver efficient, scalable and highly available services. A practical data center has different services hardware installation and maintenance, managed power distribution, backup power systems, data backup and archiving, managed load balancing, controlled Internet access, managed e-mail and messaging, server co-location and hosting, virtual servers, GRID and Cloud computing services, managed user authentication and authorization, firewalls, data security, etc. [28].

Building a datacentre need to address various area, power connection (dirty power), backup generator, automatic transfer switch, main distribution board with phase monitoring, modular

and scalable UPS solution and power feed and distribution evenly/redundant to every racks in the datacentre and equipment's housed within the rack. Rack with complete accessories for cable management and power distribution. Fire and smoke detector, alarms and suppression access floor to manage cables underneath the racks. False ceiling to manage light, gas pipes and cables, redundant air-conditioner solution, environmental controls (Temperature, Humidity, physical access, power events, etc.) – for monitoring and control of the environment in the datacentre and physical surveillance and access control. The main component of data centres are electric supply system, low voltage cable routing, raised floor, environmental control, fire protection and security [28].

2.6.1. ELECTRIC SUPPLY SYSTEM

Two aspects of energy use are critical for datacentres. Firstly, both IT equipment and all supporting equipment are very energy consuming. Some data centres facilities have power densities that exceed more than 100 times than in typical office use. For higher power density facilities, electricity costs are a dominant operating expense and account for over 10% of the total cost of data centres ownership. Secondly, it is not less important to have guaranteed energy for IT equipment and also for other equipment like cooling, or access control systems used in the datacentre. Backup power systems consist of one or more uninterruptible power supplies (UPS) and/or diesel generators. To prevent single points of failure, all elements of the electrical systems, including backup systems, are typically fully duplicated, and computing facilities are connected to both power feeds. This arrangement is often marked as N+1 redundancy. Static switches are sometimes used to ensure instantaneous switchover from one supply to the other in the event of a power failure. For comparing electro-effectiveness in different data centres and also to evaluate different solutions, power usage effectiveness (PUE) is introduced. The most popular measurement of that is the proportion between total facility's power and IT equipment's power. In addition to IT equipment the other energy consuming equipment, mainly consists of cooling systems, power delivery and other facility's infrastructure, like lighting. Data centres support equipment recalled as overhead. Often IT equipment consumes only 33% of the power in the data centre. The most popular power components are generators, UPS, grounding, power and environmental control [28].

2.6.2 LOW VOLTAGE CABLE ROUTING

Communications in data centers today are most often based on networks running Internet protocols and special protocols for computing equipment interconnection. Data centers contain a set of ports, routers and switches that transport traffic between data centers computing equipment and the outside world. Redundancy of the Internet connection is often provided by using two or more upstream Internet service providers. Network security elements are also usually deployed: firewalls, VPN gateways, intrusion detection systems. Data cabling is typically routed through overhead cable trays in modern data centers. But some are still recommending under raised floor cabling for security reasons and to consider the addition of cooling systems above the racks in case this enhancement is necessary. Structural cabling elements are service provider cables backbone cables (to data center and in-between floors) horizontal cables (within floors) zone distribution (in data center) [28].

2.6.3 RAISED FLOOR

Data centers typically have raised flooring made up of 60 cm removable square tiles. The trend is towards 80–100 cm void to cater for better and uniform air distribution. These provide a plenum for air to circulate below the floor, as part of the air conditioning system, as well as providing space for power cabling. Raised floors have better appearance than overhead cabling and allow higher power densities, better control of cooling, and more flexibility in location of cooling equipment. Most stand-alone computer systems are designed for cabling from below. Overhead cable trays are less expensive than raised floor systems, cable trays can be attached to the top of racks (if they are uniform in height). Cable trays suspended from the ceiling provide more flexibility for supporting racks of various heights and for adding and removing racks. Cable trays can be installed with several layers, for example, a cable tray system for low-voltage signals, a middle layer for power and a top layer for fiber [28].

2.6.4 ENVIROMENTAL CONTROL

The requisite physical environment for a data center is rigorously controlled. Air conditioning is used to control the temperature and humidity in the data center. The temperature in a data center will naturally rise because electrical power used heats the air. Unless the heat is removed, the

ambient temperature will rise, resulting in electronic equipment malfunction. By controlling the air temperature, the server components at the board level are kept within the manufacturer's specified temperature/humidity range. Air conditioning systems help control humidity by cooling the return space air below the dew point. In data centers there are several technologies being used to realize environmental control. The principles of data centers cooling-air delivery, movement, and heat rejection are not complex. The under-floor area is often used to distribute cool air to the server racks. Eventually, the hot air produced by the servers recirculates back to the intakes of the CRAC units (the term Computer Room Air conditioning was introduced in 1960) that cool it and then exhaust the cool air into the raised floor plenum again [28].

2.6.5 FIRE PROTECTION

Data centers feature fire protection systems, including passive and active design elements, as well as implementation of fire prevention programs in operations. Smoke detectors are usually installed to provide early warning of a developing fire by detecting particles generated by smoldering components prior to the development of flame. This allows investigation, interruption of power, and manual fire suppression using hand held fire extinguishers before the fire grows to a large size. A fire sprinkler system is often provided to control a full scale fire if it develops. Fire sprinklers require 46 cm of clearance (free of cable trays, etc.) below the sprinklers. Clean agent fire suppression gaseous systems are sometimes installed to suppress a fire earlier than the fire sprinkler system. Passive fire protection elements include the installation of fire walls around the data center so a fire can be restricted to a portion of the facility for a limited time in the event of the failure of the active fire protection systems, such as making sure the door is not left open or if they are not installed. For critical facilities these firewalls are often insufficient to protect heat-sensitive electronic equipment, however, because conventional firewall construction is only rated for flame penetration time, not heat penetration. There are also deficiencies in the protection of vulnerable entry points into the server room, such as cable penetrations, coolant line penetrations and air ducts [28].

2.6.6 SECURITY

Physical security also plays a large role in data centers. Physical access to the site is usually restricted to selected personnel, with controls including bollards and mantraps. Video camera

surveillance and permanent security guards are almost always present if the data center is large or contains sensitive information on any of the systems within. The use of finger print recognition mantraps is starting to be common place [28].

2.7 EVOLUTION OF DATA CENTER

Critical IT services were no longer tied to individual physical servers, and applications gained dramatic improvements in density, scalability and portability. Today, the growth of big data and analytics and the emergence of the Internet of Things have created more storage, networking and security complexity. This complexity is expensive, not only because of the capital expense of hardware, the ongoing operational expense of managing it and the lack of visibility and reporting, but also because of the lack of agility and flexibility of traditional data centers [12]. Data centers have greatly changed characteristics and purposes throughout the last six decades, mirroring the transformations that computer systems have undergone over the same period. Nevertheless, it is important to observe that this evolution has occurred with varying pace among different industries and regions of the world [16]. Figure 2.3 shows that the evolution of data center from early stage, mainframe up to the usage of virtual server.

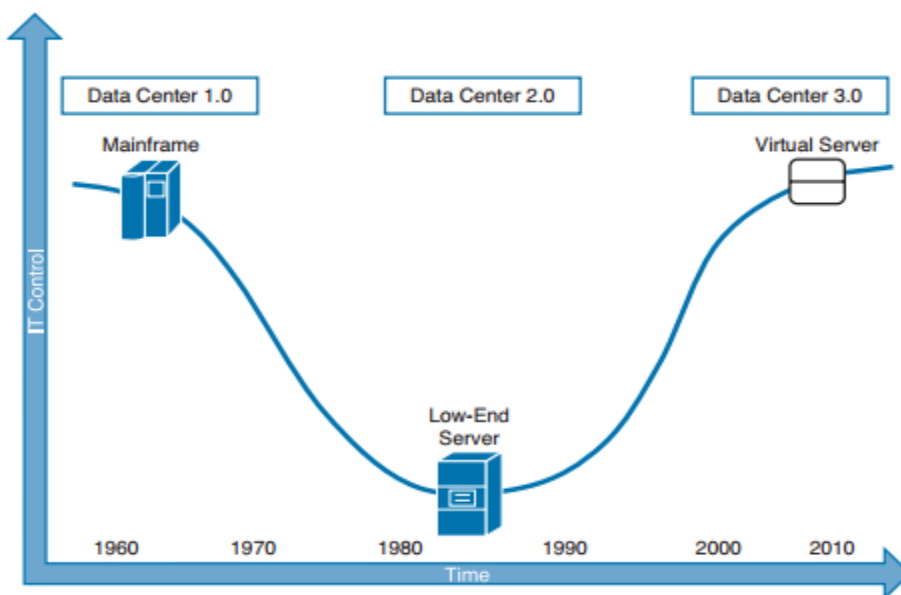


Fig. 2.3 Data center evolution phase [16]

Data Center 1.0 phase [16] name an “artistic license” because these facilities were simply known as computer rooms then. Large and special installations, these rooms supported mainframe systems since the 1950s and, consequently, were usually designed by IBM and other manufacturers to better accommodate their central processing units (CPU) and peripherals (storage devices, terminals, printers, among others). Based on a monolithic software architecture, these centralized systems allowed a tighter control from an IT perspective and, with that, a higher resource utilization.

The Data Center 2.0 phase [16] began to take shape as the client-server application model increased its adoption in the 1980s. Leveraging the popularity of personal computers (PC), application environments started a migration from mainframes to smaller “server” platforms that were accessed through client applications installed on PCs. With low costs of computer hardware and the scarce bandwidth of wide-area network (WAN) links, servers in this phase were commonly deployed closer to the clients and, consequently, away from the centralized IT management. Therefore, this phase was first characterized with a multitude of low-end servers accommodated into distributed, and sometimes improvised, data centers. With the Internet boom in the 1990s, computer power was once again compelled to be concentrated into Internet data centers, which were sometimes adapted from deactivate mainframe computer rooms. The development of internetworking and web-based applications generated a perfect storm that further increased server centralization into properly designed data centers. In the name of performance predictability and software modularization, the client-server model evolved to include application tiers, where each tier embodied dedicated servers that were deployed to execute specific functions. The best-known example of a tiered application architecture is the three-tier, which includes presentation, application (or business logic), and database servers.

The Data Center 3.0 phase [16] shares its origins with the exposed limitations of these facilities. Around the turn of the century, data centers were continuously approaching space and power saturation, while expansions and new facilities were the obvious expensive solutions. This phase is better characterized with a series of data center transformation projects that intended to improve resource utilization and increase operational simplicity. Most of these initiatives consisted of infrastructure consolidation projects, which standardized

and reduced the number of components, processes, and even facilities in a corporation. A history of data center begins in 1940.

- 1940s Early mainframe computers emerge.
- 1960s Mainframes go main stream. Compute functions are partitioned (virtualized) to improve utilization.
- 1970s ARCNET and ARPANET are early precursors of the Internet.
- 1980s The personal computer arrives. Early virtualization technologies are abandoned as multitasking moves out of the data center.
- 1984 Dell Inc. is founded in a dorm room at the University of Texas.
- 1990s Client-server computing begins. Affordable x86 –based computing moves to the data center.
- Late 1990s the emergence of the Internet creates an explosion in demand for data centers with advanced capabilities.
- Early 2000s Internet demands catch up with the data center, creating massive power and efficiency challenges.
- Mid 2000s x 86 servers virtualization arrives to help improve the efficiency and utilization of the Internet-era data center.
- Late 2000s Software as a Service (SaaS) and cloud arrive — and multi-tasking functions begin to move back into the data center.
- Late 2000s Modular data centers appear and advanced virtualization opens the door for “the cloud.”
- Early 2010s Virtualization extends to storage and networking.
- Today Cloud technologies are increasingly automated and hybrid in nature.
- Tomorrow welcome to the world of software-defined everything.

2.8 COMPLEXITIES IN DATA CENTER

The freedom to design systems and develop applications any way you want has been beneficial in that it has allowed applications to be developed and released very quickly, keeping time-to-market very short. While this can be a tremendous competitive advantage in today's business environment, it comes at a substantial cost. As applications become more mission critical and as desktop server's move into formal data centers, the number of servers in a data center grows,

making the job of managing this disparate environment increasingly complex. Lower service levels and higher service level costs usually result from increased complexity. As complexity grows, so does the cost of managing it. The organizational structures that are typically imposed on those who make the business decisions that affect data centers and those who manage data centers further add to this complexity. In most of the IT environments we deal with, multiple vertical entities control the budgets for developing applications and for funding the purchase of the servers to run them, while a single centralized IT operations group manages and maintains the applications and servers used by all of the vertical entities. This organization is found in nearly every industry including, but not limited to [30]:

- Commercial companies: Business units, product lines, departments
- Government: Departments, agencies
- Military: Service, division, military base
- Academic: Department, professor, grant funds

In this type of environment, vertical entities have seemingly limitless freedom in how they develop and deploy applications and servers. Further, operations groups often have little or no control over the systems they manage or over the methods they use to manage them. For these reasons, it is very common for each application server combination to be implemented and managed differently, and for a data center to lack the operational discipline found in most main frame environments [30].

2.9 DATA CENTER INFRASTRUCTURE MANAGEMENT

Today's data centers are more complex, more interdependent and more critical than ever before. This has led to the need for more intelligent and automated IT infrastructure management. The tools which enable the data center team to effectively and efficiently operate this complex environment have been grouped into a classification of solutions known collectively as Data Center Infrastructure Management (DCIM) [7]. Gartner defines [7] DCIM as "tools that monitor, measure, manage and/or control data center use and energy consumption of all IT-related equipment (such as servers, storage and network switches), and facilities infrastructure components (such as power distribution units [PDUs] and computer room air conditioners

[CRACs]).” Multiple DCIM models have been put out by analyst firms such as Gartner, Forrester and the 451 Group [7].

2.10 DATA CENTER INFRASTRUCTURE MANAGEMENT MODELS

There are different models designed by different scholars for managing the data center infrastructures. Some of are:

2.10.1 GARTNER MODEL

In Gartner model, Figure 2.4 the primary components of a DCIM solution are Input, Process and Output. Various sensors and other system feeds (BMS system, user input, etc.) comprise the input. This raw data then sent through an analysis process to create actionable data — real information which can be used to manage the data center. The processed data is then presented as output to the user, perhaps in the form of a dashboard or trend graph, and is also used as control data back into the input component [7].

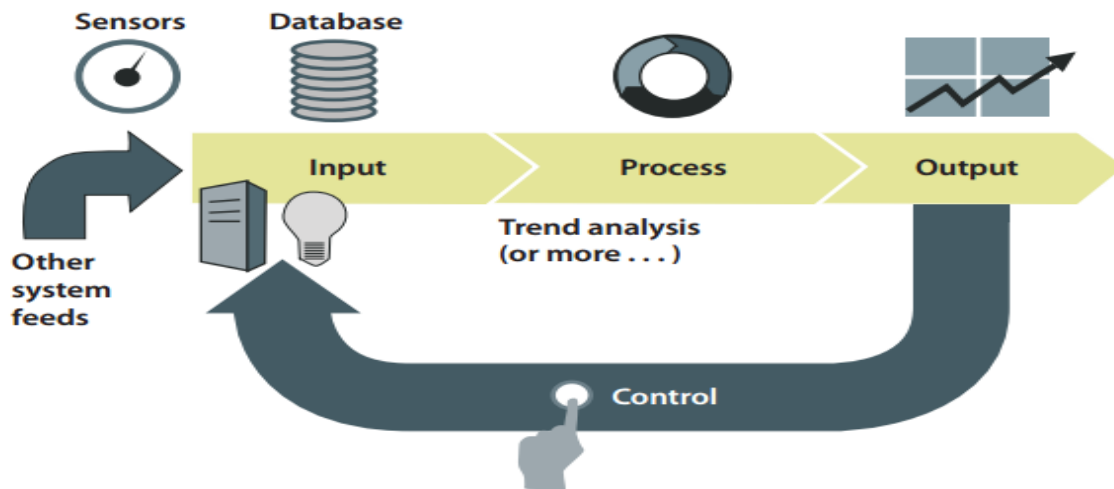


Fig.2.4 Gartner Model [7]

2.10.2 451 GROUP MODEL

The 451 group model, Figure 2.5 breaks down DCIM into functional blocks with data collection at its base. The data is used as input to the other functional areas, including Asset and Change Management, environmental Monitoring, Power and Energy Measuring and Modeling, Power

Management and IT Service and Systems Management. A data management layer integrates data from the lower layers to facilitate reporting as well as providing input to higher level planning, forecasting and optimization layers[7].

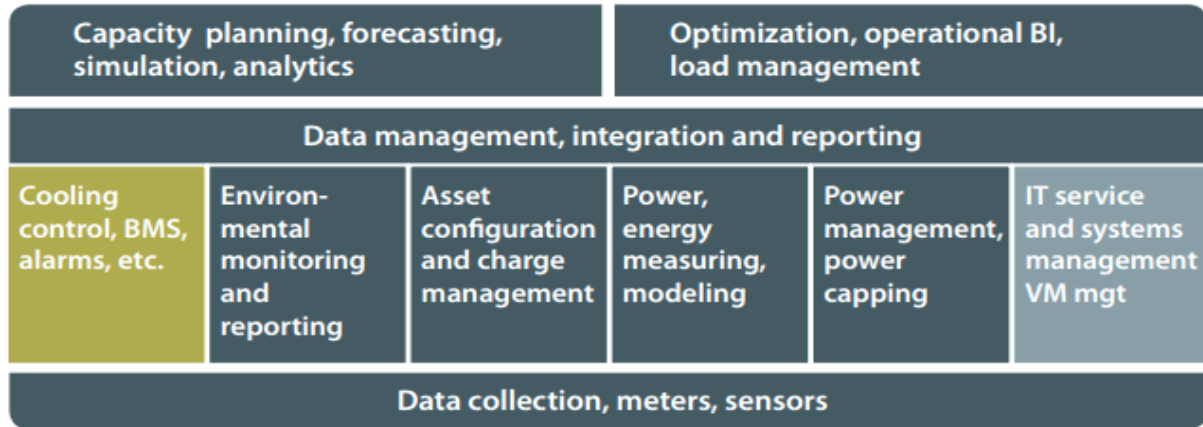


Fig. 2.5 451 group model [7]

2.10.3 FORRESTER MODEL

The Forrester model in figure 2.6 focuses on DCIM as a component of the overall data center management architecture. In this model, DCIM interacts with other management systems, with DCIM tools providing input to virtual infrastructure management, workload management tools and the enterprise service desk [7].

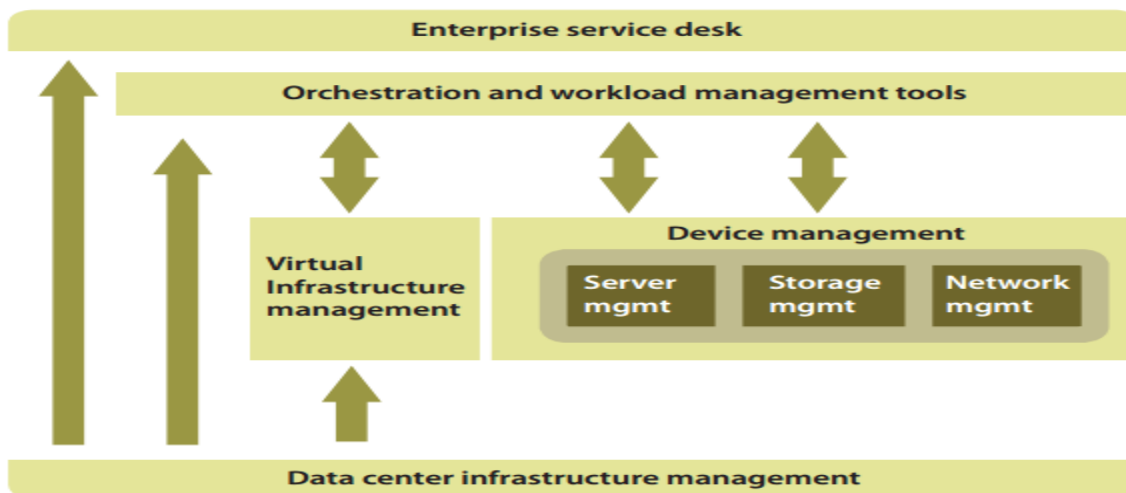


Fig. 2.6 Forrester model [7]

2.11 DATA CENTER MANAGEMENT COMPONENT

Design phase, DCIM provides key information in designing the proper infrastructure. Power, cooling and network data at the rack level help to determine the optimum placement of new servers. Without this information, data center managers have to rely on guesswork to make key decisions on how much equipment can be placed into a rack. Too little equipment strands valuable data center resources (space, power and cooling). Too much equipment increases the risk of shutdown due to exceeding the available resources. In the Operations phase, DCIM can help to enforce standard processes for operating the data center. These consistent, repeatable processes reduce operator errors which can account for as much as 80% of system outages. In the Monitoring phase, DCIM provides operational data, including environmental data (temperature, humidity, air flow), power data (at the device, rack, zone and data center level), and cooling data. In addition, DCIM may also provide IT data such as server resources (CPU, memory, disk, network). This data can be used to alert management when thresholds are exceeded, reducing the mean time to repair and increasing availability. In the Predictive Analysis phase, DCIM analyzes the key performance indicators from the monitoring phase as key input into the planning phase. Capacity planning decisions are made during this phase. Tracking the usage of key resources over time, for example, can provide valuable input to the decision on when to purchase new power or cooling equipment. In the Planning phase, DCIM can be used to analyze “what if” scenarios such as server refreshes, impact of virtualization, and equipment moves, add and changes. If you could summarize DCIM in one word, it would be information. Every facet of data center management revolves around having complete and accurate information [7].

DCIM has different functional components as figure 2.7 shows.

- Planning used for translating the business need into data center.
- Design is used for in designing the proper infrastructure based on the data center requirement.
- Operation is related to repeated processes for running data center.
- Monitoring is used for collection for data to ensure data center running as designed.
- Predictive analysis which analyzes data for input into planning process.

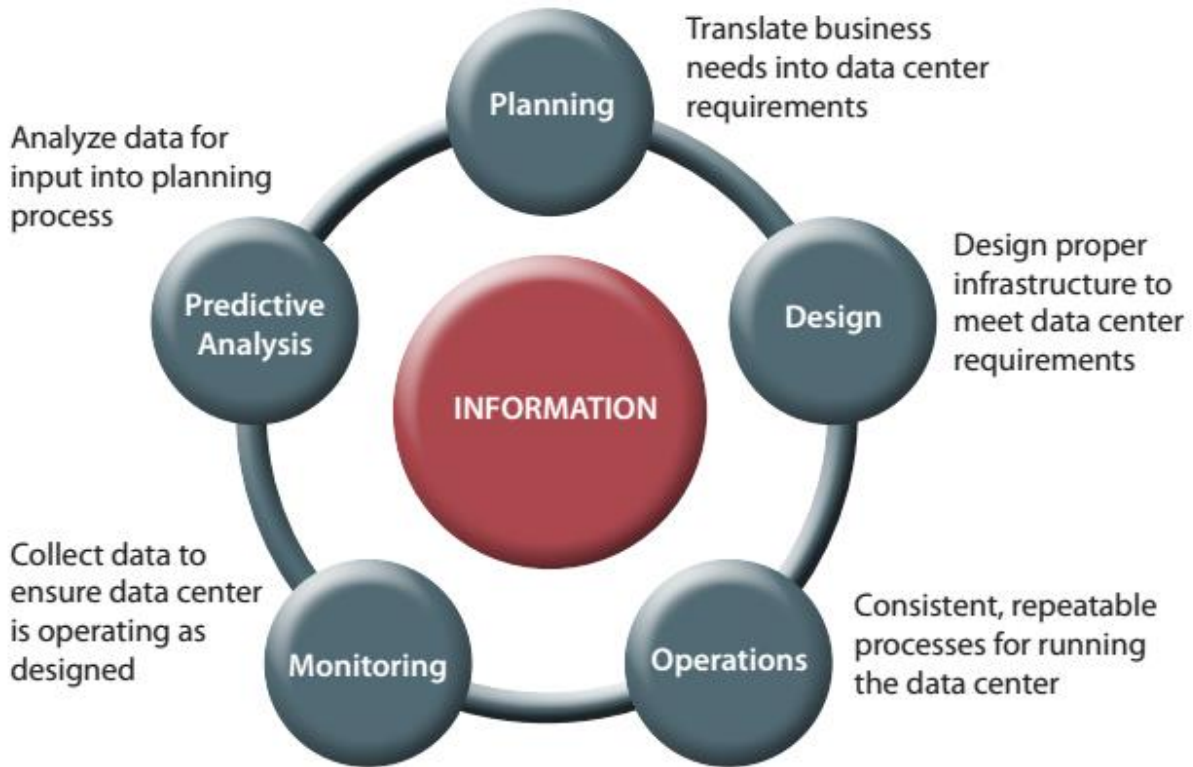


Fig.2.7 DCM components [7]

There are a number of benefits in implementing a DCIM solution [7].

- Access to accurate, actionable data about the current state and future needs of the data center
- Standard procedures for equipment changes
- Single source of truth for asset management
- Better predictability for space, power and cooling capacity means increased time to plan
- Enhanced understanding of the present state of the power and cooling infrastructure and environment increases the overall availability of the data center
- Reduced operating cost from energy usage effectiveness and efficiency

2.12 VIRTUALIZATION

Nowadays technologies are changed frequently at an alarming rate as business grows through IT infrastructure innovations. This infrastructure becomes the most important component for business continuity, reliability and mission critical environments, which are going to be, deployed in data centers. Virtualization is one of the technologies for agile, flexible and scalable need for service delivery in data centers that gives different benefits through resource usage and allocation.

Virtualization is a term that refers to the abstraction of computer resources. The purpose of virtual computing environment is to improve resource utilization by providing a unified integrated operating platform for users and applications based on aggregation of heterogeneous and autonomous resources. More recently, virtualization at all levels (system, storage, and network) became important as a way to improve system security, reliability and availability, cost reduction, and provision of greater flexibility.

Virtualization is commonly defined as a technology that introduces a software abstraction layer between the hardware and the operating system and applications running on top of it. This abstraction layer is called virtual machine monitor (VMM) or hypervisor and basically hides the physical resources of the computing system from the operating system (OS) [18]. Since the hardware resources are directly controlled by the VMM and not by the OS, it is possible to run multiple (possibly different) OSs in parallel on the same hardware. As a result, the hardware platform is partitioned into one or more logical units called virtual machines (VMs). “Virtually” differs from “reality” only in the formal world, while possessing a similar essence or effect. In the computer world, a virtual environment is perceived the same as that of a real environment by application programs and the rest of the world, though the underlying mechanisms are formally different [18].

2.13 GENERATION OF VIRTUALIZATION

Virtualization is divided in to three generation depending on technological invention on first paging as a method of to store and transmit data up and down, then the introduction of the

concept of hypervisor and at last virtualization not only in application level but also in data center level. And this generation briefly discussed below.

From 1950 to 1970:

The concept of virtual memory in 1950 introduced automatic page replacement in Atlas system, a transistorized main frame computer. The principle of paging as a method to store and transmit data up and down, the memory hierarchy is to automate the process, providing the first working prototype of virtual memory. The term virtual machine dates to the 1960s. One of the earliest virtual machine systems comes from IBM. Around 1967, IBM introduced the System/360 model 67, its first major system with virtual memory. Integral to the model 67 was the concept of a self-virtualizing processor instruction set, perfected in later models. The model 67 used a very early operating system called CP-67, which evolved into the virtual machine (VM) operating systems. VM allowed users to run several operating systems on a single processor machine [27].

In the mid-1960s IBM also pioneered the M44/44X project, exploring the emerging concept of time sharing. At the core of the system architecture was a set of virtual machines, one for each user. The main machine was an IBM 7044 (M44 for short) and each virtual machine was an experimental image of the 7044 (44X for short). This work eventually led to the widely used VM/timesharing systems, including IBM's well-known VM/370. The concept of hardware virtualization also emerged during this time, allowing the virtual machine monitor to run virtual machines in an isolated and protected environment. By the mid-1970s virtualization was well accepted by users of various operating systems [27].

From 1970 to 2000:

The period between 1970 and the early 1980s saw many new technologies and changes introduced to the computing world. The IBM VM family introduced the concept of a hypervisor in 1972. Specifically, the core of the IBM VM family architecture was a control program (we now refer to as a hypervisor) called VM-CP. VM-CP ran on the physical hardware and created the virtual machine environment. This arrangement made VM-CP become classified as type 1 hypervisor. Type 1 hypervisors are essentially software that runs directly on the hardware

platform and thus below the operating system in the overall system stack. The roots of virtualization on the mainframe begin in MVS (Multiple Virtual Storage was the most commonly used operating system on System/370 and System/390 machines. MVS was first introduced in 1974. The core of MVS has stayed the same throughout many revisions to this operating system), specifically with its virtual memory support. MVS allowed an unlimited number of applications to run in separate address spaces. The MVS core redirected requests from two separate applications for the same virtual memory address to different areas of physical memory [27].

From 2000 to 2011

Virtualization has changed everything, one machine can run a multitude of applications, each isolated into one virtual operating system, completely separated from the others. Finally, in 2000, OS/390 turned into z/OS, which is the current production IBM mainframe operating system. In 2005, virtualization technology came in to mainstream awareness faster than anyone could have ever imagined including many IT experts. Not only in application stage, but also for data centers virtualization stages [27].

2.14 VIRTUAL MACHINE MONITOR (VMM)

Any virtualized environment consists of the VMM or the hypervisor whose purpose is to allocate the physical resources (such as the CPU, memory, network, and storage) to each virtualized OS or to each application running on a virtualized OS. Once the hypervisor is in place, it emulates a hardware device for each virtual OS and handles each virtual OS's communications with the physical resources. As shown in Fig. 2.8 the hypervisor provides an interface between each VM and the underlying physical hardware resource.

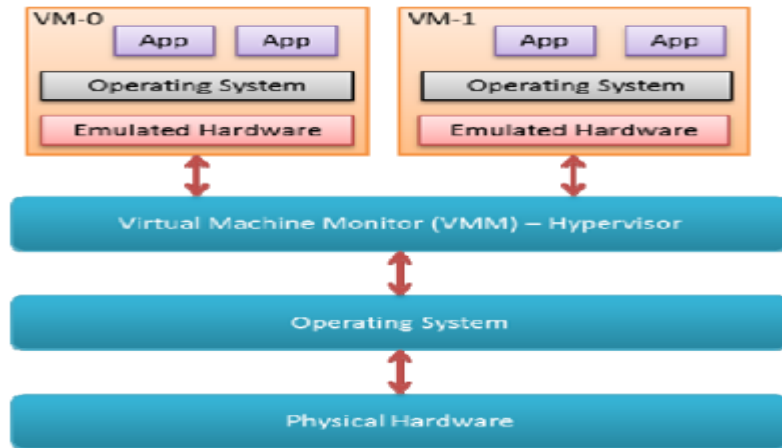


Fig.2.8 Illustration of virtual environment Architecture [11]

The hypervisor software can be either installed on its own or as a part of an OS. Hence, the way the hypervisor software is installed introduces two different forms of virtualization architectures. As in figure 2.9 shows, the first form of virtualization architecture known as bare-metal virtualization, there exists no host OS because the VMM sits just above the underlying physical hardware and intercepts the communication between the multiple VMs and the physical hardware. In this form there exists a main management VM whose core responsibility is to manage the guest VMs and the communication with the physical hardware. In the second form of virtualization architecture known as hosted-virtualization, the VMM sits just on top of the host OS and runs as an application. It is the host OS that is responsible to provide Input /Output (I/O) drivers and to manage the guest VMs.

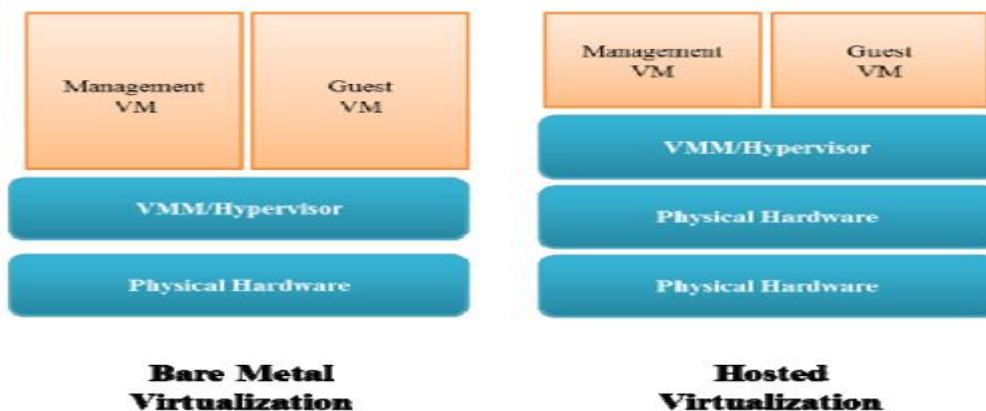


Fig.2.9 Types of Virtualization Architecture [11]

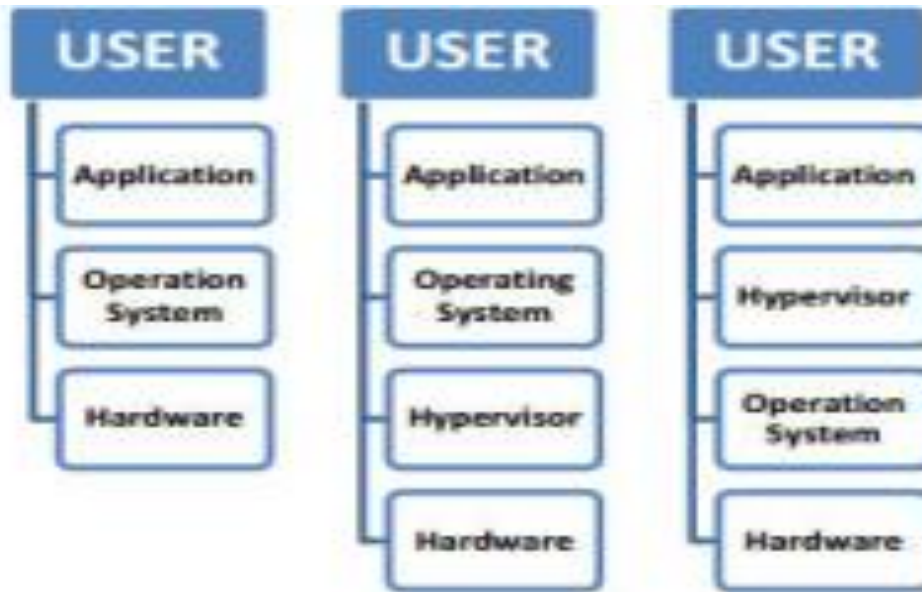


Fig.2.10 Virtualization architectures; (A) Traditional (B) bare metal virtualization; (C) Hosted Virtualization

The main characteristic of the VMM is that it removes the traditional physical hardware dependency of an OS on its physical hardware resource. In other words, the physical resources are directly controlled by the VMM and not by the host OS or the physical hardware. Due to this fine trait, multiple different OS(s) can run on the same physical hardware at the same time while being isolated from one another. As a result, the physical hardware is partitioned into one or more logical units known as virtual machines (VMs). A VM can run any x86-class physical host system, regardless of the hardware structure.

There are three primary attributes to the VMM [11]:

- a. **Isolation:** only the VMM in a virtualized environment has the responsibility to control and monitor all guest VMs residing on the physical hardware and allocate the required physical resources to each guest VMs. VMMs provide isolation; that is every VM is isolated from any other VM on the same physical hardware. In other words, applications running on one VM cannot interact or see applications that are running on a different VM. In addition, every VM is isolated from the host OS in the same way.

- b. **Interposition:** VMMs manage all administrative privileged instructions on the physical hardware. The guest OS communicates all its traps and interrupts to the VMM, which will eventually process the events by interacting directly with the physical platform on behalf of the guest OS. The VMM intercepts all I/O requests from the guest OS(s) to the virtual devices and maps them to the exact physical I/O device through an I/O abstraction. Through this abstraction the VMM manages and schedules all VMs concurrently.
- c. **Inspection:** the VMM has access to all the states of the VMs running on the physical hardware. This includes the memory state, CPU state, and I/O device states. This is necessary for VMM in order to encapsulate the state of a VM to enable capabilities such as checkpointing (i.e. capture a snapshot of the current state), rollback (i.e. restore to a previously defined state), and replay (i.e. repeat to view an event). This fine trait helps administrator to save, copy, move, compare and instantiate environments with protected states from one physical host to another.

2.15 METHODS OF VIRTUALIZATION

The data center infrastructure is a collection of servers, storage, networks, different applications and operating systems. This infrastructure can be utilized through virtualized technology. And, this virtualized technology allows to run different application and to share resources which can be implemented through different methods or approaches of virtualization, as Fig. 2.11 shows.

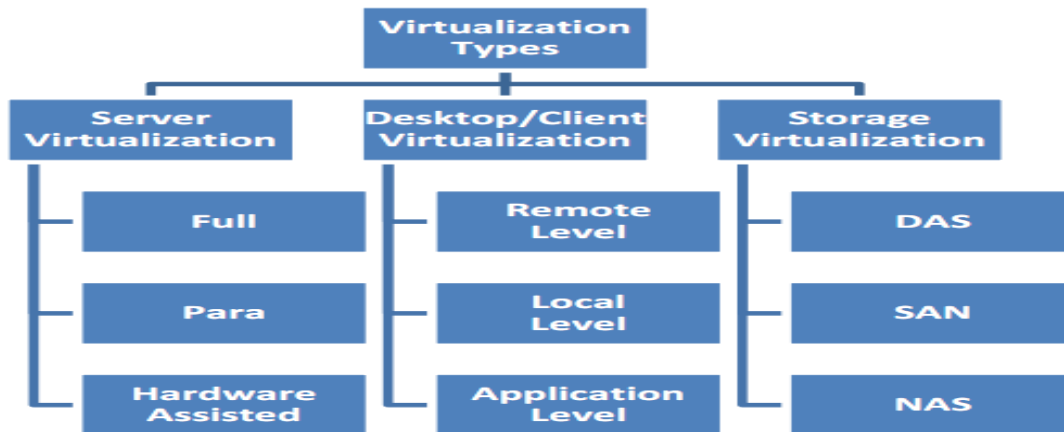


Fig.2.11 Major types of virtualization [11]

- a. **FULL VIRTUALIZATION:** It is a type of virtualization that abstracts both physical resource on the physical host and guest OS that runs on the physical hardware. It virtualizes all features of the physical hardware resource and different OS that can run at the same time [11].
- b. **PARA VIRTUALIZATION:** It differs from full virtualization, it provides partial simulation of underlying hardware and there is a thin software between the physical hardware and modified guest OS. This approaches the guest OS kernel act as a bridge between the application and execution done on host hardware level [11].
- c. **HARDWARE ASSISTED (NATIVE) VIRTUALIZATION:** This approaches differs from the above two is that, it is an approach that allow the CPU instruction set communication in which the hypervisor runs in a new level known as root level mode which resides below the OS kernel level [11].
- d. **OPERATING SYSTEM VIRTUALIZATION:** This technique is a form of server virtualization and is also known as Single Kernel Image (SKI) or container-based virtualization. This concept is based on single OS instance which means running more instances of the same OS in parallel. In other words, not the actual hardware but the host operating system is the one being virtualized and the resulting VMs all use the same virtualized OS image. The virtualized operating system image is known as the virtualization layer [11].
- e. **APPLICATION VIRTUALIZATION:** In this approach the user is able to run a server application locally using the local resources without needing the complexity of completely installing this application on the computer. Such virtualized applications are designed to run in a small virtual environment containing only the resources needed for the application to execute. Thus in application virtualization each user have an isolated application environment virtually. This small isolated virtual environment acts as a layer between the application and the host operating system [4].

- f. **NETWORK VIRTUALIZATION:** This method is characterized by three types of technologies Virtual LAN (VLAN), Virtual IP (VIP) and Virtual Private Network (VPN). Network virtualization is comprised of a set of technologies that hide the true complexity of the network and separates it into manageable parts. With network virtualization multiple networks can be combined into a single network, or a single network can be logically separated into multiple parts. The currently known network virtualizations are Virtual LAN (VLAN), Virtual IP (VIP) and Virtual Private Network (VPN). VPN and VLAN are well-known, but network virtualization is still developing and other network virtualization technologies are expected to make their appearance in the near future. Virtual LAN (VLAN) is a method of creating independent networks using a shared (physical) network it is used to logically segment and control the interaction between different network segments [4].
- g. **STORAGE VIRTUALIZATION:** This is a form of resource virtualization, where a logical storage is created by abstracting all the physical storage resources that are scattered over the network. First the physical storage resources are aggregated to form a storage pool which then forms the logical storage. This logical storage which is the aggregation of scattered physical resources appears to be a single monolithic storage device to the user [4].

All this types of virtualization are categorized under three major types of virtualization structure that are server virtualization, Desktop (client) and storage virtualization technique [11].

2.16 DATA CENTER VIRTUALIZATION

The traditional data center architecture (Fig.2.12) consists of different physical information technology devices with different capacities like storage, servers, and networking. The capacity and the number of this information technology devices has directly proportional to the business requirements, which is as the business grows the number of the IT equipment will also increases. And, this has a lot of limitation of resource utilization, management, availability, scalability, flexibility and to support different application which runs concurrently with different operating systems.



Fig.2.12 Traditional Architecture [4]

The above limitation brings the new emerging technology infrastructure, which is virtualized data center (Fig.2.13). Data center virtualization avoids the exiting traditional data center limitations of flexibility, availability, scalability, and resource utilization, management, and better security.

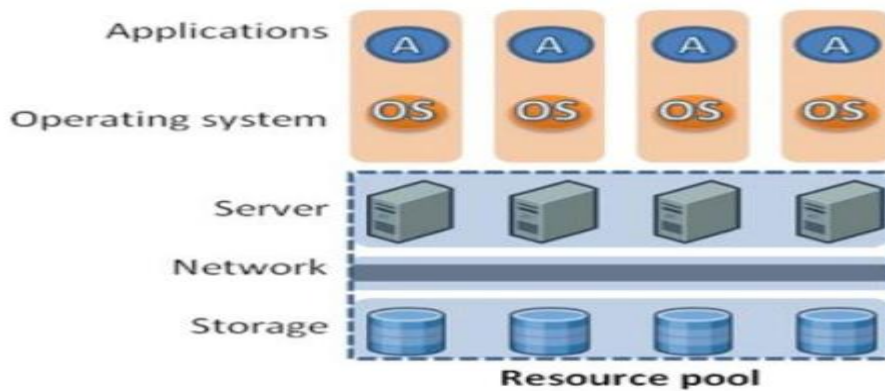


Fig.2.13 Virtual Architecture [4]

A virtualized data center (Fig. 2.14) is a data center where some or all of the hardware (servers, routers, switches, and links) are virtualized. Typically, a physical hardware is virtualized using software or firmware called hypervisor that divides the equipment into multiple isolated and independent virtual instances. For example, a physical machine (server) is virtualized via a hypervisor that creates virtual machines (VMs) having different capacities (CPU, memory, disk space) and running different operating systems and applications. A virtual data center is a

collection of virtual resources (VMs, virtual switches, and virtual routers) connected via virtual links. While a Virtualized Data Center is a physical data center with deployed resource virtualization techniques, a Virtual Data Center is a logical instance of a virtualized data center consisting of a subset of the physical data center resources [24].

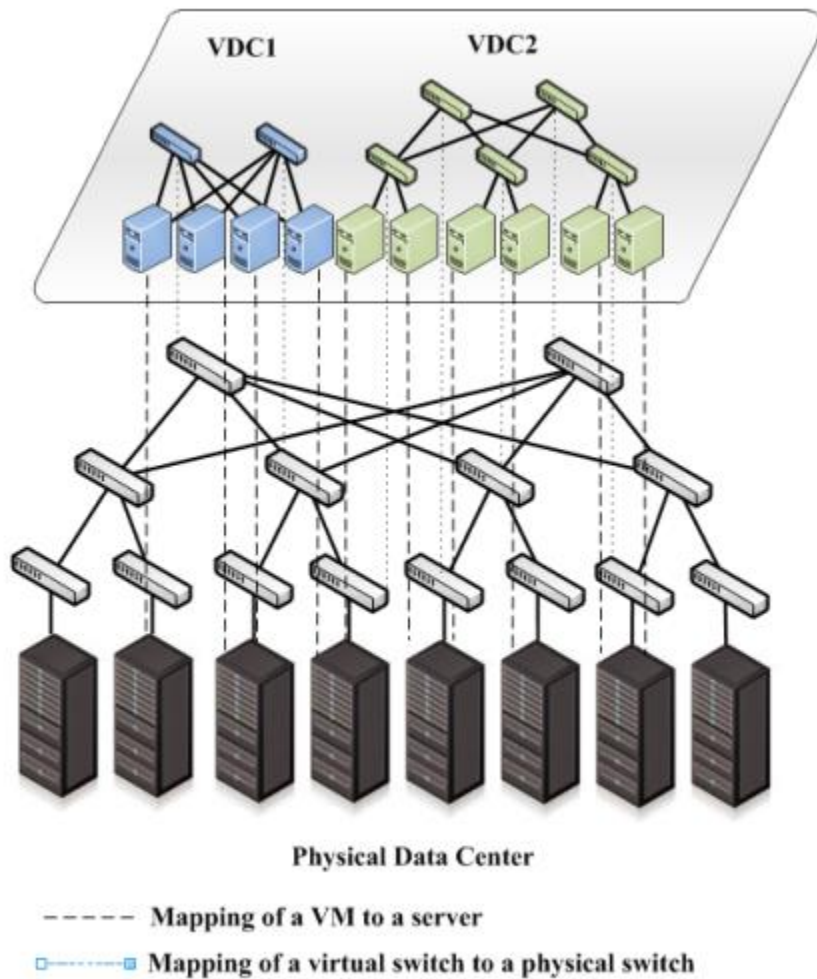


Fig.2.14 Virtualization of Data Center [24]

2.17 ICT AND ETHIOPIAN BANKING CENTER

2.17.1 BANKING OVERVIEW

A bank is one of the industries that contribute a lot to the development of a country's economy and it can be considered as bridge that links customers with capital deficits to customers with capital surplus. Some researchers presented that the history of banking begins with the first prototype banks of merchants in the ancient world, which made grain loans to farmers and traders who carried goods between cities.

There are 18 banks in Ethiopia that are controlled and licensed by the National Bank of Ethiopia, the state regulatory bank in the country. Banks need prior written approval of the National bank Ethiopia in order to transact a banking business, introduce new banking services including new banking technologies. The banking sector in Ethiopia is under the regulation and directive of National bank of Ethiopia. Among the 18, the two of banks: Commercial Bank of Ethiopia and Development bank of Ethiopia, are state owned banks whereas the rest 16 are Wegagen Bank, Awash International Bank, Dashen Bank, Bank of Abyssinia, United Bank, Nib International Bank, Cooperative Bank of Oromia, Lion international Bank, Zemen Bank, Oromia International Bank, Berhan Bank, Bunna International Bank, Abay Bank, Addis International Bank, Dehub Global Bank and Enat Bank are private banks.

The financial sector in Ethiopia is dominated by the banking industry and has a key role in the contribution of the economic growth of the country [9]. Therefore banks should deliver their services in an efficient and effective way in order to increase their role in the economic growth of the country. For this to happen, banks need to implement innovative technologies in order to satisfy their customers, introduce new services, and to cover the underdeveloped and uncovered rural areas of the country. Advances in technology are allowing for delivery of banking products and services more conveniently and effectively than ever before. Rapid access to critical information and the ability to act quickly and effectively will distinguish the successful banks of the future. The bank gains a vital competitive advantage by having a direct marketing and account able customer service environment and new, streamlined business processes [9].

Information technologies are having a great impact in the reshaping of the banking industry, by leading to the development of new financial products and new means of delivering them. With regards to the delivery of products, for instance, the last decades have seen the appearance of Automated Tellers Machines (ATMs), telephone banking, internet banking, mobile banking, and straight through processing (STP) which include Real Time Gross Settlement (RTGS) and Automated Cheque Clearing (ACH). These new channels for the delivery of products and facilitating payments have the advantage for customers of longer hours of service, but are also more efficient, cheaper means of delivering the products and enhancing the banking operations, a means for attracting customers and increasing profitability.

2.17.2 ICT CHALLENGES OF ETHIOPIAN BANKING SECTOR

Nowadays banks are using different technology to improve the process of the frontline and back office banking operations in order to gain an operational excellence. Modernizing the banking industry with information technology infrastructure has a major task which needs a huge investment. Banks can get the ability to choose the optimal solution for each service; renovating elements of their existing system, building customized solution. According to Garedachew [13] the ICT application in Ethiopian banking industry has different challenges. Some of these include the following.

1. Poorly developed telecommunication infrastructure.
2. High cost of internet
3. Inadequate banking system
4. Lack of suitable legal and regulatory framework
5. Frequent power interruption
6. Resistance to changes in technology among customers and staff because of lack of awareness, fear of risk, lack of trained staff, tendency to be content with existing structures, fear of losing employment and resistant to new payment mechanisms.
7. Cyber security issue

2.18 CHALLENGES AND OPPORTUNITIES OF VIRTUALIZATION

2.18.1 VIRTUALIZATION IN BANKING SECTOR

The banking infrastructure is challenged to deliver greater performance with reduced resource and budget. To adapt customer expectations banking services deliver a solution that

- a. Protects business and customer data and reducing.
- b. Easy to use and maintain, which reduces the systems administration overheads and costs.
- c. Delivers business and legacy applications to major devices across all channels, including web, mobile, and internet.
- d. Reduces IT infrastructural costs and complexity.
- e. Ensures business continuity for customers, with no interruptions.

2.18.2 OPPORTUNITIES OF VIRTUALIZATION

Implementation of modern virtualization environment in data center infrastructure has the following advantages [18].

- a. **Flexibility:** it is possible to run different instances and operating systems on a single computer, it is possible to migrate a virtualized instance to another physical computer and the virtual instances can be done smoothly from the host operating system with features like 'pause', 'resume', 'shutdown' and 'boot'.
- b. **Availability:** one can keep the virtualized instances running even though the physical node has to be shut down, like for hardware upgrade or maintenance.
- c. **Scalability:** it is very easy to add or remove nodes. If the demand for capacity increases over time, it is very easy to insert a physical node with the basic cluster installation, and it will contribute in running the existing virtual machines that run services. This way, the cluster will scale with the company as it expands.
- d. **Hardware utilization:** is most likely increased if more than one operating system is hosted simultaneously. This is because virtual machines utilize hardware resources that are left idle by the host operating system.

- e. **Security:** is added because greater separation of services is introduced. Using multiple virtual machines, it is possible to separate services by running one service on each virtual machine. If one service is compromised, the other services are unaffected.
- f. **Cost reduction:** It is possible to achieve cost reductions by consolidating smaller servers into more powerful servers. Cost reductions stem from hardware cost reductions (economies of scale seen in faster servers), operations cost reductions in terms of personnel, floor space, and software licenses.
- g. **Adaptability to Workload Variations:** Changes in workload intensity levels can be easily taken care of by shifting resources and priority allocations among virtual machines. Autonomic computing-based resource allocation techniques can be used to dynamically move processors from one virtual machine to another.
- h. **Load Balancing:** Since the software state of an entire virtual machine is completely encapsulated by the VMM, relatively it is easy to migrate virtual machines in to other platforms in order to improve performance through better load balancing.
- i. **Legacy Applications:** Even if an organization decides to migrate to a different operating system, it is possible to continue to run legacy applications on the old OS running as a guest OS within a VM. This reduces the migration cost.

2.18.3 CHALLENGES OF VIRTUALIZATION

As virtualization has different advantages it has also the following limitations.

- a. **Overhead:** causing decreased performance has been the biggest con with virtualization. Performance is often being compromised due to flexibility. The developers have worked hard to decrease the overhead, to bring it very close to the performance of the standalone physical computer.
- b. **Single point of failure:** even though the virtual machine is decoupled from the hardware, it is still dependent on the hardware working. Failure in the hardware will most likely lead to failure in the virtual machine, which will force a reboot.

- c. **Management interface:** is closely linked to the virtualization platform. This can be a problem as it encumbers consolidation of several platforms into the same environment.

Opportunities of virtualization of IT infrastructure for banking services include the following.

- a. Scalability and control
- b. Security and centralization
- c. Costs
- d. Reduced overheads
- e. Business continuity
- f. Compatibility

2.19 SECURITY THREATS OF VIRTUALIZED ENVIRONMENT

The crucial aspect in order to ensure information security in an organization is to safeguard the confidentiality, integrity, availability, authentication, authorization and accountability of network traffic and business data. In a virtualized environment (VE) context these crucial security aspects can be defined as follows [11]:

- a. **Confidentiality:** to ensure that the network traffic and business user data in a VE remains protected from unauthorized access while in transit and/or at rest.
- b. **Integrity:** to ensure that the network traffic and business user data in a VE cannot be modified, damaged, or deleted by unauthorized access.
- c. **Availability:** to ensure that network traffic and business user data, and services are available when in need by authorized users.
- d. **Authentication:** a process to ensure the identity of the authorized user.
- e. **Authorization:** to ensure that the authorized user has a set of privileges and rights to execute certain activities.
- f. **Accountability:** to ensure that proper audit trails and checks are in place to monitor the access rights of the authorized user.

2.19.1 THREATS OF VIRTUALIZED ENVIRONMENTS

There are different virtualization specific threats and vulnerabilities. These are [11]:

- a. **Virtualization based malware:** it is software based or hardware based malware that affects integrity.
- b. **Denial of service attack:** isolation of the guest OS virtual machine and the host OS which affects availability.
- c. **Communication attack among guest VMs and the host:** transferring malicious code between the guest OS VMs and host OS that affects confidentiality, authentication and authorization.
- d. **Virtual machine escape:** the ability to escape the guest VM environment and directly interact with the VMM will gain access over every other VM on the physical host which affects authentication, authorization and accountability.
- e. **Inter-VM Attacks and Network Blind Spots:** Network blind spots is when the traditional network security solutions are blinded and cannot detect the malicious communication behavior that might occur between the guest VMs and between the guest VMs and the host (i.e. inter-VM) residing on the same physical platform that affects authentication and authorization.

2.20 RELATED WORKS

Virtualization in data center is implemented for various benefits in IT infrastructure deployment for efficiency, security, scalability and for future green information technology infrastructure. In this section, the study describes the available literature on best practice related to data center virtualization frame works development. Unfortunately, local researcher on the assessment of framework of data center virtualization implementation for different sectors including banking infrastructure could not be found.

Research by Udin et.al [25] proposes five step models using an emerging technology called virtualization to achieve energy efficient data centers. Technology should provide sustainable and agile benefit for organizations regardless of their structure, commercial or non-commercial. As the rapid growth of technologies and the invention of different equipment's which needs huge

industry standard infrastructure that consumes high energy with high emission of gases, (CO₂) which is the highest challenges of this world. The framework highlights the importance of implementing green metrics like power usage effectiveness (PUE) and data center effectiveness, and carbon emission calculator to measure the efficiency of data center in terms of energy utilization and carbon dioxide (CO₂) emissions. The framework is based on virtualization and cloud computing to increase the utilization ratio of already installed servers from 10% to more than 50% (25). The proposed Green IT framework also helps IT business enterprises specifically data center industry to follow a virtualized Green IT framework, to save huge amount of energy and at the same time reduce the CO₂ emissions, which ultimately reduces global warming effects. It consists of five steps to be followed to properly implement virtualization at different layers and levels and then helps to identify and employ green metrics to measure the efficiency of data center in terms of energy efficiency and CO₂ emissions. The proposed Green IT framework using virtualization and green metrics should be used and followed by data center managers to implement green initiatives in their data center to make it more energy efficient and green. It consists of the following five phases [25]:

- 1) Develop plan for green data centers.
- 2) Categorize data center into measureable components.
- 3) Identify green metrics and set benchmarks.
- 4) Identify and implement virtualization type.
- 5) Measure the performance in terms of energy efficiency and CO₂ emissions.

Although virtualization is one of the utmost ways to reduce power consumption in data center, the application is not straight forward. Design and configuration of the virtualization will determine the degree of energy efficiency of a data center.

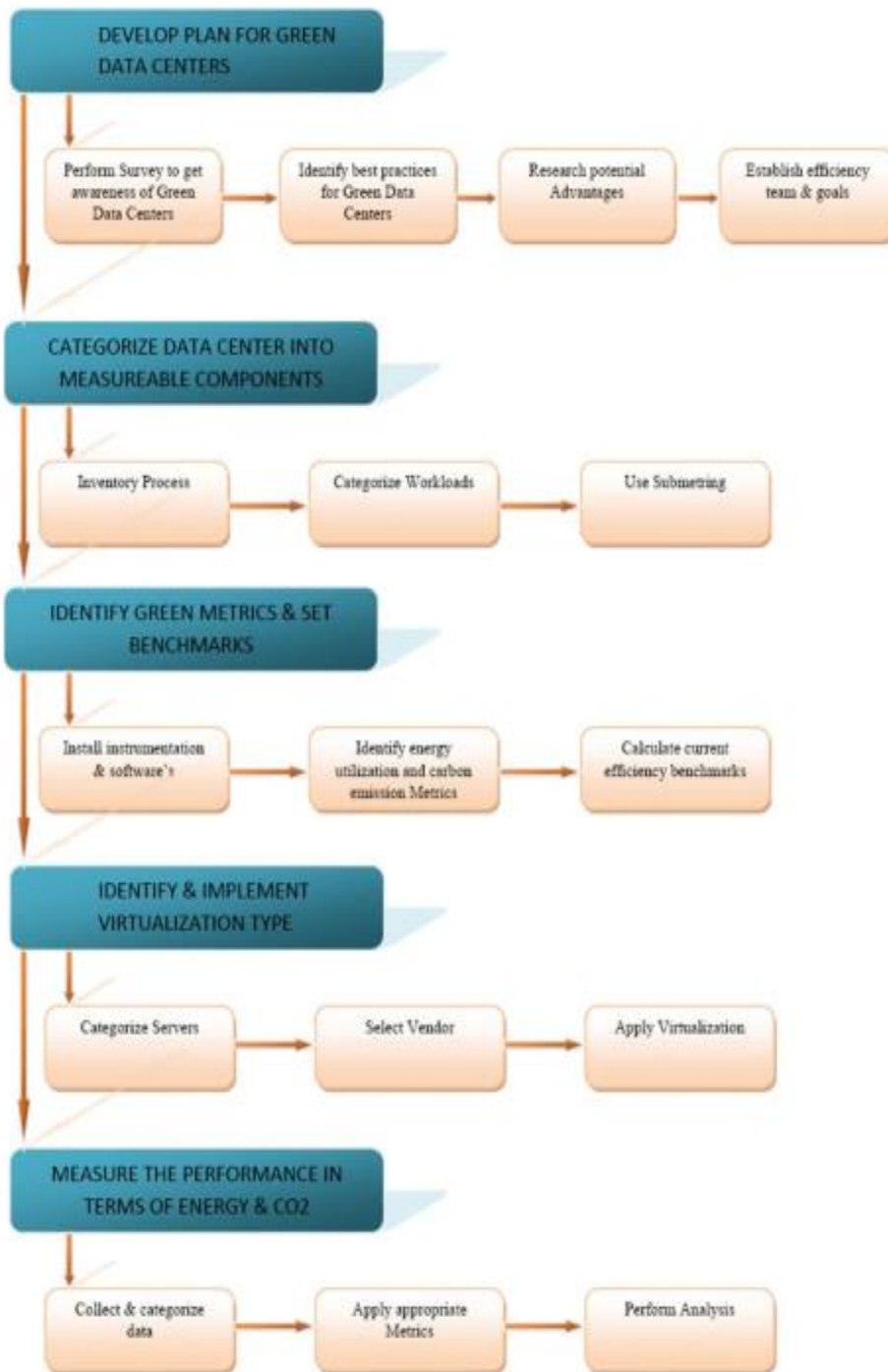


Fig.2.15 Green IT framework using virtualization [25]

The proposed research framework tested (Fig.15) in higher level data centers in Pakistan related to validity, credibility, reliability, and legitimacy. And, the result that the green IT framework using virtualization is acceptable to data center industry.

The other study investigated is the issue of virtualization based security framework [29]. The purpose of IT security relies on confidentiality, integrity, and availability of the IT systems. On the study of virtualization based security framework [29] has the primary goal of vBASE is to aid the testing of security architectures and to enhance the existing security features provided by virtualization. to provide a framework that can be deployed in Cloud Computing environments. The vBASE framework is developed by modifying the Xen VMM. The various component of the vBASE framework are as follows.

The MoCo VM: This is a DOM 0 virtual machine in which the Monitor and/or Controller is running. **Application VM:** This is a DOM U virtual machine in which the secure process/application is running.

Monitor: The Monitor is responsible for monitoring all the events at various levels pertaining to the secure processes/applications running on the security architecture.

Controller: The Controller is only used in testing mode of operation. Here, it has complete control of the memory, network and I/O of a secure process/application running on the Application VM. This is used to mount attacks on such a secure process/application. These attacks test the effectiveness of security measures provided by security architecture.

Events: Events are used to notify various actions from application, operating system and SAPI to the monitor and other components of the vBASE. Events are implemented using Hypercalls (for application, OS to SAPI communications) and VIRQS: Virtual Interrupts (for SAPI/VMM to Monitor communication). We have implemented custom hypercall VBASE OP hypercall with commands like ENTER, EXIT, ENCRYPT, DECRYPT and Virtual interrupts like VIRQ VBASE for implementing events. For ease, we will refer to VBASE OP hypercall with ENTER command as enter-vbase and likewise.

SAPI: The Secure Architecture Plugin Interface (SAPI) enables the VMM to plugin security architectures for testing and deployment purposes. A domain is associated with a security architecture through its configuration file. The secure processes/applications running on these architectures by using a new set of instructions provided by SAPI e.g. enter-vbase and exit-vbase

instructions. In testing mode, the plugged in security architecture reports the MoCo VM about the protected processes that it wants to be monitored.

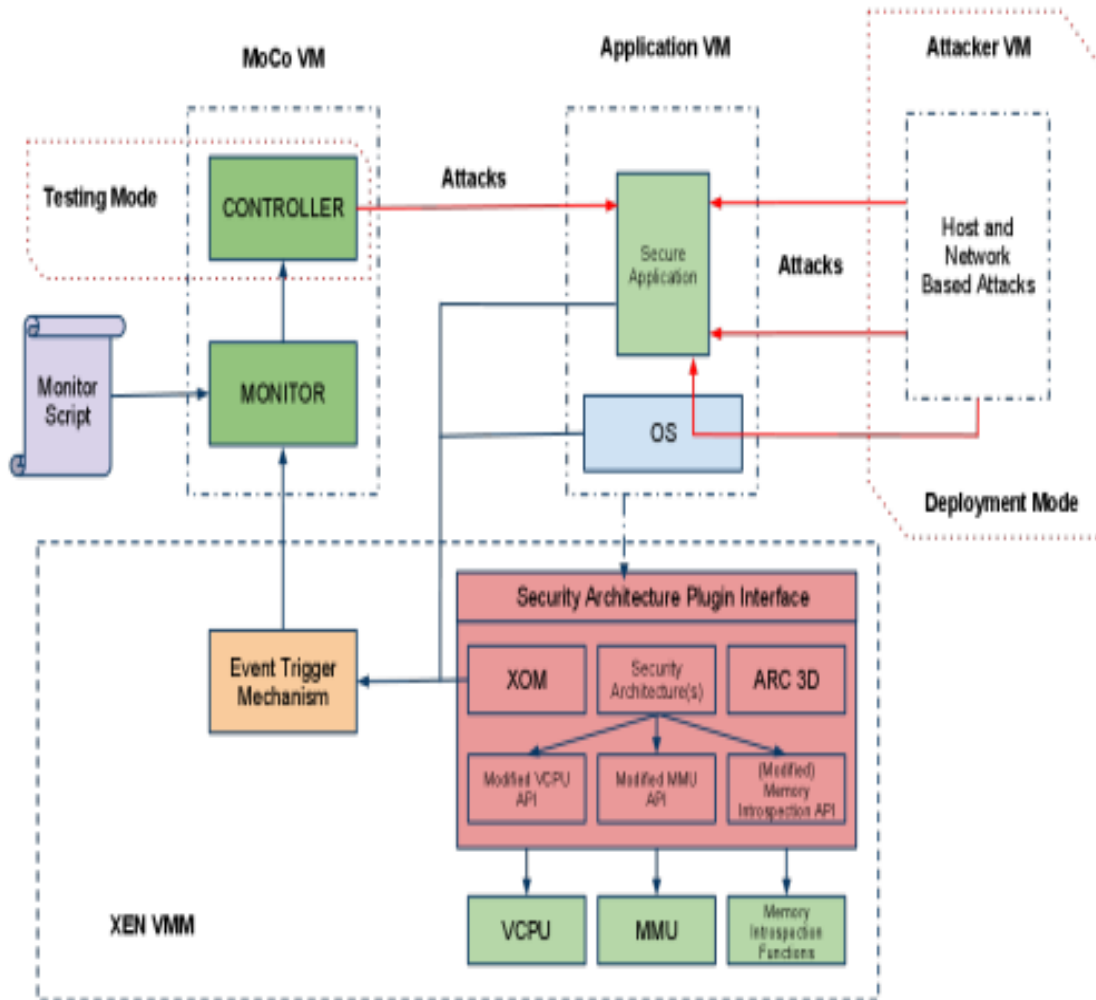


Fig.2.16 vBASE framework [29]

The framework implemented (Fig. 2.16) on hypercalls, monitor, and event trigger mechanism of vBASE and secure memory aspect of the SAPI and the future will be completing the SAPI for one of the secure architectures and implementing the controller.

CHAPTER THREE

RESEARCH DESIGN AND METHODOLOGY

The purpose of research is to discover answers to questions through the application of scientific procedure [5]. There are basically three research designs as stated and categorized by [15] and they distinguished them based on their problem structure or natures such as exploratory, descriptive and explanatory. In both descriptive and explanatory research designs the problem is structured and understood. When the research problem is badly understood an exploratory design is adequate. Exploratory studies are a valuable means of finding out “what is happening; to seek new insights, understanding and knowledge; to ask questions and to assess phenomena in a new light” [26]. It is particularly useful to clarify understanding of a problem and it is also believed that all methods are valuable if used appropriately in light of the research problem and objectives.

3.1 METHODOLOGY OF THE STUDY

The purpose of this study is to explore and examine the current data center infrastructure in Ethiopian banking sector specifically in Wegagen bank and to propose a solution for the data center infrastructure. In order to achieve the general and specific objective of this research and to propose the virtualized data center framework, a design science method is used. Qualitative data collection methods, including interviews, focus groups discussion, participant observation, and open-ended survey items have great potential for exploring new topics, assisting theory building, and providing context for quantitative data [23]. A framework is an interconnected set of ideas (theories) about how a particular phenomenon functions or is related to its parts. The framework serves as the basis for understanding the causal or correlational patterns of interconnections across events, ideas, observations, concepts, knowledge, interpretations and other components of experience.

There are several requirements, which are essential while working on a data center virtualization framework. The purpose of this study is developing knowledge related to the problems and the current solution to design the proposed data center virtualization framework. Data is collected using interview and review of relevant literature and examining related works. In developing the

data center virtualization framework the study go through by identifying the overall variables in the subject area and by pointing out the key variables in the subject, and finally focusing on the relationship between the key variables. The research method used in this study is based on the design science research methodology in information science research.

3.2 DESIEN SCIENCE RESEARCH METHODOLGY

In information system discipline most researches have two paradigms. These are behavioral science paradigm and design science paradigm. The behavioral science paradigm seeks to develop and verify theories that explain or predict human or organizational behavior. The design science paradigm seeks to extend the boundaries of human and organizational capabilities by creating new and innovative artifacts. Both paradigms are foundational to the IS discipline, positioned as it is at the confluence of people, organizations, and technology. In the design-science paradigm, knowledge and understanding of a problem domain and its solution are achieved in the building and application of the designed artifact [1]. The design science research methodology (DSRM) incorporates principles, practices, and procedures required to carry out such research and meets three objectives: it is consistent with prior literature, it provides a nominal process model for doing DS research, and it provides a mental model for presenting and evaluating DS research in IS. The DS process has the following steps: problem identification and motivation, definition of the objectives for a solution, design and development, demonstration, evaluation, and communication [20].

3.3 PROBLEM IDENTIFICATION AND MOTIVATION

In this stage the study briefly defines the specific study problem and justifies the value of the solution. In defining the study problem, developed an artifact that can effectively provide a solution. In addition, to justify the solution the researcher go through document analysis, interview and literature review on data center virtualization. The value of the solution also justified motivating the researcher and the audience of the research to pursue the solution, to accept the results, and to understand the reasoning associated with the researcher's understanding of the problem. These activities include knowledge of the state of the problem and the importance of its solution.

3.4 DEFINE THE OBJECTIVE OF THE SOLUTION

In this stage the study aims to identify the requirements for developing the proposed data center virtualization framework from knowledge of the state of problems and current solutions. The researcher infers the objectives of a solution from the problem definition and knowledge of what is possible and feasible to align with the bank's requirements. The qualitative objectives are used, which described how a proposed framework is expected to support solutions to problems not previously addressed. The researcher used the conceptual framework to inferred objectives rationally from the problem specification. In order to develop the study conceptual framework, researcher started with the literature review to gather relevant requirements and aspects of existing data center frameworks.

3.5 SOURCE OF DATA AND DATA COLLECTION TECHNIQUE

This study employed both primary data source and secondary data collection technique for data collection. Related to the primary source of data the researcher uses interview and questioners. Intensive interview with infrastructure manager, network administrators, system administrators, database administrators and data center administrators has been made for better understanding of the current(traditional or physical) data center infrastructure architecture and trends. The researcher uses open question to obtain responses from interviewee. There are different types of interviews, which includes structured interview, unstructured interview and semi structured interview. A semi-structured interview is chosen because it provides information which assures the comparability of data. It also requires a few interviewing skills than does unstructured interview. Accordingly, this activity was undertaken with purposely selected sample, key officials and experts working in IT department who have different responsibility, expertise and experiences about the major challenge encountered. Thus, interview guides which comprises of semi structured questions were developed. Open-ended questions are used in organizational research to explore, explain, or reconfirm existing ideas. Whereas quantitative methods work best in isolating variables and demonstrating correlations associated with variation. Qualitative data collection techniques are particularly effective at gaining insight into the processes and events that led up to the observed variation [8]. A questioner was developed on the analysis on the structure of data center status and its effectiveness, efficiency and availability including the

physical and technical aspects. In addition, as secondary data source relevant information was collected by consulting different documents pertinent to the study, these includes literatures on related works and concepts which are articles, journals and organizational documents.

3.6 STUDY POPULATION AND SAMPLING METHODS

To collect and present the data from the target population is time taking and costly. Sampling techniques provide a range of methods that enable to reduce the amount of data needed to collect by considering only data from a subgroup rather than all the population [26]. Sample designs are basically of two types: non-probability sampling and probability sampling. Probability sampling is based on the concept of random selection, whereas nonprobability sampling is ‘non-random’ sampling. Under probability sampling design, every item of the population has an equal chance of inclusion in the sample. Under non-probability sampling thing are not left to the chance [5]. Purposive sampling represents a group of different non-probability sampling techniques and it is also known as judgmental, selective or subjective sampling. Purposive sampling relies on the judgment of the researcher when it comes to selecting the units (e.g., people, cases/organizations, events, pieces of data) that are to be studied. Purposive or judgmental sampling enables to use judgment to select case that will best enable to answer research questions and to meet the objectives. This form of sample is often used when working with very small samples [26]. Purposive sampling was used for data collection in this study, which means that the best suitable respondents were chosen from information technology services department inside the banks who have different job descriptions in order to understand some activity or phenomenon better and discover new viewpoints instead of making statistical generalizations [26]. The investigator may select a sample which shall yield results favorable to his point of view. Accordingly different IT staffs including IT experts and infrastructure managers in the banks were selected for interviews. The selected IT experts were included in the survey sample because it is believed that those people have a good exposure with data center activities.

Respondents by ITSD department	Total Population	Target Population	Total
Director	1	1	1
Manager	4	4	4

Senior Expert	7	7	7
Expert	5	5	5
Total	17	17	17

Table 3.1 Total Population for the study

3.7 METHODS OF DATA ANALYSIS

The term analysis refers to the computation of certain measures along with searching for patterns of relationship that exist among data-groups [5]. Data analysis is bodies of methods that help to describe facts, detect patterns, develop explanations, processed and analyzed. [17] Describes that data analysis involves the following three steps:

1. Preparing the data for analysis,
2. Analyzing the data, and
3. Interpreting the data.

The researcher analyzed the data collected through survey on data center virtualization. After relevant information is collected data presentation and interpretation was the necessary next step. The information collected from both primary and secondary data sources through review of different documents and interview with key informants was organized and narrated. Explanations were supplied for each question along with respondents' justification. Ultimately generalizations were made and presented accordingly for the qualitative data by way of narrating and interpreting the situations.

3.8 DESIGN AND DEVELOPMENT

The conceptual models of DSR must produce a viable artifact in the form of models, methods or frameworks. This stage determines the desired functionality and its architecture and then creating the actual artifact. The knowledge of theory that can be brought to bear in a solution is required to move from objective of a solution to design and development of the proposed framework. Based on the required knowledge of a solution identified in stage one (problem identification and motivation) and stage two (defining the objective of the solution) with the literature review and

expert interviews analysis to develop the proposed framework with the process selected. After determining the data center virtualization framework architecture, the proposed collaborative DC virtualization framework for Wegagen bank with the implementation plan to deploy virtualized data center could be developed.

3.9 DEMONISTRATION

Demonstration is a part where the study demonstrates the use of the artifact to solve one or more instances of the problem using a prototyping tool. This includes experimentation, simulation and other activity. Resource required for the demonstration includes effective knowledge of how to use the artifact to solve the problem. Virtualization software can convert a single computer into multiple ones. Different types of virtualization software like kernel based virtual machine (KVM), Red Hat Enterprise Virtualization (RHEV), Xen / Citrix Xen Server, Microsoft Hyper-V Server and VMware V sphere / ESXi are accessed. Among this open source Microsoft Hyper-V is selected to analyze for the usage and performance of process, memory, CPU, usage of servers for demonstration.

3.10 EVALUATION

Here the study aims to observe and measure how well the framework supports a solution to the problem. This activity involves comparing the objectives of a solution to actual observed results from use of the framework in the demonstration. It requires knowledge of relevant metrics and analysis techniques. Depending on the nature of the problem venue and the artifact, evaluation could take many forms, including comparison of artifact's functionality with the solution objectives this study took the qualitative evaluation analysis techniques which include a comparison of the proposed framework functionality with the solution objectives from activity two above, objective qualitative performance measures, such as business impacts, and business continuity extents of use and user satisfaction. . To propose and design the virtualization framework an open source Edraw max version 7.7 and Microsoft Visio is used.

Evaluation is made under the following steps:

- a. **Literature review:** the study examines and assesses every necessary taxonomy and concepts on data center infrastructure environment and virtualization concepts with its

architecture, effectiveness and availability from journals, articles, conference proceedings and etc.

- b. **Evaluating the current data center exercise and challenges:** The researcher followed qualitative methods is to assess the current traditional (physical) data center trends, practices, success factors, and problems that impede the implementation of virtualized data center in Wegagen bank and other banks. The qualitative methods approach would allow for text analyses of data, and would permit more flexibility when designing questions for survey interviews which is semi-structured questions [2].
- c. **Propose the data center virtualization framework:** The conceptual data center virtualization framework is demonstrated based on literature review findings, related works and the assessment on the result of the current data center practice.
- d. **Evaluate the proposed framework:** The proposed conceptual virtualized data center framework was evaluated by domain experts who have a direct relation with information technology infrastructure. Among them are infrastructure managers, network administrators, data center administrators and system administrators.

3.11 CONCEPTUAL FRAMEWORK

A conceptual framework is an interconnected set of ideas (theories) about how a particular phenomenon functions or is related to its parts. The framework serves as the basis for understanding the causal or correlational patterns of interconnections across events, ideas, observations, concepts, knowledge, interpretations and other components of experience [22]. A conceptual framework used in this study was by limiting the scope of DSRM process discussed above and focus on specific variables and defining specific viewpoint (framework). The researcher took to analyze and interpret the data to be gathered, understanding concepts and variables according to the given definitions, and building knowledge by validating or challenging theoretical assumption.

The variables used to construct the frameworks have bi-directional of three interconnected flows. These are: factors of data center virtualization, approaches of data center virtualization and results of data center virtualization.

- a) **Factors of data center virtualization:** - the aim of this variables is to assess the opportunities and challenges of virtualization implementation in Wegagen bank
- b) **Approaches of DC virtualization:** - as data center virtualization encompasses broad ranges of technology and process that enable a data center to operate and provide services. The aim of this variable is used to determine the virtualization model, virtualization type, and virtualization implementation type in relation to the opportunities of virtualization for banking sector.
- c) **Results of DC virtualization:** - the aim of this variable is to identify the key benefits of DC virtualization.

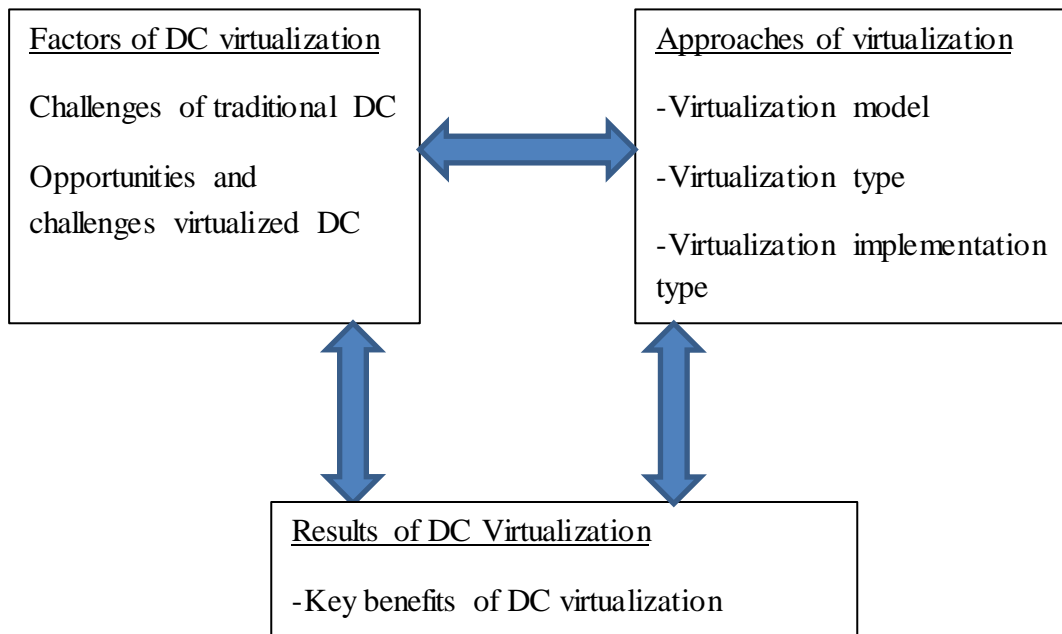


Fig 3.1 conceptual framework of the study

3.12 PROCEDURES

The data-gathering tool used in the study was designed on the basis of the reviewed literature and the intended data to be collected. The questionnaire was distributed to the respondents in terms of interview. The data collection process was administrated by the researcher. Data collections through interview were conducted by speaking to the respondents face to face. Before conducting the interview, the researcher has tried to create conducive atmosphere and explain the

purpose of the interview to them. As a result necessary information was collected, organized and processed separately for interpreting and summarizing purpose to produce the major findings. Finally, the researcher proposed a virtualized data center framework.

3.13 ETHICAL CONSIDERATION

Since the study often involves a great deal of cooperation and coordination among many different people with different responsibilities inside the organization, ethical standards to promote the values that are essential to collaborative work are considered. The researcher also considered potential risks and ethical conflicts when designing and conducting the study. Accordingly, a formal discussion was made with information technology services department staffs and higher officials to get permission to conduct the study.

Informed verbal consent was secured from all participants subjects before conducting the actual study. Confidentiality was maintained at all levels of the study. Respondents who were unwilling to participate in the study and those who wanted to quit the interview or discussion at any point in time were informed to do so without any restriction.

CHAPTER FOUR

DISCUSSION AND INTERPRETATION

The purpose of this chapter is to interpret, discuss and analyze data obtained from primary and secondary sources. Beside, primary data were also generated with the help of key informant interviews with IT experts to propose the virtualized data center framework and to assess how this framework helps on the service delivery performance and effectiveness in the banking industry.

4.1 RESPONDANTS INFORMATION

The respondents of the study include those experts that have a direct relation with data center daily activities in the bank which are Infrastructure managers, senior network administrators, senior database administrators and senior system administrators. Summary of respondents profile is shown in table 4.1 below.

Profile		Sex		Number of respondent	Number of in respondent in percentage	Remark
		M	F			
Work experience	5 -7 years	4	1	17	100%	
	> 7 years	10	2			
Education background	1 st degree	14		14	82%	
	Master	1	2	3	18%	
Position	Director	1		1	7%	
	Manger	3	1	4	23%	
	Senior experts	5	1	6	35%	
	Experts	5	1	6	35%	
Total		14	3	17	100%	

Table 4.1 Biographic information of respondents

4.2 WHAT MAKES DATA CENTER VIRTUALIZATION ATTRACTIVE

Information technology infrastructure needs are evolving rapidly as virtualized datacenters transform into service centers that deliver applications on demand and respond to changing customer requirements with speed and agility. In banks, there is an increase in data and service type (E-banking, IFB, Mobile banking, Agent banking etc.), there is a high need for greater optimization and efficiency in how infrastructure and solution that power data centers are deployed and managed. These trends are pushing IT departments to find better ways to integrate, provision, deploy, and manage systems at a faster pace. Virtualization is a key technology used in datacenters to optimize resources. As IT needs continue to evolve, virtualization can no longer be regarded as an isolated technology to solve a single problem.

The factors that make data center virtualization attractive options for financial service institutions are perceived cost savings, faster time-to-market for deploying systems, virtualization of enterprise-wide data as a service, enterprise technology standardization, and the ability to access data and applications on the move. These critical factors can drive the banking sector to implement data center virtualization.

4.3 INTERVIEW INTERPRETATION

The analysis of the collected data is done by the researcher. The target of this interpretation is to present the views and ideas of the respondents in regards of the data center virtualization. The main components that are needed to be analyzed and interpreted from the interview for the development of data center virtualization in banking sector are:

- a. Investment in IT infrastructures
- b. Benefits of virtualization
- c. The role of IT infrastructure staffs in virtualized data center, and
- d. Reason for implementation of virtualized data centers

In Ethiopia, banking services are provided on a group of networked banking channel services to the customers from a single bank infrastructure. In this context, for expanding the geographical coverage of these banking services, banks need to distribute the channels with the necessary resources (human, financial, computing etc.). Distributing branch offices and installing ATMs to

expand the market coverage of the banking services need high investment costs to acquire hardware and software infrastructure. This does not protect the investment costs of ICT that affect the financial efficiency of banks. When the market reaches at its peak time or computing needs change, banks also need to procure and install more IT infrastructures to support the banking operation. This does not provide a flexibility to respond to fluctuations of market supply and demand, because resources are procured and installed in a fixed time interval.

The finding indicates that in relation to the investments of data center virtualization, the banking technology is designed for IT managers and other IT professionals to deliver a solution that is cost effective, reliable, and meets the requirements set by the government regulation. Therefore, banks must invest in their IT infrastructure to remain competitive in the marketplace. Data center virtualization allows the banks to easily set up a secure network and centrally control all the branches' activity. At the same time, it provides for employees the ability to access corporate data in a secure fashion from anywhere, anytime. In addition, the respondents assured that the investment of this infrastructure ensures business continuity for both customer and employees, with no interruptions or crashes or of services. All Respondents agreed that high investment cost on IT infrastructures, inefficient use of IT resources, lack of collaboration among banks to share IT resources, internet bandwidth inconsistency, the changing computing needs which bear compatibility problems and other related factors were the key challenges in the current ICT usages in banking Sectors. Lack of up-to-date plan for ICT service delivery strategy also considered as a limitation for banks` to be beneficiary from latest infrastructure technology. In regards to the cost incurred on the existing traditional (physical) ICT infrastructure to support the core banking services, many respondents agreed that very expensive. The suggestions from all respondents on virtualized data center indicated that, compared with the existing IT infrastructure to support banking services, using virtualized data center in banking industry is efficient to perform banking activities at lower costs.

Moreover, all who participated in this study were asked about the overall potential benefits on the virtualization infrastructure in banking sector, all of them have general agreement on:

- a) **Security and centralization of data:** - security is the largest concern for banks. To address this concern, advanced IT infrastructures are built to support robust authentication mechanism. Current IT solution encrypts all user connections, making sure

that connections are not vulnerable to man-in-the-middle attacks. The current IT solution must be protected from within the local and wide area network.

- b) **Scalability and control:** - Scalability is a mandatory requirement for banking sector. The majority of banks have multiple branches across various states and often in foreign countries (for swift transaction). Advances in infrastructure technology have resulted in virtualization that can be easily scaled up without incurring too much cost. When investing in an IT solution, banks must be able to scale up the network with minimal effort to keep up with today's changing business demands, while retaining control of every asset along the way.
- c) **Business continuity:** - bank customers require access to their accounts anytime, anywhere. Advanced IT infrastructure solutions have all the necessary features to build a high availability virtualization solution that not only ensures maximum uptime, but also the avail resources to enable users' and customers' broad access to data when connected to the system.
- d) **Reduce overhead:** - banking sectors want a secure and scalable IT system, but they still need affordable and straightforward administration controls. Fortunately, there are many ways to achieve these requisites that don't require setting up high-end servers or investing in massive on-site infrastructure. Modern technology and virtualization allows more efficient use of hardware. Institutions can set up a system that provides enterprise features, such as load balancing, without requiring significant physical hardware or maintenance. Furthermore, a virtualization IT solution allows administrators to connect remotely to users devices and walk them through any issues they encounter.

In relation to the complication on the role of data center manager the respondents have agreed his role becomes virtual infrastructure administrators and this role introduces new capabilities. This role combines system administration duties, along with the tasks associated with the required network and storage for their virtual environment. This would typically include managing the associated resources for the VMs, including network, storage, and memory resources. Associated networking tasks would include things like adding and removing port groups, virtual Ethernet adapters and switches, or updating IP routing for the host. Newly associated storage duties would include tasks like provisioning the storage for virtual machine files, taking virtual machine snapshots, adding and reducing storage capacity for virtual machines. These new capabilities can

cause concern for the storage and network administrators who need to be sure they retain ownership of the policies directly associated with their roles. As an example, the Storage Administrator is still responsible for the overall data backup and recovery policies, and the Network Administrator is still the owner of the network and bandwidth allocation. If a new virtual machine needs to be provisioned, the VI Administrator can very rapidly create a new VM in addition to the required network and storage for that VM. At the same time, Storage and Network Administrators still own the overall policies, which would include backup and recovery settings or network security policies. As long as the VI Administrator works within those policies, tasks like configuring and deploying a new server are completed very quickly with little or no dependencies. This faster and easier infrastructure provisioning provides a more flexible and scalable enterprise, while at the same time, simplifies configuration for network and storage resulting in higher operational efficiency. While these new capabilities are providing increased efficiencies, the Database and Application administrator roles remain largely unchanged. They are still, with or without virtualization, performing a large number of day-to-day responsibilities involving deployment, monitoring, managing, optimizing and patching.

The other issue the respondents gives two reasons on the implementation of data center virtualization technology, first by explaining the insufficiency of traditional data center and secondly, by explaining the technical advantage of data center virtualization. In case of its insufficiency they try to express in terms of the traditional data center focus on business and application system stability, safety and reliability. But, the infrastructure ignores considering resource utilization rate which is too low, the poor business continuity and the high operational energy cost. The other issue in terms of its technical advantage is that the virtualization technology improves the efficiency of resource utilization and service levels, releases the potential of the data center, and brings great operational flexibility to the data center. Virtualization technology is not just a simple integration tool; it introduces more advanced automation, system management is more agile in supporting the business development to the data center and with these banks will be able to scale up their systems easily and efficiently to continuously provide the demands of their customers.

4.4 PERFORMANCE COMPARISON TEST

In addition to interview the researcher assessed to analyze the usage and performance of CPU, process, memory usage of servers without virtualization and with virtualized servers by using Hyper-V, which is Microsoft virtualization platform. Hyper-V can be used as a stand-alone product or an integrated part of windows server and it can be used efficiently to run multiple operating systems, Windows, Linux and other in parallel on a single server.

Windows application installed server machine has tools to collect all the metrics and events to be monitored. Windows Performance Monitor provides a built-in interface for graphing performance counters, either in real-time or from logs of historical data. It is possible to graph data from both local and remote hosts, as well. Performance counters are organized by class and have human-readable names as well as detailed metric descriptions. Even though, there are many tools in to windows server for monitoring system health and performance related to CPU and memory usage. Some of the tools with non-graphic user interface (GUI) are windows power shell and windows management instrumentation (WMI) and with GUI are server manager, task manager, performance monitor and resource monitor.

Windows resource monitor is a well-known task manger that provides a real time information using GUI in relation to CPU, memory, disk and network metrics. Fig 4.1 tries to show the performance of single application server without virtualization with 16 GB memory, dual core with 2.4 GHz CPU and 146 GB hard disks and it utilizes 46.25% of its memory and 18% of its CPU. In addition the figure 4.1 shows the utilization and performance of CPU and memory while users are using the Omni Enterprise application through web address.

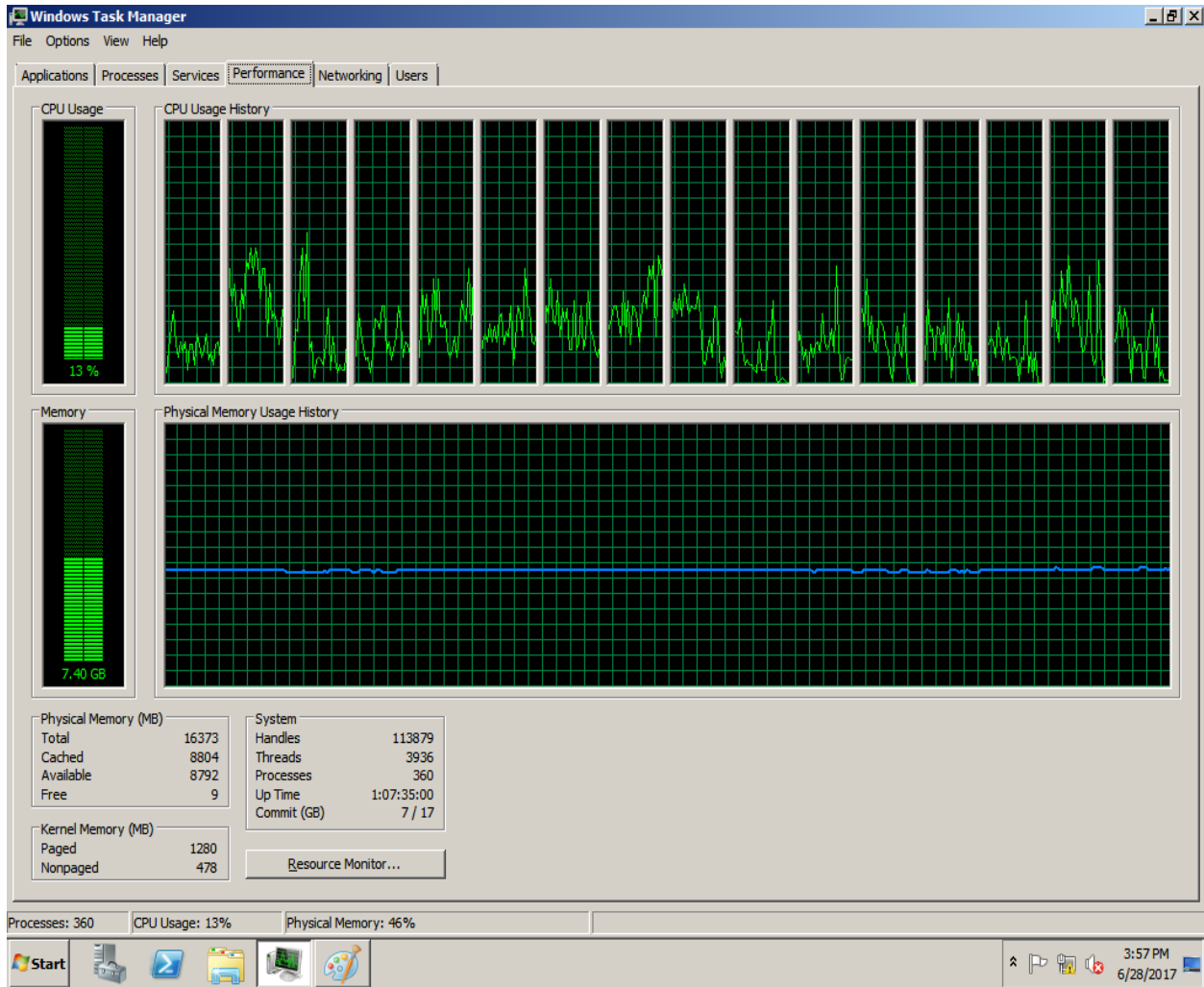


Fig. 4.1 Overview of single application server

4.5 INSTALLING AND CONFIGURING VM FOR HIGH AVIALABILITY

Microsoft installed physical server by adding Hyper-V manager roles in add roles and features column. In this physical environment the operating system assumes the ownership of all physical CPUs, Memory's, and hard disks in the system. Hyper-V implements isolation of virtual machines in terms of a partition. A partition is a logical unit of isolation, supported by the hypervisor, in which each guest operating system executes. A hypervisor instance has to have at least one parent partition, running a supported version of Windows Server. The virtualization stack runs in the parent partition and has direct access to the hardware devices. The parent partition then creates the child partitions which host the guest OSs. A parent partition creates child partitions using the hyper call API, which is the application programming interface exposed

by Hyper-V. Before creating each virtual machines first by installing Hyper V roles in windows server machine and then enable client Hyper V. From Hyper-V manger we have virtual machine wizards that provide a simple and flexible way to create a virtual machine. Figure 4.2 shows the overview virtually created using the wizard that have the physical server with a capacity of 16 core processor, 128 GB Memory and 1.3 TB HD capacities. Then, with the help of Hyper-V manager and that is created four (4) virtual machines, which has 24 GB Memory, 200 GB hard disk and for the CPU is assigned in 3 cores.

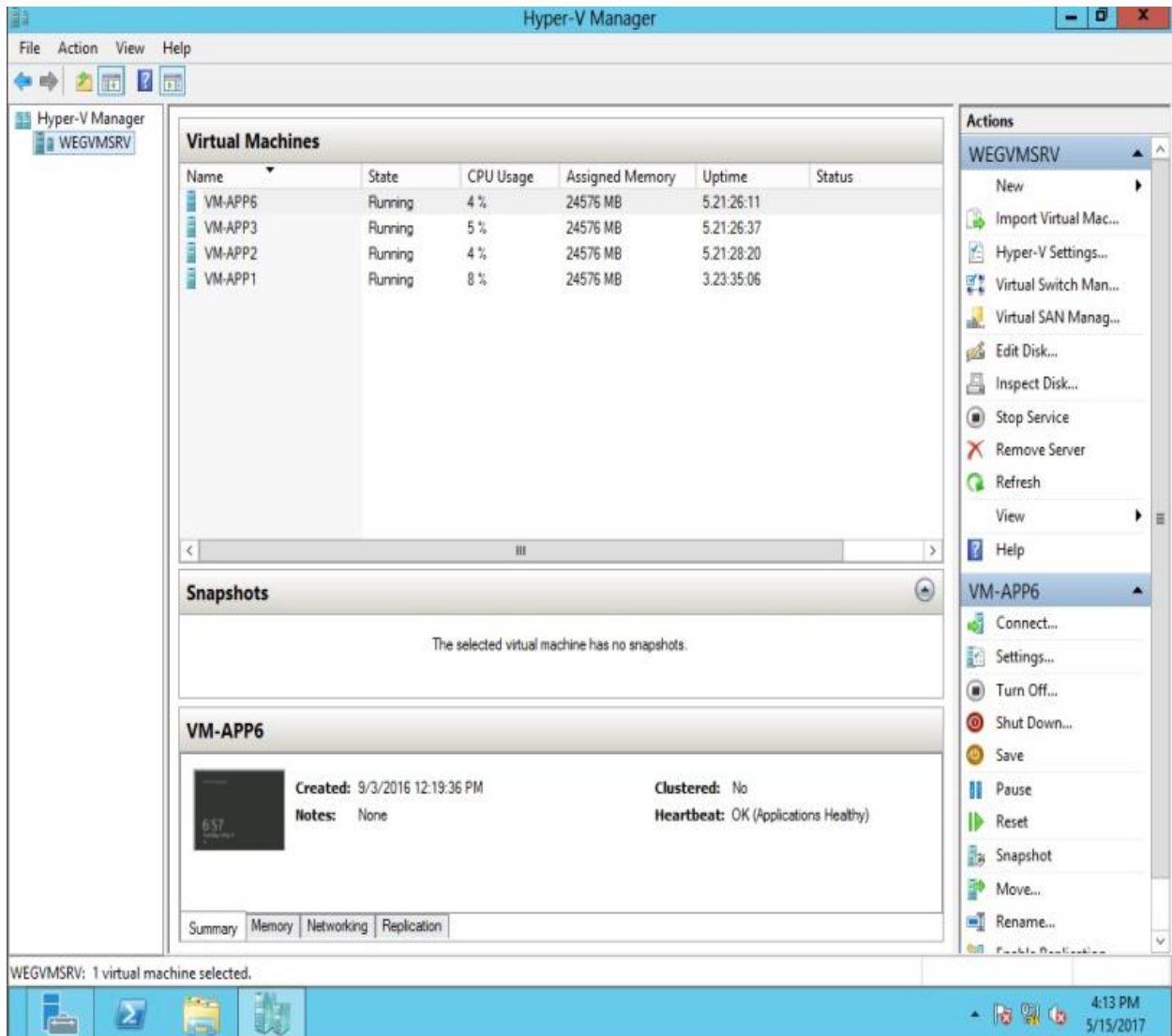


Fig. 4.2 configured virtual machines

After creation of virtual machines, it is necessary to configure the hard disk, memory and processor to provide the appropriate computing resources for the workload that is planned to run on the virtual machine. This workload consists of the guest operating system and all applications and services that will run at the same time on the virtual machine. A virtual machine needs enough memory allocated to it to run the workload. However, each virtual machine consumes memory only when it is running or paused. The number of virtual processors you should configure depends on the guest operating system. Hyper-V provides processor compatibility settings to make it easier to use an older operating system and to make it easier to perform a live migration of a virtual machine to another physical computer with a different processor version. A virtual machine can use different types of storage media, Hard disks, both virtual hard disks and physical disks. Figure 4.2 and figure 4.3 tries to show the performance of CPU, Memory and hard disk usage while users are using Omni enterprise application.

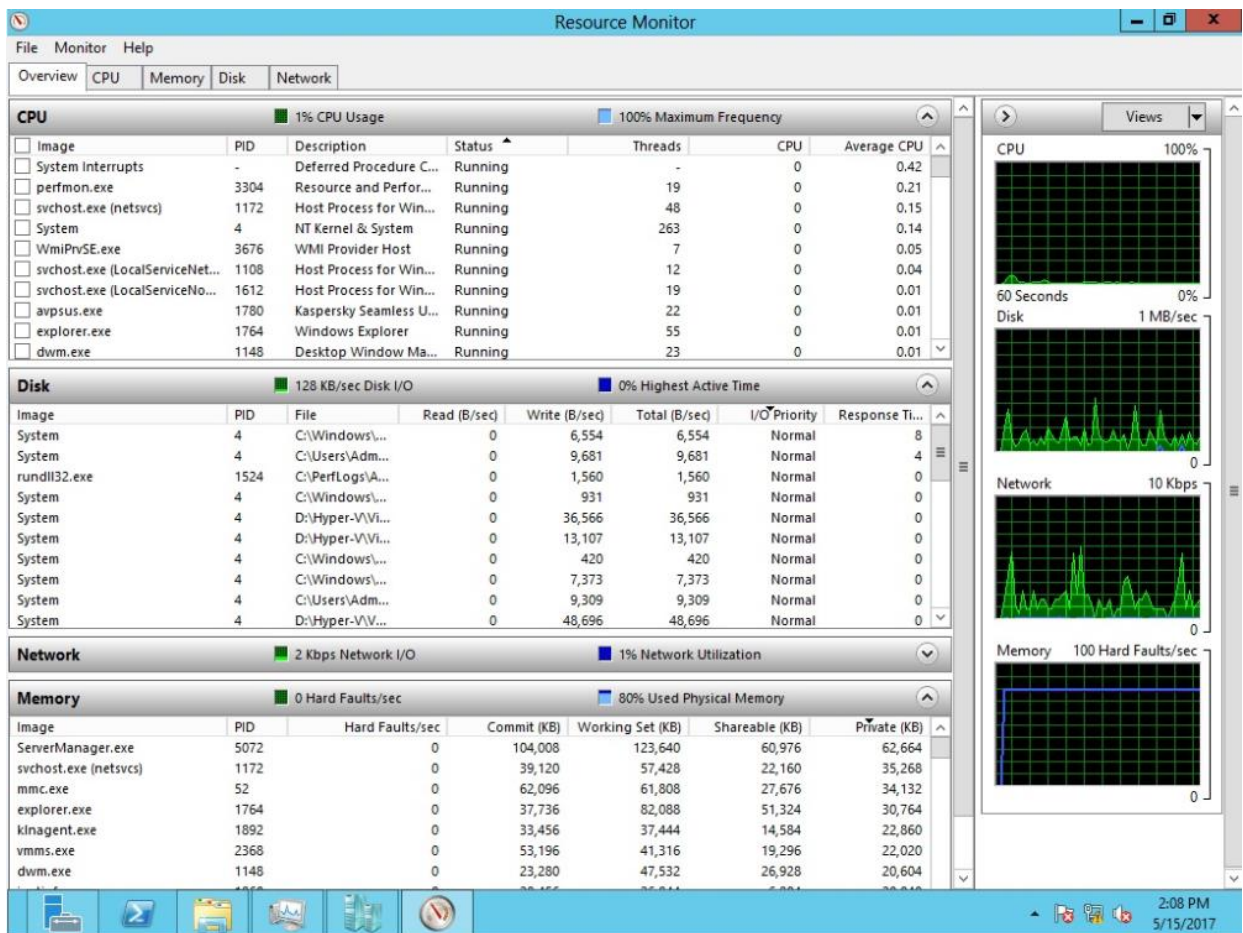


Fig.4.3 overview of Virtualized machine

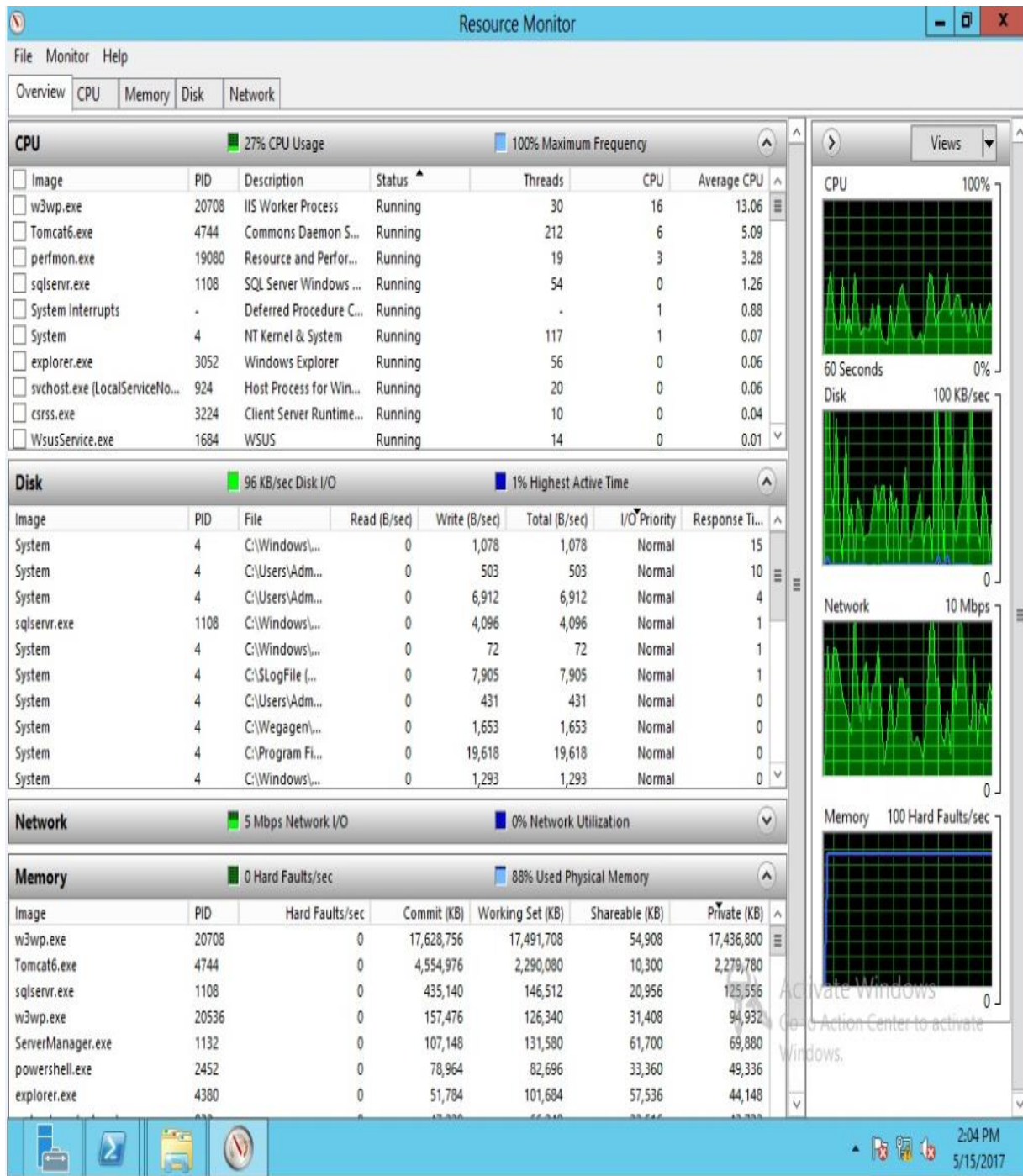


Fig.4.4 Overview of virtualized sever

4.6 SUMMARY OF VIEWS

All interviewees have agreed on the main point of building virtualized data center infrastructure is essential as a solution that have the features in building high availability, ensures maximum up time and also resource utilization. Virtualization reduces the IT infrastructure staffs overhead and enables advanced monitoring and controlling options. Moreover, as banks have multiple branches in different geographical locations it allows users to connect and access resources of sites by creating an efficient system where resources are distributed with ease in timely, balanced, and secure way. The other in relation to the implementation of modern virtualization IT solution reduces hardware cost and as security is a top priority in any banks, it fulfills the secured infrastructure.

4.7 FUNCTIONAL REQUIREMENTS FOR THE FRAMEWORK

The DC infrastructure in any organization has features in complexity of topology and technological diversity, which leads new functional requirements for virtualization. The proposed virtualization DC framework has different functional requirements.

The functional requirements of the proposed virtualized data center are based on:

- Availability
- Efficiency
- Security
- Scalability and
- Standards.

CHAPTER FIVE

THE PROPOSED VIRTUALIZATION FRAMEWORK

5.1 IDENTIFYING VIRTUALIZATION TYPE AND IMPLEMENTATION MODEL

For identifying the required virtualization solutions that can be implemented, the researcher started by interpreting the requirements of bank by means of interview to have better understanding on the idea, experience and best practice. The interpretation process was based on interviewing Information System infrastructure directorates and managers from the bank, reviewing best data center virtualization experience and practices of business companies and financial institution around the globe. Following the interpretation of the interviewee the researcher identifies the types of virtualization model which are bare model and hosted model. The hosted model and desktop/client (server) virtualization is proposed for Wegagen bank and other banks. The proposed infrastructure that best meets banks functional, service, security and regulatory requirements are discussed in the next sub sections.

5.2 DC VIRTUALIZATION METHOD FOR WEGAGEN BANK

Different types of virtualization technique are now available to banks and other financial services firms, including application, server and storages virtualization. Application virtualization is virtualized in to executable file that run from the client machine. The virtual application is isolated from operating system, ensuring compatibility no matter which version is being used like Microsoft Hyper-V, Citrix and VMware. Server virtualization performs the responsibilities of several servers by assigning out the assets of individual server over multi environment. The hypervisor layer takes in to account facilitating different applications. In storage virtualization three ways in information storing as part of virtualization, they are direct attached storage (DAS), network attached storage (NAS), and storage area network (SAN).

By considering the knowledge derived from the literatures and the banks intention from the interview result the researcher decided to propose a data center virtualization for banking sector. Banks as a service delivery organizations are very concerned about high availability and

reliability. High availability refers to the on-demand availability of a system when one or more components of a system go down. Example of these components include - power supplies, network cards, disk drives, processors, memory etc. In traditional IT infrastructure redundancy is provided at the hardware level which means there is two of every component in the system so that if the primary component fails then the software running can fail over seamlessly to the secondary or stand-by component without the applications even being aware of the failure. Enterprise applications rely on this underlying flexibility of the infrastructure. Virtualization enabled abstracting of the server hardware resources so multiple applications running different operating environments could share the same infrastructure. Virtualization has significantly improved server utilization and has hidden many of the complexities of dealing with physical systems from the operating systems and applications reducing both capital and operational expenses.

The proposed virtualization have capabilities to combine IT infrastructures such as storage, networks and servers, in which banks uses and manages some resources in disaster recovery site. The proposed virtualization approach allows banks to accelerate speed-to-market by better aligning IT and the business itself. This strategy encourages greater agility, which enables banks to better respond to new opportunities and competitive challenges. By leveraging flexible sourcing and usage based pricing, it can help to reduce both capital and operating expenses of banks and the recommended client virtualization ensures business continuity.

5.3 THE PROPOSED VIRTUALIZATION FRAMWORK

Data center virtualization technologies enable IT infrastructure to deploy both applications and desktops in a more efficient and secure manner to almost any endpoint over any network. Data center virtualization, offers the opportunity to gain more control over endpoint devices. This means they can dramatically reduce the costs of supporting these devices and users, while they improve security, compliance and disaster readiness throughout the banks. In addition, data center virtualization offers a highly scalable solution that reduces IT overhead and simplifies IT management, enabling an enterprise to be more flexible when rolling out new applications and services as needs change. There are three major ways in which data center virtualization is deployed, presentation virtualization, application virtualization and desktop virtualization.

- a) Presentation virtualization: - applications are stored in the data center and end users access them through a web portal. Application and the data are “presented” from a Windows Server session.
- b) Application virtualization: - applications are virtualized into an executable file that is run from the client device. The virtual application is then isolated from the operating system (OS), ensuring compatibility no matter which version is being used.
- c) Desktop virtualization: - the operating system and applications are stored within the data center and are presented to the end user via any client access device.

With this the proposed data center virtualization is desktop/client virtualization.

5.4 BUILDING THE FRAMEWORK

Transitioning from traditional (physical) to virtualized system based on strategic use of virtualization is crucial turning point in infrastructure development. In this infrastructure the nature of data center computing is rapidly changed through virtualized IT infrastructure. The existing information communication technology investment and usages in Ethiopia banking sector were described as unsatisfactory based on the interview results. The ICT usage practice is in its infancy stage in banking sector compared to other industries. A dramatic transformation in the way information technology departments operate has put their directors and managers at crossroads. On one side, they are under pressure to deliver higher levels of service and be more responsive to enabling competitive business objectives. On the other side, IT departments are equally pressured to constrain their budgets and reflect ROI that is as positive as possible from optimization initiatives. Here in banking sector IT directors and managers are under constant pressure to deliver more services and resources to the organization while reducing both capital outlays and expenses.

Building an efficient ICT investment and usage strategy to support these activities by leveraging the banking sector from recent technological model i.e. virtualized IT infrastructure model for ensuring quality of service was the main intention of this study. The alignment of business strategy with IT strategy is used as a competitive advantage, but there is a lack of coordination of technology and corporate strategy. The underutilization of IT can be considered as a problem for both business managers as well as IT managers. The researcher tries to propose the virtualization

framework to get primary advantage on core business and to have the main benefit of virtualized data centers which comes from server consolidation, in which multiple applications are consolidated onto a single physical machine that is resource sharing and isolation of data between users. The proposed virtualized data center framework needs to virtualize its main infrastructure core components which are servers, storage and network. Data center virtualization model (Hosted and Bare metal) and implementation type's server, client and storage are also integrated in to the data center virtualization implementation architecture. Specific beneficiary is presented, which is Wegagen bank and the virtualization implementation is identified. Figure 5.2 shows a high level virtualization core banking system delivery architecture for the proposed Wegagen and other banks based hosted model with web interface layer to facilitate the interactions among branches, ATMs, call centers and internet banking facilities.

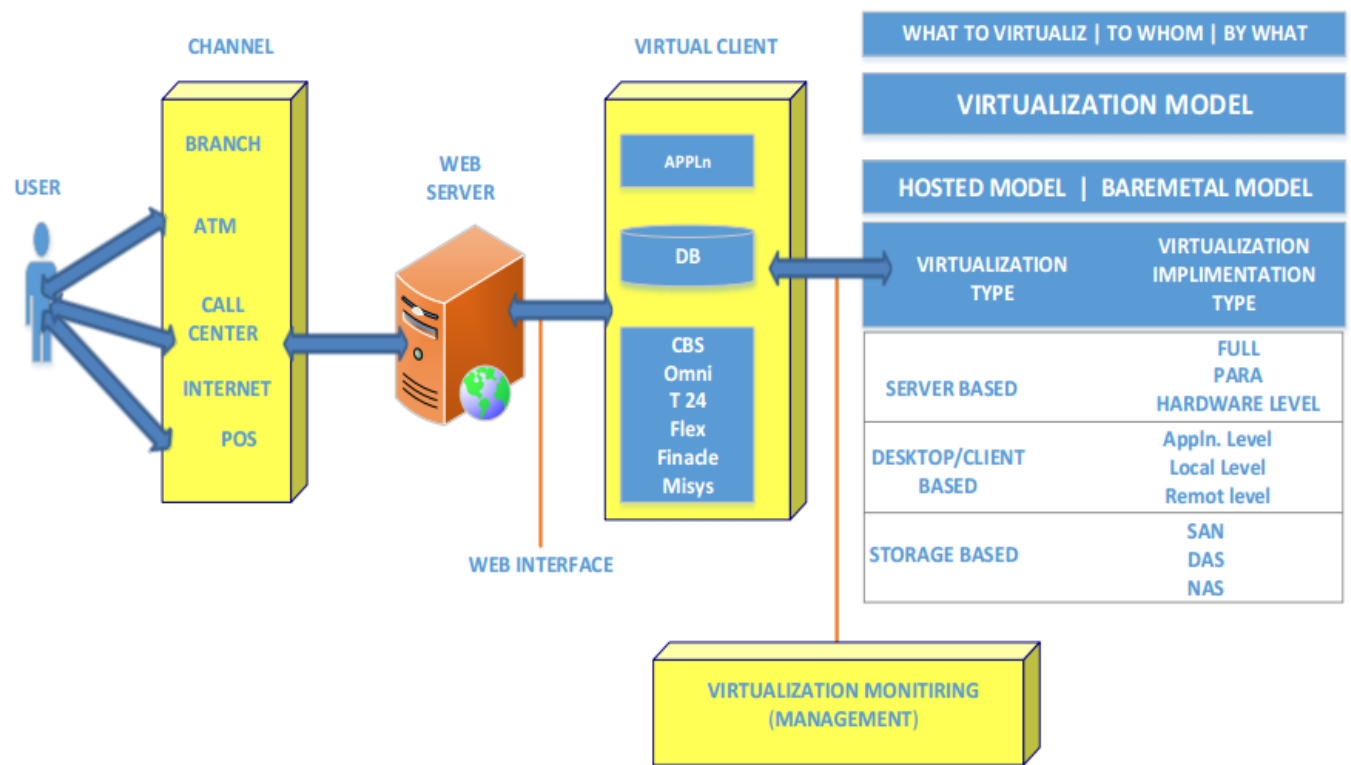


Fig.5.1 data center virtualization framework

The proposed virtualized framework contains five components (user, channel, web interface, what to virtualize/ to whom/ by what and virtualization monitoring). The following sections discuss the five service layers of the proposed framework.

USER

A user can be a customer who has an interest to be served and to get any services given by the bank. A customer can visit a local branch to open account, to transfer and to get credit facilities or can call to call center for different support. In addition a user can be a walk-in customer in which they may use international cards (VISA, Master Card).

CHANNEL

There are different and potential channels through which business services are consumed by user. In principle channel should be independent of both users and functions to allow them to be used in financial business. Channels are means of communications to get the type of business services.

- a) Branches: - which needs physical presence
- b) ATM: - services related to cards and it can be local or international
- c) Call centers:- that gives different supports internal or external
- d) Internet: - to get a service like internet banking, mobile banking, agent banking, etc.
- e) POS: - service related to purchasing items in shops, supermarket, etc.

WEB INTERFACE

It is an interface integrated to the core banking system to get banking services using web address. Web-based GUIs are quite commonly used now for virtual clients, as example desktop applications, and most user-device platforms are equipped with at least one and often several web browsers. The web browser is the most commonly deployed software platform across computing devices.

VIRTUAL CLIENT

It is a virtual client that have an operating system and that is managed centrally on a server and executed locally on the client device using web interface to access core banking application. The hypervisor provides an interface to local hardware that interacts with operating system and its application and the end point may be PC, thin client or mobile device.

WHAT TO VIRTUALIZE/ TO WHOM/ BY WHAT

In the proposed framework the main variables are what to virtualize, to whom and by what. These variables will ensure the continuous operation with integrated virtualization technology strategy. What to virtualize focuses on computing device or all devices, storage, server and network that can be virtualized. To answer to whom, the researcher emphasizes on identifying the actors in which they are banking sector specifically Wegagen bank. And, to answer by what, it focuses on the virtualization implementation model. In implementation phase the rollout strategy should be done with assessment based on the requirement company's goal and budget allocation, in addition by defining the architecture and designing by developing a detail operational plan.

VIRTUALIZATION MONITORING (Management)

One of the main benefits of virtualization is simplicity of infrastructure monitoring and management. Virtualization monitoring is used to analyze and monitor virtual machines in relation to virtual infrastructure. It monitors the availability and performance (CPU, Memory, Network and hard disks) of the virtual machines.

5.5 EVALUATION OF THE PROPOSED FRAMWORK

Several methods are proposed to test and evaluate functionalities, performance and quality of different data center virtualization frameworks. And, this evaluation method may vary between researchers. In order to evaluate the proposed framework the researcher performed a theoretical demonstration as a presentation for domain experts inside the bank. Respondents, which are 27 (twenty seven) of them are domain experts in the Wegagen banks, appreciate the relevance of the proposed virtualization solutions.

Some of the comments interpreted in relation to technology and business continuity are the following: -

TECHNOLOGICAL INTERPRETATION

- a. Standardization and modernization: - to meet the banks mission, the ISO 20022 standard for bank transaction.

- b. Maximum utilization of servers
- c. Availability of hardware capacity shared between different application and this brings optimization of hardware cost and total cost of ownership of their IT infrastructure.
- d. By consolidating their servers banks can achieve cost saving on power needed to run and cool the data center as well as the cost of expanding their data center facilities.
- e. Allowing new level of automation, agility and scalability for mission critical applications.
- f. Simplify configuration and administration.

BUSINESS CONTINUITY INTERPRETATION

- a. Quality of service delivery
- b. Fast service delivery can increase the number of users and services anywhere and anytime from end devices.
- c. Transforms IT as a source of business service.
- d. Operational improvement and excellence
- e. Simplified the banking process and workflows by orchestrating different services.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 CONCLUSION

Data centers need to capitalize on the real opportunity available to maximize their system reliability for continuous operations by moving towards an integrated and holistic virtualization technology. High availability, redundant control, combined with a set of virtualization capabilities, allows data center user to monitor, manage and control all critical systems. By implementing virtualization technologies data center can position them to attain highest level of availability, reliability and operational efficiency. That was the main aim of this research work. For developing virtualization based framework`s for Ethiopian banking sector specifically Wegagen bank.

Recognizing this fact, this research work aimed to assess the current data center practices of banking sector, and to propose and develop virtualization framework. In this work, attempts were made to examine and compare the available frameworks and best practices. This research combines TIA 942 data center standards and the researcher`s own experience to assess the data center practices in banking sector. Qualitative research approach was used. Data collections were done using document analysis and interviews. To analyze the data Hyper-V virtualization monitoring tool is employed.

To develop the data center virtualization framework the researcher follows the approach sequentially literature review, assessment, proposes the conceptual framework and finally the proposed framework is evaluated by domain experts.

Finding of the assessment, document analysis and interview indicated that the current physical infrastructure has lack of availability, proper use of computing device and infrastructure management. This has a direct impact on business continuity. Thus, the proposed virtual framework gives a new insight for banking sector and to have data center performance at high level of mission critical system services availability, continuous operation and active backup system at moment of failures. Banks are becoming more and more customer centric with

different service delivery, and customers are becoming more and more real time service demanding. This study proved that by considering customer demand factor as an important consideration. Banks need to take advantage of new technologies like infrastructure virtualization in order to satisfy their customer's demand and stay in the market. Similarly, consistency was found to be an important factor. Virtualization implementation infrastructure need to be consistent especially, in the service rendering sectors like banks. Banks cannot afford their services to be inconsistent therefore, the virtualization infrastructure consistency is crucial. Last but not least is the cost factor. Whenever banks invest in new technologies, the return on investment is what really matters. Review of literature explains the main advantage of the virtualization to be the cost advantage that shifted the capital expenses which are very costly to operational expenses. Therefore, the cost of virtualization in computing for data center solutions should be significantly advantageous for banks to implement this solution.

From the aforementioned discussion, it can be concluded that the proposed virtualization framework based on the assessment results is valid and applicable in the banking sector to address the challenges related to traditional (physical) data center infrastructure. Any weakness or challenges observed in the current study that needs further research.

6.2 RECOMMENDATION

The results of this research are promising, although further work needs to be done in order to recognize the proposed framework to Ethiopian banking sector. The proposed framework brings a high level availability of services and minimizes infrastructure costs for Wegagen bank as well as other banks to be beneficiary from the virtualization technology. The proposed framework should be implemented on the selected financial service sectors and tested with iterative feedback reflection from the users so that the proposed framework will be modified based on the feedback before the framework's full implementation in all banks and financial institutions. Future studies can be carried out on exploring security models of virtualization implementation models. Researchers can assess the different infrastructure virtualization models and their differences according to their service delivery model. In particular, it should be analyzed as to what different capabilities and service models are required from the services provider, which is the banking sector.

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APPENDIXES

INTERVIEW QUESTIONS

1. Would you please mention which type of Data center Architecture the bank uses?
Traditional (physical), full Virtualized or Hyper converged.
2. Which type of data center standard your bank follows? Tier 1, Tier 2, Tier 3, or Tier 4.
Tier 1 basic site infrastructure
Tier 2 redundant capacity component site infrastructure
Tier 3 concurrently maintainable site infrastructure
Tier 4 Fault Tolerant Site Infrastructure
3. What are the challenges in your data center infrastructure architecture?
4. What is annual budget for ITSD department related to your data center? And do you have standard and legal framework or policy guideline for new technological infrastructure implementation? To what extent its functional level?
5. If data center virtualization infrastructure is too built in your bank to provide banking services, what will be your opinion?
6. What kinds of benefits could you expect from fully virtualized infrastructure?
7. Do you believe most of your data center infrastructure are outdated and has limited capabilities for banking services? Yes/ No and Why?
8. Do you believe the banking industry should follow the traditional data center infrastructure or should run with virtualized technology? Yes/ No Why?
9. Can you confidently suggest your organization can use virtualized data center? Yes/ No Why?
10. Do you believe most top management members and IT infrastructure decision makers are usually change resistant? Yes/ No Why? If so what would be the reason?
11. Do you believe virtualized data center solution can cause unnecessary complication for the bank and data center administrators? Yes/ No Why?
12. How do you rate the existing traditional (physical) data center infrastructure related to security and management issues?
13. Do you believe the current infrastructure is fully capable of the banking service which satisfies the mission and vision of the bank? Yes/ No Why?
14. How the bank identifies its requirements prior to select best practices in data center?
Does it use a framework?

