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Design and Implementation of E-health over Private Cloud Computing

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Abstract: **This Paper presents design and implementation of private cloud computing system using a combination of two HP servers as a physical resources and VMware ESXi as virtualization software. The proposed system provides reliable, cost effective services, which can be accessed at any time and from anywhere. Hospital management information system (HMIS) is designed to utilize the proposed private cloud computing. The proposed HMIS will fill part of Iraqi hospitals needs to offer e-services. Additional services have been designed and demonstrated over the proposed cloud computing, includes an on-demand use of VMs, E-Mail and VoIP. For security issues, firewall software is enabled on each ESXi host to increase the security of the proposed system, drop any packets that come from other networks and to provide protection against malicious attacks.**

Keywords: **Cloud Computing, Storage Area Network, High Availability, E-health, vCenter, ESXi, HMIS, VMware virtualization.**

I. INTRODUCTION

Cloud Computing is defined as a virtualization of resources (networks, servers, applications, data storage and services) which the end user has on demand access to. Cloud Computing is also defined as an Internet-based computing, whereby shared computing resources, software, services and applications are provided to users on demand at any time anywhere in the world. These resources can be provided with minimal management or service provider interaction. The Cloud computing offers the end user resources without the requirement of having knowledge of the systems that delivers it [1,2,3].

Cloud Computing brings with it many benefits to the end user, these benefits include [1,4];

i. Access to a huge range of applications without having to download or install anything.

ii. Access of applications from any computer, anywhere in the world.

iii. Avoidance of expenditure on hardware and software.

iv. Real time monitoring of resources.

v. Manage a variety of different workloads, including the batch of back-end operations and user-oriented interactive applications.

vi. Rapidly deploy and increase workload by speedy providing physical machines or virtual machines.

a. Classes of cloud computing services

Cloud computing services are divided into three classes, according to the abstraction level of the capability provided and the service model of providers, as follows [5];

- Infrastructure as a Service (IaaS): IaaS provides infrastructure components to the end user these components may include virtual machines, storage, networks, firewalls, load balancers, and so on. IaaS is the responsibility of the clients to run and maintain the OS and the software applications on these virtual recourses. IaaS uses virtualization technology to convert physical resources into virtual resources that can be dynamically provisioned and released by customers as needed [5,6 ,7].
- Platform as a Service (PaaS): PaaS delivers a pre-built application platform to the end user. The customer can manages and runs the application software under the operating system and on the virtual resources provided by the cloud service provider (CSP). PaaS can automatically scales and provisions required infrastructure components

depending on application requirements. PaaS gives the customer an opportunity to design, build, model, develop and test applications directly on the cloud [2,5,6,7].

- Software as a Service (SaaS): SaaS provides ready online software solutions. The SaaS software provider has complete control of application software. The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, storage, or even individual application capabilities, with the possible exception of limited user specific application configuration settings [5,6,7].

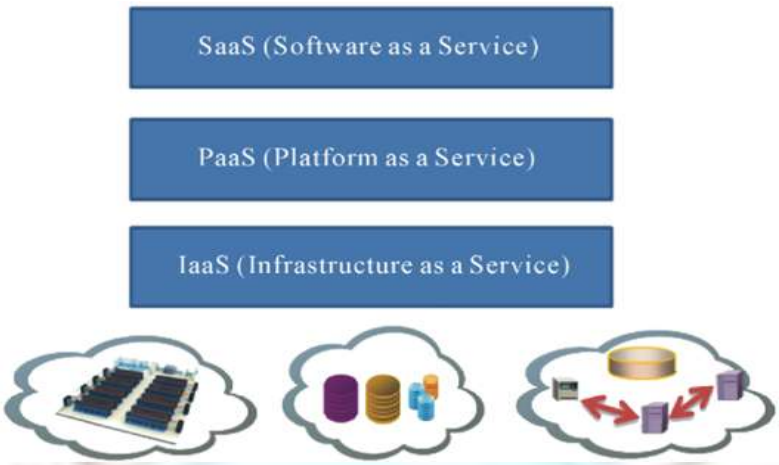

Figure 1. Layered structure of cloud computing platform [2].

b. Cloud computing deployment models

Cloud computing systems are classified as public cloud, private cloud, community cloud and hybrid cloud. These classes are known as deployment models and they describe the scope of services offered on the cloud to the customers. Figure 2 depicts different cloud deployment models [6].

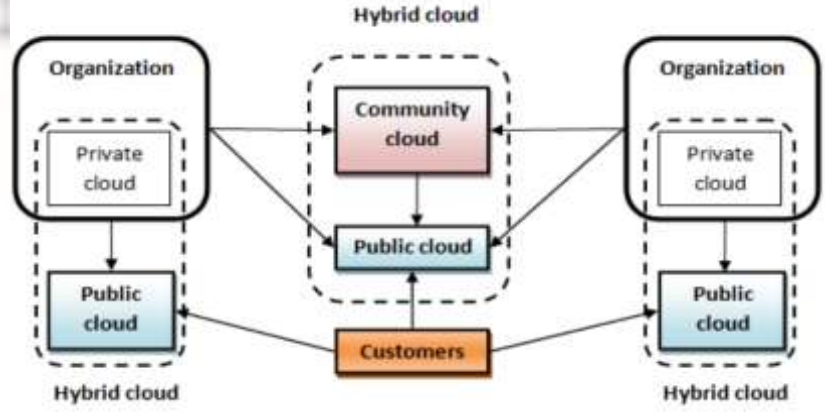

Figure 2. Cloud computing deployment models [6].

- Public Cloud:In public clouds the infrastructure and cloud services are made available to the general public users over the Internet. The cloud is owned and managed by a Cloud Service Provider (CSP) who offers services and applications to the end user on a pay-per-use basis. Public cloud users are by default treated as untrustworthy; thus, the privacy and security are big concerns in public cloud. Many popular cloud services and applications are public including Google App Engine, Amazon EC2 and Salesforce.com [6].
- Private Cloud:In private clouds the computing resources is provided by an organization or its designated service provider and offers a single-tenant operating environment with all the benefits and functionality of elasticity and the accountability and utility model of Cloud computing. The physical infrastructure maybe owned by and managed by the organization or the designated service provider with an extension of management and security control planes controlled by the organization. Private clouds are considered to be more secure than public clouds since their users are trusted individuals inside the organization [6,8].
- Community clouds:Community clouds are similar to private clouds but the cloud infrastructure and computing resources are shared by several organizations that have the same mission, policy and security requirements .An

example for the community cloud is the educational cloud used by universities and institutes around the world to provide education and research services [6].

- Hybrid Clouds: This model of Cloud computing is a composition of two or more Clouds (public or private) that remain unique entities but are bound together by standardized or proprietary technology that enables data and application portability .Hybrid clouds allow organizations to optimize their resources, so the critical applications and activities can be run under the control of the private component of the hybrid cloud while other tasks may be outsourced to the public component [6,8].

c. Motivations of Cloud Computing

Cloud computing systems satisfy many interesting characteristics that make them promising for future IT applications and services [6]:

- On-demand self-service: cloud services such as web applications, remote service, storage and networks can be provisioned automatically as needed by the consumers without requiring human interaction.
- Broad Network Access (mobility): Customers can access cloud computing resources at any time and from anywhere over the Internet by using different platform types such as mobile phones, Laptops and Personal Digital Assistant (PDAs).
- Resource Pooling: physical and virtual resources are pooled into the cloud. Resource pooling allows CSPs to pool large-scale IT resources to serve multiple cloud consumers.
- Scalability: cloud computing provides the CSP the ability to add new servers and applications with minor modifications to cloud infrastructure and software.
- Reliability: high reliability makes the cloud a perfect solution for disaster recovery and business critical tasks by using multiple redundant sites.
- High performance: cloud computing technology provides users with a high performance computing environment due to extremely large storage and powerful computing resources of the cloud infrastructure.
- Economies of scale: in order to take advantage of economies of scale, clouds are implemented to be as large as possible.
- Maintainability: Cloud service providers reduce software and hardware maintenance burden of the users.
- Virtualization: cloud provides a virtualization of computing resources; therefore the users do not need to worry about physical resources since the cloud isolates them at the virtual level.
- Green technology: cloud computing shares resources between users and does not require large resources that consume a lot of power.

D. VMware vSphere Virtualization

VMware vSphere is one of the most virtualization platforms for optimizing, monitoring and managing IT environments using virtualization technology; from the Personal Computer (PC) to the data center. VMware Infrastructure abstracts the OS from the hardware that's running on, providing combined logical hardware for operating systems and their applications, which allows the virtual machines (VMs) to run independently and simultaneously on multiple shared processors [9]. The advantages of VMware virtualization are summarized as follows [10]:

i. Most Trusted Virtualization Platform: VMware vSphere with Operations Management adopted to be the rock-solid virtualization platform on which all other solutions are built. Best Platform for Critical Applications: VMware VSphere provides a fully flexible, scalable, secure and rich performance environment to support important critical services and applications.
ii. Lowest Cost of Ownership: VMware VSphere with Operations Management makes reduction in both capital expenditures and operational expenses by delivering high hardware utilization, simple resource management, and greater administration efficiency.
iii. A Secure and Reliable Hypervisor: vSphere includes the ESXi hypervisor platform which is a hypervisor for x86systems and designed for virtualization purposes.

E. E-health over Cloud Computing

E-health over cloud computing is an application oriented and service based infrastructure where resources are pooled, allowing services to be widely deployed and rapidly shared in response to changing healthcare business and regulatory requirements. As the world is increasingly moving away from development-centric view to one that is focused on applications, information, and people thus more towards to the new paradigm of cloud computing [11,12].The e-Health Cloud can be divided into different implementation models that based on whether it is created internally (private Cloud), outsourced (public Cloud) or a combination of the two (hybrid Cloud). The e-Health Cloud consists of three generic layers which help optimize the healthcare data facility environment, to create a platform that provides pre-built software tools for specialized providers and software designers [4]:

i. Software as a Service: SaaS provides Cloud-based software solutions such clinical systems (CSM) where consumers such as healthcare providers receive access to the software capabilities of the cloud.
ii. Platform as a Service: PaaS extends the basic infrastructure with High-level integrated environment to design, build, test, deploy and update online healthcare applications.
iii. Infrastructure as a Service: IaaS provides physical processing and storage resources.

Figure 3 presents the e-Health Cloud architecture that provides IT services to improve patient care while increasing operational efficiency. Typically, the Cloud consists of an array of layered elements, starting at the most basic physical layer of storage and server infrastructure and working up through the application and communication layers [13].In healthcare, the security and privacy and other domains are generally the same issues mostly raised as the cloud clients look to move their data and applications to the cloud. Security and privacy protection of patients' records is important and involves various requirements. First, creating and maintaining of healthcare cloud e-records of any type should protect content authenticity, integrity and privacy. Second, all healthcare data should be guarded in secure storage with protective access mechanisms and secure transmissions. Finally, the access and sharing of healthcare data should provide an end-to-end source verification, confidentiality and auditing capabilities. Thus, the common privacy and security issues in the e-Health Cloud include [3,13,14]:

i. Confidentiality: ensuring that healthcare data is not accessed by unauthorized parties.
ii. Integrity: ensuring the accuracy and consistency of healthcare data.
iii. Authentication: ensuring that users are the persons they claim to be.
iv. Access control: ensuring that users access only healthcare data that they are allowed to access based on their authentication and access levels.
v. Non-repudiation: ensuring that a party of a communication cannot deny having sent or received the data.
vi. Privacy: ensuring that patients maintain the right to control what healthcare data is collected about them, how it is used, who uses it, who maintains it, and what purpose it is used for.
vii. Audit: recording and monitoring all users and data access activities in order to ensure the safety of healthcare data and the e-Health cloud system.

Benefits of E-health Cloud are summarized as follows [3,13,14]:

i- Better patient care: is the ability to offer a unified patient medical record containing patient data from all patient encounters across all operators.
ii- Reduced cost: This feature is very suitable for small and medium sized healthcare providers where they can utilize advanced IT infrastructures and services to support their healthcare operations without facing high initial and operational costs.
iii- Reliability and efficiency: reliability is totally based on cloud provider who provides services to the customer. Many of respondents told that efficiency is helpful to speed up the services and get the fast results.
iv- Data Sharing and availability: Data sharing is the major benefit to e-Health from cloud computing when adopting cloud computing in e-Health. Data availability is an easy access to medical data remotely with the permission of patient from anywhere in the world.

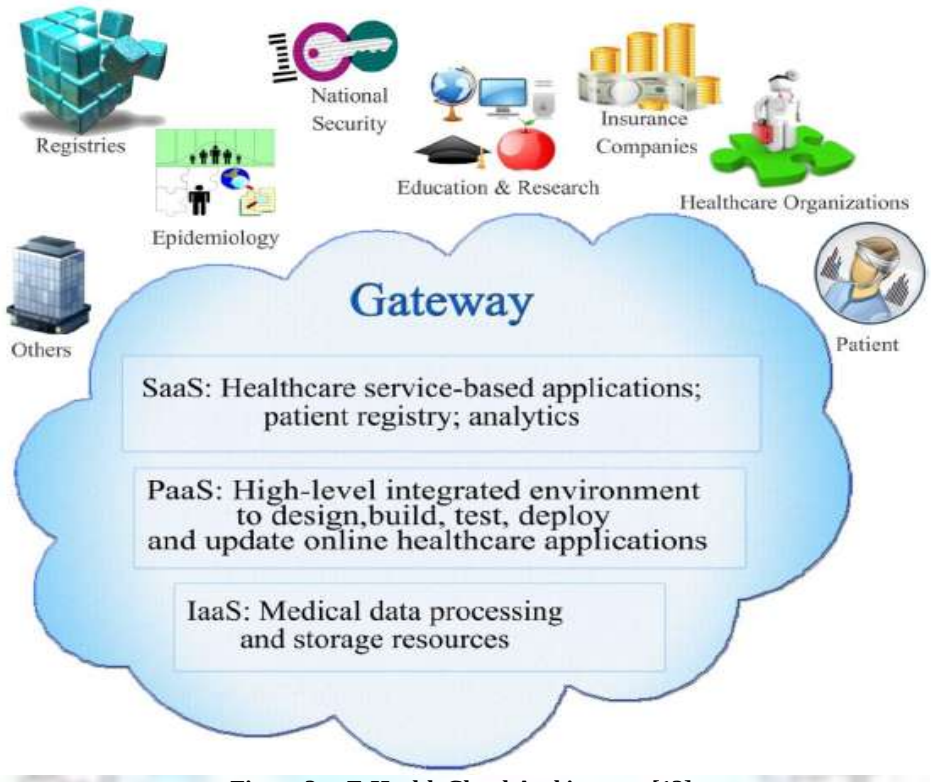

Figure 3. E-Health Cloud Architecture [13].

II. CLOUD COMPUTING ARCHITECTURE

The design and implementation of the proposed cloud environment can be a daunting task. It depends on several factors that should be considered like availability, security, cost, scalability and business community. In order to build a private cloud computing, the first thing is to prepare the hardware implementation requirements (Servers, storage and network topology) and software requirements (hypervisor, machines operating system, cloud computing security and management software). The design and implementation of the proposed system depends not only on the needs but also depend on the cost and Service Level Agreement (SLA). The Architecture of the proposed cloud is shown in Figure 4.

In the proposed cloud computing architecture, VMware vSphere is adopted as a cloud computing virtualization platform. VMware ESXi server (which is a virtualization layer that runs on physical server to share resources: processors, memory, storage and networks into multiple Virtual Machines) is assumed as the cloud computing hypervisor. VMware vCenter server, which used for configuring, provisioning and managing the virtualized environment, is adopted as cloud computing configuration and management software. Four physical machines are used for cloud computing deployment; first one is used as a management server which the VMware vCenter server is installed on it. The other two machines are used as hosts (hypervisors) on which the VMware ESXi server runs where the virtual machines will be created and run; the last one is used as a MS Windows server Active Directory (AD), Domain Name Server (DNS) and Storage Area Network (SAN). Servers and management node are connected to each other using private network (cisco switch) which is also used to connect the cloud computing to the Internet.

The Shared SAN is used as the storage location for VMs files to allow the use of High Availability (HA) clustering with Distributed Resource Scheduler (DRS) technology, which in case of one host fails; affected VMs are restarted on the other available host. With vSphere HA, VMs are automatically shifted and restarted on a different physical server in a cluster if a host fails.

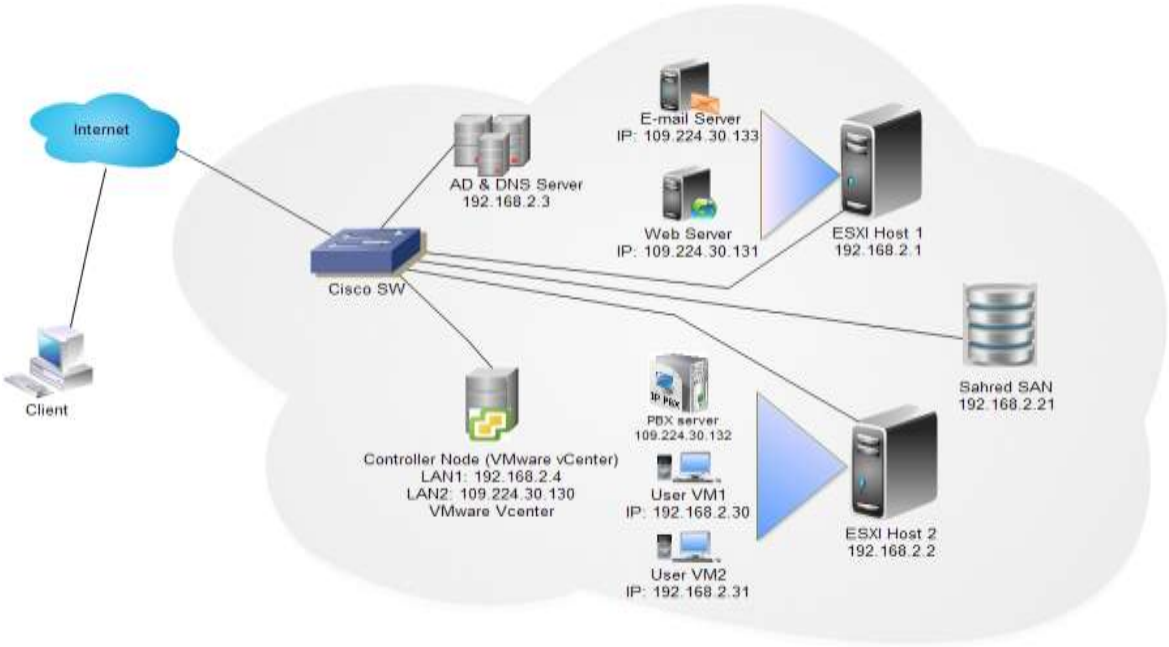

Figure 4. proposed cloud computing architecture.

III. CONFIGURATION OF STORAGE AREA NETWORK (SAN)

An attached SAN is created and configured by using OpenFiler software to deliver the storage as an attached iSCSI SAN to be used as the storage location of VMS in the proposed private cloud computing [15]. Using SAN with ESXi can improves efficiency, flexibility and reliability and also supports centralized management, failover, and load balancing technologies, such the data can be stored securely and multiple path are configured to the storage, eliminating a single point of failure. Using a SAN with ESXi systems extends failure resistance to the server. The main purposes of using an attached iSCSI SAN in the proposed private cloud computing are: monitoring hosts and VMs to detect failure, support high availability of VMs and applications and to reduce the downtime of applications and services by automatically restarting VMs upon detection of a hardware or OS failure.
Figure 5 shows the SAN volume that created by using OpenFiler. It presents the type, name, size of the SAN volume (vmcloud volume). OpenFiler is configured through the web interface by writing the combination of the IP address of the OpenFiler and port number in the browser as follows: https:// 192.168.2.21:446.

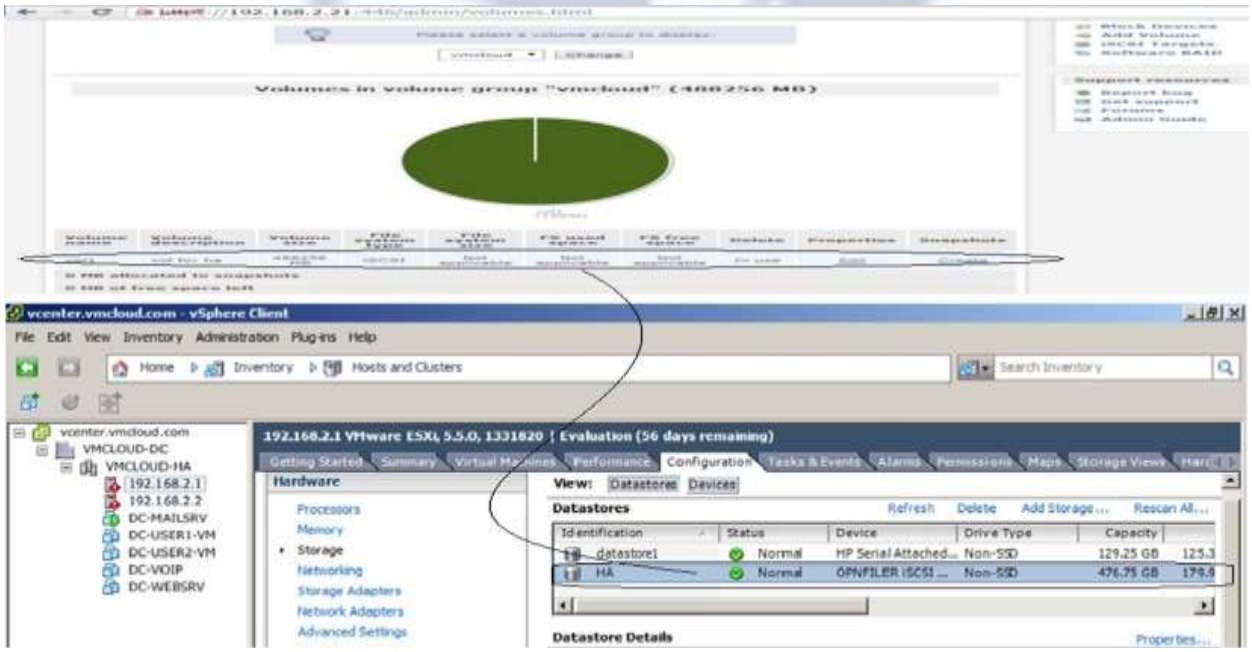

Figure 5. Configuration of SAN storage using open Filer

IV. CONFIGURATION OF HIGH AVAILABILITY (HA) CLUSTERING

A cluster is a collection of hosts and their associated VMs with vSphere High Availability (HA) and Distributed Resource Scheduler (DRS) are enabled. VSphere HA delivers the availability for most applications and services that running in VMs, independent of the OS and application running in it.

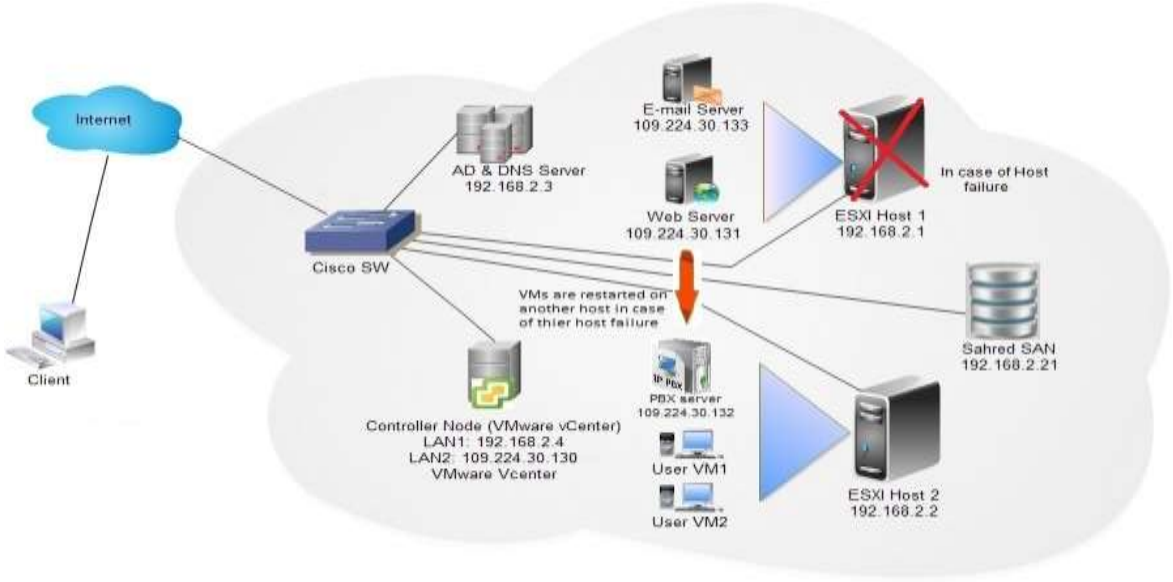

Figure 6. High availability in proposed cloud computing.

In this work vSphere HA Cluster with DRS is implemented and the purposes from implementing the cluster in the proposed cloud computing are:Providing a high availability to the VMs and host server that in case of the physical server fails then the VMs are restarted on another server, Providing high availability for all VMs at a low cost, when physical server fails is detected, the VMs are automatically restarted on other hosts, monitors hosts and VMs to detect hardware and guest OS failures. Figure 6 shows how the HA are implemented over the proposed cloud computing.

V. E-HEALTH APPLICATION ARCHITECTURE

The goal from the design and implementation of Hospital Management Information System HMIS was to facilitate the process of patients' registration, examination, storing data and documents related to patients and save them from damage with the possibility of fast access to data and medical documents. HMIS includes all medical departments of a hospital and facilitates the process of registration and treatment of patients in all the different departments of the hospital. HMIS implements the connectivity between various medical departments of the hospital and facilitates: the process of interaction between them and the process of examining the patient with effective time and effort.

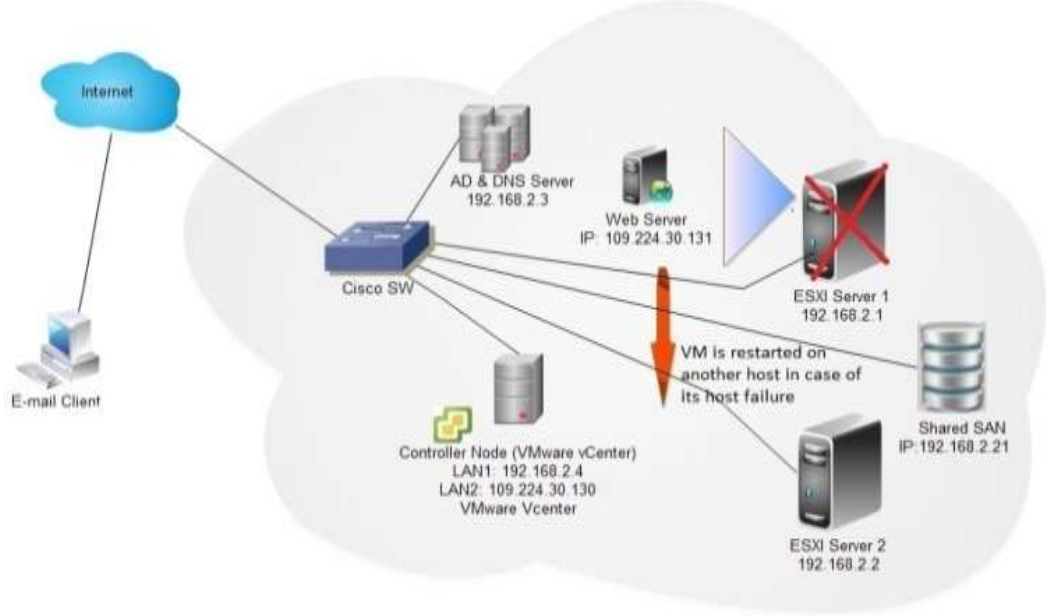

Figure 7. Proposed HMIS network design

The HMIS is deployed using two physical servers from them the HMIS virtual machine (VM) is virtualized, cisco switch, AD and DNS server, SAN and vCenter server connected to each other using cisco switch as shown in Fig.7. High Availability (HA) technology is used to provide high availability to web server that in case of one physical server fails then the VM is restarted on another physical server. WAMP web server is installed on the virtual web server, which acts as PHP, MySQL database and File Transfer Server (FTP) server [16]. The database in each web server contains patient records and documents. The users can access to HMIS web application anywhere at any time over the internet via web browser.

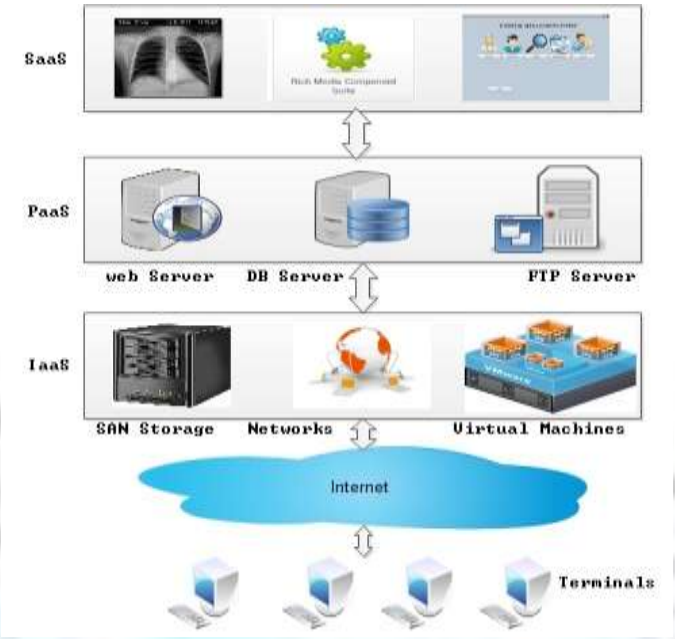

Figure 8. HMIS Architecture

Figure 8 shows the architecture of the HMIS web application. From this figure we can see that our HMIS contains three layers: IaaS, PaaS and SaaS. At IaaS layer provides the Infrastructure services that contains Storage Area Network (SAN), network components and Virtual machine (VMs). HMIS is resides HMIS web application is resides on (DC_WEBSRV) virtual machine over the proposed cloud computing which has the following specifications: 2 CPUs with 2 cores, 4GB Memory, 40 GB Virtual Hard Drive Two NIC Adapters, and Windows server OS. WAMP server which is a web development server used for windows environment is used as a web server. It allows the creation of web application using HTTP apache server, PHP and MySQL database [17].

At PaaS layer, the HMIS is rely on web server to provide an online web services, MySQL to provides database services and FTP server to provide FTP services, all these services are provided by WAMP server that installed on DC-WEBSRV virtual machine. Relational Database is used to store the data of the proposed HMIS using structured indexes. Many relationships are used between HMIS tables: one-to-one, on-to-many and many-to-many relationship. These relationships are established using indexes (PKs and FKs), which is the search criteria used to return the data from the database. In each table of the proposed database, the row is called a record and column is a field. Finally, HMIS web application operates at SaaS layer to provide software services to clients. The HIMS is developed using PHP, CSS, HTML and JavaScript programming languages. PHP is a server side programming language that used insert and fetch data from the database. MySQL database is used to store the HMIS data.

VI. HMIS Work Flow

System workflow illustrates the process of patient treatment which includes registration, examination, treatment and patient discharge. Figure 9illustrates the proposed HMIS workflow. The arrival patient is being registered inregistration department and his information is saved in the proposed HMIS database and convey to the consultation department according to his state. After receiving the consultation request from the registration department, the consultant will examine the patient and decide if the patient will need medical test or not,if yes then the consultant will send a medical test request to examine the patient and send the result back to consultation department. After that the patient will convey to surgery, medication or pharmacy according to his exam result and consultation test. Figure 10 shows the flow chart of HIMS which illustrates the cycle the patient will take from his arrival to discharge.

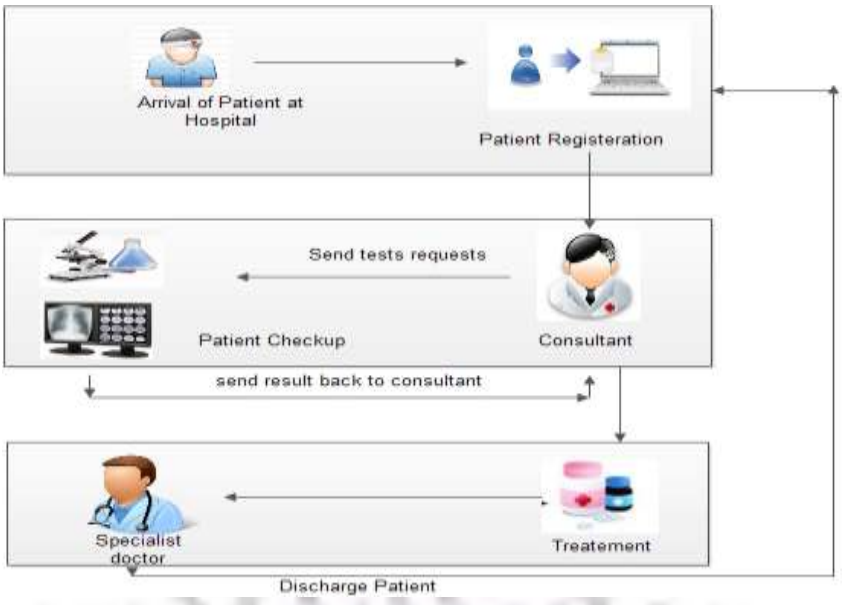

Figure 9. Proposed HMIS workflow

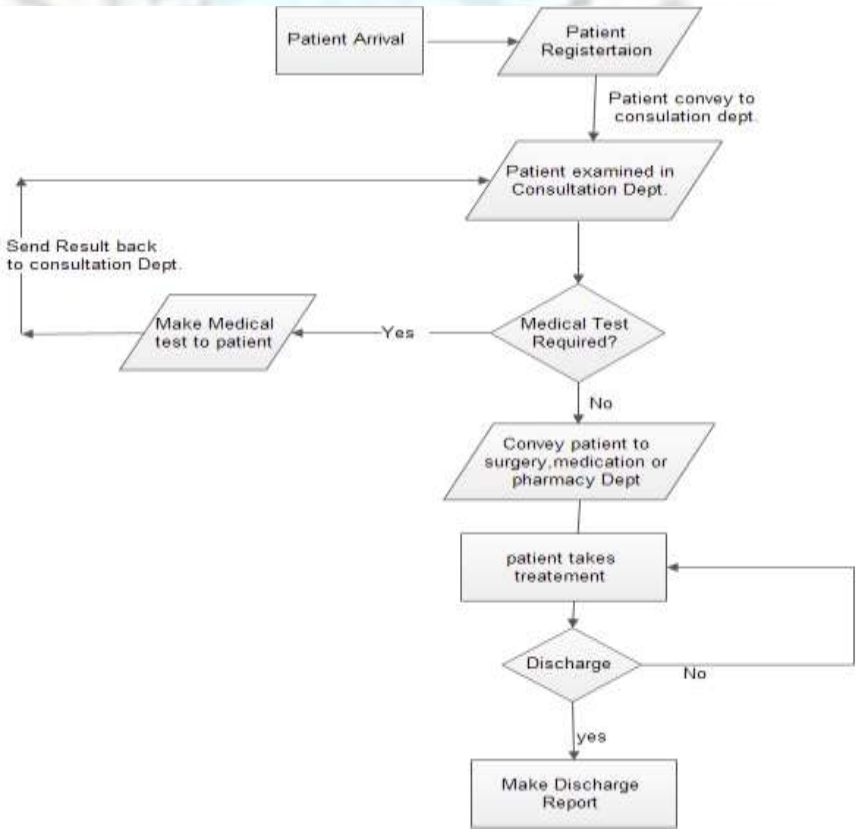

Figure 10. HMIS Flow Chart

VII. STARTING AND ACCESSING THE PROPOSED SYSTEM

The proposed system can offer both IaaS and SaaS, it started as follows:

- Start AD and DNS Server.
- Running hosts (host1 and host2).
- Running SAN.
- Login to vCenter Server as Administrator or to cloud services as a user using vSphere client.

The proposed system provides the ability to its users to access their VMs, applications and services at anytime and anywhere over the internet. The administrator can access locally to the vCenter server (controller node of the proposed cloud computing) by using the combination of user name and password through the vSphere client or the vSphere web client by writing https://192.168.2.4:5090 in a web browser. Figure 11 shows how the administrator Login to the vCenter console using vSphere client by writing the IP address of the vCenter server (192.168.2.4), user name and password. Users can access to their VMs over the proposed cloud at anytime and anywhere over the internet using public IP of vCenter (109.224.30.130) or locally using IP (192.168.2.4) through the vSphere client or vSphere web client that installed in the client device.

Figure 11. Administrator Login to vCenter Home Page.

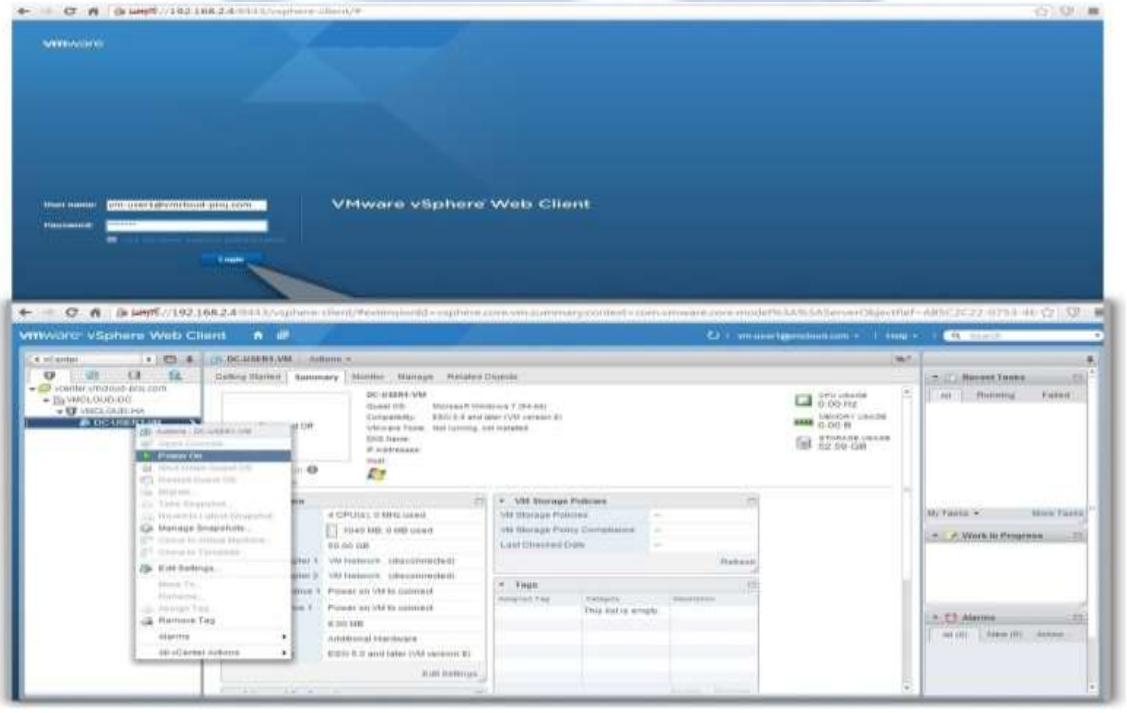

Figure 12. Administrator Login to vCenter Home Page.

Figure 12 shows how the user (vm-user1) accesses the VM through vSphere web client at https://192.168.2.4:9443 by using the combination of username and password. The user name is a combination of the user that created, granted in AD and added in vCenter Server followed by the domain name (@vmcloud-proj.com). Accessing and using the VMs is determined by roles that assigned to the users by the administrator of the proposed cloud, username and password to give him an authorization to access and use the VM. Users can access to the HMIS application over the proposed cloud computing at any time anywhere over the internet by writing the IP address (http://109.224.30.131) in the web browser.

CONCLUSION

During the design and implementation of a HMIS over a private cloud computing, we conclude that the Implementation of the HMIS over the proposed system could decrease the cost of renting servers, increase the security and privacy, which the HMIS is administrated and monitor under an authorized person and to accommodate any development process in the HMIS. Using of VMware ESXi as virtualization software in the proposed cloud could provide a fully reliable, secure, scalable and high performance environment to deploy and manage critical application and services. Also using High Availability (HA) clustering in the proposed cloud could provide high availability to cloud computing virtual machines and application which provides protection against hardware, Operating system failure and planned and unplanned downtime. Offering an on-demand use of Virtual Machines (IaaS) over the proposed system could decrease the cost of buying computer devices and renting servers as well as provisioning the processing, storage, networks, and other fundamental computing resources. Most of Iraqi hospitals don not offer any electronic services, the proposed HMIS represented an attempt to fill part of this need.

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