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Design and Implementation of a Cloud based Rural Healthcare Information System Model

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Abstract — **Modern information technology is being increasingly used in the healthcare sector with the sole objective of enhancing the availability of improved medical services at a reduced costs. In this context, outsourcing of computation and storage resources using cloud infrastructure has become a potential alternative. Rural healthcare centers can largely benefit from cloud based models in terms of cost reduction and resource utilization. It will not only reduce the development cost but improve the maintainability and adoption of evolving technologies. This can ensure use of up-to-date technologies and skilled technical manpower to manage rural healthcare systems in an effective and efficient manner. A cloud based information system can offer new possibilities, such as easy and ubiquitous access to medical data, and opportunities to utilize the services of medical experts which are otherwise unavailable in rural areas. However, they also raise new risks and challenges with respect to security and privacy aspects. In this paper, we propose a cloud based model for developing a rural healthcare system. We present the overall system architecture along with the functional components and highlight the advantages, open issues and prospects for further improvements of this model.**

Keywords: Cloud Computing, Cloud Information System, Rural Healthcare Services, Online Information Services

I. INTRODUCTION

Information management in hospitals, dispensaries and healthcare centers particularly in rural areas is a complex task. High quality healthcare depends on extensive and carefully planned information processing. The current development of cloud computing in the healthcare context will have a big impact on the healthcare sector. It is evolving as a key computing platform for sharing resources that include infrastructures, software, applications, and business processes. Virtualization is a core technology for enabling cloud resource sharing. Cloud Computing may be applied to solve problems in many domains of Information Technology like GIS (Geographical Information Systems), Scientific Research, e-Governance Systems, Healthcare Industry, Decision Support Systems, ERP, Web Application Development, Mobile Technology etc. Information Support Systems are computer based Information Systems that supports business or organizational information processing and information dissemination activities. Information Support Systems serve the management, operations, and planning levels of an organization and provide information accessibility to a wide range of users distributed over a large geographical area.

Health care organizations use variety of IT applications and infrastructures which always need to be updated as a result of the rapid growth in health care services. And the cost of IT systems in health care services is very expensive, considering that IT is not their primary activities, and many of health care organizations pass this cost to their patients. Many of these health care organizations have developed their own or purchased IT systems to support their operations. But, also many of other health care organizations are still use manual or paper-based form in their operations, especially the small-medium health care organizations, because they think that IT investment is costly. The diversification on how the health care organizations maintaining their operations, especially on maintaining patient's medical information resulted in the difficulty of accessing patient's data. Cloud computing introduces a new business model and way of delivering service and value to the medical community, as well as

medical-related trading partners, business associates and customers. There are a number of benefits—point-of-care service delivery, cost-savings, the leveraging of new applications and support for an increasingly mobile workforce—that are enabled through adoption of cloud technologies.

Information Support Systems serves as the computer technology/network support system for varied users. Information Support Systems manages and provides technical support and service for centrally administered services such as software and hardware support. Information Support Systems is responsible for the upgrade and maintenance of both hardware and software for different shades of users of an organization/enterprise. Over the past few years most of Information Support Systems are more and more dependent on high performance computing (HPC) environments such as clusters and computational grids. Most of Information Support Systems usually deal with large volume of data (structured and unstructured) that requires huge CPU power to produce results in reasonable time on which wide range of users are dependent which may be located over a large geographical area. However, configuring and maintaining a cluster or a computational grid is usually a very cumbersome activity that requires specialists to support it. In addition, the high cost to acquire this computational apparatus can be considered a serious problem to the effective use of the Information Support Systems in terms of timeliness service and availability. Furthermore with the passage of time needs have emerged for enormous infrastructure, unlimited system accessibility, cost effectiveness, increased storage, increased automation, flexibility, system mobility and shift of IT focus. Since

Cloud Computing is a fast growing trend that includes several categories of service, all offered on demand over the Internet in a pay-as-you-go model, it promises to increase the velocity with which applications are deployed, increase innovation, and lower costs, all while increasing system agility. Using a Cloud Computing strategy for Information Support Systems will help in conducting core business activities with less hassle and greater efficiency. Organizations can maximize the use of their existing hardware to plan for and serve specific peaks in usage. Thousands of virtual machines and applications can be managed more easily using a cloud-like environment. Businesses can also save on power costs as they reduce the number of servers required. And with IT staff spending less time managing and monitoring the data centre, IT teams are well placed to further streamline their operations as staff complete more work on fewer machines. Information Support Systems in Cloud would refer to a collection of technologies that include hosted infrastructure (IaaS), like virtual servers, network equipment and disk space; hosted operating systems (PaaS), like Windows Azure and Google App Engine; and application-level services (SaaS).

II. EXISTING SYSTEM

The use of the traditional IT Application in rural healthcare centers to solve the growing information gap between the limited resources available and the people cannot but be over-emphasized. This System allowing the health services are huge investment of infrastructure and technical resources. The users of this system being the people, patients, health professionals, and government's etc. can make quick enquiries as to the availability of health care systems, health manpower (Doctors, Pharmacists, and Specialists), hospitals, Drug Stores and so on nearest to them. This in turn will break the barrier of lack of information to the people and also help the federal government to make available services to the people while the health Industry catches up with its expected goal of providing correct and good health services in every neighborhood.

III. EXISTING SYSTEM DESIGN AND ARCHITECTURE

Figure 1 shows a brief relationship between the Unified Data Repository which contains the details of the health services available, health human resources, locations, health schemes, the health data and its users, primarily the people (the public) who need this information. The question arises of how the Databank gets its data? This is provided by the health service providers, health practitioners, the Administrative body in charge of this Information System and a web

service technology discussed in later sections of this paper.

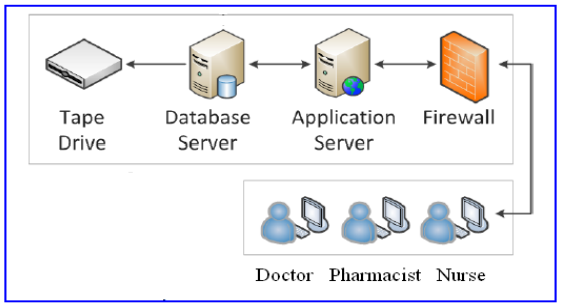

Figure 1. Traditional IT Model used in Rural Healthcare Centers

A. Issues Related to the existing system

- Huge Investment
- Legacy Systems
- More IT Staff for management
- Not possible to adopt for all healthcare organizations including rural healthcare centers

B. Existing challenges

- Lack of Computer equipment
- Lack of computer skills
- Lack of internet connection
- Cost of internet connection
- Lack of information
- Lack of Training and technical support
- Lack of Electricity
- Lack of Service providers

IV. Proposed System

We present a cloud based rural healthcare information system model. In the past, health care providers (such as the family doctor) have stored medical records of their patients on paper locally. This allowed a controlled environment with easy management of data privacy and security: keeping the paper records in a locked cabin at the doctor's practice. Even the increasing use of personal computers and modern information technology in medical institutions allowed for a moderate effort to manage privacy and confidentiality of individual medical records. This was due to the decentralized and locally managed infrastructure of each healthcare organization. But nowadays outsourcing of IT infrastructure (e.g., cloud computing) and other services (e.g., billing processing and accounting for medical practices) leads to a complex system where privacy-sensitive data are stored and processed at many different places. Hence, it becomes attractive to store and process healthcare data \in the cloud" (at outsourced data providers that can be accessed via the Internet). While such information processing systems promise improved service quality, the complexity to manage data security and increases privacy.

V. Proposed System Design and Architecture

The requirement of the Cloud based information system is to create secure, state-of-art facility to store the data / information available in different healthcare centers and to provide access to users in a secured manner, as per their roles and privileges.

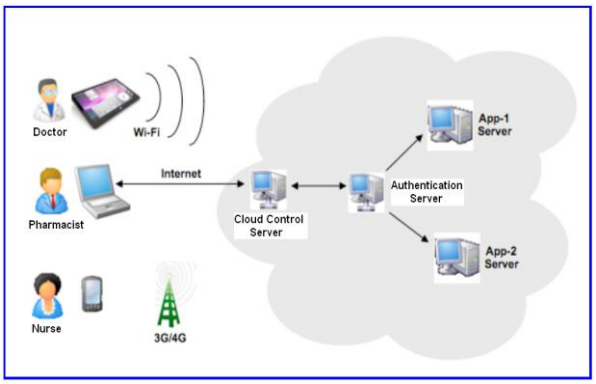

Figure 2. Architecture of Cloud Based Model Rural Healthcare Center

A. The components of proposed model

Cloud Control server: In a typical cloud, the cloud controller is responsible for managing physical resources, monitoring the physical machines, placing virtual machines, and allocating storage. The controller reacts to new requests or changes in workload by provisioning new virtual machines and allocating physical resources. This server also helps several ways in order to facilitate better control over the network as given below.

(a) The cloud central server accepts network policy specifications (in addition to requests for VMs) and parses them to generate a communication matrix for the tenant's resources. The matrix captures the requirements for the network between tenant VMs. An entry in the matrix indicates whether the virtual network between the source and the destination VM (row and column, respectively) should permit packets; if so, whether layer 2 broadcast is allowed, or layer 3 traffic is allowed, or both are allowed. And when layer 3 traffic is allowed, the entry also specifies bandwidth reservations and any middlebox traversal required by traffic between the endpoints. The matrix is then passed to the network controller which interfaces with the programmable switches.

(b) It prior to placing a VM on a physical host, the cloud controller consults the network controller to determine which hosts are candidates for placing the VM. The network controller utilizes a placement algorithm designed to minimize the network state and maximize the performance and the number of virtual networks that can be supported in the cloud

(c) It manages a software programmable virtual switch on each physical host that supports network services for tenant applications. The software switch is configured to connect any number of virtual machines to the physical network. The software switches are crucial for extending network control beyond the physical switches and into the end-hosts themselves. Once configured, the cloud controller informs the network controller of the location of the software switches and subsequently sends updates about the set of virtual machines attached to the switches (e.g., if a VM is removed or moves to a different host).

Authentication Server: Because in the application and data is hosted outside of the organization in the cloud computing environment, the cloud service provider has to use Authentication and Authorization mechanism. Authentication means that each user has an identity which can be trusted as genuine. This is necessary because some resources may be authorized only to certain users, or certain classes of users.

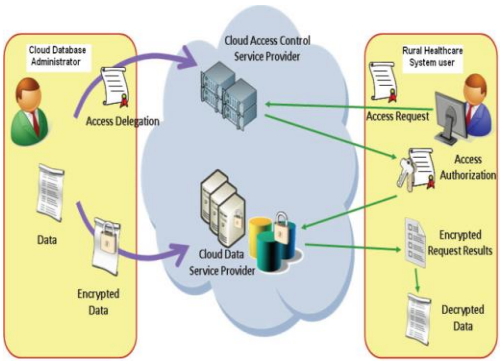

Figure 3. Authentication Server architecture

Authentication is the mechanism whereby systems may securely identify their users. Authentication systems provide answers to the questions:

Who is the user?
Is the user really who he/she represents himself to be?

Authorization is the mechanism by which a system determines what level of access a particular authenticated user should have to secure resources controlled by the system. Authorization systems provide answers to the questions:

Is user X authorized to access resource R?
Is user X authorized to perform operation P?
Is user X authorized to perform operation P on resource R?

Authorization: Authorisation means that each resource - be it the spare computing power on a computer of an organization or a set of astronomical data - will have a set of users and groups that can access it.

Resource Access: Resource Access means that remote resources can be accessible to Grid users. These resources could mean anything from CPU time to disk storage, to visualization tools and data sets. Everyone should not be able to access all resources.

Resource Discovery: Resource Discovery means that users can access remote resources that they can use.

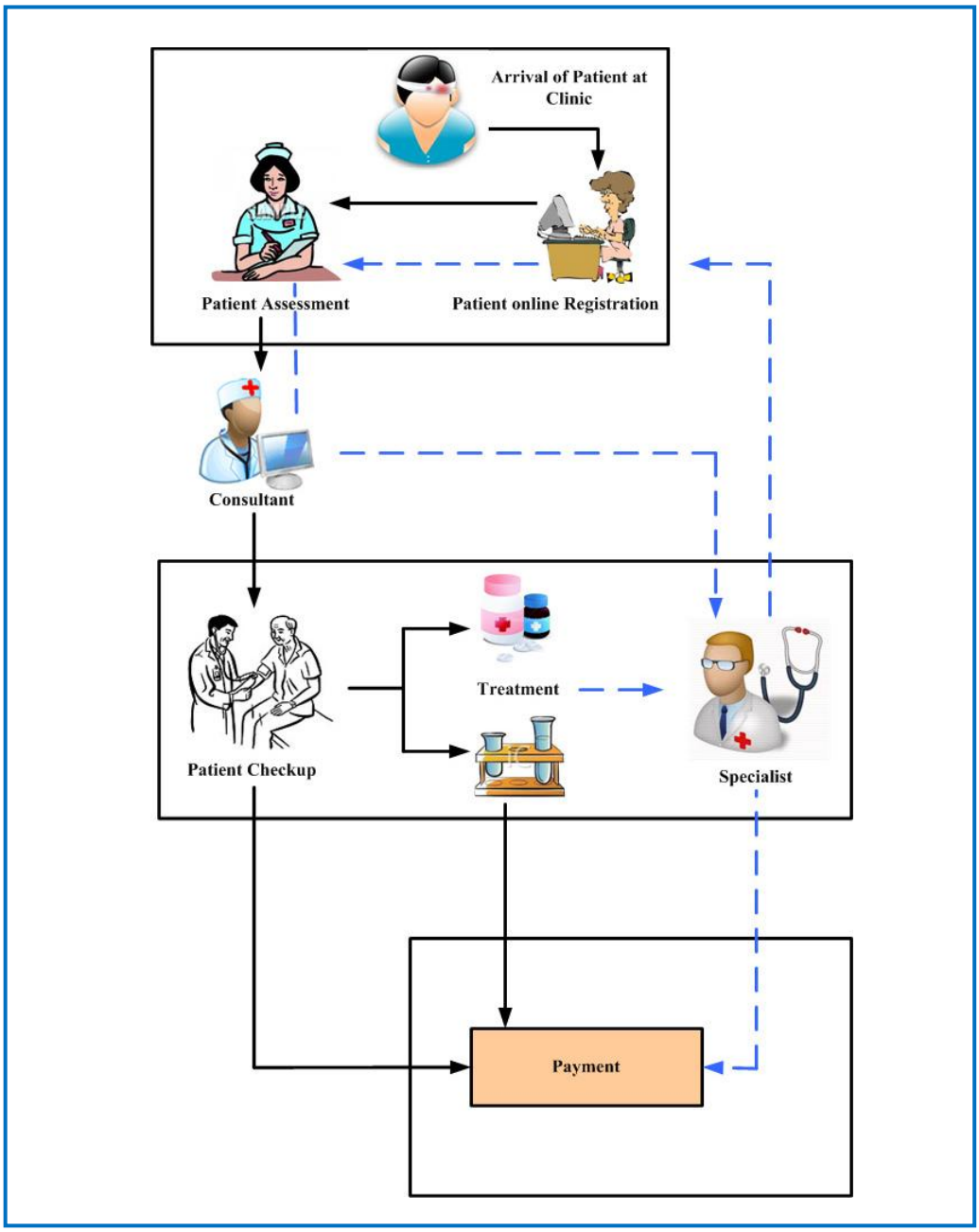

Figure 4. Workflow of the proposed system

VI. Connectivity between Cloud Service Provider and the Rural healthcare Center

The connectivity and configuration of the Cloud based Rural healthcare Information system is based on the service provider policy and domain location, i.e cloud data center location. Internet is the main communication link between the service provider and the Rural Healthcare center. Users access cloud computing using networked client devices, such as desktop computers, laptops, tablets and smartphones. Some of these devices - cloud clients - rely on cloud computing for all or a majority of their applications so as to be essentially useless without it. Examples are thin clients and the browser. Many cloud applications do not require specific software on the client and instead use a web browser to interact with the cloud application

Device's required at Rural Healthcare Center for connection purpose is given below.

WAN connections: In the case of WAN (Wide area Network) , the cloud represents the switching equipment and links of the service provider network, over which data will travel between locations.

WAN Switch: A multi-port internetworking device used in carrier networks. These devices typically switch traffic such as ATM, and operate at the Data Link layer of the OSI reference model. Public switched telephone network switches may also be used within the cloud for circuit-switched connections like Integrated Services Digital Network (ISDN) or analogue dialup.

Modem: Modems enables digital data to be sent over an analogue medium during transmission and receiving of information. A voice band modem converts the digital signals produced by a computer – the 1s and 0s- into voice frequencies that can be transmitted over the analogue lines of the telephone network. On the other side of the connection, another modem converts the sounds back into a digital signal for input to a computer or network connection.

Router: A Router Provides internetworking between the LANs, and WAN access interface ports that are used to connect to the service provider network. These interfaces may be serial connections or other WAN interfaces. With some types of WAN interfaces, an external device such as a DSU/CSU or modem (Analogue, Cable, or DSL) is required to connect the router to the local point of presence (POP) of the service provider.

VPN's and Tunnels: The VPN client installs easily and only requires a few configuration parameters, including the IP address of the appliance to which it is connected along with a username and password for authentication. The VPN client is extremely flexible in terms of where they can be used, whether in a hospitals, Rural healthcare center or a highly secure remote site, the client can typically be easily deployed. Because the client operates using the SSL protocol and not IPSec, it does not have issue with firewalls which NAT the connections, or other networking equipment like proxy servers. Virtual private network technology is based on the idea of tunneling.

VPN tunneling involves establishing and maintaining a logical network connection (that may contain intermediate hops). On this connection, packets constructed in a specific VPN protocol format are encapsulated within some other base or carrier protocol, then transmitted between VPN client and server, and finally de-encapsulated on the receiving side. VPN supports two types of tunneling - voluntary and compulsory. Both types of tunneling are commonly used.

Wi-Fi: is a mechanism that allows electronic devices to exchange data wirelessly over a computer network. A device enabled with Wi-Fi, such as a personal computer, video game console, smartphone, tablet, or digital audio player, can connect to a network resource such as the Internet via a wireless network access point. An access point (or hotspot) has a range of about 20 meters (65 ft) indoors and a greater range outdoors. Hotspot coverage can comprise an area as small as a single room with walls that block radio signals or a large area, as much as many square miles, covered by multiple overlapping access points.

3G enable mobile devices: Example Mobile Devices with 3G

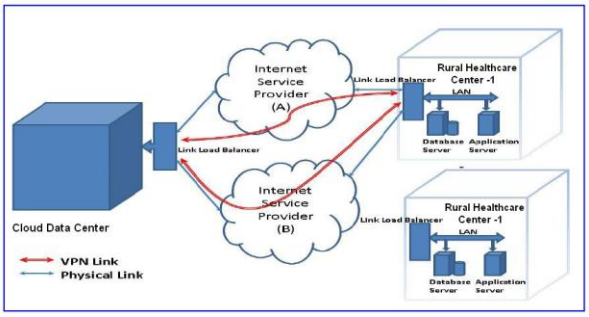

Figure 5(a). Connectivity between Cloud Data Center and Rural Healthcare Centers

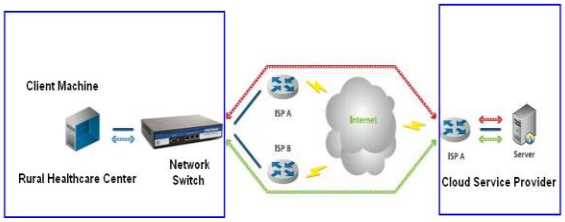

Figure 5(b). High Level View of Cloud Connectivity between Service provider and Rural Healthcare Center

Figure 6. Inside network connectivity view of a Rural Healthcare Center

Rural Healthcare Center message flow

When a patient visits a Rural Healthcare Center then a nurse documenting a visit of that patient. the Rural Healthcare Center Information support center supports an interface that closely used the SOAP protocol for documenting a visit. SOAP is an acronym comprising of the four stages involved; Subjective which captures a patient's conditions in her own words, Objective consisting of notes made from measurements, physical examination and tests, Assessment consisting of a summary and differential diagnosis and finally Plan which is the care-provider's recommended course of action that includes prescriptions and referrals. As part of the plan, the care provider also recommends, if she deems necessary, a follow up to be done by the Health Extension Worker.

Every visit documented by the nurse goes through an approval by a doctor.
For every patient, the health care provider can access the history of visits.

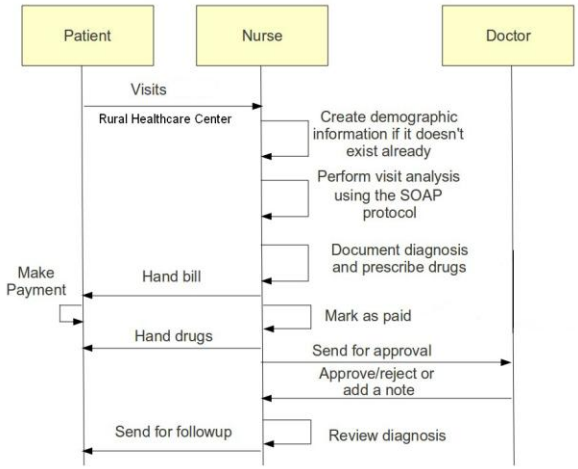

Figure 7. Sequence diagram of the proposed model

Advantages of this Model

- Eliminating the time and efforts needed to roll a healthcare IT application in a hospital.
- Patients can view their health records and prescriptions on their mobile phones on a request basis
- It can also be used to share information seamlessly and in near-real-time across devices and other organizations.
- In this cloud model, customer providers only pay for what they use.
- Significant Cost Reduction: The cost of implementing the Traditional Healthcare System
- is very high but in cloud computing available at a fraction of the cost of traditional IT

services; upfront capital expenditures eliminated; dramatically reduced IT administrative burden.

- Increased Flexibility: On-demand computing across technologies, business solutions and large ecosystems of providers; reduced new solution implementation times.
- Access anywhere: The services will accessed from a single computer or network. Use different computer or move to portable devices, and applications and documents follow.
- Elastic scalability and pay-as-you-go: Add and subtract capacity as per the needs change. Pay for only what is used.
- Easy to implement: No need to purchase hardware, software licenses or implementation services.
- Service quality: Reliable services, large storage and computing capacity, and 24X7 service and up-time.
- Delegate non-critical applications: Outsource non-critical applications to service providers and focus agency IT resources on business-critical applications.
- Always the latest software: Updates are automatic in cloud computing.
- Private Public Partnership: Applications and documents accessible from anywhere in the world, facilitating group collaboration on documents and projects.

Disadvantages of this Model

- No fail over system in case of communication failure
- In particular for smaller hospitals and physician practices, typically don't have the IT staff, required to support new technologies; and the cloud removes the burden of hiring internal IT staff to maintain it.
- This makes it necessary to maintain a secure, safe, and authorized environment for the prevention of information leakage.

Conclusion

There is a tremendous promise for cloud computing infrastructure in the healthcare industry. Cloud computing would help rural healthcare centers to achieve efficient use of their hardware and software investments and to increase profitability by improving the utilization of resources to the maximum. The purpose of implementing cloud computing systems in health care is not to compete with each other but serves to facilitate and improve the quality of patient care. There is no one system which is superior from the other but they have their own uniqueness. However, there is a need to synchronize these systems so that the system can communicate with other outside systems to ensure the maintenance and continuity of care. We shall continue our work to explore means of pooling various healthcare IT resources into large clouds so as to facilitate ease of record sharing, medical image processing, analysis, and diagnosis.

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