Indian perspective Architecture for Advancement of Biomedical Telemedicine and mHealth System

Govind Maheshwari[1] and Ankit Jain[2]
[1]Software Engineer, eMorphis Software Technologies Solution Pvt. Ltd., Indore, INDIA
[2]Dept. of Comp. Sc. and Engg, Prestige Institute of Engg. and Sc., Indore, INDIA
Email: [1]govindmaheshwari12@gmail.com, [2]ankit_jaincs@yahoo.co.in

Apurva Gaiwak[3] and Prashant Bansod[4]
[3]Dept. of Elec. and Comm., Truba College of Engg. and Tech., Indore, INDIA
[4]Department of Electronics and Instrumentation, S.G.S.I.T.S., Indore, INDIA
Email: [3]agaiwak@yahoo.co.in,[4]ppbansod43@gmail.com

***Abstract*— Healthcare delivery is becoming a big challenge for the increasing population in the world. This is even a bigger challenge for the developing and under developed countries due to scarce resources. Taking the case of India, where majority population lives in rural areas and far furlong regions like Andaman and Nikobar Islands or eastern parts of the country, getting desired level of medical facilities has become dream for the citizens of these areas. This inadequate healthcare delivery system is facing constraints due to increased number of patients, which is reflecting as long waiting queue, shortage of hospital beds and inadequate intensive care/emergency units. The existing healthcare delivery model, if supported by the modern wireless and web technologies can give solutions to some of the problems and this in turn can make appropriate healthcare feasible for more number of people without their relocation. With the use of information and communication technologies in healthcare many terms like Telemedicine, eHealth and mHealth are frequently used. This paper briefly introduces these terms and proposes new telemedicine mHealth architecture.**

***Index Terms*— Telemedicine, Mobile Telemedicine System, HER, EMR, Healthcare System, eHealth, mHealth.**

I. Introduction

Telemedicine can improve the existing healthcare scenario. The term telemedicine is used to deliver healthcare at remote locations or at distant areas, with the use of smart mobile devices the term "mHealth" is also used frequently. In addition to these terms if internet is used for healthcare data applications the term eHealth is used. If medical data and service delivery uses cloud based applications then an additional term 'Cloud Health' is also used in the literature. The capabilities of smart mobile devices like their computing power and their accessibility is increasing on regular basis. These powerful mobile devices with their elaborate communication and computing capabilities can be used for betterment of healthcare services.

Various terms as above are defined as:

1) *The term "Telemedicine" refers to the utilization of telecommunication technology for medical diagnosis, treatment and patient care [1]. Telemedicine also can be described as the transfer of electronic medical data from one location to another [2]. Telemedicine includes "the use of audio, video, and other telecommunications and electronic information processing technologies for the transmission of information and data relevant to the diagnosis and treatment of medical conditions, or to provide health services or aid healthcare personnel at distant sites" [3].*
2) *eHealth can be defined as "Use of Information and Communication Technology (ICT) - such as computers, mobile phones and satellite communication to deliver health services and information regarding patient condition" [4].*
3) *mHealth can be defined as "Using mobile communications - such as Personal Digital Assistants (PDAs) and mobile phones - for health services and information". mHealth involves using wireless technologies such as Bluetooth, GSM/GPRS/3G, Wi-Fi, WiMAX, and so on to transmit and enable various eHealth data and services. Usually these are accessed by the health workers through devices such as mobile phones, smart phones, PDAs, laptop and tablet PCs [4].*

A survey by Indian Council of Medical Research states that a large number of people living in rural India have very limited access to specialist care and advice in medical field. Telemedicine can be used to fill up this gap by enabling delivery of specialist's medical advice to remote areas. Recent advances in broadband technologies for mobile phones may enable anytime, anywhere access and this adds new dimensions to telemedicine delivery. One of the benefits of telemedicine system is that it is no longer required for the patient to be physically present at the hospital centre [5].

Mobile technologies can also be used for telehomecare purpose, where patient's vital health parameters can be

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monitored by the mobile devices and in case of emergency, medical treatment related advice can be sent by the central hospital or medical centre [6].

Portable medical devices allow telediagnosis, teleconsultation and long distance support of mobile healthcare. These devices are helpful in remote areas, with the use of mobile telephony, network devices allow transmission of vital bio signals and still images of the patient from the emergency site to the consultation site and telematically bring an expert specialist doctor at the site of the medical emergency; facilitating evaluation of patient health data and issue for treatment procedures and first aid until the patient is brought to the hospital. This can be very useful in case of emergency care [7].

There are limitations in the bandwidth of network and data transmission through mobile devices, but with the improvement and advancements in the mobile technologies and with the 3G, 4G applications and specific data structures used for medical records which can be used in smart phones and smart mobile devices these limitations can be overcome.

There are many protocols and Application Programming Interfaces (APIs) tools developed to store Electronic Medical Record (EMR) or Electronic Health Record (EHR) through mobile devices and computer based technologies like Health Level Seven (HL7), Health Insurance Portability and Accountability Act (HIPAA) etc. Considering the sensitivity and importance of medical data formal adoption of these protocols by central agency in India will help to deliver telemedicine in Indian scenario. Comprehensive efforts would be required so that these application protocols can be deployed to deliver telemedicine using the underlying communication technologies in order to deliver effective healthcare through telemedicine, an integrated telemedicine grid at national level would be required, so that dream of quality healthcare access to anytime, anywhere and to anyone will be fulfilled.

Section II in this paper presents issues related to the conventional telemedicine system. Section III and IV discuss the system architecture of mobile telemedicine and mHealth respectively, section IV also presents a new architecture for telemedicine cloud. The paper is concluded in section V.

II. Telemedicine System with Ehealth and Mhealth

A. Conventional Telemedicine System

Healthcare systems deployed in different parts of the world have many electronic devices for the patient's diagnosis and treatment. Most of the available medical equipments nowadays produce digital outputs and results. These digital data can be stored and used for analysis and diagnosis locally as well remotely after transmission. Data can be stored with different formats like pictures, images, digital signals, graphs, charts etc. in the computers. Doctors can analyze these data and diagnose patient's ailment. Patient past records may also be needed in the medical diagnosis. Patient's medical history stored in the EMR (Electronic Medical Record) can supplement the diagnosis process. This EMR scheme is implemented in a few countries only.

In India one of the existing telemedicine solutions, supported by Indian Space Research Organization (ISRO), in which telemedicine infrastructure is set up at a specialty hospital and connectivity is established with different remote areas of the country using VSAT or other means. A nodal centre (referred as telemedicine unit) is created in a local hospital in these remote areas where patients can directly interact with specialists at the specialty hospitals. The nodal centers are equipped with of vital parameter measuring devices which connect to a desktop PC. The PC records the device readings. The health worker then connects to the server at the specialty hospital and uploads the reports, using these reports specialist at these hospitals send back comments and advice. The waiting patient at the other end may receive the reports personally and thus gets specialist consultation at remote location [5]. In this system use of PCs may be replaced with the mobile devices and mobile phones. Use of smart mobile devices may facilitate anytime, anywhere access of healthcare services.

Fig. 1 shows the information flow of mobile telemedicine system in which different mobile technologies can be used for creating Indian perspective telemedicine system.

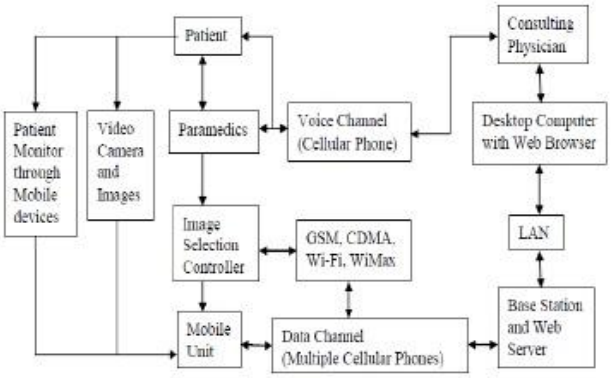

Figure 1. Information flow of mobile telemedicine system

B. Scalability Issues for Telemedicine System in India

As the volume of medical data increases through EMR or EHR and telemedicine transmissions; existing infrastructure of the hospitals will not be able to handle large scale users need. Collaboration between hospitals and a distributed arrangement may help to scale up the system.

The present telemedicine infrastructure requires the specialist to be available at the centre whenever the data is received. This is important to ensure that patient must get instant response/advice. However, this constraint for specialists to be always available may not be feasible as the number of requests increases. This necessitates a centralized system maintained in such a way that if specialist doctors are not available at that centre than communication to other centre can be possible so that online help can be provided. Advanced cloud applications and web services may be used to utilize the resources

effectively. In order to take in account the possible growth of mobile system's user, there is need of nodal centre at higher level of hierarchy. This will fulfill the requirements of growing number of mobile users. Data can be distributed and presented in such a way that if patients, users or doctors need data than it is available according to their uses and needs.

The security aspects and optimum resource requirements which are important for success of telemedicine deployment are related to the scale of the system. Cloud or web-based applications can be used to address the scalability issues. The cloud development can be utilized in future for an integrated nationwide telemedicine grid. It is possible to facilitate availability of patient's medical records anytime and anywhere through cloud based services if data is stored on the cloud. Access of patient's date can be made possible with the proper authentication and authorization.

Telemedicine can provide great benefits to rural population, rural clinics and remote clinics may be provided appropriated telecommunication connectivity to the specialty hospitals. These clinics may be connected with the available communication technologies in that area. Fig. 2 presents the connectivity between different hospitals at different levels of hierarchy of the health delivery system prevalent in the country.

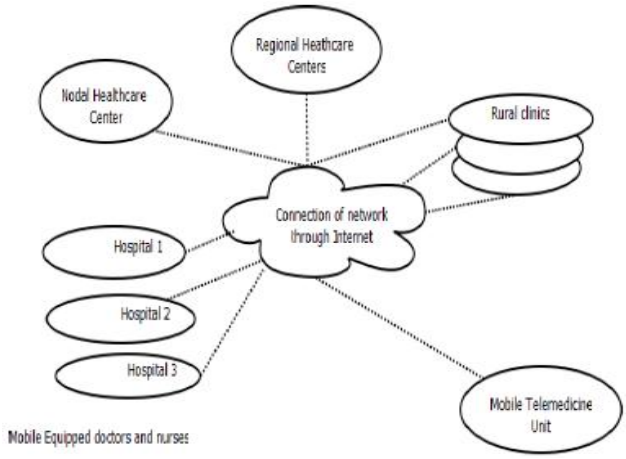

Figure 2. Virtual Mobile Enterprise structure for Telemedicine Grid

It is not possible that specialist doctor is available all the time for all types of diseases for online help, therefore this system must be deployed in such a way that if doctors with particular specialization are not available in a center than patient can contact to other centers for online help related to the same specialization; there is need for a mechanism that can handle this issue.

Most of the available smart mobile devices have the capability to store and retrieve data from cloud or web server and process them for multimedia uses. Availability and adoption of these devices will facilitate deployment of telemedicine effectively. It is possible to integrate Unique Identification system (UUID) with telemedicine cloud so that history of patients, futuristic healthcare precautions/advice and health insurance related issues can be taken care.

In the proposed system reports of patients and users are generated on regular basis, in order to handle large volume of data both common and distributed data structures for patient's records and monitoring can be used at each and every remote healthcare centre.

C. Other Challenges with the System

In telemedicine system, security of medical data is an important issue. Patients or people have their private medical records in the system; security measures are required to avoid tampering and unauthorized access of the individual record. Only authorized person can view data based on access privileges.

The telemedicine system must be robust i.e. the patients must be able to communicate with the telemedicine system even during emergencies. For this, the system must guarantee services despite partial infrastructure failures [5].

Handling and storage of bulky data resources is needed. Maintenance and managing of changing data is also a major concern related to the scalability. In emergency conditions data should be available in minimum time without failure.

III. System Architecture for Mobile Telemedicine in India

A. System Overview

In this section important components of the proposed telemedicine health architecture are discussed. The architecture is shown in Fig. 3.

1) *Smart ecard:* In the proposed healthcare system when a patient is admitted for the medical treatment an electronic card with all the information related to the patient is prepared and given. Further test reports, diagnosis and treatment related data can also be stored in this ecard. All the reports of the patient are stored in this card and also on the central web server which is used to keep history of the patients. This obviates the need to keep all the reports in the paper format and it is useful when the patient is transferred from one medical centre to other because all the data related to the patient is either stored in the card or accessible through internet services.
2) *Mobile ambulance*: In case of emergency, patients can call the ambulance sevices, this ambulance may be equipped with the latest computerized wireless system. This ambulance will connect to the destination hospital using the available mobile communication devices, the current condition of the patient and the vital physiological parameters of the patient may be communicated to the hospital so that time lag in providing immediate cure to the patient can be reduced. The reports of the patient can be sent to the doctor's association server during the travel time, thus can save vital time which is very important in case of emergencies.

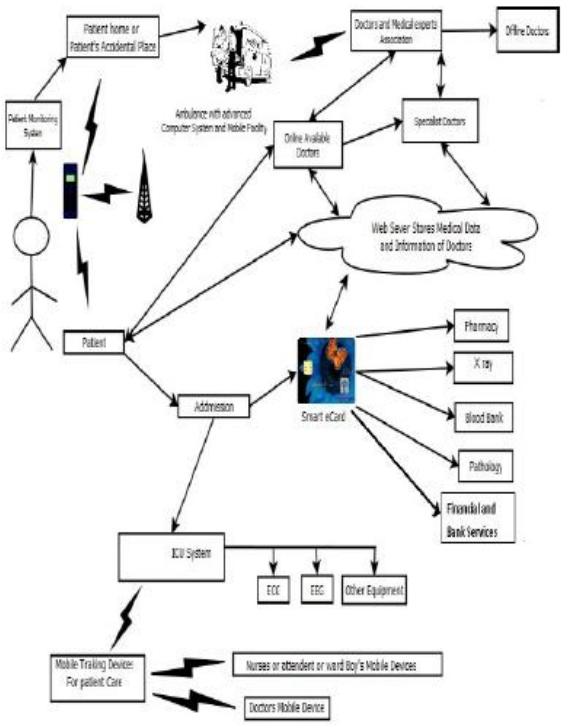

Figure 3. System architecture for indian perspective advanced healthcare system

3) *Doctors association:* In the doctor association server the current online doctors who are available for the medical service can analyze the patient's condition after receiving the reports sent from the ambulance and respond according to it so that immediate care can be given in the ambulance before going to hospital or medical centre. If situation is not handled by the available doctors, then some message can be sent to the specialist's mobile device so that they can help. The data of current situation of patient can be sent to the experts. Experts can analyze the condition of patient and respond according to that. These situations can be handled by association server and a user friendly interface in the mobile browsers. If required, modifications in the protocol implementation can be done to support this.

4) *Advanced ICU system:* If the patient is admitted in the ICU then it is possible that there is lack of availability of trained medical staff in the ICU for a particular patient at all time because of many patients in the medical centre or hospital. Automatic detection facilities in the ICU may be provided which can facilitate monitoring and alarm generation. The current condition of patient can be informed to the attendant or doctors periodically also. A smart communication device connected with the bed equipped with different interfaces to connect various medical equipments which are used to monitor patient's vital parameters may enable this. Software implemented in this mobile device can monitor the current vital parameters of the patient. During the monitoring of these parameters any abnormal condition leads to alarm generation and instant messaging to the appropriate person.

5) *Mobile file:* In the existing healthcare system daily prescriptions, test reports, diagnosis and medical prescriptions to the patient are maintained in the manual file format. It is possible to use mobile devices (like tablets etc.) at the bed of the patients to store all the above. If these devices are connected to the pharmacy system, supply of the medicine can be automated. In case of any emergency leading to change in the prescribed medicine, messages can be sent to the pharmacist immediately. Through this device, e-card records of the patients can be updated or retrieved on the cloud.

Due to limited power and size constraints mobile devices have their own limitations. As the technology develops with passage of time, these limitations will be overcome. At present some application development has been carried out in the architecture presented in Figure 3. As the development of the technology in mobile devices goes to next higher levels more application development will be possible in near future.

It is possible to upload data through mobile devices easily on the cloud. Amazon Web Services (AWS), Google App Engine and Windows Azure are now supporting mobile development APIs for their cloud based services. In future easy availability of cloud services and tools for application development may add to telemedicine deployment.

IV. System Architecture for MHealth System

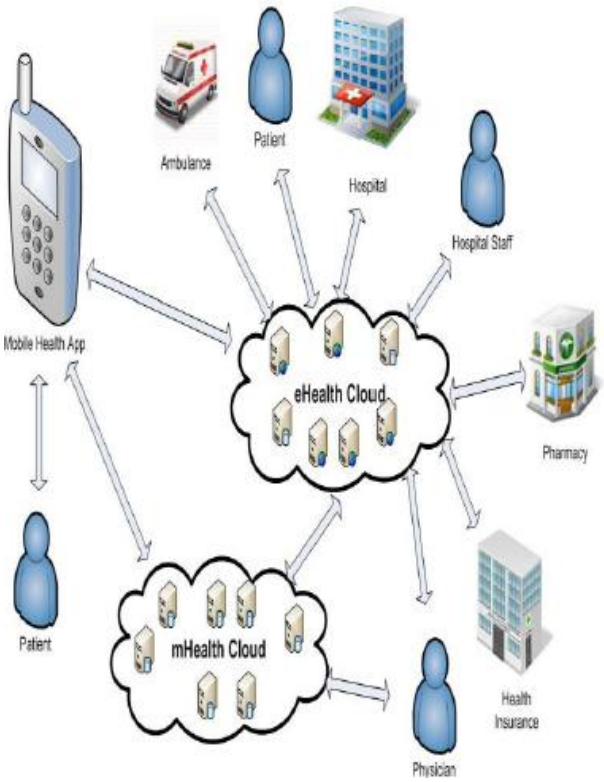

Figure 4. mHealth system architecture with cloud services

Functioning of mobile healthcare information system requires an advanced information network to support clinical care, personal health management etc. There are a few challenges such as acceptable standards, technological choices, jurisdictional boundaries, investments and risk management to the privacy, confidentiality and integrity of information [9].

The mHealth and eHealth system architecture for cloud technology is presented in Fig. 4. Mobile devices have limited storage capacity. Data fetching and data storage to and from mobile devices can be done on cloud based services. Cloud services can be used for data, image, graph storage, monitoring requests and improvement of data transfer. This is possible with the existing mobile devices.

In the Fig. 4 different end points of healthcare system are connected with the cloud based services and these are required to be implemented for mobile devices and PCs. As a part of this architecture a mHealth application is developed and installed within institute laboratories for testing and demonstration. This Android based mobile application is developed for blood pressure, sugar, heart rate and web services were implemented to share this data of different patients.

V. Conclusions

This paper proposes architecture for telemedicine system. With the increasing use of smart phones in the developing countries like India, in near future use of m-health may greatly enhance telemedicine delivery for medical service improvement. The objective of proposed architecture is to provide quality health services which can contribute in the improvement of healthcare sector. There is an uncountable opportunity at hand to fulfill promises of improvement of healthcare services through mHealth system. To accelerate the mHealth development system and fully use of potential of mHealth applications, dynamic multi-sector help and collaboration is needed, governments, multilateral organizations and the private sector is needed to work jointly. Joint action directed toward the creation of a national wide mHealth infrastructure will make effective healthcare feasible.

As the number of users of mobile phones and mobile devices and their increasing number day by day as well as their penetration and adoption in masses make mHealth a feasible possibility. With the use of Smart mobile devices and enhancement in cellular mobile services from 2.5G to 3G and 4G, telemedicine systems can be very effectively deployed in India. The data stored for the medical purposes can be further used for large scale simulation in the field of medical research. This model may prove to be very helpful in the country with huge population and less resources for medical facilities in the rural and remote areas.

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Dr. Prashant Bansod received the Bachelor of Engineering in Electronics and Instrumentation Engineering from Shri Govindram Sakseria Institute of Technology and Science, Indore, Madhya Pradesh, India, in July 1989 and the Master of Technology in Electronics Engineering from Visvesvariya Regional College of Engineering (Now VNIT), Nagpur, India, in April 1992 and Ph.D in Biosciences and Bioengineering in 2010 from IIT Bombay.

He worked as Assistant Professor at S.G.S. Institute of Technology and Science from April 1993. He is currently working as Associate Professor in Electronics and Instrumentation at SGSITS, Indore.

Dr. Bansod's fields of specialization include Medical Signal and Image processing, Measurement systems and VLSI Design. He actively participated in the Special Manpower Development Project in VLSI, a project funded by Ministry of Information and Communication Technology, Govt. of India. He has teaching experience of over nineteen years at undergraduate level and 15 years at PG level. He persuaded research in field of Medical signal and image processing and integrated sensors. He has published about four research papers and attended five conferences. He has undergone about 20 Instruction enhancement programmes, summer/winter schools at various National level Institutes.

Mr. Apurva Gaiwak obtained his B.E. Electronics from Madhav Institute of Technology & Science Gwalior in the year 1988 and M. Tech. Electrical Engineering (Telecommunication Networks) from IIT Kanpur in 1994.

He has 24 years working experience in industry, academics and research. He is Fellow of Institute of Electronics and Telecommunication Engineers India, life member of Computer Society of India and Indian Society for Technical Education India. He has contributed 23 research papers in national and international journals and conferences. At present he is working as Professor (Electronics and Communication Engineering department) and Lead research at TRUBA college of Engineering & Technology Indore.

Govind Maheshwari has completed Master of Engineering (Computer Science and Engineering) in the year 2011 and Bachelor of Engineering (Computer Science and Engineering) in the year 2008 from Medi-Caps Institute of technology and Management, Indore, Madhya Pradesh, India.
He is working as a Software Engineer in eMorphis Software Technologies Solutions Pvt. Ltd., Indore, India. He has more than 3 years working experience in industry, academics and research. He is a member of Computer Society of India. His research interests are Mobile Computing, Cloud Computing, Healthcare and Education web based and mobile applications, EDI and HL7 software development, Service-Oriented Architecture, Big data analytics.

Ankit Jain has completed his M.E. in Computer Science and Engineering from Medi-Caps Institute of Technology and Management, Indore, MP, INDIA in 2011 and B.E.in Computer Science and Engineering from Jawaharlal Institute of Technology, Borawan (Khargone), MP, INDIA in 2007.
He is presently working as Assistant Professor in Prestige Institute of Engineering and Science, Indore. He has published 1 international and 3 national paper in various conferences. He is a member of CSI, life member of ISTE and his research interests are Cloud Computing, Healthcare IT, and Service-Oriented Architecture.