A Sensor-Cloud Framework for Provisioning Remote Health-Care Services

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ABSTRACT
In this paper, we describe the design of a sensor-cloud framework for hosting remote health-care services. First the requirements for delivering remote health-care services are analysed. Next an overview of the sensor-cloud framework is presented. Maintaining health records is an important issue for delivering health-care services remotely. Therefore, a data model for the health record is proposed and issues related to storage and retrieval of health records are also discussed.

Categories and Subject Descriptors
H 3.4 [***Distributed systems***] *Sensor-Cloud Framework, Health-Care Services, Data Storage and Retrieval.*

General Terms
Design

Keywords
Health-Care, Sensor-cloud, Preliminary EHR, Big Data

1. INTRODUCTION
Currently 1.2 billion people reside in India and its population is increasing at a 2% annual rate. By 2030, India is expected to surpass China as the world's most populous nation [2]. Although, India's thriving economy is driving urbanization rapidly, nearly three quarters of the population in India still lives in rural areas.

The healthcare infrastructure in rural India has been developed as a three tier system and is based on certain population norms. For example, a sub-centre is set up for every 5,000 population (3,000 in the hilly area), a primary health centre is set up for every 30,000 population (20,000 in the hilly area) and a community health centre is established for every 1,20,000 population (80,000 in the hilly area) [1]. The sub-centre is the first contact point of the rural community. Each Sub-Centre is manned by one Auxiliary Nurse Midwife and one Male Health Worker and One Lady Health Worker is entrusted with the task of supervision of six sub-centres. Each primary health center with 4 to 6 beds is manned by a Medical Officer and 14 paramedical and other staff. Community health centres are manned by four medical specialists i.e. Surgeon, Physician, Gynecologist and Pediatrician supported by 21 paramedical and other staff. A CHC has 30 in-door beds with one OT, Xray, Labour Room and Laboratory facilities. Considering the large and booming population of India, the above healthcare infrastructure, even if it functions efficiently, is certainly inadequate. Besides, the existing infrastructure often fails to function satisfactorily, as there is overall shortfall in the manpower.

The rural healthcare infrastructure is supported by hospitals and health centres in the urban areas providing secondary and tertiary level health services. However, when patients from different corners of the country arrive at a city hospital, they feel lost because of its vastness, because of the complicated system and because of the lack of proper interface between the hospital personnel and the patients (or their companions). It was observed that more than 80 percent patients who come to the city hospitals could be treated in the rural health centers if proper support in terms of manpower and funding and precise and timely information was available to them. Due to lack of this support, they move to the main hospital and as a result, the main hospitals become overloaded. While India has several centres of excellence in healthcare services, these facilities are limited in their ability to improve healthcare standards because of the inadequate number of public health facilities compared to the vast population of the country and the poor infrastructure to facilitate the healthcare services for all, particularly those residing in the rural area.

While restructuring the entire healthcare system is a long-term issue, efficient use of technology and proper training for using the technology can improve the reachability of healthcare amid the marginalized sections of Indian citizens, can generate proper health knowledge which is necessary for a better standard of living and help to control disease load of the country. This paper proposes building a *remotely accessed, low-cost* healthcare system based on Sensor-Cloud environment. The basic objectives are (a) to increase the accessibility of rural people to basic healthcare, (b) to help the medical practitioners to gather relevant and timely information about the patients and, more importantly (c) to assist the governments to carry out important tasks like family welfare and child immunization and to maintain a database about the health of citizens.

Rest of the paper is organised as follows. Section 2 analyses the requirements for remote delivery of health-care services. Section 3 discusses why Sensor-Cloud environment can suitably be used for hosting health-care services. Section 4 provides an overview of Sensor-Cloud framework with specific consideration of the requirements discussed in Section 2. Section 5 discusses the issues related to storage of health records in a sensor-cloud environment and presents a preliminary data model for the health records that include sensor data measuring clinical parameters. Section 6 puts forward sertain issues related to storage and retrieval of health data in a sensor-cloud environment. Finally Section 7 concludes with a discussion of future work.

2. REQUIREMENTS FOR REMOTE HEALTH-CARE

The ideas presented in this paper are based on the understanding that only doctors can make a diagnosis and interpret a diagnosis. Therefore, the proposal does not aim at developing an expert system for providing health-care services. Instead, it intends to assist a doctor or caregiver to make or interpret a diagnosis by providing all the required data along with necessary alert messages through the use of information and communication technologies.

A diagnosis of a doctor is based on certain details of the patient, which include the patient's demography, personal history, history of past illness and his or her present complain. The first three components of the above mentioned details can be made available by maintaining patients' records in digital form. In our country, often the patient records are not maintained in digital form. Even if some patient records are maintained in electronic format in specialized healthcare centres, they are maintained in fragmented and inefficient manner. Ad hoc health records are generated and kept only at the site of the service. This fragmentation of the patient details leads to duplication and obscurity of data which force the doctors to diagnose without getting complete information about the context. The situation can be improved by maintaining patient details in the form of an *electronic health record (EHR)* which must be updated regularly. Therefore, the first requirement is to adopt a standard model of EHR which is fit for our context.

The second requirement is to develop a framework for storage and timely retrieval of the patient records anytime and from anywhere on demand basis.

The data related to the fourth part of the patient details, i.e. his or her present complaint, are gathered based on some dialogues between the caregiver (doctor or nurse or paramedic) and the patient. This part needs to be supported by certain clinical parameters, such as body temperature, blood pressure etc., which should be measured at the time of patient examination (or should be monitored regularly). With the advent of sensing technologies, there are many health-sensors which can effectively measure certain clinical parameters. If the patient is in the proximity of the doctor or caregiver, these parameters can be easily observed or monitored. However, in the context of remote health-care services, these measured data should be transmitted to a place from where the doctor can retrieve the information. Therefore, sensor data are required to be electronically transmitted to distant places, preferably through wireless communication networks.

Lastly, it is expected that huge amount of data will be generated through this process. In order to retrieve required information, it may be necessary to run analysis or data mining algorithms over these data. Thus, the proposed framework must be supported by high computational capabilities.

Keeping in mind the above requirements, the following sections propose a sensor-cloud infrastructure for hosting the remote health-care services.

3. WHY SENSOR-CLOUD

In a country like India, quite contrary to popular belief, cell-phones and wireless networking have reached in places where clean, drinking water is yet an illusion. Technologists rightfully claim that “mobile era” has started in India and mobile technology is penetrating rural India at a rapid pace than ever. Latest Census data (Housing and House Listing Report, Census 2011) released in March 2012 revealed that half of rural India now uses a mobile phone (while about one third has access to a proper toilet). It can therefore be expected that essential contents and services can be delivered using mobile phones to foster inclusive growth in India and digitally empowering the citizens across all cross-sections of the society, both urban and rural. It is envisaged that in order to increase the accessibility of health-care services for rural and marginalized people, this expansion of mobile and wireless technologies will become effective.

As discussed in the earlier section, there are three specific technological requirements in order to reach health-care services to corners of the country. These are:

- sensing the clinical parameters
- transmitting the data wirelessly
- storing the data for analysis and timely retrieval

Medical sensors can be used for measuring clinical parameters of the patients. These sensing devices can be carried by a paramedic or a trained health worker to the patient's house and relevant data (useful clinical parameters) can be transmitted over the wireless communication network for analysis and mining and diagnosis by a doctor. Sensors can also be deployed on the patient's body for continuous monitoring. Such sensors can actually develop a *Body Sensor Network*.(BSN) and can continuously be engaged in transmitting data for monitoring by the caregiver or for raising alerts when required. Cellular mobile phones can also be used as sensing devices or for capturing and transmitting data. Sensors can also be deployed inside a health centre for monitoring admitted patients or outdoor patients. These sensors when equipped with transmission capabilities can form small sized *PANs (Personal Area Networks)* along with edge routers. Such PANs are ranged over only a limited area. Nevertheless, the data gathered by these sensors are also required to be transmitted for analysis and diagnosis.

The huge amount of data gathered using health sensors are required to be stored and be made available for anytime, anywhere access by the medical practitioners, caregivers, government and others in a secured manner and under the security and confidentiality norms defined by the organizations involved in the development of international healthcare informatics standards, such as HL7 [3] or ISO/TR 20514 [4]. Such on demand services are offered by a cloud environment. Cloud environment offers flexible way of accessing data at low cost. It provides high computational power, high capacity and highly available storage and scalability. Further, cloud environments ensure location independence and optimized resource utilization. Thus, we propose to integrate sensor and mobile technologies with a cloud environment.

Recently there have been many research efforts on the development of Sensor-Cloud infrastructure and for managing physical resources (e.g., sensors) on the virtual platform. For example, OGC or Open Geospatial Consortium [5] defines Sensor Modeling Language (SensorML) [6] to provide standard models and an XML encoding for physical sensors’ description and measurement processes. A Sensor-Cloud Infrastructure is also proposed in [7] which virtualizes a physical sensor as a virtual sensor on the cloud computing environment. Dynamically grouped virtual sensors on cloud computing can be automatically provisioned when the users need them. In [8], a publisher-subscriber based model is described that simplifies

integration of sensor networks with cloud based community-centric applications.

In our framework, we do not intend to add sensors simply as endpoints in the cloud environment, but they should be dealt with in the same way as computing and storage resources. Thus, sensing can actually be offered as a service just like computing resources (“Infrastructure as a Service” - IaaS) and storage resources (“Data as a Service”) [9]. Such environments may also involve mobile devices.

4. SENSOR-CLOUD FRAMEWORK FOR HEALTH-CARE APPLICATION

We have proposed a generalized sensor-cloud framework [10] that can be used for different applications, such as environment monitoring, habitat monitoring, and health-care management. However, it is observed that there are specific issues for a sensor-cloud framework when a health-care application is deployed on top of it. In this section, some of the challenges related to sensor-cloud framework are discussed with particular focus on health-care application..

A) Communicating seamlessly over heterogeneous wireless networks (e.g., cellular network, WiFi, IEEE 802.15.4 enabled sensor networks, the Internet).

Cellular networks are nowadays spread over a huge geographical area and many remote corners of the country are connected through cellular network. However, access to cellular networks is costly, in particular when Internet access is made through this network. On the other hand, wireless LANs (WiFi) can be deployed in an indoor environment (in a health centre) and can be provided with Internet connectivity (e.g. through broadband) to provide cheaper communications. But, firstly wireless networks work within a limited range and secondly, broadband services may not be available everywhere. Furthermore, sensor networks normally operate on a completely different standard, namely IEEE 802.15.4. Currently, there have been research efforts for implementing Internet standards in sensor networks using technologies like 6LowPAN [11,12]. Thus, it is required to deal with these heterogeneous communication networks within the sensor-cloud environment.

B) Routing data and managing mobility

Health-care applications do not require large-scale sensor networks as required in applications like environment-monitoring, habitat monitoring etc. Thus, routing is performed only within a small-ranged network. Nevertheless, use of sensor and mobile devices in an indoor environment (in a health centre) or on a patient's body may give rise of some routing and mobility issues. Even in an outdoor environment, e.g., when a patient is carried in an ambulance, or a patient is on move, but requires continuous monitoring, mobility issues need to be handled efficiently.

C) Resource Management

A primary task is accepting and interpreting queries from the users and sending the queries to appropriate resources. The resources can be computational, storage and sensors. As for other resources in cloud like computational and storage resources, sensors are also required to be abstracted, virtualized, and grouped. Moreover, as one of the objective is to enable access to the sensors in data-centric manner (instead of accessing in an id-centric way), some mechanisms for mapping a id-centric network to a data-centric network is necessary. Besides, queries are to be scheduled to appropriate sensors or other resources while maintaining quality of services (QoS) requirements. In a sensor-cloud framework, QoS requirements will include real-time data transmission, cost optimization etc.

D) Data management

Managing health data raises some additional issues. Firstly, health data are diverse and are available in different forms, such as textual, image etc. Secondly, sensor data are dynamically available from heterogeneous types of sensors and often in the form of continuous streams. Such continuous streams need to be managed and filtered for extracting necessary information. Thirdly, there are the issues of security and confidentiality which are to be handled in sensor-cloud environment.

Thus, the sensor-cloud framework proposed in our research work broadly functions in the four layers depicted in Figure 1.

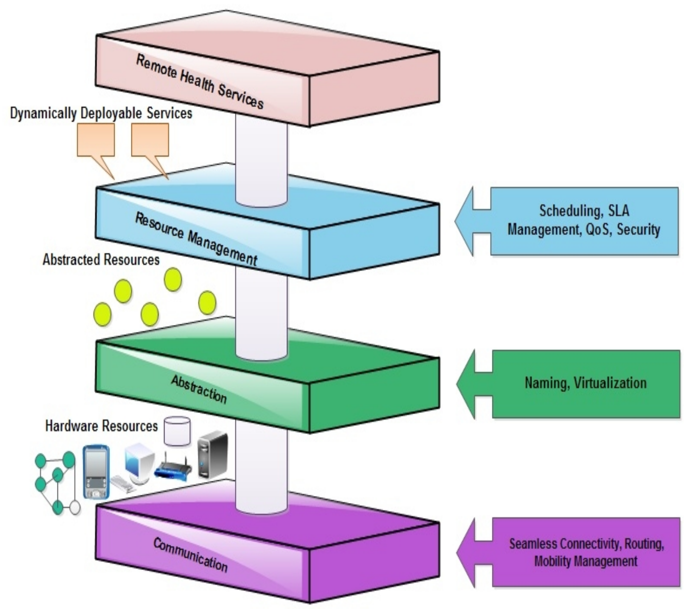

Fig. 1 - A Layered Architecture for Sensor-Cloud Framework

5. MAINTAINING HEALTH RECORDS

The concept of a patient’s medical information stored electronically instead of on paper is not a new one. The concept of EHR dates as old as 1960. The Mayo Clinic in Rochester, Minnesota, and the Medical Center Hospital of Vermont were some of the first clinics to utilize electronic medical records in early 1960s. Since then, the EHR model has been further extended to include more information, such as drug dosages, side effects, allergies, and drug interactions, which enabled the medical practitioners to learn the complete history of a patient when planning the treatment. Electronic diagnostic and treatment plans were integrated into electronic medical record systems. Some academic and research institutes developed their own computerized medical record systems as tools to track patient treatment [13].

In India also certain steps have been taken for standardization of medical record maintenance facility. In 2003, Ministry of Communications and Information Technology had prepared and published a recommended framework for IT infrastructure for healthcare including recommendations on guidelines, standards and practices for telemedicine in India. The taskforce set up by Ministry of Health and Family Welfare in 2005 for telemedicine also looked at the issues and standards related to EHR. EMR Standards Committee, constituted by an order of Ministry of Health & Family Welfare, Government of India and coordinated by FICCI has published their recommendations in 2013 [14].

While extensive discussion on EHR is not within the scope of this paper, it highlights certain issues regarding storage and maintenance of health data in sensor-cloud environment.

1) Health data inflows in the system in huge volume.
2) Health data is stored in heterogeneous format, such as textual, image etc.
3) Different parts of the health record will be required to be updated at different frequencies. Specifically, when a patient's record will be stored, part of this record will be stored only once (e.g., demography and personal history), part of this record will be updated less frequently (e.g., patient's past history of ailments and treatments), part of this record will be updated more frequently and will be retrieved in real-time (e.g., sensor data for patient requiring continuous monitoring).
4) Continuous streams of data may arrive at certain times which need to be handled.
5) Analysis results of a set of data may generate requirements for collection of further data using sensors or other resources.
6) Collection of health data (history and present clinical features) depends on specific complaint of the patient. Generally, data need to be gathered in a particular context to ensure that the information gathered is relevant and excessive and misleading information can be avoided.
7) Health data need to be represented in a standardized format and should be retrieved by using interoperable standardized service framework.

Thus, while considering the structure and storage of data model, the above issues need to be dealt with.

Figure 2 presents a data model (without details of each class) for maintaining health information on top of our sensor-cloud environment.

6. DATA STORAGE AND RETRIEVAL

Researchers opine that EHR data does not fit in normal relational tables or models as it contains huge amount of sensor data, image data and numerous data files. Therefore EHR data should be treated as unstructured data [15]. In case of EHR in Indian context, it is felt that Volume, Velocity and Variety, all these traits are present. Thus, not only huge volume of data, but also heterogeneity of data types, representation, and semantic interpretation along with the rate at which data arrive and the time in which it must be acted upon

impose new challenges in data management that need to be dealt with. Data changes frequently and thus, need to be captured with temporal information. Garlasu et al suggest that a fourth characteristic is also present; sometimes a big portion of the data is such that it is not required in totality [16], instead some meaningful extracted part is required from that big amount of data. So research must target to deal with the above issues in appropriate manner.

For retrieval and representation of health data, standard cloud services may be developed. However, there is a requirement for representing sensor data in an interoperable format. As mentioned earlier, Open Geospatial Consortium [5] has developed standards for accessing sensor observation through web. Sensor Model Language (SensorML) is an XML modeling that enables us to represent virtually any sensor system in a uniform manner. However, to make sensor observations accessible through web using standard HTTP protocol, SensorML along is not enough. OGC has also defined two other XML modelings and four services. The other two modeling languages are “Transducer Model Language” (TransducerML) and “Observation and Measurement” (O&M). TransducerML is applicable for streaming multiplexed data and O&M for encoding sensor observation in XML format. Four services are “Sensor Observation Service”, “Sensor Planning Service”, “Sensor Alert Service” and “Web Notification service”. These services are equally important in the processes of Web Enablement of remote health-care services based on sensor-cloud. These services can be deployed in a sensor-cloud environment and sensor measurements can be made accessible via web, where client/user can submit collection requests to the sensor-cloud platform and register for an alert from sensor system through web.

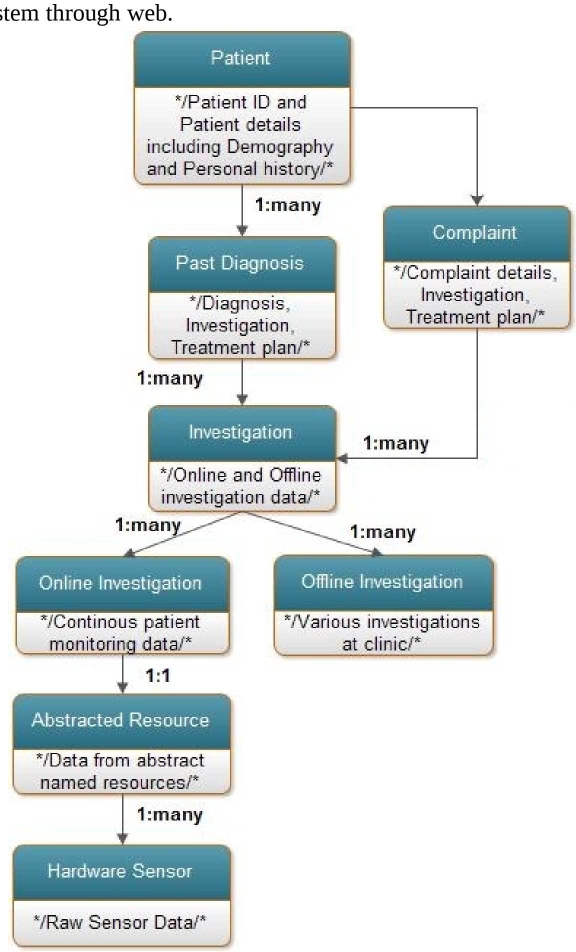

Fig 2 – Class Diagram for Health Record

7. CONCLUSION

The paper proposes a low-cost *Remote Health-Care System* based of Sensor-Cloud. The requirements of the remote health-care system have been discussed and an overview of the Sensor-Cloud framework is presented. The paper also discusses how health record should be extended to include sensor data. It also discusses issues related to storage and retrieval of health records in a sensor-cloud environment.

Our future endeavor will be development of the sensor-cloud framework and implementation of remote health-care services on top of the sensor-cloud framework.

8. ACKNOWLEDGMENTS

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