Aspects of Network Architecture for Remote Healthcare Systems

Rakesh Kumar Mishra, Rashmikiran Pandey
Department of Computer Application
F.G.I.E.T
Rae Bareli, Uttar Pradesh, India
rakesh.mishra.rbl@gmail.com, rashmikiran@hotmail.com

Abstract—Disasters are inevitable aspects of the human civilization and the limitation of extending the medical infrastructure to every corner of the demography is a challenging task. Technology can cater to the need of the availability of medical expertise for each affected individual in the disaster virtually. A medical infrastructure can be envisioned using existing LAN and WAN communication technology standards that can be deployed at shortest time interval and intelligent enough to deliver assistance along with virtual availability of the medical expert. The main issues posing challenge in such deployments include load balancing for both WAN network access points and local data gateways by exploiting all available interfaces. The addressing of the actuators directly from the remote server is another bottleneck in the scenario besides the fairness of the stream schedules and quality of service and/or experience.

Keywords—e-health; remote health; body area network; No network access; Direct network access, gateway, health monitoring.

I. INTRODUCTION

In exigency situations such as Kedarnath / Srinagar Flooding in India, train derailment / accident or epidemic eruption like swine flu in a remote village demands immediate healthcare support at shortest interval. These situations require a quick arrangement of medical equipment, medical experts. Arranging medical facilities on demand are tedious tasks as spread and count of affected population is not known. Also, medical expert-patient ratio in developing countries fails to full fill the requirement with utmost efficiency. An extended version of conventional Remote Healthcare Monitoring system is required which not only can be easily expandable but also enable the patient-doctor-care giver interaction.

Remote healthcare monitoring system is defined as “Remote Health Monitoring / Mobile patient monitoring is the continuous or periodic measurement and analysis of a mobile patient’s bio signals from a distance by employing mobile computing, wireless communications and network technologies” [1]. In such RHM, sensors are ported over patient body to collect patient’s medical data such as temperature, Blood pressure, heart rate, oxygen level, ECG, body temperature, sweating, falling etc. Later on these sensors forwards their data to the other end with the help of available dedicated communication gateway or directly to the server for analysis and diagnostic. An infrastructure can be envisioned by extending the conventional Remote Health care Monitoring (RHM) system that not only makes the medical statistics of the patients available at remotely located medical expert but also enables virtual availability of expertise(s) for patients/caregivers/paramedics. Such RHM will enable healthcare services at remotest geographic location using wireless telecommunication and local area networking infrastructure. These RHM systems must encourage local gateway sharing among the multiple patients for the sake of cost benefit and salability simultaneously pose a serious issue for managing the traffic load between the gateways and available network cells. The entrusted flexibility for scalability and re-configurability demands that the data streams must easily migrate between the available gateways / interfaces and maintain their flow. The seamless flow of the information between remote data centre and servers need a mechanism for addressing sensors / sensor clusters such that these will be accessible through some sort of nomenclature with certain assured quality levels. Most essential elements for the realization of RHM systems will be the assurance of connectivity of reasonable quality through all possible interfaces.

II. STATE OF THE ART REVIEW OF VARIOUS HEALTHCARE SYSTEMS

In any Remote Healthcare Monitoring System patient’s medical data is transmitted to the server via different networks including BAN, LAN, WAN wired or wireless network. These networks are responsible for accessing and establishing the connections between system subunits from client end to server end. Accessing and connecting to remote server / services in remote healthcare system may be either directly from the client end through predefined link or a gateway. Therefore, the taxonomy of Remote Health Monitoring system can be done on the basis of how the network is accesses by the any of the subsystem within Remote Healthcare System. The three broad classes of network access are “No Network Access System”, “Direct Network Access System” and “Network Access through Gateway”.

A. No Network Access RHM Systems
Remote Health care system referred as No Network Access system (Fig. 1) are those systems which store health related information within the PDA/Smartphone or any other such device. No-network access remote health monitoring systems are highly user specific. Such systems are reporting and generating alert for the concern patients or caregiver only. Entire data, analytic engines and other utilities resides within the patient owned device designed dedicatedly for the purpose. These are the standalone closed systems.

In [2, 3, 4, 5, 6, 7] authors have proposed Remote Healthcare Monitoring system following 1-tier architecture. These Healthcare systems use smartphone/PDA as a back end. These devices determine the result and provide health related solutions. Sensors ported on patient’s body or on smartphone/PDA accumulate their medical data and transmit the data to the smartphone/PDA via either wired or wireless medium.

**B. Direct Network Access RHM System**

Direct Network Access systems (Fig. 2) access the network directly without any intermediate device. The network interface is onboard within the device. Sensors though wired / wireless medium ports data to the coordinator which in turn uploads the data directly to the remote server. The data analytics and other relevant task are accomplished at remote station. These systems follow 2-tier architecture and are relatively open system i.e. that data is available beyond the patient device. In [8, 9, 10] authors have proposed Remote Healthcare Monitoring systems following the 2-tier architecture. In [8] a system is proposed to automate the data coming from sensor nodes and transfer the data to the cloud. This automation includes aggregation, processing and distribution of patient medical data at backend. The data from heterogeneous sensors are available for doctors and caregivers through predefined exchange services. System discussed in [9] uses remote monitoring device to collect the data from human body and transfer data to the health care center with the help of any of the available wireless interface. An optimal scheduler is devised to maintain a queue for buffering of patient data and select a network among available networks, system also provisions patient mobility. In [10] the system is especially for the diabetic patients and collects the data coming from sensors and transfers it to the web server. Data driven and domain expert logic is executed at remote server.

**C. Network Access through Gateway**

Remote Healthcare systems classified as Network Access through Gateway (Fig. 3) use a dedicated intermediate device as gateway, a smart phone or PDA or simple cellular phone, are three tier systems. The gateway stores and transmits the data to the remote server using standard dedicated API and services. This gateway device has numerous facilities such as data storing, filtering, data forwarding to server etc. The data actuators in some instances also form the multi-hop ad-hoc routing network alongside of the gateway for data transmission.

**D. Wireless Device as Gateway**

In [11, 12, 13, 14, 15, 16, 17, 18] remote health monitoring systems have 3-tier architecture. Such systems use BAN (Body Area Network) to collect sensed medical data from patient’s body and forward the data to the gateway. Then the data from gateway is transmitted to the remote end server to perform further operations.

The RHM used in [11] is for long term, real time and continuous health data collection. The system was designed for physically challenged persons and detects the changes in body postures. The system concludes the events and trigger
diagnostics using the information from ambience and body mounted sensor. In [19], author has compared [13, 14, 15, 16, 17, 18] and found that except for [15] others have reported technical errors and glitches during the trials. Further, except form [13, 17] others are using wired network at their core raising a serious issues of scalability of such networks. Most of the case studies had been implemented for indoor environment with standard legacy TCP/IP protocol except for [13] others are wired networks and using conventional protocol stack.

In [12] a personal health monitoring system has been proposed and focuses on monitoring the patient physiological vital signs and deliver feedback support for patient assistance. Personal Server used at second tier used to provide common interface for the sensors, users and the medical server besides the resource and process scheduling. In addition, third tier may contain other servers like emergency server, informal caregivers, commercial health care providers etc.

E. Indoor ZigbeeBased System

In [20, 21] indoor based Healthcare Monitoring systems proposed and are 3-tier architectures. Predefined infrastructure is formed with the help of short range technologies such as Zigbee etc. and medical data transmitted to the remote end server via gateway. Gateway may be smart phone/PDA. System proposed in [20] uses Zigbee wireless network to collect the data and forwards to the healthcare center through communication domain. Data analyzing and alert raise services are available at healthcare center end. In [21] Personal Mobile Hub(PMH) used as gateway to forward the medical data from wearable sensing devices. Other important services performed by PMH are personal agent, personal repository, user interface of sensors data, aggregator and service extender.

F. Others in the League – Hybrids

Author [22] has proposed such architecture to store, manage and share sensor data directly to the Internet. This architecture can be beneficial for e-health care services, smart environment etc. Sensor Layer consists of group of wireless sensors nodes referred as End Devices forming a Mesh Network. Each device within the network forwards the message, complying with ZigBee standard, to the base station. The base station at Coordinator Layer acts as gateway between sensor layer and supervision layer. Supervision Layer consists of base station with a facility of web services; those in turn are responsible for establishing the connection and sharing the sensor data to the Internet. This layer offers users to access and manage their data as a web interface.

In [23] a Hospital Healthcare Monitoring system has been implemented using the same architecture of [22]. This system also follows the same three tier architecture replacing intranet service with cloud based services. The proposed setup was evaluated for parameters like energy, delay, sampling rate etc. The effectiveness of the system has emphasized over the multilayered architecture rather than one or two layer architecture.

III. REMOTE HEALTHCARE MONITORING SYSTEM: NETWORK COMPONENT

The study categorized the system on the basis of the communication device used, technologies and protocols used for the implementation of the monitoring the patients remotely. Using this classification we will be trying to establish the generic architecture for any Remote Healthcare Monitoring System and identify the essential components of such systems.

It has been perceived and evident from the study that wireless links are the most preferred options for the communications even though few earlier systems designed using wired links. Hybrid network access (Accessing network through more than one interface) is now gaining momentum and is almost equally favored in comparison to WLAN and Cellular Network (Fig. 4).

The RHM systems though initially being deployed in indoor environment but scalable systems are now the choice of deployment. The research thrust is now drifting towards performance, study and realization of such systems (Fig. 5). The RHM systems are mostly being tested with fewer than 10 sensors. Presently, medical kits are coming with 10+ sensors on board. The presence of multiple sensors in proximity has a dual effect; first in wireless body area network these sensors contributes towards self-interference and secondly in wired systems the rate of influx of data onto the host board increases considerable amount of computational overhead. The studies on interference and computational overhead in near real world scenarios are need of an hour (Fig. 6).

In this study it has been proven that smart phones are becoming inevitable and integral part of the modern RHM systems. The reasons are obvious like smart phone can be programmed, reconfigured, relocatable and above all are easily available. In exigency scenario smart phones of the nearby population can be used for the purpose (Fig. 7).

Some of the commonalities in all the systems are:
Most of the solution follows 3-tier architectures because more the sub-components are independent more will be the scalability of the system.

Each solution or prototype implements standard APIs hence ensuring the adaptability and scalability of the system.

Sensors are interfacing through wireless interfaces and very few are using the wired or serial interface for data transportation.

Except for the personalized solutions rest are interfacing to remote server for decision support services.

The main drawbacks that are evident from the study are

1) **Gateways** – the device(s) interfacing body area sensor network to the wide area network, are in ratio of 1:1 i.e. one gateway per patient. This choice makes systems a costly affair in terms of portable logistics.

2) **Deployment Site** – mostly systems are either meant for indoor or personal level deployment. In such scenarios certain parameters are fixed like number of patient admitted, availability of network and allocation of monitoring equipment. These parameters in case of ad-hoc medical health solutions are undetermined and unpredictable. Resources like network and service availability are unreliable and volatile.

3) **Sensor Count** – the number of sensor present over the body of the patient are very limited and there are few solution / prototype are having more than 5 sensors per patient. In case of ad hoc remote healthcare system such restrictions can be unrealistic. Increasing the number of sensors over and around the patient possess altogether new set of challenges like interference management, channel allocation and acquisition, management of sensor identity, mobility of sensor or set of sensors etc.

4) **Display** – very restricted numbers of solutions that have capability of displaying the signals from the data actuators on to any sort of display. Further, there is no initiative towards possible presentation of different sensors signals collectively for each patient over single display.

5) **Virtual patient examination** – is a feature which is totally absent. Sensor data correlated with physical examination is common practice among the practitioners and this must continue to digital version also.

6) **Access Network** – Most of solutions are being designed for the indoor environment; hence these are using the wired network as core network access. In case of medical infrastructure assumed for our case study only cellular data network can be accessible, if available. The major problem with these networks is their service persistence and stability.

7) **Standardized Data Interface** – there are one or two

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**Device**

- 10+
- 5-10
- 1-5

**No. of Sensors Used in RHM Systems**

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**Interfacing Devices Associated with RHM Systems**

- Cellular Phone/PDA
- Dedicated Devices
- Smart Phone
- Desktop/Laptop

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**Deployment of RHM Systems**

- Personal
- In-Out door
- Outdoor
- Indoor

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**No. of RHM Systems**

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**Figure 5. RHM systems deployed for the purpose**

**Figure 6. No of sensors used in RHM systems**

**Figure 7. Types of devices used in RHM systems**

**Figure 8. Generic architecture of RHM systems**
solution that are providing the data porting to the cloud infrastructure instead of convention client server model.

IV. ARCHITECTURE AND CHARACTERISTICS OF A GENERAL REMOTE HEALTHCARE SYSTEM

RHM systems for are meant for purposes like monitoring the Diabetes level, blood flow, oxygen level, postures etc. for the patients within or outside the premises of the hospital. In such systems sensors will be sensing the patient’s bio-signals and digitizing for further analysis and diagnosis. Other variants capture complete medical dataset of patient instead of specific concerned datum. The data captured after initial cleaning and processing may be capable of generating alert and interfacing directly or indirectly to external server for decision support system.

Across all the streams, sensors communication infrastructure and decision support sub-system are inevitable part of the system. Other units like alert services, ambience intelligence etc. are auxiliary component their presence enhances the capabilities of the system.

A. Generic Architecture

In [19, 23] author has proposed a general architecture for Remote Health monitoring system as shown in Fig. 8. Group of sensors or sensors end devices are used as a primary source for medical data collection from patient body. Intra sensors network communication may or may not be present totally depend on the reusability, scalability and deployment scenario of the health care services. In order to have system more open and reconfigurable, it is recommended to have intra sensors network communication provisioned within remote health care network. Patients’ medical data will be transmitted to the intermediate gateway via short range technologies like Bluetooth. The gateway may perform data aggregation, filtering and forwarding to the next tier i.e. back end server. The gateway can be a dedicated hardware or a general hand held small device configured for the purpose like Zigbee coordinator or PDA/smart phone. Medical data from the gateway is forwarded to the remote end health care server or cloud services. Other stakeholders of the systems access and monitor the patient data from the cloud only. Auxiliary emergency services like alert/SMS to patient and caregivers may be augmented.

B. Desired Characteristics

Remote Healthcare Systems for massive deployments must have the following characteristics

1) Indoor or outdoor adaptable: Indoor based health care systems are meant for the people who are living at their home, clinics, hospital or Nursing home. Outdoor health care systems are meant for deployment at the site of eventuality where availability of health facilities and infrastructure are uncertain such as site of train derailment, flooded city, epidemic etc. Remote healthcare monitoring system must have deployment complexity almost same for indoor as well as outdoor system. It should be capable enough to form its setup within a predefined stipulated time frame independent of deployment scenario.

2) Shared gateway: Gateway is an intermediate device used to connect data actuators to the communication networks. Gateway used by a group of sensors to connect to remote end should be sharable with other group of sensors. Gateway should not be essentially a dedicated device like Zigbee coordinator rather it should be like a cell phone/smart phone or PDA that can serve the dual purpose of phone and gateway. Sharable characteristics of gateway in a group to post data streams from multiple patient ensures that the system can be started with the small number of device.

3) Low cost for deployment: Deployment time depends on two factors i.e. time taken for deployment and components required for deployment. Remote healthcare infrastructure should take its predefined time for deployment irrespective of the place of deployment. Components used to form a health care system should be lesser in number to save unnecessary cost (of equipment) and time (for setup). Deployment cost of Remote health care system should be least so that it can be made available to all and sundry.

4) Reconfigurable: The hand held or any such device when included within the system as sub component should implement all amendments as locally as possible causing least botheration for pre-existing component. Sensors should be

![Figure 9: Generic Architecture of Remote Healthcare System for Ad-hoc Deployment](image)
attachable and detachable instantly with ease over the body of patient and should adapt themselves with new deployment site quickly. Addition of the any equipment at any point of time during setup or after commencement should have least overheads. Similarly, at any point of time sensors and other reachable and configurable devices can be upgraded, if required.

5) Analytics (gateway & server): Merely, collection and submission of data to repository will have no use unless analyzed. Analytics helps in the achieving to conclusions for the event sets. The sensors / sensor gateway may be implementing data composition techniques to represent the sampled series. Similarly, data may be lost during the transition for that sake there must be provision for the prediction technique to generate lost data. At backend the analytics can be used to define the service composition like direct patient access, diagnosis services, patient pathological data access service etc. Other conventional services like precautionary measures etc. may also be incepted.

6) Use of legacy protocols: Use of Legacy protocols for remote healthcare extends dual advantage firstly; these protocols are easily adaptable to any extension of existing network. Secondly, these are already optimized for performance over conventional core network. *IP Hour Glass Model* forces that for the sake of integration and interoperability of services over the public network all the data streams must be transported in standard communication protocol i.e. TCP/IP. In remote healthcare system it is recommendable that a variant or standard of existing protocol may be used.

C. Proposed Communication Paradigm for RHM system

The requisites stated above and the scenario wherein such systems may be deployed outside the premises of healthcare centre demands the change in communication setup for RHM system. The architecture in Fig. 8 is modified and depicted in Fig. 9.

Proposed communication architecture of RHM follows multi-tier architecture thus extending flexibility of deployment and customized services. The architecture has added advantages such as shared gateway, configurability, immediate field deployment, better load balancing and reduction in network overhead. The architecture has loosely coupled sub-system hereby enabling each sub-system to setup asynchronously and independently. These can be also be reconfigured independently. The entities (gateway and sensor), communicating through standard communication interfaces, are mutually independent and establishing connection on demand allowing the proactive / reactive amendment to system at both hardware and software levels. The independence of the gateways and sensors allows for maximum reusability of the resources. This architecture intended to exploits heterogeneous communication network for seamless data transfer. The primary reasoning for the above provisioning is to ensure the availability of the remote site of eventuality for medical assistance as well as assured porting of medical data to the back end cloud. The availability of multiple gateways and networks for data collection and transportation makes the system more robust and available. The present scope of the work is confined to Network-UE stratum (Fig. 9).

Network-UE stratum is between the Cloud Stratum and Sensor Stratum acting as primary gateway of the architecture. One or more sensor groups are directly interfacing to the UE(s) to ensure their maximum availability over infrastructure. Redundancy of multiple links allows the availability of communication links. The communication from UE(s) to Network(s) is accomplished via access network (Fig. 9). Network-UE stratum comprises of Network and User Equipment (UE) stratum where first resides on the network side while other will be on gateway side. Network Stratum at any point of time will be interacting with multiple UE Stratum through one of the sub-stratum called as Access sub-stratum.

The main research focus in the domain will be:

1) **Seamless Connectivity for data transport:** Access stratum is responsible for interconnecting the Network stratum and Sensor data stratum. There can be multiple sensor stratum connected to a gateway via its access sub-stratum. Similarly, a gateway may have multiple interfaces for data connection. Essentially, in present state of art once the interface selected for the data communication it remains persistent throughout the session while other interface not even assessed for the connectivity. On the either side of the UE stratum the communication (Sensor Data Stratum and Network Stratum) needs to be transparent and consistently available. The problem on this part of the network is for redefinition / refinement to layer 3 connection management components to suit the need for RHM systems.

2) **Reliability and availability of networks:** Basic metrics of network performance includes signal strength consistency and bit error rate (BER). The signal strength consistency ensures unnecessary tuning of the hardware. This also evades the problem of unnecessary handoff problems and conserves irrelevant signaling. BER is periodically computed and communicated between the mobile station and this will be guaranty the link quality. Another thing that can be capitalized from the knowledge of the radio type is the presence of the high capacity radio for better data throughput.

V. Conclusion

A general study has been conducted on various prototypes of Remote Health monitoring systems. Several parameters are selected to study the, it is observed that majority followed 3-tier architecture and uses wired connection either in sensors intranet communication or sensors to base station connection. [13, 14] are using wireless link in sensor intranet communication and sensor to base station connection. But [24] is designed especially for personal use only and [13, 21] doesn’t display and store the bio-signals at the local caregivers or patients end. Among [12, 21, 25, 26] except [21], rests are limited to indoor while in [21] Core Network Link up communication Technology are wired. Also, none of the prototype used shared link from gateway per patient to reduce
network congestion and efficiency improvement. The conventional available Remote Healthcare monitoring systems are not up to the mark.

The proposed communication paradigm for RHM is especially used in such areas where emergency or immediate infrastructure is not available. Other major technical aspects like scalability of system, flexibility of deployment, reconﬁgurability of devices and applications, load balancing and overhead reduction capabilities need to be addressed on high tone. These issues had been at the core of the proposed system wherein a shared gateway will be exploiting the multiple interfaces to access network at the site. In this pursuit establishing the reliability and stability of network access is currently being evaluated for different operator to understand and develop model for network access and connection stability.

REFERENCES