Adopting Internet of Things for provisioning Health-care

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Abstract
In the era of Smart City, providing health-care facilities efficiently is a big issue. Developing nations lack proportionate health-care delivery solutions to serve huge population. To serve the ever increasing population, solutions for delivering health-care should be smarter. A possible solution is to use available information & communication technologies for provisioning remote health-care. Internet of Things (IoT) is seen as enabling technology to cater this purpose. We proposed a Sensor-Cloud framework aiming at proper delivery of the health-care services. During implementation, we felt the challenges of resource constrained health sensors. In my PhD, I investigate questions like how to integrate various health sensors with cloud without much fuss, how to collect health data from wireless bio-medical sensors, how to manage patient mobility and what will be appropriate routing scheme within this IoT enabled framework.

Author Keywords
Internet of Things, Sensor-Cloud, Smart City, Remote Health

ACM Classification Keywords
H.4 [Information Systems Applications]: Miscellaneous

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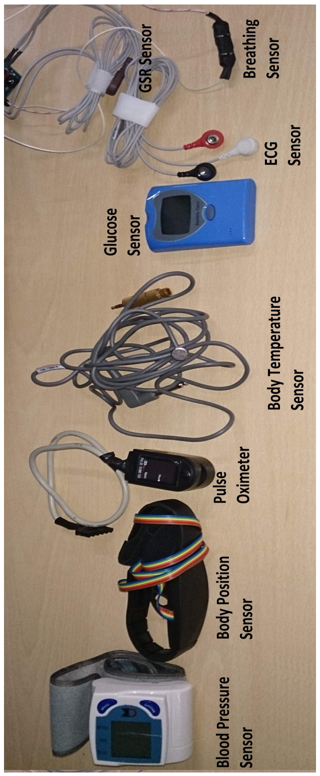

Figure 1: Health sensors

Introduction

Nowadays Smart City is the buzzword world wide. It is poised to turn our surrounding smart and day-to-day life smarter using cutting edge technologies in environment friendly manner.

With increasing population, smart cities must include a policy for provisioning smart and efficient health-care services to its citizens. But there is a huge need-gap between the requirement of health-care facilities and available resources. Also, professional manpower is scarce. Building health-care infrastructure from scratch is long drawn procedure. Moreover, it involves huge capital cost at one go. Therefore, in the era of smart city, remote health-care monitoring services, aided with Internet of Things (IoT) [1], are more effective.

Within this IoT paradigm, health sensors are described as *things* which are connected to Internet making it possible to access health parameters of patients pervasively.

A remote health monitoring system mainly consists of a portable, wearable and battery powered sensing unit that is assigned with the task of sensing various physical parameters of the human body. This unit also has the responsibility of transmitting the sensed data wirelessly to the remote environment for storage and diagnosis of the patient. Therefore it should be utilized in an efficient manner, so that communication as well as energy resources are not wasted due to unnecessary actions.

Motivation

During diagnosis, doctor requires certain details along with health parameters of the patient which must be updated regularly. With the advancement of sensing technologies, there are lot of bio-medical sensors which can measure certain clinical parameters effectively. However, in the context of remote health-care services, sensor data are required to be transmitted to distant places through wireless networks.

The huge amount of data gathered using health-sensors are required to be stored and be made available for anytime, anywhere access. Such services are offered by Cloud environment. Cloud offers flexible way of accessing data at low cost. It provides high computational power, high capacity and highly available storage and scalability. Furthermore, it ensures location independence and optimized resource utilization. So, a Sensor-Cloud framework [2] is envisioned integrating wireless sensor network with cloud environment.

The integrated infrastructure is well suited for adaptive and pervasive computing applications enabling Internet of Things (IoT) and aimed to be used in real-world applications. However, it is observed that there are specific issues within this IoT enabled framework when a health-care application is deployed on top of it. Among them, I have identified following few challenges to investigate. Unlike [3], I emphasize on challenges involving wireless health sensors within this integrated infrastructure.

1. *Seamless Communication:*
   In this framework, wireless health sensor modules play pivotal role for health-care faciliation. Sensor networks normally operate on IEEE 802.15.4 standard using proprietary protocols. It involves design and management complexity when coupled with Internet. So, how can we integrate sensor paradigm with cloud environment which relies on Internet? Which method or technique will enable seamless communication?

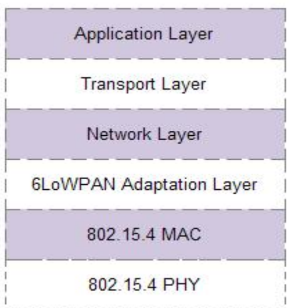

Figure 2: 6LoWPAN Stack

2. *Mobility Management:*
   In most health-care applications, continuous monitoring is required but patient may happen to be mobile. Patients are given wireless health sensors for monitoring them from distant location. But precious health data should not be lost during mobility. So, how can we handle mobility of health sensors? What will happen if the patient (sensors) go beyond the coverage area of the de-facto access technology?

3. *Routing:*
   When the wireless nodes comes in vicnity, it is possible to communicate among themselves. Latency for health-data forwarding should be minimal. Which will be appropriate routing scheme to ensure optimal data packet delivery?

4. *Data Collection:*
   Health data come dynamically from heterogeneous types of sensors and often as continuous streams. Also, it is diverse in nature and available in different forms. Which procedure will be able to manage these heterogeneous streams of health data? How can we extract necessary and meaningful information from the enormous data? Also, security and data confidentiality issues should be handled in the framework.

Contribution

For seamless communication within the infrastructure, usage of Internet Protocol (IP) as common networking layer provides greater robustness and flexibility [4]. As a standardized IP based Wireless Sensor Network (IP-WSN) protocol, IPv6 over Low-power Wireless Personal Area Network (6LoWPAN) [5] is adopted. Figure 2 shows the 6LoWPAN stack. It supports unique addressability. TinyOS is used to program the Berkeley sensor nodes. Apart from setting up the preliminary infrastructure, I focus on the following topics within this integrated infrastructure.

Routing
6LoWPAN incorporates an adaptation layer between network and data link layers. Routing decision is taken by either adaptation layer (mesh under) or network layer (route over). A comparative study for both of the schemes, are done on TinyOS using various performance metrics, such as average round-trip time delay, end to end delay and packet delivery ratio. Suitability of the two schemes are analyzed with focus on health-care.

In case of health-care applications which are data-intensive and data-sensitive, reliability of data is very much crucial. Loss of data is not affordable here. Therefore, we prefer the route-over scheme to be implemented. But it suffers from greater delay. To overcome this, we proposed a modification of the route-over scheme [6] and attempt to optimize the performance of route-over scheme, mainly in terms of latency.

While deploying the health sensors, I faced problem regarding routing algorithm because there are many routing parameters of the network and the limited resources of the sensor node. In most of the existing routing algorithms, next hop is selected randomly or based on residual energy, node density or distance from the sink node but single criterion does not always provide efficient routing decisions. So an ideal next hop selection is made based on the multiple criteria [7]. Handling of multiple criteria to select the next hop is solved by multi criteria decision analysis (MCDA).

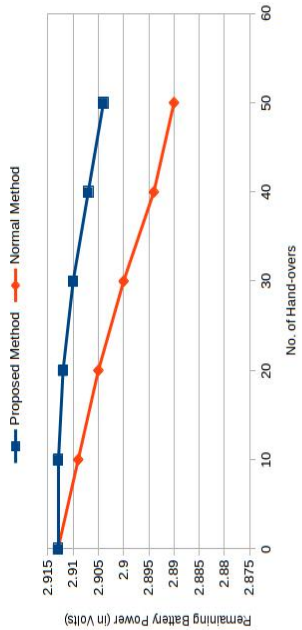

Figure 3: Remaining battery power in mobile node

Table 1: Packet Drop

Normal Method	Proposed Method
2-10%	0-2%

Mobility
In health-care applications, a fast and seamless handover becomes an important criterion for supporting mobility in 6LoWPAN. A scheme to manage intra-pan and inter-pan mobility of nodes based on received signal strength and link quality, is proposed and implemented. Simple load-balancing technique is also incorporated. Also, timer driven and message driven approaches are incorporated for mobility management [8]. The mobility schemes are tested for their efficiency using metrics like time taken for hand-over, packet drop, energy depletion etc.

Later, we came across the problem of wrong hand-over due to lack of direction component during the decision process. The health sensor may perform hand-over in one direction but went in just opposite direction. Thus, signalling cost incurs on these resource constrained health sensors. So, a fuzzy assisted horizontal handover decision making system is being implemented taking the direction of the sensors as one of the inputs. It has been observed that the time for handover is less in the proposed scheme than the previous threshold based normal method. In case of normal method, presence of more handover candidates implies more computation with individual network parameters. Also, more signalling overhead for decision making is expected in the absence of mobility direction. So, normal method requires more time as shown in Fig 4.

Same reasons are accountable for more energy dissipation in the normal method than the proposed method. From Figure 3, it may be observed that with more numbers of hand-overs, battery depletion is quicker in normal method. As seen from Table 1, proposed method ensures less packet drop.

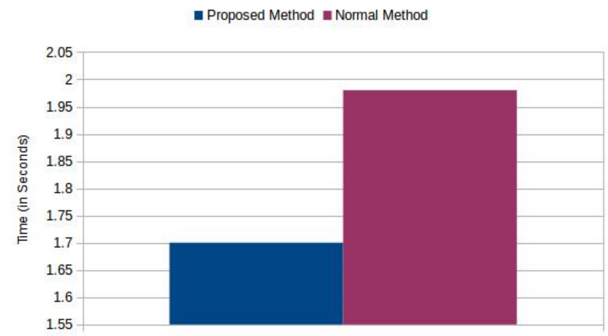

Figure 4: Time taken for handover

In addition to that, vertical handover techniques are being put in place to handle mobility of the sensors across heterogeneous networks (viz. 6LoWPAN, UMTS, WiFi, WLAN) so that precious health-data are not lost midway due to outage of a particular access technology. For this, we are taking help of media independent handover (MIH) [9]. For efficient vertical handoff, many network characteristics are required to be considered. In this work, following aspects are considered:
1. The state of the wireless access networks: received signal strength, link quality, bandwidth, network load.
2. The state of the Mobile Node: velocity and residual battery level of the sensor node.
3. User Preference: This includes ranking of networks according to the user.
Thus not only network stats, but context information is taken under consideration also during handover decision. For 6LoWPAN-WiFi handovers, we have observed around 2 seconds handover latency on average.

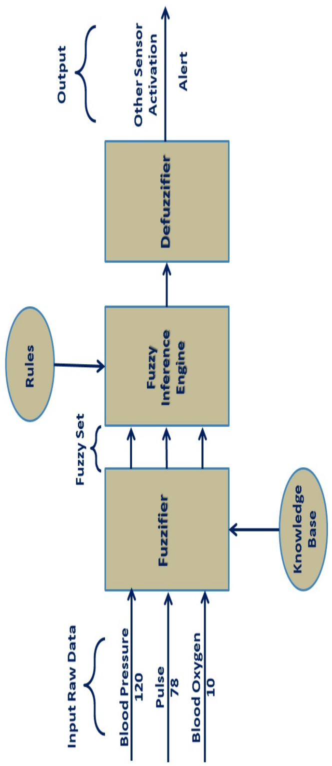

Figure 5: Fuzzy inference system

Data Collection
We are using various biomedical sensors like *glucometer sensor, body temperature sensor, blood pressure sensor, pulse and oxygen in blood sensor*(SPO2), *airflow sensor*(Breathing), *galvanic skin response sensor* (Sweating), *electrocardiogram sensor*(ECG).

A big issue is periodic data update from these sensors. It may incur in greater communication overhead and higher energy consumption. Also, large payload may lead to packet fragmentations which play a crucial role in overall performance of data forwarding scheme. The amount of data exchanged should be minimized in order to decrease energy consumption and increase network lifetime.

In health-care applications, sensors are typically used to monitor some parameters or events which are complex, ambiguous and vagueness embedded in their nature. Therefore, a fuzzy based event driven data collection approach is a suitable option [10]. All the health parameters are not required to be transmitted at once. Only selected set of health data is sent on occurrence of a particular event. Proper analysis of the data may be done as undesired data will not be picked up from the sensor nodes.

Raw sensed data are converted in a suitable format such that those can easily be posted to the cloud data-storage services for future use. Furthermore, the data is processed for analyzing health status of patient.

Another issue is interference. A scheme is implemented to mitigate possible interference among various sensors while transmitting wirelessly [11]. Different sensors are polled at various time intervals depending on the specific requirement of the attribute that the sensors are measuring. In figure 6, it is shown that wrong ECG is plotted (flat line) due to interference and then correct ECG is displayed using the aforesaid scheme in figure 7.

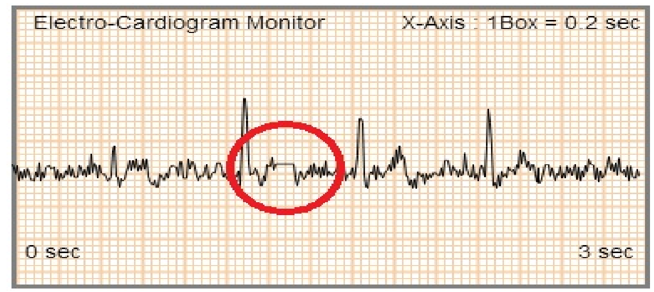

Figure 6: ECG without scheduling

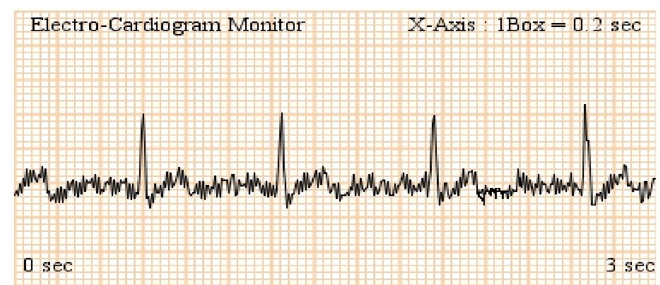

Figure 7: ECG with proper scheduling

Thus, the Sensor-Cloud helps care-givers to make decisions diligently and patients get medical attention in timely manner.

Conclusion

In this paper, few issues and possible solutions are discussed within a IoT enabled framework focussing on delivering remote health-care at low cost. Next plan is to use the gathered health sensor data for generating knowledge and insights in order to help care-givers, policy makers and health-care administrators.

Objective for attending the DS

My main objective to attend the UbiComp 2015 Doctoral School is to present my work to fellow PhD students and senior researchers, to highlight the already achieved results, and to get feedback for the next plan of my research. In my opinion, UbiComp Doctoral School is a great platform to receive expert feedback and exchange knowledge with peers. I think it is a very good opportunity to take a critical look on my work. I hope by attending this School, I shall be able to further shape and direct my research in coming days.

Brief biographical sketch

Suman Sankar Bhunia is a PhD student at School of Mobile Computing & Communication, Jadavpur University, India. Suman joined as TCS Research Scholar in November, 2012. His doctoral study is supported by Tata Consultancy Services through their prestigious Research Scholarship Program (TCS-RSP). He is working under supervision of Prof. Nandini Mukherjee. It is expected that he will graduate by the end of 2016.

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