International Journal of Engineering Applied Sciences and Technology, 2016
Vol. 1, Issue 11, ISSN No. 2455-2143, Pages 28-33
Published Online September-October 2016 in IJEAST (http://www.ijeast.com)

APPLICATION OF INTERNET OF THINGS IN HEALTHCARE SECTOR FOR BOTTOM OF PYRAMID IN INDIA

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***Abstract*: The Internet of Things (IoT), when applied to different domains offers to deliver better services to its consumers at any time, any place through a variety of mediums. This paper aims to explain its role in the important sector of healthcare, with focus on the Bottom of Pyramid (BoP) in India, where the need for better healthcare services is strongly felt. Interviews of five practicing physicians in Pune were conducted. The interviews focused on current healthcare practices, BoP rural healthcare practice, and awareness of IoT and acceptance of its concepts such as remote monitoring by the physicians. Given the disparate infrastructure state in BoP and rural areas, and the problems faced by the urban physicians in treating needy patients, opens up new scopes for IoT and remote monitoring. These responses and inferences would be helpful in developing future business models for IoT in BoP and rural healthcare in India.**

Keywords: **IoT, wearables, remote monitoring, patients' data, Healthcare, Bottom of Pyramid (BoP), Rural India**

I. INTRODUCTION

Internet of Things (IoT) ,which can be described as enabler of communication between everyday objects like smart-phones, Internet TVs, sensors and actuators is one such technology that will play a significant role in how business operates and how customers are served. According to Gartner, there will be nearly 26 billion devices on the Internet of Things by 2020 [1]. IoT, when applied to different domains, like healthcare, logistics, transport, insurance, energy, home automation, agriculture, education, and telecommunication offers to deliver better services to its consumers irrespective of time, place, by any device, and through any medium. IoT has a wide range of applications in the field of healthcare such as remote patient monitoring, smart clinical care, smart hospitals, managing chronic diseases etc. Application of IoT to healthcare domain will ensure that suitable treatment is provided to individuals at the right time through most efficient mediums with minimal errors which would lead to overall improved outcomes for relevant micro-societies and nation. An individual's social-economic status captured by healthcare workers, together with IoT devices to monitor biological symptoms can be integrated to diagnose medical status. Thus, timely analysis results can help early detection of abnormal health conditions, and focus on prevention or quick response. IoT can enable unbroken monitoring and early detection of abnormalities of patients, thus augmenting a successful existing technology *telemedicine* ,which has been instrumental in providing solutions remotely through voice, video, medical data and collaboration tool solutions.

However, anticipating challenges, harmful outcomes and implementation problems are requisite before converting the theoretical studies into reality. To address these, the current research includes physicians' interviews and concerns from the socio-technical viewpoint.

IoT is completely dependent on internet and smart mobile devices to realize its true value. Bandwidth availability, lack of technological infrastructure and adequately trained technical staff can become major hindrances to applying IoT, especially in BoP and rural India. IoT mainly uses devices to monitor health and if security breaches are not prevented, which can new privacy issues may begin. Potentials of the several advances in the field of medical science offer ample opportunities to improved healthcare, especially for BoP, where accessibility is the key concern. Such benefits can be better realized by introducing IoT applications for healthcare domain.

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II. OBJECTIVES

- To explore openness of physicians regarding applying IoT in healthcare domain.
- To study concerns raised by Physicians regarding applying IoT in healthcare domain.
- To articulate feasibility of implementing IoT concepts such as remote monitoring for the Indian rural masses.

Methodology: IoT is still in its nascent stage and hence most non-IT professionals are unaware of its advantages and challenges. Qualitative data was collected by conducting semi-structured interviews with five physicians in Pune, India. The responses obtained were categorized, and inferences drawn to address feasibility of IoT application in health care domain for Indian BoP.

The rest of the paper is organized as follows: Section II, reviews previous work and current IoT capabilities. Section III reviews current socio-technical issues and presents emerging technologies that can resolve them. Section IV concludes with insight into future actions desired.

III. CURRENT IOT CAPABILITIES

According to Kulkarni et al [2], IoT applications can be categorized into four domains: personal and healthcare, enterprise, utilities and mobile. Personal and healthcare IoT is at the scale of an individual or home, enterprise IoT at the scale of a community, utility IoT at a regional or national scale and mobile IoT which is usually spread across other domains due to nature of connectivity and scale [3]. This categorization depends on the type of network availability, coverage scales, heterogeneity, repeatability, user involvement and impact.

The main contributor of IoT can be attributed to the growth of smart phones and tablets which act as a window to link patients with doctors in the IoT world, with an ability to deeply change the delivery of health services. IoT has dynamic capabilities to connect humans, machines, smart devices, and dynamic systems which bestows effective healthcare. Smart, connected systems can analyze patient conditions from many different perspectives. They can aid intelligent clinical decisions, in real time and save lives. However today's systems of advanced devices that cannot work together are rife with opportunity for error [4]. Readings from one device go unverified, causing far too many false alarms. Hence they require clinical staff interpretation and intervention.

The real source of market promise is not the wealthy few in the developing world, or even the emerging middle-income consumers. It is the billions of aspiring poor who are joining the market economy for the first time [5]. Here, the Indian population, mainly the underprivileged are the ones who need uplift in their socio economic status. Considering the present disparate status of healthcare in BoP and rural India, IoT for healthcare can penetrate deeper. Healthcare systems that aim for gross profit margins will miss the prospects to innovate and provide socially just services. Enabling IoT for BoP serves long-term socio-economic rewards for society.

IV. ANALYSIS OF SOCIO-TECHNICAL ISSUES

A. State of Indian Rural HealthCare

As the adage 'Health is wealth' declares healthcare and socio-economic development go closely associated. If the population of a nation is in good health then it can progress effectively. According to Gandhiji, true India is not in its few cities, but in its thousands of villages [6]. If the villages perish, India will perish too, given the resources and man power availability at rural level. However, improvements in rural healthcare have not gathered momentum, with poor access to hygienic, quality and well maintained healthcare facilities. A harsh indicator of this is India's 112th position under World Health Organization's Ranking of the World's Health Systems [7].A few highlights of WHO 2015 report:

- *Selected Infectious Diseases*: Among the countries in South-East Asian Region identified by WHO, India accounts for an astonishing high 99.3% of cholera cases reported, 81.7% for leprosy, 54.6% for malaria and 59.3% for tuberculosis. India with 5.1 million HIV/AIDS cases has the highest number as a country outside Africa.
- *Non-communicable diseases (NCDs)*: NCDs are 5.87 million deaths that account for 60% of all deaths in India. India shares more than two-third of the total deaths due to NCDs in the South-East Asia Region (SEAR) of WHO.
- *Health Service*: 23% of the population still lacks the attention of skilled health personnel during birth. Only 36% of the population has access to improved sanitation. 30% of the people do not have access to improved drinking water sources. Unsafe drinking water and inadequate level of sanitation and hygiene increases the probability of infectious diseases.

Due to rapid urbanization of cities post liberalization and globalization, about 75% of the infrastructure and resources investments were allocated in urban areas [8] .Many primary healthcare clinics in rural areas are devoid of electronic systems to maintain patient records [9]. Lack of quality infrastructure, dearth of qualified medical practitioners and non-access to basic medicines and medical facilities thwart its reach to more than 60 % of population in India [10]. Hence special focus is required on the rural population, which suffers the same or more than the overall BoP.

Bottom of Pyramid (BoP): The concept of BoP became a catchphrase when C.K. Prahlad and Stuart Hart presented their views on extracting fortune from the BoP [11]. Low-income markets provide an exceptional opportunity for top MNCs to invest, and gain better returns *along with development of the poor*. Currently BoP consumers are separated from the population at top of pyramid due to unaddressed needs, poor infrastructure, corruption, lack of equity capital and low purchasing power [12].These may be eliminated by introducing new technologies and business models to ensure

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affordability, accessibility and availability of products and services. The problems at BoP are:

1. *Infrastructure:* McKinsey Global Report [13] says that India's BOP represents 835 million (around 69%) people who require access to better products and services such as food, drinking water, health care and sanitation, education, and insurance. A balance between demand and supply of medical facilities is necessary in India, especially for the rural and semi urban population.
2. *Lack of healthcare manpower:* 75% of the healthcare infrastructure and man power concentration is towards urban area where only 32% of the population resides [14]. India was ranked 98th out of 144 countries in its physician to population ratio [15] lagging far behind the international norm of 1:1000 [16].One of the reasons for medicare deficiency is migration of doctors towards rewarding urban areas or the private sector, instead of rural or BoP, which leaves a large population of India unattended for primary healthcare services. Furthermore, irrational deployment, disorganized placement of staff (for example, a gynecologist in a facility without an anesthetist or vice versa) perpetuates the low availability of specialist services [17].

To increase the reach of doctors, specialist and surgeons in BoP and rural areas a few steps have been implemented by a few states in India. Adopting incentives methods, compulsory rotation based postings, and public-private partnership help. To sustain these changes, the important innovation would be prudent adoptions of IoT hinging on existing success of Information Communication Technologies. The right adoptions could transform healthcare sector for BoP in India.

B. Information Technology and Healthcare

Healthcare sector has embraced the use of IT in the form of healthcare information systems (HIS), electronic medical data (EMR), electronic health data (EHR), patient identification system (PIDS), and recently telemedicine. Since then, every major turnaround and improvement in application of IT has changed healthcare services availability to the public. Evolutions of automations in healthcare sector are:

I. *Manual Healthcare System***:** The health information management (HIM) was introduced as early as 1920s when American College of Surgeons (ACOS) sought to improve the standards of records being created in clinical settings [18].With the advent of computers in 1950s, records took to automated forms in patient admission, discharge, scheduling, clinical information systems such as nursing, laboratory, pharmacy and radiology documentation, which improved the quality parameters.

II. *Healthcare Information System*: In 1960s, mainframe computers processing and shared service systems; many manually operated systems such as administrative, financial, and billing systems were automated. Evolving mini computers and vendors' turnkey systems aided the expanded reach of healthcare services.

III. *Sophisticated Healthcare Information Systems*: With the advent of local area network, distributed data processing, computer based health applications started to develop. Telemedicine, defined as the use of electronic communication technology to exchange patient information and provision of health care services at remote locations [19], pre-dominantly existed during this period and the 1960s in the form of pilot projects when NASA put first men in space. With costs decreasing and the growth of internet, real time implementation of telemedicine reached new heights.

IV. *Millennial Healthcare Information Systems*: Mobile technologies offered significant improved back office operations and eliminated need for multiple systems working in silos. To reduce the medical errors and enhance transparency in procedures, e-healthcare and m-healthcare services with voice based recognition, bar coding, RFID, PDAs, multipurpose cell phones, Web 2.0 technologies were introduced. Medical inventory analytics to predict future trends in health and disease patterns, helped to take preventive measures thus improving healthcare quality standards.

However, IT is facing challenges in the healthcare sector. IT enables healthcare service providers to transmit information about patient health status but they couldn't adequately attend to the actual physiological disorder.

Healthcare stakeholders are frequently skeptical to invest in technological breakthroughs. Capturing patient related data from admission to discharge is burdensome data entry. Also, many physicians prefer to diagnose patients by interacting physically without any technological assistance since they believe that power of technology cannot overtake the power of practical diagnosis skills. We observe that technology is not the complete answer, but an ideal enabler for improving the quality of healthcare services, with a framework of: (i) devices that transmit and store appropriate medical information, to improve treatment accuracy with less human intervention (ii) systems that not only transmit the physiological readings of the patient's health status but monitor and communicate at regular intervals to doctor, leading to effective disease treatment (iii) remote monitoring and diagnosis of the patient, with reduced dependence on doctor's presence.

C. Proposed Solution and Technical Discussion

After the above four levels of automation, IoT for healthcare (IoHT), can be the next level of automation where there will be exchange of information from any place, anytime from and to any healthcare and medical device. WSN (Wireless Sensor Network) and M2M (Machine-to-Machine Communication) are other examples of IoT [20]. The ability of mobile devices to continuously perform together with uninterrupted data connectivity between devices has fostered better access to information on demand. Medical devices and daily objects with sensors, tags and readers can track and monitor different physiological parameters such as blood sugar levels, heart rate, blood pressure and other vital functions and communicate the

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same to doctors and Medicare staff to enable faster attendance to issues. Remote monitoring of patients with chronic diseases can be a major application in other areas such as citizens on duty in remote locations, monitoring vital signs of sportspersons, and control of conditions inside freezers storing vaccines and medicines [21]. Other medical application are installation of modern hospital beds that can turn an incapacitated patient to prevent bedsores, elevate legs for better circulation and sound an alarm when the patient falls off the bed [22]. Hospitals are also coming up with wearables for new born to monitor their movements. Currently, all these devices and equipments are capable of recording and storing data. With IoHT, these devices shall further be able to interact among themselves and convert data into useful information and help quicker diagnosis to provide smarter streamlined healthcare services [23]. To achieve IoHT, acceptance of leveraging non-living IT systems stakeholders by living stakeholders of multiple medical staff of doctors, nursing staff, paramedics, lab assistants, is needed.

D. **Physician Interviews***:*

In order to verify the acceptance of remote monitoring, interviews of physicians and specialists in cardio related diseases and diabetes of urban Pune were conducted. Their views on current healthcare practice, rural healthcare, IoT in healthcare and remote monitoring, suggestions and warnings on potential negatives, impacts of using technology in healthcare sector were gathered. Despite recent advances in technology leading to availability of digital devices, conventional analog devices such as sphygmomanometer, stethoscope, and glucometers were used by respondent physicians. An important practice among all respondents is the follow up visit or telephonic conversation post-diagnosis and post-treatment. Most respondents, to keep focus on treatment, hired receptionists to maintain documents and for office work. They wished to automate some processes, for long term efficiency.

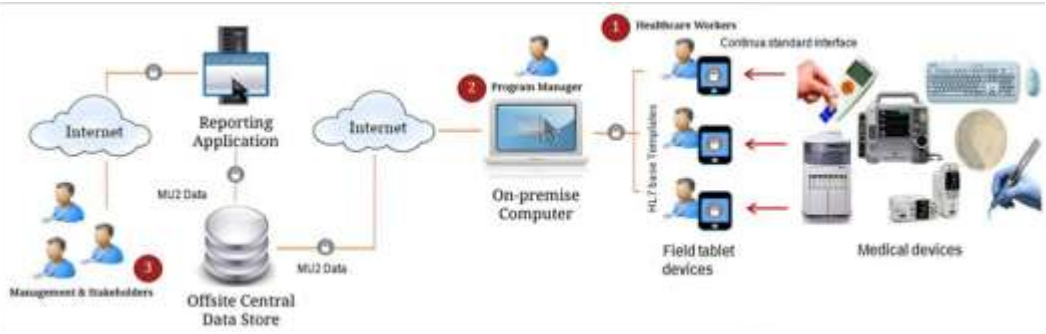

Fig. 1. IoT Applications (Source: http://pmibangalorechapter.in/pmpc/2014/tech_papers/healthcare.pdf)

Out of the five physicians interviewed, only three of them practiced in rural areas for not more than two years and later moved on to urban areas citing various reasons. Deterrents and reasons for moving away were: unfriendly government policies, lack of infrastructure to irrational deployment of different specialists, standards of personal life negatively affected. Rural patients needed reminders to overcome unawareness, and periodical monitoring to check if they are following doctor's advice. Overall time dedicated to monitor is comparatively more for rural patients than urban patients. Causes for lack of dedication and practice of urban specialists are summarized as medical technology unavailability, travelling time, medicines unavailability, paramedical staff and pharmacists, awareness and literacy of the people and hygiene. IoT presents suitable assistance such scenarios.

After discussions on remote monitoring and IoT for BoP, it was observed that most of the physicians were open to idea of technological intrusion in healthcare sector to enhance the quality of services, especially for chronic diseases like diabetes, blood pressure and heart related diseases, implementations for rural area. However, opinions regarding safety and patient consensus of remote sensors were divided. Issues raised include barriers of high cost, same infection affecting two people in different ways and machines diagnosing them with same therapy. The technology solution of an IoT decision system trained with conditional statements based on patient's historic and current data was explained. Physicians may feel separated from vital parameters measurement. Diagnosing involves direct observation and symptoms based on respiration sound, heart-beat, abdominal examination (hard or soft), sweating, shivering etc. Physician respondents did not feel these can be measured effectively without personal inspection and proximity. Physicians also feared self medication by patients based on remote measurements may prove fatal.

Concerns of cost effectiveness of sensors and other equipments were raised, questioning affordability and effective distribution for rural India. Remote monitoring being a continuous process, the life of such sensors and the possibility of malfunction in sensors causing errors were raised as concerns. One physician commented that advanced methods can obstruct the practice of existing small time physicians in rural areas and hamper their revenue potential. However, the idea to connect rural patients

to urban specialty doctors and hospitals was welcomed. Technology together with trained healthcare assistants to identifying primary cause for multiple diseases with guided and step-by-step clinical decision making was considered to be fruitful. Acceptance of mobile doctor buddy apps was missing as they were not meant to be the replacement for experience of the doctors. They were expected to work collaboratively with the doctor. In this approach of complementing the doctor with the technology based inputs, the new trends in IoT has the capability to transform the way the primary healthcare is delivered to the patients [24].

Four out of five physicians were ready at the time of interview to dedicate and donate few hours per week for BoP and rural patients by studying the remotely acquired medical data. The challenges of establishing the concept of remote monitoring as per physicians: system implementation and set up, availability of internet connection, bandwidth, quality of the data transfer and connectivity, educating the stakeholders of the system who should be capable enough to handle the devices and new technology of IoT, fear of clinical error by such devices, maintenance or repairs of technological devices in rural areas. One physician commented on possible additional workload of remote monitoring. Few were of the opinion that the conventionally strong doctor-patient relationship shall weaken, if technology is forced. A key warning is that introducing many devices will commercialize the healthcare sector and the positive impacts nullify if not backfire.

A physician mentioned that practical instruments like cholesterol strips cost less (few hundred rupees), can be easily understood and used by patients. If IoT devices became easy to understand and use, cost-effective, and unobtrusive to doctor-patient relationship, then acceptance is achievable. On concerns of patient records privacy, the technology solution of security by encryption and decryption of patient's medical data with the help of hashing key or hash value in WBAN(Wireless Body Area sensor Network) to capture real time information was explained. When asked for opinions on impacts of technology in healthcare, respondents strongly believed that machines can only transmit information but final interpretation of the diagnosis has to be done by the doctor. Time can be saved for readings and reports are ready, but a threat to the role of doctors was unacceptable. Role of paramedics was seen as prominent in spite of advanced technology. It was opined that treatment quality will increase as well as an increased capacity to attend to a numerous patients. A warning stressed upon setting limits to technology that can be used for selfish and unethical benefits of listing unnecessary costs and superfluous charges to increase billing.

Feasibility of Applications for BoP and Rural healthcare sector, based on Interviews: The interview responses reveal that all physicians welcome the use of technology in healthcare sector to reduce manual workload and automating processes. Majority of urban physicians interviewed are ready to accept and practice remote monitoring of rural patients provided a demarcation of direct and indirect diagnosis with IoT is included. Major concerns on lack of infrastructure and maintainability of operating model equipments at BoP and rural areas were raised. Selfishness and unethical practices by business stakeholders were warned as disincentives. The cost of equipments and affordability were categorized as challenges to technology. Educating all stakeholders in medicare, especially awareness campaigns for rural population in IoT based healthcare was suggested.

V. Conclusion

The responses reveal that Indian BoP is not completely ready for implementation of such advanced technologies in healthcare sector. The interpretation of primary qualitative data are useful for anticipating socio-technical challenges that may arise in developing remote monitoring for the Indian population. Future scope of research includes study of perceptions of BoP and rural people in accepting the IoT techniques for healthcare domain. The scope of this paper was limited to views on practicing remote monitoring by the urban physicians of Pune for BoP and rural patients. This can further be extended to recording responses of many other stakeholders related healthcare domain such as Medicare technicians, Healthcare workers, industry experts, and rural doctors of different demography, patients with long-term illnesses, citizens in BoP and rural areas.

The IoT based health care system will provide services in a timely manner and may save the life of millions. The basic constituents of healthcare services need to be organized and delivered in a right way to the right people at right time. The Internet of Things has the potential to enable health organizations to extract critical data from multiple sources in real-time, and provide a better decision-making capability. This trend can transform BoP and remote rural healthcare sector, increasing its efficiency, lowering costs and providing avenues for better patient care.

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APPENDIX:

Key Questions Of Interview with Physicians:

i. Are you involved with non-value-added activities like office administration activities? Do they hinder your work towards the patient?
ii. How do you currently monitor the vital functions such as BP, sugar, heart rate of your patient ?
iii. How do you monitor the patients after they are discharged from hospitals?
iv. Have you earlier practiced in rural areas? If yes, how frequently do you visit rural areas for practice?
v. What are the challenges faced in practicing in rural areas?
vi. Do you know about Internet of Things (IoT)?
vii. What is your opinion on embracing advanced technology such as mobile devices and IoT with healthcare?
viii. What do you think of devices that will help you monitor patient with chronic diseases, remotely without visiting the rural places? What can be their effect on human body?
ix. What can be the challenges or difficulties in remote monitoring of patients?
x. Any other ideas/thoughts on improving the implementation of IoT in remote monitoring?
xi. Any drawbacks/negative impacts of using technology in healthcare sector?