Healthcare Services – IoT Enabling Technologies, Usage and Impact

Varsha Dubey Upadhyay
Faculty of Computer Science, PAHER University, Udaipur, India
E-mail ID:dubeyvarsha46@gmail.com
Nitika Vats Doohan
Computer Science Department, Medi-Caps University, Indore, India
E-mail ID:nitika.doohan@gmail.com
Naresh Menaria
Department of Mathematics, PAHER University, Udaipur, India
E-mail ID: naresh.menaria14@gmail.com

Abstract- The concept of integrating physical world integrating with digital world is possible with Internet of Things (IoT) technology. It has paved way for plethora of use cases which were not imaginable earlier. The unprecedented possibilities in distributed environments with IoT bring certain issues and implications with it. At the same time, healthcare industry in the contemporary world needs integration with IoT to reap benefits of the ultimate technology. The technologies associated with IoT such as Radio Frequency Identification (RFID), networks with sensors and actuators, wearable devices, Service Oriented Architecture (SOA), smart mobile devices make the integration with healthcare units possible. The existing research found in the literature shows the need for further focus on this technology usage in healthcare domain with comprehensive research framework. In this paper we present a comprehensive conceptual framework containing the combination of research methods such as quantitative, qualitative and case study. Key areas of Research covered are IoT integration with healthcare unit and patient-centric healthcare services, unprecedented growth in service quality, technology innovations, technology barriers, security issues, and data analytics for business intelligence. This paper summarise the usage, impact and issues of IoT integration with healthcare units besides testing hypothesis, giving conclusions and recommendations.

Keywords - Internet of Things (IoT), healthcare units, technology barriers, security, standards, usage, impact.

1. INTRODUCTION

This study is about the integration of IoT technology with healthcare units for covering usage, impact, privacy and security issues involved when IoT is integrated with healthcare infrastructure. IoT is a definitive innovation that exploits inter-disciplinary technologies to realize a dream network of things that connect physical world with digital world for maximizing benefits which could not be imagined otherwise. Xu et al. [16] opined that the use of IoT in healthcare and other domains result in exponential growth of data. Managing such data and having ubiquitous approach to data access is challenging. Using Radio-Frequency Identification (RFID) physical objects can have ability to have identity and participate in integration with digital world. Lee & Lee [8] stated that there are five technologies that are essential for realizing IoT. They include RFID, Wireless Sensor Network (WSN), IoT Middleware, cloud computing and IoT application software. Catarinucci et al. [3] proposed IoT-aware smart architecture for monitoring and tracking medical devices, patients, and personnel automatically. In their architecture RFID, Wireless Sensor Network (WSN) and smart mobiles play an important role. Gandy [6] Health map is an application that can monitor disease trends across the globe. It can provide outbreaks in current location or any location in which people would like to know. It gives appropriate message to the users on diverse diseases and their severity. With IoT integration, these services can be made real time and improve quality and accuracy.

Ahmad et al. [2] proposed the concept of smart cyber society (SCS) as a platform with different communication layers. They focused on Cyber Physical System (CPS), Web of Things (WoT) and with the use of Internet of things to realize SCS. They investigated the system with different things in mind including emergency, healthcare, safety and security. They opined that the proposed system can improve healthcare services. They also found that technologies like Web Services provide interoperability and Machine to Machine (M2M) interaction. They could also identify the role of wearable devices in healthcare when integrated with CPS.

Sakr et al. [14] proposed a CPS for comprehensive data analytics and healthcare monitoring. In the context of big data produced by healthcare integrated IoT systems, their study assumes importance. They focus on big data analytics, IoT, cloud computing. Rathore et al.[12] proposed an IoT based system for integrating smart cities, IoT and big data analytics. Especially the focus was on IoT applications for healthcare units.

Wan et al. [15] opined the use of Mobile Cloud Computing in healthcare. They opined that incorporation of mobile cloud computing in conjunction with body area

networks where body wearable equipments receive health data of patient as and when required in a given point in time. Service Oriented Architecture supports in the incorporation of assorted applications with interoperability. This is highly recommended technology for realizing IoT in distributed environment.

Addo et al. [1] studied privacy and security in IoT applications. They proposed a reference architecture that can be used to build cloud-based IoT applications in the real world. They stated that privacy and security are essential part for maintainable IoT development in healthcare domain.

Popescul & Radu [11] explored security related issues such as hacking, loss of boundary, messy complexity and hyper connectivity in case of smart cities involved in IoT integrated healthcare. . Roman et al. [13] explored that distributed character of IoT along with associated technology propel security and privacy concerns. Kamoun et al. [7] studied data breaches in healthcare domain. Data breaches are related to misuse of health information which leads to identity theft, fake health insurance, financial identity theft, medical identity fraud, and privacy violations. . IoT and its security concerns are also studied by Li [9]. They listed top 10 vulnerabilities of IoT such as poor physical security, insecure software, insecure configuration, insecure mobile interface, insecure cloud interface, privacy concerns, lack of transport encryption, insecure network services, authentication inefficiency, authorization inefficiency, and insecure web interface.

2. KEY AREAS OF RESEARCH

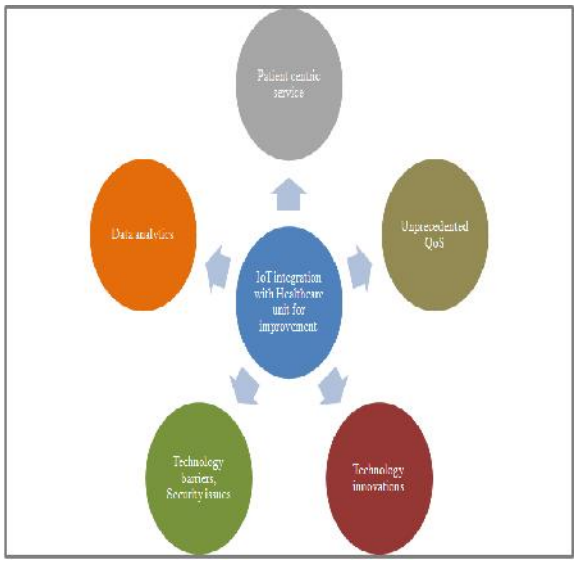

Fig.1 Key areas of Research

1. Investigates the effect of IoT integration with healthcare units on promoting patient-centric healthcare services. Since patient-centric healthcare services can improve service quality, it is considered for the study.
2. Investigates the effect of IoT integration with healthcare units in achieving unprecedented quality of service (QoS).
3. Investigates effect of technology innovations. It is considered as technology plays vital role in implementation of IoT in healthcare units.
4. Security issues and technology barriers. Since IoT is the conglomeration of many standards and technologies, it play vital role in probing the facts.
5. The effect of data analytics in healthcare units for improvement of quality of service

3. METHODOLOGIES

The research methodology used in this study includes multiple approaches. They include secondary research, case study and primary research methods such as structured survey and interview. The results of these approaches are interpreted in order to have conclusions on the application of IoT in healthcare units and the impact. The review of literature provides useful insights to ascertain the present state-of-the-art and gain knowledge to frame research questions or hypothesis for the completion of the study. Besides it leads to survey questions and interview questions that are used in the primary research. The secondary research is made on wide variety of technologies such as RFID, WSN, and EPC and so on that are required for the realization of IoT and leverage of quality services in healthcare units.

In this research two types of data collection method are used. Questionnaire as structured survey using online survey tool Surveymonkey.com. Interview as a qualitative method using GoTo Meeting as video conferencing medium.

The sample size for structured survey is 150. It does mean that around 150 people participate in the survey. Respondents industry association with medical industry is in the range of >1 year to more than 10 years. Respondent's age is in the range of 25 to 60 years. Random sampling method has been used to collect sample data. Responses have been gathered from healthcare experts such as technicians, physicians and other stakeholders from various representative healthcare units. Sample size for Interview method is 25.

In this research data analysis is done using two approaches as quantitative and qualitative. Quantitative analysis is computed using SPSS tool and Minitab (Chi-square test) which is meant for statistical analysis. Qualitative analysis is made to interpret the results of interview.

4.RESULT

To compute and validate results, Minitab software tool has been used to conduct statistical analysis on the basis of collected data. Minitab offers the opportunity to run various Hypothesis statistical tests.

Case Processing Summary

Number of cases:

Valid = 150, Excluded = 0, Total=150

The industry association or Experience of respondents with medical industry revealed that, 38% of

respondents have 1-5 years of experience and equal share of 38% have less than 1 year of experience and 10 % people got rich experience i.e. more than 10 years. The age of the respondents indicating that, 38% of respondents are aged between 25-30 i.e. very young generation people, and 40 % are 31-40 years category followed by 10 % & 11% each in 41-50 and 51-60 years category.

Chi-square test for association,

Pearson Chi square statistic:

$$\chi^2 = \sum_{i=1}^{r}\sum_{j=1}^{c}\frac{(O_{ij}-E_{ij})^2}{E_{ij}}$$

Likelihood ratio Chi square statistic:

$$G^2 = 2\sum_{i=1}^{r}\sum_{j=1}^{c} O_{ij} ln\left(\frac{O_{ij}}{E_{ij}}\right)$$

Here, Oij is observed frequency, Eij is expected frequency, DF equal to {(r – 1) * (c – 1)}. Here r represents number of rows and c represent number of columns

Expected cell count:

$$E_{ij} = \frac{n_{i+}\, n_{+j}}{n_{++}}$$

Here, ni+ means number of observations from ith row, n+j means number of observations from jth column, n++ means total number of observations

Contribution to Chi-square statistic:

$$\frac{(O_{ij}-E_{ij})^2}{E_{ij}}$$

Here, Oij is observed frequency, Eij is expected frequency

Summary of Hypothesis Tested

The null hypotheses defined for the present study has been tested using Chi-square analysis. A set of methods such as Observed value, Expected value, Contribution to Chi-square, Pearson, Likelihood ratio, degree of freedom are used. Finally significance is computed. The computed significant value and the standard significance value (P-Value - 0.05) is shown in Result column in Table 1.

To conduct Chi-square test for association, collected data has been arranged to put into Minitab worksheet. Minitab command Stat > Tables > Chi-square test for association has been run.

H01: No significant association among Age of respondents and their opinion of RFID, EPC can eliminate mistakes in Identification and tracking in healthcare services
Pearson Chi-Square Value =133.656, DF=1, P Value = 0.000
Likelihood Ratio Value =135.026, DF=1, P Value = 0.000

H02: No significant association among Age of respondents and their opinion of GPS can help to improve locating ambulances and medical equipment in healthcare services
Pearson Chi-Square Value =150.000, DF=1, P Value = 0.000
Likelihood Ratio Value =155.502, DF=1, P Value = 0.000

H03: No significant relation between Industry association and their opinion of IoT associated with healthcare services can help improving patient experience thereby improving QoS.
Pearson Chi-Square Value =138.784, DF=1, P Value = 0.000
Likelihood Ratio Value =140.289, DF=1, P Value = 0.000

H04: No significant association among Age of respondents and their opinion of Privacy and Secure health information sharing is required in the context of integration with IoT
Pearson Chi-Square Value =138.784, DF=1, P Value = 0.000
Likelihood Ratio Value =140.289, DF=1, P Value = 0.000

H05: No significant association among Age of respondents and their opinion of Patients health records are to be handled, accessed with high level security, with IoT in place
Pearson Chi-Square Value =138.784, DF=1, P Value = 0.000
Likelihood Ratio Value =140.289, DF=1, P Value = 0.000

H06: No significant relation between Industry association and their opinion of Cloud computing technology can enable storage and data analytics in efficient health information system
Pearson Chi-Square Value =144.458, DF=1, P Value = 0.000
Likelihood Ratio Value =151.483, DF=1, P Value = 0.000

H07: No significant relation between Industry association and their opinion of Big data analytics can improve IoT integration with healthcare services
Pearson Chi-Square Value =150.000, DF=1, P Value = 0.000
Likelihood Ratio Value =160.565, DF=1, P Value = 0.000

H08: No significant association among Age of respondents and their opinion of MCC enable healthcare centres in monitoring Patient's health
Pearson Chi-Square Value =150.000, DF=1, P Value = 0.000
Likelihood Ratio Value =155.502, DF=1, P Value = 0.000

H09: No significant relation between Industry association and their opinion of CPS can help IoT integration with healthcare services
Pearson Chi-Square Value =150.000, DF=1, P Value = 0.000
Likelihood Ratio Value =160.565, DF=1, P Value = 0.000

H10: No significant relation between Industry association and their opinion of SOA play a crucial role in realization of IoT
Pearson Chi-Square Value =133.253, DF=1, P Value = 0.000
Likelihood Ratio Value =131.361, DF=1, P Value = 0.000

Table 1 Explain hypothesis, result and derived interpretation of chi-square test

Table 1 Chi Square Analysis Results

Hypothesis	Result	Interpretation
H_{01}: No significant association among Age of respondents and their opinion of RFID , EPC can eliminate mistakes in Identification and tracking in healthcare services	Computed significant value .000. (Standard sig. value is <0.05) *Reject null hypothesis*	As per expert's opinion, EPC and RFID usage in medical field can eliminate mistakes in tracking and locating medicines, patients, doctors, and wearable devices used by patients as part of IoT.
H02: No significant association among Age of respondents and their opinion of GPS can help to improve locating ambulances and medical equipment in healthcare services	Computed significant value .000 (Standard sig. value is <0.05) Reject null hypothesis	As per medical expert's opinion, the role of GPS will improve the locating medical equipment and vehicles associated with healthcare.
H03: No significant relation between Industry association and their opinion of IoT associated with healthcare services can help improving patient experience thereby improving QoS	Computed significant value .000 (Standard sig. value is <0.05) Reject null hypothesis	As per doctor's opinions, patient centric approach with IoT associated with healthcare services can reduce costs, improve treatment results, real time disease monitoring, minimize errors and improve patient experience in terms of improved Quality of Service (QoS).
H04: No significant association among Age of respondents and their opinion of Privacy and Secure health information sharing is required in the context of integration with IoT	Computed significant value .000 (Standard sig. value is <0.05) Reject null hypothesis	As per expert's opinion, there is need for privacy preserving and secure data sharing in healthcare units as they are integrated with IoT.
H05: No significant association among Age of respondents and their opinion of Patients health records are to be handled, accessed with high level security, with IoT in place	Computed significant value .000 (Standard sig. value is <0.05) Reject null hypothesis	As per age wise medical experts, with IoT in place, patient health records are to be handled, accessed with high level of security
H06: No significant relation between Industry association and their opinion of Cloud computing technology can enable storage and data analytics in efficient health information system	Computed significant value .000 (Standard sig. value is <0.05) Reject null hypothesis	As per medical expert's opinion, Cloud computing technology can enable storage and data analytics in efficient health information system
H07: No significant relation between Industry association and their opinion of Big data analytics can improve IoT integration with healthcare services	Computed significant value .000 (Standard sig. value is <0.05) Reject null hypothesis	As per medical expert's opinion, Big data analytics can improve IoT integration with healthcare services
H08: No significant association among Age of respondents and their opinion of MCC enable healthcare centres in monitoring Patient's health	Computed significant value .000 (Standard sig. value is <0.05) Reject null hypothesis	As per medical experts opinion, (MCC) enables healthcare centres to monitor patients' health through smart and wearable devices to provide patient centric services.
H09: No significant relation between Industry association and their opinion of CPS can help IoT integration with healthcare services	Computed significant value .000 (Standard sig. value is <0.05) Reject null hypothesis	As per medical expert's opinion, CPS can help IoT integration with healthcare services. CPS role is to protect digital infrastructure from cyber attacks
H10: No significant relation between Industry association and their opinion of SOA play a crucial role in realization of IoT	Computed significant value .000 (Standard sig. value is <0.05) Reject null hypothesis	As per medical expert's opinion, SOA play an essential part in comprehension of IoT. SOA can help in interoperability among different platforms and technologies in the context of enhancing QoS in healthcare centers

Table 2 Comparative Study of Results

Studied Parameters	Findings from Previous Research(s)	Findings from Current Research
RFID	RFID implementation help in improving patient safety – 70% respondents agreed. RFID & EPC enable availability of information in an automated way which helps in required medication to patients.	EPC & RFID usage help in eliminating errors in locating, tracking of Patients, medicines - 82 % respondents agreed
GPS	Help in Patient emergency situations through location tracking, informing nurse or doctor for quick rescue.	Help in locating medical equipment and healthcare vehicles - 84 % respondents agreed
Efficiency, Performance	Technology help in automating processes reduced task time and enhanced quality of service delivery.	Patient centric approach can reduce costs, improve treatment results, real time disease monitoring, minimize errors, and improve patient experience - 83 % respondents agreed
Privacy and Security	Identified the importance of study around Security and Privacy challenges from distributed approach of IoT integration.	Patient health information should be provided with at most level of security. Necessity of data access policies with controls for providing electronic health records - 75 % respondents agreed
Data Analytics	Possibility to capture vast individual health data and embedding Business analytics tools into IoT devices for real time decision making.	Healthcare units produce huge amount of data and that needs data analytics and cloud for sustainable utilization - 75 % respondents agreed

CPS	CPS integrates with multifunctional sensors and help in continuously monitoring physical environment (Healthcare) for its improvement.	CPS helps integrate healthcare systems, GPS, bio-sensors, Internet of vehicles and smart devices in the context of IoT. CPS plays a significant role in protecting digital infrastructure from cyber attacks. - 75 % respondents agreed

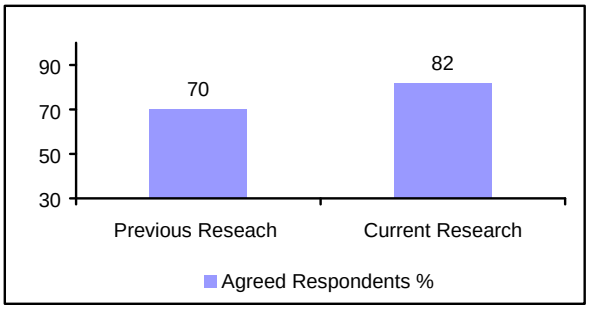

Fig 2: Graphical representation of % Respondents agreed that RFID usage and implementation help in IoT

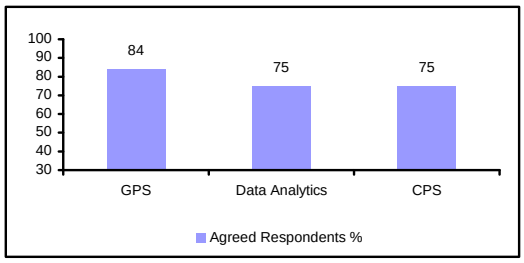

Fig 3: Graphical representation of % Respondents agreed that GPS, Data Analytics and CPS play vital role in IoT integration with healthcare unit for improvement

5. DISCUSSION

Several studies (Dlodlo, 2013; Madanian, 2016) opined that RFID and EPC contribute in achieving Internet of things and its integration with healthcare. There is 82% respondents agreed on the proposition that is EPC and RFID usage in medical field can eliminate mistakes in tracking and locating medicines, patients and doctors.

A few researchers (Dlodlo, Mofolo, & Kagarura 2013; Wan, 2016) explored that the use of GPS technology with integration of IoT in healthcare services will improve the quality of life. When an accident happens, immediate family, a doctor, or a nurse are immediately informed, and they attempt rescue according to the GPS location. Also, if a patient falls seriously ill, they can conveniently request help. This proposition has 84% support which reflect the role of GPS in locating medical equipment and vehicles associated with healthcare.

Dlodlo [5] explored potential applications of IoT including patient centric services in healthcare domain. This proposition has 83% support that is patient centric approach with IoT associated with healthcare services can reduce costs, improve treatment results, real time disease monitoring, minimize errors, and improve patient experience in terms of improved QoS.

Addo et al. [1] stated that privacy and security are essential part for maintainable IoT development in healthcare domain. It has 77% support in the research .It reveals that there is need for privacy preserving and secure data sharing in healthcare units as they are integrated with IoT. Roman et al. [13] explored that distributed character of IoT along with associated technology propel security and privacy concerns. This proposition has 75% support. That reveals privacy challenges.

Lee & Lee [8] stated that cloud computing technology is essential for realizing IoT. This Preposition has 78% support. It reflect that healthcare units produce huge amount of data and that needs data analytics and cloud for sustainable utilization .Exponential development of data is likely to be formed by IoT Xu et al. [16] there is 82% support for this proposition. It exposes the connotation of correlating IoT integrate healthcare unit with big data processing by means of distributed programming frameworks and data analytics can improve healthcare services.

Wan et al. [15] explored the usage of MCC in healthcare services. They stated that integration of MCC with body area networks where wearable devices get health information of patient in real time .The responses towards this were encouraging as 76% of the participants supported the proposition that is MCC enables healthcare centres to monitor patients' health through smart and wearable devices to provide patient centric services.

Ahmad et al. [2] explored on CPS and WoT in development of the usage of IoT to comprehend smart cyber society and healthcare monitor. This preposition has 77% support. It reveals that CPS can help IoT integration with healthcare services

Chen, Hsu and Leu[4] SOA is an architecture that helps in integration of heterogeneous applications with interoperability and SOA and AJAX technologies can help achieve seamless integration among applications and devices. This preposition has 76% support which reflects SOA helps in integration of heterogeneous applications with interoperability.

The research provides insight that standard identification technologies like RFID can help improving healthcare services. EPC and RFID usage in medical field can eliminate mistakes in tracking and locating medicines, patients, doctors and wearable devices used by patients as part of IoT.

It is revealed from the research that role of GPS, wearable sensor devices, patient centric approach for improved QoS, data privacy concerns, handling exponential growth of data using cloud computing and the usage of distributed programming frameworks for data analytics are to

be considered in the knowledge sharing and training programs to bring awareness among the stakeholders.

The research provides the interesting information that Utility of big data science, need for high level of security, utility of MCC are to be considered for further awareness.

It has been revealed in the research that SOA, use of cloud computing technology, increased utility of CPS, mobility based healthcare, privacy preserving and secure health information sharing, big data analytics and unimaginable impact of IoT in healthcare units are crucial aspects in IoT integration with healthcare unit for improvement.

6 .CONCLUSION AND FUTURE WORK

The aim of this research is to investigate the application of IoT and related technologies to improve healthcare services besides issues or challenges involved. The primary data collection with survey and the results interpretation provided ample evidence that IoT integration with healthcare units can bring about plethora of benefits such as real time healthcare, patient centric services and unprecedented improvement in QoS.

The results of survey showed problems faced in the integration barriers such as lack of standards, legacy systems and interoperability, uncertainty on IoT benefits, non-availability of well defined workflows, and technologies are still immature. Security issues such as cyber attacks, ransomware like WannaCry (recent outburst of malady), data confidentiality and eavesdropping, and identity threats are raised in the interviews. Need for technology standards, interoperability improvement, and protection of sensors are other concerns.

The insights of the research methods revealed that IoT integration with healthcare units should provided security, standards, data privacy and business intelligence concerns are taken care of. Technologies i.e. RFID, EPC, GPS, MCC, CPS, Cloud computing and Big data analytics are key IoT levers to improve Healthcare services. In future we intend to focus on the research based on the feasibility of remote health services in particular with IoT.

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