

# Internet of Medical Things (IOMT): Applications, Benefits and Future Challenges in Healthcare Domain

Gulraiz J. Joyia, Rao M. Liaqat, Aftab Farooq, and Saad Rehman

National University of Sciences and Technology, Islamabad, Pakistan

Email: {ingrgulraiz, muzammilliaqat, aftabfarooq2012}@gmail.com; saadrehman@ce.nust.edu.pk

**Abstract**—Internet of Medical Things (IOMT) is playing vital role in healthcare industry to increase the accuracy, reliability and productivity of electronic devices. Researchers are contributing towards a digitized healthcare system by interconnecting the available medical resources and healthcare services. As IOT converge various domains but our focus is related to research contribution of IOT in healthcare domain. This paper presents the peoples contribution of IOT in healthcare domain, application and future challenges of IOT in term of medical services in healthcare. We do hope that this work will be useful for researchers and practitioners in the field, helping them to understand the huge potential of IoT in medical domain and identification of major challenges in IOMT. This work will also help the researchers to understand applications of IOT in healthcare domain. This contribution will help the researchers to understand the previous contribution of IOT in healthcare industry.

**Index Terms**—iot, IOMT, healthcare, challenges

## I. INTRODUCTION

All manuscripts must be in English. Internet of things is not a new concept but it is hot topic in the world. This is not astonishing that around the world, 18.2 billion devices are connected using internet of things (iot) [1]. This includes all categories of iot in the world. Basically iot is the internetworking of electronic devices to enable exchange of data between devices for specific domain applications. This concept of internetworking in internet of things (iot) makes human life much easier than before. According to WHO, Pakistan is facing health problems and our life expectancy in 2015 for males is 64.5 and for females it is 67.3 years [2]. This has gained our attention on iot and more over iot is most promising solution for health care industry because it helps patients to manage their own disease and receive help in most emergency case via mobile [3].

It is anticipated that the demand for personal healthcare applications will increase sharply. In the traditional medical mode, the quality and scale of medical service can't meet the needs of patients [4]. It is of great significance to establish a set of family oriented remote medical surveillance system based on mobile Internet. Generally, the provision of healthcare facilities through

mobile devices is called m- health, which is used to analyze, capture, transmit and store health statistics from multiple resources, including sensors and other biomedical acquisition systems. M-health offers an elegant solution to a problem commonly faced in the medical field: how to access the right information when and where needed in highly dynamic and distributed healthcare organizations [5]. These health applications can guide different type of spectators such as guardians of patients, patients itself, doctors, nurses and healthy peoples too. These m health provide better medical services, efficiency, more effectiveness of health plan and services so this reduce the cost of health maintenance.

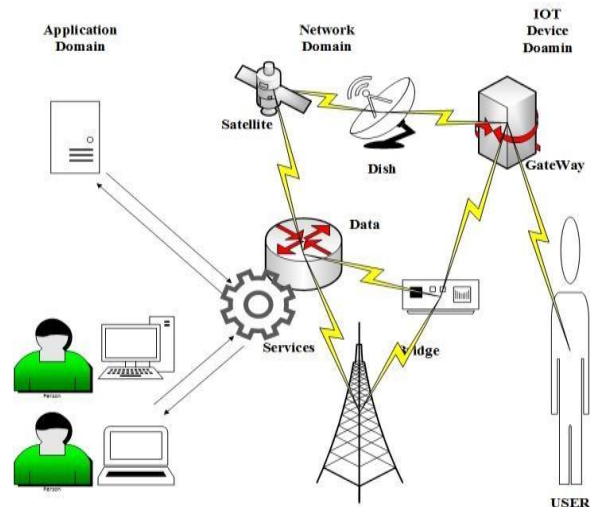


Fig. 1. Communication of IOT

Above Figure shows how iot does communicate with other network devices. Doctors, patients and rest of the networking system is connected to each other. All record is digital and save in the databases which is accessible by the doctors and clinical staff as well.

By this m health service we can reach easily the standard of medical services and quality of medication as per patient needs [4]. The iot based system is responsible for the full care of the patient and these systems are flexible to the patients conditions and there parameters can be set as per patient illness. With this approach we will be able sure about present and future health states of patient.

In this research paper, we will be discussing mainly the applications, benefits and future challenges of internet of

things (IoT) based on the work done by different researchers in the field of iot. The main aim of this paper is to provide an overall idea of what Internet of Things is, the different form of applications it has adopt, and how it is providing a solution for the problems faced by the global health care industry [6].

## II. LITERATURE REVIEW

Shu-yuan Ge *et al.* introduced a design which is basically integration of 11073 IEEE Service/DIM and CoAP to apply on devices of healthcare so they can be used in iot settings. They also showed the comparison of performance of Both HTTP and 11073 DIM by help of CoAP. They also evaluated performance with CoAP and HTTP with respect to packets abundance in single transaction, packets loss rate and syntax by using JSON and XML. Finally they concluded that CoAP is able to transmit few packets as compare to HTTP. In terms of consumption of resources they said that XML is not better than JSON [7].

Georges Matar *et al.* proposed a technique to monitor patient posture by using patient body weight that exerts pressure on specially designed mattress, he used the measured pressure for monitoring patient posture. He also ensures his work by the help of Cohen's Coefficient, the value of the coefficient is .866 which means high accuracy of detection. He also revealed that purpose of this work was to reduce storage requirement and cost on computation [8].

Chao-Hsi Huang *et al.* explained the designed MNS (medical nursing system), his system is based on iot architecture and used 2G-3G, WSN, RFID, sensor, ZigBee, Wi-fi and Bluetooth for data transferring. His system also enables supply of drugs with accuracy [9].

Yuan jie fan *et al.* in his research he used SOA techniques, iot technology, optimization technique, resource allocation and ontology for diagnosis to design a rehabilitation system. He also presented a methodology for designing of rehabilitation system by using Iot Technology. In the paper two key features are mentioned which include construction of the rehabilitation and easiness of sharing of the domain information [10].

Willian D. de Mattos *et al.* represented the linkage of m-health domain with m2m (machine to machine) and 5G technologies. According to him new technologies will open gate ways to solutions of m-health [5].

Iuliana Chiuchisan *et al.* in the literature for Parkinsons's infection test, presented an intelligent system. He mentioned monitoring system for home and support system for decision making which not only support also assist the physicians in medical treatment, prescriptions, diagnosis, rehabilitation and patient progress [11].

Robert S .H. Istepanian *et al.* in his research he introduces a unique concept of iot in medical health. According to him his concept is very helpful by mean of functionalities of iot and medical health for upcoming

applications of 4G health, which will base on IPV6 connection [12].

Dr. Salah S. Al-Majeed *et al.* in the research he proposed to develop a device which is basically a medical sensing device, low cost and iot based device to monitor patients physiological conditions. The main focus of his research is communication of messages and synchronization. Time minimizing algorithm is applied to keep separation between consecutive messages and measure the queue size for individual health care nods, to avoid conjunction [13].

Hyun Jung La *et al.* due to the increasing scope of iot, he come up with a concept to maintain the data of the iot application. He adopted semantic approach to deal with challenges in his research and he presented a cloud based proposal which provide core set of functionalities to help individual diagnosis on network [14].

Beibei Dong *et al.* researcher mentioned the problems in detection of a patient in health monitoring system. In this paper he provide solution to noise in signals and low rate of accuracy in detection [4].

Diego Gachet P     *et al.* in this research author provided key solution for initiation of services which will base on internet of things and data engineering concepts [15].

K. B. Sundhara Kumar *et al.* author provides a system that monitor autism patient automatically, using sensors for an individual patient. This system not only monitors but also keeps track of sensors readings collected from brain signals of pretentious individual [16].

K.Divya Krishna *et al.* proposed an algorithm CAD for detection of abnormality in kidney ultrasonic image files on FPGA. Research is dependent on two stages; first stage is LUT – look up table technique and second is SVM-support vector machine. Mentioned algorithm is implemented over FPGA based kintex – 7 [17].

Boyi Xu *et al.* author proposed a new framework for medical healthcare monitoring, which is based on cloud computing and specially this framework is designed for implementation of healthcare monitoring. This framework is implemented in different modules which are also discussed in the paper [18].

Allavi Chavan *et al.* researcher key objective in this research is to design android application in healthcare area by using the concept of internet of things and cloud computing. Paper also focuses on waves of ECGmonitoring using an android application platform [19].

Harshal Arbat *et al.* researcher worked to design a new tool due to increasing trend in internet of things and its demand. In the domain of m-health researcher focus on keep track of patient health by reading heart rate value , this heart rate value is obtained by a band called smart health band. On this obtained value specific message will be transmitted to his family or friend [20].

Lei Yu *et al.* Researcher presented a scheme and architecture of smart hospital, which is based on iot to

have a better hospital system. This hospital system will help to manage information of old hospital system [21].

Avik Ghose *et al.* author has designed a monitoring system for aged patients. His research present a method of end to end medical healthcare system to monitor the patient. System basically use internet of things technique (iot), which is back end platform [22].

K. M. Chaman Kumar *et al.* research presented a new technique to monitor such patients which are diseased OSA (obstructive sleep apnea) and also help full for diseases similar to this. [23].

Rashmi Singh *et al.* presented a model for electronic health care unit by using internet of things based on India statistics of health. According to the research it is easy to implement such research with the help of RFID tech and experienced healthcare system, as he mentioned Mycin. Indian medical units can be digitized easily by this presented model [24].

Chetanya Puri *et al.* researcher is aimed to present a new dimension in the domain of cardio signals, so to make this happen researcher presented a new technique for cardiac patient, as this will intimate early about any warning. Researcher named this technique iCarMa. This also include the severity of cardiac patient and its timely detection and diagnosis [25].

Ihor Vasytsov *et al.* author basically has focus on gaining entropy from heart rate on the basis of biomedical signals. Some mathematical models are presented to obtain entropy. More over these results of entropy will be used for security of health-care system and useful for device certification [26].

Vivek Chandel *et al.* has found a way to consistently monitor the patient health by means of IMUs (inertial measurement units). So to use this they presented a accurate and improved algorithm for sensing the events of patient, similar to counting of steps, length of stride, immobility and fall etc [27].

Michael Fischer *et al.* the idea is very simple, train a bot using information in the book. Bot will help nonprofessionals to know about the disease, even this bot can be integrated with different sensors on mobile phone to provide more flexible service by using iot (internet of things) [28].

Mrs. Anjali S. Yeole *et al.* done a survey on enabled iot devices and there practices in healthcare domain for medical dispense, children, operation theaters, serious patients monitoring, toddler and chronic care [29].

TABLE I: APPLICATIONS OF IOT

Sr. #	Applications In Medical Domain			
	Application	Author <i>et. al.</i>	year	Reference
1	Medical Nursing System	Chao-Hsi Huang	2014	[9]
2	Smart Rehabilitation System	YuanJieFan	2014	[10]
3	Iot based Kidney abnormality detection system using ultrasound imaging	K.Divya Krishna	2016	[17]
4	Application for patient posture recognition using supervised learning	Georges M Atar	2016	[8]
5	Monitoring patient physiological conditions	Dr. Salah S. Al-Majeed	2015	[13]
6	Decision making and home based medical health monitoring system for neurological disabled patients	Iuliana Chiuchisan	2014	[11]
7	Autistic patient monitoring medical health care system using iot	K.B.Sundhar aKumar	2016	[16]
8	Smart medical nursing healthcare system for patients	Karan Motwani	2016	[6]
9	Remotely ECG monitoring system based on cloud	Pallavi Chavan	2016	[19]
10	Secured and smart medical healthcare system	Duddela Dileep Kumar	2016	[30]

11	Iot based smart medical health band	Harshal Arbat	2016	[20]
12	Iot based smart Hospital	Lei Yu	2012	[21]
13	Monitoring of OSA (obstructive sleep apnea) diseased patient	K.M. Chaman Kumar	2016	[23]
14	Mobile electronic medical health care system based on iot	Rashmi Singh	2016	[24]
15	Inexpensive cardiac arrhythmia management (ICarMa) system	Chetanya Puri	2016	[25]
16	Iot based medical healthcare monitoring system.	Vivek Chandel	2016	[27]
17	Medical Bot	Michael Fischer	2016	[28]
18	Ubiquitous medical Healthcare Monitor System (UbiHeld) for Chronic diseased Patient	Avik Ghose	2013	[22]

1. Searched number of applications in the field of iot in medical domain

TABLE II: CHALLENGES OF IOT

Sr. #	Challenges In Medical Domain	References
	<i>Challenges</i>	
1	Managing device diversity Scale, data volume and performance Flexibility and evolution of applications Data privacy Need for medical expertise CPU capacity	[31]
2	Memory of the system Constrained over network performance like bandwidth	[7]
3	Data exchange Availability of resources Privacy	[3]
4	Hardware implementation and design optimization issues	[8]
5	Security challenges	[12] [3],[32], [24]
6	Interoperability	[3],[31],[18]
7	Technical challenges: Modeling relationship between acquired measurement and diseases. Software implementation of medical analytic schemes.	[14]
8	Intelligence in Medical Care.	[9]
9	Real time processing System predictability Low power consumption	[32]
10	Data integration	[31], [18]
11	Unstructured, growing and diverse data at exponential rate	[19]

2. Searched number of challenges in the field of iot in medical domain

Sultan Alasmari *et al.* has discusses the patient healthcare information is the most critical information that should be kept in safe hands. Iot has bought a tremendous change in the domain of medical. Author specifically discusses the challenges and survey the security and

privacy with context to iot. According to him the use of cloud for iot has introduced the non-compliance and risk factor in medical environment. He proposed a solution to this problem is the people from multiple disciplines, should be included in the research to evaluate the issue and find the facts of the problem to resolve it [33].

Ghulam Muhammad *et al.* discusses the importance of integration of cloud computing with iot in healthcare domain. He raised some issues in medical domain with context of iot those should be resolved to improve the domain in healthcare. He has proposed a system for monitoring the audio pathology for people monitoring by the help of cloud computing. Ease of use and interoperability are the problems which are addressed and resolved in his framework. According to him the scalability of dynamic nature can be achieved by integration of different voice models. Finally he also suggested a new framework can be proposed to tackle the huge data using cloud technology [34].

S. M. Riazul Islam *et al.* in the paper author discusses technologies, industrial focus, application and framework of iot. The major focus of the paper was taxonomies attack, models, requirements of security, iot privacy and security features. He also discussed how iot is playing a role in different fields of medical domain. Author proposed intelligent model to decrease risk of security and discusses the advancement of technology in the domain of iot with context of medical things and also proposed e-health with iot policies for the sake of different stakeholders. Author finishes his research by commenting that his work will be beneficial for engineers, researches and policymakers in the field of iot [35].

Darshan K R *et al.* has discussed that if serious disorders are predicted in the early stage then it will be

very beneficial for the patient. He said iot is providing the remote healthcare systems to facilitate the society. In this literature the author discuss the uses, challenges and reviews of all previous work done related to iot in medical or healthcare domain and a methodology presented is also discussed in this paper. In his research he also aimed to increase the quality and efficiency in the field of healthcare [36].

Dapheny *et al.* he depicted the framework or infrastructure plays an important role in the field of iot. He reviewed different models that enable optimum and progressive decision making reviewed in context of iot. Many opportunities and challenges associated with this were also discussed. According to author smart living is a good option to provide smart healthcare to the peoples [37].

Kuo-hui yeh *et al.* the advancement in the communication brings new era of iot which is based on networks. In the literature he proposed a new iot based system which works on body sensor network, to reach robustness and efficiency in public iot network. Author also kept security parameter in mind to secure the proposed system. He mentioned to guarantee the proposed system and scheme it is more suitable to apply the scheme to the common mobile object [38].

### III. APPLICATIONS OF IOT IN HEALTHCARE

Table I Shows number of applications researched in the field of iot from year 2012 up to 2016. There are five columns each represents some attribute, serial number, application, author name, published year and reference of the paper from where we researched. All the applications we researched are from the medical healthcare systems. Most of the applications are from the research papers which are published in 2016. So, our researched applications are up to date.

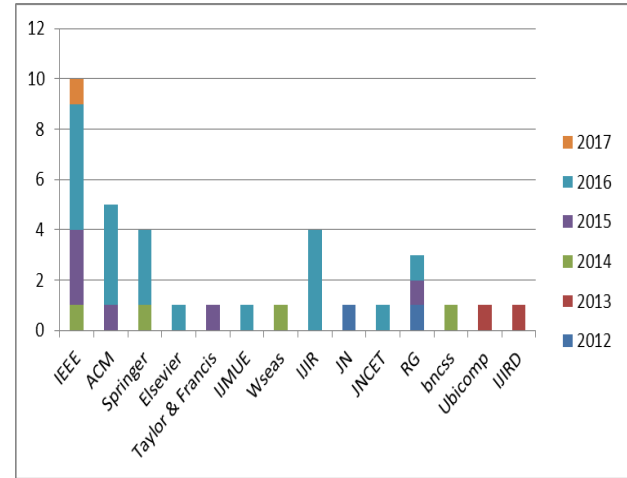
We have selected these applications on the basis of contribution of different researchers in the field of IoT from different resources. On the basis of selection and rejection criteria we have selected papers from different authentic repositories like ACM, IEEE and Elsevier etc. We have included those applications which were most recent in the field of IoT with context of healthcare. The purpose was to list applications of IoT in medical healthcare domain.

#### A. Depiction of Yearly Contribution in Context of Multiple Databases

Bar Graph I depicts that different colors are assigned to each year and on x-axis there are names of data base that is used for applications research. It is very visible that most of the papers are from year 2016 shown in sky blue color. On y-axis there are number of the paper with respect to the researched data bases for applications only Maintaining the Integrity of the Specifications only.

This graphical view depicts the number of researches we took in our research. Our main focus was to select the most recent research papers related to IoT in the field of

medical health care. Latest researches are shown with high peaks in the graph.



1. Depicting yearly contribution in context of IOMT

#### B. Challenges of IoT in Healthcare

After a brief research we listed some significant challenges in the domain of iot. We believe that if these challenges are met in the field of iot, we can improve iot standard in the field of medical care. IoT can provide more reliable and better services in the field of medical health care.

Due to IoT there is revolutionary change in the field of internet communication; this has a lot of contribution in the growth of many challenging domains but especially in the field of medical things. This is the one of major reasons to close the gap between doctors, patient and healthcare services by its ease, accuracy and flexibility. IoT enable the doctors and hospital staff to do their work more precisely and actively with less effort and intelligence.

We have selected these Challenges on the basis of contribution of different researchers in the field of IoT from different resources. On the basis of selection and rejection criteria we have selected papers from different authentic repositories like ACM, IEEE and Elsevier etc. We have included those challenges which were most recent in the field of IoT with context of healthcare. The purpose was to list challenges of IoT in medical healthcare domain.

#### C. Benefits of Iot in Healthcare

Iot has many advantages to individuals, society, the environment, consumers and business, as with every technology there are some benefits with some drawbacks.

Following table provide the list of major benefits we have from iot. Though, iot is very beneficial in the domain of the medical health care. Iot based applications and systems have transformed the world into an imaginary world which human of 90's thought about. Due to Iot there is revolutionary change in the field of internet communication; this has a lot of contribution in the growth of many challenging domains but especially in the field of medical things. This is the one of major reasons to close the gap between doctors, patient and healthcare

services by its ease, accuracy and flexibility. IoT enable the doctors and hospital staff to do their work more precisely and actively with less effort and intelligence. Proof of this is above mentioned table II of applications.

This integration of iot in the field of medical has provided incredible advantages to patients; iot is very easy to use.

TABLE III: BENEFITS OF IOT

Sr. #	Benefits In Medical Domain	References
	<i>Benefits</i>	
1	Make life more convenient Healthcare is cheap Outcome of patient is improved Management of diseases is real-time Life quality is Improved user end experience is improved care for patient is increased costs reduction Ultimate benefit is healthier and longer lives, Maximum diseases management and prevention children's / elder parents progress is monitored Major change in health of patient will make an automatic alert to different parties, save lives and time Resources of iot other iot devices	[31]
2	Medication is on time Patient care will be intimated to family members	[9]
3	Simplicity Affordability Ease to use	[25]
4	Doctors can manage patients records easily	[30]
5	Energy efficiency which include time, money etc.	[24]
6	Doctors Off time medical services by IoT	[28]

2. Searched number of benefits in the field of iot in medical domain

We have selected these benefits on the basis of contribution of different researchers in the field of IoT from different resources. On the basis of selection and rejection criteria we have selected papers from different authentic repositories like ACM, IEEE, and Elsevier etc. We have included those benefits which were most recent in the field of IoT with context of healthcare. As the field of the iot is emerging and expanding very quickly, so it was very important to list the benefits of the iot in medical healthcare. The purpose was to list benefits of IoT in medical healthcare domain.

#### IV. EXPLANATION OF WORK

In this research paper, we have discussed mainly the applications, future challenges and benefits of internet of things (IoT) based on the work done by different researchers in the field of IoT. All the applications we researched are from the medical healthcare systems. Most

of the applications are from the research papers which are published in 2016. Actually there are many challenges that has to be counter but we have briefly identified some of the significant challenges in the file of iot in context of healthcare that are detailed discussed in section III. We believe that if these challenges are met in the field of iot, we can improve iot standard in the field of medical care. iot can provide more reliable and better services in the field of medical health care.

As a result we can say that Iot based applications and systems have transformed the world into a imaginary world which human of 90's thought about. Iot enable the doctors and hospital staff to do their work more precisely and actively with less effort and intelligence. That is mentioned above in the Section III.

#### V. CONCLUSION & FUTURE WORK

In this paper, we provided an overview related to IoT services and technologies in healthcare. A number of research challenges have been identified, which are expected to become major research trends in the next years. The most relevant application fields have been presented, and a number of use research benefits identified. We hope that this work will be useful for researchers and practitioners in the field, helping them to understand the huge potential of IoT in medical domain and identification of major challenges in IOMT. This work will also help the researchers to understand applications of IOT in healthcare domain.

#### REFERENCES

- [1] Internet of Things (IoT): Number of Connected Devices Worldwide From 2012 to 2020 (in billions). [Online]. Available: <https://www.statista.com/statistics/471264/iot-number-of-connected-devices-worldwide/>
- [2] Institute of Health Metrics and Evaluation. (2015). [Online]. Available: <http://www.healthdata.org/pakistan>
- [3] F. Andriopoulou, T. Dagiuklas, and T. Orphanoudakis, *Integrating IoT and Fog Computing for Healthcare Service Delivery*, Springer International Publishing Switzerland.
- [4] B. Dong, J. Yang, Y. Ma, and X. Zhang, "Medical monitoring model of internet of things based on the adaptive threshold difference algorithm," *International Journal of Multimedia and Ubiquitous Engineering*, 2016.
- [5] W. D. de Mattos and P. R. L. Gondim, *M-Health Solutions Using 5G Networks and M2M Communications*, Published the IEEE Computer Society, 2016.
- [6] K. Motwani, D. Mirchandani, Y. Rohra, H. Tarachandani, and A. Yeole, "Smart nursing home patient monitoring system," *Imperial Journal of Interdisciplinary Research*, vol. 2, no. 6, 2016.
- [7] S. Ge, S. M. Chun, H. S. Kim, and J. T. Park, "Design and implementation of interoperable IoT healthcare system based on international standards," in *Proc. 13th IEEE*

- Annual Consumer Communications & Networking Conference*, 2016.
- [8] G. Matar, J. Lina, G. Kaddoum, and A. Riley, "Internet of things in sleep monitoring: An application for posture recognition using supervised learning," in *Proc. International Conference on IEEE Healthcom*, 2016.
  - [9] C. H. Huang and K. W. Cheng, "RFID technology combined with IoT application in medical nursing system," *Bulletin of Networking, Computing, Systems, and Software*, vol. 3, no. 1, pp. 20-24, January 2014.
  - [10] Y. J. Fan and Y. H. Yin, "IoT-Based smart rehabilitation system," *IEEE Transactions on Industrial Informatics*, vol. 10, no. 2, May 2014.
  - [11] I. Chiuchisan and O. Geman, "An approach of a decision support and home monitoring system for patients with neurological disorders using internet of things concepts," *Wseas Transactions on Systems*, vol. 13, 2014.
  - [12] R. S. H. Istepanian, A. Sungoor, A. Faisal, and N. Philip, "Internet of M-Health things 'm-IOT'," *IET Seminar on Assisted Living*, April 2012.
  - [13] S. S. Al-Majeed, I. S. Al-Mejibli, and J. Karam, "Home Telehealth by internet of things (IoT)," in *Proc. Canadian Conference on Electrical and Computer Engineering Halifax, Canada*, May 3-6, 2015.
  - [14] H. J. La, H. T. Jung, and S. D. Kim, "Extensible disease diagnosis cloud platform with medical sensors and IoT Devices," in *Proc. 3rd International Conference on Future Internet of Things and Cloud*, 2015.
  - [15] D. G. Páez, F. Aparicio, M. de Buenaga, and J. R. Ascanio, R. Hervás, *et al.*, "Big data and IoT for chronic patients monitoring," in *Lecture Notes in Computer Science*, 2014, pp. 416-423.
  - [16] K. B. S. Kumar and K. Bairavi, "IoT based health monitoring system for autistic patients," in *Proc. Symposium on Big Data and Cloud Computing Challenges, Smart Innovation, Systems and Technologies*, 2016.
  - [17] K. D. Krishna, V. Akkala, R. Bharath, P. Rajalakshmi, and A. M. Mohammed, *Computer Aided Abnormality Detection for Kidney on FPGA Based IoT Enabled Portable Ultrasound Imaging System*, AGBM, Published by Elsevier Masson SAS, 2016.
  - [18] B. Xu, L. Xu, H. Cai, L. Jiang, Y. Luo, and Y. Gu, "The design of an m-Health monitoring system based on a cloud computing platform," *Talor & Francis*, 2015.
  - [19] P. Chavan, P. More, N. Thorat, S. Yewale, and P. Dhade, "ECG - Remote patient monitoring using cloud computing," *Imperial Journal of Interdisciplinary Research*, vol. 2, no. 2, 2016.
  - [20] H. Arbat, S. Choudhary, and K. Bala, "IOT smart health band," *Imperial Journal of Interdisciplinary Research*, vol. 2, no. 5, 2016.
  - [21] L. Yu, Y. Lu, and X. Zhu, "Smart hospital based on internet of things," *Journal of Networks*, vol. 7, no. 10, October 2012.
  - [22] A. Ghose, P. Sinha, C. Bhaumik, A. Sinha, A. Agrawal, and A. D. Choudhury, "UbiHeld: Ubiquitous healthcare monitoring system for elderly and chronic patients," in *Proc. ACM Conference on Pervasive and Ubiquitous Computing Adjunct Publication*, Zurich, Switzerland, September 8-12, 2013.
  - [23] K. M. C. Kumar, "A new methodology for monitoring OSA patients based on IoT," *International Journal of Innovative Research & Development*, vol. 5, no. 2, 2016.
  - [24] R. Singh, "A proposal for mobile E-Care health service system using IOT for Indian scenario," *Journal of Network Communications and Emerging Technologies*, vol. 6, no. 1, January 2016.
  - [25] C. Puri, A. Ukil, and S. Bandyopadhyay, "iCarMa: Inexpensive cardiac arrhythmia management – an IoT healthcare analytics solution," in *Proc. First Workshop on IoT-enabled Healthcare and Wellness Technologies and Systems*, June 30, 2016.
  - [26] I. Vasylytsyov and S. Lee, "Entropy extraction from bio-signals in healthcare IoT," in *Proc. 1st ACM Workshop on IoT Privacy, Trust, and Security*, April 14 -17, 2015.
  - [27] V. Chandel, A. Sinharay, and N. Ahmed, "Exploiting IMU sensors for IOT enabled health monitoring," in *Proc. First Workshop on IoT-enabled Healthcare and Wellness Technologies and Systems*, June 30, 2016.
  - [28] M. Fischer and M. Lam, "From books to bots: Using medical literature to create a chat bot," in *Proc. First Workshop on IoT-enabled Healthcare and Wellness Technologies and Systems*, June 30, 2016.
  - [29] A. S. Yeole and D. R. Kalbande, "Use of internet of things (IoT) in healthcare: A survey," in *Proc. ACM Symposium on Women in Research*, 2016.
  - [30] D. D. Kumar and P. Venkateswarlu, "Secured smart healthcare monitoring system based on IOT," *Imperial Journal of Interdisciplinary Research*, vol. 2, no. 10, 2016.
  - [31] Digital Strategies for Big Picture Results. [Online]. Available: [http://www.tcs.com/resources/white\\_papers/Pages/Internet-of-Things-Medical-Devices.aspx](http://www.tcs.com/resources/white_papers/Pages/Internet-of-Things-Medical-Devices.aspx)
  - [32] V. Tsoutsouras, D. Azariadi, K. Koliogewrgi, S. Xydis, and D. Soudris, "Software design and optimization of ECG signals analysis and diagnosis for embedded IoT devices," in *Components and Services for IoT Platforms*, 2017.
  - [33] S. Alasmari and M. Anwar, "Security & privacy challenges in IoT-based health cloud," in *Proc. International Conference on Computational Science and Computational Intelligence*, 2016.
  - [34] G. Muhammad, S. M. M. Rahman, A. Alelaiwi, and A. Alamri, "Smart health solution integrating IoT and cloud: A case study of voice pathology monitoring," *IEEE Communications Magazine*, January 2017.
  - [35] S. M. R. Islam, D. Kwak, M. H. Kabir, M. Hossain, and K. Kwak, "The internet of things for HealthCare: A comprehensive survey," *IEEE Access*, 2015.



- [36] K. R. Darshan and K. R. Anandakumar, "A comprehensive review on usage of internet of things (IoT) in healthcare system," in *Proc. International Conference on Emerging Research in Electronics, Computer Science and Technology*, 2015.
- [37] D. S. Zois, "Sequential decision – making in healthcare IoT: Real – Time health monitoring, treatments and interventions," in *Proc. 3rd World Forum on Internet of Things (WF-IoT)*, 2016.
- [38] K. Huiyeh, "A secure IoT-based healthcare system with body sensor networks," *IEEE Access*, 2016.



**Gulraiz Javaid Joyia** was born in Punjab Province, Pakistan, in 1989. He received the B.S. degree in computer engineering from the University College of Engineering and Technology (I.U.B), Bahawalpur, in 2013 and he is currently the research scholar at College of Electrical and Mechanical Engineering (EME), NUST, Islamabad, Pakistan. His research interests include IoT, Bioinformatics, Data Engineering, Requirement Engineering, and computer networks security.



**Rao Muzamal Liaqat** was born in Punjab Province, Pakistan, in 1992. He received the B.S. degree in computer engineering from the University College of Engineering and Technology (I.U.B), Bahawalpur, in 2013 and he is currently the research scholar at College of Electrical and Mechanical Engineering

(EME), NUST, Islamabad, Pakistan. His research interests include computer networks security, Data Engineering, Requirement Engineering, and IoT.



**Aftab Farooq** was born in Punjab Province, Pakistan, in 1991. He received the B.S. degree in Computer Sciences from the University Dr. A. Q. Khan Institute of computer science and information Technology (KICSIT), Kahota, in 2014 and he is currently the research scholar at College of Electrical and Mechanical Engineering (EME), NUST, Islamabad, Pakistan. His research interests include Data Engineering, and Network Security.



**Dr. Saad Rehman** was born in Punjab Province, Pakistan. He received the B.S. and M.S. degree in Computer Engineering from the College of Electrical and Mechanical Engineering (EME), NUST, Islamabad, Pakistan. He did Ph.D. (Computer Engineering), from UK. He is currently the Associate Head of Department at College of Electrical and Mechanical Engineering (EME), NUST, Islamabad, Pakistan. His research interests include Digital Systems Design, Digital Image Processing, Digital Signal Processing, Advance Computer Architecture, IoT and Operating Systems