Deploying Internet of Things in Healthcare: Benefits, Requirements, Challenges and Applications

Issa M. Shehabat[1] and Noor Al-Hussein[2]
[1]Yarmouk University, Irbid 21163, Jordan
[2]Jordan University of Science & Technology, Irbid 22110, Jordan
Email: ishehabat@yu.edu.jo; nkalhussein@just.edu.jo

***Abstract*—**The rapid development of information and communication technologies led to the evolution of internet of things (IoT). IoT supports the mechanism of connecting things together through sensors and microprocessor chip facilitating the way of exchanging data via the internet. The number of devices connected to the internet is increasing, it is estimated to reach 50 billion in 2020. Today modern hospitals and medical centers incorporating IoT technologies in various medical fields such as remote monitoring, patient information management, telesurgery, and healthcare management in order to achieve convenience to both medical staff and patients within affordable costs. This paper aims to provide a comprehensive review of the adoption of IoT in healthcare applications, benefits and limitations of some Internet of medical things (IoMT) systems suggested by the researchers, and clarify the main technologies required to apply IoMT.

***Index Terms*-**Internet of things, healthcare, RFID, wireless sensor networks, remote surgery, medical devices.

I. Introduction

The Internet of Things (IoT) is a modern paradigm shift in IT field. It was coined from the two words "Internet" and "Things". The Internet is a global system of interconnected computer networks that use the standard Internet protocol suite (TCP/IP) to serve billions of users worldwide. It is a network of networks that consists of millions of private, public, academic, business, and government networks, of local to global scope, that are linked by a broad array of electronic, wireless and optical networking technologies [1]. In our context the Internet of Things (IoT) refers to the use of intelligently connected devices and systems to leverage data gathered by embedded sensors and actuators in machines and other physical objects.

IoT refer to incorporation of physical objects 'things' into information technology infrastructure to gather and transfer data through a network to be sensed and oriented distantly upon a wireless network. The point "things" distinguish IoT from traditional internet, things refer to physical objects in real worlds (living and non-living) embedded with sensors to enable the traceability of them. Hospitals now must think about how to espouse IoT in order to simplify their medical services or to find opportunities to gain a competitive advantage over rivals in medical care [1].

Modern countries are now giving more attention to shift from hospital-base to home-base care, as the number of chronic diseases and global ageing are in growth, by performing this, the health services delivered in relaxing way within any time from home, in addition this will reduce the cost of reserving large departments in hospitals for routine monitoring, so that the hospitals' resources will be available for patients with emergency cases [2].

As a result, health industries should incorporate information and communication technology (ICT) into home environment, by doing so, early revealing of any dangerous signs are treated on real time, likewise keeping an eye on taking daily prescribed drugs. "Internet-of-Things (IoT) has been recognized as a revolution in ICT since it started at the beginning of the 21st century" [3].

The rapid expansion of intelligent devices brought the growth of internet of things which become greater concern for many industries as it is considered as one of the most important field in future technology.

There are many application of IoT in our life that emerge in different domains to make life easier like healthcare, transportation, agriculture, education, industry and so on [4].

II. Problem Statement

A. Research Questions

1. What are the key enabling technologies that achieve the IoMT?
2. What are the main application domain of IoMT?
3. Is there any challenges affect the deployment of IoMT?
4. Which complementary technologies can firms used to overcome IoMT issues?
5. What is the key benefits of deploying IoMT?

B. Research Significance

Because of the great development of modern hospitals and technologies, and according to the huge volume of heterogeneous data related to patients health status, medical centers think about approaches to fulfil their strategic objectives as, maintaining rapid agility and efficient integration of business resources, preserving competitive advantage and being special among rivals,

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minimizing data redundancy and improve the data consistency and data sharing, on time efficient decision making, real time diagnoses and monitoring, all these and more motive the medical center to utilize internet of things technology in their services.

III. Background

IOT is the internetworking of physical devices, vehicles (smart devices), buildings and other items embedded with electronics, software, sensors and actuators all associated together through network connectivity that enable these objects to collect and exchange data. The IoT allows objects to be sensed and controlled remotely across existing network infrastructure [5], creating opportunities for more direct integration of the physical world into computer-based systems, and giving rise to improved efficiency, accuracy and economic benefit.

The concept IoMT used to characterize the integration of medical science and IoT technologies (smart objects) with telecommunication technologies that allow rapid connectivity to the World Wide Web in order to gain personal and social profits [6].

Most patients who need frequent monitoring wish to have the medical services at home rather than hospitals. So the concept of IoMT is to assist medical staff to pursue the status of patients to determine if the patients need to move to hospital or to change drugs, this will minimize the cost of treatment with same quality [7]. Countries who incorporate IoMT earn many advantages, as cutting the cost of patient transportation especially for elders and children, also it shorten the geographical barriers by enabling remote treatment for patients, furthermore it enhance remote education and provide base for medical research also it facilitate medical communication [8].

One of the main technologies that affects the advancement in IoT is RFID technology, that uses automatic identification and data capturing methods, the second dominant technology is wireless sensor networks(WSN) that intelligently connect sensors, in addition to many more technologies that are being utilized to assist IoT like cloud computing, big data analytics, smart devices, barcode and social networks [9].

IV. Literature Review

The main technologies that participate in the improvement of IoT are:

RFID technology: RFID considered as the main building block of IoT technology. RFID consists mainly of active/passive RFID tag and RFID reader, RFID tag attached to objects or things in order to be tracked. It consists of two parts, the integrated circuit for processing and storing the information, and antenna for receiving and transmitting the signal sent by reader. Many industries rely on this technology according to its capability to give accurate and on time information related to objects connected to, thus reduce the need to large number of employees giving the industries opportunities to effectively automate and facilitate business process [10].

RFID tags influence medicine growth in large scale, it can be integrated to patients and equipment in order to monitor and track their health status, such as temperature, pressure, heart rate, etc. [11]. Without the need for patient to be in the hospital thus reduce the cost of providing traditional health monitoring and the patient will be more relax in his/her home as if problem arise it will be controlled instantly and remotely by doctors, also RFID tags can be integrated to emergency Ambulance helping the doctor to monitor and treat the case remotely until it arrive the hospital [12].

Wireless sensor networks: Considered as set of distributed sensors used to trace and observe physical and environmental cases like vibration, light, temperature, ECG ,pressure, and so on, for transmitting data to processing center through wireless network without the need to human interference.

WSN is used widely in many fields including monitoring as military, environmental as forest firing, water quality and air pollution and health care field as machine health monitoring [11].

Cloud Computing: "Is an intelligent computing technology in which number of servers are converged on one cloud platform to allow sharing of resources between each other which can be accessed at any time and any place" [13].

The integration between IoT and cloud computing lead to efficient improvement in the expansion of IoT. Cloud computing compensate IoT limitations according to its unlimited processing and storage capabilities that IoT miss. The exchangeable benefits between cloud and IoT is clear, as cloud assist IoT with its unlimited processing and storage capabilities, and the IoT support cloud computing with providing the opportunities to expand its coverage area to become interacted dynamically and in pervasive manner with real world objects regardless of its centralized displacement [14]. As a summary cloud computing will complement IoT to give more precise, efficient and competitive services which motivate researches to study the cloud IoT model.

Internet of Medical things Applications: The literature in IoMT cover many applications including home health, hospital health, telehealth, mobile health, alarm system and emergency health. The proper choice of IoMT applications will be fundamental to the success of business model [6]. In order to deploy strong infrastructure for IoMT application, [5] assume that we should keep in mind software engineering processes and technologies to design complete business model. Fewer researchers keep attention to SE technologies, despite of considering these technologies lead to meet not only the functional requirements but also the non-functional one.

Hospital health services: The authors propose a health care system supported by IoT technology applied

in Intensive Care Units (ICU) in hospitals, this system allow in the real time supervising and monitoring the patients who require intensive monitoring and accurate awareness, those who left form major surgery or need special medicine or pained dangerous wounding, aiding to discover suitable medical environment for patients who demand intensive support, and reducing the cost and effort of health care personnel to be alongside with the patients, also ensuring real time proper help to admitted patients. The architecture of the proposed system consists of:

1) "Intensive Care Unit bedside monitor" for observing physical body functions as heart rate, oxygen, blood pressure, breathing rate, body temperature and so on.
2) "Kinect sensors" which have set of sensors that trace the motion of patients, recognize face and speech. These sensors doesn't need to place with patients, it will use Natural User Interface to detect Skeletons.
3) "Sensor board for monitoring of environmental parameters" which consists of group of sensors to collect information about environmental conditions like temperature, humidity, gases. In addition to movement and shaking. The information gathered send to server through network, therefore it accessed by doctor /nurse to make appropriate decision regarding patient case through graphical user interface [7].

Home health services: The researchers apply CogSense system that facilitate home tele-health, through which IoT achieve real time monitoring for patients, clinics, hospitals and healthcare staff minimizing the need of being aside with patients. CogSense system consists of three main modules:

1) Data analytic module
   Help to perform analysis on the data collected by sensors in order to make effective medical help for patients, also the module rely on "patients past history though using cloud infrastructure".
2) Communications module
   This module enable connectivity to network by using three types of protocols as" IP over GPRS, IP over IEEE802.15.4 and Wireless M- Bus (EN13757-4)". Also it preserves the security of networks by valid authentication to the device helping to prevent insufficient privilege tasks.
3) Sensor access and signal processing module.
   This system allow supervising patients in the real time, it consists of devices like "camera, microphone, bed and toilet sensor, ECG and Pulse oximeter", these devices will find out and anatomize patient action, motion, speech and body language in order to take appropriate support.

The proposed module overcome processing limitation of huge data gathered, and provide secure connection, furthermore it minimize delay among data packets by managing network congestion [2]. Another application in home health suggested by Yang, Geng is Ihomesystem that consist of three parts the iMedBox, the iMedPack, and the Bio-Patch [2]. The iMedBox function as home center that manage the interoperability and the connectivity of IoT devices, the iMedPackis responsible for providing alarm for taking prescribed drugs in the right way. The Bio-Patch responsible for supervising patient's vital signs.

Tele-health: Another application of IoMT technology is the intervention of My Health Avatar (MHA) system by Spanakis, MHA is defined as "a personal digital health related collection bag, carried by individual citizens throughout their lifetime able to sustain in a meaningful manner all collected information" [15]. MHA store medical information about individual past history in addition to personal data about person as age, environment, genetic data. Thus guide to huge amount of data that can be used as repository for medical survey in order to discover knowledge, also it allow direct interaction between doctor and patient for proper treatment and advice. MHA provide different capabilities for implementing e-health monitoring presented as a follow:

- ✓ The data are collected using smart phones and social network, also web information extraction is used to capture useful data and eliminate unreliable data.
- ✓ Use of ontology for heterogeneity of collected data.
- ✓ Cloud architecture to facilitate the sharing of resources as data and storage at larger scale.
- ✓ Big data analytic and simulation model to support decision making.

While [16] offer smart diagnostic chair for recording heart rate and blood pressure without human involvement. By embedded electrodes on chair back and conductive textiles on the chair seat for registering electrocardiogram data according to clothing type in convenient manner.

M-health: Home healthcare is now improving to be transported via mobile devices, [17] introduce mobile phone to act as a gateway for capturing the data from sensors embedded within medical devices and store it on server in IoT Cloud for further analyzing and detecting diagnoses. As another application for mobile health [18] offer mobile service for disabled people on wheelchair based on wireless body sensor network nodes for measuring ECG, heart rate, pressure and the surrounding environments for wheelchair user. These nodes help in increasing the reliability, portability and interactivity with environmental conditions. on the other hand [19] overcome the limited storage capabilities of mobile devices by incorporating cloud computing facilities with IoT to process and store vast amount of captured data, the researcher propose system that collect information either by mobile sensors or by wearable medical sensors, then the data are posted on the internet through sensor gateway using mobile phone and through lightweight REST-based

API as communication mechanisms. Likewise [5] utilize the notion of combing IoT and cloud computing in order to achieve private, secure , scalable and reliable e-health application, they use IOIO microcontroller board with ECG electrodes as mobile application to capture ECG data and store it in binary format for secure access on server side in order to taking the benefits of centralized architectural design that lead to higher storage capability, less of redundancy, and more secure access according to user authentication and authorization. This minimize the cost of buying ECG monitor device by having android application for monitoring ECG in any location. whereas some mhealth application suffer from security issues like [20] who suggest mobile phone hiring tele-monitoring framework for elderly persons suffering from chronic disease depending on simple graphical user interface that facilitate the understanding of system functions, the proposed application has a view to minimizing the need to establish wireless link by deploying both Bluetooth technology and near field communication (NFC technology) in automatic manner to facilitate the process especially for those who have limited technical tact. But this model proves lightly shortcoming with respect to security concerns. As adverse of this[21] dominate major problem that arises with the adoption of m-health, as latency of transmitted data packets, preserving the privacy of patients medical data, and ensuring maximum lifetime of mobile device, through introducing new protocol called YOAPY which allow persistent observation, robust connection, and reliable and secure controlling.

Major challenges of IoMT: The availability of large volume of information flow among smart medical things, unauthorized access, patient's privacy, network congestion, big data analytic, all of these become major challenges of IoT Healthcare.

Interoperability: The growth of internet of things generate opportunity for connecting several smart things over the internet, in addition to that the diversity of different devices, applications, users, firms and countries that IoT connect lead to data heterogeneity as consequences, which make data accessibility and storage of information more difficult. [9] Develop IoT-based system for emergency medical services which employ resource-based data accessing method (UDA-IoT) and semantic data model for enhancing the flexibility of accessing and storing data.

"The medical data collected in IoMT is rarely standardized, often fragmented, or generated in legacy IT systems with incompatible formats. This great challenge needs to be addressed as well" [22]. Indeed healthcare staff should cognizant of stating real time proper decisions; big data analytics has potential to support data processing and cleaning schema while maintaining privacy, quality assurance, security, availability, scalability, flexibility of use and guarantying standards and governance issues. [22] Mentioned that in order for big data analytics to pass it should be designed with user friendly interface derived as menu driven, by doing so it become easy for non-technical persons (health staff) to have informed decisions.

In [23] noted that it is useful to take healthcare assessment through efficient illness management that take the time into consideration, the literature introduce CARE system that rely on big data analytics as a proactive in IoMT to help physicians assess their patients status through facilitating way of negotiations between patients and physicians, also alarm sent to physicians when there is risk on patients life, furthermore CARE suggest possible diagnosis based on historical data, in addition to that it provide wellness plan to patients.

Another approach used to manage the huge volume of medical data is through designing IoT-Based Information System for Emergency Medical Services based on resource-based data accessing method that unify the data format and simplify data accessibility, and semantic model for storing and clearing data, the literatures prove the dynamic functionalities of their system especially for emergency services that can be classified as short value chains process [24].

Delay of data transmitted over network: deploying internet of medical things enable transmitting of critical medical information that must be available on real time and with higher reliability and accuracy, the doctor or medical staff will suppose drugs or treatment according to information captured from sensors so the availability of these information affect patients life, as well it is very critical to have real time information with lower latency reached to few milliseconds in case of remote surgery. 5G network achieve essential improvements in IoMT, through its "superfast connectivity, intelligent management, and data capabilities"[25]. 5G network lead to higher quality of reliable services in medical application. (West and Darrell) introduce the using of 5G networks through wireless communication by radio waves using short transmission interval, this way enable higher reliability and lower latency. Likewise [25] propose ISHSC infrastructure that emerge 5G with IoT, cloud of thing and artificial intelligence. The proposed system allows intelligent connectivity and enables large and efficient scalability in smart home.

Privacy and security: [26] think that it is important to keep attention on the security aspects of IoMT environment according to its telecommunication base. Because of the dynamic infrastructure and the openness of IoT, security and privacy issues gain greater concerns from literatures, many problem regarding security arises through deploying the application of IoT, like unauthorized access to user data, unauthorized remote controlling of smart devices, inefficient use of personnel data by third party [27], so [28] suggest user controlled privacy preserved access control protocol and improved privacy protection mechanisms that enable the user to supervise their personal data by controlling who, when, and how the access done.

Energy Consumption: Basically IoT depends mainly on sensors to gather real time data from smart objects, one of methods to increase the efficiency of sensors capability is managing energy consumption of sensors to increase life time of it, this lead to preventing the breakage of the communication.

[28] Suggest several approaches to preserve energy of sensors as developing strong batteries, introducing energy efficient protocol, maintaining energy of access points and gateways.

Many researches focus on preserving the energy of sensors, like [29] offer wireless sensor network that depends on ZigBee radio and WiMax radio, energy efficiency achieved by selecting the gateway that has minimum link cost depending on how far from internet and on the remaining energy of sensors. On the other hand [30] think that the integration of cloud and IoT provide efficient utilization and management of energy consumption.

Advantages of IoMT: The adoption of IoT in medicine reduce the cost of visiting doctors from far cities, and reduce the work overhead on hospital through leaving hospitals for emergency cases and monitoring after major surgery.

Improved patient outcomes: By referring to inclusive knowledge base organized from historical cases, also the availability of real time health data enable doctors and physicians to observe abnormal diagnoses early thus reduce risk of patient life, this provide ground truth knowledge base for medical staff helping them to make efficient and right decisions. In addition to that almost patients prefer to take their routine care at home by feeling relax rather than being physically at hospital especially for elderly and disabled peoples, likewise doctors and nurses observe and monitor patient care from their comfortable office.

Improve medical researches: IoMT enhance communication and collaboration between medical staff, and facilitate consultation between distanced doctors and experts, also it help in improving dieses information management.

Medical centers with competitive advantages: The rapid growth of ICT technology including IoT, encourage medical center to applying it in order to gain competitive advantages and to be special over rivals.

V. Discussion and Conclusions

For efficient utilization of IoT technologies in any field like healthcare, it is important to integrate IoT with creative business models that are cleverly stating their vision, mission, and SWOT analysis for their business. It is recommended for any system to address the nonfunctional requirements just as important as the functional one. The nonfunctional requirements are related to ”safety, security, privacy, reliability, robustness, stability, availability, resilience, usability, accessibility, scalability, interoperability, flexibility, extensibility, modifiability, testability, portability, maintainability, power efficiency and quality of service” [6]. Any shortage to fulfill the above nonfunctional requirements will lead to poor systems that may not satisfy customers' needs. So it is necessary when designing IoMT systems to fulfill the nonfunctional requirements to gain personal and social profits. Almost researchers in this field aim to achieve functional requirements excluding nonfunctional ones; unfortunately most of the healthcare applications does not meet the security and privacy requirements that have important impact of patient’s life. Likewise some systems lack from usability and flexibility requirements, also the designed systems may be used by elderly and disabled people who don’t have technical skills to deal with. On the other hand many systems suffer from covering wide range of area relating to scalability and extensibility requirements.

Many issues should be considered in the development of IoMT system. Security issues are the most important one especially in healthcare applications, unauthorized access and inappropriate use of patient’s data may affect patient’s life. According to applying IoMT through mobile devices, the targeted system should incorporate large storage capacity because of huge volume of data collected via mobile phone as integrating cloud computing with IoT to overcome storage capability. Indeed because of the sensitivity of healthcare cases that affect patients life, the availability of fast processed information become critical challenge, system should enforce big data analytics applications to gain higher processing capability and real time information for medical staff in order to make right decision on the right time.

Internet of things achieve competitive advantage in medical field, through smart management and real time monitoring of medical information, with deploying IoMT hospitals avoid unnecessary cost and efforts for monitoring the status of patients, doctors decide appropriate medical treatment at the right time, also physicians assist in providing health services for elderly and disabled people though interaction with smart devices.

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Dr. Issa Shehabat received BSc, MSc, and PhD degrees in Computer Engineering from National Technical University (KHPI) – Ukraine. He has more than 20 years of Teaching, Training, Research, Accreditation and Quality Assurance experience. Worked as Vice Dean of Faculty of Information Technology, Head of Software Engineering Department, and in

charge of the Accreditation and Quality Assurance at the faculty of IT. Worked as Director of the Accreditation and Quality Assurance Unit at King Saud University - Huraimla Community College, and Worked as Assistant Dean for Accreditation & Quality Assurance at Yarmouk University of Jordan – Faculty of Information Technology & Computer Science.

Currently, he is an assistant Professor at MIS Dept. Yarmouk University, Jordan – Faculty of Information Technology & Computer Science.

He has published more than 30 research papers in International journals and leading international conferences. Furthermore has authored two book chapters. He has obtained some research grants and supervised several MS and PHD theses.