VOL 3 (2019) NO 2

e-ISSN : 2549-9904
ISSN : 2549-9610

INTERNATIONAL JOURNAL ON INFORMATICS VISUALIZATION

The Internet of Things in Healthcare: A survey for Architecture, Current and Future Applications, Mobile Application, and Security

Ali Mohammad Alqudah [#]

[#] *Department of Biomedical Systems and Informatics Engineering, Yarmouk University, Irbid, Jordan*
E-mail: ali_qudah@hotmail.com

***Abstract*— The internet of things (IoT) are developed toward making the objects smart and connectable using recent development in miniaturizing and communication technologies, IoT has wide application domains one of them is healthcare. this paper focusing on the IoT and their applications, integration, and advances in use in the healthcare sector. IoT is promising technology which will provide an advancement in healthcare providing techniques especially in telemetry and home care. Moreover, IoT will provide a framework for health data collection and sharing. This paper will discuss recent developments in applications and innovation of using IoT in healthcare such as miniaturizing technology and wearable technology as well as the changes facing the application of IoT in healthcare.**

***Keywords*— Internet of Things, Healthcare, Technologies, telemetry, network, Privacy, Security, mobile Applications.**

I. INTRODUCTION

Internet of things (IoT) reflects the concept of connecting a set of anything, anywhere, anyplace and anytime for any service and through any network. IoT is a big jump in the next-generation technologies which will impact the whole spectrum of life, it can be simply defined as a group of interconnected and identifiable devices and smart objects through the body of the current internet infrastructure which became broader with recent wireless internet technology such as 4G with extended benefits. The benefits usually include the advanced connectivity of these smart objects and devices, services, and systems that go under the machine-to-machine (M2M) scenario [1, 2].

Therefore, since the IoT affect the whole life sectors it's important to introduce the automation in nearly all fields especially the fields that affect human life directly. The IoT provides perfect solutions for wide range of applications such as smart cities, telemedicine, security, emergency management, industrial automation and control, health care, environmental studies and logistics [3, 4].

Medical health care and telemedicine represent the most important and attractive field for applying the IoT [5, 6]. The motivation for applying IoT in the health field is the ability of IoT to provide solutions and give rise to the most important sections of this field such as telemonitoring, chronic disease management, fitness care and elderly care [7, 8]. Dealing with providing and management medication at home by specialized people is another dilemma that must be considered. Since there are many sensors based medical devices used in diagnostic, therapeutic, and imaging applications, these devices can be converted into smart objects or devices which will, in turn, comprise the core part of IoT [8].

Introducing IoT in the healthcare field is expected to reduce the cost and increase the quality of health services and life in addition to enriching the collected health data that can be used in health research. IoT has the ability for maximizing the benefits of current network infrastructure by optimizing the time and scheduling of limited resources for providing the supplies and collecting data to ensure the smooth and normal working of smart devices [8].

Easy to setup and connectivity with high stability and security, in addition, to cost-effective solutions through the patients, medical staff, clinics, hospitals, and healthcare organization are important to tend. Up-to-date healthcare data and networks that are expected to be driven by the recent advancement in the wireless technologies will be able to support the monitoring and management of chronic disease, real-time and early diagnosis of critical disease as well as medical emergencies [9]. During recent years, the healthcare application field for IoT attracts the attention of researchers to achieve the maximum benefits from IoT in the field, the researchers focus on the architecture, communication methods, mobile applications, and security. Figure 1 shows the recent trends of IoT in healthcare [10].

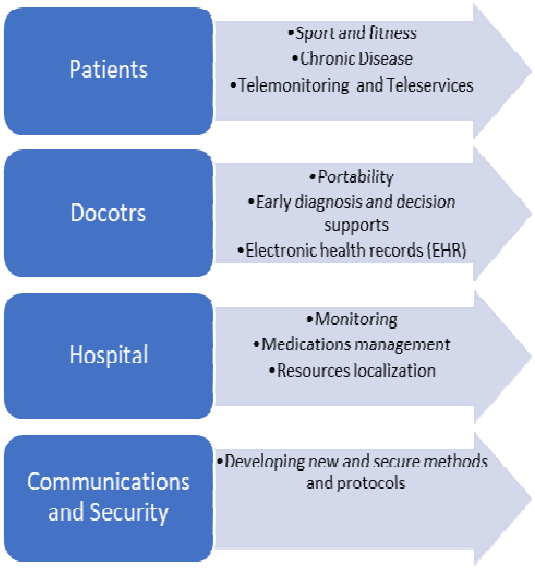

Fig. 1 Recent trends of IoT in healthcare.

This paper will examine the recent issues in IoT-based healthcare research systems from the following points of view:

- The architecture of the systems (sensors, Multibiosensors on the chip, communication ...etc).
- Classifying the field of application (monitoring, elderly care, diagnosis …etc.).
- Discussing the mobile-based IoT healthcare systems.
- Security in healthcare IoT applications (challenges, algorithms …etc).

It should be noted that the initial research and development blocks in the telemedicine and internet-based healthcare started from the wireless sensor networks (WSN), which used the sensors as network nodes to transferee data to the main system [11] [12].

II. The Architecture of the Systems

Fig. 2 general overview of system architecture.

The recent advancement in the manufacturing technology of electronic devices such as micro-electro-mechanical systems (MEMS) and nano-electro-mechanical systems (NEMS) introduces the ability to integrate a complete system in a small chip which is known as the system on chip (SOC) or multi-sensor on the chip. These systems have the ability to acquire health signals such as ECG, EEG, PPG and EMG, processing acquired signals and transmit these signals over wireless networks [13]. Figure 2 shows the general overview of IoT-based healthcare system architecture.

A. Sensors

Sensors, in general, referred to any device that converts the physical measurement to an electrical signal that can acquire, processed and making the decision based on it. Sensors in healthcare design toward acquiring biological signals and measure biological reactions for diagnosis, table 1 shows different biological signals and reactions done by healthcare sensors [14, 15].

TABLE 1
LIST OF BIOLOGICAL SIGNALS AND REACTIONS.

Signal / Reaction	Diagnosis Result
ECG	The state of heart and its activity
EEG	The state of the brain and its activity
EMG	The state of muscle and its activity
SpO2	The concertation of oxygen in the blood
Temperature	The body temperature
Tumor markers	Detect malignant neoplasm
Concentration of organism	Counting RBCs, WBCs ...etc.

Typical sensor systems use wires to transmit acquired signals to other devices, this architecture is insufficient in case daily and continuous monitoring of a patient is required because wires could limit the motion of a patient. Hence, another technology rises with new advancement such as MEMS and NEMS, and which are called sensor on a chip. The sensor on a chip integrates sensor with other required hardware [16,17,18].

In sensor on chip technology, a sensor is integrated on a single chip with other functional units such as ADC, signal processing unit (DSPIC) and data transmission unit. Figure 3 shows the general structure of sensor on-chip system [19, 20, 21].

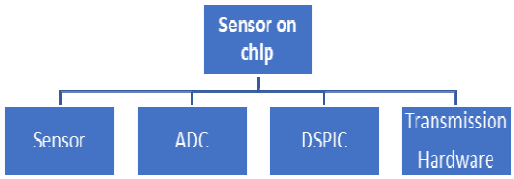

Fig. 3 sensor on the chip.

Recently with the revolution of flexible and stretchable electronics as a result of nanoelectromechanical systems (NEMS) and printed electronics, a new type of sensor is released which is known as biomedical tattoos [22, 23]. The tattoos can be easily attached to the body and provide information about the health status of the patient, these tattoos also integrate the ADC, DSPIC and transmission hardware. Figure 4 shows example of tattoos [24]- [28].

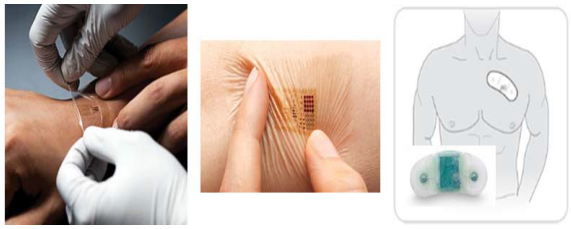

Fig. 4 Biomedical tattoos.

All previously mentioned technologies are integrated when only one sensor is required with the device. This integration is valid only when a single specific parameter from the patient is acquired, figure 5 shows the system on chip architecture for multi biomedical measurement. If more than one parameter is required, we need a separate chip or tattoos for each parameter which requires multi-senders and receiver, ADC and DPSIC which renders it more expensive [29].

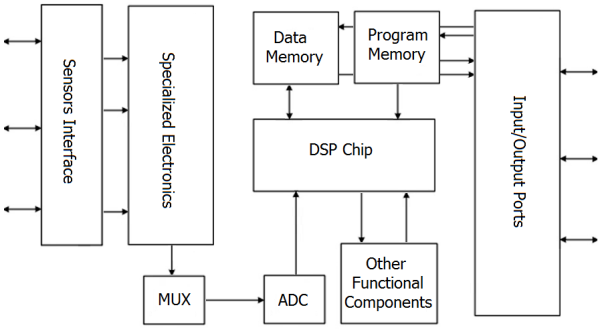

Fig. 5 System architecture for single biomedical signal acquisition and processing.

B. *Multibiosensors on chip*

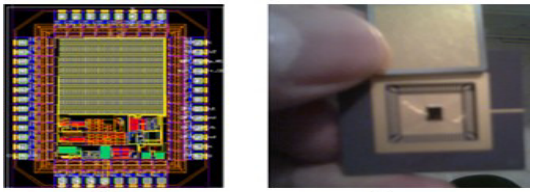

Fig. 6 Multi-Labs-On-a chip; (MLoC); Multi-biosensors; (a) layout of layout of MLoC (b) the die mounted on PGA 68 sockets (CMC) [32].

Due to the high cost and the requirement for high compact multi-measurement and purpose system on a single chip, a new trend in sensors architecture in IoT called Multibiosensors on chip (MLoC). This type of system provides the ability to make simultaneous multi-measurement by integrating multi-biological sensors on the single chip, so the system will be able to measure different biological signals and reaction by sharing same resources such as power [30, 31]. Figure 6 shows an example of MLoC.

This single chip can integrate up to 10 different types of biological sensors with different types of technologies such as interdigitated microelectrode array (IDMA), Electrochemical Impedance Spectroscopy (EIS), Optical and Magnetic measurements. In addition, this chip can also integrate the ADC and DSPIC and data transmission, but current researchers focus on how to integrate the largest possible number of sensors on this small chip. Due to small size, low cost and multi-simultaneous functionalities of biological signals for such type of technology it is important to start thinking about integrating the IoT with it and provide the ability toward developing a complete diagnostic system on small single chip with remote monitoring, diagnosis and data analysis [32,33].

C. *Communication*

One of the important aspects of the IoT-based systems is communication. communication is the way that IoT is connected to a local and global network. Due to its importance researcher started to construct standards and develop technologies that are suitable to IoT. Figure 7 shows the architecture of the IoT network.

IoT-based systems are not complicated to construct but it is challenging to design them in a way to perform a complex task, the task usually consists of large numbers of things connected to each other through the network, so it is very important to develop network standards and technologies that are able to deal with a large number of things and data. Many technologies and standards were developed in recent years to make the IoT usable and applicable, these technologies are IPV6, WIFI, Bluetooth and IEEE 802.15.4 [34].

1) IPV6

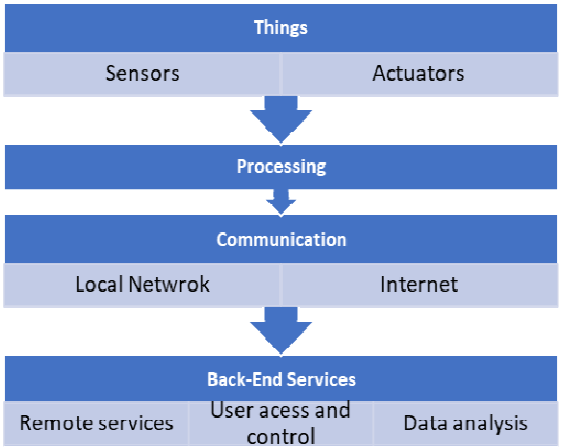

Fig. 7 IoT Based on network architecture.

If M2M network is local it will not be an obstacle, as current technology or IPV4 consists of 32 bit which means you can have 2^32 (4.29 billion) different addresses and devices which cause a problem when these devices are connected to the internet. Due to the increasing number of connected devices to the internet, the internet may run out of address, to solve this problem as the extension of IPV4 is

released called IPV6, IPV6 consist of 128-bit which mean there is 2^128 (340,282,366,920,938*1018) different address and devices can be connected simultaneously to the internet. This version of internet protocol sometimes called IoT protocol because it is founded to solve the problem of IoT connectivity [34].

2) IEEE 802.15.4

It is a standard basic lower network layer of a type of wireless personal area network (WPAN) and its focus is to obtain low-cost, low-speed, ubiquitous communication between devices. This standard forms the fundamental of Zigbee and MiWi, wireless technologies which offer high bandwidth and requires high power when comparing it to IEEE 802.15.4 which provides smaller bandwidth and require less power.

The basic framework of the standard covers a 10 meters' communication range with a rate of 250 Kbit/sec, trade-offs may be possible in embedded systems when lower power consumption or higher range are required. This standard was improved two times in 2006 and 2011. The power consumption of devices with RF communication is now cut in half compared to only a few years ago, and we are expecting another 50% reduction expected with the next generation of devices [35].

3) WI-FI

The first broadly known communication technology and the most suitable solution for IoT connection are the wi-fi. Almost all houses and locations that own internet connections have a wi-fi router. however, wi-fi has a high-power consumption when compared to other technologies, so it might be infeasible when it comes to battery powered devices [34].

Currently, research is focused on developing a wireless technology that has low power consumptions to be used with IoT device and energy harvesting technologies, that harvest energy from the device environment. Such technologies will have a high impact on IoT technology [35].

4) Bluetooth

Bluetooth is a wireless technology used as a standard for low-range and medium rate data transfer between fixed and mobile devices, the technology can be used for building wireless personal area network (WPAN) so it is suitable to be used with IoT devices.

Currently, Bluetooth technology is embedded with all smart mobile phones and most other devices, power consumption with Bluetooth technology is less wi-fi and more than IEEE 802.15.4 [34,36].

TABLE 2
COMPARISON BETWEEN WIRELESS TECHNOLOGIES USED IN IOT.

Standard	IEE 802.15.4	Bluetooth	Wi-Fi
Frequency	868/915 MHZ, 2.4 GHz	2.4 GHz	2.4, 5.8 GHz
Data rate	250 Kbps	723 Kbps	11 to 105 Mbps
Range	10 to 300 m	10 m	10 to 100 m
Power	Very Low	Low	High
Battery Operation	Alkaline (months to years)	Rechargeable (days to weeks)	Rechargeable (hours)

III. FIELDS OF APPLICATION

Since the internet of things (IoT) based systems can collect and transfer the health data more accurate and faster than previous systems, the reliance on the IoT increased and especially the healthcare domain which required systems with these specifications [37] [38]. Nowadays the world is going toward provide the healthcare at person levels regardless the community level, community level which provide the services required by whole community while the person level provide the service required by single person by applying the term "the right person, the right service at the right time" which would be cost-effective and increase the health status of peoples [39].

A sustainable service which focuses on providing pathological, diagnostic and monitoring services at home regardless periodic expensive checks at clinical, IoT provide the ability to anticipate disease and providing preventive medicine based on medical data analysis and applications of artificial intelligence for smart patient diagnosis systems [40]. Application of IoT in the healthcare domain can be categorized into three main domains: telemonitoring, teleservices and fitness. The scale of application for these categories starts from personal, home, community, organization and nation [41, 42]. Figure 8 shows the real-time healthcare monitoring system.

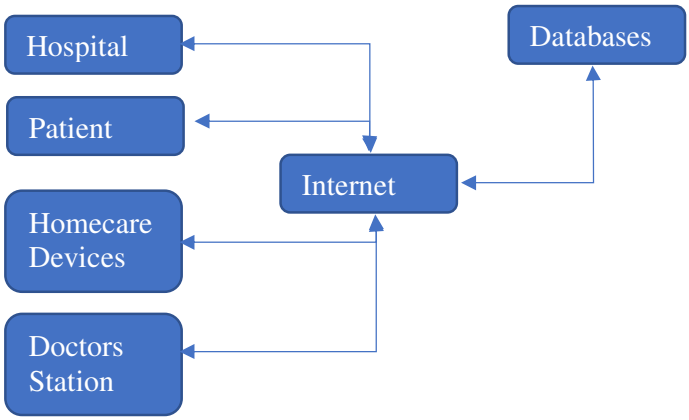

Fig. 8 Real-time monitoring of patient health through IoT.

1) *Telemonitoring*

In these systems, the general patient health status is under monitoring when they are at their works or home. The acquired data by the system is transmitted over the internet to a server where data analysis and storing are performed. Tele-monitoring medical information system refers to an information system that can remotely monitor the patient's physiological status and physiological parameters [40, 43].

The benefit from telemonitoring is that the healthcare institutes are kept up to date with recent advancement in patient health status hence it can provide the required medication at the time. Which are powered by the ubiquitous identification, sensing, and communication capacity, all the objects (people, equipment, medicine, etc.) can be tracked and monitored by wearable WSN devices on a 24/7 [44, 45]. Figure 9 shows the architecture of mobile-based telemonitoring systems.

Fig. 9.Mobile-based telemonitoring system.

2) *Tele-services*

After monitoring the patient status and collecting Information about his physiological status, services can be provided. The services can range from providing advice to the patient to medication and medical doctor visiting suggestion and finding the nearest hospital healthcare center or pharmacy and calling emergency services for the patient at his location automatically when the health status requires intensive care [46].

The main difference between this type of systems and telemonitoring systems is in these systems the decision is made and the procedure is done by the mobile directly without waiting for the response from the server, but after this procedure is performed the data will be sent to the server to be saved in the patient's record. Figure 10 shows the architecture of mobile-based teleservices systems [47].

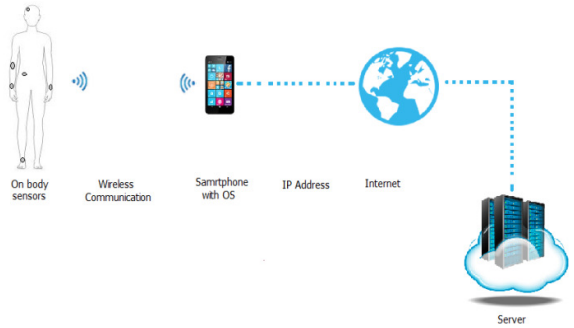

Fig. 10.Mobile-based teleservices system.

3) *Fitness*

Due to modern lifestyle, people favor fast food which causes the problem of obesity and non-healthy lifestyle in addition to the increased death rate many people started to track their lifestyle and try to keep it in limitation of healthy life, tracking includes the calories per day, several steps per day, kilometers per day, heart rate and stairs per day. All these parameters can be used to determine the fitness status of the person and track it [48].

Many companies started to concern about this discipline in recent years such as Microsoft, Fitbit, Apple, and Jawbone. The companies compete to provide more parameters in a single device with the lowest possible cost. Usually, fitness trackers are coming with a computer and mobile application to upload data to a server and track your healthy [49]. Figure 11 shows the common sensor in the fitness tracker.

Fig. 11 Common sensors in the fitness tracker.

The software might provide information about the user's activity using built-in sensors in mobile phones such as GPS and gyroscope. In this case, the collected data are less accurate compared with data collected using specialized hardware, but it provides a good alternative when activity data are only required to be collected [50].

IV. Mobile-based IoT systems

Due to rising of smart mobile phones sales around the world and as it is exceeding the sales of other smart technologies such as laptops, desktop, and tablets and because it is becoming all too prevalent as a means to communicate and interact on a daily basis, many mobile based applications were released to provide services of personal healthcare. Figure 12 shows the number of healthcare applications released per mobile operating system in recent years [51].

The mobile operating system in which mobile application is deployed and run, have a key role in the performance and the ability of the tracker to perform analysis and to keep connectivity with the hardware. Nowadays, windows mobile, IOS and Android, are the most competitive operating systems in the market [50,51].

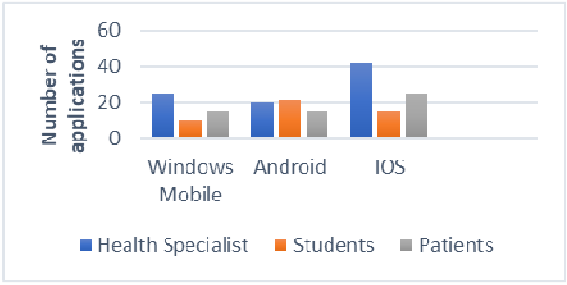

Fig. 12 number of healthcare mobile applications per mobile OS.

Most of these applications focus on five main domains: patient monitoring, diagnosis, drug information, medical education and fitness, the purpose of this focus is due to the ease of setup for this application with required hardware if needed to be provided by the vendor in addition of saleability of such applications in approximately all counters.

1) location based health services providing

health services providing for personnel based on their locations is one of the important technologies due to recent advancements information technologies, location-based

Mobile Healthcare mobile systems integrated with the latest technology in wireless communication and location localization; will introduce a personalized and customization of such services.

Based on the location services which are already integrated within mobile and the profiles of mobile user's services will be provided, the movement of services provided to the patient from desktop platform to mobile technology can bring significant impact on healthcare services [50].

In this method, the systems will call or localized the nearest health services provider for the patient based on his health status, the main benefit from such applications is to connect the patient with the nearest physician or call the emergency services, this will help in saving lives which can be lost due to delay in diagnosis or providing necessary health services [51].

2) Melanoma (skin cancer) diagnosis

Melanoma is one of the fatal cancers which can be spread through metastasis, statistics revealed that most of the deaths resulting from skin cancer are a result of melanoma so, due to this the melanoma is classified as one of the most dangerous cancers [53].

In such systems, the application uses the mobile camera to capture the image for the suspected region of the skin, applying to process in this image and classify the region if it's cancerous or not. The importance of these applications is the capability to provide an early diagnosis of melanoma since it is difficult to distinguish between the skin burns and melanoma which results in not providing the required treatment [53].

3) Lung cancer patient breath regulating

As the number of smokers is increasing dramatically all around the world lung cancer is considered as number one in causing mortality. Therefore, research on lung cancer early diagnosis, prevention, and treatment have received much attention from researchers in the medical and engineering fields [54].

To utilize the spread of mobile technology in our daily life, a mobile application is developed toward providing help in regulating the breath of a patient who has lung cancers. The application records the breath sound of the lung cancer patient, after the cancer stage, age, gender, and height are being entered by the patient. Based on this information the application will provide instruction to guide the patient [54].

4) Medicine management

Recently, many types of research focused on developing a mobile-based system with radio frequency identification (RFID) tags for building a medicine identification and localization system. The systems generally based on integrating the RFID reader with mobile and RFID tag with medicine, so the user can identify the medicine and read brief information about it and instruction for taking it and side effects.

In addition, RFID readers can spread through the home, so the user can easily localize the location of medicine easily. Also, the system can automate the medication doses and remind the user to take and localize the place of the medicine. A system provided in [56] and [57] presenting a porotype and mobile application for such systems.

V. Security and Privacy Requirement and Challenges in Healthcare IoT

IoT applications in healthcare are increasing rapidly and in recent years, it's expected that the healthcare sector will take the largest portion of researchers in IoT. So, the most important aspect of healthcare applications and industries is security. Because healthcare devices and application expected to deal with vital and personal information and no one must access except the authorized peoples, to facilitate the full adoption of the IoT in the healthcare domain, it is important to identify and analyze distinct features of IoT security and privacy including the requirements and challenges [58, 59].

TABLE 3
LIST OF SMARTPHONES APPS.

Application	Descriptions
Health Assistant	Keeps track of a wide range of health parameters such as body water and fat, weight, BP, body temperature, lipids, the glucose level, and various physical activities
Healthy Children	Can search for pediatricians by location and request their advice for quick answers.
Calorie Counter	Keeps track of food consumed by the user as well as his or her weight and measurements, among others.
Dosecast medication Reminder	Reminds the user of medication times, tracks the inventory and maintains a log for drug management.
Noom Walk	Serves as a pedometer to count the user's steps at all times.
Pedometer	Records the number of steps the user takes and displays related information such as the a number of calories burned per unit of time.
Cardiax Mobile ECG	Serves as a companion app for Cardiac Windows's full-scale, 12-channel personal computer (PC) ECG system.
iOximeter	Calculates the pulse rate and SpO2
Eye Care Plus	Tests and monitors vision.
Blood Pressure (BP) Watch	Collects, tracks, analyzes and shares BP data.
Water Your Body	Reminds the user to drink water every day and tracks his or her water-drinking habits.

Application	Descriptions
Runtastic Heart Rate	Measures the heart rate on a real-time basis.

A. *Security and privacy requirements*

The communication security requirements in IoT-based health care systems are like requirements in standard communications systems, and concentrated in 8 points [58]–[62], as following:

1) *Confidentiality*

A requirement that ensures that only authorized people can access the medical information's, in addition, confidential messages resist revealing their content to eavesdroppers [58].

2) *Integrity*

A requirement that ensures that transferred medical data through the transmission media are not altered, in addition, it ensures that the stored data also are not altered, and content should not be compromised [58].

3) *Authentication*

A requirement that enables the IoT-based health systems to ensure the identity of the peer with which it is communicating [59].

4) *Availability*

A requirement that ensures that IoT-based healthcare services (either local or global) are always available to authorized parties when needed even under denial-of-service attacks [59].

5) *Up to date data*

A requirement that ensures each IoT-based health care network provides some time-varying measurements, there is a need to ensure that each message is fresh. Up to data basically implies that each data set is recent and ensures that no adversary replays old [60].

6) *Authorization*

A requirement that ensures that only authorized nodes are accessible for network services or resources [61].

7) *Error tolerance*

A requirement to ensures that security scheme should continue to provide respective security services even in the presence of a fault [61].

4) *Resiliency*

If some interconnected health devices are compromised, then a security scheme should still protect the network/ device/information from any attack [62].

B. *Challenges*

Due to high requirements required by systems to provide the highest possible security, there are challenges facing these systems, the challenges can be summarized in the following points [62]- [66]:

1) *Computation limitation*

Since IoT-based health care systems are built with embedded low-speed processors, the central processing unit (CPU) in such devices are now powerful in scenarios where speed is required. These devices are not designed to perform complex and computationally expensive operations. In general, finding security solutions that minimize the requirement for highly complex and computationally expensive algorithms is the challenging task [67].

2) *Memory limitation*

As in processor challenge, most of the IoT-based healthcare systems came with low built-in memory. Such systems are activated using an embedded operating system (OS), system software, and an application, Therefore, their memory may not be enough complicated security protocols [67].

3) *Energy limitation*

Typically, IoT-based health systems and small devices are powered by the meaning of batteries, the batteries are limited and usually, most of the devices conserve energy by switching to the power-saving mode when no reading came from sensor reading needs processing. In addition, they operate at a low CPU speed if there is nothing important to be processed [68].

4) *Mobility*

In general, healthcare devices and systems are mobile in nature, such devices are connected to the internet through IoT service providers. For example, wearables are connected to the home network when the user is at home, whereas they are connected to the office network when the user is at the office. Different networks have different security configurations. Therefore, developing mobility-compliant security algorithms is a challenge [69].

5) *Communication media*

In general, IoT-based healthcare systems and devices are connected to both local and international networks through wireless links such as Bluetooth, Bluetooth Low Energy, Wi-Fi, GSM, WiMAX, and 3G/4G. Different characteristics of these networks make traditionally wired security schemes less appropriate. Therefore, it is difficult to find a comprehensive security protocol that can treat both wired and wireless channel characteristics equally [70].

6) *Architecture and Dependencies*

IoT must have an architecture provides easy connectivity, control, and communication. For the dependencies, the things in IoT must be protected from other devices [71].

7) *Huge generated data*

In IoT, there is a huge amount of transferred data, so it is necessary to convert this data into usable knowledge. For example, the data generated from medical purposes can be converted to usable knowledge to patients [72]. Also, data must be compressed during transmission through transmission medium to save channels capacity [73].

C. research of Security solutions

After defining the challenges that faced the security of IoT in healthcare, this section will talk about recent research solutions for challenges introduced in the section before:

1) *Encryption Mechanism*

For the encryption mechanism, there are two approaches to encryption, by-hop, and end-to-end encryption. Hop encryption is done on the links which need to be protected, in other word the encryption is done on the network layer. This gives end users convenient and a variety of applications. Also, this mechanism has low latency, low cost, and high efficiency. But this mechanism has a drawback which is the plaintext can be extracted because decryption is done on the transmitter node, so encryption needs to be highly trusted on the transmission nodes [70].

End-to-end encryption, it depends on the application used, which gives high-security policies for its application. But this approach has a drawback which is the destination address will not be encrypted, because this address will be used on the transmission nodes, this drawback may bring many malicious attacks [71].

As a conclusion, by-hop is used when security requirements are not very high, and end-to-end is used when high-security requirements are needed.

2) *Security of Communication*

There are many protocols concerned with communication security, such as IPSec, TLS/SSH. These protocols can provide authenticity and confidentiality of communication. IPSec provides security on the network layer, and TLS/SSH provides security on the transport layer [72, 74].

Communication security is very important in IoT; because IoT small objects have less power, which leads the communication, security may be weak. For example, of communication attack is a Distributed Denial of Service (DDoS) which will destroy the availability of the link. So, it is very important to have a disaster recovery plan for the DDoS attack [72].

3) *Protection of Sensors*

There are two main research areas for protection of sensors. The first one is the confidentiality of sensors data, which is the attacker can put another sensor near to the sensor and can collect the data of the original sensor [73].

The second research area is privacy. Most people didn't know about the sensors in their life, so it is very important to have regulations about the privacy of these sensors. For example, there are many guidelines to solve this issue [72] such as the users must know that they are being sensed, or the user can choose if he wants to be sensed or not, or the user will choose to be anonymous and not be sensed.

4) *Cryptographic Algorithms*

There are many algorithms used in cryptography, each one has its own purpose. Advanced Encryption Standard (AES) algorithm provides confidentiality. Rivest Shamir Adelman (RSA) provides digital signatures. Diffi-Helman (DH) provides key agreement [74]. And many other algorithms.

For the implementation of these algorithms, available resources are necessary such as memory size or processor speed. There are research areas about implementing these algorithms on IoT with the low-speed processor and low memory [75].

5) *IoT Certification*

IoT applications can be certified on the network layer or application layer. Network layer certification can be used when a supplier provides the application; in this case, you do not need application layer certification [70]. Application layer certification can be used when the service provider does not trust the security of the network, also it can be used when the service is sensitive to financial services.

In general, when the service of IoT application is simple, network layer certification is used, and when the service is complex and needs special authentication, application layer certification is used [70, 71].

VI. CONCLUSIONS

Researchers around the world start to pay attention for improving the provided healthcare services through the integration of different technologies which introduced in recent years such as internet of things (IoT), Multibiosensors in the chip, system on chip (SoC) and 4G/LTE communication.

The use of such technologies improves the provided health services and decrease the rate of deaths caused by chronic diseases or by taking wrong medications or non-Suitable dose of medications or by non-dealing with emergency cases which required direct treatment due to insufficient monitoring, by providing an up-to-date solution that can provide fast, accurate and real-time data about person's health status.

This paper surveys different aspects of IoT in healthcare technologies, architecture, applications, mobile applications, mobile platforms and security challenges, and trends briefly discussed. The paper provides a broad view of these aspects and provides a suggestion for some technologies to be developed toward IoT healthcare systems. In sum this survey expected to be useful for researcher, engineers, health professionals, and developers in healthcare division who look toward developing IoT based systems.

REFERENCES

[1] J. Höller, V. Tsiatsis, C. Mulligan, S. Karnouskos, S. Alves and-and D. Boyle, "M2M and IoT Technology Fundamentals", From Machine-To-Machine to the Internet of Things, pp. 81-143, 2014.

[2] J. Höller, V. Tsiatsis, C. Mulligan, S. Karnouskos, S. Aves and and D. Boyle, "M2M to IoT – A Market Perspective", From Machine-To-Machine to the Internet of Things, pp. 39-59, 2014.

[3] J. Höller, V. Tsiatsis, C. Mulligan, S. Karnouskos, S. Aves and and D. Boyle, "Real-World Design Constraints", From Machine-To-Machine to the Internet of Things, pp. 225-231, 2014.

[4] J. Höller, V. Tsiatsis, C. Mulligan, S. Karnouskos, S. Aves and and D. Boyle, "M2M to IoT – An Architectural Overview", From Machine-To-Machine to the Internet of Things, pp. 61-77, 2014.

[5] M. Gigli and S. Koo, "Internet of Things: Services and Applications Categorization", Advances in Internet of Things, vol. 01, no. 02, pp. 27-31, 2011.

[6] Bandyopadhyay and J. Sen, "Internet of Things: Applications and Challenges in Technology and Standardization", Wireless Personal Communications, vol. 58, no. 1, pp. 49-69, 2011.

[7] Diaz, M., Juan, G., Lucas, O. and Ryuga, A., 2012, July. Big data on the internet of things: An example for the e-health. In Innovative Mobile and Internet Services in Ubiquitous Computing (IMIS), 2012 Sixth International Conference on (pp. 898-900). IEEE.

[8] G. Suciu, V. Suciu, S. Halunga and O. Fratu, "Big Data, Internet of Things and Cloud Convergence for E-Health Applications", New Contributions in Information Systems and Technologies, pp. 151-160, 2015.

[9] Doukas, C. and Maglogiannis, I., 2012, July. Bringing IoT and cloud computing towards pervasive healthcare. In Innovative Mobile and Internet Services in Ubiquitous Computing (IMIS), 2012 Sixth International Conference on (pp. 922-926). IEEE.

[10] K. Vasanth and J. Sbert. Creating solutions for health through technology innovation. Texas Instruments. [Online]. Available: http://www.ti.com/lit/wp/sszy006/sszy006.pdf.

[11] Lee, B.M., 2014. Design requirements for IoT healthcare model using an open IoT platform. Computer, 4, p.5.

[12] J. Gubbi, R. Buyya, S. Marusic and M. Palaniswami, "Internet of Things (IoT): A vision, architectural elements, and future directions", Future Generation Computer Systems, vol. 29, no. 7, pp. 1645-1660, 2013.

[13] Miorandi, S. Sicari, F. De Pellegrini and I. Chlamtac, "Internet of things: Vision, applications and research challenges", Ad Hoc Networks, vol. 10, no. 7, pp. 1497-1516, 2012.

[14] Yuan Jie Fan, Yue Hong Yin, Li Da Xu, Yan Zeng and Fan Wu, "IoT-Based Smart Rehabilitation System", IEEE Transactions on Industrial Informatics, vol. 10, no. 2, pp. 1568-1577, 2014.

[15] Kortuem, F. Kawsar, V. Sundramoorthy and D. Fitton, "Smart objects as building blocks for the Internet of things", IEEE Internet Computing, vol. 14, no. 1, pp. 44-51, 2010.

[16] L. Gao, "Building of Smart Home Medical System Based on Internet of Things", IOTCC, vol. 4, no. 3, p. 34, 2016.

[17] Fernandez, F. and Pallis, G.C., 2014, November. Opportunities and challenges of the Internet of Things for healthcare: Systems engineering perspective. In Wireless Mobile Communication and Healthcare (Mobihealth), 2014 EAI 4th International Conference on (pp. 263-266). IEEE.

[18] Boyi Xu, Li Da Xu, Hongming Cai, Cheng Xie, Jingyuan Hu and Fenglin Bu, "Ubiquitous Data Accessing Method in IoT-Based Information System for Emergency Medical Services", IEEE Transactions on Industrial Informatics, vol. 10, no. 2, pp. 1578-1586, 2014.

[19] Yang, G., Wan, Q. and Zheng, L.R., 2011, October. Bio-chip ASIC and printed flexible cable on paper substrate for wearable healthcare applications. In Proceedings of the 4th International Symposium on Applied Sciences in Biomedical and Communication Technologies (p. 76). ACM.

[20] Romero, L.E., Chatterjee, P. and Armentano, R.L., 2016. An IoT approach for integration of computational intelligence and wearable sensors for Parkinson's disease diagnosis and monitoring. Health and Technology, 6(3), pp.167-172.

[21] Tan, L. and Wang, N., 2010, August. Future internet: The internet of things. In Advanced Computer Theory and Engineering (ICACTE), 2010 3rd International Conference on (Vol. 5, pp. V5-376). IEEE.

[22] Marques and R. Pitarma, "An Indoor Monitoring System for Ambient Assisted Living Based on Internet of Things Architecture", International Journal of Environmental Research and Public Health, vol. 13, no. 11, p. 1152, 2016.

[23] Gubbi, R. Buyya, S. Marusic and M. Palaniswami, "Internet of Things (IoT): A vision, architectural elements, and future directions", Future Generation Computer Systems, vol. 29, no. 7, pp. 1645-1660, 2013.

[24] Z. Pang, ``Technologies and architectures of the Internet-of-Things (IoT) for health and well-being," M.S. thesis, Dept. Electron. Comput. Syst., KTH-Roy. Inst. Technol., Stockholm, Sweden, Jan. 2013.

[25] L. Yang, Y. Ge, W. Li, W. Rao, and W. Shen, ``A home mobile healthcare system for wheelchair users," in Proc. IEEE Int. Conf. Comput. Supported Cooperat. Work Design (CSCWD), May 2014, pp. 609_614.

[26] X. Jia, H. Chen, and F. Qi, ``Technical models and key technologies of e-health monitoring," in Proc. IEEE Int. Conf. e-Health Netw., Appl.Services (Healthcom), Oct. 2012, pp. 23_26.

[27] Zhang, G., Li, C., Zhang, Y., Xing, C. and Yang, J., 2012, October. SemanMedical: a kind of semantic medical monitoring system model based on the IoT sensors. In e-Health Networking, Applications and Services (Healthcom), 2012 IEEE 14th International Conference on (pp. 238-243). IEEE.

[28] X. M. Zhang and N. Zhang, ``An open, secure and flexible platform based on Internet of Things and cloud computing for ambient aiding living and telemedicine," in Proc. Int. Conf. Comput. Manage. (CAMAN), May 2011, pp. 1_4.

[29] N. Van Helleputte, J. Tomasik, W. Galjan, A. Mora- Sanchez, D. Schroeder, W. Krautschneider and R. Puers,"A flexible system-on-chip (SoC) for biomedical signal acquisition and processing", Sensors and Actuators A: Physical, vol. 142, no. 1, pp. 361-368, 2008.

[30] Tashtoush, Abdullah. "Detection of Fluorescent Bacteria Using VPNP Phototransistors Arrays Integrated on Multi-Labs-On-A-Chip System (MLoC)."

[31] Tashtoush, Abdullah. "Multi-labs-on-a chip based optical detection for atto-molar cancer markers concentration." In Information Technology: Towards New Smart World (NSITNSW), 2015 5th National Symposium on, pp. 1-7. IEEE, 2015.

[32] Tashtoush, Abdullah. "Novel Multibiosensors and Biomedical Application." In 2014 8th Asia Modelling Symposium, pp. 235-240. IEEE, 2014.

[33] Tashtoush, A.M., 2014. Miniaturized IC Biosensors on a Single Chip for Biological/Biomedical Applications. International Journal of Simulation--Systems, Science & Technology, 15(6).

[34] Yau, Chiew-Lian, and Wan-Young Chung. "IEEE 802.15. 4 Wireless mobile application for healthcare system." In Convergence Information Technology, 2007. International Conference on, pp. 1433-1438. IEEE, 2007.

[35] El Bouchti, Abdelali, Samir Bahsani, and Tarik Nahhal. "Encryption as a service for data healthcare cloud security." In Future Communication Technologies (FGCT), 2016 Fifth International Conference on, pp. 48-54. IEEE, 2016.

[36] Khan, M. Fahim Ferdous, and Ken Sakamura. "Security in healthcare informatics: design and implementation of a robust authentication and a hybrid access control mechanism." In Communications, Computers and Applications (MIC-CCA), 2012 Mosharaka International Conference on, pp. 159-164. IEEE, 2012.

[37] B. Rosser and C. Eccleston, "Smartphone applications for pain management", Journal of Telemedicine and Telecare, vol. 17, no. 6, pp. 308-312, 2011.

[38] Mosa, I. Yoo and L. Sheets, "A Systematic Review of Healthcare Applications for Smartphones", BMC Med Inform Decis Mak, vol. 12, no. 1, 2012.

[39] Zhao W., Wang C., and Nakahira Y. 2012. "Medical application on internet of things". IET Conference Publications. 2011 (586 CP): 660-665.

[40] Zhibo Pang, Lirong Zheng, Junzhe Tian, Sharon Kao-Walter, Elena Dubrova, and Qiang Chen. 2015. "Design of a terminal solution for integration of in-home health care devices and services towards the Internet-of-Things". Enterprise Information Systems. 9 (1): 86-116.

[41] Luo, Jingran, Yulu Chen, Kai Tang, and Junwen Luo. "Remote monitoring information system and its applications based on the Internet of Things." In 2009 International Conference on Future BioMedical Information Engineering (FBIE), pp. 482-485. IEEE, 2009.

[42] Xu, Boyi, Li Da Xu, Hongming Cai, Cheng Xie, Jingyuan Hu, and Fenglin Bu. "Ubiquitous data accessing method in IoT-based information system for emergency medical services." IEEE Transactions on Industrial Informatics10, no. 2 (2014): 1578-1586.

[43] Chiuchisan, Iuliana, Hariton-Nicolae Costin, and Oana Geman. "Adopting the internet of things technologies in health care systems." In Electrical and Power Engineering (EPE), 2014 International Conference and Exposition on, pp. 532-535. IEEE, 2014.

[44] Rohokale, Vandana Milind, Neeli Rashmi Prasad, and Ramjee Prasad. "A cooperative Internet of Things (IoT) for rural healthcare monitoring and control." In Wireless Communication, Vehicular Technology, Information Theory and Aerospace & Electronics Systems Technology (Wireless VITAE), 2011 2nd International Conference on, pp. 1-6. IEEE, 2011.

[45] Pang, Z., 2013. Technologies and Architectures of the Internet-of-Things (IoT) for Health and Well-being (Doctoral dissertation, KTH Royal Institute of Technology).

[46] Li, Xu, Rongxing Lu, Xiaohui Liang, Xuemin Shen, Jiming Chen, and Xiaodong Lin. "Smart community: an internet of things application." IEEE Communications Magazine 49, no. 11 (2011): 68-75.

[47] Hu, Z., 2011, August. The research of several key question of internet of things. In Intelligence Science and Information Engineering (ISIE), 2011 International Conference on (pp. 362-365). IEEE.

[48] Swan, Melanie. "Sensor mania! the internet of things, wearable computing, objective metrics, and the quantified self-2.0." Journal of Sensor and Actuator Networks 1, no. 3 (2012): 217-253.

[49] Hassanalieragh, Moeen, Alex Page, Tolga Soyata, Gaurav Sharma, Mehmet Aktas, Gonzalo Mateos, Burak Kantarci, and Silvana Andreescu. "Health monitoring and management using internet-of-things (iot) sensing with cloud-based processing: Opportunities and challenges." In Services Computing (SCC), 2015 IEEE International Conference on, pp. 285-292. IEEE, 2015.

[50] Yang, Geng, Li Xie, Matti Mäntysalo, Xiaolin Zhou, Zhibo Pang, Li Da Xu, Sharon Kao-Walter, Qiang Chen, and Li-Rong Zheng. "A health-IoT platform based on the integration of intelligent packaging, unobtrusive bio-sensor, and intelligent medicine box." IEEE transactions on industrial informatics 10, no. 4 (2014): 2180-2191.

[51] Kizhakkepurayil, Sarin, Oh Jeon-Yeoul, and Young Lee. "Mobile application for healthcare system-location based." In Innovations and Advances in Computer Sciences and Engineering, pp. 297-302. Springer Netherlands, 2010.

[52] Doukas, Charalampos, Thomas Pliakas, and Ilias Maglogiannis. "Mobile healthcare information management utilizing Cloud Computing and Android OS." In 2010 Annual International Conference of the IEEE Engineering in Medicine and Biology, pp. 1037-1040. IEEE, 2010.

[53] Abuzaghleh, Omar, Miad Faezipour, and Buket D. Barkana. "SKINCURE: AN INNOVATIVE SMART PHONEBASED APPLICATION TO ASSIST IN MELANOMA EARLY DETECTION AND PREVENTION." Signal & Image Processing 5, no. 6 (2014): 1.

[54] Abushakra, Ahmad, and Miad Faezipour. "Augmenting Breath Regulation Using a Mobile Driven Virtual Reality Therapy Framework." IEEE journal of biomedical and health informatics 18, no. 3 (2014): 746-752.

[55] Al Alkeem, Ebrahim, Chan Yeob Yeun, and M. Jamal Zemerly. "Security and privacy framework for ubiquitous healthcare IoT devices." In 2015 10th International Conference for Internet Technology and Secured Transactions (ICITST), pp. 70-75. IEEE, 2015.

[56] Amendola, Sara, Rossella Lodato, Sabina Manzari, Cecilia Occhiuzzi, and Gaetano Marrocco. "RFID technology for IoT-based personal healthcare in smart spaces." IEEE Internet of things journal 1, no. 2 (2014): 144-152.

[57] Santos, Alexandre, Joaquim Macedo, António Costa, and M. João Nicolau. "Internet of things and smart objects for M-health monitoring and control." Procedia Technology 16 (2014): 1351-1360.

[58] Patra, Litun, and Udai Pratap Rao. "Internet of Things—Architecture, applications, security and other major challenges." In Computing for Sustainable Global Development (INDIACom), 2016 3rd International Conference on, pp. 1201-1206. IEEE, 2016.

[59] Ometov, Aleksandr, Pavel Masek, Lukas Malina, Roman Florea, Jiri Hosek, Sergey Andreev, Jan Hajny, Jussi Niutanen, and Yevgeni Koucheryavy. "Feasibility characterization of cryptographic primitives for constrained (wearable) IoT devices." In 2016 IEEE International Conference on Pervasive Computing and Communication Workshops (PerCom Workshops), pp. 1-6. IEEE, 2016.

[60] Laranjo, Isabel, Joaquim Macedo, and Alexandre Santos. "Internet of things for medication control: Service implementation and testing." Procedia Technology 5 (2012): 777-786.

[61] Tan Xue-Qing, Fu Rui-Ping, Gao Qian. Identification is the Foundation of Internet of Things[J]. Automatic Identification Technology of China, 2009.

[62] Salehi, S.A., Razzaque, M.A., Naraei, P. and Farrokhtala, A., 2013, July. Security in wireless sensor networks: Issues and challanges. In Space Science and Communication (IconSpace), 2013 IEEE International Conference on (pp. 356-360). IEEE.

[63] Suo, H., Wan, J., Zou, C. and Liu, J., 2012, March. Security in the internet of things: a review. In Computer Science and Electronics Engineering (ICCSEE), 2012 international conference on (Vol. 3, pp. 648-651). IEEE.

[64] G. Gan, Z. Y. Lu, and J. Jiang, "Internet of Things Security Analysis," in Proc. of 2011 Int. Conf. on Internet Technology and Applications (iTAP), Aug. 2011.

[65] Mayer, C.P., 2009. Security and privacy challenges in the internet of things. Electronic Communications of the EASST, 17.

[66] M. Langheinrich, "Privacy by design-principles of privacy-aware ubiquitous systems," In Proc. of Ubicomp, pp. 273-291, Oct. 2001.

[67] T. Polk, and S. Turner. "Security challenges for the internet of things," http://www.iab.org/wp-content/IAB-uploads/2011/03/Turner.pdf.

[68] Liang Zhou, Han-Chieh Chao, "Multimedia Traffic Security Architecture for the Internet of Things", IEEE Network • May/June 2011.

[69] Chen, M., Gonzalez-Valenzuela, S., Zhang, Q. and Leung, V., 2010. Software agent-based intelligence for code-centric RFID systems. IEEE Intelligent Systems, (1).

[70] L. Zhou et al., "Context-Aware Multimedia Service in Heterogeneous Networks," IEEE Intelligent Sys., vol. 25, no. 2, Mar./Apr. 2010, pp. 40–47.

[71] Lu Tan, Neng Wang, "Future Internet: The Internet of Things", 2010 3rd International Conference on Advanced Computer Theory and Engineering(ICACTE).

[72] "Gartner Says the Internet of Things Installed Base Will Grow to 26 Billion Units By 2020." [Online]. Available: http://www.gartner.com/newsroom/id/2636073. [Accessed: 18-Oct-2015].

[73] Alqudah, Ali Mohammad, et al. "Developing of robust and high accurate ECG beat classification by combining Gaussian mixtures and wavelets features." Australasian physical & engineering sciences in medicine (2019): 1-9.

[74] Institute de l'audiovisuel et des télécommunications en Europe (France), Internet of Things: Outlook for the Top 8 Vertical Markets. IDATE, 2013.

[75] Miranda Mowbray, HP Internet of Things Research Study,1 Aug. 2015.