Survey Based Analysis of Internet of Things Based Architectural Framework for Healthcare System

[1] Mohammad Nuruzzaman Bhuiyan, [2] Dr. Md. Mahbubur Rahman, [3] Md. Aktarujjaman

[1] (Ph.D. Fellow), [2] Professor, Islamic University, Bangladesh, [3] BSc in Software Engineering, Daffodil International University, Bangladesh

[1] mdnuruzzaman2001@yahoo.com, [2] drmahbub\_07@yahoo.com, [3] akhtarspondon@gmail.com

***Abstract*— Healthcare is an important gradation in life and IoT has made this healthcare a get-at-able, easy way to live. Its popularity in the world of technology and the internet, IoT is increasing in every field of life with the health sector. Due to the hypnosis feature, IoT is becoming more focused on the healthcare industry. However, although, it has not yet been implemented for the wider scope of hospitals around the developing countries. Among many IoT tools, IoT brings tools to strengthen the workplace such as health, safety, and the medical environment. In this paper, introduce and describing a comprehensive survey of IoT concerning IoT Technologies, Healthcare methods, statistics, System architecture, enabling technologies, security and privacy issues and success cases applied in healthcare. This paper will explore the relationship between Physical System in Healthcare (PSH) and IoT based Healthcare, both in which play an important role in intelligent Cyber worlds but IoT is a vital role. Moreover, we surveyed to investigate between the edge computing and IoT based Healthcare and discuss issues in edge computing. The results of the investigation can be applied in developing countries.**

Keywords— **Physical System in Healthcare (PSH), Hospital Management System (HMS), Survey, Internet of things (IoT).**

1. INTRODUCTION

The term of IoT (Internet of Things) defines a network connected to the physical objects through the Internet. These physical objects include technology to interact with the internal factors as well as the external environment. IoT is an interconnected computing device, the mechanical and digital machine that provides unique identifiers (Unique identifiers UIDs are commonly used in the healthcare industry, reporting medical information such the patient's name, creating the personal code) to the objects, animals or humans, and the ability to transfer data through a network, which can perform human-to-computer interactions [1]. The Internet of Things (IoT) seamlessly opens up a world of possibilities treatment in the biodiversity and the advancement of technology changing the world of thought as well as the development of smartphones and other handheld gadgets.

Over the past few years, modern technology and gadgets have been developed to monitor the critical resources in healthcare and other hospitals. But most of these systems are just maintaining a database of patients. These systems have just implemented telemedicine by the way of technologies of telecommunication, teleconferencing and video conferencing. Literature has shown that these systems lack of quality and are expensive and we need a better communication and monitoring system.

If we talk about HMIS from all around the world, there are some countries, which have better mobile patient care systems. We have discusses the basics of IoT for Healthcare such as IoT Technologies, Healthcare Methods, System Architecture, Enabling Technologies, Security issues and success cases applied in healthcare and describe the relationship between physical and IoT in Healthcare. In the Physical system, we need to physically attend our hospital and be treating in our modern life. But IoT in Healthcare we don’t physically attend the hospital. So, we save time and cost. Finally, we will analyze the Hospital Management system with real data.

1. RELATED WORKS INSTANCE OF ACCOMPLISHMENT IN IOT HEALTHCARE

The broader centralization and interconnection capabilities of IoT technology are difficult to over-review. Let’s contemplate on IoT endowments in healthcare in more details. IoT smart healthcare brings health observation, remote monitoring, physical hospital and digital infrastructure of IoT organization and we say that in the age of medical health is a whole new balance is relevant in IoT. NHS England - an 'executive non-departmental public body of the Department of Health and Social Care'- announced that it will support a remote diabetes treatment solution in 2018 [2]. They also stated that thousands of people with diabetes across the country are benefited from glucose monitors on the NHS. Monitoring data can be easily accessed through mHealth technology.

An investigation, the survey [3] by Amna Pir, M. Usman Akram has shown that the statistical data in the Medical sectors. He presented an IoT based on the architectural framework with a context of awareness for hospital management systems. This survey to investigate the decision to adopt the IoT based system in Pakistani Hospitals. The accumulated results indicate that participants want to adopt this system and most of the group of people agreed that IoT based HMIS would provide better monitoring and earlydiagnosis to improve the outcomes.

The survey [4] by Asst. Prof. M. Gokilavani discussed numerous healthcare IoT strategies and processes, and also end up with some major problems. They faced challenges during the developing those systems and the security issues and also have the concern of identification as a future extension for upcoming projects.

In [5] Lei Yu et.al proposes an architecture of smart hospital bases on IoT in order to overcome the disadvantages and his experiment proves the smart hospital can effectively solve the prominent problems existing the diagnosis and treatment of hospital and it brings a positive and profound effort for the present diagnosis and treatment model in hospital.

Luca [6] et.al proposes a smart architecture automatic monitoring and tracking of patients, biomedical devices within hospital and nursing institutes. A smart hospital system (SHS) which relies in technologies, specifically RFI, WSN and smart mobile. The SHS is able to collect in real time data with the Hybrid Sensing Network (HSN).

By Aminian [7] et.al presents a monitoring system that has the capability to monitor physiological parameters from multiple patient bodies. In the proposed system, a coordinator node has attached on patient body to collect all the signals from the wireless sensors. This system can detect the abnormal conditions, issue an alarm to the patient and send a SMS/E-mail to the physician. And the system in multi-patient architecture for hospital healthcare and compared it with the other existing networks based on multi-hop relay node in terms of coverage, energy consumption and speed.

In [8] G. Zhang et.al design a kind of semantic medical monitoring system model in the cloud based on the IoT sensors. All massive sensor data will be stores into the HDFS. Design two algorithm (1) massive semantic medical roles processing algorithm without external communication and (2) massive semantic medical roles processing algorithm with external communication.

In [9] Lin Yang et.al recommended to the architecture of the Internet of Things, toward a home health monitoring Service. The polishing index method is applied to the data observations from the human health index, a body temperature detection test, have tested the potential of the proposed four-session (Perception layer, Coordination layer, Network layer, and Application layer) system.

Lin Yang [10] et.al presents a home mobile healthcare system for wheelchair consumer and this paper focused on the wireless body area network.

Jeon, Soobin [11] et.al propose smart shoes system a simple, out-towing and in-towing gait to provide the gait information to the customer. This paper also showed that the proposed system can measure accurate gait distortion.

Meetoo [12] et. al in this paper shown that the smart tattoo represent a nascent nanotechnology, which is the technology reliable glucose detection for individuals diagnosed with diabetes.

1. CONTRIBUTIONS OF THIS WORK

The oddment of this paper are organized as follows. In the main enable technologies of the section IV, highlighting various IoT healthcare services platforms where a patient can be use healthcare technology. Section V, We discuss supported healthcare technology in the hospital management system for a Patient. In section VI, We will classifying existing IoT based healthcare network infrastructure such as Topology, Architecture and the platform. In section VII, we addresses the miscellaneous healthcare services and applications using a real life case study in the medical domain. Providing a comprehensive survey in IoT healthcare industry trends and status in section VIII. Section IX, Providing extensive acumen in the IoT market opportunity. Section X, we discuss security and privacy for the solution of IoT. Section XI, providing various IoT healthcare policies for supporting the physician, doctor and policymakers in over the world, Section XII, XIII, XIV, we includes a discussion benefits, challenges, and future of the IoT healthcare,

**describe about Smart wearable technologies in the modern age of life and shows some statistical date.**

1. USED OF IOT TECHNOLOGIES IN HEALTHCARE
2. *Radio Frequency Identification (RFID):* Radio Frequency Identification (RFID)is a technology and system that transmits data and which is used to detect sensors.

The Healthcare system is becoming more and more invested in RFID technology.So, recent market research has revealed there will be an exponential growth of RFID technology in that industry by 2021 [13]. One of the reasons that RFID is expanding considerably in the industry is the sheer number of applications that can benefit. In hospitals that have been outfitted with the technology, RFID is present in many forms – from the tracking of surgical tools to tracking patients and staff. RFID Collected data and sent to a Local Area Network a database installed server. Users can retrieve the data using an application installed on the server (Togt, Bakker, and Jaspers, 2011) [14]. While RFID has been implemented in Healthcare, limited adoption and use of RFID remains some challenges (Chong, Liu, Luo, and Boon, 2015) [15].

Some of the RFID applications being deployed in hospitals all over the world:

1. **Medicine** Inventory Tracking and Authentication:

RFID can be achieved with tracking inventory almost any type of clauses or items however, but effectively the tracking RFID systems can be challenging when tracking liquid-filled assets. There is a growing and changing supply of hospital medicine that should be tracked to keep them in bulk for their patients. RFID can reduce the amount of time spent counting, pharmaceuticals can be calculated, accurate data can be confirmed, and medicines are available in the right type and quantity in hands. Some hospitals and pharmaceuticals also use RFID tags for authentication [16].

1. **Patient,** Attendees Tracking:

Some hospitals are using RFID technology as well as instances of active RFID to track patients and Attendees throughout the hospitals. Patients and staff are given RFID Tags for 4 reasons.

* + - 1. For verify patents information.
      2. Reduce waiting time for patents and staff.
      3. To locate patents.
      4. For staff workflow.

Hospitals have used active RFID in Real-Time Location Systems (RTLS) to identify problems [17].

1. **Medical Equipment’s** Tracking:

Medical equipment such as hospital beds, testing machines, doctors useable scalpels, scissors, clamps, and retractors, etc. are needed for surgeries that need to always be on hand, clean, disinfect, and ready to use. The RFID tags ensure that each equipment was disinfected before use, a properly implemented system can apply lighting to individual equipment in a sterile manner. Using an RFID tag is the way to keep tracking of these assets for the smart hospitals [18].

1. **Security:**

Security is another factor such as unauthorized access, access ability, and use of hospital equipment to certain rooms or areas to prevent people. By using the RFID tag, the hospital's security can be ensured and secure for all systems [16]. Theinformation provider should able to use from observing the use of the system. A system administrator must be able to implement access control on user information.

1. *Edge Computing:* With a healthcare industry important as, the adoption of Edge Computing will drive the healthcare towards a brighter future. Edge Computing offers the healthcare sector a very practical, accessible and deployable technology that is likely to be a game-changer for hospitals and clinics around the world. The network architecture, pushing specific data, processing, and services away from the centralized infrastructure of the cloud to the edge of the network where the data raise [19] [20]. The edge computing is compacted between the cloud and all IoT Health devices add important features to the system:
   * + 1. **Real-time data analytics and solve data problem:** Time-sensitive application is a necessity to process and act on health data in seconds. Creating a large amount of data through these IoT edge devices can be valuable, but the responsibility of managing and maintaining it also poses a challenge for healthcare providers. Numerous of this data is unstructured and not well-defined, flooding cloud infrastructures that are often not ready to run the powerful analytical programs needed to manage it in an easy-to-use way. Edge computing applications have the efficient to solve this data problem. The powerful machine learning algorithms hosted in edge computing data centers that maintain the highest standards in regulatory compliance [19] [21].
       2. **Traffic Reduction:** The limited network bandwidth, it is not enough and not necessary to transfer enormous the volume of raw big data from millions of e/mHealth devices to the cloud. Edge computing reduces data transport costs, reduce data stolen, and filter and compact the medical data before delivering which can be significant for data-intensive applications [20].
       3. **Device Management and Data Delivery:** Device management includes device discovery, count how many devices are used in hospitals, device registration and login, and device control. Edge nodes can use three data delivery techniques (i) Message-based (ii) Request-based and (iii) Publish-based [19].
       4. **Supply Chain Management:** The more exciting edge computing uses involves the operation of industrial supply chains management. The way medical facilities on sensor-equipped IoT edge devices can revolutionize the way of handle inventory. Inventory management based on smart RFID tags can remove time-consuming papers and manual sequences when data collection devices on usage patterns can use predictive analytics to determine the hardware is likely to fail. Fleet cars equipped with GPS and other sensors can track the location of important shipments in real-time. For organizations struggling to control rising costs, IoT health care supply chain innovations provide an opportunity to gain operational efficiency at the margins and represent one of the most compelling edge computing uses [19].

Edge computing can soon qualify the Medical industries with the ability to perform without connecting to a remote data center. On-edge computing with intelligent of IoT will be able to collect patient data, transfer, analysis data to the local clinic or doctor, and give physician staff almost real-time information. Patient data, can be reviewed with the doctor if the patient is not present and without an appointment.

1. *Two-dimensional Code:* A barcode is a visual means of representing data that can be read by a machine to retrieve the data. Barcode must be readable by barcode scanners. The common formats are 16 color BMP, GIF, JPEG, PNG, TIFF, two-dimensional bar code image etc. Those data are generally either handwritten or typed into an electronic medical record (EMR) system frequently missing or incorrect reports. The 2D barcode can allow fast, accurate, and automatic capture of these data by a handheld imaging device, which can prolong these fields to an EMR and / or IIS. The critical component is that the 2D barcode is used for identifying the medicine information, medicine expiration date etc. [22].

***Patient info Identification Wristbands*:** The patient's wristbands of the hospital identification system, and display patient identification is enhanced using 2D barcodes. 2D barcode wristbands can make scanning easier when printed around the surface of the band and facilitate patient identification [23].

1. *Sensors:* Sensors and wearable devices are more precise and more efficient treatment, and providers are affordable in the healthcare sector.Healthcare IoT sensors enable medical equipment to be assembled and share data with each other, along with the cloud, to facilitate the collection data that is analyzed at a constant speed. The Healthcare IoT sensors must be wearable, cloud-based, or device-embedded and the Healthcare sector accumulation of patient data for preventive treatment [24]. A sensor device monitors insulin dosages and transmits information to an application on the user's mobile phone [28]. This reduces the need for the manually record insulin and provides optimal diabetes management [24]. One type of sensor, the solid-state image sensors are integrated circuits that includes a number imaging sites for the purpose of convert optical images focused on the electrical signals. These devices can be classified into three main types: (1) charge-coupled devices (CCDs), (2) charge injection devices (CIDs), and (3) CMOS image sensors (CISs) [25] [26] [27].
2. IOT HEALTHCARE APPLICATIONS

The section addresses the miscellaneous healthcare applications of Authentication for patients, doctors and Internal and External stakeholder, Identification, sensing and Communication, Remote Monitoring Mobile Personal Assistance, Smart Devices, Telemedicine, Data Collection, Smart phone apps Solution through smart applications.

* + - 1. **Authentication and Identification:** Authentication is a process that ensures a user's identity that is username and password to the healthcare system for gaining access.It includes patient identification that can be reduced maintenance and identification of elaborate electronic medical records for the prevention of miscellaneous patients. In relation to the staff, identification, and authentication is often used to allow and improve employee morale access by addressing issues related to patient safety. Identification and authentication are primarily used to meet the requirements of security procedures to avoid theft or losses important products [28].
      2. **Remote Health Monitoring:** The health monitoring system is growing in popularity day by day. Because Remote health monitoring has the potential to significantly improve a patient's quality of life and both patients and doctors want to monitor health without the clinical environments. A monitoring device requires a sensor that measures recent patients physiological data compare with old data. It can wirelessly communicate with patients and doctors. [Here add a figure]

A wireless body area network (WBAN) sensor devices located inside or outside of the patient body. Patient data can be accessed online using the internet remote locations with MQTT (Message Queuing Telemetry Transport) layer protocol which is used to transmit message services. A Pattern matching algorithm is comparing the recent health data with exiting data enable to analyze further. If there any diseases is identified, then pass the information to the caretaker and if the situation is serious then data can be transmitted to the doctor or alarm for an ambulance [29] [30]. [Here add a figure]

* + - 1. **Mobile Personal Assistance:** The personal assistants are not a new trend. The daily activities and personal health work for many years. Mobile personal algorithm automatically collects information about a patient location, heart rate, diabetics etc. Then it forwards the collected information to a caretaker or doctor, and they will take proper actions. It works with mobile gateway service acts as a liaison. Intelligent Personal Assistants for IoT situations can increase mHealth capacity for gain to more knowledge and awareness of their environment.

Available enables the creation of Mobile Personal Assistant technology on smartphones well-known Personal Digital Assistant (PDA) such as Apple's Siri, Google Now, Samsung's S Voice, and Microsoft’s Cortana, Amazon's Alexa, Google Assistant [31].

* + - 1. **Smartphone apps Solution:** Doctors and engineers have combined forces to develop these knowledgeable medical smartphone applications for healthcare. The smart devices we use to access data will take away the burden of a limited number of human specialists we have. AI Applications can communicate the human body, collect the patient health information/data and forward it to the doctor for future treatment. These applications include from diabetes monitoring tools to Artificial Intelligence (AI) with diagnostic devices. Some applications working for Real-Time Data Gathering, Remote Monitoring, Tracking and Alerts, and Aging with Peace of Mind by capturing users' blood glucose information and transmitting it to real-time data the healthcare professionals.

Various research studies focused on common diseases such as diabetes. The goal of other research is to increase the health of the general people. Here we have listing some of the life-changing medical technology smartphone applications developed over the past few years where patients and doctors can communicate with each other [32].

Diabetes Manager by WellDoc.

Medici.

Clinical Trial Seek.

Skin Vision.

Ada - health guide.

Babylon.

Lumify

1. HEALTH WEARABLE’S SMART TECHNOLOGY

Wearable devices will continue to play a significant role in providing huge benefits to patients and healthcare providers. Long-term patient data using a wearable device can help medical professionals get a better view and better treatment. Using this technology properly, it can be healthier and reduce the strain on the healthcare system potentially reduce 20% healthcare costs and decrease their sickness [33]. Here we have to do discus how a person improves his or her quality of life based on smart wearable devices. It also shows some statistical data about the consumers that relevant to buy, how much and what consumers want to track next. Most wearable’s interface interconnected with mobile apps (mHealth).

|  |  |
| --- | --- |
| Popular mHealth Wearable Devices | Types of Biometric Collected data |
| Pedometers/Smart Shoes | Calories burned, Movement patterns, Steps |
| Activity-tracking bands | Time of activity |
| Mobile blood pressure monitors | Body temperature, blood pressure, Sweat analysis, Tissue oxygenation, Glucose level, Oxygen level |
| Chest, calf and ankle straps/bands | Heart rate (heart rate variability) |
| Virtual reality and augmented reality headsets | Sleep quantity and quality |
| Hearables Earwear | Emotional state |
| Smart jewelry | Heart rhythm |
| Mobile electrocardiogram(ECG) | Muscle bio-signals (electromyography).  Cardiorespiratory function, ECG |
| Smart Glasses | Brainwaves(electroencephalogram), Cognitive function |

Table 1: Wearable’s Technology and Types of Biometric data collected.

[Source: Consumer Technology Association, Forbes.com. ( Kraudel, Ryan. National Wearables Survey Reveals Accelerating Convergence of Consumer Wearables and Personal Health & Medical Devices. Valencell [33]. ]

* + - 1. **Smartwatch:** Smartwatches look like a fashion but its uses is very essential for health monitoring. Smartwatches are the perfect associate in maintaining patient health. The watch has an integrated heart rate detector or monitor that helps evaluate the heart rate. This device sends notification that needs to do more exercise, or it can alarm when consumers exerting too much effort. The Smartwatch can effectively monitor users' heart rate, it is a great way to avoid damaging your health [37].
      2. **Wrist Sensors:** The most convenient place to wear a wrist device it is on the wrist because it is a very common place to wear a watch and other modern devices. The wrist has been in used ever since to wear a dawn bracelet and watch, for reason attaching a device to the wrist and it’s easy to reading.The wrist biological sensors and actuators measurements physiological information such as temperature, skin electrical transport, altimetry, blood oximetry, and heart rate. The Wrist Monitoring Device the wearable component gathers vital information. Wrist Monitoring Device transmit the data to a remote telemedicine center for further analysis and emergency care, using GSM cellular infrastructure [34].
      3. **Smart Clothing:** Smart clothes monitor the wearer’s heart, breathing, body temperature promise to revolutionize medication by reducing hospital visits and conform patients to lead better lives. There are two types of Smart Clothes (1) Biomedical Smart Clothes (Sensor close to skin, Biomedical Purpose), (2) Communication (Sensor Device, in pocket, and fabric).

The Smart Clothing monitor of chronic diseases, heart rate, skin blood flow, temperature, pressure mapping etc. The T-shirt incorporates smooth, dry ECG electrodes, a fall sensor, a breathing-rate sensor, two temperature sensors, and a GPS receiver. T-shirt connect to the GPRS module used for data transmission [34].

* + - 1. **Smart tattoos:** Researchers at Harvard and MIT have created a smart tattoo ink capable of health monitoring. On the human skin, the tattoo sensor shows on the skin only after exposure to UV light and the other skin sensor becomes visible at different temperatures. Researchers have tested this chemical sensor on pig skin. After testing on the pigs, some of the tattoo sensor now it works on the human body [35].
      2. **Smart shoes:**

The Wearable Smart Technology helps the consumers for understand health in three ways: Tracking daily activity, sharing daily activity with friends and family, sharing personal health information with doctor, coach, or trainer.

|  |  |  |  |
| --- | --- | --- | --- |
| Consumers want to buy | | Consumers want to track next | |
| Fitness Monitoring | 55 % | Would like to monitor blood pressure, up from 46% in 2016 | 55 % |
| Smartwatches/Smart glasses | 46 % | Would like to monitor stress, down from 55% in 2016 | 50 % |
| Wrist Sensors | 25 % | Would like to monitor heart health | 49 % |
| Smart Clothing | 15 % | Would like to monitor blood sugar levels | 33 % |
| Smart Shoes | 10% | Would like to monitor gait assessment. | 30 % |
| Smart Contact Lenses | 4 % | Would like to Emotional state | 10 % |
| Smart Tattoos | 3% | Would like to blood Glucose level | 5 % |

Table 2: Consumers Try To Make Sense Of Wearable Technology.

[Source: Consumer Technology Association, Forbes.com. ( Kraudel, Ryan. National Wearables Survey Reveals Accelerating Convergence of Consumer Wearables and Personal Health & Medical Devices. Valencell [33]. ]

CHALLENGES OF IOT IN HEALTHCARE

**As much as the Internet of Medical Things seems** to be revolutionary and highly-efficient, there are still some major challenges of IoT in healthcare this tech concept must overcome down the road. With large, game-changing integrations such as this one, there comes along a myriad of technical difficulties and adaptation issues. The main include:

Underdeveloped initiatives. Many IoMT initiatives directed at battling chronic diseases or other issues still need time to grow and develop. This technological niche as a whole must grow a lot in order to start providing regular enhancement results.

Possible lack of available memory. IoT sensors and devices can general colossal amounts of data, all of which is important and needs to be analyzed. This poses a question of huge data repositories that must hold all those volumes of info for indefinite terms.

Difficulties with regular updates. With so many hardware solutions comes as much software for powering and managing it all. This software must be timely updated in order to run smoothly and stay at its latest version. And here’s where constant updates will require lots of effort and might spawn many technical issues.

Personal sensitive data security. An IoT-powered medicine is a hardware-backed system that functions through the Internet. And online systems get hacked and breached. This spawns a chance of important private data being potentially undermined.

Global healthcare regulations. The IoMT still has to be approved by global healthcare regulatory bodies worldwide. This will take time and may keep many innovations at bay just because of some formalities.

ADVANTAGES AND DISADVANTAGES OF IOT IN HEALTHCARE

Considering the above-mentioned challenges of IoT in healthcare, there are, indeed, downsides as well as benefits when it comes to the medical IoT.

Advantages of IoT in healthcare

The ‘all-consuming’ connection of health devices and data centralization brings many significant benefits to the table, such as:

All-around technological enhancement. Renderinghospital visits unnecessary, passively accumulating and deeply analyzing important health data, etc. We’ve already pondered on all these advanced techcapacities galore enough. The IoMT provides space for fantastic long-term innovations.

Cost savings. One of the greatest advantages of IoT in healthcare is that efficient autonomous systems will cost less to manage and ‘employ’ in the long run. Things are even better when it comes to patient cost savings due to fewer hospital journeys as well as accelerated diagnostics and treatment.

Accessibility. Doctors can view all the necessary data on command and check real-time patient conditions without leaving their office.

Disadvantages of IoT in healthcare

Alternatively, some downsides that come along with the massive implementation of the IoT in healthcare include: Privacy can be potentially undermined. As we’ve already mentioned, systems get hacked. Lots of attention will need to be focused on data security, which requires significant additional spending. Unauthorized access to centralization. There is a chance that dishonest interlopers may access centralized systems and realize some cruel intentions.

Global healthcare regulations. International health administrations are already issuing guidelines that must be strictly followed by governmental medical establishments integrating the IoT in their workflow. These may restrict possible capacities to some extent.

IOT TRENDS IN HEALTHCARE OF 2019

In 2019, there can be defined several IoMT trends implemented by majorities of startups worldwide. Wearables continue to top the market. Major mobile technology providers like Apple and Android are enhancing and updating their authentic wearables, adding them with more health tracking features. And the rest of the world isn’t shy to follow the tendency, spawning numerous various-purpose mini devices. Surgical robotics become a common reality. AI-powered, robotic surgical means show to be more precise than real doctors on more than one occasion. There are still limitations and risks involved, but the technology is definitely in the spotlight and is looking to become more widespread in the nearest future. Integration of other prominent technologies with the IoT expands the horizon. AI, AR, Machine Learning, Big Data, blockchain, and smart contracts — all of that fuel up and expands the IoT powers even further. AI is already better and far more precise in predicting, for one instance, women’s breast cancer.

FUTURE OF IOT IN HEALTHCARE

Full-blown smart hospitals by 2020, mHealth as a regular, common thing on a global scale, and reduced physical visits to hospitals — this is only an approximate picture of the IoMT success. With that being said, as young as the concept is, it isn’t really regarded to be that novel by progressive hospitals of the now. Most of them are either implementing major IoT techniques or capabilities or already have enhanced parts that are in their calibration stage.

SUMMARY

Let us emphasize once more that the IoT can be nothing short of a revolution in the field as important on the global scale as healthcare. There are still many difficulties, peculiarities, and technological obstacles to overcome. And even though there are, currently, downsides as well as advantages to the concept, things seem to go very well for this technological innovation.

We are pretty confident that if you ask most medical professionals about their opinion on the subject, they will say that full IoMT integration and adaptation is the only logical way of development for advanced medicine of the future.

With that being said, enjoy the life-saving, health-improving fruits of the massive technological progress.

1. Patnaik, Alankrit, and Deepak Gupta. "Unique identification system." International Journal of Computer Applications 7, no. 5 (2010): 46-51.
2. <http://www.pharmatimes.com/news/nhs_to_fund_continuous_blood_glucose_monitoring_system_1260230>
3. Amna Pir Muhammad; M. Usman Akram ; Muazzam A. Khan "Survey Based Analysis of Internet of Things Based Architectural Framework for Hospital Management System".
4. Asst.Prof. M.Gokilavani, Asst.Prof. Gripsy Paul Manickathan, Dr. M.A.Dorairangaswamy "A SURVEY ON IOT MEDICARE APPLICATION: ISSUES AND CHALLENGES", International Research Journal of Computer Science (IRJCS) ISSN: 2393, Issue 04, Volume 6 (April 2019)
5. Lei Yu School of Computer and Information, Hefei University of Technology, Hefei, China 2 School of Medical Information Technology, Anhui University of Traditional Chinese Medicine, Hefei, China Email: fishstonehfut1006@163.com Yang Lu, XiaoJuan Zhu School of Computer and Information, Hefei University of Technology, Hefei, China Email: luyang.hf@126.com, xjzhu@aust.edu.cn “Smart Hospital based on Internet of Things” ,10 October 2012.
6. Catarinucci, Luca, Danilo De Donno, Luca Mainetti, Luca Palano, Luigi Patrono, Maria Laura Stefanizzi, and Luciano Tarricone. "An IoT-aware architecture for smart healthcare systems." IEEE Internet of Things Journal 2, no. 6 (2015): 515-526.
7. Aminian M, Naji HR (2013) A Hospital Healthcare Monitoring System Using Wireless Sensor Networks. J Health Med Inform 4: 121. doi:10.4172/2157-7420.1000121
8. 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 2012 IEEE 14th International Conference on e-Health Networking, Applications and Services (Healthcom) (pp. 238-243). IEEE.
9. Jingjing, Yang, Hao Shangfu, Zhang Xiao, Guo Benzhen, Liu Yu, Dong Beibei, and Liu Yun. "Family health monitoring system based on the four sessions internet of things." Telkomnika 13, no. 1 (2015): 314
10. Yang, L., Ge, Y., Li, W., Rao, W., & Shen, W. (2014). A home mobile healthcare system for wheelchair users. Proceedings of the 2014 IEEE 18th International Conference on Computer Supported Cooperative Work in Design (CSCWD). doi:10.1109/cscwd.2014.6846914
11. Jeon, Soobin, Chungsan Lee, Youngtak Han, Dongmahn Seo, and Inbum Jung. "The smart shoes providing the gait information on IoT." In 2017 IEEE International Conference on Consumer Electronics (ICCE), pp. 108-109. IEEE, 2017.
12. Meetoo, D., Wong, L., & Ochieng, B. (2019). Smart tattoo: technology for monitoring blood glucose in the future. British Journal of Nursing, 28(2), 110–115. doi:10.12968/bjon.2019.28.2.110
13. I. Erguler, “A potential weakness in RFID-based Internet-of-Things systems”, Pervasive and Mobile Computing, vol. 20, pp: 115-126, 2015.
14. Piet. J.M.Bakker Monique W.M.Jaspers, “Journal of Biomedical Informatics”, Volume 44, Issue 2, April 2011, Pages 372-383, Received 27 March 2010, Available online 17 December 2010.
15. Yee-Loong Chong, A., Liu, M. J., Luo, J., & Keng-Boon, O. (2015). Predicting RFID adoption in healthcare supply chain from the perspectives of users. International Journal of Production Economics, 159, 66–75. doi:10.1016/j.ijpe.2014.09.034
16. <https://blog.atlasrfidstore.com/7-things-can-track-hospitals-using-rfid>
17. <https://www.atlasrfidstore.com/rfid-readers/>
18. <https://www.atlasrfidstore.com/sensor-rfid-tags/>
19. Firouzi, Farshad, Bahar Farahani, Mohamed Ibrahim, and Krishnendu Chakrabarty. "Keynote paper: From EDA to IoT eHealth: promises, challenges, and solutions." IEEE Transactions on Computer-Aided Design of Integrated Circuits and Systems 37, no. 12 (2018): 2965-2978.
20. <https://www.healthitoutcomes.com/doc/edge> computing-and-healthcare-looking-to-the-future-0001
21. <https://dzone.com/articles/the-future-of-healthcare-starts-with-edge-computin>
22. Tan, Jasper, and Simon GM Koo. "A survey of technologies in internet of things." In 2014 IEEE International Conference on Distributed Computing in Sensor Systems, pp. 269-274. IEEE, 2014.
23. Solving the miz of the dimensional and one dimensional linear barcides in healthcare environments.“<https://www.zebra.com/content/dam/zebra_new_ia/enus/solutionsverticals/product/barcodescanners/imagers/solutionbriefs/2dscanathcaresolutions-brief-en-us.pdf>”
24. Istepanian, Robert SH, Sijung Hu, Nada Y. Philip, and Ala Sungoor. "The potential of Internet of m-health Things “m-IoT” for non-invasive glucose level sensing." In 2011 Annual International Conference of the IEEE Engineering in Medicine and Biology Society, pp. 5264-5266. IEEE, 2011.
25. Stancampiano, C. V. (n.d.). Solid-state image sensors. Proceedings of Eighth International Application Specific Integrated Circuits Conference. doi:10.1109/asic.1995.580756
26. Collet, M. G. (1986). Solid-state image sensors. Sensors and Actuators, 10(3-4), 287–302. doi:10.1016/0250-6874(86)80051-8
27. Fowler, B. (2015). Solid-State Image Sensors. Handbook of Digital Imaging, 1–76. doi:10.1002/9781118798706.hdi006
28. Atzori, Luigi, Antonio Iera, and Giacomo Morabito. "The internet of things: A survey." Computer networks 54, no. 15 (2010): 2787-2805.
29. Castro, Diego, William Coral, José Cabra, Julián Colorado, Diego Méndez, and Luis Trujillo. "Survey on IoT solutions applied to Healthcare." Dyna 84, no. 203 (2017): 192-200.
30. Sasippriya Saminathan, K.Geetha, "A survey on healthcare monitoring system using IoT", International Journal of Pure and Applied Mathematics,Volume 117 No. 17 2017, 249-254, ISSN: 1311-8080; ISSN: 1314-3395, url: <http://www.ijpam.eu>
31. Santos, J., Rodrigues, J. J. P. C., Silva, B. M. C., Casal, J., Saleem, K., & Denisov, V. (2016). An IoT-based mobile gateway for intelligent personal assistants on mobile health environments. Journal of Network and Computer Applications, 71, 194–204. doi:10.1016/j.jnca.2016.03.014
32. Life changing mobile applications, <https://interestingengineering.com/7-life-changing-medical-technology-smartphone-apps-too-good-to-be-true>
33. Jeon, S., Lee, C., Han, Y., Seo, D., & Jung, I. (2017). The smart shoes providing the gait information on IoT. 2017 IEEE International Conference on Consumer Electronics (ICCE). doi:10.1109/icce.2017.7889246
34. Axisa, F., Schmitt, P. M., Gehin, C., Delhomme, G., McAdams, E., & Dittmar, A. (2005). Flexible Technologies and Smart Clothing for Citizen Medicine, Home Healthcare, and Disease Prevention. IEEE Transactions on Information Technology in Biomedicine, 9(3), 325–336. doi:10.1109/titb.2005.854505
35. Smart Tattoos’ Could Someday Monitor Your Vitals No Batteries Required <https://www.healthline.com/health-news/scientists-develop-tattoo-that-can-reveal-blood-sugar-level>
36. Eskofier, B., Lee, S., Baron, M., Simon, A., Martindale, C., Gaßner, H., & Klucken, J. (2017). An Overview of Smart Shoes in the Internet of Health Things: Gait and Mobility Assessment in Health Promotion and Disease Monitoring. Applied Sciences, 7(10), 986. doi:10.3390/app7100986
37. Reeder, Blaine, and Alexandria David. "Health at hand: a systematic review of smart watch uses for health and wellness." Journal of biomedical informatics 63 (2016): 269-276.