IoT in Health Care Industry: A Promising Prospect

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Abstract—In the twenty-first century, Internet of Things (IoT) has boomed to be impossible to relate to. From computers, mobile phones to your smart watches or virtual assistants, everything is connected to the complex web of IoT. With the technological development in this century, healthcare sector has also had its fair share of innovations including innovation related to healthcare, diagnostics, sensors, or even data analytic along with development in Machine Learning and Artificial Intelligence. IoT in healthcare is expected to help improve the quality of life for the people due to the flexibility that it provides. We looked at the significant amount of work done in this sector, and we found a trend that COVID-19 has only spurred the development of this field. We explored both the benefits and challenges that IoT in Healthcare might possess. We have addressed challenges such as data security, cloud integration problems. Additionally, we looked at the issue of data security in depth and along with the current method of LSCSH being used, we have recommended that Zero-trust architecture being used as well as it caters to the needs of the evolving data management space. Also, we found that IoT in healthcare comes with lots of benefits including healthcare being easy to afford, being able to access it from anywhere and anytime, being able to save time and resources, medical records being easily accessible to the healthcare providers, and many more.

We investigated the rapid advancements of IoT in healthcare with devices available for use as of March 2021, and devices to be available soon. From 2013, IoT in healthcare has dominated the space as new devices are released and there has been a boom of devices that are being developed and being researched on. Most of the devices are affordable and some can even be accessed with a small subscription fee. Our results show us that IoT has started to pick up its popularity since 2015 as companies succeeded to win the trust of the market. Also, the advantages that it provides over regular healthcare has made IoT in Healthcare dominant. It looks like IoT in healthcare is just getting started as these IoT technologies are ready to pick up its popularity in the coming years. Even though most of the development for these technologies look to come in the future, the progress made in the recent years look promising.

Index Terms—IoT, Healthcare, Internet of Things in Healthcare

I. Introduction

Today there exists a platform that connects every device in our day-to-day use with the internet and other devices connected to the web. This platform collects data from devices and shares it with other connected devices to explain the way devices are used and the environment around the devices [1]. This platform is known as the Internet of things.

Now "Internet of Things (IoT) is a paradigm that is rapidly gaining ground in the topic of modern wireless telecommunications" [2]. One of the paradigms for IoT defined by Luigi Atzori is "Identification, sensing and communication technologies". In this subsection he introduces the idea of advancing communication technologies and how they have played a key role in our lives.

For example, they introduced the concept of machine-to-machine communication through the development of RFID chips and showed how sensor networks have been used with RFID systems to better track status of things, i.e., movements, temperature, location, etc. Above RFID refers to Radio-frequency identification. It refers to the idea that if all objects and people in daily life are equipped with identifiers, they can be managed easily and inventoried by computers [3]. And RFID only refers to one of several methods to tag things into a web.

These devices developed with sensor networks have been used in various fields to benefit people by addressing societal challenges by introducing various major contributions [2]. One of those sectors being healthcare, focusing on the health and well-being of people and making attaining them easier.

Currently IoT is becoming a utility in the daily lives of a lot of people with increasing sophistication in sensing, actuation, communications, control, and in creating knowledge from vast amounts of data [3]. This will result in qualitatively different lifestyles from today for people as health problems can be easily predicted at their beginning stages with the use of IoT devices. Smart healthcare can play a significant role in healthcare through embedding sensors and actuators in patients and their medicine for tracking purposes [3]. A proper summation of the process can be broken down into three phases: capturing or retrieval of data regarding patient health/disease, parsing of data through a computing device

which sends said data to the cloud, and finally the display of information in a user-friendly device, providing continuous process monitoring by specified doctors [4].

Smart sensors which combine micro-controllers and sensors together makes tracking patient data even more of a convenience for doctors by accurately measuring, monitoring, and analyzing an abundant amount of health status indicators. A few years ago, one of OhioHealth's hospitals were working with IBM which utilized RFID technology to track hand washing after checking each patient. The operation was set place to tackle a huge problem within the healthcare industry of spreading infections, causing 90,000 deaths, and costing the country 30 billion dollars annually [3]. Such ideas which may have seemed trivial at the time now have garnered public acclaim in the past year with the global pandemic causing many systems, including healthcare to undergo very drastic changes.

IoT brings significant changes to improve the medical facilities and information systems during the COVID-19 Pandemic. The improvements in the digitization of the medical process with IoT has helped patients be far more connected with their doctors who, in times, need constant information on their patients while being farther away in distance than ever before [4]. New advances in Virtual Reality and Augmented Reality are further reducing the boundaries patients must get through to receive medical access. The recently announced HoloLens by Microsoft aims to, among other areas, bridge the gap between doctors and patients no matter where they may be at any time, by providing new and innovative low latency, special AR headsets. The future for IoT in healthcare is bright and aim to reduce barriers as much as possible to be able to have, ideally, patient-doctor synchronicity.

II. Objectives of IoT in healthcare

After learning about the IoT architecture and reviewing it using an example in healthcare services. We must not forget the objectives of IoT in healthcare and they are:

- It is crucial to develop ambient intelligence as users, clients, and customers of IoT devices are people.
- To provide more extensive interconnection among information equipment for feasibility. [5]
- To gain real time information about people through IoT devise, to provide ambient intelligence for the continuous learning of patient data.
- Preprocessing acquisitioned data of an individual if required.
- Analyzing data and predicting chronic disorders in early stage through the data mining techniques and seeing data trends which provides the methodology useful for decision making.
- To provide easy access of IoT-based healthcare solutions anytime, anywhere for anyone. [6]

Again, "IoT enabled devices such as fit-bits that have RFID chips enable wireless data collection from patients such as blood pressure and heart rate monitor ring" [7]. This gives patients access to personalized attention and can also be tuned to categorized people based on fitness and level of activities as well as allow people leisure by not giving them concern. For example, by self-booking appointments or providing alerts when there is a change in a patient's normal body routine.

The above example displays the objective of IoT by allowing prediction of Chronic Disorders in the early stage [6]. Showing that IoT facilitated remote health monitoring systems provide more benefits over customary health monitoring system, as it can "explore and mine the raw data to abstract more valued information such as correlations amongst things and services to afford web of things or Internet of service" [6].

III. Benefits of IoT in Healthcare

Just like any other technological development, IoT also has its risks and challenges, however, it does come with a lot of advantages that can help individuals and the society in many ways. A few decades ago, this was something that people could only dream about, but now in 2021, it has become a reality. With the recent events, specifically the global pandemic of COVID-19, the process has just been sped up more than ever and this just shows how much it can have an impact positively. IoT in healthcare removes the barrier between healthcare providers and patients. IoT in Healthcare provides the flexibility that an in-person visit to a healthcare facility cannot. Here are some advantages that IoT in healthcare can have:

- Providing healthcare will be much cheaper. At the same time, it becomes very convenient for people who are not feeling well to get diagnosed and treated. We have all felt unwell at some point but were too tired or weak to go to a doctor and did not end up going to a doctor. However, with IoT in Healthcare, the process becomes much more convenient. And the data obtained from IoT devices not only help in effective decision making but "they also ensure smooth healthcare operations with reduced errors, waste and system costs" [7].
- The medical records of patients can be easily managed and can be retrieved by doctors whenever needed. Each patient's record can be stored in a server. Most of the times, the records are stored in cloud which can be accessed from anywhere and anytime as long as they have the required key to get in [8].
- Treatment from the comfort of home and care from family members. Sometimes people might feel uncomfortable going to hospitals and are skeptical about the entire process of getting taken care of by a nurse. IoT in healthcare removes this factor and make the process more comfortable for patients.
- Less-time consuming for someone who might be having a hectic and busy life. Saves time, money and energy. Someone who is busy, maybe a student or a businessman or a worker who do not have enough spare time, but something has been bothering them, they can get diagnosed on the go which saves them time, money and energy to visit a hospital or healthcare facility.

- Affordable timely medical service. A patient can be diagnosed with medical condition before it can get serious or before it can get dangerous. Also, it will be affordable as well as when a medical condition is diagnosed at an early stage, it is easier to treat than when diagnosed when it starts causing a lot of harm to the patient [9].

The next section addresses the challenges developers face when dealing with IoT face in the current year, especially in the medical field. Medical data is highly sensitive and private. Being able to provide secure and reliable data transfer between patients and their doctors is a huge hurdle to overcome.

IV. CHALLENGES RELATED TO THE USE OF IoT IN HEALTHCARE

As mentioned before, IoT technology has its applications in various fields and it can play a huge role in the healthcare sector. From being used to provide effective emergency services to patients to assisting in early detection of medical conditions, the significance of IoT application in the healthcare sector cannot be ignored. IoT really provides efficient and effective solutions to problems in the healthcare sector [10]. Although it has its prospects, it also does come along with its own set of challenges which needs to be addressed before IoT in healthcare can prosper. From data security, sensor battery life to energy consumption by cloud computing, these challenges might hold back the idea of IoT being fully implemented in healthcare [11].

A. Cloud Integration

There are mobile applications that can provide remote health monitoring systems which collect IoT data and store it on a cloud platform and use flexible and scalable methods to process the data using cloud computing. When a sensor reads the IoT data, it gets stored in the cloud storage repository which has a high level of medical processes and research integrated in it. When all the data is received, it gets sent to a cloud subsystem for diagnosis. Based on the diagnosis, the patient's hospital, caretakers, or doctors are informed for any necessary action. All in all, this is the process of cloud integration in a Healthcare IoT application or system.

This is a simple process but is still plagued with various problems which need to be addressed. One of the main problems is the network issues that can be present on the server side or the patient side. Network delay is known to be the major problem when it comes to remote healthcare. There have been several research studies and multiple frameworks have been proposed including UbeHealth which analyzes the challenges in network delay and quality of service [12].

B. Data Security in IoT Healthcare System

In the twenty-first century, where technology is readily available to anyone and everyone, IoT data has been a major target for hackers and attackers. Data privacy is a big concern which is why this problem needs to be addressed by reviewing the security measures in place. The method should focus on optimizing energy consumption and resource utilization but should maintain the data privacy at the same time. A strong encryption method should be used on multiple layers so that the cloud/remote healthcare service can run smoothly and safely without risking private information being leaked to the public. Recently, UHBigDataSys and Lattice-Based Secure Cryptosystem for Smart Healthcare (LSCSH) has been proposed which might be a huge stride towards a secure system for IoT Healthcare applications.

Currently, LSCSH is being used in smart healthcare systems to secure IoT data. LSCSH consists of four different phases: Setup, Key Generation, Data Encryption and Data Decryption. In this method, random lattice polynomial vectors are used as input which in turn generates the private and the public key which is sent to the Database Server through a secure channel which can only be accessed by the healthcare provider using the secret key pair [13]. Additionally, we suggest the Zero Trust Architecture for the data security in the IoT in Healthcare Sector as the existing security systems might soon be outdated for the necessities that these new IoT devices might create.

V. ZERO TRUST ARCHITECTURE

One of the biggest challenges that IoT faces is data privacy issues. The increasing use of IoT technologies means that there are more and more possibilities for data breaches because more points of entry, exit, and data access will exist than ever before [14]. Existing security systems using network isolation, firewalls, and defense-in-depth will not be able to meet the emerging security requirements of smart healthcare in the upcoming future. Thus, it is urgent and necessary to break the physical network boundary and establish a new network security framework based on services and applications to achieve the security goal [15]. To address this issue, developers have a major interest in Zero Trust architecture as a promising solution to satisfy the requirement for a better secured network. Zero Trust is a set of cybersecurity principles used to create a structure that focuses on moving network defenses from wide, static network perimeters to a narrower focus on subjects, enterprise assets (devices, infrastructure components, applications, virtual and cloud components), and individual or small groups of resources [14]. Because of its unique design, a Zero Trust Architecture (ZTA) environment follows the principle of no implicit trust towards any assets and subjects, regardless of their physical or network locations. In other words, this implies that a ZTA will never grant access to resources until a subject, asset, or workload are verified by a reliable authentication and authorization. In short, the zero-trust framework includes these following ideas: [15]

- Using identity as the authentication of access control
- Using 'least privilege' principle for resource allocation
- Real-time calculation of access control strategy
- Only allowed controlled and secured access to view resources
- Continuous evaluation of trust level from multiple data sources There is no single formula to implement ZTA, however, we need to keep in mind these following topics when designing this type of architecture: [16]

- Ensure all data are securely accesses based on user and location
- The use of access control is strongly recommended
- Inspect de logs of all traffics

With ZTA, the way we use networks will change completely: no longer exist a trusted interface in our devices, no longer exist trusted users. Looking at the traditional hierarchical network architecture (fig1), we have several layers of the network that contain several layers of security methods [16]. This architecture is considered to be antiquated, especially with the rise of IoT, cloud computing, and social networks, as it proves to be eventually make the network heavy, unmanageable, hard to keep the data safe, and costly to maintain all the security methods [17].
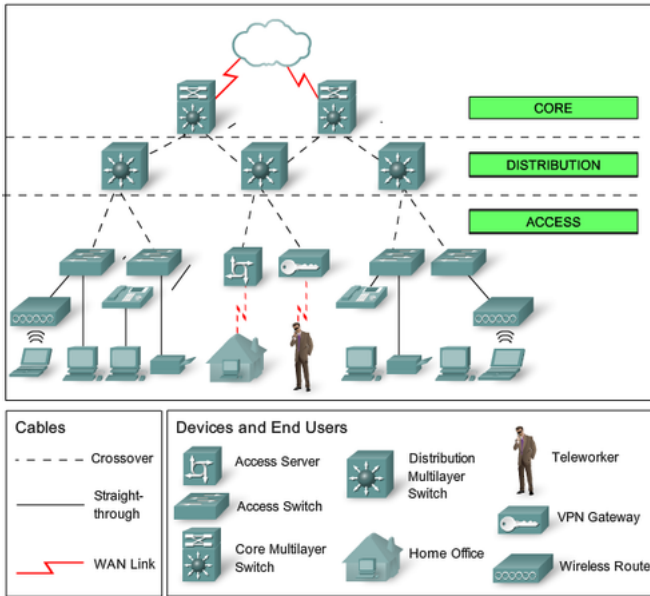

Fig. 2. Zero Trust Architecture

Fig. 1. A Traditional Hierarchical Network Architecture

Zero Trust model redraws the network of this old hierarchical model and creates a new idea of segmentation gateway. This concept is built to concentrate all the resources that are currently active in a modern network such as content filtering, access control, firewall, cryptographic engines, package forwarding. One of its outstanding features is that it can adapt to any type of business, without having to restructure the entire network structure. This is extremely cost effective and less time consuming to implement in healthcare sector in the future. This segmentation gateway model is considered to be the future of firewall, since it is developed to increase the micro-segmentation of the networks, becoming versatile in terms of being scalable, adapting to all types of business and virtualization-friendly [16].

In the figure above (fig 2), a segmentation gateway is represented in the center of the network, making the separation in micro-segmentation (MCAP) to inspect all the traffic of the network. With the segmentation and next-generation firewalls, we can control all the access activity including who, what,
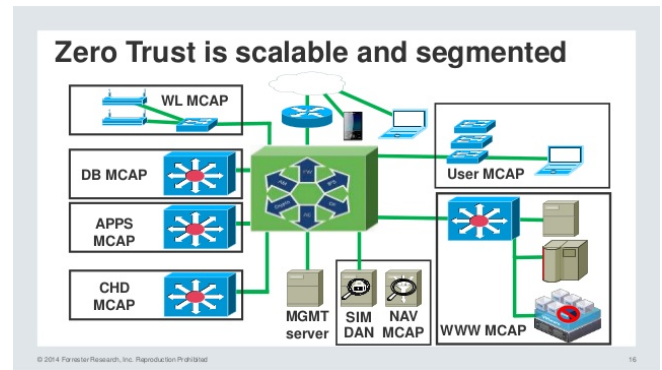
where, when someone gets connected to the network. After the access is granted, the user is still being managed tightly. Another purpose of this way of design is to prevent lateral movement inside the network after being compromised, reduce the range of damage caused from these unauthorized access [16].

Although ZTA is a promising security solution for IoT in healthcare, challenges still exist. Current challenges include: [14]

- Maturity of vendor products to support a ZTA
- Organizations' willingness to implement ZTA
  - Heavy investment in other technologies
  - Absence of identity governance
  - Lack of ability/resources to develop a transition
- Security concerns
- User experience
- Integration considerations of ZTA products with legacy technologies

Even though ZTA might have challenges that need to be addressed, its benefits and its promising impact on healthcare sector outweigh the difficulties. ZTA has the potential to address security challenges that IoT still has and will continue to improve and expand the use of IoT in healthcare.

VI. POSSIBLE CHALLENGES

Like mentioned before, small problems like limited battery life of the sensor and devices which need to be recharged periodically or very limited amount of research or resources available in some areas or even high energy consumption plague the IoT Healthcare sector. However, some of these problems can turn into major ones fast. Here are some of the major problems that could occur:

- Some of the devices required for IoT Healthcare Applications which might include sensors among other things might possibly require assistance of a professional or a nurse which somewhat defeats the purpose of the entire idea. Sensors when not used properly might generate incorrect data or skewed data because of which a patient might be falsely or wrongly diagnosed with a medical condition which can have dangerous consequences.

- Sensors are not always accurate due to a phenomenon called 'noise'. When data is transmitted to the database server, it can be affected by noise which can deteriorate the condition in which the data is received by the healthcare provider. For this reason, noise reduction technologies and techniques need to be improved to improve the data quality.
- IoT in healthcare will utilize a huge amount of storage as there will be multiple patient's data being stored and processed at the same time. However, this can be solved by using cloud storage. But the downside is that it is more likely that the process is going to be more complex when the IoT healthcare system is integrated with the Cloud.
- Earlier, we talked about how data could be secured on the server side so that attackers or hackers could not access the data. However, the problem of the client data being under attack is still prominent if the precautions are not taken by the users themselves on their devices [18].

These unique challenges that IoT in healthcare faces can be solved by different solutions. For challenges regarding cloud integration, UbeHealth has proposed its idea that analyzes the challenges in network delay and the quality of service. Further, Data security issues can be mitigated as new security architectures are developed including LSCSH or zero trust security architecture and many more.

VII. Future of IoT in Healthcare

With the rapid increase in network speeds, such as the incoming standardization of 5g throughout the world providing 100x the data transfer speed when compared to its predecessor, technological improvements and a drastic increase in competitors occupying the sector, the future of IOT is looking very promising.

Looking at this year's CES, which is a hub for new and innovative technologies, we can see the importance of IOT in healthcare with dozens of companies providing hundreds of new devices that are already in high demand. As an example, let us look at Pulxion Medical Technologies personalized mobile hospital PulStroke, a novel risk assessment device for strokes. Using motion analysis, it extracts necessary information from the user's pulse. After taking a 20 second video clip aimed at the neck, the device can produce a report in under five minutes indicating high or low stroke risk. A few other advantages provided by this portable device is its affordability when compared to what is offered in the market right now, ease of use as the user only needs to press one button just to start the process. Unlike MRI and CT this technology has no risk of radiation and no need for contrast. The most important statistic of the device is its 90 percent accuracy with patients in its current development stage. [19]

This is just one of more than a hundred innovations that is in RD today, and with rapid advancements in technologies such as IBM's recent unveiling of their 2nm chip sets, which will lead to greatly faster and far more portable devices being produced in the future, hardware wise IOT is already a more than viable alternative to the current healthcare providers.

Experts predict that by 2025 the wearable technology market will reach 74.03 billion dollars, a significant increase from the 27.91-billion-dollar valuation in 2019. Anything in the healthcare sector that is not already implemented through IOT can and will be replaced by IOT devices.

Beyond its obvious uses, IOT can be adopted by healthcare organizations to improve their existing facilities, through the help of equipment tracing and inventory management. Also referred to as real-time location systems, these devices will help hospitals track the movement of equipment and their general use. This provides more foresight for hospitals regarding potential equipment shortages, and all who have encountered the said equipment. This is essential in helping prevent the spread of infections and diseases, such as COVID-19. With smaller chipsets being produced, as stated before, it will even be possible to implement such tech into even the smallest of hospital equipment. [20]

The future of IOT in the health sector is bright and with the dedication of a global IT think tank, patients will soon be able to experience care that is more efficient, cheaper, instant, and easily accessible than ever before.

VIII. Findings/Survey

In this survey, a table with a list of IoT devices were assembled along with some information regarding its production date, its price or subscription fee in US dollars ($), its primary function and the areas of its usage. We came up with 12 of the devices that looked prominent to us as they stood out due to either its functionality, production period, price or even its usages.

TABLE I
IoT Devices in Health Care

Device	Year	Price ($)	Function	Areas of Usage
RCW - 360 wifi Temperature And Humidity Data Logger Wireless Remote Monitor Cloud Data Storage [21]	2021	359.99 [22]	Temperature and humidity data logger	Food, health care services, catering
Propeller's Breezhaler	2020	Subscription fee [23]	A connected sensor that makes the management of asthma or COPD easier	Healthcare, daily use
Philips' Medication Dispensing Service	N/A	Subscription Fee [24]	Focused on patients who may find it difficult to manage medication independently	Health care, daily use

The first device was the RCW-360 Wi-Fi Temperature and Humidity Data Logger Wireless Remote Monitor Cloud

Device	Year	Price ($)	Function	Areas of Usage
Zanthion Smart Personal Emergency Response System	2019	99 [25]	Medical alert system that is worn by patient to measure the health and welfare of the wearer	Health care, daily use
QardioArm Wireless Blood Pressure Monitor	2014	99 [26]	ECG monitor designed to provide continuous medical grade data, blood pressure monitor	Health care, daily use
Kinsa Smart Thermometer	2013	39.99 [27]	Detect patient illness, provide analysis for better care, and map human illness through the collection of data	Household
Philips BioSensor BX100	2020	N/A	Early patient deterioration detection, including clinical surveillance for COVID-19	Health care
Pfizer & IBM Parkinson's sensor device	Coming soon	N/A	Track Parkinson's drugs' effectiveness, which helps them in necessary with dosage adjustment in real-time	Health care
EIGHT The Pod Pro	2020	2995	Determine the ideal sleep temperature required based on environment sensors, Smart Temp technology	Daily use, Health care
Aeroscout Stanley Healthcare T2s Wifi Ultrasound Tag	2017	127.99	Facilitates patients real-time location through a wireless radio frequency identification	Health care
Swallowable Sensors [28]	Coming soon	N/A	Non-invasive way of measuring instantly what's happening in a person's stomach	Health care
NHS test beds [29]	Coming soon	N/A	Detect deterioration earlier to enable more timely interventions	Health care

Data Storage. With wide range of temperatures available and multiple sources of power supply, this device can log the temperature and humidity data without any problem. The unique feature it has is the Elitech cloud that supports parameter configurations, graph analysis, report export etc. which makes it a very attractive device to own. This device also consists of various audible or visual alarms that makes it easy to use as well. This device can be used in various areas including food catering, healthcare, and services.

The next device was the QuardioArm Wireless Blood Pressure Monitor which makes blood pressure monitoring easy which reduces the need for a professional to be present at all moments. This device is clinically validated, portable stylish and most importantly the data can be directly shared which makes it easier for the healthcare providers to keep tabs on their patient's health.

Zanthion Smart Personal Emergency Response System was another interesting device which informs caregivers whenever something wrong happens, or the patient needs something. This device can not only be used in healthcare but also in daily life for other purposes such as security. Another device that can also be used in day-to-day life is the Propeller's Breezehaler. This device comes with an online platform called Propeller which helps you manage your Asthma, other respiratory problems, and other needs. These devices use sensors to detect any problems. It can also detect the amounts of allergy agents such as pollen in the environment and display it in the online platform to make the patient aware.

Philips' Medication Dispensing Service is a simple rather effective solution to a few healthcare problems. This dispensing service can take in data about what medications are needed at what times and can dispense it and notify and remind elders who live alone to take their medicine. This device prevents accidental usage of wrong medication or wrong dosages. This device is primarily focused on patients who may find it difficult to manage medication independently.

The Kinsa Smart Thermometer is another brilliant device which is an ear thermometer which helps patients keep track of their health. It also comes along with an app that lets patients log their symptoms and get fast real-time feedback and personal guidance from a professional. The next device is the Philips BioSensor BX100 which adheres to the patient's chest detecting all the vital signs of the patient in addition to posture and activity. This device also detects deterioration of a patient's health which helps in early interventions and can save lives in many cases. This device can be a life changing invention.

The next device comes from the partnership of IBM and Pfizer. IBM and Pfizer's Parkinson's sensor device tracks the effectiveness of the Parkinson's drugs which can be used in the adjustments of the dosages in real-time to help the patient. Even though these are small strides, these devices have come very far. The next device is a mattress that is called EIGHT the Pod Pro. This mattress helps in room Climate and weather Response, GentleRise Wake Up Technology, and double the number of sensors enabling new Heart Rate Variability monitoring and a Daily Health Check report. There were other mattresses with the weather response and GentleRise technology, but this new development of 2020 can help patients monitor their health daily while sleeping.

The next device, AeroScout T2s Tag utilizes Wi-Fi, ultrasound, and low-Frequency (LF) receivers to keep track of patient's real-time location. This device does not directly

monitor any aspect of a patient's health but helps a healthcare provider or facility to keep track of its patients can allowing them to manage their assets in a better way.

The next device is a swallowable sensor being developed by Dr Kourosh Kalantar-zadeh from RMIT. If the invention is successful, this sensor will be able a non-invasive way of detecting what is happening in a patient's stomach. This can be an alternative to colonoscopy. The next device is also a device under development by United Kingdom National Health Service. NHS is developing its own hospital beds with more than basic functions that can keep track of the patient when a professional is not around. This bed will also have the basic emergency buttons if a person needs immediate attention.

All these devices look like they have great usages and are or will be popular due to its advantages in general. However, to take a deeper look at the progress of IoT in Healthcare, we must carefully look at both the pros and cons of these devices. So, a table with the pros and cons of each device have been assembled to assess the development of these devices.

TABLE II
PROS AND CONS OF IoT DEVICES

Device	Pros	Cons
RCW - 360 wifi Temperature And Humidity Data Logger Wireless Remote Monitor Cloud Data Storage	• Can be used to measure wide range of temperature along with humidity, • Cloud support for data analysis.	• Limited to only monitoring and recording humidity and temperature.
QuadrioArm Wireless Blood Pressure Monitor	• Wireless, portable, easy to use with Android, iOS and Kindle support, • Data Sharing Feature with friends, family or doctor, • Detects irregular heartbeats and sends alerts.	• Device looks bulky which makes it impractical for 24 hour monitoring.
Zanthion Smart Personal Emergency Response System	• Easy to use and affordable, comes with voice control capabilities, • Has a help button, fall detection, records heart rate, activity level, and location.	• Needs to charge on a regular basis.

Device	Pros	Cons
Propeller's Breezhaler	• Detects the amount of allergens in the surrounding, • Comes with a mobile application for ease of use.	• Limited to detecting the allergens in the surrounding
Philips' Medication Dispensing Service	• Effectively dispenses medicine making which removing the risk of wrong dosage or wrong medication. • Suitable for elders.	• Monthly Subscription Fee
Kinsa Smart Thermometer	• Can be used professionally • Facilitates real-time diagnosis through its mobile application • Medication tracking and reminders available • Affordable	• Battery Powered, might need frequent charging
EIGHT The Pod Pro	• Automated cooling/heating, • Track vital signs, including sleep cycles • Uses GentleRise Technology for natural wake up experience.	• Expensive • Cannot be applied on a large scale medically due to its price
Aeroscout Stanley Healthcare T2s Wifi Ultrasound Tag	• Suitable for asset location, patient or staff • WiFi communication	• Uses replaceable batteries

IX. RESULTS

According to the table, we can observe that IoT in healthcare is promising and still being researched. IoT devices started being produced as early as 2013 with devices such as Kinsa Smart Thermometer being introduced. From the year of 2013 to 2015, government funds for science were decreasing as people looked at IoT devices skeptically in the medical field, which led to many unsuccessful projects related to IoT in healthcare. Projects like NHS test beds or Swallowable sensors were all promising projects that could potentially change the way the healthcare system worked. Unfortunately, around that period (2013 - 2015), IoT was not the trend or was proved to be a cost-effective and beneficial method yet. With the

number of patients that has been increasing in recent years, IoT has once again been introduced to aid hospitals and form a home-centered healthcare system. According to the data, most of the devices are used specifically by remote patients. These devices deliver real-time information of the patients' conditions back to their medical caregivers or their emergency contact if the device detects any unusual signals from the patients. The prices vary from $40 to 100$, which can be considered an affordable healthcare device for anyone in need. The proven benefits and the affordability of these IoT devices are promoting the development of IoT as it is the future of healthcare. There are more IoT devices that are being developed and researched such as Pfizer and IBM Parkinson's sensor device and unsuccessful projects before are also being developed again such as swallowable sensors from RMIT university. For the year of 2021, IoT devices such as Philips BioSensor BX100 are also being developed and used to fight against COVID-19.

Also, when we look at the pros and cons of these IoT devices, based on the demand of the current world, the pros side outweighs the cons. We can observe that most of these devices are accessible and easy to use. These devices usually come with mobile support which makes it uncomplicated to use without requiring professional training to use. We also realized that the data sharing features of most the devices makes it viable to be used in large scale directly in the medical industry with just a few exceptions. However, these devices are yet to be perfected as it has its cons as well. Most of the devices run of battery power which need frequent charging which can be complicated for some patients whereas others were somewhat expensive to be practically used in hospitals. With devices still in progress, we could not judge their advantages or disadvantages, it certainly looks like IoT technology will continue to expand its dominance in the healthcare sector in the upcoming years. The future of home-based healthcare will be possible with the development of IoT technologies and COVID-19 has only spurred this process as devices are being pushed by companies at a higher frequency after 2019.

X. Conclusion

As IoT is a recent development, there is still a lot of potential for its growth that we can all look forward to in the upcoming years. IoT is a paradigm that connects every device with the internet and uses this connection to transfer data from one device to another. For the healthcare sector, IoT appears in many different forms, such as RFID chips, sensor networks, and embedded sensors and actuators. IoT's developers have clear objectives for their devices: developing ambient intelligence, providing more extensive interconnection among information equipment, gaining real time information, preprocessing acquisitioned data, analyzing and giving immediate decisions, and providing easy access to solutions. IoT has a lot of promising benefits, however, it also has a handful of problems that the developers and the users need to be aware of. With the amount of big data that IoT stores, cloud integration and data security are inevitable problems. Besides those two biggest challenges, there are small problems that could potentially, if not being treated as soon as possible, become major problems. However, the benefits that IoT brings are more valuable than the threats that IoT are posing if the healthcare sector decides to adopt it soon. IoT makes healthcare cheaper, more easily managed, more flexible in the treatment places, less time consuming, and most importantly, easier for the prevention of different illnesses.

According to our study, IoT devices tried to make its appearance around 2013 which was unsuccessful at the time as it was a very new concept to be accepted immediately. Companies struggled from that period to around 2015 as the budget for IoT Healthcare devices were not enough as the ideas did not have enough trust from the investors or the market. Eventually, IoT devices in the healthcare sector have expanded and are expanding its coverage over the past few years (2017 - present). The number of devices being developed in the upcoming years shows that IoT is being an important part of the future of healthcare. With its proven benefits and results, we could hope for more investors and researchers to get into the field of IoT, which can bring back a lot of potential projects but must stop because of the lack of funds. Especially during the year of 2020 - 2021, with COVID-19 stopping us from physical interaction, IoT could play a large part to aid doctors and nurses for managing patients' conditions for distant treatments. We can expect to see a future of healthcare system that is dominated by IoT technology.

References

[1] J. Clark, "What is the internet of things, and how does it work?," Aug 2020.

[2] L. Atzori, A. Iera, and G. Morabito, "Understanding the internet of things: definition, potentials, and societal role of a fast evolving paradigm," *Ad Hoc Networks*, vol. 56, pp. 122–140, 2017.

[3] B. S. Babu, K. Srikanth, T. Ramanjaneyulu, and I. L. Narayana, "Iot for healthcare," *International Journal of Science and Research*, vol. 5, no. 2, pp. 322–326, 2016.

[4] M. Javaid and I. H. Khan, "Internet of things (iot) enabled healthcare helps to take the challenges of covid-19 pandemic," *Journal of Oral Biology and Craniofacial Research*, vol. 11, no. 2, pp. 209–214, 2021.

[5] H.-D. Ma, "Internet of things: Objectives and scientific challenges," *Journal of Computer science and Technology*, vol. 26, no. 6, pp. 919–924, 2011.

[6] Darshan K R and Anandakumar K R, "A comprehensive review on usage of internet of things (iot) in healthcare system," in *2015 International Conference on Emerging Research in Electronics, Computer Science and Technology (ICERECT)*, pp. 132–136, 2015.

[7] R. Karjagi and M. Jindal, "Iot in healthcare industry: Iot applications in healthcare."

[8] D. D. Kumar and P. Venkateswarlu, "Secured smart healthcare monitoring system based on iot," *Imperial Journal of Interdisciplinary Research*, vol. 2, no. 10, 2016.

[9] G. J. Joyia, R. M. Liaqat, A. Farooq, and S. Rehman, "Internet of medical things (iomt): applications, benefits and future challenges in healthcare domain," *J Commun*, vol. 12, no. 4, pp. 240–247, 2017.

[10] V. Subramaniyaswamy, G. Manogaran, R. Logesh, V. Vijayakumar, N. Chilamkurti, D. Malathi, and N. Senthilselvan, "An ontology-driven personalized food recommendation in iot-based healthcare system," *The Journal of Supercomputing*, vol. 75, no. 6, pp. 3184–3216, 2019.

[11] V. Gupta, H. Singh Gill, P. Singh, and R. Kaur, "An energy efficient fog-cloud based architecture for healthcare," *Journal of Statistics and Management Systems*, vol. 21, no. 4, pp. 529–537, 2018.

[12] T. Muhammed, R. Mehmood, A. Albeshri, and I. Katib, "Ubehealth: a personalized ubiquitous cloud and edge-enabled networked healthcare system for smart cities," *IEEE Access*, vol. 6, pp. 32258–32285, 2018.

[13] R. Chaudhary, A. Jindal, G. S. Aujla, N. Kumar, A. K. Das, and N. Saxena, "Lscsh: Lattice-based secure cryptosystem for smart healthcare in smart cities environment," *IEEE Communications Magazine*, vol. 56, no. 4, pp. 24–32, 2018.

[14] A. Kerman, O. Borchert, S. Rose, and A. Tan, "Implementing a zero trust architecture," *The MITRE Corporation, Tech. Rep*, 2020.

[15] B. Chen, S. Qiao, J. Zhao, D. Liu, X. Shi, M. Lyu, H. Chen, H. Lu, and Y. Zhai, "A security awareness and protection system for 5g smart healthcare based on zero-trust architecture," *IEEE Internet of Things Journal*, 2020.

[16] P. Assunção, "A zero trust approach to network security," in *Proceedings of the Digital Privacy and Security Conference 2019*, 2019.

[17] J. Kindervag *et al.*, "Build security into your network's dna: The zero trust network architecture," *Forrester Research Inc*, pp. 1–26, 2010.

[18] S. Selvaraj and S. Sundaravaradhan, "Challenges and opportunities in iot healthcare systems: a systematic review," *SN Applied Sciences*, vol. 2, no. 1, pp. 1–8, 2020.

[19] P. M. Technology, "Pulxion medical technology co., ltd.," *Welcome to Livetour*, 2021.

[20] M. Javaid and I. H. Khan, "Internet of things (iot) enabled healthcare helps to take the challenges of covid-19 pandemic," *Journal of Oral Biology and Craniofacial Research*, vol. 11, no. 2, pp. 209–214, 2021.

[21] P. Commerce and Elitech, "Real time temp monitoring for vaccine and pharmaceutical," 2020.

[22] I. Elitech Technology, "Elitech rcw-360 plus 4g wireless temperature and humidity data logger with external probe email sms app push alert," 2020.

[23] L. Lovett and H. M. Publication, "Novartis, propeller health co-package new asthma treatment," Jul 2020.

[24] K. P. N.V., "Automated medication dispensing service: Presented by philips lifeline ®," 2020.

[25] C. edge Tech Solutions for Seniors and Caregivers, "Zanthion smart watch," May 2020.

[26] I. Qardio, "Qardioarm, qardioarm smart blood pressure monitor is wireless, portable and easy to use.," 2014.

[27] K. Inc., "Kinsa quick smart ear bluetooth thermometer, kinsa health," 2021.

[28] B. Gorrilla, "Gut feeling: the swallowable gut sensor that could replace a colonoscopy, the sydney morning herald," Jan 2017.

[29] . United Kingdom National Health Service, "Accelerated access collaborative: Test beds," 2021.