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TECHNOLOGIES AND ARCHITECTURES OF THE INTERNET-OF-THINGS (IOT) FOR HEALTH AND WELL-BEING

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ABSTRACT

A healthcare system is a collection of hardware and software tools designed to offer individuals, such as patients and healthcare professionals, a variety of healthcare services and applications with the goal of enhancing health and well-being in a way that is both broadly applicable and practically applicable. The goal of a healthcare system is to improve health and well-being in a way that is both broadly applicable and practically applicable. The Internet of Things offers novel concepts, methods, and possible answers that can contribute to the development of new ways to enhance the delivery of healthcare in its current form. In addition, the Internet of Things may offer the chance to improve upon the medical processes that are now in use in order to give patients with customised medical treatment. By leveraging open-source platforms and operating systems, it is possible to increase the overall level of quality, safety, and accessibility of healthcare systems. This is one such method that may be utilised for the aforementioned enhancement. Because they make it possible for devices, programmes, and entire systems to reliably expose application programming interfaces (APIs) to one another, open-source solutions that are already in existence may also be able to improve the process of building and operating healthcare information systems. It's possible that this will be beneficial to the healthcare business. Because of this, interoperability will improve, and the costs associated with administering and maintaining networks consisting of numerous devices will decrease. At the present time, members of the general public have access to a wide range of open-source technology. These kinds of technology are often available online for general use. These technologies provide platforms that are safe and cost-effective, making them perfect for building and prototyping state-of-the-art healthcare solutions.

Keywords: Technologies, Architectures, Internet-Of-Things, Health, Well-Being

1. INTRODUCTION

The World Health Organisation (WHO) uses the term "e-health," which is also known as "the transmission of health resources and health treatment via electronic means." It focuses on three main areas, including the online and other forms of communication used to provide health information to consumers and professionals working in the healthcare industry. Through the use of information technology and electronic commerce in various settings and context-specific contexts, such as the education and training of health care professionals, the overall level of public health services may be improved. the use of e-commerce and other e-business techniques to the management of health care systems' physical infrastructure. E-health presents a novel method for using financial, informational, and pharmaceutical resources in the field of health care. Over time, this method should help to use these resources more effectively overall. Additionally, the Internet offers a brand-new platform for companies, experts, and members of the general public to interact and collaborate on initiatives.[1-5]

Promote well-being and health in a powerful and common way.

The area of advanced and ambient learning that is most directly related to information and communications technologies (ICTs) is improved living environments (ELEs), a subfield of AAL. The ELEs take into account any ICT

successes that support AAL, regardless of their form. In order to maintain their independence and self-sufficiency, ELEs use a wide range of information and communications technology (ICT) solutions. This necessitates the creation of innovative apps and services. An ELE is also a person who develops Internet of Things (IoT)-based information and communication technology solutions that enhance human health and welfare. [6-13]

The personal, home, community, and hospital levels in the future healthcare system should be grouped in a tiered structure, for instance, from low to high. According to Poon and Zhang (2008), the lowest layer should have lower labour intensity and operating expenses, greater usage frequency for chronic diseases, and lower usage frequency for acute diseases. The utilisation frequency for acute illness should be reduced in the upper tiers. Additionally, there should be a decline in the proportion of patients with acute illnesses in the lowest tier. Additionally, the lowest layer need to have the same qualities as the one above it. IoT-based in-home healthcare (IHH), also known as health-IoT, is a service that might have positive effects on both the traditional healthcare sector and the information and communications technology sector. It is offered through the Internet of Things (IoT). The broad availability of personalised health-information technology services will hasten the shift in the healthcare sector from a career-based paradigm to one that is focused on patients. Since careers have historically been the main focus of the firm, this change is crucial.[14]

The components of a typical Health-IoT system include the ones listed below:

Tracking and monitoring. Because of their ubiquitous identification, sensing, and communication capabilities, wearable WSN devices are able to continuously track and monitor any and all commodities (including people, equipment, drugs, and so on). This includes the ability to track and monitor any and all movements of such commodities. Monitoring and observing are both components of this process.

- **Remote service.** People are now able to get medical treatment and other services, including those that allow them to live independently, through the use of the internet and other external technology. These include the management of these services, the identification and treatment of emergencies, the rehabilitation and training for stroke victims, as well as the provision of food and medicines.
- **Information management.** Because of the Internet of Things, all of the information that pertains to medical care, such as logistics, diagnosis, treatment, recuperation, medicine, management, finances, and even day-to-day activities, can now be gathered, managed, and used across the whole value chain. This includes information about therapy, recuperation, medicine, management, and finances. This also includes information on the healing process. This encompasses everything, from day-to-day activities to the handling of finances..
- **Cross-organization integration.** In addition to being connected into bigger healthcare systems that may span a whole town, city, or even state, hospital information systems (HISs) are fast expanding to include patients' homes as an additional point of care for medical treatment. These HISs, which stand for home health information systems, are known by their acronym.[15]

2. IMPACT OF IOT IN E-HEALTH

Over the course of the past decade, the complex network referred to as the Internet of Things (IoT) has expanded at a rapid rate. The Internet of items, more commonly referred to as IoT, is fundamentally a decentralised network of networked items that are capable of self-deployment and can adapt to any environment that is dynamic. [16] The Internet of Things (IoT) makes use of sensing devices that are both extremely tiny and relatively affordable. The use of these sensor devices contributes to the development of an intelligent environment. As a consequence of this, adjustments have been made to the ways in which we travel, conduct business, and generally live our lives. Improvements have been made to the systems that are used in a variety of fields, including business, education, housing, transportation, and security, among others. [17-18]

2.1. CLOUD ACCESS CONTROL FOR APPLICATIONS USING THE CLOUD

One of the most significant and essential components of the healthcare sector is the provision of e-health services to a varied range of patients and actors. To promote user acceptability of electronic health records, cloud models are crucial. These models need to be always and from everywhere accessible. Consumer-focused programming is readily available to the patient community from any location in the world. Managed care and self-service choices are only two examples of the various onboarding models that the design must be flexible enough to handle. Integration with a variety

of different systems is essential to ensuring a constant flow of important information on board the device. This integration is required to meet the requirements. The architecture has to protect against web-based attacks including phishing, drive-by downloads, and the use of insecure browsers to stop access to the installed applications and data. The public's health and safety are seriously threatened by each of these elements. [19-21]

2.2. IOT APPLICATIONS IN HEALTHCARE

In the following sections, we will discuss three current uses of the Internet of Things in the healthcare industry.

1) Streamlining patient data remotely so that it may be used at home or in an emergency situation.
2) The apparatus is able to perform normal maintenance procedures without the intervention of a human being. IoT medical devices make it possible for experts in the healthcare industry and manufacturers of medical equipment to communicate with one another. It has a threshold that is rather low, allowing it to be detected. [22, 24]
3) Through the use of cameras and a variety of other electronic actuators, it is now feasible to do remote patient monitoring thanks to the Internet of Things (IoT).

2.3. ADVANTAGES OF IOT IN HEALTHCARE

The Internet of Things is becoming increasingly prevalent in use within the medical business. As a consequence of this, a solution of this kind provides a plethora of important advantages. Let's go into even more detail about these benefits that the internet of things offers in the medical field so that you can have a better understanding of them.[25]

1) Health Monitoring

A clever piece of technology may be used to keep track of someone's health. The Internet of Things can instantly notify a doctor of a patient's condition if they are suffering from a condition like asthma or heart failure. The Apple Watch has a fall detection system and Internet of Things capabilities. An alert will sound if the user loses their balance and tumbles. In a variety of different situations, the Apple Watch may summon various emergency agencies on its own. Additionally, messages will be delivered to the people you've listed as your emergency contacts. [26-27]

3. DRUG MANAGEMENT

One of the primary benefits that the Internet of Things may bring to the area of medicine is an improvement in the way medication is given. Because of (IoT), you have full authority over the quantity of your medication to be taken. It's possible that doctors will monitor the dosage and evaluate how well the drug is working. As a result of the Internet of Things, patients now get reminders to take their medications at the appropriate times. If a patient does not take their medication at the prescribed time, it is possible to notify a member of the patient's family. [28-30]

3.1. OBJECTIVES OF THE STUDY

- To study on Impact of IoT in E-Health
- To study on Cloud-based Application Access Security

4. RESEARCH METHOD

The study was based on Internet of Things (IoT) technologies, which employ open standards to connect a variety of objects to the internet. The study was also founded on IoT protocols and services, as well as the importance of these features. Despite the fact that several unique protocols have been created, not all Internet of Things applications will demand their simultaneous use. When deciding which Internet of Things protocols are best for a certain application, the features of that application are taken into account. The Internet of Things protocols that are most often used.[31-34]

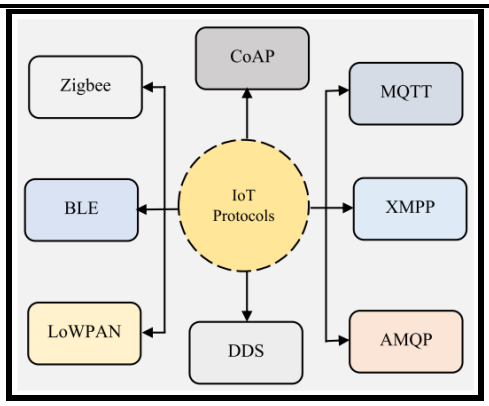

Figure 1 The most prevalent new IoT communication standards that are widely utilised to create smart IoT applications.

Constrained Application Protocol: The restricted restful environments application protocol, often known as CoAP, is a functional and condensed application layer protocol that was developed by the constrained restful environments (CoRE) research team of the Internet Engineer Task Force (IETF). The bulk of IoT devices have limited power and storage, which is why the CoAP protocol was developed. This was done in order to improve the possibilities of HTTP. The HTTP protocol is already a little bit challenging. It accomplishes this by catering to the one-of-a-kind requirements that devices connected to the Internet of Things present.[35-36]

Data Distribution Service: The DDS protocol enables connections between M2M devices that are not only real-time but also adaptive, accessible, and extremely resilient.

ZigBee: ZigBee data transmission is guaranteed to be reliable, low-power, and cost-effective despite the fact that the communication range of ZigBee is very modest. ZigBee is capable of supporting a variety of network topologies, including the star, cluster tree, and peer-to-peer models. A controller is typically in charge of the structure of a P2P topology, and they can be positioned anywhere, including the core of a star network, the base of a tree or cluster design, or any other point. ZigBee and ZigBee Pro are two stacks that are good examples of those that are included in the ZigBee standard. These stacks make it possible for mesh network topologies to work with a diverse set of applications and enable implementations with minimum needs for storage and processing power.[37]

4.1. OPEN-SOURCE IOT PLATFORMS AND OPERATING SYSTEMS

The availability of open-source platforms and operating systems has increased significantly in recent years. These platforms and systems were built with the purpose of supporting a broad variety of diverse systems in addition to providing for their fusion, sharing, and secure storage of data. This part of the article contains a listing of the most important platforms and operating systems that are used for the Internet of Things. These computer operating systems and platforms are well-known for their ability to facilitate the creation of innovative features. Additionally, they have the potential to be exploited in the development of healthcare systems that are both scalable and secure. A list of the relevance of each of these platforms and operating systems for the creation of innovative and distinctive features may be found below, arranged in descending order of importance.[38]

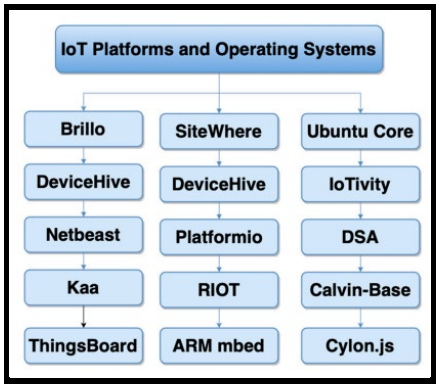

Figure 2 IoT operating systems and platforms

5. DATA ANALYSIS

5.1. SMART HEALTHCARE APPLICATIONS

The ones who will be most adversely affected by this are likely to be those who already deal with a variety of serious health difficulties, including at least one chronic disease, such as the elderly or the crippled. It is crucial to adopt technology that is both substantial and effective in order to meet the criteria for long-term care and remote monitoring of medical issues, and this technology must be backed by computers. This is required to guarantee that patients have a sufficient quality of life and to lessen the financial burden that is put on the healthcare system.[39, 40] Because of this, the quality of treatment given to patients has substantially improved and grown. The field of healthcare has benefited greatly from the Internet of Things, especially in the areas of disease diagnosis and treatment, sickness prevention, helping patients live independently, and remote patient monitoring. This has been the case, especially in the areas of sickness prevention. In each of these fields, it has been shown that this is the case. The Internet of Things application ecosystem for intelligent healthcare also includes additional components, one of which is electronic healthcare, in addition to hospital administration, home healthcare, mobile healthcare, and other applications. Mobile healthcare and mobile healthcare applications are additional elements. Mobile medical treatment is one of the extras available. Figure 1 shows the whole network of Internet of Things (IoT)-based intelligent healthcare systems, together with each of the many parts that make up these systems. In the process of gathering data from the perspective of the patient, a range of sensors and other pieces of medical equipment are used. Help may come from the patient or a member of the medical team. Utilising communication methods like Wi-Fi or LoRa, the data is transmitted via the network layer before being collected for use in the healthcare sector at the perception layer. The perception layer, the next tier in the stack, comes right after the network layer.[41]

Table 1 IoT Communication Protocols With Some Foundational Components

Protocol Name	Network Standard	Latest Version (Year)	Transport Protocol	Messaging Model	Architecture	Security and QoS	Application Levels
MQTT	OASIS, Eclipse Foundations	MQTT version 4.0 (2018)	TCP	Publish, subscribe, and ask and answer	Tree	Both	Online messaging
CoAP	IETF, Eclipse Foundation	RFC 8323 (2018)	UDP	Request/response	Tree	Both	functional field
BLE	802.14.0	6Lo-BLEMesh (2019), MRT-BLE (2018)	TCP/UDP	Publish, subscribe, and ask and answer	Star	Security	Wearable technology
AMQP	OASIS, ISO/IEC	AMQP v 1.4.0 (2019)	TCP	Publish/subscribe	1'2 P	l3oth	Business integration
LoWPAN	IEEE 801.13.3	6Lo-BLEMesh (2019)	TCP	Publish/subscribe	Star, mesh	Security	structural observation
XMPP	(RFC 3921-RFC 3922) RFC 4622, RFC 4854, RFC	XMPP v 1.2.1, XEP-0128 (2019)	TCP	Publish, subscribe, and ask and answer	Client-server	Security	Remote control
Zigbee	IEEE 801.14.3	Zigbee 2.0 (2018)	UDP	Publish/subscribe and request/response	Star, mesh, hybrid	Security	electronic devices
DDS	OMG	DDS v.1.4 (2015)	TCP/UDP	Publish, subscribe, and ask and answer	Bus	QoS	Military

Data Distribution Service The DDS protocol, a publish/subscribe-based data distribution service protocol, offers connections between M2M devices that are not only very reliable but also in-the-moment, flexible, and available. Finding and extracting edge outliers, presenting them to the data analytics engine, and alerting users to their existence are all tasks that fall within the purview of DDS. Both publishers and subscribers are accountable for maintaining application-specific data on a distributed server. Publishers and subscribers are separately responsible for producing and consuming the distributed relational information model.[42]

Bluetooth Low Energy: Bluetooth Low Energy, or BLE, is an improved version of Bluetooth that has a radio that is smaller and uses less power. Applications that need to monitor and control things may thus use it for extended lengths of time. The main distinction between Bluetooth Low Energy (BLE) and conventional Bluetooth technology is that BLE has a greater coverage area with a much lower latency of about 100 metres. Each of these systems makes use of the same protocol stack. The master and the slave categories are used to categorise the numerous electrical devices that adhere to the BLE standard. A subset of each of these categories is contained within the other. The elements of the system that are connected to the slaves and perceived as the masters are those that carry out the most important tasks. The slaves can subscribe to any of the available master devices, and they also have access to a variety of master devices.[43]

ZigBee: ZigBee is a communication standard that supports a small number of communication applications yet offers consistent data transfer, consumes very little power, and is relatively inexpensive. ZigBee may make use of a number of network topologies, including peer-to-peer, cluster trees, and stars. The structure is often under the control of a controller, which might be positioned anywhere in a P2P topology or at the hub of a star network. This controller is movable within the network. Additionally, it could be seen in a cluster configuration or adjacent to a tree's trunk. Two stacks that are excellent examples of those that adhere to the ZigBee standard are ZigBee and ZigBee Pro. These stacks allow mesh network topologies to work with a variety of applications while also needing little implementation effort in terms of CPU and storage resources.

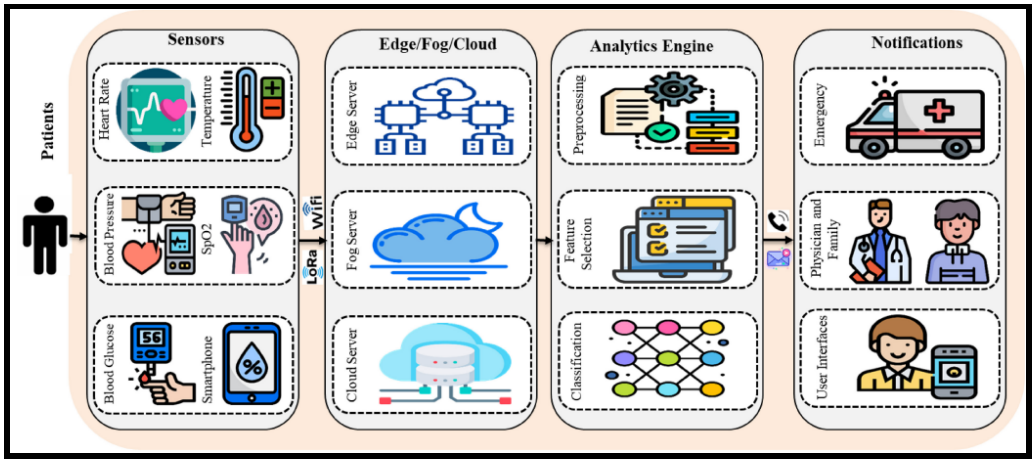

Figure 3 Intelligent healthcare solutions built on the Internet of Things (IoT) are currently being developed. Information is gathered from the real-time medical environment via the sensors, which include the smartphone, heart rate monitor, temperature monitor, blood pressure monitor, and oxygen saturation metre. Even if some data is handled by edge or fog servers, the majority of data processing is done on cloud servers. The data analytics engines that generate the forecasts regarding the patient's condition are housed on these servers. The most recent details on the patient's condition and the required next steps are sent to the patient's family, the attending physicians, and other emergency responders

Some of the data that was gathered is processed on a server known as a fog server that is located closer to the network's edge. This is done in an effort to reduce the amount of strain that is placed on the server that is hosting the cloud.[44] A significant portion of the data analysis, which included pre-processing, feature selection, and classification, was carried out by predictive analytics engines that were hosted on cloud servers. These engines were responsible for the bulk of the work that needed to be done. These engines have recently switched to using AI-based approaches. At the middleware level, all actions pertaining to data analysis are carried out. The outcomes of the analytics engines are communicated via phone calls and text message alerts to the personnel who respond to emergencies, medical professionals, and family members. The findings are also disseminated by means of user interfaces that make it possible

for users to participate. The responsibility for the job that required the consumption of information was split between the business layer and the application layer. In spite of the fact that the Internet of Things has a broad variety of applications in the field of medicine, the following are some of the most recent and promising initiatives to apply it:[45]

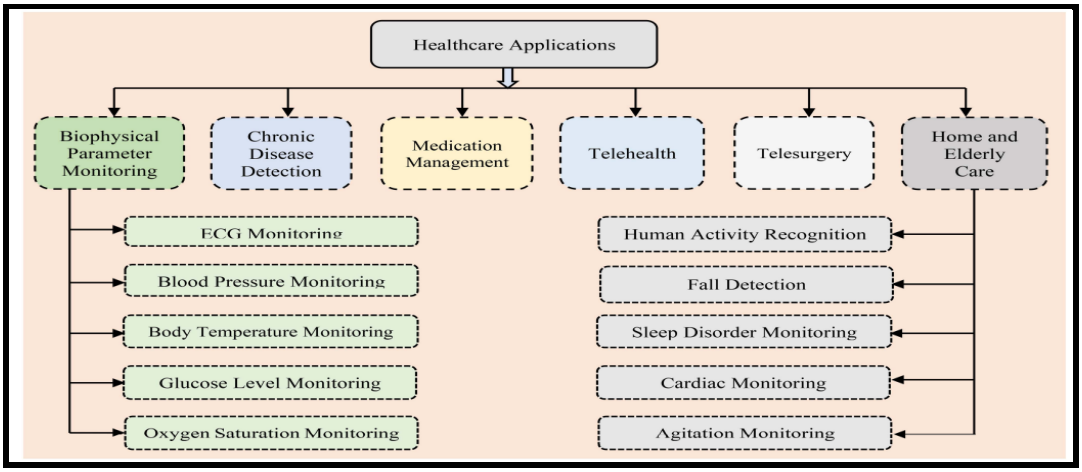

Figure 4 Applications in the field of healthcare that focus on the Internet of Things include the diagnosis of chronic illnesses, the monitoring of biophysical parameters, the administration of pharmaceuticals, telemedicine and telesurgery, as well as home and senior care.

Chronic Disease Detection A chronic disease is a sickness or condition that progressively becomes worse over time and has repercussions that last for a protracted length of time on the health of the person who has it. Around the world, a sizable proportion of the population suffers from chronic conditions including cancer, diabetes, asthma, and coronary heart disease, to mention a few. One of the most frequent unfavourable effects of having a chronic condition is having problems with one's mental health because these problems are frequently the root of additional disorders, making them one of the most common adverse effects. The development of healthcare systems for people with chronic conditions has benefited significantly from the ongoing change that (IoT) has brought about.

Medication Management The development of intelligent medication is one of the most significant obstacles that must be overcome by Internet of Things-based smart healthcare applications. It is necessary since it has a direct impact on human health and because missing a drug dosage might lead to undesirable side effects. The elderly have a higher propensity to not take their prescriptions as directed, which, over the course of time, can raise the risk of cognitive decline as well as disorders such as dementia. As a consequence of this, individuals have to rely on a wide variety of assistive gadgets in order to keep track of when and how much medication to take. In recent years, a number of studies have been carried out with the primary purpose of utilising IoT technology in order to monitor patients' compliance with the treatment regimens that have been advised to them.

6. COMPARISON OF THE IOT PLATFORM ARCHITECTURES

A piece of software called an Internet of Things platform has been developed and customised specifically for one or more of the application domains it will support. There are several application areas that may be addressed. In addition to providing storage, analytics, analytics integration, device administration aid, security support, data collecting support, and support for data gathering, it could be able to manage a large number of distinct domains. An IoT platform could, on the one hand, provide improved capabilities that shorten the time needed to develop IoT applications. This is achieved by addressing the fewest possible scalability and interoperability issues with heterogeneous devices. [46] In this study, 15 different IoT platforms and operating systems were chosen for comparison and contrast. In this part, the writers evaluate the open-source operating systems and platforms that the internet of things may presently use. The comparison's findings are thoroughly explained in Table 2. The support for device administration, data collection, security, integration, analytics, visualisation, and storage is broken down into its component parts in the table.

Table 2. IoT platform and operating system comparison (√ : apply; ×: not apply)

Iot Platform	Device Management	Security	Open-Source	Data Collection	Integration	Analytics	Visualization	Storage
Things Board	√	ITS	√	MQTT, CoAP, HTTP	REST API	√	√	√
Kaa	√	TLS/DTLS	√	MQT, CoAP	REST API	√	√	√
Net beast	√	TLS/SSL	√	HTIP, MQTT	REST API	√	√	√
Contiki	√	x	√	REST API	REST API	√	x	x
Brillo	√	x	√	REST API	REST API	√	√	√
Cylon.js	√	x	√	REST API, MQTT	REST API	x	x	x
Calvin-Base	√	x	√	REST API, HTTP	Calvin Script	√	x	x
DSA	x	Basic Authentication	√	HTTP	REST API	√	x	√
IoT ivity	√	DTLS/TLS	√	Message Queue	REST API	√	x	x
Ubuntu Core	√	RSA, SSH	√	MQTT, AMQP	REST API	x	x	√
ARM mbed	√	a, X.509 Certificate	√	REST API, MQTT	REST API	x	x	x
RIOT	x	x	√	COAP, MQTT	REST API	x	x	x
Platformio	√	SSL	√	REST API, MQTT	Continuous Integration	x	x	x
DeviceHive	√	JSON Web Tokens	√	REST API, MQTT	REST APL MQTT	√	x	x
SiteWhere	√	SSL, Spring Security		MQTT, JSON,	REST API	√	x	x

If one is creating a healthcare application, the authors advise using the Kaa platform. In addition to offering tools for data analysis, visualisation, and storage, this platform also offers data security via open protocols and encryption channels. This platform has tried-and-true features like gateway support, flexible credential lifecycle management, flexible application versioning, scalability, use of datagram transport layer security or transport layer security (TLS) to secure communication with devices, and support for open Internet of Things protocols like MQTT, CoAP, and JSON encoding. [47-50]The healthcare sector has made substantial use of the internet of things (IoT) to boost the efficiency of systems for monitoring patients and providing care to the elderly. In an effort to enhance both the general health and quality of life of its clients, ELE has also integrated a number of healthcare systems. Internet of things-based platforms may be able to offer a foundation that is both desirable and practical for the development of creative and improved healthcare delivery systems. Users have access to these platforms' necessary built-in features, which are needed for analytics, device management, data security, data collection, and visualisation. The aforementioned activities require these qualities. Additionally, the foundational elements of the Internet of Things platform make the process of creating new healthcare systems substantially quicker. One of the numerous elements that are included in these features are techniques for building things that are scalable and interoperable from the bottom up. Platforms for the Internet of Things provide standardised techniques that may be used to gather data from a wide range of devices, each of which is able to communicate with other devices using a unique set of network protocols. Additionally, some of these systems offer over-the-air firmware updates for the system-connected devices as well as remote device setup and control.

7. CONCLUSION

The main subjects discussed in this article are the features, designs, and communication standards of modern Internet of Things devices. These elements work together to provide the conceptual framework for the Internet of Things (IoT). You will get the chance to look at the whole functionality of the underlying hardware and software technologies used by IoT devices here. Service-oriented architectures (SOAs), middleware-based designs, and the more traditional three-layer architecture are a few examples of potential Internet of Things architectures. Innovative approaches,

concepts, and methods for tackling problems are now more easily accessible thanks to the Internet of Things, which will improve healthcare delivery systems. With the objective of giving patients more individualised medical care, the Internet of Things has the potential to make it feasible to create innovative medical therapies. It is feasible to raise the general level of quality, as well as the level of safety and accessibility that healthcare systems offer, by utilising open-source software for both platforms and operating systems. Given that open-source software is accessible for free, this is a possibility. As a result, there will be an increase in interoperability, which will lower the expenses related to managing and maintaining different device networks. Several open-source technologies are currently made available to the general public. These technical developments lay the groundwork for the creation of risk-free, economically viable prototypes of cutting-edge healthcare delivery systems. Because of the Internet of Things, they can be created, and they should be able to support mobile devices like smartphones and wearables. This is done in order to actively urge consumers to use their smartphones and smartwatches as highly significant and effective alerting devices to improve their own health and, as a result, public health. This will ultimately improve people's general health.

CONFLICT OF INTERESTS

None.

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None.

REFERENCES

Universal Open Platform and Reference Specification for Ambient Assisted Living. Available online: http://https://www.universaal.info/ (accessed on 7 September 2019).

Dohr, A.; Modre-Opsrian, R.; Drobics, M.; Hayn, D.; Schreier, G. The Internet of Things for Ambient Assisted Living. In Proceedings of the 2017 International Conference on Cyber-Enabled Distributed Computing and Knowledge Discovery (CyberC), Las Vegas, NV, USA, 12–14 April 2010; IEEE: Piscataway, NJ, USA, 2010; pp. 804–809.

Al-Janabi, S.; Al-Shourbaji, I.; Shojafar, M.; Shamshirband, S. Survey of main challenges (security and privacy) in wireless body area networks for healthcare applications. Egypt. Inf. J. 2017, 18, 113–122.

Koleva, P.; Tonchev, K.; Balabanov, G.; Manolova, A.; Poulkov, V. Challenges in designing and implementation of an effective Ambient Assisted Living system. In Proceedings of the 2015 12th International Conference on Telecommunication in Modern Satellite, Cable and Broadcasting Services (TELSIKS), Niš, Serbia, 14–17 October 2015; pp. 305–308.

Azimi, I.; Rahmani, A.M.; Liljeberg, P.; Tenhunen, H. Internet of things for remote elderly monitoring: A study from user-centered perspective. J. Ambient Intell. Human. Comput. 2016, 8, 273–289.

Tenner, E.; Rall, J.E. Why Things Bite Back: Technology and the Revenge of Unintended Consequences; Vintage Books: New York, NY, USA, 1997; ISBN 0-679-74756-7. 7. World Population Ageing: 1950–2050; UN: New York, NY, USA, 2001; pp. 11–13.

Kumar, R.K. Technology and healthcare costs. Ann. Pediatr. Cardiol. 2011, 4, 84.

Centers for Disease Control and Prevention. "The state of aging and health in America 2007," N. A. on an Aging Society. 2007. Available online: https://www.cdc.gov/aging/pdf/saha_2007.pdf (accessed on 7 September 2019).

Park, K.; Lim, S. A Multilayer Secure Biomedical Data Management System for Remotely Managing a Very Large Number of Diverse Personal Healthcare Devices. BioMed Res. Int. 2015, 2015, 1–17

G. Marques, R. Pitarma, N. M. Garcia, and N. Pombo, "Internet of Things architectures, technologies, applications, challenges, and future directions for enhanced living environments and healthcare systems: A review," Electronics, vol. 8, no. 10, p. 1081, Sep. 2019.

F. Alshehri and G. Muhammad, "A comprehensive survey of the Internet of Things (IoT) and AI-based smart healthcare," IEEE Access, vol. 9, pp. 3660–3678, 2021.

S. Ketu and P. K. Mishra, "Internet of Healthcare Things: A contemporary survey," J. Netw. Comput. Appl., vol. 192, Oct. 2021, Art. no. 103179.

Z. Ashfaq et al., "A review of enabling technologies for Internet of Medical Things (IoMT) ecosystem," Ain Shams Eng. J., vol. 13, no. 4, Jun. 2022, Art. no. 101660.

[R. Maskeliunas, R. Damaševi ˘ cius, and S. Segal, "A review of Internet ˇ of Things technologies for ambient assisted living environments," Future Internet, vol. 11, no. 12, p. 259, Dec. 2019.
J. Cahill, R. Portales, S. McLoughin, N. Nagan, B. Henrichs, and S. Wetherall, "IoT/sensor-based infrastructures promoting a sense of home, independent living, comfort and wellness," Sensors, vol. 19, no. 3, p. 485, Jan. 2019.
A. Mavrogiorgou, A. Kiourtis, K. Perakis, S. Pitsios, and D. Kyriazis, "IoT in healthcare: Achieving interoperability of high-quality data acquired by IoT medical devices," Sensors, vol. 19, no. 9, p. 1978, Apr. 2019.
H. Abdelghaffar and M. Abousteit, "Internet of Things (IoT) interoperability success criteria," Int. J. Enterprise Inf. Syst., vol. 17, no. 1, pp. 85–105, Jan. 2021.
Z. N. Aghdam, A. M. Rahmani, and M. Hosseinzadeh, "The role of the Internet of Things in healthcare: Future trends and challenges," Comput. Methods Programs Biomed., vol. 199, Feb. 2021, Art. no. 105903.
M. N. Bhuiyan, M. M. Rahman, M. M. Billah, and D. Saha, "Internet of Things (IoT): A review of its enabling technologies in healthcare applications, standards protocols, security, and market opportunities," IEEE Internet Things J., vol. 8, no. 13, pp. 10474–10498, Jul. 2021.
M. Rath and B. Pattanayak, "Technological improvement in modern health care applications using Internet of Things (IoT) and proposal of novel health care approach," Int. J. Human Rights Healthcare, vol. 12, no. 2, pp. 148–162, May 2019.
B. Pradhan, S. Bhattacharyya, and K. Pal, "IoT-based applications in healthcare devices," J. Healthcare Eng., vol. 2021, Mar. 2021, Art. no. 6632599.
M. M. Alam, H. Malik, M. I. Khan, T. Pardy, A. Kuusik, and Y. Le Moullec, "A survey on the roles of communication technologies in IoT-based personalized healthcare applications," IEEE Access, vol. 6, pp. 36611–36631, 2018.
S. B. Baker, W. Xiang, and I. Atkinson, "Internet of Things for smart healthcare: Technologies, challenges, and opportunities," IEEE Access, vol. 5, pp. 26521–26544, 2017.
H. Baali, H. Djelouat, A. Amira, and F. Bensaali, "Empowering technology enabled care using IoT and smart devices: A review," IEEE Sens. J., vol. 18, no. 5, pp. 1790–1809, Mar. 2018.
P. Sethi and S. R. Sarangi, "Internet of Things: Architectures, protocols, and applications," J. Electr. Comput. Eng., vol. 2017, Jan. 2017, Art. no. 9324035.
B. N. Silva, M. Khan, and K. Han, "Internet of Things: A comprehensive review of enabling technologies, architecture, and challenges," IETE Tech. Rev., vol. 35, no. 2, pp. 205–220, Mar. 2018.
H. K. Kondaveeti, N. K. Kumaravelu, S. D. Vanambathina, S. E. Mathe, and S. Vappangi, "A systematic literature review on prototyping with Arduino: Applications, challenges, advantages, and limitations," Comput. Sci. Rev., vol. 40, May 2021, Art. no. 100364.
D. K. Halim, T. C. Ming, N. M. Song, and D. Hartono, "Arduino-based IDE for embedded multi-processor system-on-chip," in Proc. 5th Int. Conf. New Media Studies (CONMEDIA), Oct. 2019, pp. 135–138.
S.-M. Kim, Y. Choi, and J. Suh, "Applications of the open-source hardware arduino platform in the mining industry: A review," Appl. Sci., vol. 10, no. 14, p. 5018, Jul. 2020.
J. Mesquita, D. Guimaraes, C. Pereira, F. Santos, and L. Almeida, "Assessing the ESP8266 WiFi module for the Internet of Things," in Proc. IEEE 23rd Int. Conf. Emerg. Technol. Factory Autom. (ETFA), Sep. 2018, pp. 784–791.
I. Gunawan, A. Sudianto, and M. Sadali, "Measuring body temperature based Internet of Things (IoT) using ESP8266 and firebase," SISFOTENIKA, vol. 11, no. 1, p. 91, Jan. 2021.
T. Z. Asici, B. Karaduman, R. Eslampanah, M. Challenger, J. Denil, and H. Vangheluwe, "Applying model driven engineering techniques to the development of contiki-based IoT systems," in Proc. IEEE/ACM 1st Int. Workshop Softw. Eng. Res. Pract. Internet Things (SERP4IoT), May 2019, pp. 25–32.
Y. B. Zikria, M. K. Afzal, F. Ishmanov, S. W. Kim, and H. Yu, "A survey on routing protocols supported by the Contiki Internet of Things operating system," Future Gener. Comput. Syst., vol. 82, pp. 200–219, May 2018.
C. Sabri, L. Kriaa, and S. L. Azzouz, "Comparison of IoT constrained devices operating systems: A survey," in Proc. IEEE/ACS 14th Int. Conf. Comput. Syst. Appl. (AICCSA), Oct. 2017, pp. 369–375.
F. Jaskani, S. Manzoor, M. Amin, M. Asif, and M. Irfan, "An investigation on several operating systems for Internet of Things," EAI Endorsed Trans. Creative Technol., vol. 6, no. 18, Jan. 2019, Art. no. 160386.
E. Baccelli et al., "RIOT: An open source operating system for low-end embedded devices in the IoT," IEEE Internet Things J., vol. 5, no. 6, pp. 4428–4440, Dec. 2018.
B. Karaduman, M. Challenger, R. Eslampanah, J. Denil, and H. Vangheluwe, "Platform-specific modeling for RIOT based IoT systems," in Proc. IEEE/ACM 42nd Int. Conf. Softw. Eng. Workshops, Jun. 2020, pp. 639–646.

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.

H. Fotouhi, A. Causevic, K. Lundqvist, and M. Bjorkman, "Communication and Security in Health Monitoring Systems – A Review," 2016 IEEE 40th Annual Computer Software and Applications Conference (COMPSAC). 2016.

M. Belesioti et al., "e-Health Services in the Context of IoT: The Case of the VICINITY Project," IFIP Advances in Information and Communication Technology. pp. 62–69, 2018.

P. S. Suryateja, "Threats and Vulnerabilities of Cloud Computing A Review," International Journal of Computer Sciences and Engineering, vol. 6, no. 3. pp. 297–302, 2018.

O. Debauche, S. Mahmoudi, P. Manneback, and A. Assila, "Fog IoT for Health: A new Architecture for Patients and Elderly Monitoring," Procedia Computer Science, vol. 160. pp. 289–297, 2019, doi: 10.1016/j.procs.2019.11.087.

A. Paul, H. Pinjari, W.-H. Hong, H. C. Seo, and S. Rho, "Fog Computing-Based IoT for Health Monitoring System," Journal of Sensors, vol. 2018. pp. 1–7, 2018, doi: 10.1155/2018/1386470.

K. S. Awaisi, S. Hussain, M. Ahmed, A. A. Khan, and G. Ahmed, "Leveraging IoT and Fog Computing in Healthcare Systems," IEEE Internet of Things Magazine, vol. 3, no. 2. pp. 52–56, 2020, doi: 10.1109/iotm.0001.1900096.

R. M. Abdelmoneem, A. Benslimane, E. Shaaban, S. Abdelhamid, and S. Ghoneim, "A Cloud-Fog Based Architecture for IoT Applications Dedicated to Healthcare," ICC 2019 - 2019 IEEE International Conference on Communications (ICC). 2019, doi: 10.1109/icc.2019.8761092.

ITU (2005). The Internet of Things-Executive Summary [online]. Available from: www.itu.int/osg/spu/publications/internetofthings [Accessed 17 Oct 2012].

ITU-T (2008). Ubiquitous Sensor Networks (USN), ITU-T Technology Watch Briefing Report Series, No. 4, February 2008.

Jedermann, R., Palafox-Albarran, J., Jabarri, A., Lang, W. (2011). Embedded Intelligent Objects in Food Logistics Technical Limits of Local Decision Making. In M. Hülsmann et al. (eds.), Autonomous Cooperation and Control in Logistics, DOI:10.1007/978-3-642-19469-6_16, Berlin Heidelberg, Springer-Verlag.

Jeffry, S. W.; Higgins, J. E; Gilbert, M. D.; Cogan, S.F.; (2003). Evaluation of Electrically Disbonding Adhesive Propertites for Use as Separation Systems. 44th AIAA/ASME/ASCE/AHS Structures, Structural Dynamics, and Materials Conference, 7-10 April 2003, Norfolk, Virginia.

Jones, P. (2006). Networked RFID for use in the Food Chain. In proceedings of IEEE Conference on Emerging Technologies and Factory Automation, 1119 – 1124, doi: 10.1109/ETFA.2006.355252