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MedThings: A Model Based on Cloud Computing and IoT to Support E-Health Systems in Saudi Arabia

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***Abstract*— According to the vision of 2030, which focuses on improving healthcare, and providing high-quality services for hospitals and patients, it is essential to meet these requirements to make Saudi Arabia compete with advanced countries. The main aim of this paper is to support e-health systems in Saudi Arabia based on cloud computing and internet of things (IoT). Most of the existing e-health frameworks that based on IoT used cloud or edge and did not support all three cloud layers, cloud, fog, and edge to handle some cloud computing issues, and not all of these models consider the patient's privacy aspects. Therefore, in this paper, we propose Medical model based on internet of internet of things (MedThings) e-health model that based on cloud computing and IoT, this model support edge, fog, cloud layers to ensure online monitoring, improve latency, and support rapid alerts. The proposed architecture of medical systems would maintain the privacy of patient's data, provide health services for different members of the community and cover large areas, support early warning, and have the ability to predict diseases. MedThings would be a starting point towards the transformation of the medical systems in Saudi Arabia.**

Internet of things; e-Healthcare system; Edge computing; Fog computing; Saudi Arabia.

I. INTRODUCTION

The health care information system is defined as "an arrangement of information (data), processes, people, and information technology that interact to collect, process, store, and provide as output the information needed to support the health care organization" [1]. It has two types, the administrative system such as staff scheduling system and the clinical systems such as patients care monitoring system. The health care domain does not adapt with information technology as fast as other domains because of its difficulties. In other words, its systems' nature is not as the same ease of other domains such as the banking system. Another factor is that its medical data are heterogeneous. With the rapid improvement in technology, E-health starts to take advantage of some technology solutions such as cloud computing. Which provides chances to improve E-health but on the other side, cloud computing is still in its development phase [2]. Therefore, E-health models still suffers from some problems specially in the security and privacy of the data and the users. More researches to contribute and improve this field by using IoT and cloud, fog, and edge computing is still needed.

Several related works have been previously surveyed different aspects related to the IoT healthcare such as [3]-[5]. Islam et al. in [3], a comprehensive survey for the IoT in healthcare, which discusses several aspects related to IoT in healthcare, such as architectures, applications, and services. And define the set of challenges in the Health systems based on IoT. Then proposed a secure model that minimizes the security risk. BAKER at al. in [4], focused on IoT healthcare systems with wearable sensors and showed their weaknesses, strengths, and compatibility. Furthermore, the study showed that security and privacy are the most concerning IoT medical system challenges. Greco et al. in [5], give an overview of the solutions for health care from the wearable sensors until the latest trend for the IoT based solutions for health care based on the edge and fog computing.

Therefore, this paper makes a unique contribution by focusing on the health record systems and solving the challenges related to it, and overviewing the different IoT models introduced for the healthcare field by using cloud computing. The main contribution of the paper is to introduce MedThings a secure comprehensive model for the IoT healthcare system in Saudi Arabia based on cloud, fog, and edge computing in order to meet the vision of 2030. The rest of the paper is organized as follows. Section (II) gives a broad background of the concepts related to the research. Section (III) presents an overview of the literature using cloud computing to enhance the E-health record. Then the models that were introduced using Cloud and IoT to enhance the e-health systems. Section (IV), Will discuss the introduced studies for the E-health record systems and the limitation of the existing systems using cloud and IoT. Then we introduced MedThings, our proposed framework for the e-medical field in Saudi Arabia. Concluding and future recommendations remarks are laid out in section (V).

II. BACKGROUND

A. E-health

E-health cloud is the situation when cloud computing capabilities and information technologies are used to support and improve patient care and operational efficiency of health institutions [2]. Figure 1 shows the e-health cloud architecture. Electronic Medical Records (EMR) is defined as "Electronic Medical Records are electronic health related information of an individual that can be created, gathered, managed and consulted by authorized clinicians and staff within one healthcare organization" [1]. EMR consist of: Data repositories, Order entry, Decision support systems, Pharmacy,

Figure 1 E-health cloud architecture [2]

and clinical documentation. It is used in order to improve patient care and provide healthcare staff with tools to manage healthcare services. Electronic Health Records (EHR) is the same as EMR in storing and processing patients' information but it is designed to be shared with other organizations. There are some Challenges of implementing EHRs or EMRs: Financial challenges such as lack of the resources that are needed to develop and support the e-health systems. Also, Organizational challenges such as How much the healthcare staff accepted to use these systems. And Technical challenges such as lack of standards for interoperability [6][1].

When cloud computing is integrated with other techniques, its efficiency would be increased. Internet of things (IoT) is an example of the technology that would improve cloud-computing capabilities. IoT is one of the wireless new models, its main idea is a pervasive presence of things around us for example sensors, actuators, mobile phones, etc. that are connecting and interacting with each other to perform previously specified objectives[7]. This technique could be create a relations between humans and devices[8]. Also, the need of big data analysis is came to handle huge amount of data that comes from a variety of sources to survive a dedicated needs [9]. Blockchain is another important technology which considered as a distributed database of records that could be executed, its main features it to improve decentralization and enable sharing between parties easier and faster[10].

B. Challenges

There are many challenges and technical issues in healthcare some of them are: privacy, Security, Quality and Interoperability. Patients' information privacy is a very critical point that should be taken in consideration when using electronic records either to present them, exchange them or store them on media. About the security, Healthcare systems, and Healthcare record systems must be protected from many threats. Such threats can be environment related such as fires, other threats may relate to IT problems such as misuse of hardware or software, No available Backup or viruses. About the quality, high workloads of doctors reduce the time of patients care. So, this resulted to the employment of healthcare assistants who are responsible for collecting and storing patients' information that affects the quality. Interoperability means that each organization's EHR system is serve it locally with isolation from other healthcare providers. Interoperability weakness cause: reduce the level of patient's care and it waste of available resources. Legacy EHR systems developed to serve internal healthcare provider's requirements. On the other side, exchanging information with others is ignored. Future EHR systems will be designed to provide interoperability property[6][11].

III. LITERATURE REVIEW

A. Using cloud to enhance the E-health record systems

Cloud-based systems are commonly used to serve and support health sector, one of these systems utilize cloud to provide analysis services for example MedCloud [12], which is web-based health information management system (HIMS) its main idea is to provide statistical data processing, check the validity of data before insertion, support online surveillance and data exchange, and GIS support. This system focuses on solving the problem of health systems in Pakistan, because the existing systems do not support data exchange or data analysis. MedCloud supports GIS, open source, scalability, alerts, interoperability, real-time data, and data analysis. As a result, MedCloud is considered as an important step to improve health systems in Pakistan. Another type of medical cloud-based system focuses on administrating aspects, as the model that suggested in [13] which is e-health framework has the ability to adapt with any e-health environment, this framework has two main parts: one is related to how manage large data, and another part focus on security issues. This framework comes to solve some problems for example: some countries are still used papers in their health sector, also the existing systems are based on object-oriented architecture this way makes them require more time and cost to be able to adapt with any environment. The proposed system is directly connected to the health data store, also this system is based on biometric confirmation to provide more security mechanisms to access and retrieve patient data. As a result, the proposed framework enhances administration tasks by saving time, cost, protect patient data, also this framework can work in any sector.

Riad et al. in [14], proposed a new access control mechanism (SE-AC) for the Electronic Health Records (EHR) in the cloud-based IoT healthcare systems. The mechanism has been introduced to solve the patients' security issues related to EHR. The SE-AC mechanism provides preserving-privacy for the cloud EHR, it can adapt dynamically with the users' privileges, deal with a large number of users from different domains and with different roles, and enables patients to control their own EHRs data and set their policies. As a result, the mechanism provides confidentiality for the patients' data. On the other side, Most Electronic Health Record (EHR) systems suffer from interoperability issue such as the used systems in China's hospital as mentioned in [11]. This mean that these legacy systems are serve locally. They don't exchange data with other hospitals which leads to poor patients care. For example, if a patient needs to change his treatment plan to another hospital, he needs to take his records as a paper and CDs then the second hospital should rewrite his information to the system. Hybrid cloud is used to solve this problem. Firstly, the data is extracted from the legacy systems then it converted to unified form because of its inconsistency. Then deploy the data index center on a public cloud and HashMap are used to index data. The indexed data include non-sensitive patients' information and EHR information, this mean that not all the patients' data are uploaded on a public cloud. And EHR is stored locally in its hospital's private cloud and it is sent to a specific hospital if it requests that. This point guarantees the privacy of the patients. Also, the system uses two-way authorization by the doctor and the patient. The results show that the system is reliable and scalable. But the efficiency of the proposed system depends on the services provided by the chosen public cloud. Med-share system provides a solution to interoperability issue between health care provider by apply Hybrid Cloud with secure sharing of patients' data. Also, Information security is a common challenge in cloud applications. The proposed application in [15]is a solution of this issue. They develop a cloud application that allows patients to upload their records to the cloud with using encryption schema which is identity-based broadcast encryption scheme (IBBE). Then it is decrypted by an authorized doctor. Also, doctor can re-encrypt the record by using Ciphertext-Policy Attribute-Based Proxy Re-Encryption (CP-ABPRE) in order to share it with the specialist. Also, Identity-based encryption with equality test (IBEET) is used to allows patients to communicate with other patients with the same status. This study provides security solution in cloud application. The used encryption techniques provide securely management of patient records.

By integrating cloud and big data to build smart healthcare system we can manage huge amount of healthcare data which come from wide variety of devices in a short time as what done in [16]. The solution provides unified layer to collect data and support integration between public medical resources and personal health devices, ability to analyze heterogeneous healthcare data, and unified application programming interface for developers and unified interface for users. As a result, when we combine cloud and big data in e-healthcare systems, the performance of these systems would be improved. The blockchain technology can also be utilize to support e-health cloud systems. For example, the researchers in [17]proposed an adoptive leader election algorithm (ALEA) that implemented using blockchain technology to support electronic personal health record E-PHR in cloud environment. This technique proposed to handle synchronizing access when more than one user want be access to shared files in e-health system, which may lead to conflicts and problems in consistency and correctness of data. This problem could be solved by blockchain technology which can support distributed system, and leader election algorithm which able to allow exclusive access. As a result, by combining Blockchain technology with ALEA would support decentralization, robustness, ownership, security and privacy, and immutability. However, it has a drawback because it requires high cost for communication. Table1 shows a comparison between existing systems.

B. Using Cloud with IoT

We can improve the functionalities of cloud in healthcare by integrating cloud with Internet of Things (IoT) capabilities. In [18]the researchers propose a health cloud platform with IoT, this platform aims to refine elder people live who have chronic. Because elder people's life in china threatened by chronic diseases, for example, hypertension and diabetes. This system contains subsystems, which are IoT health services subsystem, health cloud application service subsystem, and data management subsystem, to provide two main services: real-time medical care technology and personalized health service. As a result, applying this system would be to support large areas coverage, high quality, and low cost to elder people. Khan et al. in [19] introduced a framework based on Modified Deep Convolutional Neural Network (MDCNN) for heart disease prediction. The problem is that the accuracy of the IoT based systems for heart disease diagnosis still needs improving. The proposed system consists of three stages: pre-processing the data, feature selection based on mapping-based cuttlefish

Table 1 Comparison between existing e-health cloud system.

Paper no.	Contribution	The used technology	The solved challenge
[11]	Build Hybrid Cloud to exchange patients records with using de-identified indexing of patients' information. Also, two-way authorization are used.	Hybrid Cloud	Interoperability and privacy
[12]	Build a cloud-based disease surveillance system to provide statistical data processing, check the validity of data before insertion, and support online surveillance and data exchange in Pakistan.	Cloud capabilities.	Scalability, interoperabili ty, and online data support.
[13]	Propose a framework that has ability to adapt with any e-health environment and it is based on biometric confirmation to provide more security mechanisms to access and retrieve patient data.	Cloud capabilities, and biometric confirmation.	Security and adaptability.
[14]	Build a new access control mechanism (SE-AC) for Electronic Health Records (EHR) in cloud-based IoT healthcare systems to provide confidentiality for the patients' data.	Access Control	Security, privacy, scalability, accessibility, confidentiality
[15]	Develop mobile application that use cloud storage with using some encryption schema which are IBBE, IBEET and CP-ABPRE	Cloud storage and Encryption techniques	Security
[16]	Integrating cloud and big data in smart healthcare system to manage huge amount of healthcare data, which come from wide variety of devices in a short time.	Big data	Decentralization.
[17]	Propose an adoptive leader election algorithm (ALEA) that implemented using blockchain technology to to handle synchronizing access when more than one user want be access to shared files in electronic personal health record E-PHR based on cloud environment.	Blockchain technology	Security, privacy, and decentralization.

optimization algorithm (MCFA), and classification the patients' data into normal and abnormal. The proposed method outperforms other existing classifiers with an accuracy of 98.2%. To enhance the real-time denoising and mentioning the concept of digital twin has been used with IoT and cloud computing. Liu et al. in [20], Introduced a novel healthcare framework based on the digital twin, cloud computing, and the internet of things for the elder people. That can be used to solve the problem related to real-time monitoring, diagnosing, giving crisis warnings, and interacting with the elder patient. This framework can make the entire lifecycle of the elderly more efficient and convenient by enhancing real-time monitoring, diagnosing, and prediction. Two experiments have been made to test the feasibility of real-time monitoring and schedule optimization.

Furthermore, some studies used fog with IoT to introduce and enhance the e-healthcare field [18]-[20]. Abdel-Basset et al. in [21], introduced a novel decision supporting framework for monitoring and detecting type-2 diabetes patients in real-time. Having type-2 diabetes and not knowing could have significant consequences on the individuals' health wherefore, the existed models for detecting type-2 diabetes patients need enhancement, especially that the existing models result still not accurate. The model has been built based on a hybrid technique of type-2 neutrosophic numbers and višekriterijumsko kompromisno rangiranje (VIKOR). The framework can provide better accuracy for diagnosing the patients and minimize the execution Time by 9.8%. Furthermore, monitoring health system are time sensitive. So, they need some techniques such as fog computing to reduce latency. As In [22] the proposed system is a real time monitoring system that depends on using fog computing. It consists of sensors that collect data about the patient and his environment. Then these data are sent to the fog node to classify the situation whether it is normal or not by using Bayesian belief network (BBN) classifier. If it is abnormal then fog node send alert to the responder (the doctor). Also, the data is sent to the cloud for data mining and analytic purpose because fog layer just deal with simple events. Then, cloud is sending the data to the responder and if the status is urgent, an alert is sent to the family members. As a result, the used classifier (BBN) achieves high accuracy and response time. So, this model provides Remote monitoring, real time processing and reducing latency. A proposed architecture (model) is a presented in [23], it is a solution of interoperability issue. It consists of 4 modules which are client module, data filtering module, data processing module and event handler module. Client module is responsible for authentication, aggregation and pre-processing of the data that is received from IoT devices. also, client module is responsible for actions of actuator. Data filtering module is responsible for extract the health data from raw data that is received from client module. then, data are forwarded to the data processing module to be processed and analysed. Event handler module determine the suitable response to the event and forward it to the client module to determine the action of actuator. Client module is placed in fog nodes that is close to IoT devices. The other modules are placed in higher level fog nodes. As a result, the model provides interoperability and reduce latency and energy.

Even edge computing has been used with IoT to enhance healthcare application storage capabilities, real-time computing, and low latency. Several researches have been introduced that use IoT and edge computing for e-health, such as in [21]-[23]. Pustikhina et al. in [24], proposed the ETS-DNN model, a deep neural network training scheme for the internet of medical things (IoMT). The problem is that a trustworthy real-time IoMT system is still needed. The proposed model includes a Hybrid Modified Water Wave Optimization (HMWWO) that tune the deep neural network structure parameters and consist of a softmax (SM) layer that made the classification. As a result, the proposed framework can collect data quickly and process it to recognize the patterns in the data. Albdulatif et al. in [25], introduced an edge of things secure framework for smart health surveillance that can perform real-time analysis, monitor, and aggregate of the biosignal data. The problem is that the edge of things has some privacy-preservation issues, which could be a major concern in the healthcare system. The introduced framework has been built by using two machine learning clustering techniques, the K-means (KMC) clustering and Fuzzy c-means (FCM), which work based on Fully Homomorphic Encryption (FHE). As a result, it allows the distributed edge nodes to process a larger scale of heterogeneous data securely. Furthermore, it enhances the response time and the performance of processing the encrypted data. The study in [26], Propose an IoT based remote monitoring system with using edge computing that is called AIM smart edge system. It solves three challenges which are affordability, accessibility and availability. Medical sensors are used to collect data. Then they forwarded to AIM Gateway. AIM gateway could be any of these devices which are shared gateway device that is between many patients, patient smartphone or AIM vitals device. Then gateway Run the program called rapid active summarization for effective prognosis (RASPRO) that convert the data collected from sensors to clinical format. gateway also run alert technique that named criticality measure index (CMI) alerts. The system also has a view for the physicians that can be web platform or Android application. The results show that the system provide availability, accessibility and affordability. Table2 shows a comparison between exciting IoT frameworks.

I. DISCUSSION

As shown above in the literature review Table 1 [11] – [17], that studies in E-health record systems are numerous and comprehensive. It discusses the most common issues of EHRs, such as security, privacy, interoperability, decentralization, and scalability. The provided solutions are variant. Some of them are using cloud capability with security mechanisms, access control techniques, encryption techniques, blockchain technology, bigdata technique or using a hybrid cloud. All the presented solutions give good results, improve EHRs and enhance E-health. Based on the literature Table 2 [18] – [26], the most used sensors are medical body wearable sensors that measure blood pressure, temperature, glucose level…etc. For the network type, the most used network is wireless. For the analytic technique, the most used analytical techniques are data mining, decision-making, classifying, and analyzing

Table 2 Comparison between frameworks that used cloud and IoT

Paper no.	**Sensor**	**Network**	**Layers**	**Edge/fog computing**	**Analytic technique**	**Result**
[18]	Wearable sensor to collect data about blood pressure, diabetes, arteriosclerosis, osteoporosis, cardiovascular disease, and lung disease. This sensor send these data to cloud automatically.	Wi-Fi	The most works are done in the sensing layer and the network layer.	Cloud	It contains a data mining center that has many high-performance servers that perform analysis algorithms	Support large areas coverage, high quality, and low cost to elder people.
[19]	Blood pressure and electrocardiogram (ECG).	LoRa	Cloud Layer (pre-processing, feature selection, classification)	Cloud	Classification based on using the MDCNN classifier	Method achieved accuracy with 98.2% for heart disease prediction
[20]	ECG device (Huake HKW-10)	Wi-Fi	Resource layer, perception layer, virtual resource layer, middleware layer, service layer, user interface layer, application and user layers, security layer	Cloud	It performs analysis on the data such as real time monitoring, crisis warning, and medication reminder.	Make the entire lifecycle of the elderly more efficient
[21]	WBAN including: Blood pressure, heart rate, respiratory rate, motion activity, glucose recognition	Wi-Fi	Cloud layer, fog layer, wearable IoT sensors	Fog	Analysis to support the decision-making based on the symptoms	Provide better accuracy for diagnosing the patients and minimize the execution Time by 9.8%.
[22]	Medical body Wearable sensors such as sensor that measures blood pressure and environment sensors such as that measure room temperature	Wireless	Data Acquisition Layer, Fog Layer (Event Classification layer), Cloud Layer (Information Mining Layer, Decision Making Layer, Cloud Storage Layer)	Fog	Bayesian belief network (BBN) classifier (in fog layer), data mining and decision making in cloud layer	The proposed model provides Remote monitoring, real time processing and reducing latency.
[23]	IoT sensor and wearable devices such as smart watches.	Bluetooth and zigbee.	N/A	Fog	It's done in data processing module.	It reduces delay and power consumption and provide interoperable solution.
[24]	Electrocardiogram (ECG), heart rate, blood pressure, glucose level, cholesterol, and pulse rate.	N/A	Cloud layer, edge layer, wearable IoT sensors	Edge	Performs analysis to classify the data	Collect data quickly and process it to recognize the patterns in the data.
[25]	Electrocardiogram ECG data, heart rate, temperature ... etc.	5G wireless network	Cloud layer, edge layer, wearable IoT sensors	Edge	Performs analysis to classify the data in a secure way	Allows the distributed edge nodes to process a larger scale of heterogeneous data securely. provides a better response time and performance.
[26]	Medical wearable sensors	mobile, Cellular and NB-IoT	Edge (vitals sensors, RASPO, CMI) and cloud (storage, analytic, privacy and some services)	Edge	It done in cloud for simple purpose such as detect anonymized patients' data.	Increase availability of physicians (doctors), it reduces energy consumption (accessibility), It reduces bandwidth cost of sending medical data remotely (affordability).

techniques. In conclusion, all of these studies gave good results. As a gap, the existing e-health cloud frameworks with IoT used cloud or edge and did not support all three cloud layers, cloud, fog, and edge to handle some issues like online monitoring, improve latency, and support rapid alerts. And use Wi-Fi to allow the provisioning of health services for wide range and cover large areas, at the same time maintain the security and privacy of patients, since not all the models considering the security aspect.

C. MedThings model

The proposed model for the e-health system in Saudi Arabia has been suggested based on the vision of 2030 for the medical field [27], [28]. It considers the literature reviews that proposed models for e-health based on IoT and cloud computing. The model consists of the data of the patients, which can be measured with the help of smartwatches and wearable sensors from Wireless Body Sensor Networks (WBSN) such as sensors for measuring heart rate, respiratory rate, motion activity, cholesterol, glucose recognition, and electrocardiogram (ECG). The data from the sensors will be collected and transmitted to the edge layer. Wireless Fidelity (Wi-Fi) can be used for the short and long-range of communication. The edge layer will ensure low latency and optimal utilization of the IoT resources. On the other hand, the fog layer which contains routers, will perform local processing and simple analysis of the patients' data, such as classifying data and giving medication reminders. It enhances real-time processing, scalability, reliability, adaptability, and energy awareness. In contrast, the cloud layer which contains cloud servers, will be responsible for higher performance computing tasks such as predicting diseases and remote big data storage, such as the patients' health records. The security of the data and the privacy of the user can be provided by encrypting the data in the fog and the cloud by using encryption schemas such as fully homomorphic encryption (FHE) and emerging Attribute-based Encryption (ABE). The community member from the patients to their family members, the doctors and medical staff, third parties, different hospitals, and governmental organizations, can all be involved in the system. The model can serve hospitalized patients, non-hospitalized patients, older patients, patients with chronic diseases such as heart diseases and diabetes, and even healthy individuals. The machine learning methods can be used for disease identification, behavioral modifications, and grouping user logs. Furthermore, the digital twin concept can help real-time supervision, crisis early warning, and optimize the scheduling. The proposed model has been shown in Figure 2.

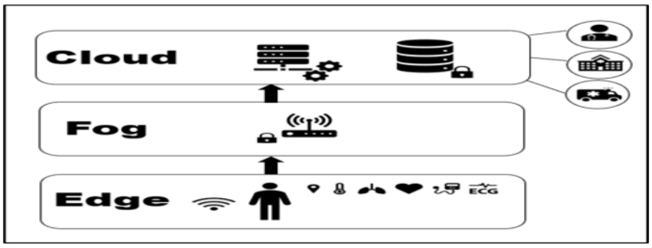

Figure 2 MedThings a three-tier based architecture for SA medical systems

IV. Conclusion

In Saudi Arabia, all the systems in the different sectors should be improved to meet 2030 vision requirements. In this paper, we propose MedThings e-health model, which supports edge, fog, and cloud layers. This model will facilitate the life of patients, doctors, and medical staff. The patient will wear a wearable sensor, this sensor measure patients' data such as heart rate and blood pressure. This data will be transmitted to edge layer, which ensures optimal utilization of the IoT resources. After that, data will be analyzed to give medication reminders in timely manner at the fog layer. Finally, the cloud layer, which is responsible of big data storage and disease prediction. The security and privacy can be provided by using encryption mechanisms. The communication in this model is based on using Wi-Fi. MedThings would be a starting point towards the transformation of the medical systems in Saudi Arabia. As a future work, we plan to generalize the model to be adaptable in the different other sectors.

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