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A Novel Architecture for Internet of Things Based E-Health Systems

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The emerging Internet of Things (IoT) technology has revolutionized existing medical devices to act smartly towards creating digital world related to health. IoT endeavors an enormous promise in the area of electronic health (e-health) where existing technologies have been deployed to provide rapid access to patient care. IoT based e-health systems involve significant technologies and connected things to monitor, identify, track, manage and store patients' information for ongoing healthcare. A mechanism is required that assures interoperability between devices for processing and use of resources in an efficient manner for the successful deployment of IoT within e-health. The study has coined a unique idea through an exclusive induction of e-governance layer in the concept and implementation of IoT based e-health systems. Therefore, the study targets to develop a novel architecture for incorporation of IoT in the e-health systems by intensively focusing its different layers i.e., sensing, application, transmission, fog and e-governance for having emphasis to get quick response and secured transmission with improved healthcare services. An exploratory study has been conducted to investigate existing literature regarding cutting-edge developments in the arena of e-health. The proposed IoT based e-health architecture is extremely impressive novelty with much comprehensiveness of the concept with the inclusion of very a crucial but previously unnoticed component of Emergency Medical Services (EMS) having its integration through blockchain technology. Another novelty has been presented with the idea of explicitly defining the e-governance layer that encompasses all layers of the proposed architecture in order to achieve quality healthcare services.

Keywords: Application Layer, Blockchain, Cloud Platform, E-Governance Layer, E-Health, Emergency Medical Services, Fog Layer, ICT, IoT, Sensing Layer, Transmission Layer.

1. INTRODUCTION

Health is the most valuable wealth of human beings. Therefore, it is required to adopt state of the art technologies in edict to enhance quality of healthcare services. E-health means to increase the efficiency and scale up the e-health services for better utilization of technologies in healthcare systems [9]. Due to this fact, e-health has ever growing demand for efficient coverage, facilities and timeliness in healthcare centers. E-health systems support various stakeholders like doctors, patients and paramedical staff to keep track of their patients and monitor their health condition continuously. Majority of e-health systems use embedded technologies for the better services, care and association with patients [44]. Internet of Things (IoT) is an evolving terminology that collects and communicates data through smart sensing devices in faster yet accurate manner [3, 5, 39]. IoT technology connects multiple things (devices) via internet to formulate smart environment where things communicate having their computing capabilities [6]. It has been applied in several grounds of life with smart homes, smart cities, transportation systems, traffic monitoring and health units [5, 26]. IoT endeavor an enormous promise in the field of e-health where it applies its existing technologies to increase quality and access to care [7, 8, 18, 47]. With the deployment of IoT in health units it brings ease to the doctors and patients by enabling real time monitoring and keeping track of the patients from everywhere. With the rapid growth of technologies, there is a need to adopt these innovations to expand the effectiveness of the systems overall or especially in e-health where increasing quality of patients' health is vital.

However, for the successful deployment of IoT in e-health, there is need to assure efficient processing and use of resources to increase the performance of healthcare centers. Different techniques like cloud computing, fog computing and blockchain are

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being utilized to assure efficient processing in e-health systems. Therefore, e-health systems need to adopt IoT for communication between e-health systems and patients from everywhere. Existing studies have demonstrated the integration of IoT technology with fog and blockchain terminologies separately but, existing studies lack to provide IoT based architecture that embed these new terminology like edge fog layer and blockchain layer [45]. The focus of the study is to integrate e-health and IoT in an improved and secured way. The EMS has also been integrated with e-health system that would help by saving many invaluable human lives. The induction of e-governance layer in the proposed IoT based e-health architecture is one of the major contributions of the study as it has never done before. Such incorporation of the e-governance layer in the architecture ensures the interoperability and compatibility of the entities not only within a single e-health unit but also among the others in a much broader way. The proposed architecture increases performance of e-health systems to a suitable level by adjusting dynamic changing situations of IoT, with usability, extortions, variety, and heterogeneity.

The rest of this paper is arranged in such a way that Section 2 discusses background of the study which includes various existing literature findings and descriptions. Section 3 defines methodology adopted to conduct this study. Section 4 elaborates the proposed architecture for IoT centered e-health system and Section 5 provides limitation along with Section 6 that provides delimitations of the study. Section 7 concludes the study, the future directions are presented in Section 8 while in the Section 9 the disclosure statement is delineated.

1.1. Motivation

IoT connects a lot of devices including several technologies and sensors. It helps to encourage trade of belongings, information and facilities between technologies and people in extra dependable and protected way [5, 15, 22, 28]. With the rapid increase in the implementation of various systems in IoT, e-health systems have also been integrated with IoT. With this integration health units can inherit the functionalities and facilities of IoT system. IoT has three layers for the smooth communication between sensing devices [55] through which it enables consistent communication of facts over the system. It processes the facts intelligently and includes acuity of records from all over the place. IoT sensing objects have pretentious structure as well as heterogeneity. IoT network gathers ongoing information from Radio Frequency Identification Devices (RFID), Global Positioning Systems (GPS), coordination's, human services units like e-health including sensors, for example, body sensors, infrared sensors, shrewd meter, observing sensors and other installed detecting sensors and so on Ref. [38, 55, 57]. The various approaches applied in IoT have not been properly investigated. A significant concern is, with respect to the vulnerability instigated by real time processing and offline elements, the mode which guarantee the nature of data in a safe manner. A portion of the worries are the following: to make existing items more brilliant and how to configure the object so that only authentic operators may have the access to the assets. As security plus privacy matters are the severe worries that must be measured very seriously because IoT based e-health units deal with huge amount of special and private data. So there is necessity of reliable solution for the security of e-health system. Thus, it is required to utilize the advance technologies for handling smart objects and their processing appropriately. Similarly, it helps to sort out the security issues through fog approach and blockchain technology. Blockchain technology enables devices for interconnection in a protected way. The grouping of blockchain with IoT canister creates influential aliens. This study contributes by proposing a novel architecture of IoT in e-health system. The suggested architecture incorporates fog approach and blockchain technology to process patients' personal information in an efficient and secured manner.

EMS is one of the crucial components of healthcare but unfortunately it remained overlooked in the existing literature. Moreover, addition of EMS in e-health system would help in saving a large number of invaluable lives of the critically ill patients. Such type of integration would enable the Emergency Medical Technicians (EMTs) to interact and get on the way guidance from the consultant doctors available at the nearby e-health units during their patient shifting through ambulances.

2. BACKGROUND

E-health can be described as a model which incorporates activities for electronic exchange of data and information regarding the e-healthcare of patients [16]. E-health comprises of Information and Communication Technologies (ICT) to aid health related services and fields [9]. E-health uses ICTs to accommodate the stakeholders including citizens, patients, hospitals and doctors to enhance the quality of life by providing access to healthcare facilities [27]. E-health applications facilitate to collect, process, store and retrieve the required information for e-healthcare units to manage the record of their patients [43]. The state-of-the-art literature has discussed the importance of e-health and its implementation mechanism to achieve the desired outcomes. The initiation of e-health systems enable traditional health systems to improve quality in automatic and cost effective manner [49]. E-health systems help administration to maintain and develop health infrastructure through proper planning. The important factors, described in state of the art literature, are the adaptableness, complexity and charge for the execution of e-health system [46].

Many studies have pointed out e-health readiness to adopt it in evolving countries [27]. Developing countries has taken initiatives to improve delivery and quality of health services through adoption of technologies in healthcare units [2, 35, 42]. The adoption of technologies in health units reduces cost of many operational activities. Existing literature has emphasized to implement e-governance in healthcare centers to increase their transparency, performance through provision of cost effective quality services to users or stakeholders [50]. Health centers require strong leadership to implement existing technologies to make it efficient. Pakistan is a developing country that has great variations in healthcare departments all over its territories. The World Health Organization (WHO) states that usage of ICTs like cell phones and computers has increased in developing countries including Pakistan [42]. Pakistan has started to deploy e-health systems to improve access to healthcare units and provide delivery services in metropolitan areas. Telemedicine is the form of e-health where applications are deployed to connect doctors and patients through video chats in order to interact with each other for the provision of healthcare services remotely. The Khyber Pakhtunkhwa province has initiated first online treatment facility telemedicine center named as E-Ilaj that means to provide

specialized healthcare services in diverse areas [19]. This system connects specialized doctors to the remote patients through Internet connections where doctors suggest treatment to patients without having their visit to the hospitals in Peshawar which are part of E-Ilaj. E-Ilaj has been launched in Mansehra district and prospects to expand in other districts. As discussed in Ref. [53], currently, the Punjab Emergency Service (PES) Rescue 1122 is successfully providing its remarkable emergency services throughout the Punjab province of Pakistan since its launching as a pilot project for Lahore city in 2004 through a Toll-Free Helpline 1122. All the aforesaid emergency cases are dealt by the concerned specialized wing in alliance of its EMS wing. The PES renders its versatile emergency services for medical, fire, collapsed structure, and rescue related emergencies.

The state of the art literature shows a significant work done in the form of the proposed IoT based EMS inclusive E-health Architecture. This study is a subsequent extension of Ref. [17] the aforesaid proposed architecture in order to have a smooth integration of multiple IoT based e-health systems up to any level with several additional features, especially the interoperability and compatibility. Hence, the study intends to propose a novel architecture for IoT based e-health systems for better provision of the healthcare services in a much effective and efficient way. The integration of EMS and IoT based E-health Systems can ensure prompt response, effective management and provision of quality healthcare services to the patients. It can assist especially in critical condition while being shifted to any e-health unit through EMS. The need for such integration becomes essential especially in case of mass casualty incidents which requires prompt dissemination of incident detail to the nearby e-health units so that the administration may arrange the required resources accordingly in order to accommodate the patients.

Recently the PES has employed an Android based Mobile Application namely Rescue Monitoring System (RMS) and an Electronic Dashboard through which the emergency details are saved and shared with the Punjab Information Technology Board (PITB) which coordinates with different departments for provision of e-services. Based on the scenario it is a dire essential to integrate EMS with the IoT based e-health systems for prompt response, effective management and to improve the excellence of healthcare facilities.

2.1. Impact of IoT in E-Health

IoT is a varied system that is expanding enormously swiftly throughout the last era [5]. IoT in an essence is a distributed network of interconnected things that are smart enough to adapt and deploy any dynamic environments [15]. The interconnected things in IoT are small and low-cost sensing devices that participate to create smart environment. It has improved our way of moving, working and overall life. It has also upgraded industries, institutes, home, transportation and monitoring systems [6, 23, 28, 55, 56]. IoT has three principle standards comprising middleware, sensors and information. Over the innovation of IoT additional technologies like big data, pervasive, and cloud computing and participatory sensing are being operated. IoT technology encompasses of the three covers that mean to work with smart technologies for connection among IoT devices [6]. The layers of IoT include sensor layer, transmission layer and application layer. These layers of IoT gather facts from atmosphere and convert it into beneficial evidence to make the plain substructure and facilities for smart buildings, grids cities, homes, transportation etc. in order to better utilize the more aware, intellectual and creative information [22].

IoT benefit health middles to classify and path patients to enhance the services of healthcare centers and maintain patient's records. The integration of IoT in e-health helps to authenticate people including hospital staff and patients for quick data sensing and processing. IoT sensing data constitutes real time data that decrease the stay for behavior of critical patients enhancing traditional medical services. Furthermore, IoT supports wireless connection between health monitoring devices and patient's location like home, office, town etc. IoT and e-health association supports systems to maintain the services while providing smart services to the participants. IoT technology helps to collect and process data from various sensing devices located in various environments [5]. Existing studies have integrated various concepts and technologies with IoT to increase its efficiency and performance. The integration of these technologies helps IoT systems to manage real time processing of data accurately. Current e-health systems provide healthcare facilities to the patients through the provision of better services and the effective management of their health record. The integration of IoT in e-health facilitates the stakeholders to manage all aspects of a patient e.g., to analyze the patient's health at home, observing the state of diseases, managing appointments, giving suggestions, maintaining diet plan of patients and monitoring. In the light of existing literature, IoT can be integrated into e-health to facilitate health centers for delivery of better services as shown in Figure 1. IoT and e-health systems association facilitate the e-health sectors to adopt new technologies to reduce cost and increase quality of services in an efficient way.

IoT system consists of a large number of distributed sensing devices (as illustrated in the Fig. 1) which are integrated through programming and system technologies that empower them to connect, interact and exchange information with each other. Sensing devices in IoT are vigorous objects, things or contributors which are allowed to interconnect, subordinate and carry evidence in current environment. E-health consists of technologies that direct patients towards the specialized doctors in a compact manner. E-health systems facilitate patients to get quicker response from health units and to manage the patients' health record in a systematic way. The incorporation of IoT in e-health increases the performance of overall system and enables multiple health centers to connect and manage patients' record as well as provides the capability to monitor the vital signs and other required health conditions of the patients along with the provision to give prescriptions remotely in an effective way.

Existing literature has suggested the deployment of IoT in e-health to maintain health status by using sensing devices and other technologies of IoT in health units. Abie and Balasingham [1] provides a threat grounded security basis for the adoption of smart IoT in e-health centers. Various security perspectives have been discussed to propose an adaptive security model. A case study has been described to gauge and validate the proposed model. In Ref. [36], Paschou introduces the metrics and methods to overcome overhead problems caused due to data transfer. This study has discussed IoT and available architecture for data transfer including SMS, 3G and Wi-Fi mechanism. The importance of IoT in health domains is highlighted through providing map to adopt metrics to deploy IoT in e-health and to maximize cost effectiveness. Lake et al. [30] explores the

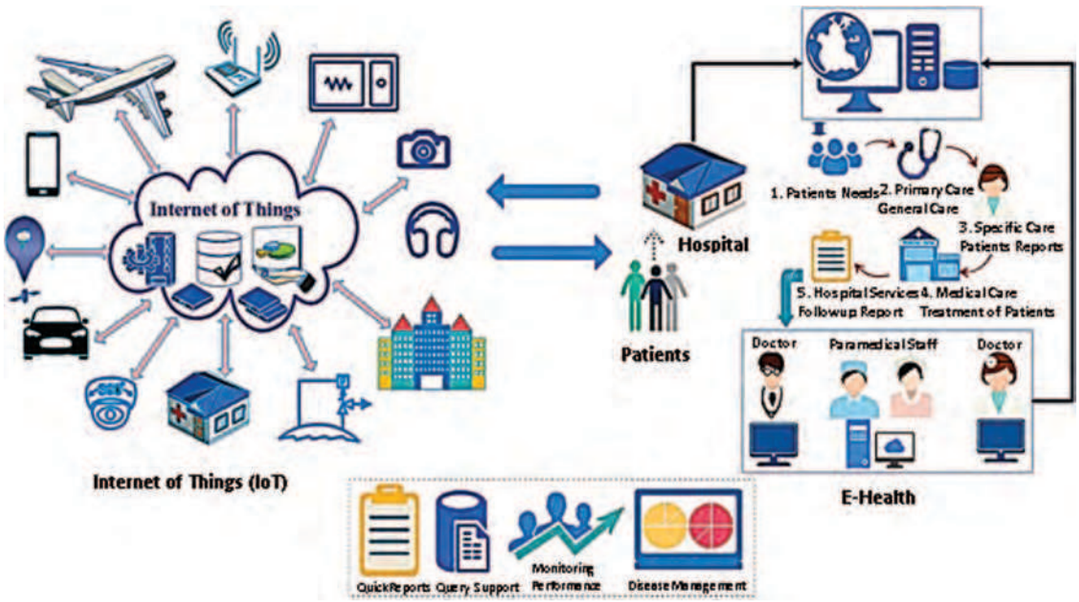

Fig. 1. Association between IoT and E-Health.

issues of IoT including security and privacy that effect the functionality of IoT systems in e-health. This study has proposed architecture for the secure e-health systems with the execution of IoT technology. The security perspective of e-health systems has been discussed including endpoints, cloud, network, data storing and landscape access security. Islam et al. [25] has reviewed the current trends and has analyzed IoT based architectures for healthcare centers. This study has reviewed the security features, various architectures and models developed for the health care centers. Shah and Pasha [48] has proposed a model of Smart Health Units (SHU) for health units to make them smarter and connected with health care headquarters. Mainly, the model has been proposed by using PSTN and mobile operators with IoT technology to facilitate health services in developing countries. The implementation scenario for the proposed model is given for the developing countries like Pakistan.

In Ref. [47], Santamaria et al. presents an IoT sensing device that connects the user activities and send it to the Cloud. This study introduces data filtering techniques for the better transfer of information through wearable devices while using cluster-based services. Human Activity Recognition (HAR) classifier has been proposed for the identification of any activity that needs attention through IoT devices. Rahmani et al. [44] presents a gateway for the control of system to support motion management and energy efficiency of smart e-health monitoring systems. Gateways enable enhanced data filtering and mining of data while providing cloud and fog computing facilities. A framework for the IoT based smart health systems directing on interoperability problem has been developed [37]. It utilizes existing technologies, protocols and designs to solve this problem. The study shows that a particular entry and web skills can be used instantaneously in to create small efficient health systems. This work has only focused on interoperability problem however there is a need to consider the interoperability of IoT layers in e-health environment. The concept of IoT has been integrated with e-health but there is need to provide hierarchy of IoT layers in e-health system for the execution of IoT based e-health in unindustrialized countries like Pakistan.

Over the last decades, IoT technology has revolutionized every field into a smart world of interconnected devices. With the rapid increase in the espousal of e-health in industrialized and unindustrialized countries it can be integrated with IoT to connect stakeholders with healthcare services. The integration of IoT into health centers develops a smart e-health system with the increased performance and quick services. Existing literature has discussed the concept of IoT and e-health while providing the basic IoT based e-health systems' interoperability and metrics. To the best of our knowledge, currently there is no architecture for the IoT based e-health systems. However, literature lacks to provide IoT based e-health system's architecture that can facilitate health centers to implement IoT based e-health systems for providing additional services to the patients through efficient and smarter mechanisms. This study has proposed a layered architecture for the IoT in e-health systems, especially for the developing countries which lacks to adopt IoT based e-health systems.

2.2. Impact of Fog Approach in IoT Based E-Health

E-health comprises of critical systems which cannot afford high latency. It is important to analyze sensitive data of patients as soon as possible. Current cloud services cannot provide amenities at wide geographical areas [18]. Consequently, it is not good to rely upon traditional cloud models to process sensitive medical data in various environmental conditions. Hence, fog computing is an efficient approach which delivers cloud services (as shown in Fig. 2). Fog approach provides computing services at the control of the system to manage and process data in an efficient manner [18]. As fog approach is constructed on the edge servers, so it delivers the partial computing, storage, and interacting facilities in a distributed way amongst end devices and the traditional cloud computing. In e-health systems fog layer helps to manage sensitive information at the centers and data is directed to the

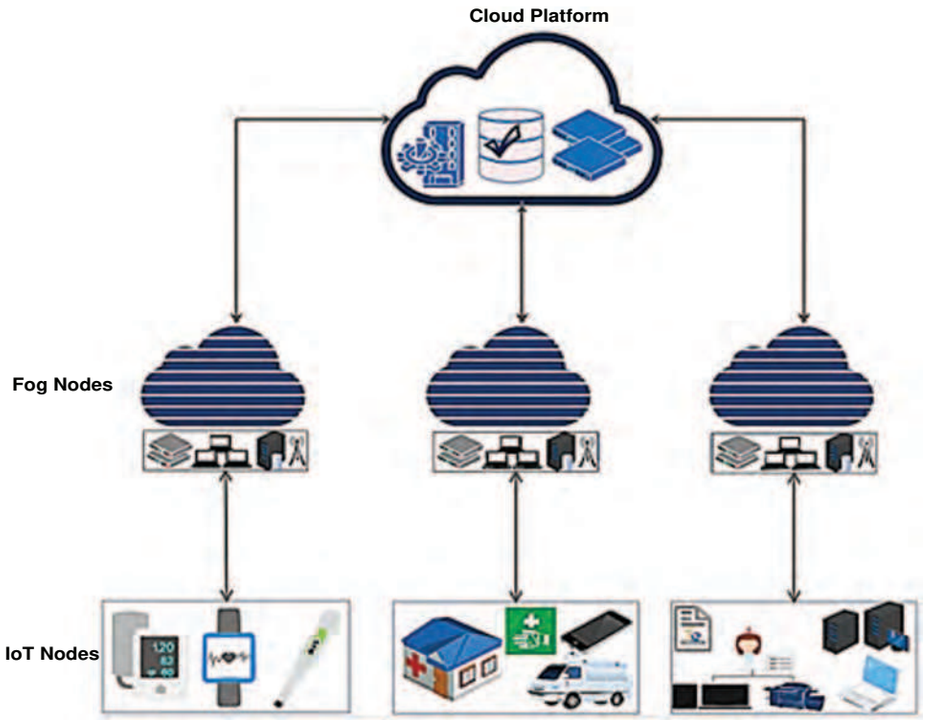

Fig. 2. Fog approach in E-health.

cloud for the enduring storage. Fog nodes can establish communication with the e-health sensing devices to deliver reliable and secure connectivity between sensors, across the networks.

2.3. Impact of Blockchain in IoT Based E-Health

Blockchain technology consists of dispersed database conserving smart connected devices record groups as novel thing [12, 29, 32]. There is no ace and slave idea in blockchain, each sensor has equivalent specialist and a duplicate of in general chain. Blockchain record can be actualized as public and private blockchain [34]. Public blockchain enables each member to peruse and compose the records where each member check and confirms the archives to be put away. Bitcoin and Ethereum are few examples of public or open blockchain. Private blockchain permits just important and precise gathering of members to peruse and compose records where a few members have the special privileges to confirm and control the changes made. Blockchain has been adopted in IoT and e-health to secure the confidential personal data of users [14, 24, 33, 58, 59]. The blockchain technology is being accepted in healthcare departments to incorporate its trusted features in healthcare. IoT is varied in environment which builds intricacy of security and privacy components of e-health units. For the most part IoT devices are taken care of by brought together cloud system that can harm the complete system in the event of interruption assault. IoT based blockchain innovation has transfigured the correspondence connection with its regionalization finished the organization and fast change settlement for autonomous sensing devices. In any case, to keep up the mechanical regularly becoming computerized value-based records from diverse sensors in IoT, it is required to pay regard towards these peer to peer companion tied straightforward business capacities and begins to investigate different blockchain enabled applications. So, there is a need to acquire the privacy and security advantages of distributed blockchain with smart things in order to make smart environment more reliable and secure. In addition to that, it can be possible by preserving the intensive data in a protected way that can be received from diverse sensor devices as a number of applications are shown in a Figure 3. Intensive data received from diverse sensor devices, as several applications, can also be preserved with the help of blockchain. Consequently, Figure 3 presents some of the significantly studied applications of the blockchain in agreement with IoT.

Blockchain contract offers a self-explaining digital writing showing communicational substructure that exist in blockchain [12]. Basically it is an executing computer program that could be implemented on dispersed objects deprived of the necessity of reliable external expert witness, they transfer the esteemed resources on system's nodes. It is serious to perform vulnerability identification in order to avoid security attacks [4]. Additionally smart contract might be used for extra informational connections as an addition to get the important data from smart objects through sensors, called smart property kept the digital archives in agreement to reputation management [10]. Crypto currency is the explanation of worth transformation [40] because these values can be received from diverse sensors in an IoT based network. Ripple technology delivers a worldwide protocol for expense as Ripple laps, to change the cash amid universal finance organizations on different distributed system nodes [20, 40], regardless of whether there are numerous distinctions of different moneys or geographical borders [40]. Ripple Transaction Protocol (RTXP) delivers continuous facilities and safety on all the levels of transactions for example, it verifies each occasion paying little heed to money type, settlement, item or any unit of

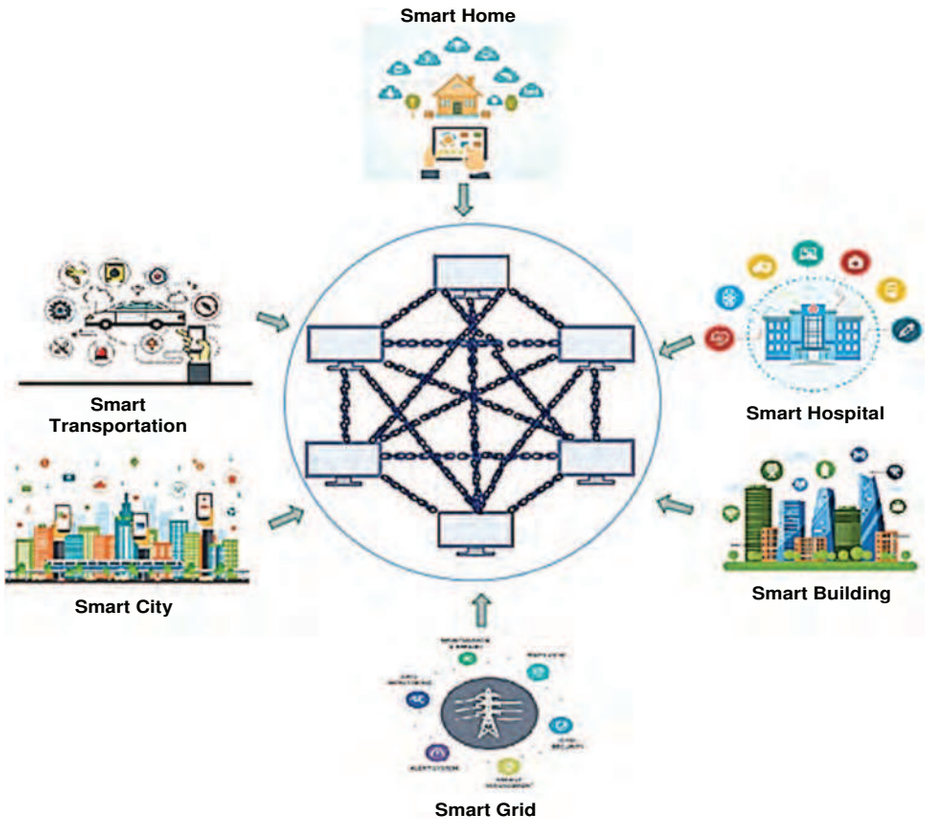

Fig. 3. Applications of blockchain in IoT.

significant worth by its design of authorization or consent less to give a half breed arrangement [52]. Ripple algorithms brings a dispersed arcade wherever everyone can participate based on trust in blockchain IoT based system. Bitcoin gives an electronic shared installment framework by dispersed blockchain with electrical communication between the concerning gatherings to decide the consolidated change on every exchange. It presents various sorts of square mining just as concealing methodologies and procedures [21]. On the other arrow bitpay in blockchain provides decentralized system with authentication over notary and NASDAQ which handle the digital properties in such transactional system [11]. In the same way the security and consistency of information is ensured in different fields of life including IoT based healthcare systems.

In accordance with e-health for patients, doctors and other stakeholders; it is required to focus some important considerations between a trader and customer with admiration to the fundamental creation [54]; The key worries are faith, adjustment, legitimacy and transparency in each and every newly established relationship. The same concept is implemented while deploying an IoT based system with blockchain mechanism. Nowadays with technological advancements all the required resources are connected in IoT to provide controlled smart environment and to ensure ease for its smart access. Blockchain allows only a consensus-based mutability of ledger in IoT to ensure the source chain with restrictions on proper archive for the creation's following and documentation of environmental, locational and safety oriented issues of diverse areas. Blockchain similarly aids in occupational reductions and promotions with encoded user data due to its anonymity nature [31, 54]. Consequently improved security conventions and cryptosystem are required in e-health so as to guarantee the protected cooperation between the objects. In this way, security has been one of the important difficulties that is essential be hindered so as to energy IoT in real world. With the expansion in security subjects of IoT devices, the circumstance facilitates to adjust new novelties, joining blockchain in IoT plans to give the dispersed record the motivation behind expanding the security and privacy [51, 61]. Blockchain joining in IoT fortifies the general IoT arrange and makes a powerful secure distributed system. Blockchain innovation momentously affects the IoT sensing devices by methods for improving security, protection and approving brilliant devices to frame keen situation. This study is inspired because of the present ejection of enthusiasm about blockchain and IoT. We look at whether the incorporation of IoT and blockchain will make ground-breaking e-health system architecture connect with joined functionalities of the two technologies. To the best of authors' knowledge the incorporation of blockchain within IoT based e-health systems will handle the security problems in IoT devices as blockchain permits only reliable contributors to cooperate with each other.

3. METHODOLOGY

The concept IoT and e-health has been debated during the last decade. There are some architectures those has been proposed for IoT implementation in e-health, however there is a need of novel

architecture to address the technical aspects specifically regarding incorporation of fog and blockchain technologies in IoT based smart e-health systems. Exploratory research method is adopted in this study to discover existing idea besides to review the state-of-the-art literature intensively. Exploratory model is helpful if the battered issue has not ever been talked or inadequate indications are achievable and researcher aims to review the research ground [41, 60]. This approach is infrequently known as the inductive research method. Therefore, exploratory research delivers an suitable way to support scholar with the basic effort for future studies [13, 60]. We have adopted the exploratory method to find the difficulties which have not been intensively considered and addressed.

4. PROPOSED ARCHITECTURE

Recently with the development in communication technologies various devices and applications have been designed to monitor healthcare units. Many people use Internet through their cell phones and Public Switched Telephone Network (PSTN) for communication and exchange of information. IoT based e-health systems connect specialized doctors to patients in the hospitals through Internet connections where doctors suggest treatments to patients. So, there is dire need of IoT based e-health units for the prompt distribution of healthcare services to patients even in remote areas. Such enhanced health services need to embed new technologies, such as IoT, in the existing e-health systems. IoT based health systems connect various health units to communicate and transfer important information in case of any emergency. In this study IoT based e-health architecture, shown in Figure 4, has been proposed for the better utilization of existing technologies in health units. This architecture consists of layered structure of IoT where each layer takes part in IoT erected e-health system. IoT integrates diverse novelties and sensors through which it inspires trade of things like products, facts and administrating personnel among technologies and entities in more safe way. The execution of these inventions and sensor-based mechanisms along with the advanced technologies for secure communication, like blockchain, requires a well-defined integration of multiple software and hardware components.

The proposed architecture comprises of five layers which employs smart technologies for connectivity among identifying devices. In order to handle security, privacy and trust issues an essential component namely blockchain has been included to give security to every single brilliant sensing device. Blockchain technology is a suitable solution for adding the distributed computing facility in a secure manner and its implementation is more secure and faster to reduce security attacks in IoT. In the proposed architecture blockchain works in two ways i.e., public and private; in this mechanism each block in the blockchain grasp a small unit of information which might be any data that is essential to be reserved secure and consistent. In this technology data is stored on participating system and the data can be viewed by any authentic participant having the cryptographic key, however the stored data cannot be altered without mutual consensus of all the participants of the system. The information archives are time imprinted, giving a reliable and synchronized record of the additional information. In addition, the fog layer has been deployed in edict to raise the performance of e-health systems. In this scenario, patients can visit hospital or health unit that has implements IoT technology where doctors can attach sensors to the patient body that relate to health center to collect important information regarding the health of patient like sugar level, blood pressure and heartbeat etc. These sensors collect information from the body and send it to the cloud where doctor has access to check the condition of patients and suggest medicines to patients. The hospital maintains the record of patients and provides the details to the doctor and patients.

The proposed architecture has been sketched in accordance with the real-world existing way of action adopted by all the concerned departments. The partial reflection of implementation with reference to the proposed architecture can be viewed through the defined mechanisms, real-world scenarios and the SOPs followed by the PES, Punjab Health Department [almost all the District Headquarter (DHQ) Hospitals] and PITB. The PES and E-health Facilities [Basic Health Units (BHUs), Rural Health Centers (RHCs), Tehsil Headquarter (THQ) Hospitals, DHQ Hospitals or any of the other Higher-level Hospitals] may be effectively linked as per the requirement via the provincial-level interdepartmental coordinating body i.e., PITB to materialize the under reference architecture established on the basis of IoT and ICT.

However, the concept of IoT based e-health system is novel in Pakistan so it would take some time to be amalgamated with the prevailing infrastructure. The proposed architecture's compliance with the real existing working mechanisms of all the concerned departments as well as the proposed technological procedures to ensure the reliability, security, efficiency and optimum resource utilization. The proposed architecture validates to be applicable and operational in all the required perspectives of keeping in view the aforementioned supportive points. The details of each layer in the proposed architecture have been given herewith.

4.1. Sensing Layer

The sensing layer is a collection of devices, RFID labels, fixed devices or additional subtle sensors in many assemblies. This layer is responsible for facts gathering from devices or implanted devices. In e-health systems this layer consists of various medical sensing devices that are attached with the body of patients and/or placed in the vicinity of patients. Mainly these devices are camera, thermometer, blood pressure and heartbeat devices etc. that can sense and transfer data used in IoT based e-health systems. A sensing node first sends its request for becoming part of the network then this request is transferred to the network through a secure channel. After it, the currently deployed network accommodates the request by validating the node and a block is created for it. Beside this a special key is generated by using a crypto hashing function for secure communication. The sensing layer in the architecture collects real time data from the body of patients located anywhere away from hospitals and transfer the important data to the doctor or the hospital. The sensing devices connected with the houses of patients can enable monitoring and tracking of patients to maintain health conditions.

4.2. Application Layer

This layer is accountable for meditation of information as per requirement of the end users. The users interact with system through the application layer and may request to visualize data/reports, acquire answer of the requests and so on. By utilizing information delivering techniques end users can view information that is credible, secure, ensured and as indicated by the user's necessity or question. Blockchain idea in IoT facilitate by

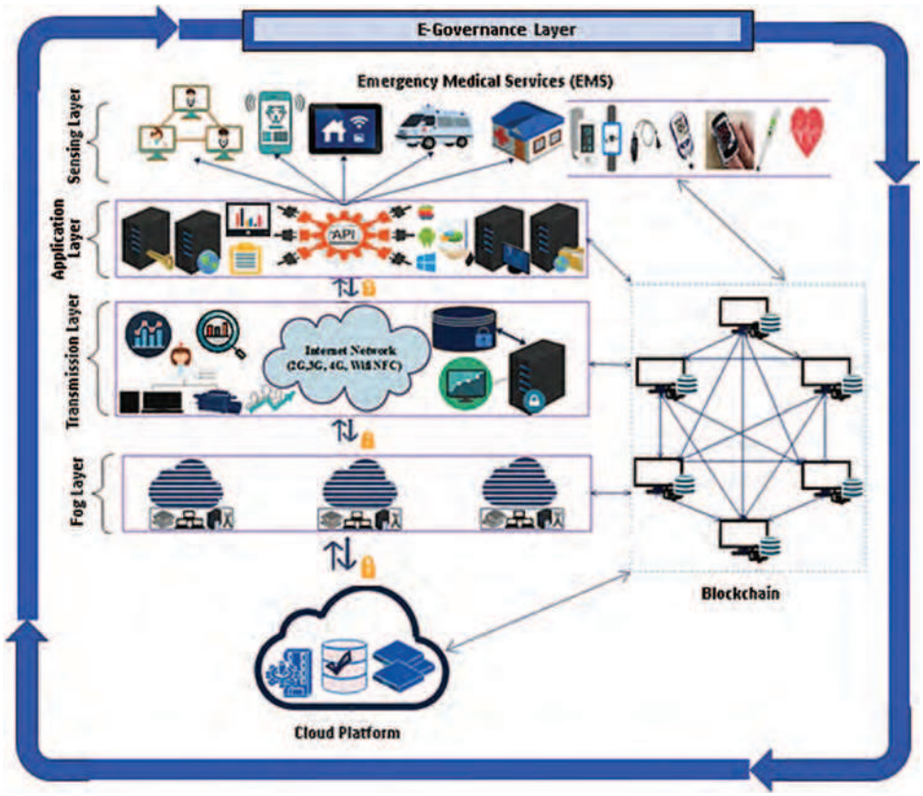

Fig. 4. Proposed IoT based E-health architecture.

giving no compelling reason to include server framework also for questioning huge databases utilized to store and coordinate secure information from identifying objects. Application layer composed data is further measured by servers. Application layer proposals provide services to its users that are using different infrastructure. The e-health systems include application for the visualization of patient's information. The IoT based e-health systems consists of Application Programming Interfaces (API) that works for various stakeholders. The API manages and monitors real time information. If there is any fluctuation in the condition of patients, it can warn as emergency and/or pledgee for services to save life of patients. With the adoption of IoT created e-health schemes in the proposed architecture the hospitals can ease patients with extra facilities that live far away but need serious kindness. Various facilities providing to the patients comprises doctor visiting patients at home, emergency ambulance services, appointment scheduling, maintenance of record of patients, availability of patient records in case of emergency to additional health units and monitoring patient's health every day.

4.3. Transmission Layer

This layer contains of various interacting technologies that are responsible to transfer data from sensing devices to data storing centers for storage and further processing. In the proposed architecture transmission layer means to delivery data from one place to another based on outdated message systems for the addition of perception and communication systems. Sensing layer transfers data from sensing devices towards the application layer. Sensing layer collects all the data from environment and transfers it through the network by RFID, Bluetooth, 2G, 3G or any other technologies. The proposed architecture consists of transmission layer along with cloud approach for the transmission of data in secure and compact manners. The transmission layer collects data and performs processing for the extraction and mining of important information. The hospital staff can manage and run various standards and protocols to maintain personal data of patients in secure way. The hospital administration will manage the data and if the feel any changing or alarming situation they can provide treatment facility to the patients.

In IoT different technologies are used for communication between various networked sensing objects with the consideration of secured data transmission. In order to become a part of the blockchain it is required for an object to get permission from present network so it could be integrated into a safe network for lifetime. Once a sensing object is validated it can participate through blockchain where each sensing device has its own certificate and database management. These are open that anybody can get to and conceivably add to, and there are private blockchain utilized inside an association or consortium. This is finished by requiring a member's PC to play out a lot of computational work before it can attempt to add another thing to the common blockchain. Permanent records from objects are stored in blockchain and authorize and empower the crucial trust to connected objects, people, and gadgets to coordinate effectively. Every entity works in a skillful way as the read and writes procedures are performed by the legal objects. Whenever there is a need of modification or alternation every object must agree so that modification can be done. When blockchain distributed record of digital events has been stored then it is transferred in a secure database where it will be integrated so that analytics can

address the user's query. In IoT objects connected at the edge of the network will become a part of blockchain that will reduce objects processing overhead and to eliminate the IoT gateways procedure.

4.4. Fog Layer

E-health comprehends critical systems which cannot afford high latency so, it is significant to analyze sensitive data of patients as soon as possible. Traditional cloud provided centralized information which has higher latency in case of wide geographical range and mining big data. Consequently, it is not good to depend on traditional cloud models to process sensitive medical data in various environmental conditions. Hence, fog computing is an efficient approach which deliver cloud services in distributed manner. Due to this reason fog layer has been embedded in the proposed architecture which enables the dispensation of data at the edge of network. In the proposed architecture fog approach provides computing services at the edge of the network to manage and process data in an efficient way. In e-health systems fog layer helps to manage sensitive information at the centers locally and data is sent to the cloud for the permanent storage. Fog nodes can establish communication with the e-health sensing devices to deliver consistent and safe connectivity between sensors, between networks and across the networks. The fog approach is implemented on the edge servers to provide the partial computing, storage, and interaction of the entities in a distributed way between the end devices and the traditional cloud computing.

4.5. E-Governance Layer

In regard with the proposed architecture, it can be safely stated that no concept of e-governance layer has been previously noticed in the literature while discussing IoT based e-health systems. The study frames and presents an innovative architecture that explicitly defines an umbrella like e-governance layer that encompasses all the layers of the proposed architecture for performing its regulatory role from various perspectives. In addition to its regulatory role locally at the respective e-health units, it also ensures interoperability and compatibility between the e-health systems for having their seamless integration. The e-governance layer plays its central role for the delivery of quality healthcare services to the end users by appropriately employing the ICT and IoT at the different layers. It works as a bridge between the public and the government to optimally avail the offered services and to get awareness through a well-defined communication mechanism. Moreover, it is responsible for several impartial arrangements and services among government to citizen (G2C), government to business (G2B), government to government (G2G) and government to employees (G2E) including the back office processes and interactions among the governmental infrastructure and other concerned entities.

The role of e-governance in healthcare sector has not been much utilized in most of the countries like Pakistan and this utilization has been graded at its initial level [50]. There is much need for the provision of implementation facilities required for e-governance in emerging countries like Pakistan. The adoption of e-governance in healthcare enhances the accessibility, accountability, responsiveness, transparency, efficiency and overall quality standards of the healthcare services [50]. The concept of the proposed e-governance layer is extensible even up to the global level through integration of IoT based e-health systems operating in different countries. Such an extension would provide the required level of interoperability and compliance with respect to technology, standards and legislative bindings with the objective of quality healthcare services. Moreover, the proposed IoT based e-health architecture would not only be much helpful to materialize the defined objectives stated in Ref. [50] for the Khyber Pakhtunkhwa (KPK) province but also for the whole country of Pakistan.

4.6. Blockchain Network

The key issue that must be vanquished to impulse the IoT implementation in actual world scenario is security and privacy. Private data identified with client is put away and gotten to by numerous applications for giving better benefits. In IoT systems all devices relate to each other in a distributed manner that makes it less secure. In this mechanism various techniques have been suggested in the literature but still a lot of questions are raised regarding the security of IoT devices. The incorporation of blockchain in IoT can deal with all the security and privacy protection challenges. In relation to the proposed architecture blockchain is a distributed ledger that is simulated, synchronized and public among all the contributors (participants of e-health system) of the network. The participants in the network shall be approved by consensus for any read and write in the e-health network. The main benefit of blockchain in this architecture is that there is no third party that is responsible for the maintenance of the information or records. Every record has its own timestamp as well as cryptographic signatures. The integration of blockchain in IoT is adopted by all connected devices, so that a more secure network could be created. The proposed architecture has adopted blockchain technology to grip existing security and privacy challenges of IoT based e-health. Implementation of blockchain in IoT environment can create a more secure network with IoT devices.

5. LIMITATIONS

The limitations of the study are stated below:

1. The lack of adopting Information and Communication Technologies (ICTs) and IoT especially in the prevailing infrastructure of the governmental organizations in Pakistan has remained one of the major limitations.
2. The proposed interactive mechanism of the EMTs in the ambulances and the consultant doctors at the health units has been based on the prevailing general SOPs of the PES (Rescue 1122). According to the under reference SOPs, each responding emergency vehicle (ambulance) is moved with two EMTs. While the PES doctor appointed as a District Emergency Officer is usually not supposed to move along with the EMTs for providing the pre-hospital treatment to patients in ambulances, rather he/she administers the whole district-level setup of the PES.
3. Some other additions would also be there in the proposed architecture but the general isolated nature of the departmental operations in Pakistan especially in the government sector has become a significant obstacle in this track.

6. DELIMITATIONS

The delimitations of the study are given as follows:

1. The study has been proceeded mainly by focusing the existing setup of the PES, Punjab Health Department and PITB. Though,

the proposed architecture can be made applicable for the integration of any emergency service and e-health system with the necessary adaptation (if required) as per need.
2. The study has been proceeded mainly by focusing the existing setup of the PES, Punjab Health Department and PITB due to feasible circumstances and accessibility to the system for exploration. Though, the proposed architecture can be made applicable for the integration of any emergency service and e-health system with the necessary adaptation (if required) as per the need. The study is specifically based on the provincial-level governmental departments of the Punjab province. However, the proposed architecture may be effectively utilized to establish such setup in other provinces to have the quality e-health services countrywide or up to any level.

7. CONCLUSION

IoT idea is praiseworthy, robust and real that wants further widespread study to completely accept it in every domain of life. IoT based e-health systems are usually in discussion and the large scaled implementation of e-health systems has demonstrated the adoption of IoT based e-health systems. Numerous architectures for e-health are proposed with their pros and cons but these architectures failed to overcome various issues especially the scalability. This study has proposed specialized architecture of IoT based e-health systems for enabling basic health facilities and access to healthcare services for the patients at remote locations in a much better way. The proposed IoT based e-health architecture is extremely impressive innovation with much comprehensiveness of the concept through the inclusion of very a crucial but previously overlooked component i.e., EMS and its integration through blockchain technology. Another novel idea has been put forward by explicitly defining the e-governance layer that encompasses all the layers of the proposed architecture. It has also been suggested that being an important component of the proposed architecture, the EMS in general and the PES (Rescue 1122), Pakistan in particular should employ a fully IoT based mechanism in its fleet of ambulances in order to monitor the vital signs and other required conditions of the patients in real-time. Such a mechanism would also facilitate the ambulance staff particularly the EMTs for having their required interaction with the consultant doctors present at the nearby e-health unit while shifting the emergency patients there.

8. FUTURE DIRECTIONS

IoT based e-health system will change the role of healthcare systems dramatically where they can monitor and serve patients more efficiently and securely. However, the implementation of IoT based e-health systems is very challenging in the developing countries but somehow both developing and developed countries share a common objective to offer health monitoring and evaluation to the people with no healthcare facilities. The increasing number of IoT devices, participatory sensing, cloud computing and ubiquitous computing successfully leading towards the Wearable Internet of Things (WIoT) that means to transform healthcare units into more customized healthcare systems. These WIoT requires edge analytics to overcome various challenges for the successful implementation of its framework for the healthcare units. Special attention shall be given towards the development and implementation of edge gateways along with edge analytics in order to develop more flexible system. Moreover, a focused study may also be carried out to propose an IoT based e-health architecture having the minimum possible technological infrastructure required for the adoption of IoT based e-health system with some defined basic healthcare QoS standards for rural and remote areas of developing countries like Pakistan.

Disclosure Statement

No potential conflict of interest was reported by the researchers.

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