

Healthcare Technology Evolution And Adoption Of Fog Computing In Healthcare: Review, Issue And Challenges

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Abstract

Health Information System (HIS) is a combination of hardware, software, process, infrastructure, people and protocol which is developed for management of healthcare data including collection, storage, analysis, decision making and transmission. It supports functional management of a hospital as well as provides an infrastructure that support policy decisions over healthcare data. HIS grown decade by decade starting from 1960 to present era and divided into four generation versions, starting from HIS V.1.0 to HIS V.4.0. HIS V.4.0 is dedicated for smart medical technology with fog-based computing system including disease-oriented sensing system, IoT, artificial intelligence, high speed internet and advanced internet protocols. Fog Computing is a distributed computing framework and provide an extension to cloud computing. It lies between medical sensor (IoT devices) and cloud datacenters. This paper presents various HIS generations and technologies used in HIS V.4.0. Include review of cloud computing, IoT and Fog computing. Further this paper provides a systematic review of existing research in fog computing with various issue and challenges. Finally, paper describes comparison of fog computing with cloud and edge computing and present discussion, open challenges and recommendation in Fog-based HIS.

Keywords: HIS, fog computing, IoT, cloud computing, healthcare, medical sensors, literature review

1.0 INTRODUCTION

Healthcare is a term used to provide qualitative treatment to maintain as well as improve the health of patient against specific disease. Patients are given Healthcare services in hospital up to the home. From post-mid of last century up to now, healthcare industry has been continuously evolved with respect to hardware as well as software evolution [1]. This results in emergence of various technologies for improving the lifestyle and healthcare of the patients with minimum cost and reduced time. Evolution of healthcare industry includes its various generations that are classified from healthcare industry V.1.0 at 1970s to healthcare industry generation V.4.0 in current era [2]. Evolution of healthcare generation is shown in figure 1. Every generation was dedicated to provide better and qualitative care to patients with available resources. Resources available in healthcare V.1.0 were very limited and were based on mechanical automation and engineering and this generation were continued up to 1990. Next generation V.2.0 (1990 up to early 2000) was the era when mechanical automation was further upgraded into electrical energy engineering-based system and computing system became cohesive network capability. This time information and communication technology (ICT) were also growing that gave outstanding bounding to healthcare industry for enhancing technology in medical equipments and services. This era extensively used clinical and medical imaging for healthcare services that were clubbed with ICT service to provide networking services among healthcare organization [3] During this era various computing technologies were evolved that included software-machine integration, digital industrialization, machine-based control and decision making, expert systems etc.



Figure 1: Evolution of healthcare generations

Year 2005 up to 2015 is said for Healthcare generation V.3.0, when there was improvement in computational methods and approaches. This included advancement in medical data processing software and hardware that provided effective medical diagnosis and treatment. Medical records were organized into electronic healthcare records (EHRs) which were stored, and processed in central computing system and further accessed quickly for analysis by healthcare provider. Medical devices became wearable and implantable in patient's body for pervasive and Realtime health monitoring. At the same time internet technology became more popular and easily accessible that provide countrywide sharing of EHRs and patient's physiological data to provide early and accurate diagnosis to the patients. This time EHRs from multiple hospitals were stored in huge volume in the form of bigdata with enterprise data warehousing technology. Further data mining technologies were advanced for extracting, analysing and interpretation of healthcare data. This included finding normal and abnormal patterns in EHRs, and decision making for detection and prevention of diseases etc. This time sensor-based technology including wireless sensor network and mobile adhoc network, 3-D printing and cyber physical spacing has been emerged and researched extensively in all most all application areas of world domain.

Healthcare generation V.4.0 started around 2015, when wireless medical sensors became automated to take preliminary decision about health of patients and to alert them. In this generation, artificial intelligence with machine and deep learning is playing very important role in decision making in healthcare industry. Intelligent sensing technology deployment becoming more advancing day by day that gives real-time monitoring and accurate decision making about patient without restriction of time and place. In present era, healthcare industry is globally connected with the involvement of artificial intelligence and medical data analytics [4]. Application of sensing, computational and communication technologies become one of the pillars of Healthcare system to provide sound and reliable information at real-time to all stockholders including healthcare providers and patients. Following table 1 shows the generation shift from V.1.0 to V.4.0.

Table 1: Generation shift in healthcare with various features

S. No.	Healthcare 1.0	Healthcare 2.0	Healthcare 3.0	Healthcare 4.0
Purpose	Reduce paper work and improve working efficiency	Improve data sharing and its productivity	Concentrate on centralized server based on patient requirement	Provide real-time solution for healthcare with efficient data
Tracking	Emphasis Data automation	Connecting multiple organizations at same floor	Patient interactivity with system	Real-time monitoring of patient data and diagnosis with the help of AI tools
Restrictions	Limited functionalities because of standalone feature	No interaction with patients and data sharing is also limited	Patient data interoperability is very less because of heterogenous data	Patient sensitive record concern as latest technologies are not fully tested and verified
Data sharing	Within an organization	Within a group of related organizations	Within a country Data is shared	globally to support supply chain of healthcare
Technology used	Administrative system and LIMS software	Cloud computing	Big data	IoT, AI

Above evolution shows continuous growth in the technology to advance and uprise the healthcare industry that includes advanced healthcare devices and data processing and analysis tool that make healthcare technology as a system called Healthcare Information System (HIS) that is dedicated to provide effective, accurate and reliable diagnosis and treatments for better quality of life for ever growing world population.

2.0 HEALTH INFORMATION SYSTEM IN GENERATION V.4.0

Health Information System (HIS) [5] refers to a system that provides management of healthcare data including collection, storage, manage and transmit a patient’s Electronic Health Record (EHR), support functional management of a hospital as well as provides an infrastructure that support policy decisions on healthcare data. In every healthcare system including traditional or electronic system, comprehensive and consistent information becomes basis of accurate decision-making and is important for development and implementation of healthcare policies.

According to WHO [6], “The health information system provides the underpinnings for decision-making and has four key functions: data generation, compilation, analysis and synthesis, and communication and use. The health information system collects data from the health sector and other relevant sectors, analyses the data and ensures their overall quality, relevance and timeliness, and converts data into information for health-related decision-making”.

HIS technologies in generation V.4.0 include Wireless sensors, IoT and communication technologies for connected healthcare, Client-Server technologies for comprehensive database management system. The emerging field of wireless sensor networks and IoT combines sensing, computation, and communication into a single tiny device. Applying IoT toward health care monitoring of patient allows for new ways to provide quality ambient healthcare to patients. From last few years, cloud technology becomes new trends for data storage and computation of Patient’s EHR management as an online backend centralized system. But centralized cloud storage often fails to provide real-time services due to network overcrowding problem, especially with healthcare system, that results loss of life of patients. To overcome this problem of overcrowding and congestion of network, CISCO suggested as solution called Fog Computing infrastructure, that became an extension of cloud technologies [7].

3.0 SENSING TECHNOLOGY USED HIS GENERATION V.4.0

HIS system is equipped with various hardware devices includes medical sensors and communication devices that are implanted over patient’s body and referred as Wireless Body Area Network (WBAN). Medical sensing nodes in WBAN composed of several devices that that includes sensor embedded motes that sense and gather the physiological data from the patient’s body [8]. These sensors collect both extrinsic and intrinsic values with respect to medical sensing environment. Extrinsic values are characterized as the temperature, location, and so on. Intrinsic values are physiological value from patient’s body viz. blood pressure, blood glucose level, heartbeat, and so on. The patient can also get their health status information by his or her smart phone, and these data will then be made available for processing. The hardware components of sensor can be divided into (1) Memory, (2) Sensing, (3) Energy/Power supply, (4) Processing; and (5) Communication. Hardware platform of the sensor mote [9] is shown in following figure 2:

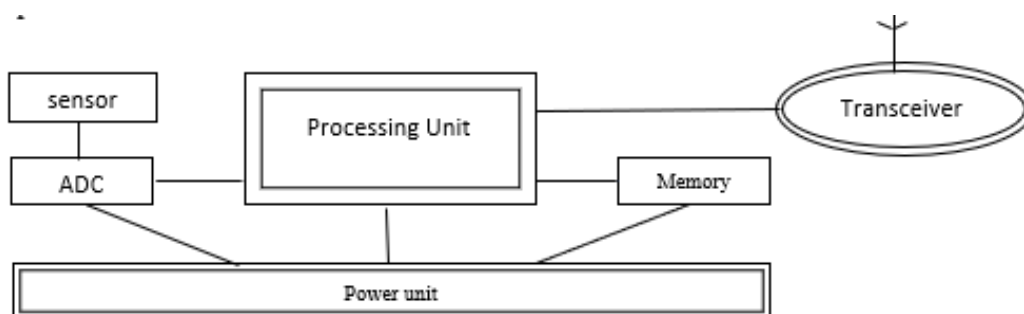


Figure 2: Hardware platform of a typical Wireless Sensor mote

A WBAN can include a number of physiological sensors depending on the end-user requirement. An extensive set of physiological sensors includes ECG (Electrocardiogram), EMG (Electromyography), EEG (Electroencephalography), Blood pressure sensor, Breathing /Respiration sensor, Body temperature sensor, Movement sensor, Smart sock sensor or a sensor equipped shoe insole and so on [9].

The standard of connected things has made sure that healthcare industries are able to work intelligently with an enormous amount of data being sensed and collected by the wearable wireless sensors. As data is at the core of healthcare setup, the role of sensors is unquestionable to make the entire environment smarter and for better decision. The sensors that are used in the current healthcare industries are more accurate, low on cost, optimum power requirements and of reduced size, resulting enable the healthcare industries to work with enhanced efficiency that will bring a substantial change in healthcare automation environment. Some of commonly used sensors in the health sectors automation application [9] are summarized in the table 2 below:

Table 2: Wearable wireless body area network sensors and their functions

Sensor Name	Data it Senses	Communication Protocol	Sensor hub	Application or Usage
ECG (Electro cardio gram)	skin / chest electrodes	ZigBee or Wi-Fi	Wi-Fi	for monitoring heart activity
EMG (Electromyography)	Skin electrodes	ZigBee or Wi-Fi	Wi-Fi, Ethernet, 3G, GSM	for monitoring muscle activity Electrical activity of the skeletal muscles (characterizes the neuromuscular system)
EEG (Electroencephalogram)	Scalp placed electrodes	ZigBee or Wi-Fi	Wi-Fi, Ethernet, 3G, GSM	for monitoring brain electrical activity, Measurement of electrical spontaneous brain activity and other brain potentials
Blood Pressure (BP) (systolic and diastolic)	Arm cuff-based monitor	ZigBee or Wi-Fi	Wi-Fi, Ethernet, 3G, GSM	Refers to the force exerted by circulating blood on the walls of blood vessels, especially the arteries
Body Temperature	Temperature probe or skin patch	ZigBee or Wi-Fi	Wi-Fi, Ethernet, 3G, GSM	For monitoring body temperature
Respiration rate	Piezoelectric, Piezoresistive sensor	ZigBee or Wi-Fi	Wi-Fi, Ethernet, 3G, GSM	monitoring respiration breathing Number of movements indicative of inspiration and expiration per unit time (breathing rate)
Heart Rate (Pulse Oximeter)	Pulse Oximeter/ Skin electrodes	ZigBee or Wi-Fi	Wi-Fi, Ethernet, 3G, GSM	Frequency of the cardiac cycle
Oxygen saturation	Pulse Oximeter	ZigBee or Wi-Fi	Wi-Fi, Ethernet, 3G, GSM	Indicates the oxygenation or the amount of oxygen that is being "carried" in a patient's blood
Blood glucose	Strip-base glucose meters	ZigBee or Wi-Fi	Wi-Fi, Ethernet, 3G, GSM	Measurement of the amount of glucose (main type/source of sugar/energy) in blood
Heart Sound	Phonocardiograph	ZigBee	Wi-Fi, Ethernet, 3G, GSM	A record of heart sounds, produced by a properly placed on the chest microphone (stethoscope)

4.0 IOT FOR HIS GENERATION V.4.0

IoT [7] stands for Internet of Things, is a group of devices that have sensors and actuators with embedded and distributed computing capability that made tasks easier and accurate to compute with greater efficiency. It is an emerging technology architecture that allows devices to communicate and share anything without restricting time and location using internet connectivity. It is already being utilize extensively, in various domains, namely: Wearables, Smart Home Applications, Healthcare, Smart Cities, Agriculture, Industrial Automation [7].

Nowadays, IoT is extensively utilizing in HIS [10]for remote patient's monitoring inside hospitals as well as inside the home. It has the potential to improve how physicians deliver care and also preserve patients safe and healthy. IoT enabled HIS can allow patients to devote more time interacting with their doctors, which can boost patient engagement and satisfaction. From personal fitness sensors to surgical robots, IoT in healthcare lead the way to new tools updated with the recent technology that benefits in developing better service in healthcare. IoT helps to transform healthcare and deliver pocket-friendly solutions for both the patient and healthcare professional.

Healthcare IoT application allows medical professionals for better and accurate decisions, improves medical centers service facilities and tools. Some of the benefits of IoT enabled HIS includes (a) Simultaneous reporting and monitoring of patients, (2) End-to-end connectivity and affordability with technical devices, (3) HER data assortment and analysis, (4) Tracking and alerting in emergency situation and (5) Remote medical assistance, if patient and healthcare providers are at far distance.

5.0 CLOUD COMPUTING FOR HIS GENERATION V.4.0

Healthcare data has been radically swinged in its creation, consumption, storage and sharing from generation V.1.0 to V.4.0 from traditional storage to digitalization [11].Data management process and quality of service in fourth generation has been optimized. HIS generation V.4.0 is utilizing the cloud-based technology, not only for storage of vast amount of healthcare data, but it also provides computing facility to process, analysis and decision making at real-time with minimum interaction of healthcare providers. Cloud computing is using as utility computing for HIS, that have more computational power, huge storage facility and various networking resources. Healthcare providers are now leveraging cloud technology to gain efficiencies, optimize workflows, lower the costs associated with healthcare delivery and offer personalization in care plans to improve outcomes.

Cloud based HIS facilitate benefits at services side as well as at business side. At one end it provides real-time medical services to patients and healthcare provider for better, accurate and high-quality personal care. At another side it reduced the operational cost. Thus, cloud computing in HIS provide structured and well-organized sharing of healthcare data to all stakeholders, that results in minimum risk of lose of EHRs. Some of the benefits of cloud computing in HIS environment includes (1) letting down of operational expenses, (2) ease of interoperability (3) high-powered medical analytics, (4) patient's ownership for healthcare data, and (5) telemedicine capabilities [12].

Although cloud technology becomes new trends for data storage and computation of Patient's EHRs management as an online backend centralized system, but it possessessome issues and challenges. These includes security of patient's EHRs, no compliance of security rules, processing delay with communication latency, network overcrowding, high bandwidth requirement and utilization etc. Most chronic disease, serious heart attack, stroke and emergency cases need timely action that must utilize real time data for better decisions and monitoring of the patient health status. Thus, these challenges in HIS causes complicated health issues and even loss of patient's life.

6.0 FOG COMPUTING FOR HIS GENERATION V.4.0

Fog computing is a distributed computing model that situated and works as an intermediate layer in between Cloud datacenters and Internet of Things (IoT) devices (i.e., medical sensors). Fog computing provides computing, networking and storage services, so that the Cloud computing resources and services can be extended closer to the IoT devices and sensors [10]. The concept of Fog computing was first presented by Cisco in 2012 to address the challenges of IoT applications over traditional Cloud computing. IoT devices are extremely distributed at the edge of the network along with real-time and latency-sensitive service demands. Since Cloud datacenters are geographically centralized, they often fail to deal with storage and processing demands of billions of geo-distributed IoT devices. As a result, network congestion, high latency in service delivery, poor Quality of Service (QoS) are experienced. Typically, Fog computing environment is composed of network devices, e.g., routers, switches, set top boxes, proxy servers, Base Stations (BS), etc. and can be located at closer proximity of IoT devices [10].

Fog computing enables a new kind of services at the edge to bring a wide variety of applications for the Internet of Things (IoT) devices especially in Healthcare sectors. The main aim of Fog computing platform is to reduce the data size and traffic to Cloud servers, declining latency, and to advance the quality of service (QoS). Fog computing is characterized as (1) Low latency and location aware computing model, (2) Support heterogeneity, (3) Guaranteed instant response to deal with real time application, (4) Own computing, storage, and networking services, (5) Operate locally with single hop from device to Fog node, (6) Support interoperability, (7) Provide highly virtualized platform, and (8) Offers low-cost, flexible and portable placement in terms of both hardware and software [13]. The above features make fog technology best for healthcare application. The overall architecture and positioning of Fog computing use three-tier architecture as shown in figure 3:

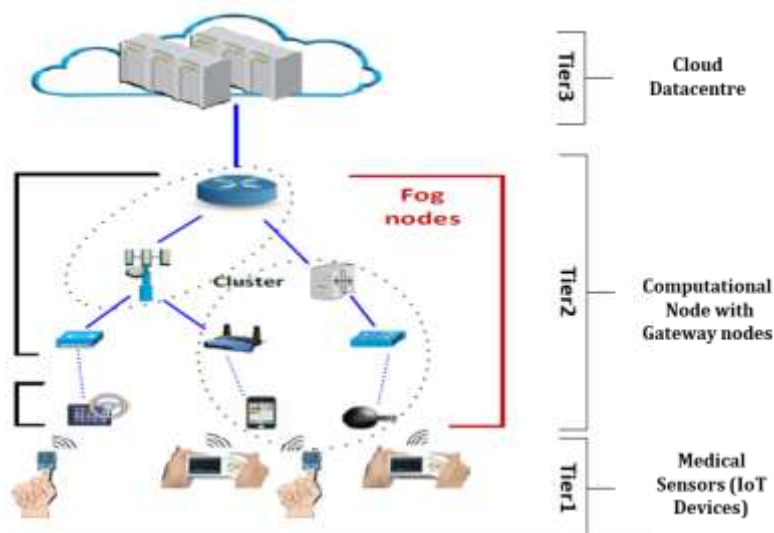


Figure 3: Three-tier Fog computing architecture

Tier-1 holds medical sensors or IoT devices that are equipped with GPS capability. These devices connected with tier-2 devices using gateways node that may be PDR, smart phone or tablet. Tier-2 is termed as Fog layer that contain nodes having certain processing and storage capability. This tier embraced with network devices such as router, switch or access point to connect fog node with tier 3 devices. Tier-3 contain cloud servers and datacenter to store massive amount of data. Use of Fog computing in HIS V.4.0 plays a significant role through embedding sensors and actuators at patient's body for monitoring and tracking purposes [14]. Here, IoT plays a vital role to monitor physiological statuses of patients through sensors by collecting and analyzing the information and then sends data remotely for further processing to the

centers to make suitable actions. The biggest advantage that fog computing provides is reduced delay or communication latency compared to the cloud [15] that helps patients and doctors to utilize real time data for better decisions and monitoring of the patient health status. Fog-based healthcare application allow patients to share information to their physicians, monitor their health status autonomously and notify the authorities quickly in emergency conditions. Historical or old data will also be accessible for further investigation by adding the fog computing with cloud towards identifying patterns that may improve medical diagnoses for future purposes [16].

6.1 Comparison of Fog computing with other technologies in HIS generation V.4.0

Fog computing is compared with its similar technologies like cloud and edge with reference to node distribution, number of nodes, latency, Speed, Bandwidth, Response time etc. Following table 3 shows the comparison of fog computing with other technologies:

Table 3: Comparison of Fog Technology with cloud and edge computing

Features	Cloud	Edge	Fog
Distribution of Nodes/Server	Centralized	Distributed	Distributed
Number of nodes	One or few	Few	Many
Location awareness	Difficult to know	Easy to know	Easy to know
Latency	Maximum	Minimal	Midium
Network type usage	WAN	LAN	LAN
Security requirement	Very high	Low	Low
Probability of Attack	Very High	Less	Less
Bandwidth requirement	High	Low	Low
Hardware Configuration	High	Low	Medium
Sharing of Data	Maximum	Minimal	Medium
Response time	High	Low	Medium
Data Abstraction	Conceptual/Functional	Virtual	Virtual

6.2 Issues and Challenges in Fog assisted HIS generation V.4.0

Fog computing in HIS generation V.4.0 has great potential to accelerate the discovery of early notification of emergency conditions to support smart decision making. But it experienced various issues and challenges when implemented in real-time healthcare scenario. These include data management, device integration, security and privacy of patient's data, scalability, interoperability and human interfaces etc. [17], that are discussed as follows:

- (1) **Data Management:** Fog computing devices (Fog nodes) are placed between IoT devices and cloud datacenter. Medical IoT devices sensed the physiological data that is first sent to fog node that store, process and transfer that data to cloud datacenter for further storage. Which data to store and how much data to store in fog node become challenge, for which efficient data storage and replacement strategy is needed, so that whenever the physiological data is accessed from healthcare provider, it will take minimum delay [18].
- (2) **Scalability:** The physical configuration of fog nodes is limited and always lower than cloud nodes. Thus, to increase the efficiency healthcare system fog nodes may be increased. So, it is an efficient scalability issue in which numbers of optimum fog nodes can be placed, so that time overhead i.e. delay or latency be optimum and quality of service (QoS) be satisfied [19].
- (3) **Service Latency:** Theoretical architecture of fog computing conclude that service latency of fog computing is significantly lower than cloud computing. Still there is latency in service delivery and timely response on fog nodes. This is because of more data processed, analyzed and stored in the edge of fog nodes [20].
- (4) **EHRs Security:** Fog-based HIS allow patients to share information with their physicians, relatives or even patient to monitor their health status autonomously and notify the authorities quickly in emergency conditions. Historical or old data also accessed for further investigation and treatment. It has many security threats and privacy issues that exploited by attackers such as forgery, tempering, spam, sybil, jamming, eavesdropping, denial of service, collusion, man-in-the-middle and impersonation etc., must be eliminated [21].
- (5) **Patient's Privacy:** User's privacy is a serious issue in HIS, which includes Identity, Data, Usage and Location privacy of patient. Thus, it is an extreme issue in fog computing since the patient's data is collected, stored, transmitted, and sharing through the network medium. Patient's privacy includes identity privacy (like phone, address, UID etc.), data privacy to preserve unauthorized and illegal usage, usage privacy to preserver patient's usual pattern, and location privacy to preserve patient's location information [22].
- (6) **EHRs format standardization:** Patient's data is stored in the form of EHRs in Fog node as well as at the cloud datacenters. This data is accessed by the patients, relatives and Healthcare provides. When patient's data is retrieved from fog/cloud node to consumers (doctors/patient), it is transformed and loaded to consumers PDA. This process is referred as ETL (Extract, Transformed and Load) process. For ETL process, set of application programming interface (API) is developed by the application programmer. These API must support the restructuring of patient's data coming from fog and cloud into a single standardized format for ease of interoperability. Other than this, API must have provision for controlling EHRs for authentication, authorization and encryption [23, 24].

- (7) **Network and technical challenges:** Fog nodes are resource constraint devices. During real implementation, if fog nodes fail due to energy depletion, insecure operational environments, memory and computational limitations, then delay will occur in treatment that may result in a life-threatening situation for the patient [25].
- (8) **Legal and Ethical issue:** HIS involves various stakeholders that include medical professionals, technical staff and non-technical staff, patient's relatives etc. This stresses the need for reconsidering rules and responsibilities, i.e. How the patient's data be stored and accessed, what type of information agreement be employed, who can access and benefit from this data, who is at risk of being exposed etc. If these challenges are not considered ethically and legally, it may result in physical, social and psychological harm to patients. Thus legal and ethical structuring is needed before implementing fog-based HIS [26].

6.3 Review of related work regarding Fog computing in HIS V.4.0

In HIS system patient's data is sensed and forwarded to base station for data processing, storage, and decision-making purpose at real time. Fast processing of large amount of healthcare data is big issue in HIS. There are various researches has been proposed regarding healthcare data processing using fog-based system that collects, process and transfer the data to healthcare provider or to storage device for further uses [27,28,29,30,31,32]. This processing also included context aware computing in which decisions are made with the change of context [28]. These fog-based frameworks provided efficient data processing technique with reduced delay and quick decision making about patient's health that increase the reliability of HIS system. Delay and Interoperability is big issue as far as HIS systems are concerned. Interoperability permits different information processing and communication technology services to transfer and exchange the data among different stakeholders configured with different technology devices with optimal response time latency. This delay sensitive and interoperability issue is managed using latest communication technology like 4G and 5G with implementation of software framework using JAVA with SDK services [33,34,35,36,37,38,39,40,41,42,43]. Real time monitoring of patient's health is the prime issue of HIS. This includes sensing, analysis and diagnose disease and alarming to patients and healthcare providers. Real time monitoring in HIS includes policies and methods that helps to healthcare providers to monitor, diagnose and give treatment to patients. The fog-based system provides timely, accurately and reliable healthcare service to treat the patients by analyzing physiological values related to particular or general diseases. Some of the researches [44,45,46,47,48,49,50,51] includes ECG monitoring, neurological monitoring, arthritis monitoring, posture monitoring, and overall healthcare monitoring at Realtime. Patient's data in HIS system is extremely sensitive and HIS is always susceptible to security attacks, that's why it must protected. The Health Insurance Portability and Accountability Act (HIPAA) is endorsed by the US government which covers privacy and security rules for the consumption and revelation of protected health information (PHI). India and other developing countries still working on such kind of act. Some guidelines are proposed by medical council of India as well as there is an information technology act regarding utilization, storage and sharing of EHRs [22]. Security issues includes confidentiality, integrity and availability of patient's EHRs. Confidentiality issues is related with unauthorized access of EHRs, integrity is related with unauthorized modification of EHRs during transmission and availability stated unauthorized blocking of HIS services. some of the researches proposed by [52,53,54,55,56,57,58,59,60,61,62,63] provided security framework that focused on maintaining patient's privacy preservation amount fog and other intermediate nodes during data transmission, preservation of network against DDoS attack, role of certification authority to ensure integrity of patient data, access control of EHRs etc. Other than above issues, some study focused on specific disease by healthcare framework using fog computing infrastructure. Morbidity and mortality issues because of Mosquito Borne disease (MBD) has been proposed by [64]. This study proposed healthcare framework for analysis and classification of MBD. Temporal Network Analysis (TNA) and decision tree J48 based classification algorithm has been included in this work. Smart fog computing system for hypoglycemia was proposed by [65] that focused on diabetes and heart problem in patient's body. It monitored ECG, temperature, and glucose level from patient's body within specific contextual environment. Diagnosis of heart disease in fog-based healthcare has been proposed by [66] that uses deep learning based system to manage the patient's data and to take real-time decision about patient's health. Another fog-based system for monitoring and controlling the blood glucose level in patient's body for tracking the diabetes in human being is proposed in [67]. This fog-based system reduced the computation and transmission latency to reliable data transmission. It utilized J48 algorithm for classification and taking accurate decision about diabetes in patient's body. Fog-based latency aware architecture that classified dengue patients into three categories: infected, uninfected or severe infected, based on systems. Architecture used IoT medical sensor, audio and video data file [68] There are various studies has been proposed regarding simulation tools and frameworks available for fog computing implementation and simulation. These includes Python based Edge-Fog cloud simulator [69], CloudSim simulator [70], Java-based FogTorch [71], FogNetSim++ [72], OMNeT++ [73], python-based Yet Another Fog Simulator (YAFS) [74], FogDirMine [75] etc.

6.4 Discussion, open challenges and recommendation in Fog-based HIS

After investigating of various fog computation frameworks and architecture in existing researches in healthcare setting, it is concluded that fog computing based HIS is moderately utilized and implemented. Most of the studies in this area overwhelmed the limitations of cloud computing by fog-based system using resource management and to reduction in delay and latency. Still there is a need for enhancement in fog computing-based infrastructure to meet the requirement of HIS. Application placement, Resource scheduling, Task offloading, Load balancing, Resource allocation, Resource provisioning are some of the existing issues in fog-based implementation [76].

Storage, data management and interoperability are still big issues to consider. These technical challenges can be handled by edge computing but again data management and lack of resource become another challenge. Security attacks including DDoS attack and Man-in-the-middle attack, impersonation attack, attacks on data integrity are another big challenge to maintain and ensure the patient's privacy and security. Efficient data processing and analysis to make accurate decision about specific disease is also an open area nowadays. Patient's mobility, energy efficiency, and scalability introduces another research opportunity to be covered in fog-based system.

Fog enabled HIS must be recommended that data aggregation, priority-based storage management and delay reduction should be primary concern when developing fog-based solution. Efficient interoperability, load balancing, and parallel data processing should be taken combinedly for query based accessing of EHRs to reduce the delay and enhance reliability of the HIS.

7.0 CONCLUSION

This paper outlined evolution of HIS versions with detail study of fog computing in Healthcare V.4.0. This study offered various technologies used to enhance the HIS including wireless medical sensors and the role of IoT, cloud and fog computing framework within HIS. As an outcome of this study, it is concluded that the fog computing provides decentralized architecture with ability to process large amount of data at the closer proximity and can be installed on heterogeneous devices. These features make fog platform highly appropriate for time and location sensitive application like healthcare. It guaranteed reduced delay in processing and communication with scalability and plays an important role in medical emergency.

After detailed investigation of different existing literature, vital information regarding fog computing-based HIS is extracted. This included available current technologies, sensing systems, and simulation platforms for developing fog based-HIS. This systematic review also identified various issues and challenges from existing research. Further, this paper compared the fog-based technology with cloud and edge computing that helped to decide and motivate to choose fog computing platform to develop HIS system. Finally, discussion, open challenges, and recommendations has been mentioned so that researchers can discover the fog-based technology deeper in the domain of HIS.

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