Fog Computing in Healthcare: A Review

Kamini Pareek¹, Pradeep Kumar Tiwari¹ and Vaibhav Bhatnagar¹

¹Department of Computer Applications, School of Basic Science, Manipal University Jaipur, Jaipur-Ajmer Express Highway, Dehni Kalan, Near GVK Toll Plaza, Jaipur, Rajasthan 303007

E-mail: pradeeptiwari.mca@gmail.com

Abstract. The Internet of things (IoT) connects multiple devices worldwide. It is a growing field in the healthcare system such as health monitoring and tracking, fitness program, and remote medical assistance. With the advent of IoT based technologies in healthcare, it can alleviate the pressure on healthcare systems and can reduce the healthcare cost, and increase the computing and processing speed. Cloud computing was introduced to manage larger and complex healthcare data in the IoT environment. Cloud computing uses centralized cloud data centers. The central server manages the data for all the IoT devices. The integration of IoT with the cloud has some major issues such as latency, bandwidth overuse, real-time response delays, protection, and privacy. So the concept of edge computing and fog computing came into existence to overcome these issues. This paper review the IoT-Fog-based system model architectures, similar paradigm, issues, and difficulties in the area of cloud computing and finally, the performance of some of these proposed systems is assessed using the iFogSim simulator.

1. Introduction

Internet of Things (IoT) is the vision of a future connected world. IoT lets devices become intelligent, powerful, and more efficient. IoT is making our life easier by connecting people and objects to one another. IoT is a technology where devices are interconnected. Devices on the Internet can communicate and exchange data with other objects in the world of the IoT. In an IoT environment, various forms of equipment, such as medical sensors, vehicles, tracking cameras and household appliances can interact, collaborate, and learn from each other. In IoT, things or devices having sensors such as wearable, implanted, and environmental are interconnected through a network. Connected sensors produce a large amount of data. To execute the desired functionality, the devices or things in the IoT are controlled remotely. IoT is improving our quality of life by making a large number of systems and applications available.

IoT is used in many fields such as smart homes, healthcare, smart cities, automation, smart grid, traffic management, agriculture, and so on [1]. Medical services and health care facilities are the most significant areas for IoT growth. IoT development in healthcare reduces cost and increase the quality of user’s life as they can monitor their everyday activities such as dietary habits, sleep cycles, and exercise routines to produce specific tips that help maintain a healthier lifestyle [2]. Moreover, the use of IoT has benefited many medical fields in the healthcare environment, such as continuous real-time tracking, management of patient information, health emergency management, management of blood information, and health management [3]. IoT devices and sensors produce a large amount of health information that gathered, processed, and analyzed. Devices containing sensors have low power, limited memory, and network and battery limitations, so IoT data needs to be computed, stored,
accessed, and analyzed [4]. There is a major issue in the storage and security of the enormous volume of data that is produced by Healthcare IoT devices [5]. A platform that handles all this is Cloud. Cloud has unlimited capabilities of storage and processing power. Figure 1 shows the conventional cloud computing structure [6].

![Cloud Computing Paradigm](image)

Figure 1. Cloud computing paradigm enables data to be generated from various sites and devices and output is again sent to the desired device.

The integration of IoT and cloud provides storage, processing, and network capabilities. Cloud computing can help in avoiding IoT limitations [1]. The key requirement for the IoT platform is the sharing of resources.

Cloud computing shares and maximizes resources. It is location independent as user access cloud services from any location and from any computer through the internet connection [7]. IoT produces an immense volume of diverse data that can be accessed via cloud computing. The integration of cloud and IoT reduces cost and gather big data. Cloud computing act as a method to track patients, keep records, and manage illnesses effectively by analyzing the collected data. The advantage of the cloud is that hospital resources are minimized and healthcare services are moved to the home. This leads to a reduction in healthcare expenses, a healthy patient environment, and an immediate release of health facilities in the event of an emergency. In healthcare, cloud computing leads to the early identification and diagnosis of abnormal situations or illnesses [1]. While the combination of IoT and cloud can solve many challenges; additional challenges are anticipated due to the integration of these two technologies [7]. Cloud is not useful for latency-sensitive applications. The huge amount of IoT data produced in the cloud; increase the burden on the cloud. It takes network bandwidth and data calculation requires some time [8].

However, the cloud is unsuitable for critical applications. Cloud-based applications have several problems associated with high bandwidth requirements, intermittent delays, and safety and security issues. Healthcare application requires real-time monitoring. Cloud cannot fulfill real-time requirements. The data is transferred to the cloud and returned to the application causes delay. These issues are critical to healthcare where a correct and timely response is needed to save a life [2][9].

Cloud-based systems allow data from different sites and devices to be collected, and output is again sent to the desired device, causing the response delay in response and requiring high bandwidth for large data. Data security and user privacy are also a major concern. These are the reasons why individuals are hesitant to use the cloud.

Fog computing has been proposed to fix these problems. To address these issues, researchers have proposed other comparable computing paradigms to fog computing, such as edge computing, mist computing, the cloud of things, and cloudlets.

The objective of this paper is to provide an in-depth fog computing analysis, its challenges, and solutions to these problems. This paper also presented the principles and functionality of fog computing. Edge computing correlates with fog computing and claims that fog computing is general type of computing, mostly because of its detailed concept of range and versatility [10].
This paper is formed into various sections. Section II offers an analysis of fog computing in the context of the healthcare system, including fundamental principles, fog computing architecture, and literature review. The distinction between edge and fog computing is presented in Section III. Section IV defines simulation tools used for evaluating the proposed method, and Section V is the discussion portion. Finally, Section VI concludes the paper with some relevant comments.

2. Overview of Fog Computing
This section introduces the basic principles of fog computing, its architecture, and features.

2.1. Basic Concepts
Sensor-to-cloud implementation is not achievable for many applications in the healthcare sector. Some applications do not allow the storing of medical data outside the hospital, and patient safety is a major concern in the case of network and data center failure [11]. Fog computing is an approach to the mentioned problems. The extension of cloud computing is fog computing. It is introduced between the cloud and IoT devices. Rather than transmitting data for storing and processing to the cloud, fog provides services near to end devices [12]. Healthcare applications are sensitive to latency and require immediate response, so that fog can analyze data formed by IoT devices with minimal overhead in real-time [9]. The fog architecture reduces the cloud burden. Fog and cloud computing offer end-user capacity, processing, and network facilities. However, fog is different from the cloud as fog nodes are closer to the network edge, so time delay can be minimized. Fog nodes perform minimal computing so only routers, set-top boxes, access points, mobile phones, etc. need to be used. Fog provides real-time analysis as storage and calculation are performed near the end devices [8]. Within the network, fog preserves sensitive data that improves user protection. These features are mandatory in healthcare; Fog based health services are used by elderly persons to monitor themselves at home and to live life healthier and longer. Patients can access their health-related information while traveling, spending time at the gym, or relaxing at home. Fog based health applications can also make life easier for disabled people. The fog layer in fog computing covers most of the challenges of the healthcare system that is associated with cloud computing. Fog computing allows the doctor to make smart choices during a case of emergencies and also helps secure confidential data with decreased delays compared to a cloud-based application [5].

2.2. An Architecture for a Healthcare System
The fog computing architecture offers the ideal distribution of networking, processing, and storage device capabilities.

![Diagram of IoT-Fog Healthcare Architecture](image_url)

Figure 2. The IoT-Fog Healthcare Architecture based on 3-layers, which are Sensor Layer, Fog Layer and Cloud Computing Layer
Fog computing refers the cloud computing concepts such as virtualization, hypervisors, and encryption. Fog computing is a modern system that offers minimal processing, memory, and network facilities at the edge of the user’s endpoint. The IoT-fog computing-based healthcare architecture is made up of three layers, which are the devices layer, fog layer, and cloud computing layer as shown in figure 2 [13].

IoT devices are on the bottom layer. On the upper layer, IoT nodes are attached to network equipment. The higher layer is capable of transferring health data to the destination layer from the source of generation. A proper balance between these layers is provided by the architecture of fog computing.

a) Device layer: Patients have sensors and monitors attached to take care of their health. In real-time, these devices can sense and transmit data. These devices are located on the device layer, have responsibility for healthcare selection and transmission of healthcare data to the fog layer for accessing via Wi-Fi or mobile network.

b) Fog computing layer: The layer of fog computing extracts medical details from different IoT health tracking devices. This layer is used for IoT health information collection and analysis in real-time.

c) Cloud computing layer: This layer is liable for the storage, preparing, and executing activities that the fog layer is unable to handle and execute. For future actions, patient condition and reports are moved to the cloud layer from the fog layer.

A health fog system was proposed by Ahmad et al. [14], where fog computing serves as an intermediate layer between the cloud and end-user. This three-layer architecture reduces communication costs.

A Smart fog computing architecture proposed by Shukla et al. [15], to decrease the latency and network. It is three-layer architecture in which requests can be processed locally and then send to the cloud. Fog computing acts as a middle layer, reduces the drawbacks of IoT health, and enhances the network services. Fog nodes are used in healthcare IoT to reduce latency.

Greco et al. [16], proposed a multilevel architecture that focuses on addressing health monitoring problems. These health monitoring problems can be static and dynamic monitoring.

Alli et al. [17], proposed an IoT-Fog-Cloud ecosystem. It is an interesting architecture in which IoT devices performs according to users’ demand. In this, end devices are at the bottom, the fog layer is the middle layer and the cloud layer is the top layer. This architecture support localized computation, Fog-edge computing, and remote computing.

Abdelmoneem et al. [18], propose an architecture that distributes healthcare tasks dynamically between cloud computing and fog computing. Various health problems and a significant percentage of patients will be treated by this architecture.

To conclude, three-layer architecture dedicated to healthcare is addressing medical cases.

2.3. Literature Review

The idea of fog computing and its impact on IoT was published in 2012. Fog computing is the fastest-growing interest area over time. Starting with four papers in 2013 and three papers in 2014, the number of publications rose to thirty-three in 2015 and twenty-two in 2016. Nearly half of these papers are directed to fog-enabled infrastructure. These architectures have mostly been designed in the context of healthcare and smart environments. The healthcare system strives to make it possible for sufferers to regularly interact with their consultants and their consultants to provide responsible patients with effective and value-added care. The key method for translating IoT healthcare from ideas to implementations and services is Fog computing. To help IoT healthcare systems, fog computing can
be used. Propose the work done so on fog systems and issues such as health monitoring, data security, confidentiality, and data protection are best discussed in the study. Fan et al. [19], propose a rehabilitation system using an ontology-based automating design methodology (ADM). This rehabilitation system helps to minimize problems related to elderly people. In fog-enabled facilities that handle sensitive data, such as health tracking, security is a key issue. Ahmad et al. [14], introduce the cloud access security broker (CASB) which strengthens privacy and confidentiality for data in the health fog framework. CASB provides the solution for improving health fog security issues, which are placed between various cloud service providers and end-users. It combines various kinds of security policy enforcement.

Quwaider et al. [20], presented a paper on the global health awareness system, which is using a multi-tier cloud system architecture. This system of multi-tier health awareness would minimize delay and allow for better exchange of health data. This system can be used for early detection of epidemic disease before it spread over a wide region. The health awareness system provides important health data on time and is used for the identification and avoidance of diseases. Wireless Body Area Network (WBAN) is the basic block of the global health awareness system. WBAN is useful in data collection and communication. The proposed system is integrated with the MapReduce technique to handle data processing and sharing issues.

Regular exercise decreased mental stress and anxiety level is beneficial to one's health. Physical health however can be seriously impaired during workout sessions. Thus, Bhatia et al. [21] focused on evaluating a person's real-time health monitoring during his warm up session by using IoT technologies and testing them for health severity evaluation. The Bayesian Belief Networks (BBN) approach is used in this paper to assess the overall intensity of health in the form of a probabilistic metric.

Gia et al. [22], proposed a cost-saving health monitoring system that consists of a fog layer and energy-efficient sensor nodes. This method lowers the expense of health care and increases healthcare service quality. The nRF protocol is the basis of these sensor nodes which are energy-efficient. The system conducts efficient decisions and offers services for immediate attention.

Today’s IoT devices are vulnerable and unable to protect themselves. Winnie et al. [23], represent that fog nodes function on the edge side and improve data protection, consistency, specificity, and lowers delays. For an application such as medical data, these are the key factors. The security of healthcare data is also improved by the use of fog computing.

To discover and regulate hypertension attacks at an initial point, Sood et al. [24], suggested an IoT-Fog-based health tracking method. The artificial neural network is used to predict the overall threat of hypertension attack in elderly communities or individuals that are functionally impaired and live isolated.

Rahmani et al. [25], proposed a fog computing approach used by healthcare applications to boost various IoT architecture features such as energy consumption, interoperability, performance, trustworthiness, etc. To explain the effectiveness and usefulness of the system in resolving a medical case study an Early Warning Score (EWS) health monitoring has been introduced.

Depending on the high, intermediate, and low-level IoT layers Khan et al. [26], survey and review primary IoT security challenges. This paper outlined security requirements, existing attacks, threats, and these solutions. Khan et al. discuss future transparent open research problems and challenges and characteristics of blockchain-based security solutions.

A massive volume of data is created by IoT and the transmission and processing of the whole data will enhance the cloud computing responding period. For the end-user, the increased system response will result in high service latency. A hybrid approach is introduced by Shukla et al. [15], which incorporates fuzzy and reinforcement learning in healthcare IoT and cloud to improve network latency.
and services. This hybrid strategy uses an algorithm to reduce latency by performing batch workloads on IoT data. By minimizing service capacity and high network, the reinforcement learning and fuzzy inference framework can help to get input from past patient health records and to make real-time decisions.

Mobility support is a crucial necessity for several real-time IoT systems, as lost or postponed data throughout mobility can have significant implications. Several approaches have recently been suggested for awareness of mobility in the remote health tracking system. Gia et al. [27], propose a mobility support strategy through an effective handover process for a WiFi-based real-time IoT health monitoring system. This approach focuses on IoT systems that collect a lot of data in real-time remote tracking of health. The handover mechanism enables the link to remain between the sensor nodes and the low bandwidth device.

Abdel et al. [28], present a fog-based IoT framework for real-time tracking of type-2 diabetes patients. To diagnose the infected individuals a hybrid technique based on type-2 neutrosophic with VIKOR method and evolving alerts were used.

For monitoring elderly health, Hasse et al. [29] proposed an e-health system. Physiological and general health parameters are regularly obtained from the elderly using Mysignals HW V2 technology and a mobile app that proposed the idea of the fog server.

The problem of arthritis is facing by many people. Regular joint health monitoring and consultation by a physician will assist patients with this chronic disease. A WBAN-based framework is proposed by Tanwar et al. [30], to evaluate real-time health care for patients problem related to arthritis. To minimize false detections in the proposed architecture, the Bayesian network classifier is used.

Using deep learning and machine learning techniques Sarabia et al. [31], present a highly efficient intelligent fog-cloud computing framework for timely detection of falls. By the DL inference method, the system detects falls on the ground. The use of the DL model to detect falls enhances and reliability as it achieves a high precision with fewer parameters than the ML model. The fog approach is responsible for achieving a timely response as the observational data does not require to be transferred to the cloud.

For real-time surveillance of an affected person, a fog-assisted remote monitoring framework by Kumar et al. [32] is used. To decrease the delay between the IoT and a cloud server, an algorithm and computational fog-assisted wearable sensor framework is used.

An emerging field of study is delay-sensitive and energy-efficient mobile health monitoring. Mukherjee et al. [33], propose a system for indoor/outdoor users that is delay-conscious and energy-efficient fog-based Internet of Health Thing (FogIoHT). The average delay, average signal attenuation, and consumption of energy are minimized by this method. In this system, the Small Cell cloud enhanced e-node B (SCceNB), cloudlet, roadway modules, gateways, and routers are used as fog equipment. The weighted majority game theory is used when many fog devices are available to choose a fog system for data processing. Qualnet network simulator is used to model a fog-based health care system network scenario. MATLAB conducts a theoretical analysis that shows that the proposed architecture is a time-sensitive and energy-efficient system.

3. Edge Computing

Edge computing was introduced to push cloud computing to the edge of the network. Edge computing provides edge services near to the data source to fulfill the critical requirements. Edge computing deploys intermediate nodes in mobile network base stations. These intermediate nodes have computation and storage capabilities. Edge computing offers cloud computing capabilities inside the Radio Area Network (RAN) to reduce latency and improve context awareness [34]. Edge computing offers many advantages such as real-time response, location awareness, and mobility. It performs
calculations at the network edge that reduces network activity. It improves security as data is processed on the device or sensors itself without being transferred anywhere. Edge computing keeps costs down by storing and processing data in real-time to maintain operations. Edge computing works by distributes the device’s work to the edge node close to both the physical distance and the cloud. In this way, figure 3 illustrates a two-way computing stream [6] that can carry out off-roading, collecting, caching, and evaluating data, and also provide the cloud-to-user request and delivery service. Refer figure 3.

![Edge Computing Paradigm](image)

**Figure 3.** Edge Computing Paradigm that Provides the Cloud-to-User Request and Delivery Service

There are no centralized computing resources for Edge computing, so the overload of data is minimized. Essential data such as private details can be analyzed without actually sending it to the cloud server, which improves data security as confidential information is processed at the edge. Edge computing has many advantages such as reducing response time by shifting computing from the cloud to the edge, but it also faces a problem with security and privacy. Edge computing inherits certain cloud computing security issues, but the security mechanism proposed in the cloud framework is not acceptable in the edge framework [35].

### 3.1 A contrast Between Edge Computation and Fog Computing

The cloud’s storage and network power are transferred to the edge network, in fog and edge computing. Edge and fog computing increases efficiency and develops innovative services. Fog computing was evaluated with edge computing in terms of architecture, the purpose and position of their nodes, and the services they provided. Table 1 summarize these characteristics.

| Features            | Fog computing                  | Edge Computing               |
|---------------------|--------------------------------|------------------------------|
| **Devices**         | Gateways, Access Points, Switches, Routers | The servers that run at base stations |
| **Location**        | Ranging from Cloud to Iot Nodes | Radio Network Controller     |
Edge computing refers to computing at the periphery of a network, any location in the network that is close to the user than the cloud. The devices communicate to the node directly at the base station via a cellular network. Fog Computing uses to support non-IP based protocols such as BLE and Wi-Fi. The proximity of the edge reduces latency to milliseconds and provides a reliable connection for users. The distinction between edge computing and fog computing is that isolated edge nodes operate on edge computing, whereas node-to-node interconnection capabilities rely on fog computing.

### 4. Simulation Tool

Simulators are used to research the behavior of the framework and know the variables that affect system efficiency as it progresses. Many simulation tools are available for fog computing with various functions and features. iFogSim is a simulation toolkit for fog computing that extends the CloudSim simulator by adding new functionalities. iFogSim is the most common Java-written tool using the JSON file format to represent physical topologies. It is used by many researchers to evaluate their research work. Experiments are conducted with the help of the iFogSim simulator which assisted researchers to assess fog computing in terms of latency, energy usage, network congestion, and operating costs.

Simulations in iFogSim were performed to prove the success of the suggested approaches in reducing delay and network usage, and the findings were compared with cloud-based systems. The findings of the simulations show that the adoption of fog-based approaches can achieve a reduction in both network usage and latency.

In [36], discuss the architecture, design, and implementations of iFogSim. iFogSim tests their application’s architecture against metrics such as cost, network performance metrics, etc. The iFogSim application model is the Sense-Process-actuate model. For two case studies; iFogSim is used to model the fog computing paradigm. The first case study is an online game application, and the second case study is a distributed camera surveillance that monitors an area and analyzes the videos created by these cameras. Both applications involve processing in real-time, where a reduced delay and reduced energy consumption are needed.
An energy-aware allocation strategy is proposed by Mahmoud et al. [37]. The efficiency of the suggested strategy is assessed with the iFogSim simulator. iFogSim combines IoT, fog, and cloud. iFogSim is a popular cloud environment simulation tool that expends its most significant components, such as the data center and cloudlets.

The algorithm for heuristic dynamic task processing is used by Fang et al. [38], to decrease process delay, increase the quality of service, and lowering the system’s power consumption. iFogSim is used to evaluate the suggested system, and observations with the iFogSim simulator indicate that the performance of the application service is a substantial increase and the power usage and the average delay of the system are reduced.

Jayasena et al. [39], suggested that the issue of task scheduling is implemented in fog computing and tackled using a meta-heuristic algorithm called the algorithm of whale optimization. The Whale Optimization algorithm was implemented to lower the power generated by fog devices. In iFogSim, a smart health monitoring application is built and executed to evaluate performance.

The iFogSim simulator is used by Bala et al. [40], evaluate the efficiency of the load balancing algorithm. This paper addresses the job distribution problem in Cloud-Fog and advised a load balancing approach which transfers the workload between cloud and Fog devices. The optimum use of the bandwidth of a network is the goal of this strategy.

The simulation outcome shows that proposed architectures are more powerful than cloud-based architecture.

5. Discussion

This paper discusses the effect of the internet of things (IoT) and fog computing in healthcare, using a systematic literature review. This review reveals that with the expansion of the IoT and smart devices, data nodes are growing at an extraordinary speed allowing massive data that is to be kept and analyze in the cloud for a variety of reasons. These reasons specially discuss the problems of central storage, challenging computation, and sharing of data. Fog computing acts to refine the whole process as a bridge between both the end-user and the cloud. Fog computing successfully minimizes excessive interaction from node-to-cloud data generation. Moreover, to ensure the protection and security of data, certain rules and regulations can be integrated into the Fog. In traditional applications that are strictly cloud-dependent, the increases in delay and the standard of services required deterioration. For this reason, it improves data security, precision, and reliability, decreases the level of delay, and improves the service quality by adding fog as a middle layer and operating on the edge side. In e-health related systems and applications, cloud and fog computing has attracted profound interest. The IoT-Fog-cloud architecture commonly uses soon as more IoT devices are being built and fast computing demand is on the rise.

6. Conclusion

The Internet of Things (IoT) is a device-to-internet connection technology. It makes it possible for devices to become more intelligent, stronger, and more powerful. It is often used in many industries, such as smart homes, healthcare, smart cities, robotics, smart grid, control of traffic, agriculture, etc. By integrating IoT systems in hospitals and households, emergencies can be alerted to health professionals in real-time to take prompt action to prevent adverse effects. Through analyzing the data collected, cloud computing serves as a platform for tracking patients, storing records, and handling diseases effectively. There are several problems with cloud-based services due to high specifications for connectivity, intermittent delays, and protection and security challenges. Fog computing has been advised to solve these issues. This paper tries to provide in-depth fog computing research. A survey on IoT-Fog-cloud architectures is presented. The methods, standards and principles are reviewed in exploring IoT and its architectural environment. In the fog cloud of things, address the latest developments, obstacles, difficulties, and perfect solutions. For future work, iFogSim can be applied in
several other directions. A first direction may be a smart city scenario with different infrastructure configurations. Smart car parking system, smart waste management system, and smart coal mining industry may be other ways. An addition to iFogSim that enables the evaluation of data placement management policies in a Fog-IoT infrastructure to reduce service latency, network traffic and consumption of energy can also be suggested for future work.

7. References

[1]. Díaz, Manuel, Cristian Martín, and Bartolomé Rubio. "State-of-the-art, challenges, and open issues in the integration of Internet of things and cloud computing." Journal of Network and Computer Applications 67 (2016): 99-117.

[2]. Cerina, Luca, et al. "A fog-computing architecture for preventive healthcare and assisted living in smart ambients." 2017 IEEE 3rd International Forum on Research and Technologies for Society and Industry (RTSI). IEEE, 2017.

[3]. He, Debiao, and Sherali Zeadally. "An analysis of RFID authentication schemes for internet of things in healthcare environment using elliptic curve cryptography." IEEE Internet of Things Journal 2.1 (2014): 72-83.

[4]. Khan, Minhaj Ahmad, and Khaled Salah. "IoT security: Review, blockchain solutions, and open challenges." Future Generation Computer Systems 82 (2018): 395-411.

[5]. Kumari, Aparna, et al. "Fog computing for Healthcare 4.0 environment: Opportunities and challenges." Computers & Electrical Engineering 72 (2018): 1-13.

[6]. Shi, Weisong, et al. "Edge computing: Vision and challenges." IEEE Internet of Things Journal 3.5 (2016): 637-646.

[7]. Biswas, Abdur Rahim, and Raffaele Giaffreda. "IoT and cloud convergence: Opportunities and challenges." 2014 IEEE World Forum on Internet of Things (WF-IoT). IEEE, 2014.

[8]. Shi, Yingjuan, et al. "The fog computing service for healthcare." 2015 2nd International Symposium on Future Information and Communication Technologies for Ubiquitous HealthCare (Ubi-HealthTech). IEEE, 2015.

[9]. Verma, Prabal, and Sandeep K. Sood. "Fog assisted-IoT enabled patient health monitoring in smart homes." IEEE Internet of Things Journal 5.3 (2018): 1789-1796.

[10]. Yousefpour, Ashkan, et al. "All one needs to know about fog computing and related edge computing paradigms: A complete survey." Journal of Systems Architecture 98 (2019): 289-330.

[11]. Kraemer, Frank Alexander, et al. "Fog computing in healthcare—a review and discussion." IEEE Access 5 (2017): 9206-9222.

[12]. Qi, Qinglin, and Fei Tao. "A smart manufacturing service system based on edge computing, fog computing, and cloud computing." IEEE Access 7 (2019): 86769-86777.

[13]. Aladwani, Tahani. "Scheduling IoT Healthcare Tasks in Fog Computing Based on their Importance." Procedia Computer Science 163 (2019): 560-569.

[14]. Ahmad, Mahmood, et al. "Health fog: a novel framework for health and wellness applications." The Journal of Supercomputing 72.10 (2016): 3677-3695.

[15]. Shukla, Saurabh, et al. "Architecture for latency reduction in healthcare internet-of-things using reinforcement learning and fuzzy based fog computing." International Conference of Reliable Information and Communication Technology. Springer, Cham, 2018.

[16]. Greco, Luca, et al. "Trends in IoT based solutions for health care: moving AI to the Edge." Pattern Recognition Letters (2020).

[17]. Alli, Adam A., and Muhammad Mahbub Alam. "The fog cloud of things: A survey on concepts, architecture, standards, tools, and applications." Internet of Things 9 (2020): 100177.

[18]. Abdelmoneem, Randa M., Abderrahim Benslimane, and Eman Shaaban. "Mobility-Aware Task Scheduling in Cloud-Fog IoT-Based Healthcare Architectures." Computer Networks (2020): 107348.
[19]. Fan, Yuan Jie, et al. "IoT-based smart rehabilitation system." IEEE transactions on industrial informatics 10.2 (2014): 1568-1577.

[20]. Quwaider, Muhammad, and Yaser Jararweh. "Multi-tier cloud infrastructure support for reliable global health awareness system." Simulation Modelling Practice and Theory 67 (2016): 44-58.

[21]. Bhatia, Munish, and Sandeep K. Sood. "A comprehensive health assessment framework to facilitate IoT-assisted smart workouts: A predictive healthcare perspective." Computers in Industry 92 (2017): 50-66.

[22]. Gia, Tuan Nguyen, et al. "Low-cost fog-assisted health-care IoT system with energy-efficient sensor nodes." 2017 13th international wireless communications and mobile computing conference (IWCMC). IEEE, 2017.

[23]. Winnie, Yumnam, E. Umamaheswari, and D. M. Ajay. "Enhancing Data Security in IoT Healthcare Services Using Fog Computing." 2018 International Conference on Recent Trends in Advance Computing (ICRTAC). IEEE, 2018.

[24]. Sood, Sandeep K., and Isha Mahajan. "IoT-fog-based healthcare framework to identify and control hypertension attack." IEEE Internet of Things Journal 6.2 (2018): 1920-1927.

[25]. Rahmani, Amir M., et al. "Exploiting smart e-Health gateways at the edge of healthcare Internet-of-Things: A fog computing approach." Future Generation Computer Systems 78 (2018): 641-658.

[26]. Khan, Minhaj Ahmad, and Khaled Salah. "IoT security: Review, blockchain solutions, and open challenges." Future Generation Computer Systems 82 (2018): 395-411.

[27]. Gia, Tuan Nguyen, et al. "Fog computing approach for mobility support in internet-of-things systems." IEEE Access 6 (2018): 36064-36082.

[28]. Abdel-Basset, Mohamed, et al. "A novel intelligent medical decision support model based on soft computing and IoT." IEEE Internet of Things Journal 7.5 (2019): 4160-4170.

[29]. Hassen, Hafedh Ben, Wael Dghais, and Belgacem Hamdi. "An E-health system for monitoring elderly health based on Internet of Things and Fog computing." Health information science and systems 7.1 (2019):

[30]. Tanwar, Sudeep, et al. "Human arthritis analysis in fog computing environment using Bayesian network classifier and thread protocol." IEEE Consumer Electronics Magazine 9.1 (2019): 88-94.

[31]. Sarabia-Jácome, David, et al. "Highly-Efficient Fog-Based Deep Learning Aal Fall Detection System." Internet of Things (2020): 100185.

[32]. Kumar, MG Sharavana, and VR Sarma Dhulipala. "Fuzzy allocation model for health care data management on IoT assisted wearable sensor platform." Measurement 166 (2020): 108249.

[33]. Mukherjee, Anwesha, Debasis De, and Soumya K. Ghosh. "Fogioht: A weighted majority game theory based energy-efficient delay-sensitive fog network for internet of health things." Internet of Things (2020): 100181.

[34]. Dolui, Koustabh, and Soumya Kanti Datta. "Comparison of edge computing implementations: Fog computing, cloudlet and mobile edge computing." 2017 Global Internet of Things Summit (GIoTS). IEEE, 2017.

[35]. Liu, Dan, et al. "A survey on secure data analytics in edge computing." IEEE Internet of Things Journal 6.3 (2019): 4946-4967.

[36]. Gupta, Harshit, et al. "iFogSim: A toolkit for modeling and simulation of resource management techniques in the Internet of Things, Edge and Fog computing environments." Software: Practice and Experience 47.9 (2017): 1275-1296.

[37]. Mahmoud, Mukhtar ME, et al. "Towards energy-aware fog-enabled cloud of things for healthcare." Computers & Electrical Engineering 67 (2018): 58-69.

[38]. Fang, Juan, and Aonan Ma. "IoT Application Modules Placement and Dynamic Task Processing in Edge-Cloud Computing." IEEE Internet of Things Journal (2020).
[39]. Jayasena, KP N., and B. S. Thisarasinghe. "Optimized task scheduling on fog computing environment using meta heuristic algorithms." 2019 IEEE International Conference on Smart Cloud (SmartCloud). IEEE, 2019.

[40]. Bala, Mohammad Irfan, and Mohammad Ahsan Chishti. "Optimizing the Computational Offloading Decision in Cloud-Fog Environment." 2020 International Conference on Innovative Trends in Information Technology (ICITIIT). IEEE, 2020