Fog and IoT Driven Healthcare

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Technological advancements have made it possible to monitor, diagnose, and treat patients remotely. The vital signs of patients can now be collected with the help of Internet of Things (IoT)-based wearable sensor devices and then uploaded on to a fog server for processing and access by physicians for recommending prescriptions and treating patients through the Internet of Medical Things (IoMT) devices.

Keywords: Internet of Things ; fog computing ; healthcare ; health monitoring ; sensors

1. Introduction

In the last two decades, electronic gadgets have revolutionised the world and have become an integral part of human life. Artificial intelligence and machine learning have made these electronic devices smart. Some of these smart devices are being used for health monitoring, diagnosis, and even treatment. For instance, now, a device can detect diabetes through an image of a patient's iris [1]. The medical devices can be connected to healthcare information technology systems using networking technologies to make medical data quickly available to healthcare practitioners. The interconnection of medical devices, popularly known as the IoMT, is an amalgamation of medical devices and applications that lessens hospital visits and allows practitioners to observe patients remotely [2][3]. The proliferation of IoMT can be judged by increases in the sale of IoT-enabled medical devices. It is estimated that the world's smart health market will expand at an average growth rate of 16.2% between 2020 and 2027 [4]. The reasons behind the proliferation of IoMT are high accuracy, low cost, and low delay in delivering healthcare services. The recent advancements in IoMT have made preliminary diagnostics possible at the patient's home. For instance, blood tests and diabetic and blood pressure monitoring at the patient's doorstep in real-time are viable. Due to this, healthcare is shifting from the hospital to a home-centric service [5][6]. Further, the developments in telecommunication services, body sensor networks, fog, and cloud computing have made monitoring and detection, medical consultations, and prescribing treatment possible at the doorstep [7][8]. The number of people globally requiring regular monitoring due to chronic diseases such as cancer, asthma, cardiovascular disease, arthritis, dementia, Alzheimer's, visual impairment, and chronic obstructive pulmonary disease has been estimated to be over 200 million [9][10]. China and India have around 110 million and 69 million diabetic patients, respectively. The total number of diabetic patients worldwide is expected to increase from 415 million to 642 million. These numbers are increasing daily and need to be processed through different technologies. IoT devices coupled to sensors in healthcare systems perform automated patient monitoring, activity tracking, detecting heart rate, calculating caloric expenditure/intake, and more. The data generated by these IoT devices are processed and analysed at either fog/edge devices or cloud data centres. Current cloud models do not appear to be the best answer for handling IoT challenges since high-transmission capacity imperatives, organised framework reliance, and flighty response time from the cloud render them inadmissible for basic applications. Another issue emerges when deciding what to offload: data, computation, or application, and more specifically where to offload: fog or cloud, and how much to unload. In terms of task-related variables such as task size, duration, arrival rate, and necessary resources, fog-cloud collaboration is stochastic. Dynamic task offloading becomes critical in order to better utilise fog and cloud resources [11]. The solution to these requirements is fog computing with the IoT [12]. IoT implementation creates enormous changes in the healthcare system, which helps reduce the volume of transmitted data and network bandwidth [1]. Fog computing is one of the characteristics of cloud computing that lies near the end-user. It has introduced services to enhance user efficiency, authenticity, and usability and provided space to store data, compute, and communicate with edge devices, improving privacy and security in real-time [13]. The fog healthcare architecture comprises three layers: (i) An IoT layer/Sensor layer, (ii) a fog layer, and (iii) a cloud layer, as shown in **Figure 1**. The body sensor network captures the physiological states of the patient, such as blood pressure, pulse rate, body temperature, pressure rate, electrocardiogram, and an electroencephalogram. The wearable sensors monitor the patient continuously and transfer the physiological data to the fog layer using wireless networks such as Bluetooth, Zigbee, IEEE 802.11, and WiMAX [14][15]. The fog layer analyses the physiological data to provide alerts on the patient's health condition to various concerned individuals, such as family members, caretakers, and authorised medical practitioners, to observe vital signs through diverse applications [16][17]. The patient's medical data are regularly pooled and sent to cloud servers for examination. In the medical field, the demand for fog computing with IoT bears distinctive characteristics for health monitoring systems.

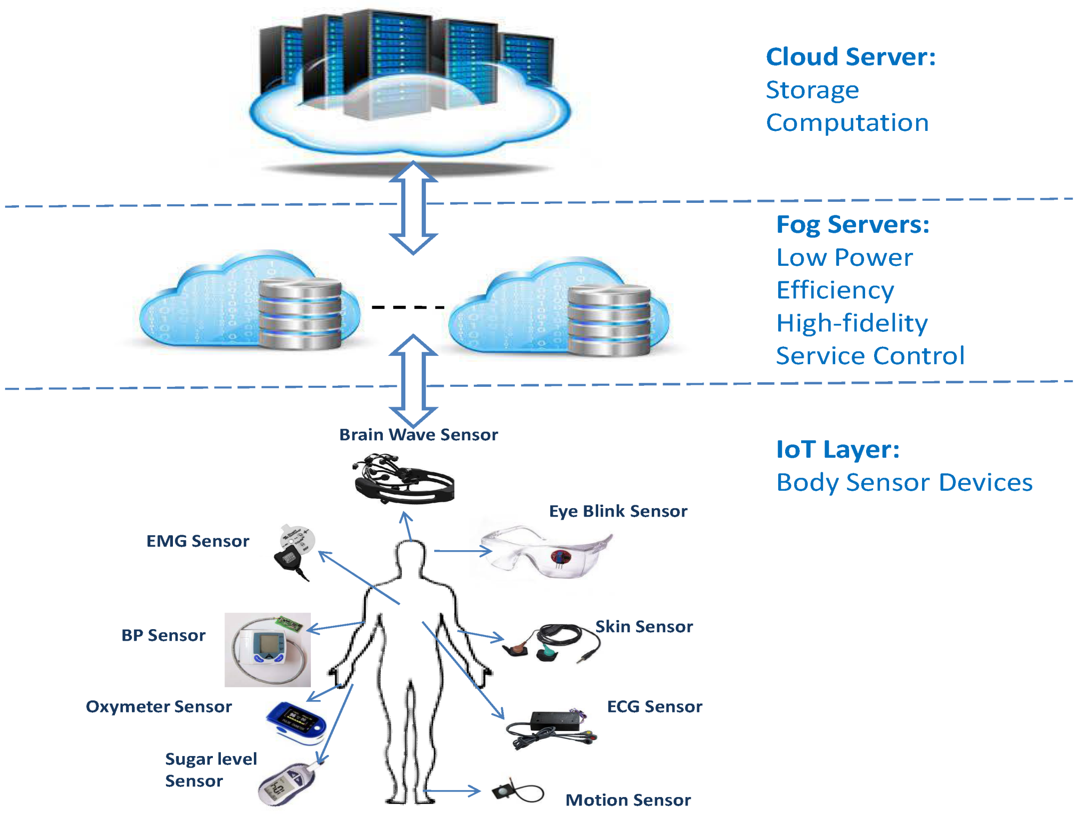

Figure 1. Architecture of fog computing in healthcare.

2. Background

Technological advancements have fostered stiff competition in the already expensive industry of healthcare. Many hospitals have converted their systems to Electronic Health Records (EHRs), as required by the Health Information Technology for Economic and Clinical Health Act (HITECHA) and the American Recovery and Reinvestment Act (ARRA) of 2009. EHRs employ an old method called client-server architecture. However, IT tech has designed more efficient and patient-centric methods, and cloud computing has made it convenient and cost-effective. The word “cloud” refers to a big area, and computing refers to calculating, enumerating, measuring, figuring out, etc. So, cloud computing implies computing large amounts of data. A “cloud” is a data centre available on the internet for users that demand extra storage [18]. Cloud computing is a good choice for healthcare businesses because it is more economical than previous methods. The services that the cloud provides are beneficial for medical facilities, with some of these services including SaaS, IaaS, and PaaS. First, with Software as a Service (SaaS), the cloud can provide on-demand managed services to healthcare organisations, provide easy access for business applications, and fulfill Customer Relationship Management (CRM) [19].

Cloud technology is an Infrastructure as a Service (IaaS) that enables on-demand processing and the storage of large amounts of medical data [20][21]. Regarding Platform as a Service (PaaS), the cloud will provide a security-improved platform for web-based applications and software application deployment [22]. It also has the advantage of connecting cloud users and medical centres to exchange health data about patients over the internet. Transforming healthcare across the cloud requires more than just delivering medical information from several computers at any moment and on almost every mobile phone device [23][24][25].

Fog computing: fog computing lies between the cloud and the location of the user’s devices [26]. Fog computing trends in all fields, such as smart homes, industries and hospitals. The use of fog computing to make smart hospitals. Many authors have designed proposals and architectures [27][28]. Many researchers have reviewed the studies and designed various architectures to show the basic concept of fog computing in healthcare [17][29]. The architecture showed fog data, which could reduce the data, make them flexible with more security, and then transfer them to the cloud [30][31][32]. **Figure 1** depicts the sensor devices collecting the relevant information from patients in the form of signals, which are transferred to the embedded computers, called “fog computers”. After filtering the signals and investigating the data, it is sent to the cloud [33]. The advantage of the architecture is that it uses less power, reduces the quantum of data, and improves the system’s efficiency. This architecture has monitored Electrocardiogram (ECG) signals and speech disorders.

The words “internet” and “things” are very common, but their practical combination is impactful [34]. The objects’ internet is used to collect and transfer data on the network. It does not need any interactions such as user-to-user and user-to-system [35]. IoT has used version 6 of the Internet Protocol (IPv6). There are sensors inbuilt into devices that are used to connect to the internet and transfer data. Many home appliances are IoT: smart refrigerators, smart TVs, smart ACs, and even edge-IoT-based smart healthcare [36]. Some of the medical care devices of the IoT include smart wearable watches which sense the pulse rate from the wrist, smart heart sensors, blood pressure sensors, and many more [37]. The architectures studied in this survey use IoT-based devices with inbuilt sensors and are connected in the network through the Internet, generally known as Intelligent Internet of Health Thing [38].

Sensors Used

Sensors play a significant role in medical innovation intending to make medical gadgets much more powerful and more secure while streamlining their activity. There are a variety of sensors in technical as well as medical fields [39][40]. Some of the successful applications of sensors in medical technology are:

- Respiratory devices
- Sleep diagnostic devices
- Sleep apnea therapy devices
- Spiro meters
- Anesthetic meter
- Dialysis machines
- Infusion pumps
- Oxygen concentrator
- Vacuum suction pumps
- Videoscopes
- Blood sugar measuring device
- Pulse oximeters
- Computer tomographs
- Gamma probes

3. Fog and IoT Driven Healthcare

Several papers have explored the perspective of the fog computing architecture, claiming effective bandwidth consumption, ensuring Quality of Service (QoS), and delivering notifications in emergency scenarios. The majority of their job is dependent on elements such as fog layer bandwidth, latency, and data processing. They also utilized a variety of sensor nodes, communication protocols, as well as heterogeneity and interoperability. Moreover, they work on online analytics at the fog layer when the connection is poor. They improve the IoT-based health monitoring system in households and hospitals. In addition, they essentially examined ECG to determine heart rate. The extraction of pulse and heart rate is visible on a secure Graphical User Interface (GUI) as well as the warning system for contemporaneous notification in an emergency. Furthermore, they offer gateways that support wireless devices such as Bluetooth, Wi-Fi, and 6LoWPAN. The papers dicuss how the user interface should be user-friendly for universal accessibility. Different network protocols should be used to improve security, and employees should be trained in data security. Researchers have used the Arduino tool to put their ideas into action [1][41].

Some of the researchers have created a health monitoring system based on IoT secondary networks and contains various sensors such as Wi-Fi and Bluetooth secondary networks. The intermediary processing layer is established by obtaining a number of smart gateways in order to demonstrate the notion of fog computing for healthcare systems in IoT. They employed a fog system to aid medical situations known as early-warning scores, and used it to monitor patients with serious illnesses by employing sensors to continuously monitor individual health problems such as ECG, Electromyogram (EMG), pulse oximeter, mica2 motes, and SpO_2 sensor. They also employed a 4G network for continuous patient monitoring [16]. Atlam et al. cite6 and Kaur et al. [42] have described the work process of a variety of objects in the fog-assisted smart-home atmosphere where the layer of fog can extract vital information related to a patient's health. The Temperature Humidity Index (THI) of the patient is calculated in the cloud layer to identify the emergency. Information can be delivered to the receiver from the cloud layer to handle emergencies. Furthermore, the last one is the real-time alert generation according to the severity of the patient's condition [23][43][44]. In [7], the authors introduced an innovative IoT-based approach for a smart healthcare system that gives a medical warning for the patient monitoring system. They employed machine learning algorithms to computerize the management of the system. This monitoring system is for cardiac patients where an ECG is used to monitor the heart rate. Here, they used the improvement of local data analytics to present warnings and latency when the internet connection is absent. They used Raspberry-pi Zero and Jetson-TK1 with different processing systems. The proposed work is to enhance the users and system and enable the method to receive local notifications in case of an emergency situation. They improve the reaction time and consistency of the system when the internet connection is lost. Bibani et al. [9] designed a demonstrative version of one of the cloud services, called PaaS. They used the Body Area Network (BAN) to collect vital information. It is connected to patients' smartphones and while they are doing their normal daily life work, it monitors them. If something happens to the user or patient, it immediately warns the emergency services, i.e., calling an ambulance and contacting the stored number of family members to warn them immediately. They used the shimmer platinum development kit known as BAN. It is a wearable and wireless sensor device that senses the health of a patient and other data and is user-friendly.

Some of the papers are reviewed based on the fog computing architecture. They investigated the state-of-the-art in fog computing, as well as its characteristics and benefits. They provide the benefits and challenges of the combination of IoT with fog computing. They reviewed many papers and discussed the comparisons to other surveys such as the IoT challenges, and will be resolved by combining fog and various applications. They report that the IoT has attracted the attention of both academic and commercial organizations. It connects almost everything to everything. They also discussed the traditional centralized cloud and its challenges, such as that they had many issues regarding latency and network failures, but soon recovered their drawbacks with the help of fog computing, which is an extension of the cloud but close to IoT devices, which is processed by fog nodes. This will reduce latency and improve time-sensitive applications [45]. In addition, they also focused on different IoT applications that will be improved by the fog. They find that many of the tasks that can benefit from fog computing can be automated. The flexibility in network structure is better in healthcare as it can alter data and also protect confidentiality and decrease the network load [26]. Moreover, it has a divided flat framework that improves the capacity of storage, computation, and networking resources with cloud computing. They have covered the difficulties of health industry 4.0 by collaborating with big data, cloud computing, EHR, and AI systems. Fog computing improves several of the significant points of cloud computing, which are: privacy, low latency against cloud network failure, and predictability [46]. They solve some of the challenges with their method, such as intelligent health sensors, service composition, cloud-edge service management, sensor-edge service management, distributed health care applications, and security and privacy solutions. They find they achieve a better result in comparison with other architectural styles [47]. In paper [48], the authors outlined the architecture, application, and analytics of a medical system. According to market analysts, the market for medical equipment, software, systems, and services will be worth $300 billion by 2022. Government initiatives are also encouraging this obligation for e-healthcare. This includes the Body Area Sensor Network (BASN), the cloud, an internet-connected smart gateway, and massive data. The data, which are produced from sensors attached to the patient, are accessible to both the doctor and family members anywhere and anytime. The advanced machine learning techniques and algorithms automatically learn from sensor measurements and patients' previous data to facilitate their health information for future purposes and can raise the alarm if required. Their records will be stored by dissimilar sensors, which are body-worn or implanted sensors, and record the different parameters of vital signs in addition to environmental information such as date, time, and temperature. Akrivopoulos et al. [49] have proposed to develop the workings of a current medicinal services framework safely by applying homomorphic encryption and, furthermore, by creating and surveying a calculation of their plan. They also plan to study the homomorphism security instrument to assemble secure human services applications for groups of individuals yet to come.

Healthcare applications over the fog computing have been discussed and deployed [50]. They enlarge the cloud computing model through moving processed data close to the production site; speed up the system's awareness to actions next to its complete awareness; and by removing the data round-trip to the cloud. Now, there is no need to off-load a large amount of data to the network; the most important thing is to improve the security and quality. This method improves the services with low acceptance of mistakes for industrial and health-care applications. This entry improves the issues of fog architecture with end-to-end computing stages. Another focus is on the application of health-care by integrating the sensors into a fog computing platform. They evaluate the ECG device with different operating parameters such as sampling rate and the number of different channels.

Sood et al. [37] basically detect and monitor the Chikungunya Virus (CHV) and are planning a method to find and manage the wearable IoT sensor-based healthcare system. The detection and observation of this contagious disease are greatly needed to control it in real-time. They have studied many published works based on some specifications such as maximum contributions, the domain of application, cloud computing, IoT, fog computing, real-time perspective, prediction model, outburst role index, awareness generation, safety mechanism, and evaluation of contagious diseases. Some of the challenges in this system are to improve the quality of the system, such as latency issues, location alertness, and broadcasting of data. They have proposed a framework for diagnosing CHV which is a mix of 3 layers: the IoT layer, the fog layer, and the cloud layer. The IoT sensor layer's job is to gather information from various well-being sensors, position sensors, sedate sensors, and some more. At that point, the information is sent to the fog layer for continuous preparation and diagnosis of contaminated clients from CHV. Subsequent to recognizing CHV, second layer fog promptly reacts to the caution on the patient's cell phone to take a prudent step on schedule. Simultaneously, this will store in the cloud aggregated clinical data of every client and compute oxygen reserve index for each of them to speak to their chances of spreading and contracting the disease. The main calculation was done by [51] which rethinks the class of client and produces an alarm; the subsequent calculation is to create and refresh the Time and Action (TNA) graph messages. They have built up a framework for expectation and forestalling chikungunya infection utilizing wearable sensor innovation, decision trees, and TNA. The J48 choice tree is utilized here to arrange the clients into various classifications. The main focuses are keeping a health record in relation to time, getting the framework ready on time, and creating a TNA chart to speak to the episode of the chikungunya infection.

The wearable telehealth was designed by some of the researchers. In [17], they have designed and implemented a prototype system that is wearable telehealth and is based on the Intel@ Edison embedded processor. The fog data architecture is useful in this type of speech disorder because it can validate the Echo-wear device. They find some aspects that can be done in the future, such as some speech features including jittery and sensory pleasantness that are the useful quality of speech. Similarly, ref. [52] have proposed a model which is a modest and remote-check IoT-based framework with fog computing and power-effective wearable sensor gadgets. The utilization of intensity is diminished by the gathering of equipment and programming-based methods. Using advanced mobile phone or PC frameworks, specialists can remotely screen a patient's well-being and speak to it in content and graphical structure. The structure of this strategy has a remote health checking framework dependent on IoT and a customized high-force 2.4 GHz radio frequency convention. They executed this framework by partitioning it into two sections; one is node usage and the other is gateway and back-end framework usage. The use of hubs such as ADS1292 is a reasonable, less loud, and simple front-end gadget for getting multi-channel ECG with high information rates of 1000 examples/s. Elmisery et al. [53] have proposed the topological development of IoHT gadgets when assembling the client's information for cloud administration. They have introduced the new methodology of the two-arrangement disguise process, which gives total security control to persistent over the essential estimations. Fast Moving Consumer Product (FMCP) guarantees the authorization of security inclinations by permitting the approach operator to naturally watch the separated inclinations for explicit solicitation, which could not abuse their protection. In addition, FMCP permits control by using Ciphertext-Policy Attribute-Based Encryption (CAABE). The fog nodes aggregate the critical estimations obtained from the concealed IoHT gadgets, type and specifically encode them in a gathering profile, and after that send them to the cloud medicinal services recommended administration.

Author proposed a model dependent on fog and IoT for recognizing and observing Type-2 diabetes persist progressively. The technique for this kind of illness utilizes the Multiple-Criteria Decision-Making (MCDM) methodology. This method is used for sorting out and explaining choices and controlling issues. Here, the two regions presented the new calculation with type-2 neutrosophic numbers. This can be determined to have VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) technique and developing notice. They recommend the WBAN for remote transmission highlights, which is capable of arranging customary framework disadvantages. The principal component of this model is the WBAN, or clinical sensor hub. It is a mixture of different sensor gadgets and little remote modules for gathering information that helps the specialist to distinguish type-2 diabetes in the early stages [54].

Fog engineering made by various gadgets specifically intended for the organization of preventing social insurance applications, utilizing extensive quality control. They used Field Programmable Gate Array (FPGA)-based devices for fog hubs, and their methodology includes a Xilinx Pynq-Z1 development board built with IoT in XC7Z020 FPGA. The utilization of FPGA based frameworks as fog hubs brings numerous advantages, including reconfiguration of the equipment custom-made for the particular application, high execution in information control and sign preparation, and low force, tantamount to other board PCs such as Raspberry PI or Beagle Board. The model has two cases: the first shows how engineering can be used to generate energy and bring issues to light about the quality of air in the workplace; the result is solid and ready to reduce CO_2 levels in the earth without the use of mechanical components. The subsequent framework is to screen for cardiovascular issues, and crisis requires a poor one [12]. Furthermore, ref. [55] proposed a technique combining the expansion of fog computing and IoT-based social insurance. They represent a new trend in imaginative e-health arrangements, with improved dormancy, vitality utilization, portability, and quality of service. They proposed a strategy of high-intensity alert for the situation of the utilization module. They contrasted their work and edge-ward technique with the default distribution strategy, which shows their proficient work, which has improved by 8.27%. The entire vitality was smaller by 2.72% and 1.61% compared with cloud-just methodologies and default models individually. It additionally limits the postponement in a full circle, undermining the default model and cloud-just techniques by 0.53% and 17.73%, respectively. Additionally, the cloud technique improved by 94.65%, which is practically equivalent to the default methodology. Saxena et al. [56] have investigated the fundamental Named Data Networking (NDN) design to build up the NDN-IoT stage for the smart healthcare system. The home server utilizes the NDN correspondence for gathering, handling, and distributing the crucial indications of the patient normally, which is controlled utilizing the Hidden Markov Model (HMM). Cloud servers and different servers can buy in the information through NDN-based distribution utilizing push-based multicast. By using the HMM and grouping, respectively, S and CS recognize the possibility of a crisis early on. Another NDN-based setting, mindful versatile sending (cumulative distribution function), is used for sending healthcare crisis traffic in the most extreme system conditions. They have additionally broadened the Workflow Instinctive Formal Approach (WIFA) model to check the precision of the NhealthIoT work process during a crisis. They are the first to develop this intuitive and insightful ongoing social insurance framework without any preparation using the NDN-IoT.

Researchers have also designed a new model for medical services. In [57], had structured a new design based on fog computing for the application of medical services. Their engineering has four layers. The first layer is the check machine, which is constantly observed by specialists for patients. This layer is associated with layer 3 fog nodes since fog nodes quickly react to the issue in the patient and guide the prudent step immediately. The subsequent layer is the bunch of physiological sensor hubs, which are associated with one another just as they are through the web. They shaped the IoT bunch and sent their information to layer 2 and ceaselessly sent the checked information to the third layer—the fog nodes. The third layer is the nearby access point or temporary storage. This can hold the information for a couple of moments, as it were. This is the significant layer that takes the physiological information constant from the layer 2 sensor hubs. The upside of having the fourth layer is that it helps in moving beyond the data of the patient and helps in the assessment of their or her clinical issues. Similarly, ref. [58] have designed the architecture of fog computing with integrated IoT for healthcare services. They have mainly used the fog server as a virtualized platform because it is closer to the equipment in order to maintain the time complexity as it is lower than the cloud and can evaluate and process the data. It is an edge network and can provide improved features such as location awareness, low latency, etc. Fog computing has more benefits, such as scalability, low bandwidth, etc. The model consists of IoT devices like medical sensors and wearable sensors that monitor the patient's vitals. IoT devices can communicate both directly and indirectly with other technologies such as Wi-Fi and internet data. Tuli et al. [59] have proposed a new system called Health-Fog for gathering deep learning in edge processing gadgets and introducing it for the genuine use of programmed coronary illness examination. It effectively deals with the information of heart patients. They used fog bus to convey and test the proposed model's performance in terms of force utilization, network data transmission, dormancy, jitter, exactness, and execution time. Their strategy for Health-Fog is configurable to different activity modes that give the best quality of service, forecast, and precision in haze calculation situations and for various client prerequisites.

Jia et al. [60] have proposed the technique for fog-driven IoT healthcare services and portrayed and planned the layers of cloud and fog. They try to minimize the latency. They are fundamentally centered on conventions planned explicitly for a fog-driven IoT individual healthcare check system. The convention which they have utilized is for matching bi linear. This convention is for the protection and security of patients. They present the defense model and show the proper security verification, just like a safety examination against basic attacks. They executed the convention and the IoT and fog layer were validated by the server cloud and imparted a typical key to three substances. This technique is officially in the Block Resource Persons (BRP) security model. They exhibited its security in the discretionary prophet model. The exhibition assessment was likewise introduced, which showed its capability to be sent to a certifying world healthcare organization. In paper [61] have proposed a technique for patient healthcare. In this case, he used Raspberry-pi to collect a patient's vitals. The strategy they have utilized is the docker compartment. The Raspberry-pi is used as an entry point for distributing the information collected by the various sensors. The sensors are connected to the clinical gear, and from this, the report is put away on the cloud, and from that point, the information is prepared by the specialists. The docker holder is the client on the server-side and the nearby database is utilized further for handling the information and giving it to the medical clinic for diagnosis. It gathers indispensable data. With the assistance of bluetooth, the information screens are sent to the Raspberry pi and afterward sent to different clients. This gadget detects the information at standard intervals. It has an amazing processor that gathers and handles them simultaneously.

The problem of task offloading in the fog-cloud model was researched by the authors [11][62]. They have used a logistic regression approach to offer a machine learning-based intelligent task offloading model in the fog-cloud collaboration network. First, an offloading-related optimization problem is handled by taking into account the threshold values of the relevant cloud data center parameters. Numerous sorts of applications, including time-sensitive and computation-intensive apps, must accomplish their intended duties in accordance with their computing resource requirements, which must be provisioned proportionally. Second, the suggested approach employs an automated task offloading management system that predicts incoming tasks generated by heterogeneous IoT and mobile devices placed in scattered remote locations.

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