A comprehensive Review on Fog computing and Healthcare

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Abstract- The future of the Internet is the Internet-of-Things (IoT), one of the most important contemporary technologies employed in all areas where everything will be linked to the Internet. One of these is the use of IoT in the healthcare industry, which includes mobile health and remote patient monitoring for ailments like high blood pressure, diabetes, and other chronic diseases. Applications for remote health monitoring must operate in real-time, and any lag brought on by data transfers to the cloud and back is undesirable. Fog computing therefore minimizes the quantity of data that must be sent between the cloud and the sensors, improves the efficiency of the entire system, and enables efficient data collection and processing. Recent years have seen the rise of fog computing as a promising technology that allows for real-time data processing, analysis, and decision-making at the edge of the network, potentially improving healthcare results. This article aims to provide a comprehensive review of the benefits, challenges, current and future applications of fog computing in healthcare.

Keywords: - Fog computing, Internet-of-Things (IoT), Healthcare.

1 Introduction:

Devices connectivity is enabled through the technology of IoT. With other IoT-enabled objects, devices on the internet can exchange data and communicate. Different types of technological equipment, including tracking cameras, automobiles, home devices, and medical sensors, can connect, work together, and share knowledge in an IoT environment. Wearable, implanted, and environmental devices with sensors are connected to one another through a network in the IoT. Sensors that are connected produce a lot of data. The IoT's devices and objects are remotely controlled in order to carry out the intended functionality. The availability of numerous systems and applications due to IoT is enhancing quality of life.

One of the fields that IoT is anticipated to revolutionize is healthcare by increasing its penetration and reducing service costs. [1]. The increasing use of the IoT, sensors, and wearable devices in healthcare has resulted in a significant rise in the quantity of data produced by patients. To help healthcare professionals make wise decisions, this data needs to be processed and analyzed in real-time. However, the traditional cloud computing model is not suitable for processing and analyzing data in real-time due to latency issues. Data calculation takes some time and uses network bandwidth [2].

Cisco introduced a new computing paradigm called fog computing in 2012 to solve the drawbacks of cloud computing [3]. Cloud services are not replaced by the existence of fog computing; rather, it somewhat enhances them [4]. Fog computing has the potential to change how healthcare professionals gather, handle, and analyze patient data. Fog computing allows the collection of patient data from wearables, sensors, and other IoT devices, processing it at the edge of the network, and sending it to healthcare providers for analysis. This can enable real-time monitoring of patients, faster diagnoses, and more effective treatments. Additionally, fog computing can enable healthcare providers to access patient data quickly and make critical decisions in real-time, which can be especially important in emergency situations. The fog computing in healthcare consists of three layers as depicted in figure 1.

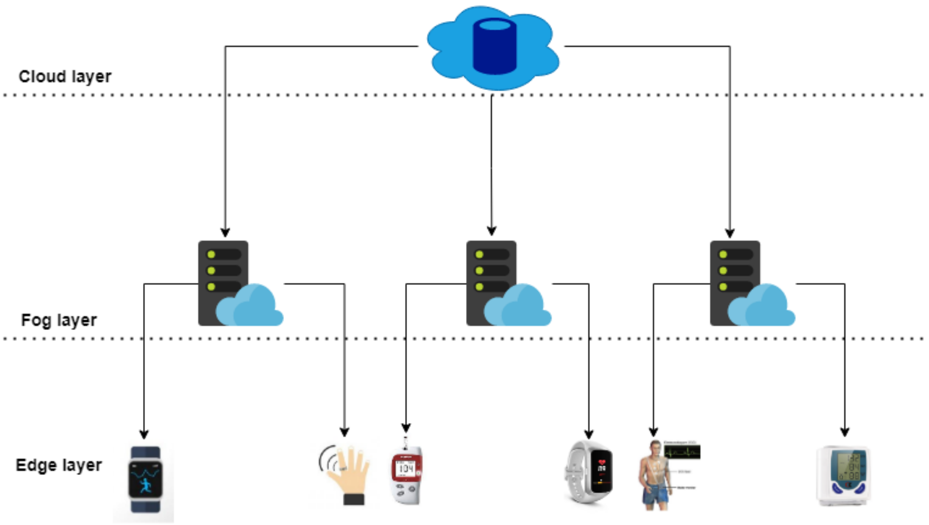

Figure 1. Fog computing architecture in healthcare

Edge layer: The edge layer, which is the first layer in fog computing, is made up of sensors, wearables, and other IoT devices that collect data from patients. The edge layer is liable for capturing and processing data, such as vital signs, blood glucose levels, and medication adherence. This layer frequently operates in real-time and is close to the patient, sending information to the fog layer for additional processing.

Fog layer: The fog layer is the second layer in fog computing and consists of a network of edge devices that work together to process and analyze data in real-time. This layer is responsible for performing more complex data processing tasks, such as identifying patterns and trends in patient data, and transmitting data to the cloud layer for storage and additional analysis.

Cloud layer: The cloud layer is the third and final layer in fog computing and consists of centralized data centers that store and analyze large amounts of patient data. More complex data analysis tasks, such as machine learning and predictive analytics, are performed by the cloud layer, which also provides healthcare providers access to patient data.

The fog layer serves as a link between the edge layer and the cloud layer, allowing access to cloud resources and real-time data processing capabilities. Fog computing can assist healthcare providers in making quicker and more accurate diagnoses, creating more efficient treatment plans, and improving patient outcomes by combining the advantages of edge and cloud computing.

This review article is divided as follows: The related work is discussed in Section 2, and the benefits of fog computing are discussed in Sections 3. The challenges with fog computing in healthcare are covered in Section 4. The current applications of fog computing in healthcare are described in Section 5. In Section 6, the future applications of fog computing in healthcare are described. Finally, Section 7 offers a conclusion.

2 Related work

To highlight the value of utilizing fog computing in healthcare, articles that use it are presented and discussed in this section. Fog computing in healthcare offers a formerly unheard possibility to enhance the effectiveness and quality of medical treatment, thus encouraging patient wellness and making better use of government funding. A health fog system that uses fog computing as a connecting layer between the cloud and the end user was introduced by Ahmad et al. [5]. The three-layer architecture lowers the cost of communication. A fog-assisted remote monitoring system by Kumar and Dhulipala [6] is utilized to monitor a patient in real-time. A computational fog-assisted wearable sensor framework and an algorithm are utilized to minimize the lag time between the IoT and a cloud server. Nandyala and Kim [7] developed an architecture for an IoT-supported healthcare monitoring system using fog computing at the edge for smart homes.

To monitor falls for stroke patients, Cao et al. [8] suggested FAST, a distributed analytics system enabled by fog computing. The authors have created a number of fall-detection algorithms, such as algorithms established on time-series analysis approaches, filtering techniques, and acceleration measurements, to aid in the fall-detection process. They created a fog computing-based real-time fall detection system that splits the fall detection work between edge devices and the cloud. When evaluated against real-world data, the proposed method has good sensitivity and specificity. Response time and energy usage are nearly on par with the most effective methods now in use. For Romanian healthcare regulations, a distributed fog computing technique was proposed [9] for patients with mild dementia and chronic obstructive pulmonary disease (COPD). The monitoring system eWall is utilized to fulfil the protocol's criteria. Fog computing decreases the amount of communication and preserves patient privacy.

A low-power embedded system called a fog computing interface (FIT), a smart gateway for processing clinical speech data, was introduced [10]. The FIT collects, retains, and analyses speech data before sending speech features to a secure cloud storage. For heart attacks and brain strokes, time-sensitive healthcare application data was suggested [11], utilizing fog computing to alert users as soon as possible. To detect and stop the chikungunya virus outbreak, Sood and Mahajan [12] presented an IoT and fog supported healthcare system. To detect the affected person and send user-generated alerts about the outbreak, they used Fuzzy-C means.

The utilization of fog computing to forecast and stop the spread of the zika virus has been suggested by Sareen et al. [13]. The suggested system gathers patients' vital signs and environmental data, then sends the information to a specialized Fog server in order to handle a large number of patients at once. By lowering the latency and transmission costs, a dispersed collection of fog servers can handle the massive data generated by the patient in real time. Based on their symptoms, FKNN is utilized to determine if a user is infected or not, and cloud computing is employed for efficient information processing and sharing. In order to learn about mosquito-dense areas and environmental factors in order to identify breeding sites, mosquito sensors are placed in various areas of risk-prone places. On a Google map, the geographic positioning system (GPS) is utilized to show Zika V-infected individuals, mosquito breeding grounds, and mosquito-dense areas. Re-routing to uninfected users using Google Map is offered, assisting users in protecting themselves from risk-prone locations.

Nguyen Gia et al. [14] suggested a low-cost healthcare monitoring system that enables the remote monitoring, analysis, and notification of ECG. Energy-efficient sensor nodes and an IoT-enabled fog layer make up the components of this health monitoring system. The sensor nodes were able to wirelessly record and send vital signs like body temperature, ECG, and respiration rate in a format that care providers could understand. A cyber-physical system using fog and cloud computing was developed by Sood and Mahajan [15] for the precise classification and detection of various diseases spread by mosquitoes. The outcome of the experiment shows that temporal network analysis is an effective technique for determining the stage of a disease epidemic by taking into account a variety of criteria. A Fog architecture-based paradigm is suggested by Singh et al. [16] that classifies dengue patients into three categories: uninfected, infected, and severely infected. According to their findings, Fog improves the response and execution time of classified applications without affecting the system's accuracy.

An IoT-Fog-based health surveillance system was recommended by Sood and Mahajan [17] to identify and control of hypertension attacks at their initial stage. The artificial neural network is utilized to forecast the total risk of a hypertension attack in isolated elderly populations or people who have functional impairments. A fog-based IoT platform is presented by Abdel-Basset et al. [18] for the real-time monitoring of type-2 diabetic patients. The infected individuals were identified using a hybrid approach based on type-2 neutrosophic with the VIKOR technique and developing alerts. A fog-based Spatial Data Infrastructure (SDI) architecture called GeoFog4Health was proposed by Barik et al. [19] for better analysis of geospatial data on malarial disease by reducing latency with increasing throughput.

An e-health system was suggested by Ben Hassen et al. [20] for tracking elderly health. Mysignals The elderly are frequently sampled for physiological and general health measures utilizing Mysignals HW V2 technology and a mobile app that suggested the proposition of the fog server. For effective Parkinson disease detection utilizing fog computing, an intelligent cyber-physical system was developed [21]. The suggested approach makes use of a classifier that combines fuzzy K-nearest-neighbor (FKNN) and case-based reasoning (CBR). Using speech samples, the FKNN and CBR classifier can be combined to differentiate Parkinson patients from healthy people.

Making use of deep learning (DL) and machine learning (ML) methods A highly effective intelligent fog-cloud computing architecture for timely detection of falls is presented by Sarabia-Jácome et al. [22]. The DL inference method is used by the system to identify falls that happen on the ground. The DL model enhances accuracy and reliability when used to detect falls since it offers great precision with fewer parameters than the ML model. The information collected by observation does not need to be sent to the cloud, therefore the fog strategy assures a quick reaction. Many people deal with the issue of arthritis. Patients with this chronic illness will benefit from regular medical consultation and joint health monitoring. Tanwar et al. [23] suggest using a WBAN-based paradigm to assess real-time healthcare for arthritis patients. The Bayesian network classifier is used in the suggested architecture to reduce false detections. Table 1 shows the overview of related work of fog computing in healthcare.

Table 1. Overview of related work of fog computing in healthcare

Authors	Purpose	Summary
Cao et al. [8]	Detection of fall	To monitor falls for stroke patients using FAST, a distributed analytics system enabled by fog computing.
Fratu et al. [9]	Mild dementia and COPD	For Romanian healthcare regulations, a distributed fog computing technique is utilized for patients with mild dementia and COPD.
Monteiro et al. [10]	Clinical speech data processing	Before transferring speech features to a secure cloud storage, a low-power embedded system called FIT collects, retains, and analyses speech data.
Zohora et al. [11]	Brain strokes and heart attack.	To alert individuals as soon as possible of heart attacks and brain attacks, fog computing was deployed.
Sood and Mahajan [12]	Chikungunya virus	To detect and contain the chikungunya virus outbreak, a healthcare system enabled by IoT and fog was described.
Sareen et al. [13]	Zika virus	Fog computing to forecast and stop the spread of the zika virus was suggested.
Nguyen Gia et al. [14]	Healthcare monitoring system	Energy-efficient sensor nodes and an IoT-enabled fog layer make up the components of this health monitoring system. The sensor nodes were able to wirelessly record and send vital signs.
Sood and Mahajan [15]	Various diseases spread by mosquitoes	Fog and cloud computing was utilized for the precise classification and detection of different ailments spread by mosquitoes.
Singh et al. [16]	Classification of dengue patients	A Fog architecture-based paradigm is utilized to classify dengue patients into three categories.

Sood and Mahajan [17]	Identification and control of hypertension attacks	An IoT-Fog-based health surveillance system was recommended to identify and control hypertension attacks at their initial stage.
Abdel-Basset et al. [18]	Monitoring of type-2 diabetic patients	For the real-time monitoring of patients with type-2 diabetes, an IoT platform based on fog is described.
Barik et al. [19]	Malarial disease	In order to improve the analysis of geographic data on malarial disease by reducing latency with increasing throughput, a fog-based SDI architecture called GeoFog4Health was proposed.
Ben Hassen et al. [20]	Monitoring elderly health	For tracking elderly health, an e-health system was proposed.
Devarajan and Ravi [21]	Detection of Parkinson disease	An intelligent cyber-physical system was developed for Parkinson diseases detection utilizing fog computing.
Sarabia-Jácome et al. [22]	Timely detection of falls	A highly effective intelligent fog-cloud computing architecture for timely detection of falls was presented utilizing DL and ML.
Tanwar et al. [23]	Arthritis detection	WBAN-based paradigm was suggested to assess real-time healthcare for arthritis patients.

3 Fog computing benefits in Healthcare

As shown in figure 2, fog computing has several benefits in the field of healthcare, including the following:

Figure 2. Fog computing benefits in healthcare

Electronic Health Records: Electronic Health Records are electronic health records (or digital versions of paper medical records) that are utilized to store data about a patient's health, medical history, and treatments. Healthcare workers consult EHRs when making decisions about patient care. Fog computing makes it possible for healthcare personnel to securely and effectively share electronic health records, which enhances care coordination and lessens the need for patients to carry hard copies of their records.

Real-Time Data Processing and Analysis: Real-time data collection and analysis are made feasible by fog computing, which is essential in the healthcare sector because immediate actions can have a significant impact on patient outcomes.

Reduced bandwidth usage: By lowering the quantity of data that needs to be sent to the cloud, fog computing can free up bandwidth and reduce costs. This may occur in a number of ways: To limit the quantity of data that has to be transmitted, raw data might be filtered, analyzed, compressed, or pre-processed [8], [24].

Improved patient care: Healthcare professionals may access real-time patient data and analytics using fog computing, enabling more individualized and efficient treatment strategies.

Increased efficiency: Healthcare professionals can speed up diagnosis and treatment by processing data locally. This reduces the time and resources needed to transport data to the cloud for processing.

Reduced Latency: By processing data at the network's edge, fog computing can lessen latency and speed up response times, which is essential for healthcare applications where delays can be fatal. Fog computing, for instance, may make sure that the real-time connection between doctors and patients in telemedicine applications is continuous and unbroken.
Improved Security and Privacy: By keeping important patient information close to its source and lowering the possibility of data breaches, fog computing can enhance security and privacy. This is particularly crucial in the healthcare sector because patient data is very sensitive and governed by tight laws. Data security is generally upheld by fog computing privacy as data travels across and is processed by the fog computing network [25].
Enhanced Patient Experience: Medical professionals can give patients with personalized treatment using fog computing, enabling remote monitoring and telemedicine services as well as raising patient participation.
Cost Savings: By eliminating the need for centralized data centers and infrastructure, which can be expensive to maintain, fog computing can assist healthcare professionals in cutting expenses. Fog computing can also cut down on the expense of in-person consultations and hospital stays by providing remote monitoring and telemedicine services.
Increased reliability: By distributing data processing and storage across a number of hardware components and nodes, fog computing increases the system's resistance to failure and lowers the likelihood of downtime.
Improved scalability: Healthcare organizations may simply extend their infrastructure by adding more edge devices as needed due to fog computing. This is what Vaquero [26] calls "mini-clouds." The demand for healthcare services is rising, and this might help healthcare organizations stay up.

4 Fog computing challenges in healthcare:

Figure 3 shows several challenges associated with fog computing in healthcare, including the following:

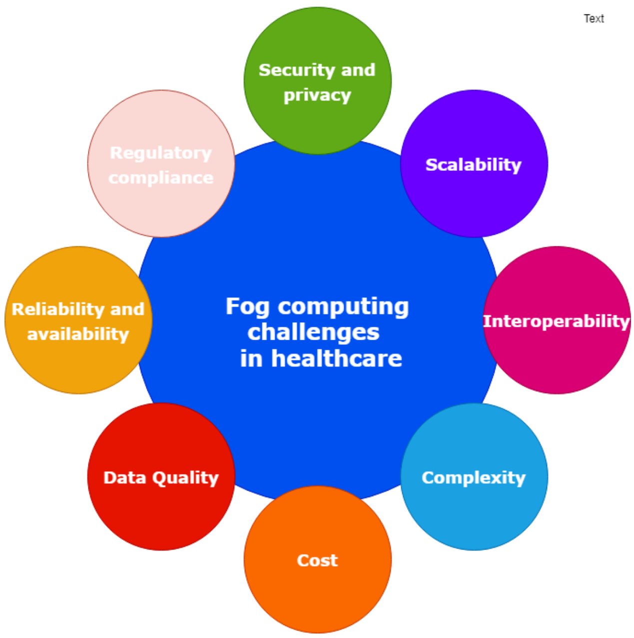

Figure 3. Fog computing challenges in healthcare

Security and Privacy: Fog computing includes processing and storing data outside of conventional data centers, raising the possibility of data breaches and cyberattacks. To protect patient data and adhere to regulatory standards, it is crucial to deploy proper security measures.
Scalability: Fog computing resources are constrained by their closeness to the network's edge. Fog computing may not be appropriate for handling and analyzing massive amounts of data as a result.

Interoperability: Ensuring interoperability across various systems and devices is one of the difficulties of fog computing in healthcare. It can be challenging to make sure that data is correctly captured, saved, and communicated when so many different systems and devices are involved.
Complexity: Fog computing infrastructure implementation can be challenging and requires specialized knowledge and abilities. Healthcare organizations must spend money on the infrastructure and resources needed to set up and run a fog computing system.
Cost: Fog computing can decrease the amount of data transmitted over the network and lessen bandwidth needs, but it also necessitates more equipment and infrastructure at the network's edge. Healthcare organizations must evaluate the advantages as well as costs of putting in place a fog computer system.
Data Quality: A challenge of distributed processing and storage is maintaining the quality of data. To maintain data's accuracy and integrity, healthcare organizations must make sure information is appropriately collected, evaluated, and managed.
Reliability and availability: In a fog computing system, edge devices are frequently less dependable than conventional servers. Healthcare organizations must make sure that their infrastructure for fog computing is highly available and ready to withstand demand spikes.
Regulatory compliance: Healthcare organizations are subject to a number of laws pertaining to data security, privacy, and accessibility. It can be difficult to implement a fog computer system that complies with these legal standards.

5 Current applications of fog computing in healthcare:

As seen in figure 4, fog computing is currently utilized in a number of healthcare applications, including:

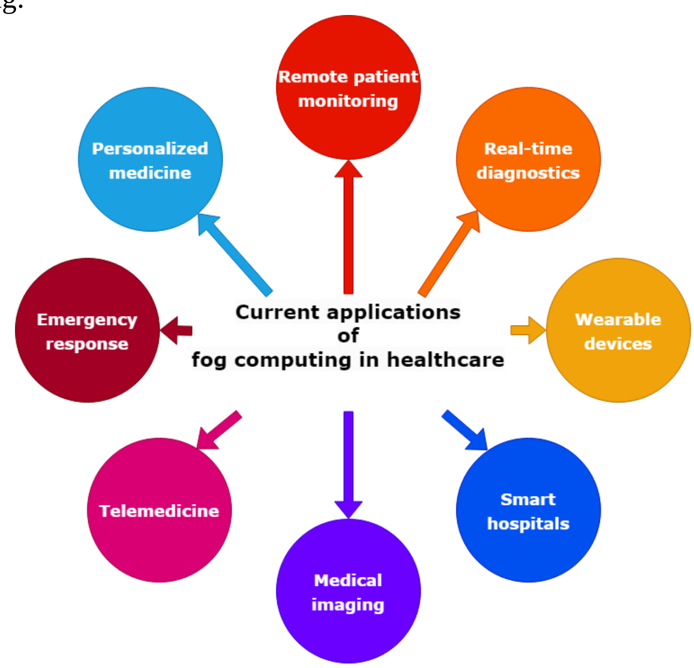

Figure 4. Current applications of fog computing in healthcare

Remote patient monitoring: It is a medical procedure in which patients' health is remotely monitored and pertinent medical data is collected without the need for in-person visits to medical facilities.

Real-time monitoring of patient health data, such as vital signs, activity levels, and medication adherence, is made possible using fog computing. Healthcare professionals can spot possible health issues and take action before they worsen by processing and analyzing this data at the edge of the network.

Real-time diagnostics: The technique of conducting diagnostic tests or assessments in real-time while giving prompt feedback is referred to as real-time diagnostics. At the point of care, fog computing can provide real-time processing of medical imaging data from CT scans and MRIs. Local processing of this data enables healthcare professionals to diagnose patients more quickly and precisely while also promptly identifying potential health risks.
Wearable devices: Wearables like fitness trackers and smartwatches that monitor patient health data can be supported by fog computing. Wearable technology can give users and healthcare professionals more quick and accurate feedback by processing this data locally.
Smart hospitals: Smart hospitals, often referred to as digital hospitals or intelligent hospitals, are healthcare facilities that make use of modern technologies and digital solutions to increase operational effectiveness, optimize patient care, and enhance the patient experience.

By processing and analyzing data from several devices and systems, including electronic health records (EHRs), patient monitoring systems, and asset tracking systems, fog computing can be utilized to construct smart hospital environments. This can assist healthcare professionals in optimizing workflows and enhancing patient outcomes.
Medical imaging: It is the practice of using a variety of tools and methods to produce images of the inside organs and bodily processes. These images are crucial for making diagnoses, organizing treatments, and keeping track of how well medical interventions are working. Medical imaging is essential to healthcare because it gives healthcare providers insightful data.

By enabling the real-time processing and analysis of massive amounts of imaging data, fog computing can improve medical imaging. This can make it easier for medical professionals to recognize and effectively diagnose health problems.
Telemedicine: The delivery of medical services using a range of telecommunications devices is known as telemedicine [27]. By processing and transmitting data in real-time, fog computing can enable real-time video consultations between patients and healthcare professionals. This could make it possible for those who live in rural or underserved locations to get medical care without having to go to a physical clinic.
Emergency response: Fog computing can let healthcare professionals swiftly access patient data in an emergency and make crucial choices in real time. For instance, hospitals can get vital signs and other data in real-time from ambulances connected with fog computing technology, allowing healthcare professionals to get ready for the patient's arrival.
Personalized medicine: Personalized medicine is a method of providing healthcare that customizes medical decisions and treatments to each patient based on their particular characteristics, such as their genetic make-up, way of life, environment, and personal health information. By taking into account the unique requirements and features of each patient, it seeks to provide healthcare interventions that are more focused and efficient.

Large-scale genetic and other health data can be processed and analyzed in real-time by healthcare professionals using fog computing, which can be used to create customized treatment programs for individuals based on their particular requirements and medical background.

6 Future applications of fog computing in healthcare:

A fast developing technology, fog computing has a number of fascinating future applications in the healthcare sector. As seen in figure 5, some of these include:

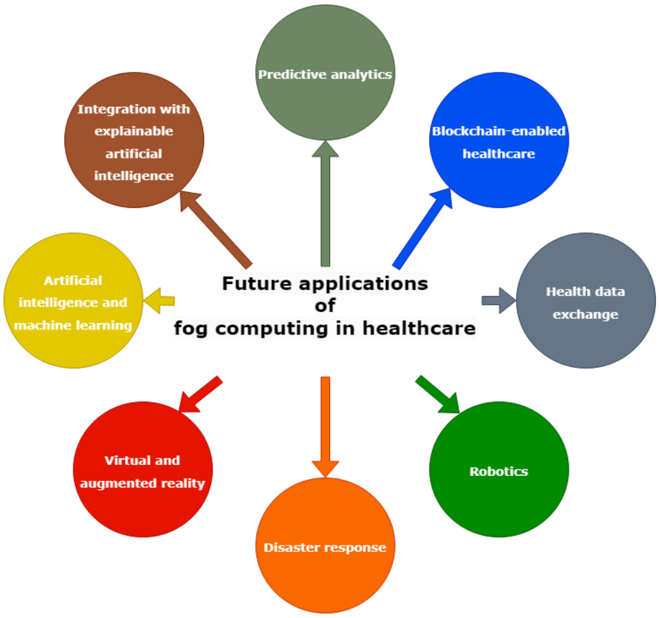

Figure 5. Future applications of fog computing in healthcare

Predictive analytics: Making predictions and forecasts about upcoming events or outcomes using previous data is known as predictive analytics. Healthcare professionals may gather and interpret massive volumes of data from numerous sources, like wearables, sensors, and electronic health records, with the utilization of fog computing. Healthcare professionals can take proactive steps to avoid or manage the issue by using this data to identify patterns and predict health issues before they arise.
Blockchain-enabled healthcare: Blockchain is a distributed and decentralized digital ledger technology that enables numerous parties to keep a transparent and safe shared record of transactions or data. Blockchain technology can be incorporated into the healthcare sector with the assistance of fog computing, allowing for the safe and decentralized exchange and storing of patient data. This can enhance data security and privacy and give individuals authority over their own health information.
Health data exchange: Healthcare providers, patients, and other stakeholders can communicate health data in a secure and effective manner thanks to fog computing. Fog computing can lower the danger of data breaches and increase the effectiveness of data transmission by processing and storing data locally.
Robotics: The study of robotics, a field of science and engineering, is concerned with the creation, advancement, and use of robots. Robots are programmable devices that can complete tasks on their own or with human assistance. They can be employed in a variety of sectors and areas and are created to interact with the real environment.

The use of robots in healthcare facilities like hospitals and clinics is made possible using fog computing. Robots can make decisions and complete jobs quickly and efficiently by processing and analyzing data locally, which enhances patient outcomes and efficiency.
Disaster response: In emergency scenarios, such as those brought on by natural catastrophes and pandemics, fog computing can enable real-time data collecting and analysis. Fog computing allows healthcare professionals to react to emergencies swiftly and efficiently by processing data locally.
Virtual and augmented reality: Virtual reality uses a system that completely simulates the virtual world in place of reality [28]. Applications for virtual reality that aid in patient rehabilitation and pain management can be created thanks to fog computing. Virtual reality games, for instance, can be created to assist patients with chronic pain by distracting them from their suffering and lowering their need on painkillers.

A system that uses augmented reality improves the real environment by adding to it [28]. Real-time visualization of medical data, like CT scans and X-rays, using augmented reality is made possible by fog computing for healthcare professionals.

Artificial intelligence and machine learning: Artificial intelligence and machine learning algorithms can be deployed using fog computing at the network's edge, allowing for real-time analysis and decision-making. This could help medical professionals make more precise diagnosis and individualized approaches to treatment.

Integration with explainable artificial intelligence: Healthcare has a lot to gain from the combination of explainable artificial intelligence (XAI) and fog computing. Combining these two technologies enables real-time data processing and analysis, as well as transparent and clear explanations for AI-generated suggestions, improving patient outcomes and facilitating better decision-making for healthcare providers.

7 Conclusion

Fog computing enables for real-time data processing, analysis, and decision-making at the network's edge, which could significantly enhance patient outcomes. Fog computing in healthcare is being implemented, however there are obstacles. The protection of patient data's privacy and security is a major concern. Sensitive patient data may be kept on devices outside of the safe healthcare network because fog computing includes processing data at the network's edge. To prevent unauthorized access to or data breaches, this necessitates the use of strong security measures. Despite these challenges, fog computing has several benefits for the healthcare sector. Fog computing is probably going to become more crucial in the healthcare sector as technology progresses. Fog computing's capabilities and prospective uses in the field of healthcare may be further increased by combining it with advanced technologies like explainable artificial intelligence, blockchain, artificial intelligence, and machine learning.

References

[1] D. Miorandi, S. Sicari, F. De Pellegrini, and I. Chlamtac, “Internet of things: Vision, applications and research challenges,” *Ad Hoc Networks*, vol. 10, no. 7, pp. 1497–1516, 2012, doi: 10.1016/j.adhoc.2012.02.016.

[2] Y. Shi, G. Ding, H. Wang, H. Eduardo Roman, and S. Lu, “The fog computing service for healthcare,” in *2nd International Symposium on Future Information and Communication Technologies for Ubiquitous HealthCare, Ubi-HealthTech 2015*, Beijing, China, 2015, pp. 70–74. doi: 10.1109/Ubi-HealthTech.2015.7203325.

[3] A. M. Elmisery, S. Rho, and M. Aborizka, “A new computing environment for collective privacy protection from constrained healthcare devices to IoT cloud services,” *Cluster Computing*, vol. 22, no. s1, pp. 1611–1638, 2019, doi: 10.1007/s10586-017-1298-1.

[4] P. Y. Zhang, M. C. Zhou, and G. Fortino, “Security and trust issues in Fog computing: A survey,” *Future Generation Computer Systems*, vol. 88, pp. 16–27, 2018, doi: 10.1016/j.future.2018.05.008.

[5] M. Ahmad, M. B. Amin, S. Hussain, B. H. Kang, T. Cheong, and S. Lee, “Health Fog: a novel framework for health and wellness applications,” *Journal of Supercomputing*, vol. 72, no. 10, pp. 3677–3695, 2016, doi: 10.1007/s11227-016-1634-x.

[6] M. G. Sharavana Kumar and V. R. Sarma Dhulipala, “Fuzzy allocation model for health care data management on IoT assisted wearable sensor platform,” *Measurement: Journal of the International Measurement Confederation*, vol. 166, pp. 1–9, 2020, doi: 10.1016/j.measurement.2020.108249.

[7] C. S. Nandyala and H. K. Kim, “From cloud to fog and IoT-based real-time U-healthcare monitoring for smart homes and hospitals,” *International Journal of Smart Home*, vol. 10, no. 2, pp. 187–196, 2016, doi: 10.14257/ijsh.2016.10.2.18.

[8] Y. Cao, S. Chen, P. Hou, and D. Brown, “FAST: A fog computing assisted distributed analytics system to monitor fall for stroke mitigation,” in *Proceedings of the 2015 IEEE International Conference on Networking, Architecture and Storage, NAS 2015*, 2015, pp. 2–11. doi:

10.1109/NAS.2015.7255196.

[9] O. Fratu, C. Pena, R. Craciunescu, and S. Halunga, "Fog computing system for monitoring Mild Dementia and COPD patients - Romanian case study," in *12th International Conference on Telecommunications in Modern Satellite, Cable and Broadcasting Services (TELSIKS)*, Nis, Serbia, 2015, pp. 123–128. doi: 10.1109/TELSKS.2015.7357752.

[10] A. Monteiro, H. Dubey, L. Mahler, Q. Yang, and K. Mankodiya, "Fit: A Fog Computing Device for Speech Tele-Treatments," in *International Conference on Smart Computing, SMARTCOMP 2016*, St. Louis, MO, USA, 2016, pp. 10–12. doi: 10.1109/SMARTCOMP.2016.7501692.

[11] F. T. Zohora, M. R. R. Khan, M. F. R. Bhuiyan, and A. K. Das, "Enhancing the capabilities of IoT based fog and cloud infrastructures for time sensitive events," in *International Conference on Electrical Engineering and Computer Science (ICECOS)*, Palembang, Indonesia, 2017, pp. 224–230. doi: 10.1109/ICECOS.2017.8167139.

[12] S. K. Sood and I. Mahajan, "Wearable IoT sensor based healthcare system for identifying and controlling chikungunya virus," *Computers in Industry*, vol. 91, pp. 33–44, 2017, doi: 10.1016/j.compind.2017.05.006.

[13] S. Sareen, S. K. Gupta, and S. K. Sood, "An intelligent and secure system for predicting and preventing Zika virus outbreak using Fog computing," *Enterprise Information Systems*, vol. 11, no. 9, pp. 1436–1456, 2017, doi: 10.1080/17517575.2016.1277558.

[14] T. Nguyen Gia *et al.*, "Low-cost fog-assisted health-care IoT system with energy-efficient sensor nodes," in *13th International Wireless Communications and Mobile Computing Conference (IWCMC)*, Valencia, Spain, 2017, pp. 1765–1770. doi: 10.1109/IWCMC.2017.7986551.

[15] S. K. Sood and I. Mahajan, "Fog-cloud based cyber-physical system for distinguishing, detecting and preventing mosquito borne diseases," *Future Generation Computer Systems*, vol. 88, pp. 764–775, 2018, doi: 10.1016/j.future.2018.01.008.

[16] S. Singh, A. Bansal, R. Sandhu, and J. Sidhu, "Fog computing and IoT based healthcare support service for dengue fever," *International Journal of Pervasive Computing and Communications*, vol. 14, no. 2, pp. 197–207, 2018, doi: 10.1108/IJPCC-D-18-00012.

[17] S. K. Sood and I. Mahajan, "IoT-fog-based healthcare framework to identify and control hypertension attack," *IEEE Internet of Things Journal*, vol. 6, no. 2, pp. 1920–1927, 2019, doi: 10.1109/JIOT.2018.2871630.

[18] M. Abdel-Basset, G. Manogaran, A. Gamal, and V. Chang, "A Novel Intelligent Medical Decision Support Model Based on Soft Computing and IoT," *IEEE Internet of Things Journal*, vol. 7, no. 5, pp. 4160–4170, 2020, doi: 10.1109/JIOT.2019.2931647.

[19] R. K. Barik, H. Dubey, K. Mankodiya, S. A. Sasane, and C. Misra, "GeoFog4Health: a fog-based SDI framework for geospatial health big data analysis," *Journal of Ambient Intelligence and Humanized Computing*, vol. 10, no. 2, pp. 551–567, 2019, doi: 10.1007/s12652-018-0702-x.

[20] H. Ben Hassen, W. Dghais, and B. Hamdi, "An E-health system for monitoring elderly health based on Internet of Things and Fog computing," *Health Information Science and Systems*, vol. 7, no. 1, pp. 1–9, 2019, doi: 10.1007/s13755-019-0087-z.

[21] M. Devarajan and L. Ravi, "Intelligent cyber-physical system for an efficient detection of Parkinson disease using fog computing," *Multimedia Tools and Applications*, vol. 78, no. 23, pp. 32695–32719, 2019, doi: 10.1007/s11042-018-6898-0.

[22] D. Sarabia-Jácome, R. Usach, C. E. Palau, and M. Esteve, "Highly-efficient fog-based deep learning AAL fall detection system," *Internet of Things*, vol. 11, pp. 1–19, 2020, doi: 10.1016/j.iot.2020.100185.

[23] S. Tanwar *et al.*, "Human Arthritis Analysis in Fog Computing Environment Using Bayesian Network Classifier and Thread Protocol," *IEEE Consumer Electronics Magazine*, vol. 9, no. 1, pp. 88–94, 2020, doi: 10.1109/MCE.2019.2941456.

[24] K. XU, Y. Li, and F. Ren, "AN ENERGY-EFFICIENT COMPRESSIVE SENSING FRAMEWORK INCORPORATING ONLINE DICTIONARY LEARNING FOR LONG-TERM WIRELESS HEALTH MONITORING Kai XU , Yixing Li , Fengbo Ren Parallel Systems and Computing Laboratory (PSCLab) Arizona State University," in *International Conference on Acoustics, Speech and Signal Processing (ICASSP)*, Shanghai, China, 2016, pp. 804–808.

[25] Y. Liu, J. Zhang, and J. Zhan, "Privacy protection for fog computing and the internet of things data based on blockchain," *Cluster Computing*, vol. 24, no. 2, pp. 1331–1345, 2021, doi: 10.1007/s10586-020-03190-3.

[26] L. M. Vaquero and L. Rodero-Merino, "Finding your Way in the Fog," *ACM SIGCOMM Computer Communication Review*, vol. 44, no. 5, pp. 27–32, 2014, doi: 10.1145/2677046.2677052.

[27] P. Buonanno, A. Marra, C. Iacovazzo, M. Franco, and S. De Simone, “Telemedicine in Cancer Pain Management: A Systematic Review and Meta-Analysis of Randomized Controlled Trials,” *Pain Medicine*, vol. 24, no. 3, pp. 226–233, 2023, [Online]. Available: https://doi.org/10.1093/pm/pnac128

[28] B. G. Çöl, M. İmre, and S. Yıkmış, “Virtual reality and augmented reality technologies in gastronomy : A review,” eFood, vol. 4, no. 3, pp. 1–16, 2023, doi: 10.1002/efd2.84.