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Review Article

REVIEW OF A FOG COMPUTING IN THE HEALTHCARE SYSTEMS

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ABSTRACT

A decentralized computing architecture known as Fog Computing (FC) distributes data, computational, storage, and applications between the data source and the cloud. As a result, Fog requires less bandwidth and involves less back-and-forth communication between sensors and the cloud, which negatively affects how well the Internet of Things functions. Numerous academics are working to speed up data processing between the cloud and end devices, resource management, and monitoring services expressly for the healthcare business. In this study, we comprehensively analyze the literature along several axes, including algorithm and methods assessment, load balancer improvement, resource management, power consumption, and latency in fog architectures, particularly in the context of health systems.

Keywords: Fog Computing (FC); Cloud Computing(CC); Internet of things (IoT); Load Balancer; Resources management; Healthcare.

INTRODUCTION

The term FC (known as fogging), introduced by CISCO, is an extension of CC used to ease wireless data transfer to distributed devices in the IoT network paradigm. FC moves computing resources and application services closer to the data generation edge. It reduces the amount of data transferred to the cloud for processing and analysis largely and decreases cloud traffic, and load balancing between resources, which improves the quality of service (QoS) and enhanced security. FC produces a virtual platform that provides networking, computing, and storage capabilities close to the source of data in the middle between cloud data centers and ends users [1], It offers a potential method for handling the enormous volume of data generated and ingested by apps, computers, and their users [2].

The researchers anticipate a substantial increase in the number of connected devices as the Internet of Things (IoT) permeates both our surroundings and our daily lives and anticipate will connect billions of gadgets and people to deliver many promising benefits. There is now an automated system in every field. Some applications that can benefit from IoT include smart cities, traffic congestion, waste management, structural health, security, emergency services, logistics, retail, industrial control, and health care. The IoT has the potential to enable several medical applications, including remote health monitoring, fitness programs, chronic illnesses, and senior care. Medical care and health care are two of the most appealing IoT application sectors. there will be far less latency when sending information and responding to applications[3].

FC specialists and professionals must manage the system complexity brought on by the many involved products and their interconnections, multiple technologies, and many applications. To handle priority problems in essential situations in hospitals and balance data between nodes, they frequently employ models to assess systems with a variety of data-balancing techniques in FC in health systems[2],[4]. The researchers present a wide range of frameworks and studies for managing and understanding the traffic data in the fog network, along with a wide range of tools for providing latency and balancing solutions. In [5]resource management is their main concern, and they switch from centralized cloud computing to distributed edge computing. They examine, prioritize, resource management, and efficiency [6],[7], Other pertinent studies look at different aspects of balancing in a foggy environment, task scheduling [8], and cost [9], analyze challenges in privacy and security in the three computing platforms (CC, FC, and IoT), particularly about the healthcare system.[10],[11],[12],[13] The authors according to editorial and techniques, the FC is used, 90 percent of data movement from the local node to the cloud and vice versa is compact, with a 20 percent latency[14],other relevant surveys energy consumption, resource utilization, and latency, the following factors were considered: load balancing, performance, resource availability, and time reduction[15], [16] increase planning speed, stability, load balancing, and makespan (FA)[17].

Numerous system model architectures, a common paradigm, cloud computing issues, some concerns with cloud-based services as a result of stringent connectivity requirements, sporadic delays, protection and security issues, all of which are solved by FC and algorithms methods such as Advanced Encryption Standard(AES),First Come First Served (FCFS), Convolutional Neural Network(CNN), and DeepNeural Network(DNN). The study of these different models will help in future works and development.

Fog Computing Architecture and Infrastructure:

Fog architecture: there is no standard Architecture for FC, the researchers work in different Architectures but the concept of FC is based on the idea of bringing network resources near the devices generating data[18].

Figure 1 explains three tires scenario in FC (cloud, fog, and end devices) [19], [20]:

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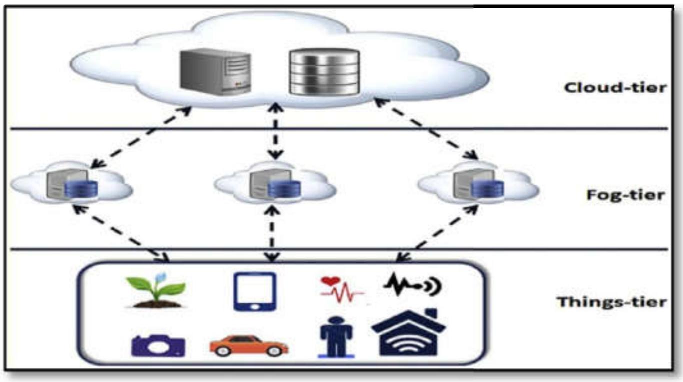

Figure 1, Fog, Cloud Computing and Things (IoT devices in multi-application) [23]

- **Things-tier (IoT Devices):** The edge layer represents physical components like sensors, actuators or things, mobile, smartphones, smart vehicles, PCs, and laptops for sensing the internal state of the object or the external environment and performing some action based on the collected data and sending it to cloud layer through fog layer [15], [20].
- **Fog tier:** Middle layer between cloud computing and end devices. It is combined with cloud computing to form a common network structure model for processing data some devices can be considered as fog and IoT smartphones, the fog layer contains processing devices, gateways, routers, and any network devices [21], [22], [20].

FC can reduce the time for processing and distributing the services to the fog nodes, FC produces a virtual platform that provides networking, computing, and storage capabilities close to the source of data in the middle between cloud data centers and end users[1].

- **Cloud tier:** Cloud providers offer computing services to the clients and charge them based on the usage of these services, some programs cannot work well in the cloud due to a fault in the system. Low bandwidth is a problem since data cannot be transmitted to the cloud at the same rate as it is generated. Delays cannot permitcritical cases, such as heart attacks, where significant amounts of data must be transmitted back to edge nodes following cloud processing. As a result, the paradigm of FC was developed to fix this challenge[1],[20].

FOG INFRASTRUCTURE TO PROCESS DATA

Fog computing is a decentralized computing infrastructure in which computing resources such as data, computers, storage, and applications are located between the data source and the cloud. This term refers to a new breed of applications and services related to data management and analysis.

Process in fog computing:

- Signals are routed from IoT devices to an automation controller, which then executes a control system program to automate those devices.
- A protocol gateway is used by a control system application to wire data.
- Data is translated into a protocol, such as HTTP or HTTPS, so that internet-based applications may readily understand it.
- The data was collected by a fog node for further processing.
- It filters the information and stores it for later use.

FOG CHARACTERISTICS AND CHALLENGES

In a variety of domains, fog computing is emerging as a modern and competitive environment: Only a few of the sectors where applications have been developed and supported by a range of fog computing technologies are smart cities, intelligent transportation systems, smart healthcare, public safety, smart grid, industry 4.0, smart home, and smart building [2].

Fog characteristics

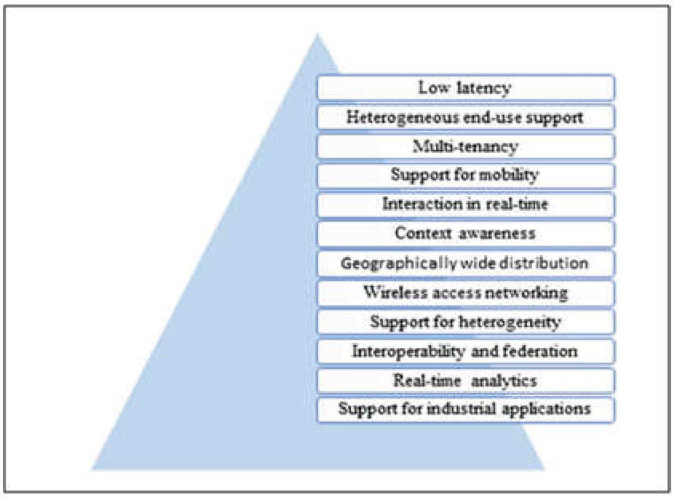

Figure (2) Characteristics [25]

- The heterogeneous nature of fog servers, with each fog server having unique computing capabilities and connectivity.
- The purpose of fog computing is to process data locally for speedier responsiveness.
- The fog system's lower scale allows for precise techniques that would be inappropriate in a large-scale cloud environment.
- Client mobility is another issue that should be addressed [24].

Fogchallenges:

The need for fog computing is crucial. However, its implementation comes with various challenges including:

- Data privacy and security.
- Control and management.
- Positioning the fog servers.
- Programming platform.
- Energy management [26].
- Fault tolerance [5].
- Low latency [27].
- Energy Consumption.
- Storage data.
- Computational offloading.
- Performance evaluated with infrastructure locally in edge [28].

FOG COMPUTING WITH BALANCER

Here are some of the benefits of combining load balancing and fog computing, as mentioned further below:

- **High availability**: Load balancing makes fog resources extremely available. When one resource does not respond, others become accessible for processing. The load balancer monitors under and overloaded resources to ensure resource availability in latency-sensitive applications [29].

- Flexibility: A load balancer distributes the workload among all resources so that if one fails, others can process the data and reply to users [30].
- **Reduced energy consumption:** All resources, whether executing a task or in idle mode, consume energy. With the help of load balancing, all resources execute tasks in approximately an equal proportion. So, by avoiding overloading and under-loading of resources energy consumption in hardware nodes is reduced [31].
- **Low cost:** Fog load balancers are not expensive because the cost determines by resources. Load balancing in fog computing can reduce hardware costs by allowing several resources to be used only when requested by the user [10].
- **Resource utilization:** Using load balancing, all resources in a fog computing environment can be completely utilized. Because load balancers distribute workload in the same proportion across all resources, they prevent under- and over-utilization of resources [32].

HEALTHCARE CONCEPTION AND FC ARCHITECTURE IN HEALTH FILES:

Most nations strive to provide their populations with high-quality healthcare services and have similar aims for improving their health. Due to the advancement of IoT technologies, the medical field has begun to use them wisely to better serve the health society because they enable the processing and analysis of real-time sensory data from patients while also collecting IoT data for centralized processing, computation, and storage [33].

Fog Computing architecture in related health files:

The combination of fog computing with healthcare based on IoT (Figures 1,3 and 4) demonstrates a unique trend in innovative e-health solutions. The combination allows healthcare services with lower energy use, higher Quality of Service (QoS), and shorter latency. Several advantages can be achieved by using FC in healthcare, energy usage, load data, traffic reduction [34], monitoring, and managing resources.

Scrugli *et al.,* and others, suggested a hardware/software/firmware architecture template for a remote-controlled Internet of Medical Things (IoMT) wearable device that uses deep learning techniques to detect cardiac abnormalities. They have created a component called Adaptive runtime Manager (ADAM) to address power efficiency which takes care of dynamically reconfiguring the device's hardware and software during execution to better adapt it to the workload and required operating mode [35]. Some researchers used the Cooja simulator to improve the performance of low-power routing protocols [36], the experiments used a sparrow search algorithm (SSA) to assign tasks based on length and fitness value, priority, and difficulty. The concept of employing IoT in healthcare, known as real-time remote monitoring, is a transition from the conventional case (coming to the hospital and taking the patient's tests) to the current situation (sending the tests immediately to the doctor or nurse) [29]. They provide how FC acts as a bridge between the end-user and the cloud, removing needless touch from node-to-cloud data production to assure data safety and security [37]. Asghar *et al.,* proposeda fog-based health monitoring system architecture to minimize latency and network usage [38], they Implemented architecture using iFogSim and the basic simulation properties of the CloudSim layer to manage the events of FC [39], [26] used a multi-layer architecture that includes IoT devices, fog, and cloud computing [5]. with a healthcare monitoring model that uses the Internet of Things framework to focus on various healthcare concerns [40]. Create a Multi-Agent FC model for healthcare essential task management to improve scheduling by assigning tasks based on their importance, network load, and resource availability. The authors developed a strategy called Load Balancing Mutation Swarm Optimization (LBMPSO) to schedule the task [41], Low-latency hybrid cloud-fog network architecture for medical big data that solves the optimization challenge in medical big data utilizing Bat algorithm(BA) [27], Task scheduling in fog-based IoT applications is the proposed result of achieving an efficient policy in terms of time and cost saving under resource and deadline restrictions [32], [42], identifying the oral cancer region structure in an IoT-based smart healthcare system that uses a modified vesselness measurement and a Deep Convolutional Neural Network (DCNN) [42], they developing, Artificial intelligence (AI) and machine learning techniques for healthcare system [43]. In[44]authors Develop a system to analyze pulse rates and predicted heart disease using AES (Advance Encryption Standard) algorithm. Authors consolidated FC resources handled by foglets for critical requests sent to the cloud for processing itcontains two servers, namely, the cloud server and fog server, Patients will send the request to the fog server via IoT. The IoT is the network of objects and the connectivity among these objects which allows them to connect and exchange data. Servers were placed locally in each city to handle the nearby requests to utilize the resources efficiently along with load balancing among all the servers, which leads to reduced latency and traffic overhead with the improved quality of service [1].

They explained the healthcare strategy enforcement, appropriate resource allocation changes, and improved communication system at different levels of the system components as the main pathways to accomplish the goals [46].

Table [1] illustrates and defines the pros and cons of the studies mention in above section and give short comparison between those studies.

References	Algorithm or method	Experimental parameters	Approach used	pros	cons
[8]	dynamic scheduling	Effective and utilize the schedule gaps	minimize the makespan	Efficient in scheduling in real-time with many Apps	Latency, load balancing
[9]	TCaS	Execution time	Optimal tradeoff between the execution time and operating costs.	Execution time, simultaneously, satisfies user's requirement	Security, efficiently in loading data
[15]	TCVC, MAX-MIN	Efficiency ,priority	Task importance	Performance, resource availability, load balance between VMs	High ability, high capability
[17]	intelligent meta-heuristic algorithm , firefly algorithm	Load balancing in CC	improve scheduling and load balancing in cloud computing	Performance, efficiency	Load balancing not defined
[20]	iFogSim	Reduction time	remote pain monitoring system in FC	reduction in both latency and network consumption	single fog device for a hospital and limits in balancing data
[23]	GA	Optimization in energy	Optimizing energy consumption	Energy consumption	Limit task, latency
[27]	Bat	Optimization	Medical fields	Reduce latency, load balancing, efficiency	Security
[29]	SSA	Performance	Remote patient monitoring	Reduce the latency, maximize throughput	Loading in FC not supported
[31]	Novel framework	latency-sensitive	Latency in health	Performance, accuracy,	Cost, All diseases not considered
[32]	DDQL, DNN	Time and cost	Task scheduling	Load balancing, Reducing service delay	Hardware need, load balancing and failure
[36]	Fuzzy system with RF, NN	Large data, reduce Time (communication, computation and network)	Minimize time in Healthcare	Performance, reduce latency	Reliability and security
[39]	ADAM	Execution time	Cognitive data analysis by wearable IoMT	Energy efficiency at runtime	Implementation cost not considered, Security
[42]	FNPA, LAB	Latency, network usage compared	Healthcare	Latency, load balancing	LBS in CC only, vary of data
[44]	Multi-Agents System(MAFC)	Blood pressure	Critical Tasks Management	Capability,	Implement in one data set, Limit task, distributed services
[47]	HTM algorithm	Detecting anomalies in physiological parameters in real time	Real time applications with big data	performance , task using	Latency, security not described
[48]	Standard ISO/IEC 27005:2018	Managing and anticipated in IoT	Monitoring for technical deficiencies	Security, mange the risk	Load balancing, latency not consider
[49]	Algorithm (ML classifier, MAC scheduler	Move the process to the end users	Reduce energy and latency	Reduce energy consumption and latency	Security loading data

The challenge in the health sector:

Storage: Considering FC architecture provides processing and storage resources near the network's edge, designing e-healthcare apps utilizing the FC paradigm is appealing to meet the low latency requirements of such applications [47].

Big data in the health system: The big data revolution is gradually taking hold, and there is no choice but to collect and organize intellectual and intelligent outcomes for better decision-making (e.g., healthcare monitoring applications and industrial-controlled IoT) [19].

Load balancing: To distribute the load equally in the network balancer is required. It effectively divides the client requests or network burden among several servers. Figure 4 illustrates fog architecture using a balancer

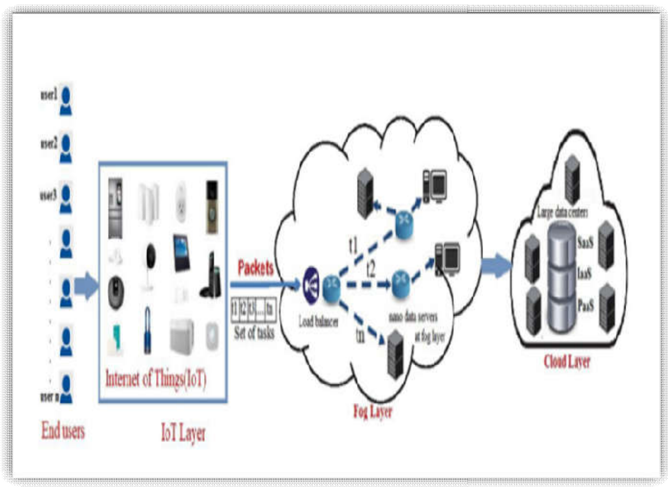

Figure 4, Load balancer in fog environment, [48]

Latency and Resource Optimization: A mathematical approach (section 5.2.5) is needed to reduce transmission data in FC, for time-sensitive applications like distributing load between nodes and health-critical situations. Multiple parameters affect communication delay (medium transmission capacity; a connection between resources and interface). The fog node itself controls the latency of computation.[49],[6].

Equations for mathematical model approach from[49]

The three-dimensional characteristic vector of the i-th data packet was established by combining the packet size, complexity, and latency limit of the data packet. indicated the CPU frequency in Hz and the current storage size of the j-th fog server. If the i-th data packet is assigned to the j-th fog server, the latency of the i-th data packet at the time of allocation to the fog servers is expressed by

$$l_{ij} = \frac{s_i^d c_i^d + b_j^s}{f_j^{CPU}}$$

They mathematically expressed the problem as yij, which denotes when the i-th data packet is assigned to the j-th fog server. At time slot t, the latency minimization function is defined as

$$\mathrm{P}(t) \triangleq \min \sum_{i=1}^{\Omega(t)} \sum_{j=1}^{\Psi} y_{ij} l_{ij}$$

$$\sum_{i=1}^{\Omega(t)} y_{ij} = 1, \forall j \in \Psi,$$

$$l_{ij} \leq \tau_i^d, \forall j \in \Psi$$

$$y_{ij} \in \{0,1\}, \forall i \in \Omega(t), \forall j \in \Psi$$

where Ω(t) and are the data packet and fog server sets, respectively. As a result, the long-term latency reduction function (fΔ) is

$$(f_\Delta) \quad \lim_{t\to\infty} \frac{1}{t} \sum_{i=1}^{t} \mathrm{P}(i)$$

To fully process the uploaded data packet, the system's computation latency between distributed fog servers reaches its maximum. The greedy method is used to make the decision, which reduces system latency when data packets are uploaded.

Graphical Environment Distribution: Fog provides globally scattered end users with resources and services. Decentralized fog architecture enables greater location resource awareness, powerful processing computational capabilities, and real-time decision-making in the context of ubiquitous computing than cloud-centralized design[6].

CONCLUSION

The difficulty in big data is latency, and optimal resources with load balancers, which are addressed in all studies and research that aim to achieve high performance in numerous applications. Researchers released various studies on the subject of cloud-fog computing between 2018 and 2022, and they discovered that as technology and smart devices progress, the amount of data generated by them grow significantly. The majority of these studies examine load data in the health field, while a few others discuss load balancers in fog computing and working closely with end users to achieve high performance and lower reaction times, particularly in human sectors. Furthermore, they determined that industrial unique health environment apps require higher data processing power.

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