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A Comparative Review of Internet of Things Model Workload Distribution Techniques in Fog Computing Networks

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Abstract: In the realm of fog computing (FC), a vast array of intelligent devices collaborates within an intricate network, a synergy that, while promising, has not been without its challenges. These challenges, including data loss, difficulties in workload distribution, a lack of parallel processing capabilities, and security vulnerabilities, have necessitated the exploration and deployment of a variety of solutions. Among these, software-defined networks (SDN), double-Q learning algorithms, service function chains (SFC), virtual network functions (VNF) stand out as significant. An exhaustive survey has been conducted to explore workload distribution methodologies within Internet of Things (IoT) architectures in FC networks. This investigation is anchored in a parameter-centric analysis, aiming to enhance the efficiency of data transmission across such networks. It delves into the architectural framework, pivotal pathways, and applications, aiming to identify bottlenecks and forge the most effective communication channels for IoT devices under substantial workload conditions. The findings of this research are anticipated to guide the selection of superior simulation tools, validate datasets, and refine strategies for data propagation. This, in turn, is expected to facilitate optimal power consumption and enhance outcomes in data transmission and propagation across multiple dimensions. The rigorous exploration detailed herein not only illuminates the complexities of workload distribution in FC networks but also charts a course towards more resilient and efficient IoT ecosystems.

Keywords: Software-defined networks; Double-Q learning algorithms; Service function chains; Virtual network functions; Internet of Things

1 Introduction

The reliance on computers and smart gadgets for daily work is growing among individuals and organisations. These gadgets are collecting data through a variety of sensors and applications. Consequently, organisations are consistently producing and retaining substantial volumes of data [1]. Following the widespread adoption of the IoT, there has been a significant surge in the volume of data generated by various sensors. In recent years, there has been a significant surge in the amount of data being generated, leading to challenges for traditional databases in handling many types of organised and unstructured data. As a result, big data analytics has garnered considerable interest. In contemporary times, there is a prevailing trend among organisations to give utmost importance to the examination of accumulated data with the objective of deriving valuable insights that can inform critical decision-making processes [2]. In contemporary times, it has been imperative for organisations to possess a flexible information technology infrastructure in response to the transition towards cloud computing (CC). This movement is mostly driven by the advantages of accessibility, scalability, and pay-per-use offered by CC. The cloud offers several services, including Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS). These services are together referred to as Anything as a Service (XaaS) [3]. Nevertheless, the vast amount of data produced by billions of sensors, also known as big data, presents challenges in terms of its transfer and processing capabilities within CC systems. Furthermore, certain IoT applications require expedited processing beyond the current capabilities of CC. The resolution of this issue can be achieved by the adoption of the FC paradigm. This paradigm leverages the computational capabilities of devices in close proximity to users, namely their idle computing capacity, to facilitate the efficient utilisation of storage, processing, and networking resources at the edge [4].

FC is a decentralised computing idea that differs from CC by not relying mainly on any central component [5, 6]. One potential solution to mitigate the issue of excessive latency in CC is leveraging the unused computational capacity of nearby devices in close proximity to consumers. Nevertheless, FC is dependent on the use of cloud infrastructure for the execution of intricate computational tasks. In contrast to CC, FC is a decentralised computing paradigm that leverages the computational capabilities of several devices in close proximity to us. At present, even a smartphone with modest specifications possesses computational capabilities, often equipped with numerous processor cores. Therefore, a multitude of devices, such as smartphones, switches, routers, BSs, and other network management equipment that possess computational capabilities and storage capacity, have the ability to function as Fog devices. The resources of these gadgets remain unused during non-peak hours. Figure 1 shows the fundamental structure of workload distribution for the FC network.

Numerous research concerns are arising in relation to FC as a result of its widespread connectivity and diverse organisational structure. The major concerns in the FC paradigm pertain to the necessary prerequisites and the implementation of an FC environment. The presence of heterogeneous devices in fog environments necessitates an examination of how FC will address the novel issues associated with resource management and failure handling in such an environment. Therefore, it is imperative to conduct an investigation into the fundamental prerequisites for all interconnected elements, including deployment considerations, simulations, resource allocation, fault tolerance, and service provision. Multiple literature reviews [7–9] have been conducted on the topic of FC. This section provides a concise overview of the key areas of interest and research covered in these review articles.

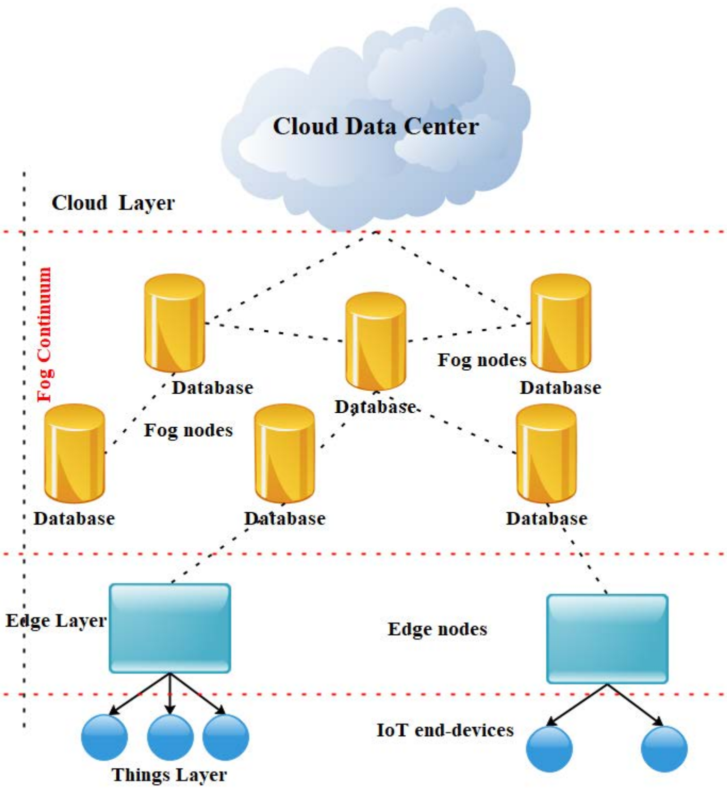

Figure 1. Fundamental block structure of the FC network

According to the findings of the study by Donno and Dragoni [10], a full description of the many facets associated with FC is provided. This description includes similar principles, definitions, application scenarios, and a myriad of obstacles. In their research, Khumalo et al. [11] presented a hierarchical architecture for FC. This framework incorporates a variety of processing, networking, and storage technologies. To be more specific, they talked about the significance of resource management, security, and privacy protection in terms of making the adoption and operation of FC easier. In their research, Bajaj et al. [12] carried out a survey that investigated the connection between FC and the Internet of Everything (IoE) from the point of view of an integrated perspective. A complete analysis of the various aspects relevant to application characteristics, system architecture, and platform abstractions was carried out by Belmahdi et al. [13] in their research. This analysis was carried out across edge, fog, and cloud ecosystems.

Within the scope of their research, Kadhim and Naser [14] carried out an exhaustive analysis of the FC domain, with a particular emphasis on the perspectives of both developers and end users. Their research was conducted with the intention of establishing a sensing infrastructure that is both sustainable and suitable for applications in smart cities. In the research that they conducted, Cheng and Qian [15] presented a classification system for FC that was based on the difficulties that were identified as well as the significant qualities of this technology.

A thorough classification of the existing body of literature on FC is provided by the taxonomy that was proposed in this study. A complete analysis of fog architecture and algorithms was carried out by Abedi and Pourkiani [16] in their research. The authors focused on six unique evaluation criteria, which were as follows: heterogeneity, quality of service (QoS) management, scalability, mobility, federation, and interoperability.

On the other hand, none of the research that has been carried out up until this point has investigated the taxonomy of FC in relation to the particular requirements of infrastructure, platform, and application. In addition, it is important to point out that none of the research described above carried out a comprehensive investigation into the topics of fault tolerance, resource management, or microservices in relation to FC. For the purpose of this research, by taking a comprehensive look at the modern difficulties that were described before, this study investigates the possible uses of CC technologies within the framework of the fog paradigm. The following is a condensed summary of the most important contributions that this review study has made:

By analysing the number of research papers that have been published and the number of times that search results have been returned on Google Scholar, the purpose of this study is to conduct an analysis of the current research trends in FC. This study gives a complete design as well as a full study of various different FC architectures [17–19]. Prior research mostly concentrated on presenting high-level structures, and as a result, it lacked in-depth details. This is something that should be taken into consideration. The purpose of this study is to offer a taxonomy for the classification of infrastructure, platform, and application requirements within the framework of the FC paradigm. The purpose of this study is to identify the research gaps that currently exist in the field of FC. More specifically, research needs have been identified in the areas of resource allocation and scheduling, fault tolerance, simulation tools, and fog-based microservices. With the purpose of highlighting various unresolved difficulties within the areas of infrastructure, platforms, and applications, the purpose of this study is to address the limits that are present in the researchers who are currently conducting research. The results of this survey provide the scientific community and the industry with useful insights into the components that are required for the construction of an FC environment using FC. Furthermore, it can result in an improvement in their knowledge of the management of resources within the fog.

2 Literature Review

Research on the distribution of workloads using FC is an important area of study, especially as the IoT and edge computing continue to grow. FC, which extends CC capabilities to the edge of the network, offers several advantages in terms of reduced latency, improved scalability, and enhanced data privacy. Researchers are developing innovative algorithms for deciding where to place workloads within an FC infrastructure. These algorithms take into account factors like proximity, resource availability, and workload characteristics to optimise performance. Edge device selection is the process of workload distribution that often involves selecting appropriate edge devices to process specific tasks. Research is ongoing to create decision-making models and frameworks that can intelligently assign tasks to edge devices based on their capabilities and current workload. Load balancing (LB) mechanisms are crucial in FC to ensure that workloads are evenly distributed across the network. Researchers are exploring dynamic LB techniques that can adapt to changing network conditions and workload demands. Since many edge devices have limited power resources, energy-efficient workload distribution is a key concern. Researchers are developing algorithms that consider both performance and energy consumption when placing workloads in the fog. Security and privacy are the major criteria in the distribution of workloads in FC, which must also address security and privacy concerns [20–22]. Researchers are working on secure data transmission, authentication, and access control mechanisms to protect sensitive information processed at the edge. As the number of IoT devices and edge nodes grows, workload distribution mechanisms need to scale efficiently. Research in this area focuses on creating scalable approaches that can handle the increasing workload. QoS is a major parameter for FC systems, which often serve real-time applications where QoS is critical. Research is being conducted to develop QoS-aware workload distribution techniques to meet the performance expectations of applications. Machine learning and artificial intelligence techniques are being used to optimise workload distribution in FC. These methods can adapt to changing conditions and learn from past experiences to make better distribution decisions. Efficiently managing edge resources is integral to workload distribution. Researchers are exploring ways to allocate and deallocate resources at the edge to accommodate various workloads dynamically.

2.1 LB Options in FC

A method that is utilised in FC to disperse workloads among available resources is known as the Power-of-Random-Choices (PRC) LB approach. To assign jobs to fog nodes (FNs) or edge devices, it makes use of approaches that involve random selection. Randomness, despite the fact that it may appear to be paradoxical, can be an effective method for LB in certain circumstances. It is common knowledge that LB algorithms make use of the PRC metric in order to achieve a significant improvement at a relatively cheap cost. Because separate FNs do not need to coordinate with each other when they decide to share their resources, these methods are a good fit for the FC model for which they are designed. Within the scope of this study, Left-to-right, leftmost derivation (LL) (F, T) is proposed, which is a distributed peer-to-peer LB algorithm that is based on PRC and operates on a collection of autonomous FNs that work together. Here, F is the protocol fan-out, and T is a threshold. In the event that the nodes' current load is greater than T, they randomly select one of the FNs associated with F. This algorithm achieves almost the same level of performance as its classical implementation, which makes use of a single global scheduler and necessitates that each job execution be preceded by a time-consuming probing phase. With the help of a mathematical analysis and some preliminary simulations, it is demonstrated that this algorithm achieves this level of performance by setting T very close to the node saturation condition. In the case of fog applications, which are required to operate at a rapid pace, this is an obvious advantage.

2.1.1 Proactive load balance system for IoV FC

The Internet of Vehicles (IoV) is a novel form of car ad hoc network that utilises the internet to establish connections between the sensors of individual vehicles as well as between the sensors of other vehicles. These sensors are responsible for sending out a variety of tasks that need to be examined and completed within a specific length of time. They then transfer the jobs to servers that are located in the cloud; however, the sending operations consume more bandwidth and take more time. FC is a straightforward cloud that is located at the periphery of the network and is utilised to perform work in a more expedient manner as opposed to sending it to a CC facility. FC is not suitable for many tasks because there are not enough resources available to complete them. Therefore, in these instances, it moves them to CC, which results in an increase in both the delay and the amount of bandwidth that is used. Additionally, there is a possibility that certain fog sites are completely devoid of fog, while others are completely covered with fog. This indicates that certain occupations are being distributed in a manner that is not fair [23]. The parked car is employed as a FC node helper in this research study, involving combining the SDN with the IoV and FC. Consequently, this has the potential to increase the usefulness of the FC layer and decrease the amount of jobs that need to be transferred to cloud servers. The likelihood that time-sensitive tasks can be completed on time is increased as a result of this. There is also a suggestion for a new strategy for distributing the load. In the context of IoT FC, Figure 2 illustrates the functional structure of LB possibilities. Through the local fog managers and the SDN controller, respectively, it operates in a proactive manner to balance the load both locally and globally. Simulation experiments demonstrate that the proposed system is superior to the Vehicular Ad Hoc Networks (VANET)-fog-cloud and IoV-fog-cloud frameworks in terms of the average response time, the percentage of bandwidth utilised, the ability to fulfil the deadline, and the utilisation of resources.

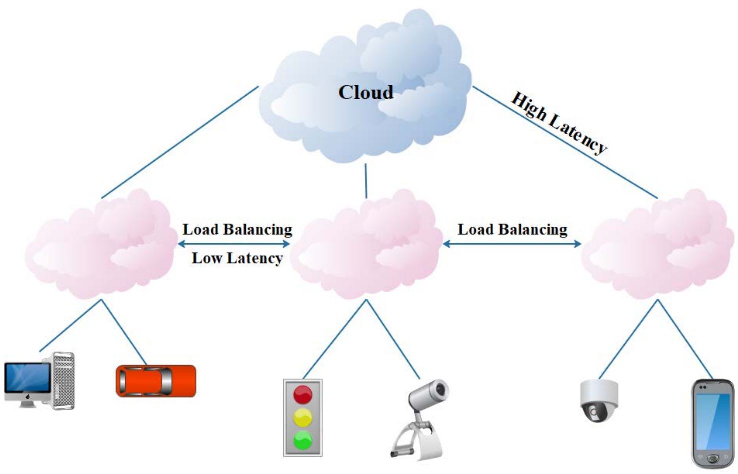

Figure 2. Functional structure of LB options in IoV FC

2.2 Graph Repartitioning-Based Dynamic LB (DLB)

CC is unable to take full advantage of the computational, storage, and other resources that are available on edge devices since the processing paradigm that it employs involves a high degree of polymerization. FC has the potential to enhance the efficiency with which the edge device utilises its resources and to provide a solution to the issue of service computing for applications that cannot wait. Cloud atomization technology is utilised in this paper to transform physical nodes at various levels into virtual machine nodes [24]. The framework of FC is investigated in this paper. A LB technique for FC that is based on dynamic graph partitioning is constructed in this study utilising graph partitioning theory as the foundation. Both the DLB mechanism and the framework of FC after cloud atomization are able to successfully set up system resources and reduce the amount of time it takes for nodes to migrate when the system changes. The results of the simulation show that the framework of FC can create the system network in a flexible manner. The repartitioning-based DLB is laid out in Figure 3, which depicts its structure.

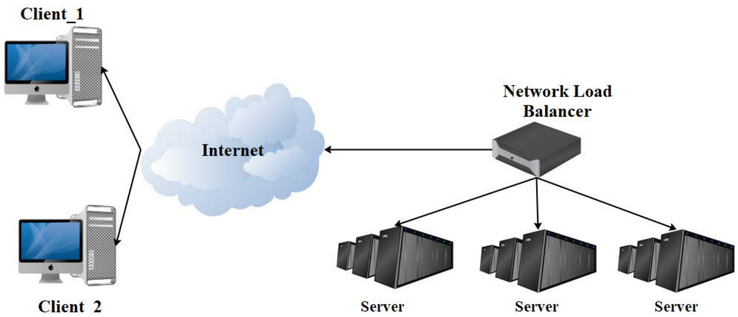

Figure 3. Structure of the graphical repartitioning-based DLB

2.2.1 LB and FC task offloading

FC makes it possible for services and resources to be available outside of the computer resources, closer to end devices on the network edge, and finally in service-level agreement-mandated areas. Along with the cloud, FNs are a great way to help with computing. It lets work happen at the edge while also letting the cloud talk to the edge. LB is an important part of fog networks because it keeps some FNs from being idle or overloaded [25]. Figure 4 shows the data flow structure of LB and FC task offloading.

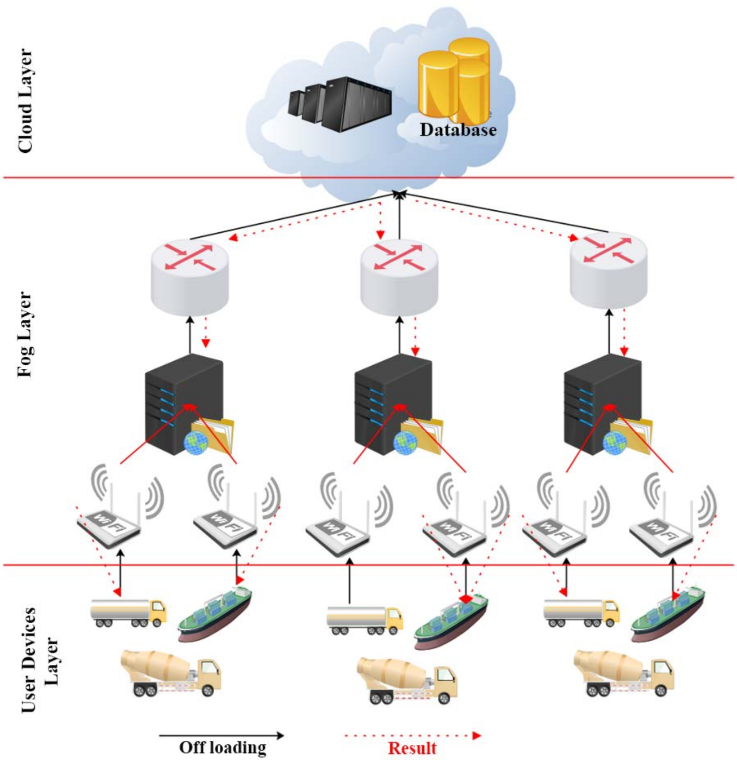

Figure 4. Data flow structure of LB and FC task offloading

Latency, resource utilisation, throughput, response or processing time, cost, and energy used by passive nodes are all examples of QoS variables that can be affected by LB. The strategies that are utilised in a fog network to transfer workloads and loads around within the network are investigated in great detail in this paper. The analysis is broken up into two sections: single-parameter optimisation algorithms and multi-objective parameter optimisation algorithms. Each of these sections deals with a different set of concepts. The review is also examined in a variety of ways, including the number of articles published by each publication, methodological approaches that are based on optimisation parameters, performance assessment metrics, simulation evaluation tools, and potential study fields in the field of FC. Figures 5 and 6 exhibit the performance analysis of numerous FC network LB methods with respect to delay and energy usage, respectively [26]. Table 1 displays the various traditional methods for LB and its settings for simulation. Figures 5 and 6 show the results of the analysis.

Table 1. Usual LB methods and simulation parameters

Si. No.	Algorithm	Delay (s)	Energy Consumption (Joule)
1.	PRC	20	235
2.	SDN	15.5	185
3.	DLB	13.3	165

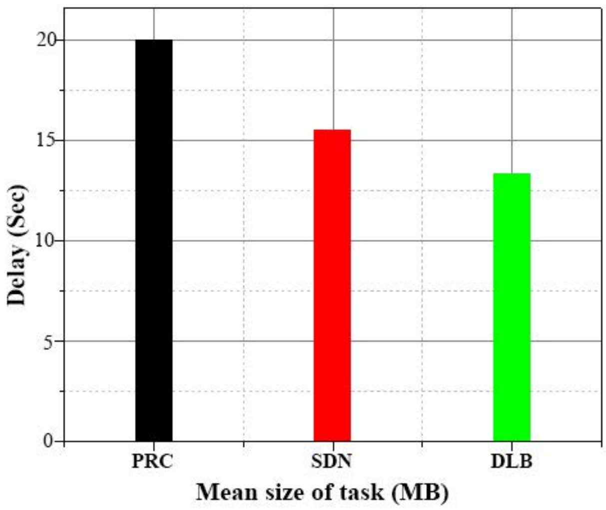

Figure 5. Performance analysis of variable method versus delay (sec)

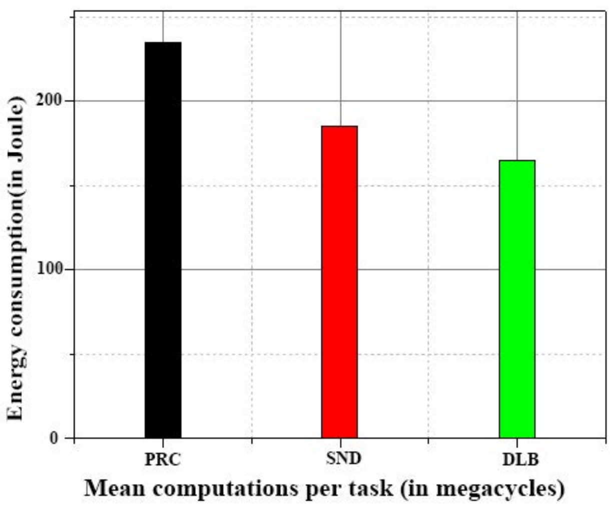

Figure 6. Performance analysis of variable methods versus energy consumption (in Joule)

3 LB Schemes and Algorithms

LB is a crucial aspect of FC, where workloads are distributed across various FNs or edge devices to optimize performance, resource utilization, and fault tolerance. Several LB schemes and algorithms have been developed for FC environments. The Round Robin algorithm distributes tasks or workloads equally among FNs in a circular fashion. It's a simple and straightforward approach, but it may not consider the varying capacities of nodes.

3.1 Blind LB Algorithm with Double-Q-Learning in Fog

In a global FC system, FNs can handle user requests close to where they are made. So that user requests don't take too long to get an answer, incoming requests must be spread out evenly among FNs. In this study, a new way is proposed to improve LB in a fog-like environment. In the suggested algorithm, a FN gets a task from a mobile device. Then, the FN chooses to use the double-Q learning algorithm to handle that task. One of the most important things about the algorithm suggested in this paper is that decisions about tasks can be made without knowing what the state of the nodes around them is. The results show that the suggested algorithm, which divides tasks between nodes in the right way, reduces the user's wait time and response time by a lot compared to other methods [27].

3.1.1 Descending SFC provisioning scheme with LB

An innovative approach to managing SFC requests for applications that just cannot wait is outlined in this letter. One of the components of the SFC is the VNF, which is mapped onto a multi-tier fog architecture with constrained resources. All of the nodes in this design are classified as either primary or secondary. Following the mapping of one VNF to each FN, deployment methods arrange service paths according to which ones have the least amount of latency or load. It is possible that these methods can result in early congestion at the primary nodes, which leaves the secondary nodes vacant because it takes longer for the links to connect properly. In order to address this issue, the plan that has been developed employs a hierarchical approach that is descending in order to enhance the rates of admission and utilisation, as well as to reduce the amount of time it takes to provide services to individuals. Group VNF mapping is performed on secondary nodes when there is not a lot of traffic. This is accomplished by employing shorter paths that bypass primary nodes that are overcrowded. In situations where there is a significant amount of traffic, it performs single mapping on the primary nodes as well as existing pathways [28].

3.1.2 FC in the smart healthcare system

It is among the most important parts of life to have access to high-quality medical treatment. These services include the diagnosis, treatment, and prevention of mental health difficulties, mental diseases, physical illnesses, and injuries. It also covers a wide range of services. The jobs in the field of healthcare that have the most influence on the life of a patient are the ones that receive the most attention to be performed. FC technology is becoming more recognised as one of the most important technologies that are now available. This is something that can be applied to the realm of medicine. The major goal of FC is to meet the need for services that have a reduced delay between end devices and the cloud. On the other hand, FC is still plagued by a significant number of problems that have not yet been successfully managed. The fundamental goal of utilising FC with health systems is to provide a high level of security for the data that is communicated through sensors that are positioned between the peripheral devices in the fog edge nodes. This is with regard to the distribution of loads, which is the primary objective. This can ultimately result in high levels of productivity and effectiveness in performance. In addition, the objective is to cut down on the amount of time needed to access resources and the amount of energy that is consumed by allocating resources and splitting them evenly among loads. This study illustrates how LB may be accomplished by utilising a number of different measures within the framework of FC.

3.1.3 Internet of battlefield things (IoBT) fog radio access networks (F-RAN)

The most recent trend in the military is to make use of knowledge of the IoT in order to improve its effectiveness on the battlefield. The IoBT is something that the researchers are concerned about as a result of this. This article discusses the ways in which the F-RAN can assist with local computing for industrial IoT and the Internet of Businesses. Fifth-generation (5G) communication is also becoming increasingly essential due to its ultra-low latency, energy efficiency, bandwidth efficiency, and vast coverage area. F-RAN has the potential to be very crucial considering the increasing prevalence of IoT devices. F-RAN is a solution that can be used in order to address the issues that are associated with cloud radio access networks (C-RAN). There is the potential for a significant number of F-RAN nodes to collaborate in order to share material and do distributed computing. IoBT's F-RAN is an excellent method for enhancing processing power because it utilises FC and edge computing at the network's edge. Due to the fact that fog equipment is not capable of performing a great deal of computing, this study presents a number of challenging issues and suggests potential solutions in order to improve the effectiveness of the battlefield. It is therefore investigated whether or not the distributed computer LB problem of the F-RAN may be solved. With regard to the F-RAN design, the simulation demonstrates that the LB strategy is more effective on the battlefield [29, 30]. Figure 7 shows the functional structure of IoBT in the FC network.

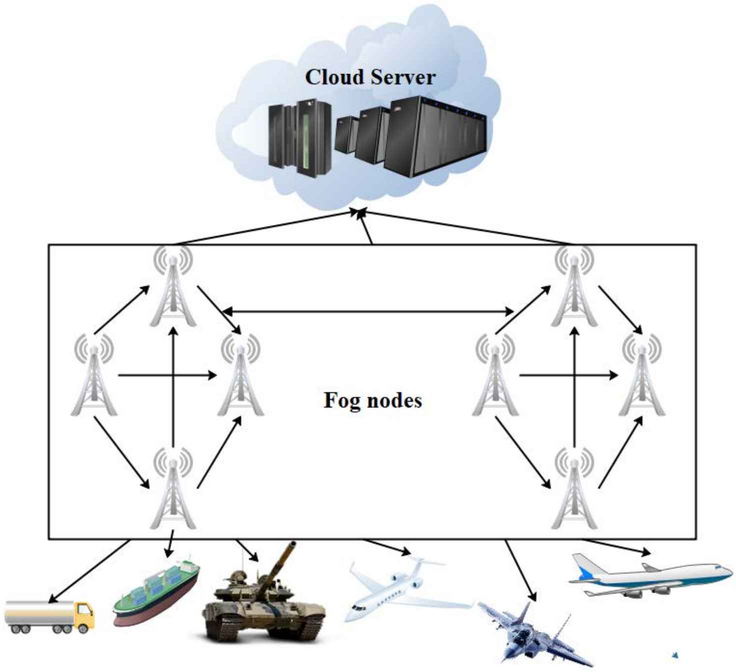

Figure 7. Functional structure of IoBT in the FC network

3.2 LB Algorithms in FC

In addition to CC, FC is a new method of providing services that involves the utilisation of an existing distributed paradigm. Data storage and processing are moved to the network's periphery by the fog system [31, 32]. This not only makes it feasible to know where you are and assist you in moving about, but it also solves the problem of service computing in applications that are unable to deal with unexpected delays. A crucial component of fog networks is LB, which prevents certain FNs from being overly busy or underutilised. In terms of things like resource utilisation, throughput, cost, reaction time, performance, and energy consumption, LB has the potential to create an improvement in the QoS. Some research has been conducted over the course of the past several years on LB approaches in fog networks; however, there is not a single study that brings together all of these different efforts. The four different types of LB algorithms that are used in FC are analysed in this work in a methodical manner. These algorithms are approximate, exact, fundamental, and hybrid. Moreover, LB measures and the advantages and disadvantages of several techniques for LB in fog networks are investigated in this paper. The approaches and instruments that were utilised in the evaluation of each of the studies that are being examined are also taken into consideration. Additionally, the most significant open problems and trends for the future of these systems are discussed as well. Figures 8 and 9 exhibit the time complexity and average throughput performance of numerous FC network LB methods, respectively. Table 2 displays common LB methods and simulation parameters. Figure 8 additionally displays the simulation parameters.

Table 2. Usual LB methods and simulation parameters

No.	Algorithm	Time Complexity (s)	Average Throughput (bits)
1.	SFC	1.3	16
2.	VNF	1.6	18
3.	F-RAN	1.8	26
4.	C-RAN	1.1	29

4 LB Method in Multi-Tier Fog Networks

LB in multi-tier fog networks is essential for optimizing the use of resources and ensuring efficient and reliable performance. FC extends CC capabilities to the edge of the network, and it's characterized by multiple tiers or layers of resources, including edge devices, FNs, and cloud servers. LB in such networks aims to distribute incoming requests or workloads evenly across these tiers to prevent overloading any single component and to maximize resource utilization.

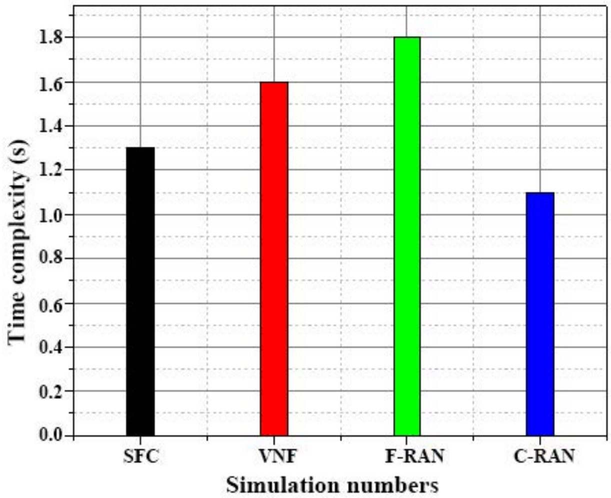

Figure 8. Performance analysis of variable methods versus time complexity

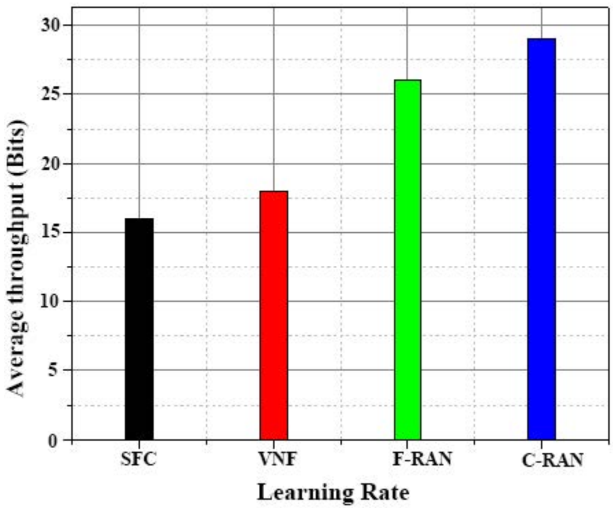

Figure 9. Variable technique performance against time complexity

4.1 Multi-Tier Fog Network SFC Provisioning with LB

SFC setup must be done on cloud or fog servers for network function virtualization (NFV). Now, FNs offer faster deployment than the cloud, but they have fewer resources. This makes FNs more likely to get full if users want services that require a lot of computing power and can't be sent to the cloud because of the long wait times. So, this letter suggests a new SFC provisioning method for fog paradigms that achieves LB and redistribution between heavily and lightly loaded nodes without going over delay bounds. Compared to popular options like stand-alone delay or load-minimization methods, the scheme has a high admission rate and less waiting time. SFC is a concept used in network architecture and management, particularly in the context of SDN and NFV [33]. It is a sequence of network services and functions that are connected in a specific order to fulfil a particular network service or application's requirements.

4.1.1 FC data replication and LB method

Information technology (IT) companies use the technological world as a place to compete in order to offer cloud services. It is important for organisations to make sure that more high-quality services, computing tools, and faster delivery are available. FC can work with CC in a lot of the same ways to speed up IT systems. The company pays for, maintains, and gives access to resources close to the access point, such as storage space, hardware virtualization, high-capacity networks, service-oriented designs, autonomous and utility computing, etc. Spreading the load as evenly as possible across as many close and simple nodes as possible can make it easier to handle big data and large tasks. In the study, a good LB algorithm for a fog-cloud architecture is suggested. The programme uses a technique called "data replication" to keep data in Fog networks up to date. This makes fog networks less dependent on big data centres as a whole. Also shown is a comparison between how LB is done now in "cloud-based" infrastructure and how it is done with the "cloud-fog" pair. The end goal is to spread out the load through fog networks and make the internet less reliant on the cloud by putting data closer to the user [34, 35].

4.1.2 Task scheduling with load balance in FC

There has been an increase in demand for services provided by the fog layer, which is a new technique to employ distributed computing that goes along with CC. This need has increased as the IoT has gotten more popular due to its widespread adoption. With the fog system, it is feasible to know where you are and to assist you in moving about. This is accomplished by transferring storage and multiplication to the edge of the network. The issue of service computing in time-sensitive applications is significantly mitigated as a result of this modification. When there are more requests coming from more individuals, virtual machines (VMs) in the fog layer have to work harder. Because it prevents some FNs from being underloaded or overloaded, LB is an essential component of fog networks. The work of the fog layer must now be distributed equitably throughout the many VMs, as this is a requirement. Utilising LB can result in improvements to quality-of-service parameters such as cost, reaction time, performance, and energy consumption [36, 37]. In spite of the fact that many LB strategies for fog networks have been the subject of research over the course of the past few years, there has been no comprehensive analysis conducted to compile all of this information. An examination of the many approaches to LB that can be utilised in FC is presented in this article. These approaches are categorised as either approximate, precise, fundamental, or hybrid. In addition to this, the study investigates LB metrics, which include the advantages and disadvantages of the approaches that are utilised in fog networks. An examination of the procedures and instruments that were utilised in the evaluations of each individual piece of research is also included in this section. There is also discussion around the most unanswered topics and emerging trends regarding these algorithms. The final section of the study presents a number of suggestions for ways in which additional research could be conducted.

4.2 Multiple Gateways in Fog-Based IoT

This piece looks at how well a LB scheme based on multiple criteria works between gateways in the IoT with help from the fog. A queueing model of the IoT system is used to figure out how long it takes for IoT devices to send data streams to apps. But because all data for Internet Protocol (IP) networks goes through the gateway, it is easy for that node to get crowded. A busy point can slow down the whole system and even cause problems with its stability. Figure 10 shows the function structure of multiple gateways in fog-based IoT. Therefore, multiple gateways are used to keep the network from slowing down and a multicriteria decision-making (MCDM)-based LB strategy is used among the gateways to make sure that the load is distributed fairly around the world. The suggested model is tested in low-power wireless personal area networks (6LoWPANs) with a single hop of IPv6. The results of the study show that the proposed LB model works well to give users quick and accurate answers to their questions [37, 38].

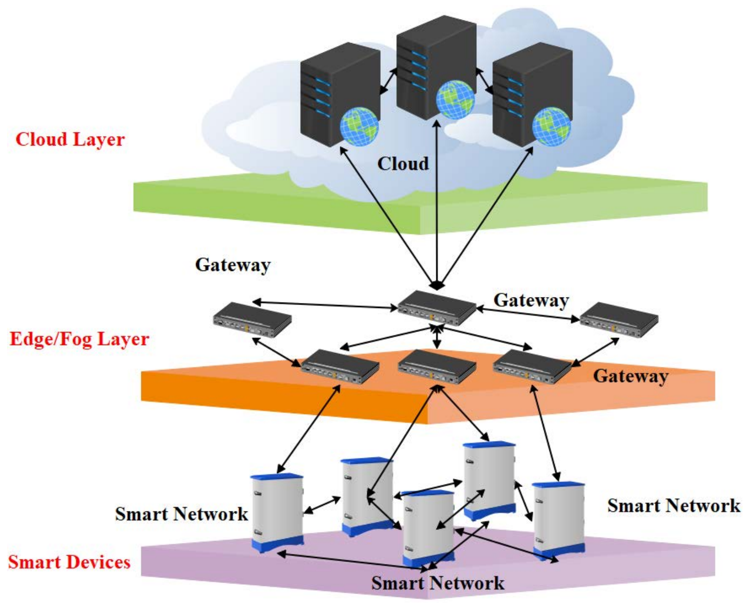

Figure 10. Function structure of multiple gateways in fog-based IoT

4.2.1 QoS-aware LB in generic and specific fog deployments

The combination of smart sector applications and services with the FC paradigm opens up new research avenues for the purpose of enhancing service broker policies, resource management, and FN efficiency. This is the case despite the fact that end-user devices and FNs are distinctly different. There was a belief that the incorporation of the fog layer into the new design would result in an improvement in the QoS for applications that are dependent on delays. Jasim et al. [39] fog evaluates the data that is nearest to it at the network border, depending on a policy, as opposed to sending massive volumes of IoT data to the cloud. After that, it takes action on the data from the IoT in milliseconds and then uploads a collection of data to the cloud for long-term storage and analysis. For the purpose of determining what the most significant findings are and where future research needs to go in the current 5G F-RAN, a comprehensive review of QoS-aware LB optimisation techniques was conducted in both general and specific fog deployment scenarios. These scenarios include smart grids, electric vehicles, health monitoring, and others. In order to evaluate the efficacy of various resource allocation and LB strategies utilised in FC, the evaluation is divided into distinct sections that are based on performance estimates, QoS metrics and simulation assessment tools. The purpose of these sections is to determine how well these strategies estimate performance.

4.2.2 Deep learning for FC workload balancing

In addition to CC, a new type of distributed computing called FC has been created in recent years. Using the fog network, storage and computation can be moved to the edge of the system. This makes the system more aware of its surroundings and helps with mobility. It can also solve the problem of how to calculate the service of apps that are sensitive to delays. Fog networks need to keep a good load balance so that there aren't any problems with FNs that aren't busy enough or are too busy. LB can improve QoS factors like how much resources are used and how much data is used. This study looks at a working charge distribution list in an IoT-fog-cloud collaboration system to reduce job latency and meet the QoS requirements of as many late-sensitive IoT applications as possible. Also, the problem of allocating workloads in an IoT-based cooperation plan is first looked at. This suggests that the best way to distribute workloads is between FNs close to each other and the cloud, so that work can be done faster. Then, Lyapunov's drift and penalty theory, which looks at how steady the IoT-fog-cloud queue plan is, is used to check the stability [40, 41].

4.3 LB Machine Scheduling in Fog-CC

FC is becoming a powerful and popular way to do computing. It builds on the CC model by letting services run at the edge of the network. For resource provisioning, mobile and IoT apps could choose processing nodes in both the fog and the cloud. In general, LB is one of the most important things to do to get the most out of your resources and avoid situations where they are overloaded, underloaded, or not being used at all. LB for the computing nodes in a fog-cloud system is still hard to achieve, though. This study proposes a method for LB in fog-CC using VM scheduling. First, a resource model and a load balance model are looked at from a technical point of view. Then, using the VM live movement method, a heuristic method for scheduling VMs is made through VM placement and dynamic scheduling of VMs. In the end, experimental evaluation and comparison analysis are done to prove that the suggested method works well and is efficient [42].

4.3.1 Unified fog network task offloading algorithms

FC is a new type of distributed computing that allows services to be offered with low delay and high throughput. But because of the different locations, there is a big problem with load imbalance, which makes the fog network work less well and use its resources less. In this study, the load for FNs is the trade-off between delay and energy use. In the meantime, the problem of minimising the maximum load in a uniform fog network is written down and shown to be NP-hard. Then, a greedy algorithm is suggested to solve the problem by moving the job from the FN with the most work to the FN with the least work in the network. Also, because FNs can be selfish, a coalition-based algorithm is suggested to solve the problem by getting FNs with light loads to share their resources to lower the maximum load [43, 44]. The performance of the proposed algorithms on NS-3 was tested. Simulations show that, in terms of the maximum load, the suggested algorithms are about 40% better than the existing ones. Table 3 presents a compilation of common LB methods and simulation settings. Additionally, Figure 11 shows the response time and execution time performance of various LB strategies employed in FC networks.

5 Management Workload for FC

Managing workload in FC is essential for optimizing the performance, resource utilization, and reliability of FNs and edge devices. Effective workload management ensures that tasks are assigned to the right nodes at the right time. LB algorithms and schemes, as discussed earlier, are crucial for distributing workloads across FNs. LB helps avoid overloading certain nodes while keeping others underutilized. Task scheduling involves determining the order in which tasks should be executed on FNs. A scheduling algorithm can prioritize critical tasks or those with deadlines, ensuring that they are processed promptly [45].

Table 3. Typical LB methods and simulation parameters

Si. No.	Algorithm	Response Time (s)	Execution Time (s)
1.	SFC	22	52
2.	NFC	15	50
3.	MCDM	16	45
4.	VM	18	32

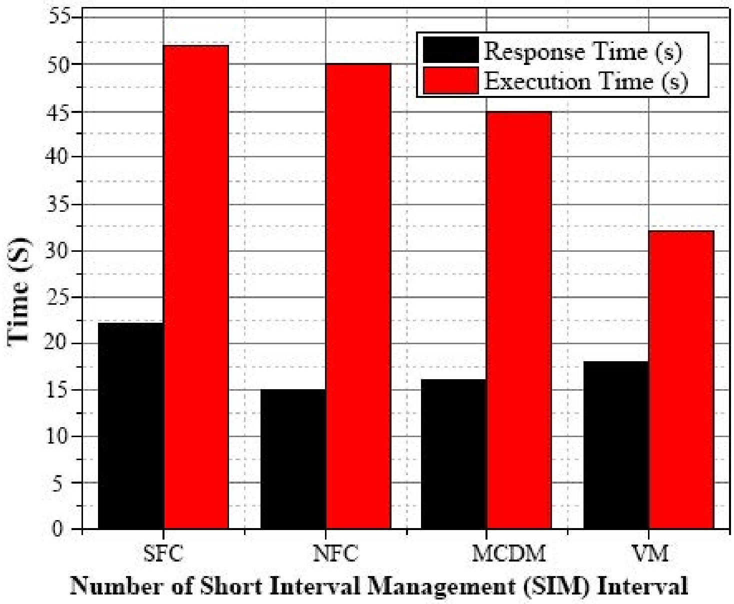

Figure 11. Response time and execution time performance of various LB strategies employed in FC networks

5.1 Reinforcement Learning LB

Because it makes it feasible to link virtualized computers to networks and brings cloud services closer to end devices, FC is a powerful concept that is now receiving a lot of interest. This is because FC is a concept that is attracting significant attention. A useful network technology that can support this intelligent platform that is spread out is SDN, which has become a good network technology in the FC context. However, a trustworthy LB mechanism is required because workloads can be difficult to forecast and FNs have varying levels of computing capacity. For the purpose of achieving the lowest feasible latency in fog networks, this paper investigates the challenge of LB as a means of achieving this goal. To determine the most effective method of offloading when the reward and transition functions are unknown, a decision-making procedure that is based on reinforcement learning has been proposed as a solution to this problem. There is a mechanism that has been described that allows FNs to deliver an optimal number of incoming tasks to a nearby FN. This is accomplished by selecting an available neighbouring FN depending on the resources that it possesses [46]. One of the objectives is to reduce the amount of time spent processing and the likelihood of the system as a whole becoming overloaded. Not only does the suggested system simplify the algorithmic framework without making any specific assumptions about the network model, but it also guarantees convergence in polynomial time, which is a significant advantage when compared to traditional means of solving problems. Although the service rate and traffic arrival rate are subject to variation, the results demonstrate that the offloading strategy that was suggested, which is based on reinforcement learning, significantly increases performance during average delays. The suggested technique reduces the likelihood of overload by 1.17 percent, 1.02 percent, and 3.21 percent, respectively, compared to random, least-queue, and nearest offloading selection methods [47]. As a result, the proposed methodology is more feasible.

5.1.1 Priority-based LB FNs

FC is becoming increasingly concerned about the manner in which the devices connected to the IoT continue to expand and the wide variety of these devices. This occurs as a result of the fact that the nodes have a tendency to remain overcrowded, which slows down reaction times. A new priority load balancer and an architecture model for FC are two solutions proposed as a response to this difficulty. These solutions assist the FNs in performing their functions more effectively. Through this study, the amount of time it takes for FC to respond can be reduced by combining information about tasks and the burden that is placed on the computer [48]. In comparison to the direct and round-robin strategies, the findings demonstrate that the one that was recommended had the quickest response time. Compared to previous load balancers, the proposed one in this study was efficient enough to reduce the amount of time it took for high-priority processes to respond by more than 56 percent.

5.1.2 Fog-based 5G radio access network service LB

In the future, fog-based radio access networks, also known as F-RAN, are projected to play a significant role in the development of 5G cellular networks. In order to accomplish this, they make use of the pooled resources of edge devices in order to provide end users with localised RAN services. The stringent latency and bandwidth requirements of 5G services and applications can be met with the help of F-RAN, which is able to take in and process end-user tasks in close proximity to the location from which they originate. Because there are a large number of edge devices with varying resource levels that can be selected by the fog access point (FAP) as service nodes to handle an end-user task, it is the responsibility of the FAP to determine which service node(s) should handle which tasks from end users in the F-RAN [49]. In Figure 12, the essential structure of fog-based 5G radio access network service LB is depicted.

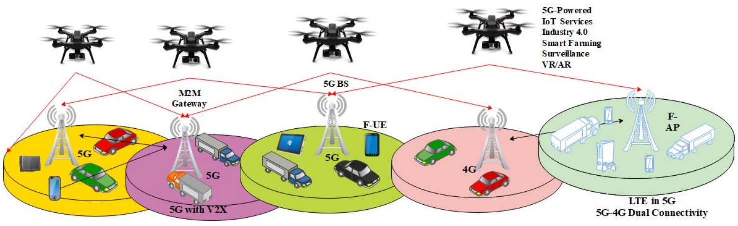

Figure 12. Fundamental structure of fog-based 5G radio access network service LB

The jobs here are user processing tasks that the FAP or the cloud would have done in the past. This study introduces the idea of virtual FAPs (v-FAPs), which are made up of a number of local devices like WiFi access points, femtocell BSs, and more resource-rich end-user devices under the coverage and control of the FAP. This paper's main goal is to solve the problem of assigning tasks by suggesting a service LB method for v-FAPs. The user jobs are shown as a task graph, and the service nodes are shown as a service graph with no edges. Then, an optimisation problem is set up to find the best way to divide up jobs so that the service nodes can handle the same amount of work.

5.1.3 Unmanned surface vehicle (USV) cluster using marine vehicular FC

It is difficult for the USV cluster to interact with one another while they are responsible for carrying out a marine operation. The condition of the wireless channels in the cluster as well as the structure of the network are both subject to rapid change over the course of time. To add insult to injury, multiple task requests can simultaneously utilise the computing capabilities of the same FNs. As a result of the fact that negative things are continually changing, it is essential to discover an efficient method of distributing the burden. Within the scope of this work, the issues of load balance in vehicular FC on the USV cluster are investigated. In addition, the mathematical models that are associated with it are established [50]. The maritime vehicular FC networks, wireless channels, and a variety of common scheduling techniques are all included in these models. It has been demonstrated through analytical models and simulations that the proposed scheduling algorithm, which is based on the shortest response time, performs more effectively than previous algorithms and has the potential to considerably cut down on the response time and the probability of task requests being blocked.

5.1.4 FC priority-aware SFC provisioning

People have come up with FC models to get around the delays that come with CC. This is done by moving the cloud's computing and storage tools, as well as its relaying and caching services, to the edge of the network. This, in turn, cuts down on delays and lags and relieves pressure on cloud hubs. Also, virtualization technologies like NFV make it easier for different services and applications to reach and share FNs. SFC deployment is an important part of making these applications available when these technologies are used. So, this paper gives the first study of SFC provisioning in NFV-based fog networks that uses the shortest path and LB to make the best use of resources [51]. Batch requests are sorted based on criteria that take importance into account, such as which functions need the most and least resources, and by chance.

Therefore, the goa is to make SFC provisioning work well while finding the best way to sort batch requests and map them to fog nodes.

5.1.5 Deep reinforcement learning (DRL) FC routing strategy

Computing in the fog is a method that allows users to circumvent the limitations of CC by relocating the services of CC closer to the network's edge. The fact that fog systems are dispersed across a large area and have limited resources means that they continue to face a number of challenges. A LB technique that is based on DRL and a Dijkstra-based link-state routing protocol is proposed in this study, which investigates the management of resources in FC and offers a suggestion for one. Through the use of this technique, the objective is to reduce the amount of time required to complete duties and discuss them. The Load Balancer Smart Controller (LBSC) was developed as a component of the proposed system in order to collaborate with a smart DRL agent in an environment that is characterised by fog [52, 53]. The LBSC takes into consideration the states of the nodes and links in order to make the most appropriate decision. It does this by selecting the most appropriate node and path to deal with each task. An experiment is conducted to determine how well the suggested strategy functions in a dynamic IoT environment that is characterised by a high rate of task generation. The proposed method, when compared to conventional LB methods, results in a reduction of around fifty percent in the average overall latency. This latency includes both processing and transmission delays. Figure 13 shows the performance analysis of various techniques with respect to workload distribution parameters, and Table 4 displays the workload for management in FC.

Table 4. Management workload for FC

No.	Algorithm	Average Data Throughput (bits)	Fault Detection Rate
1.	SDN	28	2.32
2.	F-RAN	32	4.35
3.	V-FADs	45	6.35
4.	USV	38	4.65
5.	NFV	55	5.622
6.	DRL	64	7.622

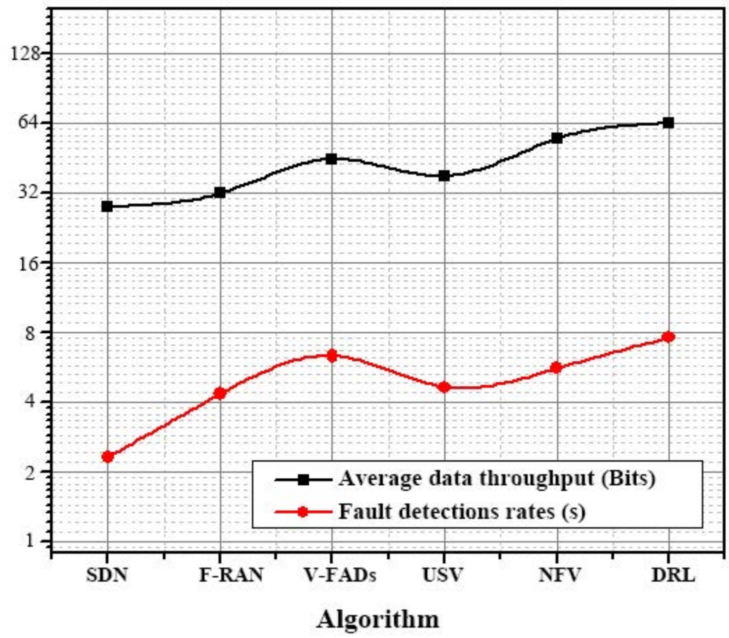

Figure 13. Performance analysis of various methods with respect to workload distribution parameters

6 FC Workload Dispersion Automation Control

FC workload dispersion automation control involves the automation of the distribution and management of workloads across FNs and edge devices to optimize performance, resource utilization, and operational efficiency. Automation control systems should employ DLB algorithms that can adapt to changing conditions. These algorithms continuously monitor the status of FNs, such as central processing unit (CPU) and memory usage, network latency, and available resources, and distribute workloads accordingly [54].

6.1 LB Hybrid Efficient Resource Allocation

Applications that are connected to the IoT are able to determine how computing FNs respond to certain resource requirements and distribute the load across the distribution network. By ensuring that resources are used effectively, avoiding bottlenecks, overloading, and delays, and distributing the load across network resources, one of the most significant jobs that must be completed in an IoT environment that is based on FC occurs. The complexity of computers, on the other hand, makes it extremely challenging to maintain a balance between the workloads. By combining a fog-IoT LB resource sharing approach with the least number of connections and a weighted round-robin algorithm, the purpose of this work is to identify the most effective way to distribute the load on the network in order to tackle these issues. Not only that, but it also provides an analysis of the many methods by which data can be transmitted, such as web requests and the uploading and downloading of files using the File Transfer Protocol (FTP). Performance can be evaluated based on a number of factors, including throughput, latency, reaction time, packet loss rate, channel idle capacity, channel utilisation, waiting time, speed, and necessary time [55, 56]. A total system latency of 140.05 seconds, a total response time of 151.379 milliseconds, and a total packet loss rate of 15.5% were all obtained via the aforementioned method, as demonstrated by the findings. The average speed for a file that is between 256 KB and 16 MB or more is 237.06 KB per second, while the average number of idle channels is 99.221%.

6.1.1 Smart factory energy-aware LB and scheduling (ELBS)

Modern information technology has led to the rise of FC, which improves the computing power of equipment and offers new ways to use old industrial processes. Most of the time, a smart metre can't be used to make a quantitative energy-aware model for LB and scheduling optimisation in a smart workplace. This study suggests a method for ELBS that is based on FC. The method is meant to solve the complex energy consumption problems of manufacturing clusters. First, a workload-based energy consumption model is set up on the FN, and an optimisation function is made with the goal of balancing the load on the production cluster. Figure 14 shows the functional structure of smart factory control using FC algorithms. Then the improved particle swarm optimisation algorithm is used to find the best answer, and the manufacturing cluster is given top priority for getting things done. Lastly, a multiagent system is presented to get the scheduling of the manufacturing cluster done in a distributed way. Tests with a candy packing line proved that the proposed ELBS method works, and the results of the tests showed that the proposed method gives the mixing work robots the best schedules and loads [57].

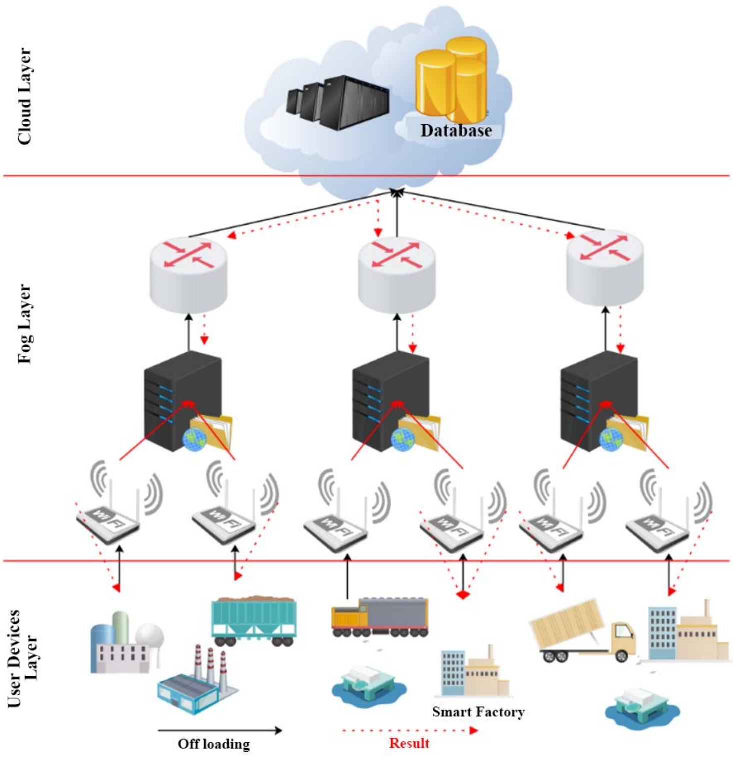

Figure 14. Functional structure of smart factory control using FC algorithms

6.1.2 FC random walk LB algorithm

The main thing that drives the FC concept is the growth of large-scale sensing applications, such as smart city applications. But as the number of people using these fog systems grows, there is a growing need for ways to coordinate them and spread out the load. The problem is made worse by local overload, which can happen when processing tasks (jobs) aren't spread out evenly across the infrastructure [58, 59]. This is common in real-world applications like smart cities, where sensors aren't always placed in the same place and the amount of work can change based on rush hours and how people act. This study discusses two ways to share work so that jobs can be sent to neighbouring nodes. The performance of these algorithms in a real-world setting was tested based on a real tracking application in a smart city. The tests show that even a simple LB plan can handle local hot spots that would happen in a fog system where no one works together.

6.1.3 Create a nature-inspired load balancer and smart health framework for delay sensitivity

A smart healthcare system that makes use of FC and the IoT is currently the most critical thing that can be done. It may be challenging to monitor the increasing load on FNs in networks that are both dynamic and varied. This is because of the significant potential for overhead that exists in these networks. Their processing requirements increase in tandem with the number of different kinds of things that are connected to the IoT. This is where the concept of FC comes into play. Things can go from bad to worse if you wait an excessive amount of time to seek medical assistance. A delay-sensitive smart health strategy has been proposed as a potential solution to this issue in the research that has been conducted. An algorithm for optimising ant colonies serves as the foundation for the framework's load balancer, which was designed with the natural world as its primary source of inspiration. Its primary objective is to lessen the issues that arise with regard to speed and delay. A methodology that is based on nature, the ant colony optimisation technique is a strategy that enhances the efficiency of a system by balancing loads, minimising reaction times, and keeping delays to a minimum when possible. All of these critical aspects, namely, latency, response time, overall system accuracy, and system stability, are areas in which the proposed solution is superior to the state of the art that is now in place. It implies that those in need of assistance receive it more quickly and with better treatment from medical professionals [60].

6.2 Fog Environment LB Resource Allocation Strategy

A relatively new technology that is both adaptable and rapidly expanding is known as the IoT. As a unique move in the direction of going green, it is also a step in the right direction. For the purpose of managing the flow of information in networks of this nature, FC is becoming increasingly popular. This network of devices is both large and complex. There is no limit to the impact that their actions have on carbon emissions and energy costs. It is possible to improve overall efficiency and reduce energy consumption by utilising LB technology, which is a combination of dynamic and efficient. The computer nodes are able to share or pass on the burden thanks to LB, which makes this possible. Therefore, the primary focus is currently on developing LB systems that are more energy efficient and may be used for edge and fog operations. For the purpose of achieving LB in systems that utilise FC, the Dynamic Energy Efficient Resource Allocation (DEER) has been developed. The user is responsible for sending tasks that need to be completed to the Tasks Manager first in the illustrated method. It is the responsibility of the resource information provider to register the resources located within cloud data centres. Once the job and resource information has been gathered, it is subsequently transmitted to the resource scheduler. In accordance with the degree to which they are utilised, the resource planner arranges the available resources in a specific sequence. When information about tasks and resources is sent to the resource engine by the resource planner, the resource engine decides which tasks should be assigned to which resources based on the order of the list. The resource load manager and the resource power manager are both provided with information regarding the current state of the resources when tasks are being carried out [61, 62]. The process of turning resources on and off is utilised by the resource power manager in order to exercise control over the amount of power that is being consumed. It is the responsibility of the resource engine to communicate the result to the user when jobs are completed successfully. According to the findings of the simulation, the implementation of the suggested technique is an effective method for distributing resources in order to achieve LB in fog situations. It consumes 8.67% less energy and costs 16.77% less to perform computations when compared to the Dynamic internal Random-access memory DIRAM technique that is currently in use.

6.2.1 Cloud and fog architecture DLB for energy savings

In the past few years, the number of healthcare IoT devices has grown by a factor of ten, which has led to the creation of a huge amount of data. IoT devices send these complicated and large amounts of medical data to the cloud, where they can be analysed and stored. Most organisations don't like this because of problems with latency, privacy, and security. To get around the problems with cloud-based systems, a new concept called "FC" was developed. Even though FNs have a lot of benefits, they need a lot of energy to work. SDN is a cutting-edge technology that lets software applications be used to "programme" and control networks in a smart and centralised way. In this work, it is demonstrated how the service rate can be used to make an SDN-enabled FC architecture for healthcare data that uses less energy. In this model, they decide whether to send the data in batch mode, which has a faster processing speed, or in listening interval mode, which has a slower processing speed. Compared to the current model, the suggested SDN-based architecture works well and saves energy. This model handles both real-time data flow and load in a dynamic way [63].

7 FC-Enabled IoT Workload Balancing

As latency is the most critical measure of speed for IoT applications, FNs that are located in close proximity to cellular BSs have the ability to transfer computing resources closer to IoT devices. As a result, IoT devices are able to transmit their data flows to FNs in their immediate vicinity rather than sending them to the cloud, which is located at a great distance. The time it takes to deliver data and the time it takes to process data are both components that contribute to the delay of data flows on IoT devices. There are some BSs and fog hubs that are not very active, while others may be overly busy and cause congestion. This is because IoT devices are dispersed in space and time. The manner in which the traffic load is distributed among BSs and the manner in which the computational load is distributed among FNs both have an impact on the level of delay that data flows experience [64]. As a solution to this issue, a workload balancing system that operates within a fog network is proposed. This scheme is designed to connect IoT devices with the appropriate BSs in order to reduce the latency of data flows during communications and processing. In addition, it is demonstrated that the proposed strategy for achieving a balance between work and personal life is not only very effective but also convergent. It was determined that the proposed LB system was superior for fog networking after conducting a number of experiments and comparing their performance.

7.1 FC Sequential Randomization LB

FC is seen as a key way to meet the computing needs of the billions of items, or "things," that are expected to be in use soon. FNs can be thought of as small clouds that are set up close to the user. They are a complement to the big cloud that is far away. Even though load balance between FNs isn't talked about much, it might make it easier for FNs to provide computation services. After looking at LB among FNs, this study tries to solve the problems that the fog model brings up. In particular, the way to use the PRC feature to take advantage of random-based LB protocols is examined. Sequential probing is suggested instead of parallel probing, which is how most randomization methods work. It has been shown that the proposed answer is better through mathematical analysis and simulations [65].

7.1.1 A fog or edge computing LB algorithm for latency equalisation

In the context of edge or FC environments, the service latency that a user experiences at a particular node can be interpreted as an indicator of the level of activity that is present at that node in comparison to the other nodes. In fact, merely observing the typical amount of time spent by the CPU or the amount of RAM that is being utilised, for instance, does not provide a clear picture of the load situation. This is due to the fact that these characteristics are not dependent on either the software or the hardware.

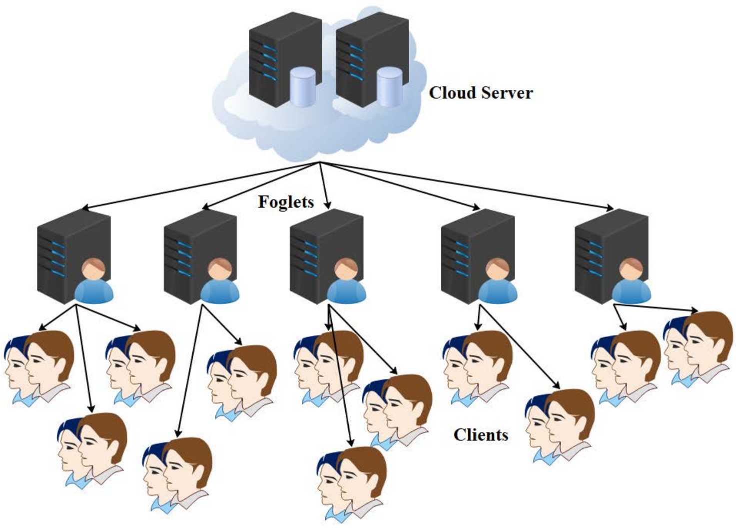

Figure 15. Data flow structure for fog or edge computing LB algorithm for latency equalisation

They do not provide information regarding how the programme is functioning from the perspective of the user. Therefore, they cannot be utilised for LB that is based on QoS. A method for LB is proposed in this work. The algorithm takes into account service latency and makes an effort to ensure that it is the same for all nodes in a manner that is entirely decentralised. No user's QoS is inferior to that of the others in this manner. A data flow structure known as the fog or edge computing LB algorithm for latency equalisation is depicted in Figure 15. Both in simulation and in a real-world deployment based on a cluster of Raspberry Pi boards, it is demonstrated that the proposed approach can level the service latency across a set of heterogeneous nodes organised in different topologies [66]. This is accomplished by providing a differential model of the system and an adaptive heuristic to uncover the solution to the problem in real-world settings.

7.1.2 Health monitoring system LB

The health monitoring systems have begun to have issues, such as the inability to process data swiftly or the slowness with which they do so [67]. This is a result of the growing volume of data and devices that generate data in healthcare settings. The IoT, CC, FC, and wireless sensor networks (WSN) have all been utilised by individuals in the development of various health monitoring platforms. Building the majority of the tools that monitor health has been accomplished through the use of CC architecture. However, the high latency that is produced by the cloud-based architecture while processing huge amounts of data makes it difficult to deploy healthcare applications on a broad scale, especially if they are sensitive to latency. The latency issue is resolved by FC, which also improves scaling, access to resources, and security levels on demand. This is accomplished by bringing computers closer to their users. This study proposes a fog-based architecture for a health monitoring system with the intention of minimising latency and network utilisation. When the health tracking system is utilised on a wide scale, it also demonstrates a new LB method that is suitable for distributing the load among FNs. A large number of simulations were carried out in the iFog Sim toolkit in order to demonstrate that the suggested method is effective. The results of these simulations were compared with those of the cloud-only version, the FN Placement Algorithm (FNPA), and the LB scheme in terms of latency and network utilisation. The proposed implementation of the health monitoring system significantly minimises the amount of network utilisation and latency when compared to cloud-only, FNPA, and LB schemes.

7.1.3 Resource management and LB in fog-IoT computing

FC is a new way to run software for the IoT. In CC, a network of computers and storage is used. In FC, devices at the endpoints are talked to directly. IoT applications are those that use fog or CC nodes to respond to resource needs. These applications are used to watch and control everything from smart cars to home appliances. LB is very important if you want to get the most out of your resources and avoid jams, overloads, or low loads. This study examines different studies about LB to get a full picture of the idea. In addition, this study compares different types of methods that are meant to spread out the work between FNs. The piece also talked about problems and opportunities in the field, as well as the different ways that LB systems are measured [68].

7.2 IoT Healthcare FC

A significant number of aspects of people's lives are significantly impacted by the presence of technology. Technology has been of great assistance in reducing the amount of material and human waste that is produced in hospitals. This has been accomplished through the utilisation of the IoT and LB of cloud nodes. This is accomplished by sending and saving data from sensors that are located on the edges of the nodes. Following the encryption of the data using a form of light encryption, the data is subsequently transmitted to other servers. This not only makes the health system more secure, but it also speeds up the servers and reduces the amount of energy that is used, which in turn saves time and reduces losses. There were dozens of research papers that had been published in international publications, and this study was a comprehensive and in-depth examination of all of those papers [69]. Here are a few instances that illustrate my point: In the first round of this study, 1,200 research articles in this area were examined and analysed. Approximately 30 of them were selected, which focused on the actual issues that were occurring within the system. A sample of ten articles that provided a summary of what had been learned from earlier research and problems was taken from a survey and study that was conducted on a total of five hundred scientific papers about LB in the healthcare system.

7.2.1 Delay-aware computation offloading

This study examines the computational offloading scheme for end-user jobs in the FC network that are sensitive to delays. A fog union of different service providers (SPs) is observed, in which each FN gives its computing resources to the end user closest to it, and a fog manager balances the load across all FNs in the network. At first, each FN tries to make the most money it can by selling computing resources to end users in a way that doesn't require it to know everything about the network. To make sure that all of the FNs in the fog federation bring in as much money as possible, the fog manager uses the underutilized FNs' remaining computing power. The extensive simulation results show that income can be increased by using fog federation across the whole network, while end-user delay performance stays the same or even gets better [70].

7.2.2 Heterogeneous network-bound FC

The popularity of IoT applications leads to an increase in the number of devices that are connected to the internet and encourages the utilisation of a "FC" model to handle huge infrastructures that are dispersed over a number of locations. To ensure that activities are carried out without any hiccups, LB solutions are required. This is due to the fact that nodes and their connections are distinct from one another. This is an extremely crucial component, particularly in situations when certain nodes experience lengthy connection delays. The sequential forwarding technique is one of the ideas that have been proposed in the articles as a potential method for LB in FC systems. The algorithms in question, however, have not been tested for a diverse set of operating parameters in an environment that is heterogeneous. The highly diverse network delays that are typical of fog infrastructures are not something that they are designed to take advantage of either. This study [71] provides two significant contributions to the conversation. First, the sequential forwarding algorithm is put through its paces by putting it through a series of tests that simulate a variety of load and delay scenarios. Then a delay-aware version of the algorithm is designed and tested. This version takes into account the fact that the connectivity between nodes in the infrastructure can easily change. A delay-blind approach to sequential forwarding may not perform effectively for LB when network delay is a significant component of the response time, as demonstrated by the findings of the experiments, which were carried out with a network topology that depicts the real world. Furthermore, it is demonstrated that the delay-aware embodiment of the algorithm has the potential to be of assistance in this scenario by reducing the reaction time by as much as 6%.

7.2.3 Task offloading in IoT-fog

Due to intermittent WAN delays and multi-hopping, IoT devices with limited resources often send tasks to FNs so they can be done on faraway cloud servers. A good allocation strategy meets the needs of users by making sure that transfer delays are kept to a minimum and giving SPs a fair share of the work. This study describes a model called LETO that reduces the total offloading delay for real-time jobs and makes sure that each FN gets an equal share of the work. Modelling the whole problem as a one-to-many matching game with maximum and minimum limits is a good way to think about it. Due to the fact that the deferred acceptance algorithm (DAA) can't be used, the multi-stage deferred acceptance algorithm (MSDA), which is a more advanced version of the DAA, is used to assign jobs to FNs in a fair and Pareto-optimal way. A lot of simulations have shown that LETO can make a more balanced assignment than the standard algorithms [72].

7.2.4 Game and transport theory

Technological advancements in FC and narrow-band IoT (NB-IoT) radio are essential for the next generation of massive machine-type communication (mMTC) applications. It is becoming increasingly difficult for NB-IoT devices to communicate with one another, despite the fact that the number of NB-IoT devices continues to expand. In addition, the problem of LB in the fog network in order to ensure that computing resources are distributed fairly is brought up when attempting to figure out how to assign different computing jobs in the most effective manner. For the sake of this investigation, a fog LB problem is devised that acknowledges the constraints imposed by communication and computing. One of the objectives is to lessen the expenses associated with LB in a FC network that makes use of NB-IoT. The challenge of how to schedule time and resources in NB-IoT is first mimicked by using a game that simulates personal insolvency. To schedule uplinks for mMTC applications on NB-IoT devices while simultaneously determining the transmission pricing of the computational jobs, the Shapley value-based strategic policy is used within the context of the game framework. Another method that is recommended is called greedy iterative time scheduling (GITS), which is comparable to the Shapley value-based scheduling method but is simpler to implement. Second, the fog LB problem is segmented into a Hitchcock-Koopmans transportation problem. This problem provides us with information regarding which FC nodes are overused and which are underused, depending on the amount of processing power that they are utilising. Vogel's approximation method (VAM) is then utilised in order to solve the transportation problem [73]. This method is designed to discover a LB solution that is both practical and effective in order to guarantee that jobs are assigned in the FC network in the most effective manner feasible. When it comes to balancing job loads on average, the findings of the simulation reveal that the proposed strategy is significantly more reasonably priced than the baseline methods.

7.3 Smart Factory Space-Time Characteristics

Intelligent production is able to produce larger results and becomes more effective now that FC is available. To provide task-related resources that are both dispersed and located in close proximity to these FNs, FNs on a FC platform have the ability to deliver these resources. When it comes to providing high-performance services with a FC platform, the right deployment of FNs is a criterion that must be met in order to effectively implement FC. Intelligent manufacturing is a space-time discipline, and FNs work in a number of various ways. This is the reason why this is the case. When it comes to intelligent manufacturing systems, standard deployment strategies, on the other hand, are incapable of meeting the performance standards that are desired. The purpose of this work is to give an analysis of the problem of FN deployment, and it does so by proposing a technique for deploying FNs that is based on space-time features (TSBP). The model of the FN deployment system is built, as well as the objective function of the FN deployment and its deployment. A model has been constructed. Optimising the system is done with the intention of reducing the amount of time it takes for the computer to reply and ensuring that the FNs are responsible for a portion of the workload. Furthermore, in order to identify the most efficient approach to configuring FNs, the discrete differential evolution method is utilised. This is done at the same time. In conclusion, a candy packaging intelligent production line prototype platform is employed in order to evaluate the efficiency of the TSBP effort [74].

7.3.1 Ant colony algorithm-based multi-objective FC task scheduling

By relocating cloud services to the edge of the network, FC has the potential to cut down on response times and make more efficient use of available resources. For FC, however, the theoretical understanding and actual work that has been done about the scheduling of activities are not sufficient. This is due to the fact that there are numerous types of fog equipment and different types of computing power. On the other hand, the cost of computing equipment, the cost of electricity, and the cost of the network were not taken into full consideration while the jobs were being scheduled. An improved ant colony algorithm serves as the foundation for the proposed multi-objective FC task scheduling approach. Because of the properties of the FN, this technique improves the ant colony algorithm so that it is more suitable for use. Additionally, it makes use of time and cost (TAC) in order to take into consideration the cost of the node in a manner that is more comprehensive. In conclusion, it implements a crucial component in the process of work allocation in order to hasten the convergence of the algorithm. Several simulations demonstrate that the modified ant colony method is superior in terms of the amount of time required for processing, the amount of money required, and the ability to evenly distribute the load [75].

7.3.2 Drone-assisted IoT communications traffic LB

Edge computing lets IoT devices store and process data in local FNs and also lets IoT users' access IoT apps through these nodes. In this case, the transmission latency has a big effect on how long it takes for IoT devices to respond to user requests. Because IoT users [i.e., user equipment (UE)] are spread out in different places at different times, drone BSs (DBS), which can be set up in hotspots in a flexible way, may be able to improve the wireless delay of IoT users by reducing the heavy traffic loads of macro-BSs. There are two big problems with drone-based communications: 1) The DBS should be set up in places with a lot of traffic so that it can serve more UE. 2) The traffic loads in the network should be split between large BSs and DBSs so that they don't cause traffic jams. Therefore, a way is suggested to balance the traffic load in a drone-assisted fog network so that IoT users have the least amount of wireless latency. In the plan, the problem is broken into two smaller ones and two algorithms to solve each one. These algorithms optimise the placement of the DBS and the way users are grouped together. A lot of simulations have been set up to test how well the suggested plan works [76–78].

8 Trends, Architectures, Requirements, and Research Directions in FC

New technologies, like the IoT, need computation that takes delay into account so that applications can run in real time. When things are tied to the internet, they create a lot of data, which is usually called "big data." IoT devices usually send data to the cloud, which can handle it because it offers on-demand services and can grow as needed. But only handling IoT application requests in the cloud isn't always the best way to go for some IoT applications, especially ones that need to work quickly. To solve this problem, FC, which is somewhere between the cloud and IoT devices, was suggested. Most of the time, IoT devices are linked to Fog devices in a FC system. Near people, these Fog devices do compute and storage in the middle. Scheduling tasks and allocating resources is one of the hardest parts of running IoT apps in a FC context. As FC research is still very new, it needs to be mapped to current research using taxonomies to look into the needs of fog infrastructure, platforms, and apps. This survey helps the research and business worlds come up with a list of FC needs. This essay starts with an outline of FC, going over what FC is, what the study trends are, and how FC is different from CC technically. Then a number of suggested FC architectures are examined and the parts that make these architectures work are deeply studied. This helps define the job of each part, and also the use of FC [78–81]. Next, a classification of FC is suggested based on the FC paradigm's needs. This study also discusses previous studies and gaps in fault tolerance, scheduling and allocating resources, simulation tools, and fog-based microservices. Lastly, some problems with the current study are discussed, and some open issues that help decide the direction of future research in the FC paradigm are raised.

8.1 FC Task Scheduling

Combining FC and CC lets some work happen closer to where the data is being made, at faster speeds and without the need for a lot of bandwidth.

FC is useful for real-time systems that need to connect to the internet quickly. The fact that FNs don't have a lot of resources makes it hard for FC to meet changing needs in real time. So, one of the problems in the fog environment is how to best assign jobs to FNs. For a scheduling algorithm to work well, it should lower costs and energy use while also taking into account how different FNs are and how committed people are to getting things done on time [82–92]. This study gives a thorough taxonomy to help us understand the research problems better and points out important problems with previous work. This article gives a structured overview of the different job scheduling methods that are available for a cloud-fog environment, along with their pros and cons. These methods are divided into four main groups: those that use machine learning, those that use heuristics, those that use metaheuristics, and those that use deterministic mechanisms. In each group, a number of works are looked at. This study also looks at how different task schedule methods compare in terms of how long they take to run, how well they use resources, how much time they take, how much energy they use, how fast they respond, how much they cost, how uncertain they are, and how complicated they are. It was found that 38% of schedule algorithms use metaheuristic-based methods, 30% use heuristic-based methods, 23% use machine learning algorithms, and the remaining 9% use deterministic methods. The most important factor that most papers talk about is energy use, which makes up 19% of the total. Lastly, a number of important ways that the FC's job scheduling methods could be made better in the future are shown.

8.2 Concept, Building, Applications, Benefits, and Open Issues of FC

The IoT is becoming more and more common in people's everyday lives. It's an exciting new technology that makes the lives easier. Connecting IoT devices to a central CC is what makes it work. CC is a huge data centre that collects data from IoT devices and can be placed anywhere needed [83, 84]. CC, on the other hand, can't send data because of the infrastructure and limits of networks, which makes it much less useful. FC technology is a new way of thinking that was created to act as a bridge between the cloud and the IoT. If you think of Fog as an extension of the cloud that offers computing services at the edge of the network, this technology can handle a lot of data locally. This study examines FC in detail and discusses the newest research that has been done to deal with and solve the problems that are already happening in FC. The FC technology is studied in a broad sense and defined based on previous research. This study also examines its design, uses, benefits, and open issues, with optimisation methods being used to get the best services.

9 Conclusion

This article presents the findings of an in-depth study that was carried out on the topic of workload allocation among IoT devices that are utilised in FC networks. The investigation was carried out by the authors of this article. The researchers who contributed to this article were the ones who carried out the study. When applying the various strategies, a substantial amount of consideration was given to a large number of different parameters. These attributes included things like latency, energy consumption, time complexity, average throughputs, reaction time, execution time, error detection rate, and a whole host of other variables. When it comes to workload allocation in FC networks, there are many different approaches that may be used. For each of these use cases, the performance has been evaluated in terms of how efficient it is in comparison to these other methodologies. These shortcomings can now be remedied as a result of the deployment of a wide variety of solutions, which include SDN, double-Q learning algorithms, SFC, VNF, and a great deal of other options. In order to meet the requirements of this paper, an exhaustive survey on the subject of workload distribution for the IoT in FC networks was carried out. In order to improve the effectiveness of data transmission inside FC networks, a comprehensive study that is centred on parameters has been carried out. It is possible to find these methods in the field. This in-depth study will prove to be of immense assistance in completing the task that is now being provided, allowing for increased adaptability, increased accuracy, and increased efficiency. As a result of this analysis, research work will be carried out to identify improved simulation tools, validate data sets, enhance data propagation, and select multipaths for optimal power consumption. The goal of this work is to achieve better results in terms of data transmission and propagation in multiple dimensions.

Data Availability

The data used to support the research findings are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflict of interest.

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