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Load Balancing Approaches in Fog Computing : A Systematic Review

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ABSTRACT

Fog computing is the extension of Cloud computing. Whenever comes under the concept of Load balancing, it distributes the n/w traffic to prevent failure caused by overloading a particular resources. Load balancing act as an invisible mediator facilitator between a clients and group of servers, such that any connection request does not get lost. Without load balancing, applications, websites, database and online services would likely fails when demand gets too high. Load balancing uses a predefined pattern known as Load Balancing Algorithm. Load balancing in the fog layer optimizes resource usage, leading to reduced latency and improved quality of service. Many load balancing techniques have been proposed for fog computing. An empirical study has examined these existing methods and presented a hierarchical taxonomy. Moreover, the article offers a detailed annual review and summary of research articles focused on load balancing from 2012 to 2023. In this literature survey, we will explore various load balancing algorithms proposed for fog computing systems.

We will examine their strengths and weaknesses, as well as their performance in different scenarios. This survey aims to provide insights into the state-of-the-art techniques for load balancing in fog computing, which can help researchers and practitioners to choose the most suitable algorithm for their specific use cases.

Keywords : Cloud computing, Fog computing, Load Balancing, Resource management, IoT

INTRODUCTION

Load balancing algorithms play a vital role in optimizing the performance of fog computing systems by efficiently distributing workloads among fog nodes. Due to the fast expansion of the Internet of Things (IoT) and edge computing, fog computing has surfaced as a viable solution for managing the escalating

volume of data produced by IoT devices. However, effective load balancing is necessary to ensure that the fog nodes can handle the workload without being overwhelmed, which can result in degraded performance and increased latency. In this literature survey, we will explore various load balancing algorithms proposed for fog computing systems. We will examine their strengths and weaknesses, as well as their performance in different scenarios. This survey aims to provide insights into the state-of-the-art techniques for load balancing in fog computing, which can help researchers and practitioners to choose the most suitable algorithm for their specific use cases.

Load Balancing Algorithms: Literature survey

In this section, we have discussed various load balancing algorithms that have been proposed by different researchers to implement load balancing in fog computing.

Nitin Kumar Mishra and Nishchol Mishra [1] demonstrated a load balancing technique based on aspect of building practical execution of a single processor and ensuring that the processing workload is distributed equally among all available resources. In the context of fog computing, load balancing algorithms are essential for efficiently utilizing the resources available in fog nodes.

Harshit Gupta and Kalicharan Sahu [2] developed a load balancing method inspired by Honey Bee behavior. This technique aims to enhance the response time of client applications by effectively utilizing available resources. These algorithms work by distributing the workload among different nodes or servers in a way that optimizes resource utilization and reduces response time. This can help prevent overloading of certain nodes and improve the overall performance of the system.

Ratan Mishraand & Anant Jaiswal [3] defined a load balancing algorithm based on Ant colony optimization, inspired by the foraging behaviour of ants. This approach has been utilized to address a range of optimization challenges, such as load balancing within fog computing environments. ACO is used to find the optimal solution by simulating the behaviour of ants in finding the shortest path between their nest and a food source.

Anil Singh and Nitin Auluck [4] talked about an ILP-based algorithm that considers minimum hop distance (MHDL), minimum load, and minimum distance aspects. This algorithm is defined the scheduling the workload among different fog nodes.

Wang et al. [5] discussed an algorithm of fog node problem based offloading load balancing to improve the resource allocation by balancing computation between fog nodes and the cloud while reducing energy consumption. The framework considers the processing capabilities of fog nodes, the amount of data to be transferred, and the energy consumed by the nodes. By offloading tasks to fog nodes instead of relying solely on fog resources, the framework improves response time, reduces network traffic, and ensures efficient resource utilization.

Pereira et al. [6] improved a Dynamic load balancing. It refers to the process of distributing tasks or workload across a network of devices that differ in their processing capabilities, storage capacity, and communication bandwidth.

Subhan Tariq and colleagues [7] developed a load balancing technique that incorporates cloud and fog computing, using a priority-based approach. In priority-based load balancing the highest priority-based job will be the first choice for choosing the fog by load balancer.

Koushik Dasgupta et al. [8] demonstrate a Genetic based load balancing strategy which is used to locate the best possible solution for a large search space. The algorithm comprises three main operations: replacement, genetic operation, and selection. These operations work together to optimize the solution and find the most efficient outcome.

Bin dong et al. [9] firstly introduced a dynamic and adaptive load balancing technique for large and dynamic file systems by using a centralised system. They have been proposed a SALB (Self-Active Load Balancing) algorithm to overcome the limitations of traditional load balancing algorithms.

Huankai Chen et al.[10] & Shyam Singh Rajput et al.[11] designed a min-min algorithm to manage the load. It is a heuristic algorithm that works by selecting the task with the smallest estimated completion time and assigning it to the resource with the lowest estimated completion time.

Kumar Nishant et al. [12] proposed a Throttled load balancing algorithm which worked on the VM selection mechanism in their Throttled Algorithm to improve its performance. Specifically, they suggest selecting the next available virtual machine (VM) based on its state when a new request arrives, instead of simply assigning it to the next available VM.

Dr. Amit Agarwal & Saloni Jain [13] defined a modified priority-based algorithm called Generalised priority algorithm. It assigned the task according to priority as well as processing power of the virtual machine of the network.

L.D.Dhinesh Babu and P. Venkata Krishna [14] introduced a load balancing concept for fog computing inspired by the behaviour of honeybees. It is bio-inspired load balancing algorithm that mimics the foraging behaviour of honey bees. In fog computing, the HBB algorithm is used to balance the workload of fog nodes by considering the available resources and the tasks' processing requirements. The HBB algorithm helps to improve the overall system performance and minimize the response time of user requests.

Elsharkawey et al. [15] performed an operation on workload using Real-time efficient (RTES) algorithm. This algorithm is commonly used in time-sensitive applications such as process control, robotics, multimedia, and telecommunications.

C Dsouza et al. [16] demonstrated Max-Min algorithm. The Max-Min algorithm is similar to the Min-Min algorithm in that it aims to minimize the execution time of tasks, but it differs in that it starts with the tasks that have the longest completion time.

Venkateshwarlu Velde & B. Rama [17] performed load balancer by using Opportunistic load balancing algorithm (OLB) which tries to keep busy every node using resource management of workload. This algorithm tries to every node in working condition.

Menon H et al. [18] introduced a new algorithm to manage the workload as Graph re-partitioning and mapping-based load balancing algorithm. The authors presented a runtime system that is adaptive and comes with an automatic load balancing mechanism.

Verma and colleagues [19] presented multiple load balancing approaches in their paper, covering both hardware-based and software-based methods. They provided an overview of load balancing algorithms, including techniques like load balancing inspired by honeybee behaviour and genetic- based algorithms for load balancing tasks.

Katyal and Mishra [20] explored two primary tasks associated with load balancing, namely resource allocation or provisioning and resource scheduling. They assessed the performance and efficiency of load balancing algorithms based on these tasks. The authors evaluated the performance of various load balancing algorithms by using the CloudSim simulator. They measured the effectiveness and efficiency of the algorithms in terms of factors such as response time, throughput, and resource utilization.

Kalraand Singh [21] introduced algorithms utilizing various meta-heuristic optimization techniques, used to solve complex problems that are difficult to solve using traditional optimization techniques.

Ahmad AA AlKhatibet et al.[22] demonstrated a random algorithm. The data centre unit selects one of the available virtual machines at random after the VMs are selected. The unit arranges the order of the virtual machines in a circular manner, and any VM that receives a request is moved to the bottom of the list.

In the below table, we have summarised the existing load balancing algorithm present in fog computing.

Table 1: Summary of existing load balancing in fog computing

Authors	Year	Load Balancing Approaches	Explanation
Nishchol Mishra & Nitin Kumar Mishra [23]	2015	A systematic workload distributed load balancing among processors	Improving the performance by redistributing work load among the fog network framework.
Harshit Gupta & Kalicharan Sahu[24]	2015	Load Balancing based on Honey Bee behaviour	Improve the response time by ensuring maximum utilisation of available assets.
Ratan Mishra & Anant Jaiswal[25]	2012	Ant colony optimization based load balancing	Ant colony optimization is employed to address load balancing challenges within fog computing.

Anil Singh and Nitin Auluck[26]	2019	MHDL (Minimum Hop Distance and Load) and the minimum distance heuristic algorithm	Load balancing aware scheduling ILP (LASILP) proposed for solving of workload.
Wang et al.[27]	2019	Task offloading challenge utilizing Stackelberg game theory	Economy-based task offloading approach
Pereira et al.[28]	2019	Dynamic load Balancing	Task distribution in heterogeneous environment
Subhan Tariq et al.[29]	2018	Load balancing with priority emphasis in cloud and fog environments	In priority based load balancing the highest priority based job will be the first choice for choosing the fog by load balancer.
Kousik Dasgupta et al.[30]	2013	Genetic-based algorithm load balancing strategy	Strategy which is used to locate the best possible solution for a large search space.
Bin dong et al.[31]	2012	A dynamic and adaptive load balancing strategy	Adaptive load balancing technique for large and dynamic file systems by using a centralised system.
Huankai Chen et al.& ShyamSingh Rajput et al.[32]	2013 2016	Min-Min Algorithm	Heuristic algorithm that works by selecting the task with the smallest estimated completion time and assigning it to the resource with the lowest estimated completion time.
Kumar Nishant et al.[33]	2012	Throttled Load Balancing Algorithm	VM selection mechanism in their Throttled Algorithm to improve its performance
Dr. Amit Agarwal & Saloni Jain[34]	2014	Generalized Policy Algorithm	It assigned the task according to priority as well as processing power of the virtual machine of the network.
L.D.Dhinesh Babu & P.Venkata Krishna[35]	2013	Honey bee behaviour inspired load balancing algorithm	It is bio-inspired load balancing algorithm that mimics the foraging behaviour of honey bees.
Elsharkawey et al.[36]	2018	(RTES) Real-time efficient algorithm	RTES algorithm is to effectively balance the workload in a real-world scenario where tasks need to be completed within a defined time frame, while also maximizing network utilization and throughput.
C Dsouza et al.[37]	2015	Max-Min Algorithm	The Max-Min algorithm aims to minimize the execution time of tasks, similar to the Min-Min algorithm, but with the difference that it starts with the tasks that have the longest completion time.
Venkatesh warlu Velde & B. Rama[38]	2018	Opportunistic Load Balancing Algorithm(OLB)	Opportunistic load balancing algorithm (OLB) which tries to keep busy every node using resource management of workload. This algorithm tries to every node in working condition.

Menon H et al.[39]	2015	Graph re-partitioning and mapping-based load balancing algorithm	Load balancing system that is automatic and adaptive in runtime.
Vermaet al.[40]	2015	Load balancing with hardware and software components	Workload depends on the Hardware and the software of the VM.
Katyal & Mishra[41]	2014	Resource management and scheduling	Effectiveness and efficiency of the algorithms in terms of factors such as response time, throughput, and resource utilization.
Kalraand Singh[42]	2015	Meta-heuristic optimization techniques	Solve complex problems that are difficult to solve using traditional optimization techniques.
Ahmad AA AlKhatibet et al.[43]	2020	Random algorithm	The data centre unit selects one of the available virtual machines at random after the VMs are selected.

Result Analysis & Discussion

A: Taxonomy of Algorithms

There are various load balancing strategies that have been proposed in the literature to achieve this. However, due to the diversity of the Fog environment, it is challenging to classify and compare the different load balancing strategies. Therefore, a taxonomy of load balancers can provide a useful framework for organizing and comparing different load balancing strategies in Fog computing. This literature survey aims to present a comprehensive taxonomy of load balancers in Fog computing based on different factors such as balancing criteria, architecture, communication, and deployment. Based on the various research papers, we summarise the taxonomy of the load balancer in fog computing using a flowchart.

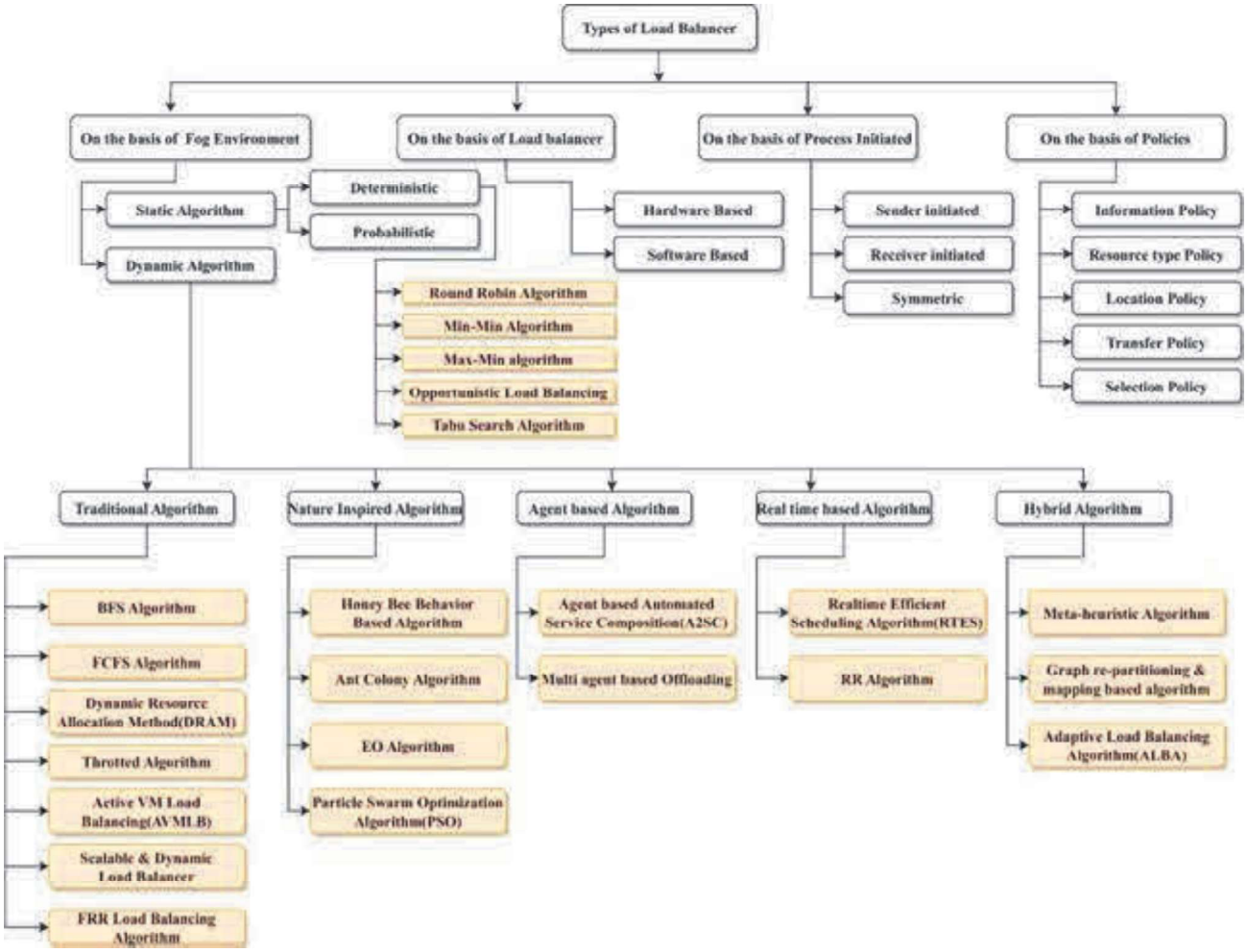


Figure 1: Show the Load Balancing Taxonomy and the Algorithm applied in fog computing.

B: Analysis of Literature study

In the previous section, we covered existing load balancing algorithms used in fog computing. This section, however, will focus on additional algorithms related to experimental setups, as well as their advantages and disadvantages in terms of their performance. We have summarized the review of the research paper in the below table and also analyzed their simulation techniques.

Table 2: Summary of the experimental setup of the researcher

Article	Main Idea	Evaluation	Tool
[44]	Load balancing algorithm using hill climbingapproach in fog system	Simulation	CloudAnalyst
[45]	Load optimization through heuristic Min-conflicts method	Simulation	CloudAnalyst
[46]	Load management approach utilizing AHP method for Multiple Gateways in fog computing	Simulation	MATLAB
[47]	Load-based resource management for fog cluster nodes	Simulation	Not-Mentioned
[48]	A heuristic virtual machine (VM) scheduling mechanism for load balancing	Simulation	CloudSim
[49]	SDN-based load balancing in cloud/fog environments	Simulation	Not-Mentioned
[50]	SDN-driven load balancing in fog/cloud infrastructure	Simulation	MATLAB
[51]	A fog/cloud system and big medical data based on bat algorithm considering load balancing	Simulation	MATLAB
[52]	Load management for large-scale machine-type communications in fog networks	Simulation	Not-Mentioned
[53]	Load distribution based on the Shortest Job First (SJF) approach	Simulation	CloudAnalyst
[54]	Load-aware resource allocation in fog/cloud environments	Simulation	CloudSim
[55]	Effective data replication considering load balancing	Simulation	CloudSim
[56]	Load distribution using metaheuristic techniques in fog-cloud environments	Simulation	Java
[57]	Load balancing method for load stabilization in fog environment	Simulation	CloudAnalyst

[58]	State-based load balancing method for SG energy management in fog	Simulation	CloudAnalyst
[59]	Integration of fog-cloud based system for load balancing by applying bin packing and genetic methods	Simulation	CloudAnalyst
[60]	A load balancing strategy based on genetic algorithm and Q- learning in the fog-based healthcare system	Simulation	MATLAB
[61]	Load distribution mechanism in live fog systems employing neural network and fuzzy logic algorithms	Simulation	iFogSim
[62]	Load distribution approach in a massive fog environment	Simulation	iFogSim
[63]	Fuzzy logic-based load balancer for fog environments	Not-Mentioned	Not-Mentioned

Conclusion & Future Scope

In conclusion, this systematic review paper has explored a wide range of load balancing techniques in fog computing. Through an in-depth analysis of research articles published between 2012 and 2023, we have identified various strengths and weaknesses of these techniques. The review highlights the importance of load balancing in optimizing resource utilization, reducing latency, and enhancing the overall quality of service in fog computing environments. Our comprehensive examination of different load balancing algorithms provides valuable insights for researchers and practitioners to make informed decisions regarding the selection and implementation of suitable techniques for specific use cases. Moving forward, further research and experimentation are warranted to address emerging challenges and improve the effectiveness of load balancing solutions in fog computing systems.

Overall, the future scope of load balancing techniques in fog computing is rich with opportunities for innovation and advancement, paving the way for more efficient, reliable, and scalable fog computing infrastructures.

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