As per UGC guidelines an electronic bar code is provided to seure your paper

International Journal for Modern Trends in Science and Technology, 8(02): 134-143, 2022

ISSN: 2455-3778 online
DOI: https://doi.org/10.46501/IJMTST0802022
Available online at: http://www.ijmtst.com/vol8issue02.html

Meta-heuristic Algorithms for Resource Allocation in Fog Computing

Asma'a Hassan salem[1*] | Ghaleb Al-Gaphari[1]

[1]Computer Science, Faculty of computer science and technology, Sana'a University, Sana'a, Yemen.
Corresponding Author: samo.aldows@gmail.com

To Cite this Article
Asma'a Hassan salem and Ghaleb Al-Gaphari. Meta-heuristic Algorithms for Resource Allocation in Fog Computing. International Journal for Modern Trends in Science and Technology 2022, 8 pp. 134-143. https://doi.org/10.46501/IJMTST0802022

Article Info
Received: 15 January 2022; Accepted: 06 February 2022; Published: 14 February 2022.

ABSTRACT

Resource allocation in fog computing is inherently a challenging task due to the increase in the number of fog users working on multifarious fog applications in some of the infrastructure. The majority of resource allocation techniques existing till have focus on providing performance driven by the workload of the applications from diverse domains like scientific and business. This paper presents a detailed review of meta-heuristics algorithms for resource allocation in fog computing environment. The reviewed meta-heuristic algorithms are capable of achieving much higher performance, reduction in a cost, reduction in time, improve utilization of resources, improve energy efficiency while resource allocation in fog.

KEYWORDS: *Fog computing, load balancing, Quality of Service, Internet of things, metaheuristic, resource allocation.*

1. INTRODUCTION

During the last few years, Cloud Computing has significantly improved access to networked computing resources and the way they can be utilized, often based on pay-as-you-go pricing models [1]. The cloud environment reduces the computing and storage load of traditional data storage system. After the development of IoT, several problems come to light in the cloud computing platform.

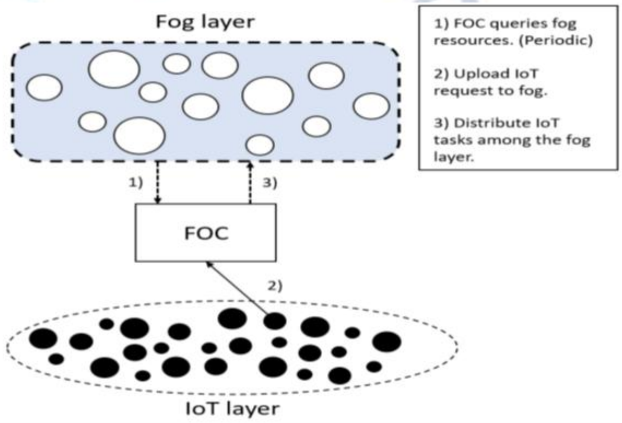
The number of Internet of Things (IoT) devices has increased for developing of new IoT applications in many different domains to enhance the quality of human life [2, 3].With the rapid development of IoT applications, In order to enhance Cloud Computing technology, another approach called Fog Computing (aka fogging) has recently been introduced [4]. fog computing is an emerging distributed computing paradigm that has recently attracted the attention of both industry and academic community for guaranteeing the requests of computational applications in IoT smart devices [5, 6]. Fog Computing is a new architecture for the internet of things, with an intermediate layer between local and Cloud. In Cloud data have been moved on large servers remotely, away and accessible via the Internet. But the Cloud model is not perfect. Above all it is designed to hold the data but not to react in real time. And the real time is the key for the internet of things: without this readiness we could not run the cars that drive themselves, smart cities, and so on [7].

Fog Computing is a highly virtualized platform that provides compute, storage, and networking services between end devices and traditional Cloud Computing Data Centers, typically, but not exclusively located at the edge of network [8]. The Fog extends the Cloud to be closer to things that produce and act on IoT data. These devices, called fog nodes, can be deployed anywhere with a network connection: on a factory floor, on top of a power pole, alongside a railway track, in a vehicle, or on an oilrig.

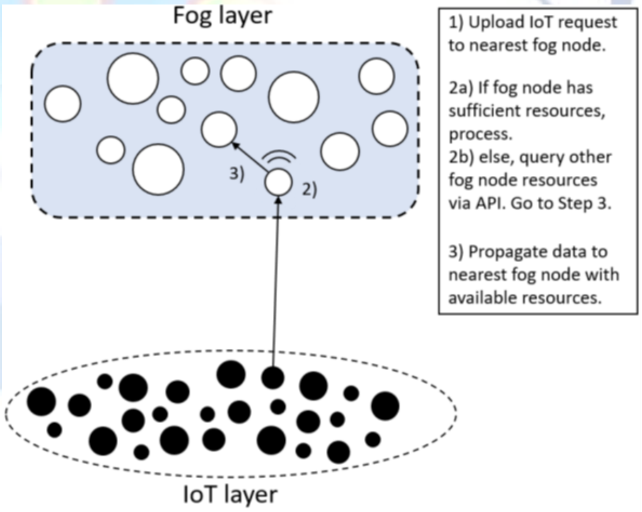
Since The resource allocation is an important issue because of the fairness in resource allocation that ensures the Quality of Service (QoS) standards, which displayed in Figure 1. In this regard, different data streams are separated and different denial-of-service attacks are disputed to ensure a high standard of security, which is obtained by resource allocation. The available resources are considered as an exchangeable energy, processing power, and storage capabilities. This network has progressed in performance by allocating these IoT resources efficiently. The IoT has distributed and heterogeneous nature, therefore, its optimal resource allocation is not negligible [9, 10]. However, there are many new challenges for resource allocation in the fog computing, which needs new solutions. Resource discovery and monitoring play an important role in supporting the resource allocation. Since resource allocation plays an important role in the fog computing. Furthermore, due to the fog nodes have generally energy consumption problem, the efficient resource allocation effects on fog nodes lifetime. On the other hand, due to the highly variable and unpredictable fog environment, it necessitates the resource management issues as one of the challenging problems to be taken into account in the fog landscape. Hence, the reasonable management of fog nodes even for the case studies maximum load and high mobility is necessary to increase the fog computing efficiency [11]. In this paper, the emergence of fog computing with different resource allocation strategies has been discussed by using various parameters such as utilization, customer satisfaction, price, reliability, demand, efficiency, power generation, resource utilization and the last but most important aspect of fog quality (QoS) [13].

1.1 Metaheuristic Approaches

Standard resource allocation methods are not enough for fog as they are depended on virtualization mechanism with distributed environments. Due to heterogeneity in the strength of Hardware, load balancing, and features towards meet the Service Level purpose of fog purchaser applications, fog computing propose new challenges for manageable and flexible resource allocation. The utmost objective of computing fog computing resources is to maximize profits received by fog suppliers and reduce the financial costs of fog users [14]. However, traditional approaches are much easier to understand, and easier to use than other algorithms such as analytical processes and identical numerical programming. The outcome is not guaranteed to be correctly generated by approaches [15].



(a) FOC method.



(b) API method.

Figure 1: A fog framework provides current resource availability information of all fog nodes to streamline the resource allocation process. Two standard approaches are to use an FOC (hardware overhead) or to use an API (software overhead) to query fog and distribute IoT tasks [12].

"Meta" and "heuristic" come from Geek, means "higher" or "beyond" and later meaning "know" or "investigate." Meta-heuristics are particularly suited for combinatorial optimization problems, given that, although they are not usually guaranteed to find the optimal global solution, they can often find a sufficiently good solution in a decent amount of time. Therefore, they are an alternative to exhaustive search, which would take exponential time. Meta-heuristics can also be easily applied to many problems, given that they are not problem-specific. Meta-heuristics often incorporate some form of randomness in order to escape from local minima. Therefore, introducing new meta-heuristic approaches to address weaknesses is a major problematic problem [16]. Some of the meta-heuristics algorithms using in resource allocation in fog computing details are given in "Table1. Some meta-heuristic algorithms from (1975 to 2021) and using in fog computing".

Table 1. *Some meta-heuristic algorithms from (1975 to 2021) using in fog computing*

Sr. No	Algorithm	Acronym	Introduced By	Year
1	Genetic Algorithm	GA	Holland[17]	1975
2	Simulated Annealing	SA	Kirkpatrick et al.[18]	1983
3	Tabu Search	TS	Glover[19]	1986
4	Ant Colony Optimization	ACO	Dorigo[20]	1992
5	Particle Swarm Optimization	PSO	Kennedy and Eberhart[21]	1995
6	Differential Evolution	DE	Storn and Price[22]	1997
7	Harmony Search	HS	Geem et al.[23]	2001
8	Artificial Bee Colony Algorithm	ABC	Karaboga[24]	2005
9	Bees life algorithm	BCO	Teodorovi[25]	2005
10	Cat Swarm Optimization	CSO	Chu et al. [26]	2006
11	Honey bee Mating Optimization	HbMO	Haddad et al.[27]	2006
12	Firefly Algorithm	FA	Yang[28]	2008
13	Cuckoo Search	CS	Yang and De [29]	2009
14	Modified Cuckoo Search	MCS	Walton[30]	2009
15	Simplified swarm optimization	SSO	Yeh, et al. [31]	2009
16	Bat Algorithm	BA	Yang[32]	2010
17	Spiral Optimization	SO	Tamura and Yasuda [33]	2011
18	Teaching Learning Based Optimization	TLBO	Rao et al. [34]	2011
19	Wolf Colony Algorithm	WCA.1	Liu et al[35]	2011
20	Termite Hill Algorithm	TA	Zungeru[36]	2012
21	Grey Wolf Optimizer	GWO	Mirjalili[37]	2014
22	Crow Search Algorithm	CSA	Askarzadeh[38]	2016
23	Dragonfly Algorithm	DA	Mirjalili[39]	2016

Many aspects of meta-heuristics exist, and the diversity of novels is often promoted by the distribution of resources in number of fields. There are numerous outstanding and significant meta-heuristic algorithms in the section of fog computing environment for the management of resources such as Genetic Algorithm (GA) ,Cuckoo Search (CS) , Gray wolf Optimization (GWO) , Simulated Annealing (SA),Ant Colony Optimization (ACO) , Artificial Bee Colony Algorithm (ABC) ,Firefly Algorithm (FA) , Honey bee , Crow Search Algorithm (CSA), Termite Hill Algorithm (TA) and many more. Some of the most important metaheuristic approaches using in fog are listed in Table 1.

For allocation of resource in fog Computing, some of the Meta-heuristic approaches are used like Teaching Learning Based Optimization (TLBO),Artificial Bee Colony (ABC), Harmony Search(HS) ,Ant Colony Optimization (ACO),Gravitational Search Algorithm(GSA), Cuckoo Search (CS) Algorithm, Firefly Algorithm(FA), Genetic Algorithm (GA), Shuffled Frog Leaping Algorithm (SFLA) , Particle Swarm Optimization (PSO) are discussed in next section.

An agenda of this paper is to study and analyze the Allocation of resources into fog environment with various metaheuristic techniques. The flow of the paper is: Section 2 contains the Review and Analysis of metaheuristic algorithms used to solve the allocation problem of resources. In Section 3, we present the conclusions and future scope.

2. ANALYSIS OF THE ALGORITHMS

In fog computing, it is preferable to explore for the right resource allocation solution in the limited time. Methods depend on Meta-heuristic have been proven to produce the right results at the right time for this type of issues. An overview of fog computing depends on set of advanced metaheuristic techniques, and a survey of these metaheuristic processes is presented.

2.1 Particle Swarm Optimization (PSO)

PSO approach, an appropriate meta-heuristic algorithm to optimize continuous nonlinear functions. This algorithm was influenced by the idea of bird cruelty, frequently seen in groups of animals, like flocks and in the sea in the concept to find the greatest solution [21]. PSO contains a community called as swarm and each candidate (birds, fishes, and insects) are taken as particles, they are developed by random situations and velocities.

This study [40] has suggested a three-layered architecture comprising of cloud, fog and consumer layers is proposed. A meta-heuristic algorithm: Improved Particle Swarm Optimization with Levy Walk (IPSOLW) is proposed to balance the load of fog. Consumers send request to the fog servers, which then provide services. Further, cloud is deployed to save the records of all consumers and to provide the services to the consumers, if fog layer is failed. In [41] To efficiently handle load balancing, a particle swarm optimization-based Enhanced Dynamic Resource Allocation Method (EDRAM) has been proposed which in turn reduces task waiting time, latency and network bandwidth consumption and improves the Quality of Experience (QoE). The Enhanced Dynamic Resource Allocation Method (EDRAM), which in turns helps for allocating the required resource by removing the long-time inactive, unreferenced and sleepy services from the Random-Access Memory.

2.2. Genetic Algorithm (GA)

Genetic Algorithm was proposed in 1970 by John H.Holland. GA is an algorithm for optimizing algorithms that mimic evolutionary processes. The process of biological evolution on chromosomes converts to the GA concept. It is depended on the concept of survivorship that is best suited to finding the best new solutions through reunification.GA are unwanted search processes designed to work on them large spaces involving wireless circuitry. These metrics are very similar, using locally distributed samples (number of threads) to generate a new set of samples. [17]

Since resource allocation is an NP-hard problem. LI, et al. [42] introduced an improved genetic algorithm (IGA) to support a massive number of device connections and transfer a huge amount of data with low latency and limited resource, they consider the deployment of non-orthogonal multiple access (NOMA) in IoT networks, which enables multiple IoT devices to of multiple IoT devices, subject to the respective QoS requirements. Furthermore, the simultaneously transmit data to the same FN at the same time, frequency, and code domain. They jointly optimize the allocation of resource blocks and transmit power optimization problem is formulated as a mixed-integer nonlinear programming problem to minimize the system energy consumption.

Also, based on offloading and resource allocation decision, Wang, et al. [43] presented a hybrid genetic simulated annealing-based latency-minimum offloading decision algorithm to optimize the offloading decision. The numerical results demonstrate that their proposed scheme gains significant performance advantages on the completion time, energy consumption, convergence speed, and accuracy. After getting the best genetics, a simulated annealing performed on them, which speeds up the convergence of their algorithm.

2.3 Firefly Algorithm (FA)

The FA is classified as swarm intelligence, meta-heuristic and nature-inspired, with an emphasis on the behavior of fireflies . In fact, a number of fireflies show bright light activities to serve as a means of attracting collaborators, communication, and warning of danger to hunters. In the design of the firefly algorithm, the objective function is associated with the flashing light features of the firefly community. Considering the optical principle of the light intensity, it is approximately equal in the square of the area, so that this objective can define the correct distance function between any two fireflies. In order to make the work more efficient, individuals are forced to move systematically or randomly in the population [28].

This study presented a new way of resource allocation using the FA to shorten the time to perform tasks. Kanza, et al. [44] proposed System there considered a Geographical area consisting of six regions. Where each region have cluster of buildings. Single cluster was associated to a single fog, which handled requests from users of clusters. One each fog there were number of VM and DC for processing tasks. Furthermore, there use Service Broker Policy known as Optimize Response Time (ORT) for the Routing of Traffic to Cloud. ORT maintains the List of all fogs available in any Geographical Region. It routes the Requests coming from Cluster of buildings to nearby Fog. It also maintains the history of RT of any Fog. It route the requests coming from a cluster to a nearby Fog with best RT.

2.4. Ant Colony Optimization (ACO)

ACO draws insight from the destructive behavior of certain types of ants. These ants put the pheromone in the ground to mark a specific path, so that other members of the colony can follow the same path. Ant colony efficiency exploits the same way of solving optimization problems [20]. In addition, to learn about proper allocation of resources of fog, for the purpose of optimizing cost, quality of services, time and load balance of resources. Javaid, et al. [45] enhance the speed of cloud computing processing edge computing is introduced, it is also known as fog computing. Fog computing is a complement of cloud computing performing on behalf of cloud. In the proposed scenario, numbers of clusters are taken from all over the world based on six regions. Each region contains two clusters and two fogs. Fogs are assigned using the service broker policies to process the request. Each fog contains four to nine Virtual Machines (VMs). For the allocation of VMs Ant Colony Optimization (ACO) algorithms are used.

2.5. Cuckoo Search (CS)

An approach was designed by Yang and Deb in 2009, and it is a biological encouraged computational search approach, this optimization technique is based on upbringing actions of Cuckoo. This algorithm works on the upbringing performance of Cuckoo in addition with Levy Flight actions of fruits flies and birds [29]. To allocation of resource Cuckoo search proposed to reducing delay and latency in fog computing, because reducing delay and latency in cloud computing environment is a challenging task for the research community. There are several smart cities in the world. These smart cities contain numerous Smart Communities (SCs), which have number of Smart Buildings (SBs) and Smart Homes (SHs). They require resources to process and store data in cloud. To overcome these challenges, another infrastructure fog-computing environment is introduced, which plays an important role to enhance the efficiency of cloud. The Virtual Machines (VMs) are installed on fog server to whom consumers' requests are allocated [46].

2.6. Artificial Bee Colony Algorithm (ABC)

It is an approach introduced in 2005, which is used to solve the continuous optimization issues. In this algorithm, only 1D food position is updated by employed and unemployed bees. During the search process the artificial agents use, one solution update rule. It consists of two kinds of bees: one is employed and second is unemployed. The employed bees gather the fluid from food resources and share the locations of food with other unemployed bees whereas, other bees search for the food sources by using the data delivered by employed bees [24].

Furthermore, Ali, et al. [47] proposed a four-layered SG-based architecture to improve communication between consumers and Electricity Company, and this model covers a huge area of residents. Three load-balancing mechanisms were applied for allocation of VM, and the service broker policies applied for simulations are dynamically reconfigurable and were the closest to data centers.

2.7. Harmony Search Algorithm (HS)

HS is a metaheuristic approach tries to mimic the process of singers' development in finding the Perfect harmony. Recently, due to certain benefits, HS has received much attention. HS is easy to use, quickly converts to the right solution and gets a good enough solution for the right amount of time. The advantage of the HS algorithm has resulted in its application to problems of the use of different engineering environments [23].

In [48] used Harmony search algorithm as another way for resources in wireless communication networks, because Wireless strategies and technologies are ubiquitous and enhancing progressively in the present world. In wireless communication technology, power and resource allocation remain the main issue due to the lack of resources by optimizing the number of subscribers and services. Hence, they discuss different algorithms and techniques such as power-efficient resource allocation algorithm, real-time scheduling algorithm, NOMA, SCMA, Device-to-Device (D2D) communication, OFDMA, power and resource distribution in 5G, wireless sensor networks (WSNs), smart grids, cloud computing, and fog computing which converges stably and quickly.

2.8. Bat Algorithm

Bat-inspired algorithm is a metaheuristic optimization algorithm developed by Xin-She Yang in 2010. This bat algorithm is based on the echolocation behaviour of microbats with varying pulse rates of emission and loudness[32].

In addition, based on resource allocation and resource management decision, Arshad, et al. [49] introduced Binary Bat Algorithm (BBA) is compared to regulate the effective management of resources so that the cost of resources can be curtailed and billing can be achieved by calculating utilized resources under the service level agreement. BBA are used to evaluate energy utilization by cloudlets or edge nodes that can be used subsequently for approximating the utilization and bill through a Time of Use pricing scheme. They appraise abovementioned techniques to evaluate their performance concerning the bill estimation based on the usage of fog servers. With respect to the utilization of resources and reduction in the bill.

2.9. Grey Wolf Optimizer

Grey Wolf Optimizer (GWO) inspired by grey wolves (Canis lupus). The GWO algorithm mimics the leadership hierarchy and hunting mechanism of grey wolves in nature. Four types of grey wolves such as alpha, beta, delta, and omega employed for simulating the leadership hierarchy [37].

Brahmi, et al. [50] propose to investigate the resource allocation problem for V2X networks. They categorize vehicle user equipment (VUEs) into safety and non-safety VUEs and cellular user equipment (CUEs) into real-time and non-real-time CUEs according to their communication types. The objective of the proposed model is to maximize the total throughput of the system while maintaining quality of service (QoS) for CUEs and VUEs, Grey Wolf Optimization (GWO) algorithm, used to solve the resource allocation problem in V2X communications. Furthermore, in [51] developed an algorithm for efficient resource allocation using grey wolves optimization technique, named as Resource Allocation Technique for Edge Computing (RATEC). The algorithm adopted the meta-heuristic technique to choose the best Edge when allocating the resources of user equipment (UE). It was considered that the UEs are composed of processing, storage, time and memory resources. The algorithm uses these resources to calculate the fitness of each Edge and decide which one to allocate, if available. The RATEC has been compared with two other policies and has managed to serve a number most significant of UEs, reducing the number of services refused and presenting a low number of blockages while searching for an Edge.

2.10 Simulated Annealing

Simulated annealing is a method for solving unconstrained and bound-constrained optimization problems. The method models the physical process of heating a material and then slowly lowering the temperature to decrease defects, thus minimizing the system energy. The benefits of simulated annealing are its easy implementation and its possibility of finding a global optimal even after finding a local minimum, as it accepts solutions that are worse than the best candidate [18]. For this reason Rezazadeh, et al. [52] focused on module placement, using simulated annealing algorithm, to find the appropriate device for the modules in a fog computing. Internet of Things (IoT) devices are growing rapidly, which itself produces a lot of data and someone must receive online responses. A typical program of the IoT consists of a set of modules that work together and interconnect. These modules typically run on cloud data centers. Fog computing designed to run these modules near the devices to minimize the response time and also to prevent large and in some cases unnecessary data transfers to the cloud.

2.11 Tabu Search

Tabu search is a meta-heuristic optimization technique, which owes its name to its memory structures, used to store recently evaluated candidate solutions. The candidates stored in these structures are not eligible for generation of further candidates and are there by considered "Tabu" by the algorithm [19].

In [53] propose a simple Tabu Search method for optimal load balancing between cloud and fog nodes, which accounts for resource constraints. The main motivation for using Tabu Search is that, on-line computations are necessary in those layers and as tasks are received they should be processed. They consider a bi-objective cost function for such purpose; the first one denotes the computational cost of processing tasks in fog nodes while the last one stands for that in cloud nodes. During the optimization process, convex combinations of the objective functions are employed in order to reduce the optimization problem to mono-objective cases.

2.12 Simplified swarm optimization

SSO is a population-based algorithm proposed by Yeh in 2009 to compensate for the deficiencies of PSO in solving discrete problems. This algorithm has recently been applied in many research areas because of its simplicity, efficiency, and flexibility [31]. Yeh, et al. [54] creates a simulated factory consisting of a cloud center, gateways, fog devices, edge devices, and different types of sensors. They build an integer-programming model and apply SSO method for determining the layout of above devices except of cloud center and all sensors so that can find the cost minimization deployment of the smart factory.

2.12 Simplified Swarm Optimization

SSO is a population-based algorithm proposed by Yeh in 2009 to compensate for the deficiencies of PSO in solving discrete problems. This algorithm has recently been applied in many research areas because of its simplicity, efficiency, and flexibility [31]. Yeh, et al. [54] creates a simulated factory consisting of a cloud center, gateways, fog devices, edge devices, and different types of sensors. They build an integer-programming model and apply SSO method for determining the layout of above devices except of cloud center and all sensors so that can find the cost minimization deployment of the smart factory.

2.13 Crow Search Optimization (CSO)

Crow search Algorithm is one of metaheuristic optimization algorithm introduced by Askarzadeh. CSA is inspired from the intelligent behavior of the crow. Crows are intelligent in storing the excess food at hiding places and recovering it whenever it is required[38].

Moreover, sarma et al.[55] suggests an optimized fuzzy clustering-based resource scheduling and dynamic load balancing (OFCRS-DLB) procedure for resource scheduling and load balancing in fog computing. For resource scheduling, they recommends an enhanced form of fast fuzzy C-means (FFCM) with crow search optimization (CSO) algorithm in fog computing. Throughput maximization, available resources optimization, response time reduction, and elimination of overloaded single resource are the goal of load balancing algorithm.

Further comparative analysis has been done of existing meta-heuristic algorithms for allocation of resources in fog computing in "Table 2. Comparison of metaheuristic approaches for allocation of resources in the fog".

Table 2: Comparison of metaheuristic approaches for allocation of resources in the fog.

Authors	Meta-heuristic	Environment	Problems	Achievement	Year	Simulation Tools
Khan et al. [40]	PSO	Fog	• Low scalability • Low security	• Low response time • Low processing time • Low cost	2019	Cloud Analyst
Zhang, et al.[41]	PSO	Fog	• low security • low scalability • high complexity	• reduce waiting time • reduce latency • reduce bandwidth consumption • improve QoE	2021	Linpack software tool + Arduino UNO R3
LI et al.[42]	GA	Fog	• Low reliability • Priorities cannot be set	• low-complexity • better performance • low energy • low latency	2019	NOMA
Wang,et al.[43]	GA	Fog	• low security • low convergence speed	• low completion time • low energy consumption • low latency • high accuracy	2020	Not mentioned
Kanza, et al. [44]	FA	Fog	• low security • maximum computational time	• high performance • low cost	2019	Cloud Analyst
Javaid, et al. [45]	ACO	Fog	• Low scalability • High cost	• Low response time • Minimizing the number of VM	2019	Cloud analyst
Javaid et al.[46]	CS	Fog	• High complexity • low security • increasing time	• better efficiency • better QoS • low latency	2019	Cloud analyst
Ali et al.[47]	ABC	Fog	• There are some changes of values in different fogs, but overall the average cost remains the	• High performance • Low cost • Low response time • Low latency	2019	Cloud analyst

			same			
Nazir, et al. [48]	HS	Fog	• Lack of an appropriate simulation • Energy consumption and delay have not evaluated	• Reducing total cost • High scalability	2021	Not mentioned
Arshad et al.[49]	BA	Fog	• High complexity • The possibility of bottleneck • Low scalability • Low reliability	• Low latency	2018	MATLAB
Brahmi et al.[50]	GWO	Fog	• Low reliability • Low security • high processing time	• success ratio • maximizing user requests within a predefined delay threshold.	2020	MATLAB
Lieira et al.[51]	GWO	Fog	• Low reliability • Low security	• Low energy consumption • Low latency	2021	Python
Rezazadeh, et al. [52]	SA	Fog	• Low performance • High complexity	• Low response time • Highly dynamic • minimized latency	2018	
Téllez, et al[53]	TS	Fog	• low scalability • high complexity	• reduced latency • improved security • reduced costs	2018	Not mentioned
Yeh, et al[54]	SSO	Fog	• high latency • low security • low availability	• minimize energy • minimize cost • minimize time consumption	2019	industry 4.0
Sarma, et al[55]	CSO	Fog	• Lack of an appropriate simulation	• Reducing total cost • High scalability	2021	iFogSim

After a thorough analysis of the meta-heuristic approaches presented to allocate resources in fog. It can be seen that the prospects for meta-heuristic methods work better. Meta-heuristic approaches act both on behalf of the fog operator and the fog provider. From the perspective of the fog user, cost, response time, the make span and execution time are important, which are used as important parameters for the provision of services to the fog computing. Another important aspect of the fog provider is that the workload, use and power consumption play an important role. Many metaheuristic techniques have used to provide the solution to serious problems such as energy aware allocation of resources, right allocation of resources , reduction in energy consumptions, VM allocation, ,dynamic resource allocation, power efficient resource allocation, efficient resource allocation, fog job scheduling. And these capabilities are used in unique simulation tools such as Cloud analyst, python, iFogSim, GridSim, Java and Matlab provide the closest solution for allocation of resources in the fog computing.

3. CONCLUSION

In this study, some meta-heuristic algorithm has been reviewed for allocation of resources in fog. Many strategies to increase the effectiveness of meta-heuristics are examined in these reviews.
However, the reviewed meta-heuristic algorithms are proficient at achieving much higher performance ,reduction in the cost, reduction in time ,improve utilization of resources, improve energy efficiency while resource allocation on fog. In future, other meta-heuristics algorithms which have not been reviewed in this paper can be used for resource allocation in fog.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

REFERENCES

[1] Islam, Mohammad Manzurul & Morshed, Sarwar & Goswami, Parijat. (2013). Cloud Computing: A Survey on its limitations and Potential Solutions. International Journal of Computer Science Issues. 10. 159-163.

[2] Jo, D., Kim, G.J.: IoT+ AR: pervasive and augmented environments for "Digi-log"shopping experience. Human-centric Computing and Information Sciences (HCIS). 9(1), 1 (2019)

[3] Ghobaei-Arani, M., Souri, A., Baker, T., Hussien, A.: ControCity: an autonomous approach for controlling elasticity using buffer Management in Cloud Computing Environment. IEEE (ACCESS). 7, 106912–106924 (2019)

[4] Mohamed Firdhous, Osman Ghazali and Suhaidi Hassan(2014) "Fog Computing: Will it be the Future of Cloud Computing? " Conference on Informatics & Applications, Kuala Terengganu, Malaysia.

[5] Miah, M.S., Schukat, M., Barrett, E.: An enhanced sum rate in the cluster based cognitive radio relay network using the sequential approach for the future internet of things. Human-centric Computing and Information Sciences (HCIS). 8(1), 16 (2018)

[6] Deng, Y., Chen, Z., Zhang, D., Zhao,M.:Workload scheduling toward worst-case delay and optimal utility for single-hop fog-IoT architecture. IET Commun. 12, 2164– 2173 (2018)

[7] Venticinque, S., Amato, A. A methodology for deployment of IoT application in fog. J Ambient Intell Human Comput 10, 1955–1976 (2019).

[8] F. Bonomi, R. Milito, J. Zhu, and S. Addepalli, "Fog computing and its role in the internet of things," in Proceedings of the first edition of the MCC workshop on Mobile cloud computing, 2012: ACM, pp. 13-16.

[9] Angelakis, V., Avgouleas, I., Pappas, N., Fitzgerald, E., Yuan, D.: Allocation of heterogeneous resources of an IoT device to flexible services. IEEE Internet Things J. 3, 691–700 (2016)

[10] Kumar, A.K., Harikrishna, P.: Allocation of heterogeneous resources of an IoT device to flexible services. IEEE Internet Things J. 3(5), 69–700 (2016)
[11] Neto, E. C. P., Callou, G., & Aires, F. (2017). An algorithm to optimise the load distribution of fog environments. 2017 IEEE International Conference on Systems, Man, and Cybernetics (SMC).
[12] Martinez I, Hafid A and Jarray A, Design, Resource Management and Evaluation of Fog Computing Systems: A Survey. September 20,2020
[13] Jayanthi S 2014 Literature review: Dynamic resource allocation mechanism in cloud computing environment. In2014 International Conference on Electronics, Communication and Computational Engineering (ICECCE) (pp. 279-281). IEEE.
[14] Mani SK, Meenakshisundaram I. Improving quality-of-service in fog computing through efficient resource allocation. Computational Intelligence. 2020;1–21.
[15] Gandomi AH, Yang XS, Talatahari S, Alavi AH and editors 2013 Metaheuristic applications in structures and infrastructures. Newnes.
[16] Beheshti Z and Shamsuddin SM 2013 A review of population-based meta-heuristic algorithms. Int. J. Adv. Soft Comput. Appl. 5(1):1-35.
[17] Goldberg DE and Holland JH 1988 Genetic algorithms and machine learning.
[18] Kirkpatrick S, Gelatt CD and Vecchi MP 1983 Optimization by simulated annealing. science. 220(4598):671-80.
[19] Glover F 1990 Tabu search: A tutorial. Interfaces. 20(4):74-94.
[20] Dorigo M and Blum C 2005 Ant colony optimization theory: A survey. Theoretical computer science. 344(2-3):243-78.
[21] Shi Y 2001 Particle swarm optimization: developments, applications and resources. In Proceedings of the 2001 congress on evolutionary computation (IEEE Cat. No. 01TH8546) (Vol. 1, pp. 81-86). IEEE.
[22] Storn R and Price K 1997 Differential evolution–a simple and efficient heuristic for global optimization over continuous spaces. Journal of global optimization. 11(4):341-59.
[23] Geem ZW, Kim JH and Loganathan GV 2001 A new heuristic optimization algorithm: harmony search. simulation. 76(2):60-8.
[24] Karaboga D 2005 An idea based on honey bee swarm for numerical optimization. Technical report-tr06, Erciyes university, engineering faculty, computer engineering department.
[25] Bitam S, Zeadally S, Mellouk A. Fog computing job scheduling optimization based on bees swarm. Enterprise Information Systems. 2018;12(4):373–397.
[26] Chu SC, Tsai Pw, Pan JS. Cat Swarm Optimization. In: PRICAI 2006: Trends in Artificial Intelligence; 2006. p. 854–858.
[27] Haddad OB, Afshar A and Marino MA 2006 Honey-bees mating optimization (HBMO) algorithm: a new heuristic approach for water resources optimization. water resources management. 20(5):661-80.
[28] Yang, and X. S. 2009 Firefly algorithms for multimodal optimization. In International symposium on stochastic algorithms (pp. 169-178). Springer, Berlin, Heidelberg.
[29] Yang XS and Deb S 2009 Cuckoo search via Lévy flights. In2009 World congress on nature & biologically inspired computing (NaBIC) (pp. 210-214). Ieee.
[30] Walton S, Hassan O, Morgan K, Brown MR. Modified cuckoo search: A new gradient free optimisation algorithm. Chaos, Solitons and Fractals. 2011;44(9):710–718.
[31] Wei-Chang Yeh et al 2019 Simplified swarm optimization for optimal deployment of fog computing system of industry 4.0 smart factory. J. Phys.: Conf. Ser. 1411 012005
[32] Yang XS 2010 A new metaheuristic bat-inspired algorithm. InNature inspired cooperative strategies for optimization (NICSO 2010) (pp. 65-74). Springer, Berlin, Heidelberg.
[33] Tamura K and Yasuda K 2011 Spiral optimization-A new multipoint search method. In2011 IEEE International Conference on Systems, Man, and Cybernetics (pp. 1759-1764). IEEE.
[34] Rao RV, Savsani VJ and Vakharia D 2011 Teaching–learning-based optimization: A novel method for constrained mechanical design optimization problems. Computer-Aided Design. 43(3):303–15.
[35] Tang R, Fong S, Yang XS, Deb S. Wolf search algorithm with ephemeral memory. In: Seventh International Conference on Digital Information Management (ICDIM 2012); 2012. p. 165–172.
[36] Zungeru AM, Ang LM, Seng KP. Termite-hill: Performance optimized swarm intelligence based routing algorithm for wireless sensor networks. Journal of Network and Computer Applications. 2012;35(6):1901–1917.
[37] Mirjalili S, Mirjalili SM, Lewis A. Grey Wolf Optimizer. Advances in Engineering Software. 2014;69:46–61.
[38] Askarzadeh A. A novel metaheuristic method for solving constrained engineering optimization problems: Crow search algorithm. Computers and Structures. 2016;169:1–12.
[39] Mirjalili S. Dragonfly algorithm: a new meta-heuristic optimization technique for solving single-objective, discrete, and multi-objective problems. Neural Computing and Applications. 2016;27(4):1053–1073.
[40] Z. A. Khan et al., "Energy Management in Smart Sectors Using Fog Based Environment and Meta-Heuristic Algorithms," in IEEE Access, vol. 7, pp. 157254-157267, 2019.
[41] Baburao, D., Pavankumar, T. & Prabhu, C.S.R. Load balancing in the fog nodes using particle swarm optimization-based enhanced dynamic resource allocation method. Appl Nanosci (2021).
[42] X. Li, Y. Liu, H. Ji, H. Zhang and V. C. M. Leung, "Optimizing Resources Allocation for Fog Computing-Based Internet of Things Networks," in IEEE Access, vol. 7, pp. 64907-64922, 2019
[43] Wang, Q, Chen, S. Latency-minimum offloading decision and resource allocation for fog-enabled Internet of Things networks. Trans Emerging Tel Tech. 2020; 31:e3880.
[44] Hassan K., Javaid N., Zafar F., Rehman S., Zahid M., Rasheed S. (2019) A Cloud Fog Based Framework for Efficient Resource Allocation Using Firefly Algorithm. In: Barolli L., Leu FY., Enokido T., Chen HC. (eds) Advances on Broadband and Wireless Computing, Communication and Applications. BWCCA 2018. Lecture Notes on Data Engineering and Communications Technologies, vol 25. Springer, Cham.
[45] Naqvi S., Javaid N., Butt H.(2019) Metaheuristic Optimization Technique for Load Balancing in Cloud-Fog Environment Integrated with Smart Grid. Springer Nature Switzerland

[46] Javaid N., Butt H., Latif K., Rehman A.(2019) Cloud and Fog based Integrated Environment for Load Balancing using Cuckoo Levy Distribution and Flower Pollination for Smart Homes.

[47] Ali M.J., Javaid N., Rehman M., Sharif M.U., Khan M.K., Khan H.A. (2019) State Based Load Balancing Algorithm for Smart Grid Energy Management in Fog Computing. In: Xhafa F., Barolli L., Greguš M. (eds) Advances in Intelligent Networking and Collaborative Systems. INCoS 2018. Lecture Notes on Data Engineering and Communications Technologies, vol 23. Springer, Cham.

[48] Nazir, M., Sabah, A., Sarwar, S. et al. Power and Resource Allocation in Wireless Communication Network. Wireless Pers Commun 119, 3529–3552 (2021). https://doi.org/10.1007/s11277-021-08419-x

[49] Arshad, H., Khattak, H. A., Shah, M. A., Abbas, A., & Ameer, Z. (2018). Evaluation and analysis of bio-inspired optimization techniques for bill estimation in fog computing. Int J Adv Comput Sci Appl, 9(7).

[50] Brahmi, I., Hamdi, M., & Zarai, F. (2021). Chaotic Grey Wolf Optimization-based resource allocation for Vehicle-to-Everything communications. International Journal of Communication Systems, 34(13), e4908.

[51] Lieira, D. D., Quessada, M. S., Cristiani, A. L., & Meneguette, R. I. (2020, November). Resource Allocation Technique for Edge Computing Using Grey Wolf Optimization Algorithm. In 2020 IEEE Latin-American Conference on Communications (LATINCOM) (pp. 1-6). IEEE

[52] Rezazadeh, Z., Rahbari, D., & Nickray, M. (2018, May). Optimized module placement in IoT applications based on fog computing. In Electrical Engineering (ICEE), Iranian Conference on (pp. 1553-1558). IEEE.

[53] Téllez, N., Jimeno, M., Salazar, A., & Nino-Ruiz, E. (2018). A tabu search method for load balancing in fog computing. Int. J. Artif. Intell, 16(2).

[54] Yeh, W. C., Lai, C. M., & Tsai, J. Y. (2019, November). Simplified swarm optimization for optimal deployment of fog computing system of industry 4.0 smart factory. In Journal of Physics: Conference Series (Vol. 1411, No. 1, p. 012005). IOP Publishing.

[55] Sarma, B., Kumar, R., & Tuithung, T. (2021). Optimised fuzzy clustering-based resource scheduling and dynamic load balancing algorithm for fog computing environment. International Journal of Computational Science and Engineering, 24(4), 343-353.