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Distributed Fog-based Resource Allocation Hybrid Approach using Metaheuristic Optimizers for Mobile Networks

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النهج المختلط لتخصيص الموارد المستند إلى الضباب الموزع باستخدام محسنات Metaheuristic لشبكات المحمول

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ABSTRACT

Background:

In recent years, the increasing use of the mobile fog server application has generated excessive amounts of data of different types, such as images, documents, multimedia, and other files. The problem is difficult to manage and control the volume of data used in fog computing, and fog-server computing has problems with latency, resource allocation, and fitness.

Materials and Methods:

Meta-heuristic algorithm implementation requirements, Harris hawks efficiency criteria for application, and Hybrid algorithm : the proposed Hybrid algorithm based on the combining algorithms Harris hawks optimization algorithm, and Meta-heuristic PSO algorithm.

Results:

The proposed system results showed that the total latency of PSO is 223.629 seconds, HHO is 167.722 seconds, and decreased latency with Hybrid as 140.943 seconds. Besides, total response times are 253.019 ms, 215.066 , 170.357 for PSO, HHO, and Hybrid respectively. In addition, Average total packet loss rate is 31.131, 27.287, and 16.853 for PSO, HHO, and Hybrid respectively.

Conclusion:

The results showed that the proposed resource allocation fog-server computing system enhanced overload and computation on each server by balancing incoming wireless mobile requests among available servers as the total latency of PSO is 223.629 seconds, HHO is 167.722 seconds, and decreased latency with Hybrid as 140.943 seconds

Key words: Distributed Fog Network, Hybrid Resourcing Allocation, HHO, Mobile Network, Meta-heuristic.

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INTRODUCTION

Networks are ubiquitous, and they not only help individuals and businesses save money, but they also assist produce income[1]. Instead of maintaining separate copies of the data in several locations around the firm and keeping them all similarly updated, a network-enabled organization may have only one shared copy of that data and share it[2].

Physical elements of the network architecture include computers, hubs, switches, routers, and various other devices. These are the devices used to help in the transfer of data from one area to another by making use of different forms of communication such as electromagnetic radiation and cables [3].

Mobile networks, like the Internet, have changed dramatically[4]. The first two generations provided phone and later text, with 3G ushering in the era of broadband connectivity, with data speeds measured in hundreds of kilo bit per-second[5]. The industry is now at 4G (assisting with data speeds commonly measured in the hundreds of megabytes per second) and migrating to 5G, which guarantees an enormous improvement in speeds for data [6].Mobile and wireless networks have grown tremendously in the previous fifteen years, with the 5G technology network providing increased and ubiquitous connection all over the world[7]. 5G communications intends to provide large data bandwidth, unlimited networking capabilities, and broad signal coverage[8].

The opportunity of 5G is mainly about transitioning out of one network gateway provider (broadband connectivity) and onto a more diversified network of edge applications and gadgets (for example, safety for the population, autonomous cars, and the IoT)[9]. Considering these applications will range from household appliances to manufacturing robots to autonomous devices, a completely new infrastructure is going to become necessary[10].

Fog Computing is a platform with extensive virtualization that links the endpoints to traditional cloud-based administrative server centers, and these are frequently, nevertheless not constantly located around the network's geographic area[11]. As mentioned due to the importance of load balancing is an important challenge because it should assure QoS requirements, it has evolved to improve performance by distributing various IoT resources allocation appropriately[12], [13]. In addition, resource allocation is essential to use in fog-server computing and the nodes themselves have a common power consumption challenge, effective utilization of resources has an influence overall fog component lifespan [14]. On the other hand, as a result of the very flexible and predictable fog nodes, the management of resources is difficult in fog computing and it requires more researcher attention[15].

Due to the rise in the number of fog-server users working on various fog applications in part of the infrastructure, resource allocation in fog-server computing is fundamentally a difficult problem [16]. The bulk of existing resource allocation strategies have focused on delivering performance driven by the workload of applications from various areas such as scientific and business[17].

The major contributions of this paper are represented by improving network and resource utilization, channel usage with decreasing processing time as minimize the computational time, and Optimal resource scheduling through distributed fog-server computing models with HHO and PSO optimizers that increase throughput, and speed for data transmission.

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Related Works

The most related works in term of improve distributed Fog-server computing performance using efficient resource allocation optimizers have been discussed and overviewed as follow:

In [18], ACO and PSO, two nature-inspired meta-heuristic schedulers, are utilized to ensured successful load balance IoT jobs among fog nodes while taking into account communication cost and required time to reply. The experimental results of the proposed algorithms showed the RR algorithm's proven resource allocation, and the suggested ACO-based scheduler outperforms the suggested PSO-based and RR algorithms in terms of IoT app with replay time and correctly resource allocation of the fog network nodes.

In [19] they suggested a task offloading strategy that optimizes the task offloading choice, fog node selection, and computing resource allocation, while also examining the trade-off between work completion time and energy usage. The weighting coefficients of time and energy usage are established depending on the user's individual needs and the residual energy of the device's battery. As a result, we formulate the task offloading issue as an NP-hard mixed-integer nonlinear program (MINLP). To tackle the specified issue, a sub-optimal method based on a hybrid of genetic algorithm and particle swarm optimization is created. Extensive simulations demonstrate the proposed algorithm's convergence and higher performance when compared to baseline techniques.

In [20] they introduced PGA, a novel fog-cloud scheduling method, to maximize the multi-objective function, which is a weighted sum of overall computation time, energy consumption, and percentage of deadline fulfilled tasks (PDST). They consider the various job requirements as well as the diverse nature of the fog and cloud nodes. We present a hybrid technique based on task prioritization and a genetic algorithm to determine the best compute node for each job. Extensive simulations are used to demonstrate the superiority of our proposed algorithm over state-of-the-art strategies.

In [21] they offer enhanced particle swarm optimization (PSO) initialization utilizing heuristic techniques. The LJFP and MCT algorithms are used to initialize the PSO. The suggested LJFP-PSO and MCT-PSO algorithms are assessed in terms of makes-pan, overall execution time, degree of imbalance, and total energy usage. Furthermore, the proposed algorithms' performance is compared to recent task scheduling methods. The simulation results demonstrated the efficacy and superiority of the suggested LJFP-PSO and MCTPSO algorithms over the traditional PSO and comparable methods.

In [22] they rely on implementing heuristic and meta-heuristic algorithms, in addition to proposing a hybrid algorithm Hyper-Heuristic Scheduling (HHS) to find the best resource allocation situation with low response time and power consumption. The results of the proposed system showed a process of reducing delay and execution time as well as improving energy consumption in the fog network architecture.

Due to resource retrained system and devices the problems statement is that Mobile network requires effective utilization of Fog Computing system. With increasing demand and requirements for enhancing the performance, fog computing scenario requires increased output, less latency, greater network performance. In this paper, distributed Fog-based resource allocation Hybrid approach using Meta-heuristic Optimizers for mobile networks has been proposed. It is totally presented as follows: 1. Introduction, 2. Method, 3. Results and Discussion, and 5. Conclusion.

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Materials and Methods

The proposed system installation is based on OMNET++ and FOGNETsim++, and C++ programming language. OMNeT++ is used in the proposed system because of it is a C++ oriented toward objects modular apart event simulation network framework that is extendable, modular, and component-based. Because of its general design, it may be employed in a fog computing of wireless mobile network areas of concern, for example: Network wired and wireless connectivity modeling, Resource management modeling of fog computing network, and Modeling of queuing, time delay, and network performance.

The proposed system is implemented with :

- Meta-heuristic algorithm implementation requirements: the proposed meta-heuristic approaches for allocation of resources in the mobile network is Particle Swarm Optimization (PSO) to enhance the effectiveness, better search speed, and improve Cost efficiency for mobile devices.
- Harris hawks efficiency criteria for application: It was utilized to deliver infrastructure cost reduction by creating an acceptable approach for mobile users while keeping the high standards of data acquired in mobile networks.
- Hybrid algorithm : the proposed Hybrid algorithm based on the combining algorithms Harris hawks optimization algorithm, and Meta-heuristic PSO algorithm.

The main aims of the proposed work are:

1. Implementing meta-heuristics algorithms for resource allocation in fog-server computing environment. meta-heuristic algorithms are capable of achieving:
2. improve utilization of resources, decrease makespan while resource allocation in fog.
3. Reduction in a execution cost.
4. Reduction in fitness value
5. Better QoS
6. Maximizing user requests speed for file uploading.
7. Consumption optimization, scalability improvement, and decrease end-to-end latency
8. Service availability it refers to the ability to ensure that the necessary resource must be accessible and decrease response time

In addition, the architecture of the distributed Fog-based resource allocation of mobile system involving three layers. Each of them is simulated and created with the C++ code design. The first layer is the devices layer, which consists of wireless Mobile as the Hosts to transmit / received data, access point to provide coverage area for wireless connection, router to provide routing purposes for arrived packets with base-broker as virtualize layer to provide computing services controlled by fog node as jobs' priority determining which should be run first. The second layer is distributed Fog load balancer (specific Fog nodes), which are control on the network components, and resource allocation through network transmission. In addition, it provided optimal decisions making for urgent requests (jobs) coming from the device layer as the huge amount of requesters, customer technical and QoS requirements, and the scope and limitations of server provider resources. The used Hybrid optimizers (HHO, and PSO) in fog node denoted fast flexibility to the abilities that can be assigned and released the resources according to request whenever.

The third layer is the servers as network services elements to provide the response for each request by mobile devices. In addition, it provided resources pooling as response processing, and storage services.

The main purpose of the proposed distributed methodology which is based on the Fog load balancing is to distribute load among a number of servers to optimize the utilization of the computation capability of every server and reduce the average task response time as well as, this is equivalent to maximize the system throughput, and network performance. The Fog nodes receive and distribute all task requests to every server in the pool according to some conditions based on the nature of optimization resource allocation algorithms used as HHO algorithm, Meta-heuristic PSO algorithm, and Hybrid approach. The basic structure of the Hybrid approach in the proposed system depending on the evaluation main function, save individual and global optimize number of request value, update rate and fog position in the active fog pool and finally verify optimization criteria for optimal fog selection to process incoming request and redirect it to the better server selection. Figure 1 showed the proposed distributed fog computing with Hybrid optimization algorithm for load balancing in Fog-based Resource allocation for Mobile network.

The integrated Hybrid approach of load balancing resource allocation in mobile network is enhanced the Fog-Server computing with : On-request self-service: A customer can singularly provision computing abilities, for example, server time and network storage according to prerequisite consequently without requiring system administration interaction. Service Management : It provided control and enhanced the resources utilization by utilizing a metering ability at some level of deliberation, e.g., capacity, handling, transmission capacity, and dynamic application of mobile requests. The proposed system integrated two optimization methods are HHO and PSO to build a value Better Fitness Load Balancing (BFLB) generated from the both optimizers based on their features and then each Fog-Server node in distributed environment evaluated the network resources periodically to decide which the optimal Fog-Server to process the incoming request. The main goals of the proposed Hybrid system are :

Decrease Cost: The cost incurred to process the task. High Scalability: This shows the capability of the load balancing mechanism which can be applicable to the machines and the tasks. High Flexibility: The joining of new nodes and revocation of the nodes mechanism are flexible. Maximum Resource Utilization: The resource utilization is maximized in the Fog-Server system. Decrease Processing Time: The total time takes to execute a service request. Increase availability: The capability of the computing system can be taken up to maintain the system performance, and High throughput: It is done through the service requests that are processed in the Fog-Server system.

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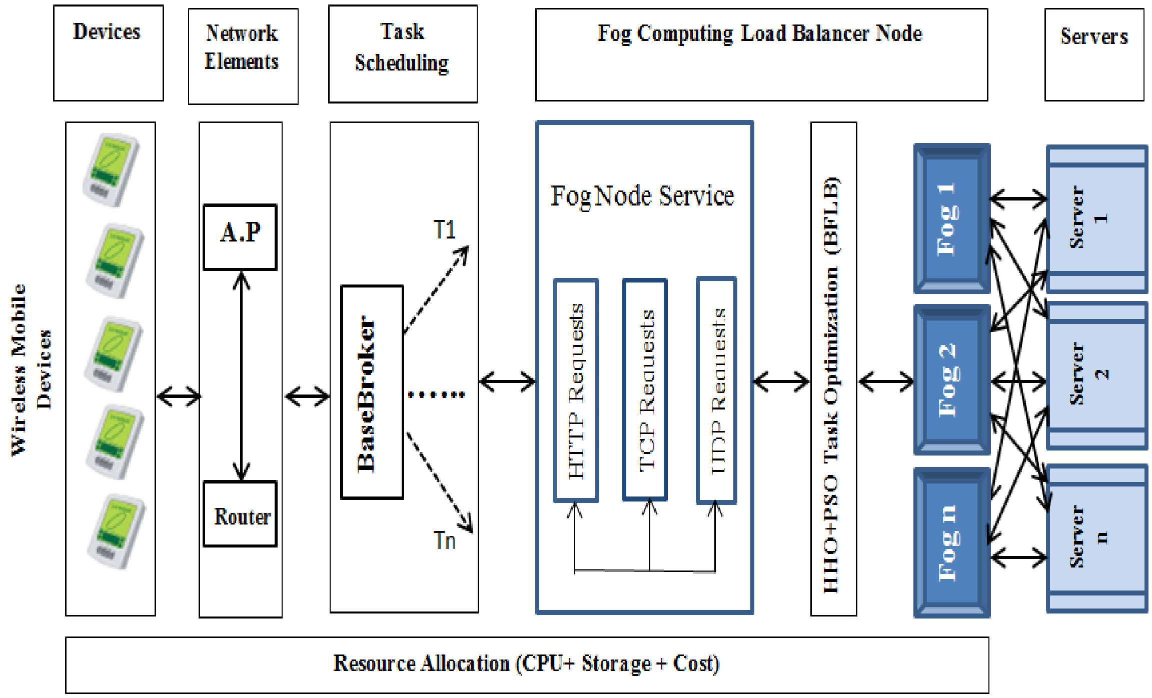

Figure (1): Resource allocation approach for distributed Fog-server.

The Fog-base-broker devices manage how to choose Fog computing nodes for responding to the wireless Mobile device for network resource requirements, and Fog load balancing is one of the key factors to achieve resource efficiency and avoid bottlenecks, overload, and low load.

The Fog node is optimized the required time to achieve each task redirected by base-broker through PSO, and HHO optimizers, in addition, it optimized computing resources such as servers, with applications, storage, and services to balance load and enhance network performance overall. Besides, it enhanced mobile network computation power by decreasing waiting time which effected on Cost of mobile as resource constraint device and resource limitation. The proposed Hybrid system steps showed in Figure 2.

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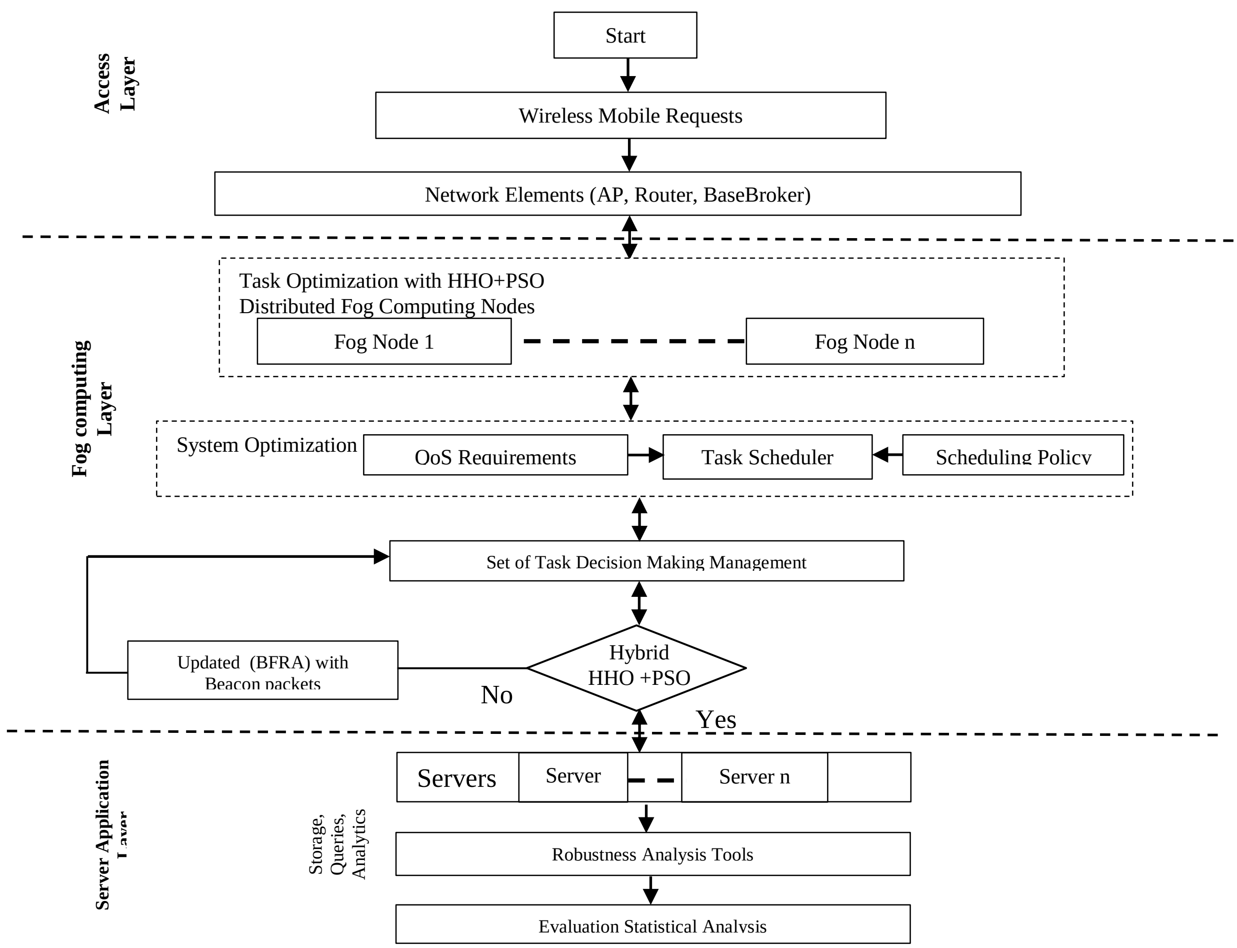

Figure (2): The proposed distributed fog computing system steps.

The use of the Hybrid (HHO, and PSO) optimization mechanism allows server with Better Fitness Load Balancing (BFLB) value calculated by fog node to be more appropriately selected for task assignments created by mobile devices. Synchronization schemes in distributed Fog systems cannot be directly applied to wireless Mobile devices due to the node connectivity could be highly unstable with dynamically change location due to mobility and disconnections unlike traditional distributed systems where stable connection exists among nodes.

In addition, it is based on the task scheduling and optimization as (HHO, and PSO)) to schedule a task to an existing resource on the Fog nodes environment, as distributed it can be happened in fog node and among servers, each Fog node in the distributed system can distribute incoming request through different servers, so it improves reply time and compensates for high data transfer rate systems by dealing with large amounts of requests and big data transportation in a distributed framework and decreasing waiting operations in queue with flexible data management, particularly with fault tolerant state for centralize fog node.

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The hybrid approach of the used load balancing based on integrated two optimization methods are HHO and PSO to build a value Better Fitness Load Balancing (BFLB) generated from the both optimizers based on their characteristics and then each Fog-Server node in distributed environment evaluated the network resources periodically to decide which the optimal Fog-Server to process the incoming request. The main goals of the proposed Hybrid system are :

- Decrease Cost: The cost incurred to process the task.
- High Scalability: This shows the capability of the load balancing mechanism which can be applicable to the machines and the tasks.
- High Flexibility: The joining of new nodes and revocation of the nodes mechanism is flexible.
- Maximum Resource Utilization: The resource utilization is maximized in the Fog-Server system.
- Decrease Processing Time: The total time takes to execute a service request.
- Increase availability: The capability of the computing system can be took up to maintain the system performance.
- High throughput: It is done through the service requests that are processed in the Fog-Server system.

The steps of the hybrid approach for explanation in example :

- Initialize the random population Xi (i = 1, 2, . . . , N pop) in a provided search space.
- Calculate the fitness values of each hawk.
- Select the best individual position as the prey position.
- Update the location using Equation (3.1) that incorporates the map-compass operator and the Cauchy mutation, calculate the individual fitness again and update Xprey.
- The position update formula of the fusion map-compass operator an it shown in Equation :

$$X_{i,j}^{t+1} = X_{prey,j}^{t} \times e^{-t \times t} + Cauchy(0, 1) \times X_{prey,j}^{t} - X_{i,j}^{t} \quad (3.1)[23].$$

where Cauchy(0, 1) is the standard Cauchy distribution.

- Mobile Device makes request to access to specific application type(HTTP requests , UDP, and FTP file upload request).
- Request passed to fog nodes to redirect it to specific server.

Fog nodes periodically send Beacon BFLB request packets to servers and it creates better value (processing cost, server specifications) for each active servers, in addition, Fog nodes still sending check packet periodically to be updated with the last servers state and evaluate servers to be optimal for processing the next request. The proposed system depended on a set of standard specifications to work optimally and obtain the desired results, as shown in the Table 1.

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Table-1: Environmental requirements.

Operating Systems	*Windows 10 pro, 64-Bit*
CPU	*Core (TM) I5-4210U*
RAM	*8.00 GB*
Implementation Tools	*OMNET++ 4.6, INET 3.3.0, and FogNetSim++, iFogSim extension*

The proposed resource allocation evaluation metrics are explained in the following:

- Throughput

The load balancer's efficacy is determined by the quantity of requests that are accomplished within a given time frame. This is a metric of successful job completion. The metric of measuring throughput is insightful as it indicates a correlation between higher throughput and increased efficiency of load balancers[26].

$$\text{Throughput} = \frac{\text{Total Number of sent and received packets}}{\text{Time}} \quad (1)\ [26]$$

- Response time

It demonstrated that the outcome is contingent upon the Mt and Et. The term "response time" refers to the duration of time that transpires between the completion of a given task and the receipt of a corresponding response. The process encompasses the transmission of the assignment, its implementation, and the subsequent submission of outcomes to the initiator [27]:

$$Rt = Mt + Et + NdL. \quad (2)\ [27]$$

- Execution time

The performance of a computer system is contingent upon several factors, including the magnitude of tasks in MIPS, Js, and CPU velocity in MIPS, CPUs, as expressed in Equation (2), where MIPS denotes Millions of Instructions Per Second[28].

$$E_t = \frac{J_s}{CPU_s}. \quad (3)\ [28]$$

- Resource Utilization

This pertains to the state wherein all of the available resources of the fog system are utilized to their maximum capacity[29].

- Latency

The term denotes the temporal duration that elapses from the moment the load balancer receives a request until the moment it transmits a response[30].

- Response time

The variable Rt is contingent upon both migration time (Mt) and execution time (Et), as demonstrated in Equation (4). The term "response time" refers to the duration of time that elapses between the completion of a given task and the receipt of a corresponding response [31]:

$$Rt = Mt + Et + NdL. \quad (4)\ [31]$$

- Packet Loss Ratio

The metric in question pertains to the proportion of successfully transmitted packets relative to those that were not successfully transmitted due to transmission errors. Every packet is assigned a specific deadline for execution. In the event that the deadline cannot be met, the scheduler will endeavor to minimize the number of lost packets that result from the expiration of the deadline [32].

$$\text{Loss rate} = \text{Total Number of sent} - \text{Total number of received packets} (5)[33]$$

- Total Network Usage

The present study examines the correlation between the overall latency and the duration of the simulation. Tuples are utilized to define the input/output relationships among modules. The allocation of network resources is contingent upon the magnitude of transferred tuples during a specific temporal interval [34].

$$\text{Total Network Usage} = \frac{\text{Total Latency}}{\text{Simulation Time}} \quad (6)\ [34]$$

- Total Execution Cost

The equation can be utilized to determine the overall cost of execution (7) [35].

$$\text{Total Execution Cost} = \text{Processing Time} + (\text{Latency} - \text{Response Time}) * \text{Fitness Value} \quad (7)\ [35]$$

- Fitness value

The allocation of Bandwidth for individual modules is established at the onset of the simulation. In order to determine the optimal scheduling, it is necessary to minimize the fitness value, which can be computed using Equation (8). The term "bits per time unit" refers to the rate at which digital information is transmitted, received, or processed, typically measured in bits per second (bps) [36].

$$\text{Fitness value} = \frac{1}{\text{sum bandwidth(send+recived)+Resource Utalization}} \quad (8)\ [36]$$

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Results and Discussion

The proposed distributed fog-server system depends on four of the study cases. The first case is a case without resource allocation in the network. The second case is based on resource allocation, using an PSO algorithm to improve the distribution of loads in the fog network, the 3rd case study is based on the resource allocation algorithm with Harris hawks optimization (HHO), and the 4th case study is based on the hybrid approach combined PSO and HHO. Table 2 showed the main parameter used for each application implemented in the proposed system.

Table-2: The proposed system configuration.

Parameter	Value
Number of Tasks	*500 to 3000*
Processing speed	*1500 MIPS*
Cost of running	*150 units*

The proposed system is founded on four distinct case studies. The first case study does not involve the allocation of resources for fog-server network services. The second case study utilizes the PSO algorithm for resource allocation. The third case study employs the HHO for resource allocation. Lastly, the fourth case study utilizes a hybrid approach that combines PSO and HHO. This approach is implemented in each fog node used in distributed fog computing in order to optimize and schedule incoming requests to specific fog nodes. Resource allocation algorithm used to manage tasks in processing (active requests) that executed on the Fog, also have different direction to specific server. Therefore, in order to acquire an optimal choice of fog, it is required to discover an ideal way to place the various responsibilities evenly on the various fogs, taking into consideration the various properties of the fog and the application. Figure 3 showed distributed fog network configuration.

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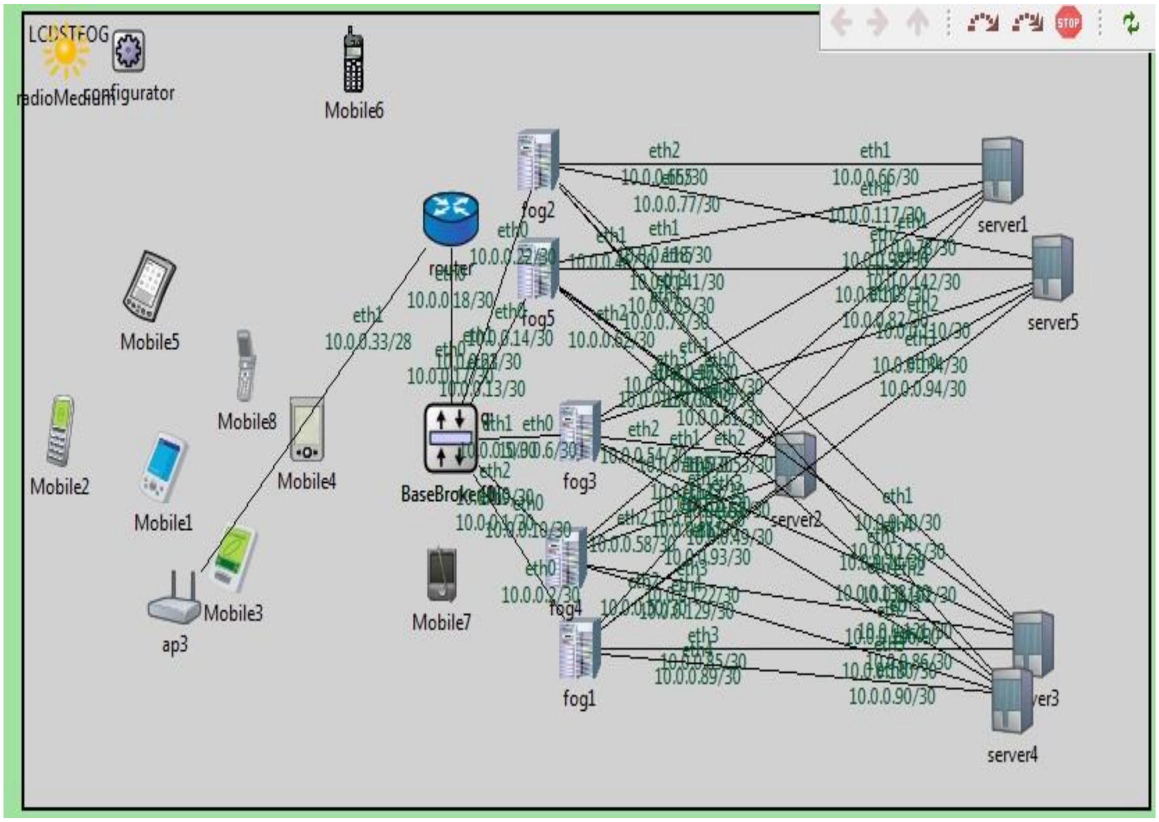

Figure (3) : Distributed Fog computing network configuration.

Figure 4 showed beacon message from access-point to mobile nodes to associated each mobile node into network elements.

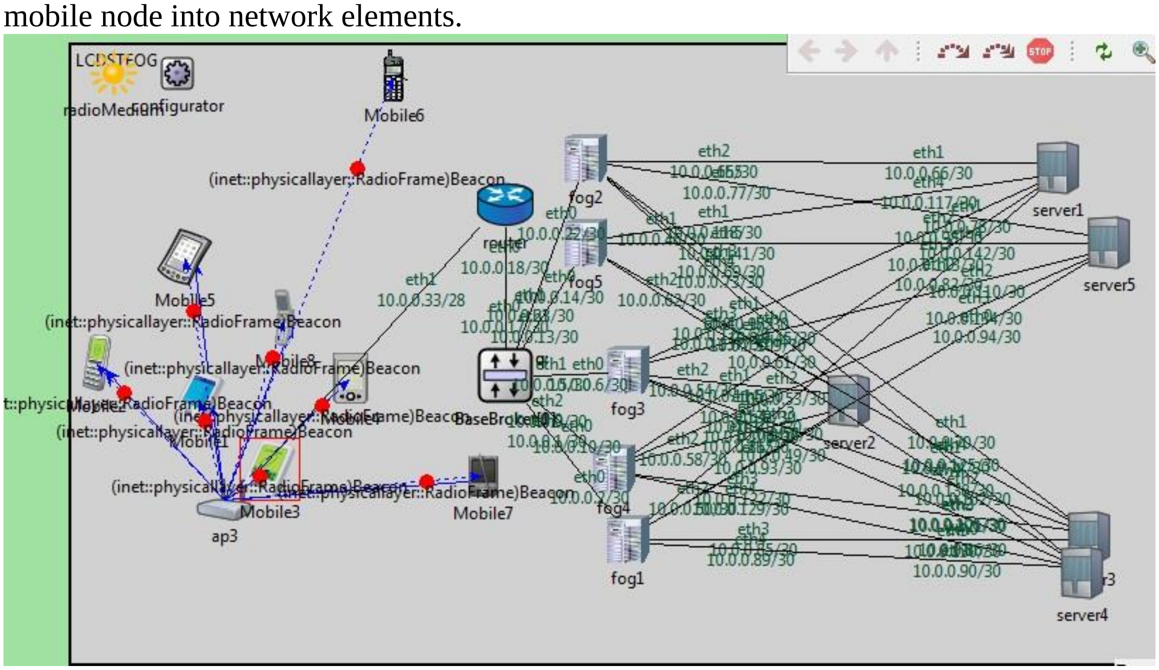

Figure (4): Beacon messages between mobile nodes and network elements.

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A- Without Resource Allocation Fog computing system

The used strategy for implementing overload is applied to simulate the state of high computation processes without any allocation of resource and traffic is high with makes pan and high required time as fitness value which required to allocate resource to manage data request among available servers. The initial case study pertains to a scenario of excessive load, necessitating the reduction of response-processing durations, enhancement of resource utilization, and optimization of QoS metrics. Table 3 illustrates the HTTP web requests made by nodes that move to the associated servers via fog node.

Table-3: distributed fog-server system evaluation of without resource allocation

HTTP Request 1024 Byte	Throughput / Bps		Latency / ms	Response Time/ms	Packet Loss Rate (%)
	Frames/sec Sent	Frames/sec Received			
Mobile 1	24.23408	23.76058	42875.71	58.73345	0.4735
Mobile 2	2.91588	1.29024	1037.837	1.245024	1.62564
Mobile 3	26.7168	25.48224	22135.45	53.51174	1.23456
Mobile 4	28.52256	27.9552	15704.41	47.30141	0.56736
Mobile 5	23.58972	22.68941	14532.25	60.54998	0.90031
Mobile 6	3.71844	2.807616	1118.938	0.558624	0.910824
Mobile 7	30.51914	28.07341	16803.71	50.6125	2.44573
Mobile 8	25.241	22.59699	15549.5	64.78849	2.64401
Server 1	1.68168	1.6128	1119.159	/	0.06888
Server 2	65.89176	60.42355	32244.77	/	5.46821
Server 3	41.5734	39.91142	20582.01	/	1.66198
Server 4	40.5262	37.02474	20993.65	/	3.50146
Server 5	11.5203	9.436784	8283.378	/	2.083516
Fog	166.5917	155.5831	85192.31	/	11.0086
Average Packet Loss Rate (%)					2.471041

Table-4: channel allocation and total network usage of without resource allocation in distributed fog-server system.

Device Type	Requests	Channel Idle (%)	Channel Usage (%)	Total Network Usage in KB
Mobile Node	**Mobile 1**	84.96758	15.03242	0.142919033
	Mobile 2	84.19879	15.80121	0.003459457
	Mobile 3	85.62637	14.37363	0.073784833
	Mobile 4	75.10307	24.89693	0.052348033
	Mobile 5	85.703	14.297	0.048440833
	Mobile 6	85.71536	14.28464	0.003729793
	Mobile 7	73.79435	26.20565	0.056012367
	Mobile 8	81.01465	18.98535	0.051831667
Servers	**Server 1**	85.6548	14.3452	0.00373053
	Server 2	85.63255	14.36745	0.107482567
	Server 3	82.27805	17.72195	0.0686067
	Server 4	80.94667	19.05333	0.069978833
	Server 5	78.17906	21.82094	0.02761126
Fog (avg all interfaces)		82.21649	17.78351	0.283974367

B- Resource allocation with Meta-heuristic PSO algorithm

The second case study presents a proposed system that utilizes a distributed fog-server architecture. This system employs the Particle Swarm Optimization (PSO) algorithm for resource allocation to effectively manage workload distribution and balance the overload of resources within the fog-server computation environment by distribute incoming mobile requests packets to the optimal server while minimizing the total makespan, fitness value and execution cost compared with centralized PSO and with the case of overloading transmission packets. Figure 5 showed PSO optimizer in Fog node resource allocator redirect packets into optimal server.

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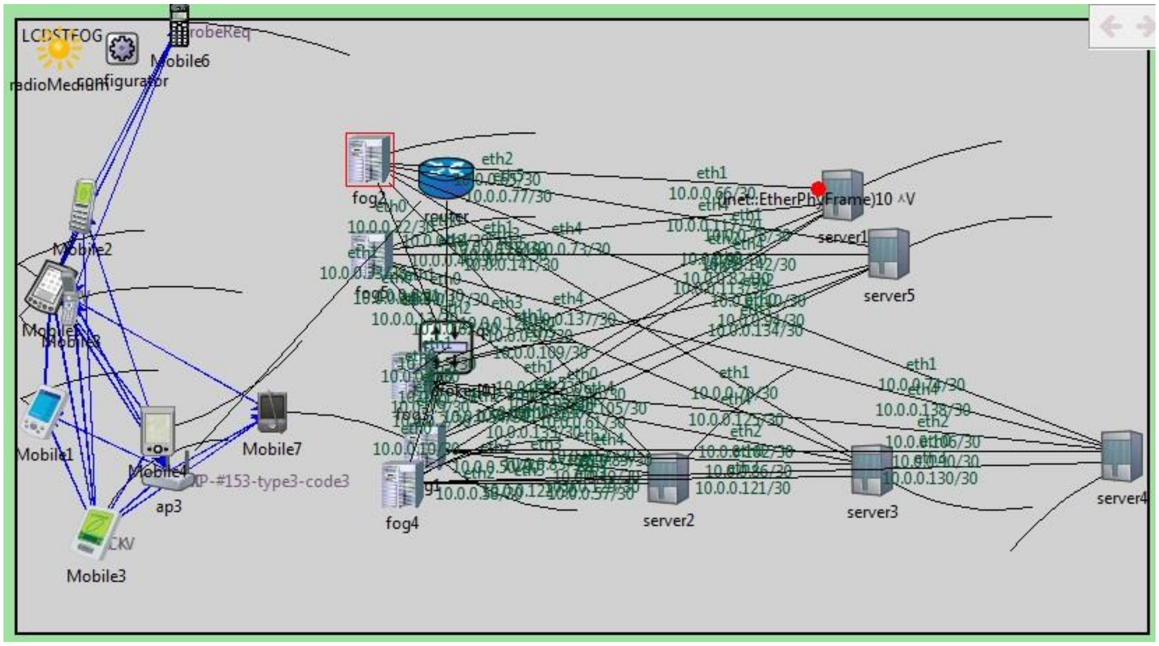

Figure 5 : Redirect packets from Fog to the servers by PSO Optimizer.

As depicted in Table 5 the allocation of HTTP requests was distributed across a total of five servers.

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Table-5: PSO case study evaluation criteria in distributed fog-server system.

HTTP Request 1024 Byte	Throughput / Bps		Latency / ms	Response Time/ms	Packet Loss Rate (%)
	Frames/sec Sent	Frames/sec Received			
Mobile 1	29.60964	29.29669	32156.78	44.05009	0.31295
Mobile 2	3.562675	2.332288	778.3776	0.933768	1.230387
Mobile 3	32.64307	31.36269	16601.59	40.13381	1.28038
Mobile 4	34.84938	34.33024	11778.31	35.47606	0.51914
Mobile 5	28.82235	28.01129	10899.19	45.41249	0.81106
Mobile 6	4.543258	4.153139	839.2032	0.418968	0.390119
Mobile 7	37.28883	35.67209	12602.79	37.95938	1.61674
Mobile 8	30.83991	29.10039	11662.13	48.59136	1.73952
Server 1	2.054707	2.04736	839.3695	/	0.007347
Server 2	80.50775	78.41226	24183.58	/	2.09549
Server 3	50.79514	48.67771	15436.51	/	2.11743
Server 4	49.51565	47.21368	15745.24	/	2.30197
Server 5	14.07571	13.22814	6212.534	/	0.84757
Fog	203.5448	187.6837	63894.23	/	15.8611
Average Packet Loss Rate (%)					2.223657

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Table-6: channel allocation and total network usage in distributed fog-server system.

Device Type	Requests	Channel Idle (%)	Channel Usage (%)	Total Network Usage in KB
Mobile Node	**Mobile 1**	93.46434	6.535658	0.107189267
	Mobile 2	92.61867	7.381329	0.002594592
	Mobile 3	94.18901	5.810991	0.055338633
	Mobile 4	82.61337	17.38663	0.039261033
	Mobile 5	94.2733	5.726696	0.036330633
	Mobile 6	94.2869	5.7131	0.002797344
	Mobile 7	81.17379	18.82622	0.0420093
	Mobile 8	89.11612	10.88389	0.038873767
Servers	**Server 1**	94.22028	5.77972	0.002797898
	Server 2	94.19581	5.804193	0.080611933
	Server 3	90.50585	9.494147	0.051455033
	Server 4	89.04134	10.95866	0.052484133
	Server 5	85.99697	14.00303	0.020708447
Fog (avg all interfaces)		90.43813	9.561866	0.212980767

C- Resource allocation with HHO

The system proposed in this instance is founded on the optimization technique known as HHO resource allocation for task scheduling in fog servers to minimize execution cost, processing time and fitness depending on the less makespan for analyzing request as the determination of the optimal server for incoming requests is based on the assigned value of required time (response time) for task completion on each server. Figure 6 showed HHO redirect request from fog to servers.

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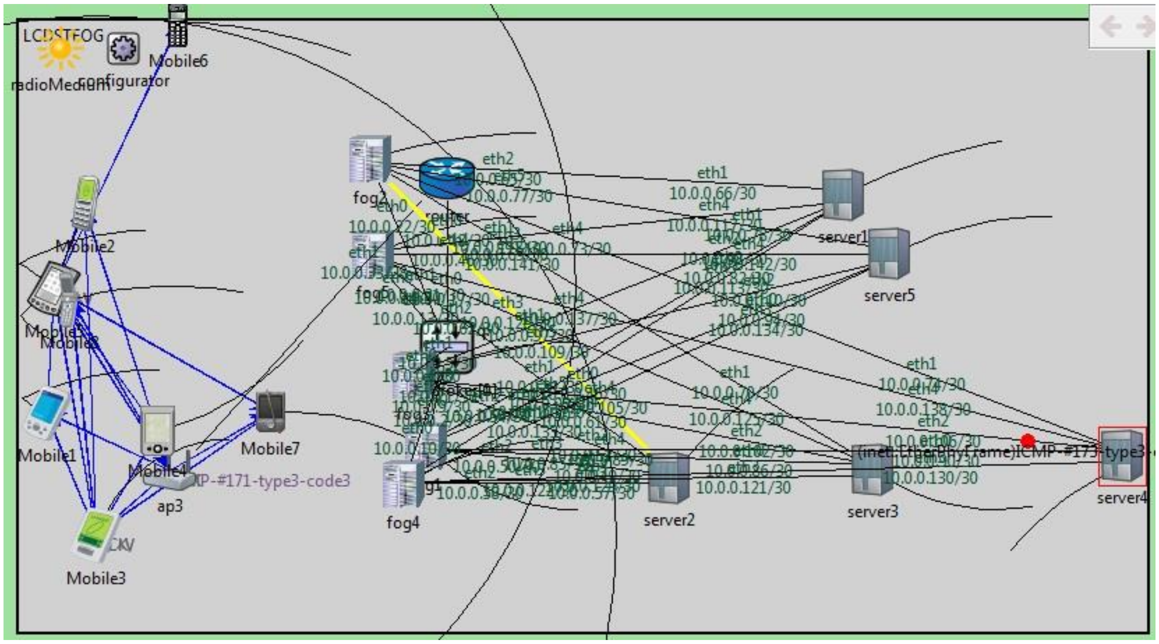

Figure (6) : Redirect packets from Fog to the servers by HHO Optimizer.

Table 7 presents the channel allocation for a fog computing environment utilizing the HHO optimization algorithm.

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Table-7: main evaluation metrics of HHO in distributed fog-server system.

HTTP Request 1024 Byte	Throughput / Bps		Latency / ms	Response Time/ms	Packet Loss Rate (%)
	Frames/sec Sent	Frames/sec Received			
Mobile 1	38.49253	37.6265	24117.59	37.44257	0.86603
Mobile 2	4.631478	3.692774	583.7832	0.793703	0.938704
Mobile 3	42.43599	40.31229	12451.19	34.11374	2.1237
Mobile 4	45.3042	44.17011	8833.73	30.15465	1.13409
Mobile 5	37.46905	35.95547	8174.39	38.60062	1.51358
Mobile 6	5.906235	4.939881	629.4024	0.356123	0.966354
Mobile 7	48.47548	48.15451	9452.089	32.26547	0.32097
Mobile 8	40.09188	37.37131	8746.597	41.30266	2.72057
Server 1	3.075968	2.671119	629.5272	/	0.404849
Server 2	104.6601	95.82075	18137.69	/	8.83935
Server 3	66.03368	63.82182	11577.39	/	2.21186
Server 4	64.37034	63.67859	11808.93	/	0.69175
Server 5	18.29843	17.52138	4659.401	/	0.77705
Fog	264.6082	260.8297	47920.67	/	3.7785
Average Packet Loss Rate (%)					1.949097

Table-8: Channel utilization and total network usage for HHO case study of distributed fog-server system.

Device Type	Requests	Channel Idle (%)	Channel Usage (%)	Total Network Usage in KB
Mobile Node	Mobile 1	96.47516	3.52484	0.080391967
	Mobile 2	95.60225	4.397751	0.001945944
	Mobile 3	97.22318	2.776823	0.041503967
	Mobile 4	85.27465	14.72535	0.029445767
	Mobile 5	97.21019	2.789813	0.027247967
	Mobile 6	97.32422	2.675781	0.002098008
	Mobile 7	83.78868	16.21132	0.031506963
	Mobile 8	91.98687	8.013135	0.029155323
Servers	Server 1	97.25545	2.744546	0.002098424
	Server 2	96.23019	3.769812	0.060458967
	Server 3	93.42138	6.578624	0.0385913
	Server 4	91.90967	8.090326	0.0393631
	Server 5	88.76724	11.23276	0.015531337
Fog (avg all interfaces)		93.26686	6.733145	0.159735567

D- Resource allocation with Hybrid algorithm

The Hybrid Distributed Fog-Server Computing approach has been proposed as a solution to address service delay issues. This approach leverages the untapped computational resources in the vicinity of fog nodes, which are utilized as servers, and the resources in the vicinity of basebrokers, which are used as fog nodes. Additionally, this approach emphasizes the optimal utilization of computational resources that are available within the network, specifically the fog nodes-servers. The fourth case study pertains to a hybrid approach for distributing incoming mobile requests to servers. This approach involves the utilization of BFLB values, which are assigned to each server and used to redirect traffic to the server with the least fitness value. The approach integrates PSO and HHO optimizers to achieve this objective. Figure 7 showed redirect request from Fog to servers and huge request is divided among servers.

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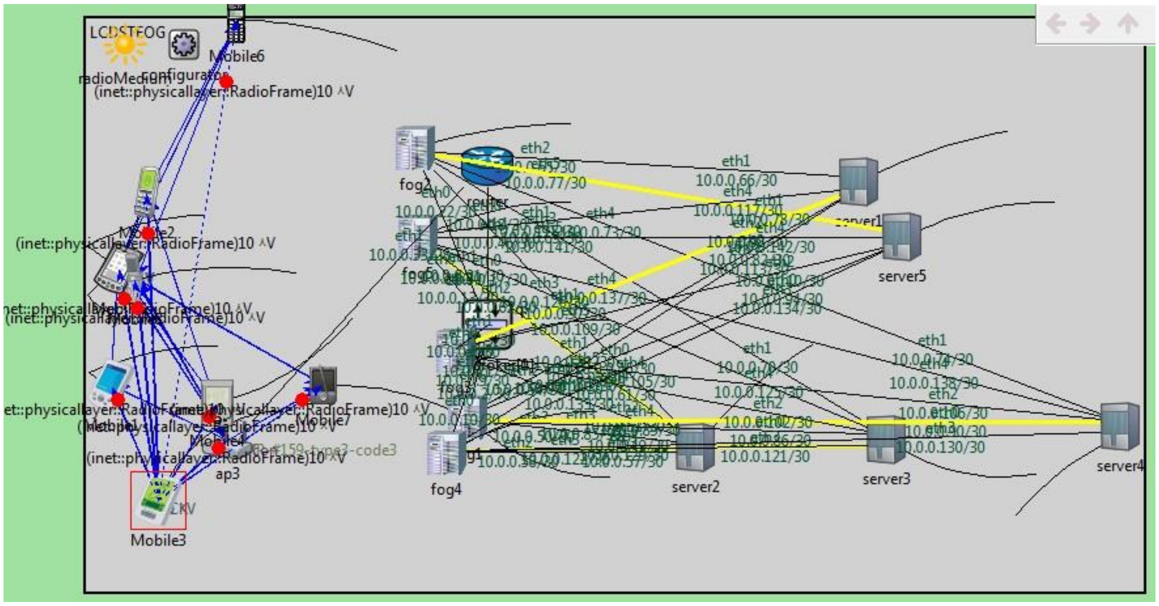

Figure (7) : Redirect request from Fog to active servers with Hybrid approach.

Table 8 presents the evaluation parameters utilized in the fourth case study.

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Table-8: The Hybrid approach of distributed fog-server main evaluation parameters.

HTTP Request 1024 Byte	Throughput / Bps		Latency / ms	Response Time/ms	Packet Loss Rate (%)
	Frames/sec Sent	Frames/sec Received			
Mobile 1	46.19104	45.9278	20266.99	29.65873	0.26324
Mobile 2	5.557774	4.863329	490.5769	0.628702	0.694445
Mobile 3	50.9232	49.27075	10463.25	27.02191	1.65245
Mobile 4	54.36505	53.78013	7423.345	23.88587	0.58492
Mobile 5	44.96286	44.04257	6869.275	30.57603	0.92029
Mobile 6	7.087482	6.703858	528.9126	0.282089	0.383624
Mobile 7	58.17058	56.99341	7942.977	25.55788	1.17717
Mobile 8	48.11025	47.74157	7350.123	32.71635	0.36868
Server 1	3.205344	2.347162	529.0175	/	0.858182
Server 2	125.5921	124.6409	15241.84	/	0.9512
Server 3	79.24041	76.28218	9728.947	/	2.95823
Server 4	77.24441	76.2383	9923.529	/	1.00611
Server 5	21.95812	20.35366	3915.485	/	1.60446
Fog	317.5299	314.0996	40269.7	/	3.4303
Average Packet Loss Rate (%)					1.203807

The channel usage together with the queue duration was displayed in Table 9 for the fourth case study.

Table-9: Channel utilization with Total Network Usage of the Hybrid in distributed fog-server system.

Device Type	Requests	Channel Idle (%)	Channel Usage (%)	Total Network Usage in KB
Mobile Node	Mobile 1	99.09143	0.908567	0.067556633
	Mobile 2	98.19486	1.805144	0.001635256
	Mobile 3	99.85974	0.14026	0.0348775
	Mobile 4	97.58718	2.41282	0.024744483
	Mobile 5	99.94911	0.050895	0.022897583
	Mobile 6	99.96352	0.036482	0.001763042
	Mobile 7	96.06092	3.939082	0.02647659
	Mobile 8	94.48142	5.51858	0.02450041
Servers	Server 1	99.89289	0.107111	0.001763392
	Server 2	99.86694	0.133058	0.050806133
	Server 3	95.95484	4.045162	0.032429823
	Server 4	94.40214	5.597855	0.03307843
	Server 5	91.17448	8.825522	0.013051617
Fog (avg all interfaces)		97.4215	2.578503	0.134232333

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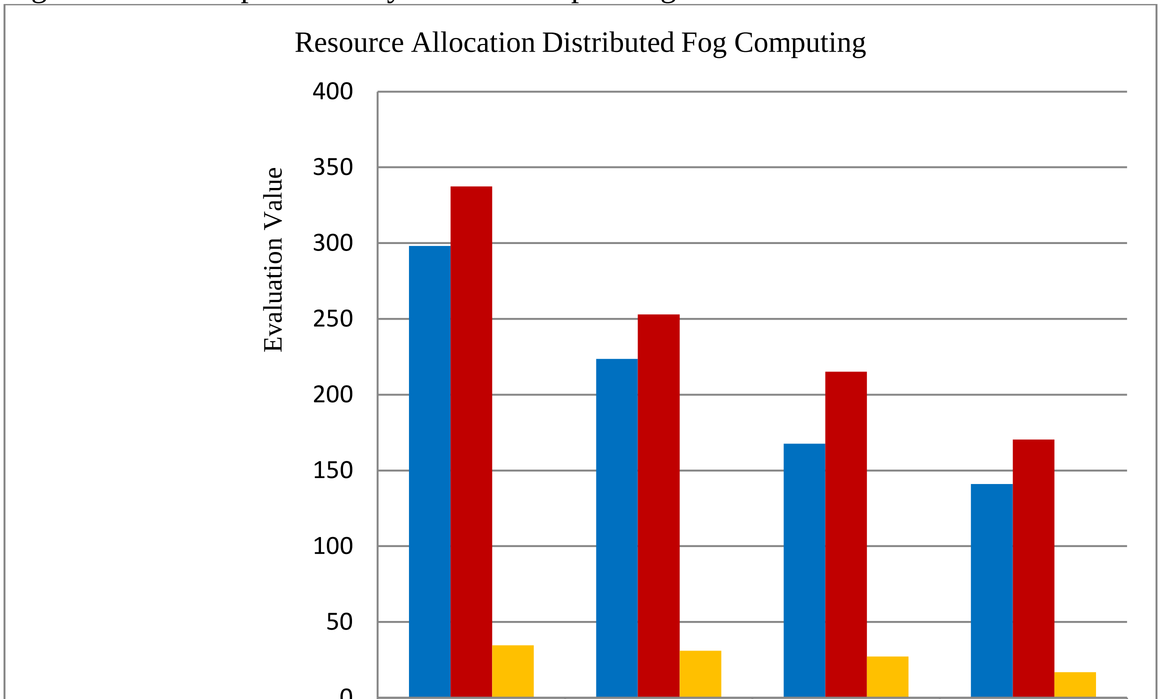
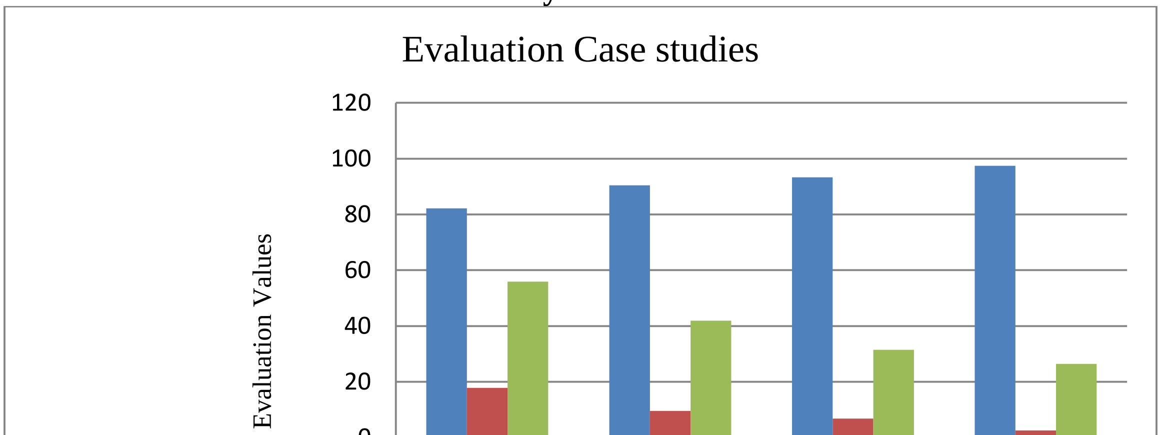
Figures 8 and 9 depicted the system a corresponding manner.



	Without R.L	PSO	HHO	Hybrid
Total Latency / sec	298.17308	223.62983	167.72237	140.94396
Total Response Time/ms	337.35995	253.01997	215.06697	170.35721
Total Packet Loss Rate (%)	34.59458	31.1312	27.28735	16.8533

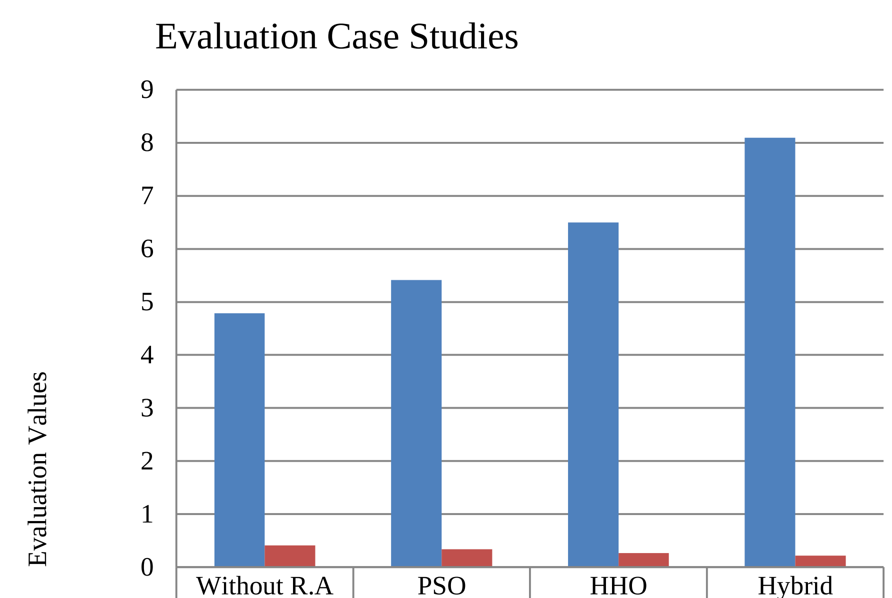
Figure (8): The total latency, response time and packet loss rate of the proposed system.



	Without R.A	PSO	HHO	Hybrid
Total Avg Channel Idle (%)	82.21649	90.43813	93.26686	97.4215
Total Avg Channel Usage (%)	17.78351	9.56186	6.73314	2.5785
Total Network Usage in B	55.9211	41.94083	31.45562	26.43344

Figure (9): Channel resource allocation for the proposed system case studies.

Figure 10 showed the transfer total resource utilization and fitness value elapsed to execute the transmission job for the used case studies, it showed that the proposed hybrid approach better compared with the other case of resource allocation. Average total resource utilization of Hybrid is 8.09462 %, and better total sum fitness value of Hybrid is 0.21863.



	Without R.A	PSO	HHO	Hybrid
Total Avg Resource Utilization (%)	4.788758	5.414981	6.497976	8.094622
Total Sum Fitness Value	0.40929	0.33703	0.26501	0.21863

Figure (10): The total average of resource utilization and required fitness time of the proposed system.

The proposed system compared with other related works and it showed better evaluation results as it showed in Table 10.

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Table-10: The comparison the proposed with the different literature survey.

Ref. Year	Algorithm	Simulation Tool	Total Makespan in Sec	Average Processing Time in Sec
[24], 2020	Hybrid gradient descent spider monkey optimization (HGDSMO)	*Hadoop task scheduler tool*	*1858.14*	*19.21*
[25], 2021	Extended Particle Swarm Optimization (EPSO)	*iFogSim*	*342.53*	/
The used PSO		***FogNetSim++, iFogSim extension***	***274.084***	***20.233***
The used HHO			***191.858***	***15.175***
The proposed Hybrid system		***FogNetSim++, iFogSim extension***	***131.024***	***10.711***

The distributed fog-server computing framework under consideration has been implemented through four distinct case studies. The allocation of resources in fog servers is implemented with the aim of enhancing performance metrics, including but not limited to reducing delay, response time, time to process, fitness value, and makes pan times, while simultaneously increasing throughput through optimal resource utilization. A comparative analysis is conducted to validate the effectiveness and efficiency of the suggested system for the hybrid allocation of resources between fog and server.

The findings indicate that the suggested system has enhanced the network's performance by ensuring the effective handling of mobile requests through the utilization of distributed services an optimizer for hybrid fog-server computing. It showed execution cost time of without resource allocation of distributed is 23.247 seconds, PSO is 17.390 seconds of distributed, besides execution cost of distributed fog-server is 13.009 seconds, The proposed Hybrid execution cost of the Hybrid approach is 9.181 seconds.

Conclusion

The resource scheduling process in fog networks is considered one of the necessary processes for load distribution, the flexibility of response, and the possibility of network expansion according to the variables necessary to make an effective decision on the selection of available servers. With the aim of facilitating the implementation of tasks in a short time, the proposed hybrid system demonstrated the possibility of achieving the goals of resource allocation within fog-server architecture to reduce implementation costs, make span time and fitness in the proposed mobile network. The results showed the proposed resource allocation fog-server computing system enhanced overload and computation on each server by balancing incoming wireless mobile requests among available servers as the total latency of PSO is 223.629 seconds, HHO is 167.722 seconds, and decreased latency with Hybrid is 140.943 seconds. Besides, total response times are 253.019 ms, 215.066 , 170.357 for PSO, HHO, and Hybrid respectively. In

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addition, Average total packet loss rate is 31.131, 27.287, and 16.853 for PSO, HHO, and Hybrid respectively. Furthermore, Total Network Usage computation is decreased into 26.433 in Hybrid module while, 31.4556 , 41.940 for HHO, and PSO respectively. The future research direction is the Fog Intelligence which involves the utilization of fog computing to enable the implementation of machine learning and AI algorithms in closer proximity to the data source, specifically at the network's edge.

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Conflict of interests

There are non-conflicts of interest

References

[1] A. Park, N. Jabagi, and J. Kietzmann, "The truth about 5G: It's not (only) about downloading movies faster!," *Business Horizons*, Oct. 2020, doi: https://doi.org/10.1016/j.bushor.2020.09.009.

[2] C.-I. Chang, Satish Narayana Srirama, and Rajkumar Buyya, "Internet of Things (IoT) and New Computing Paradigms," *John Wiley & Sons, Inc. eBooks*, pp. 1–23, Jan. 2019, doi: https://doi.org/10.1002/9781119525080.ch1.

[3] G. Fettweis and S. Alamouti, "5G: Personal mobile internet beyond what cellular did to telephony," *IEEE Communications Magazine*, vol. 52, no. 2, pp. 140–145, Feb. 2014, doi: https://doi.org/10.1109/mcom.2014.6736754.

[4] F. Nawaz, J. Ibrahim, M. Awais, M. Junaid, S. Kousar, and T. Parveen, "A Review of Vision and Challenges of 6G Technology," *International Journal of Advanced Computer Science and Applications*, vol. 11, no. 2, 2020, doi: https://doi.org/10.14569/ijacsa.2020.0110281.

[5] M. Attaran, "The impact of 5G on the evolution of intelligent automation and industry digitization," *Journal of Ambient Intelligence and Humanized Computing*, vol. 14, Feb. 2021, doi: https://doi.org/10.1007/s12652-020-02521-x.

[6] B. Barakat *et al.*, "6G Opportunities Arising from Internet of Things Use Cases: A Review Paper," *Future Internet*, vol. 13, no. 6, p. 159, Jun. 2021, doi: https://doi.org/10.3390/fi13060159.

[7] M. Raj *et al.*, "A survey on the role of Internet of Things for adopting and promoting Agriculture 4.0," *Journal of Network and Computer Applications*, vol. 187, p. 103107, Aug. 2021, doi: https://doi.org/10.1016/j.jnca.2021.103107.

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[8] A. Yousefpour et al., "All one needs to know about fog computing and related edge computing paradigms: A complete survey," Journal of Systems Architecture, Feb. 2019, doi: https://doi.org/10.1016/j.sysarc.2019.02.009.

[9] C. S. Nandyala and H.-K. Kim, "From Cloud to Fog and IoT-Based Real-Time U-Healthcare Monitoring for Smart Homes and Hospitals," *International Journal of Smart Home*, vol. 10, no. 2, pp. 187–196, Feb. 2016, doi: https://doi.org/10.14257/ijsh.2016.10.2.18.

[10] M. R. Raza, A. Varol, and N. Varol, "Cloud and Fog Computing: A Survey to the Concept and Challenges," *2020 8th International Symposium on Digital Forensics and Security (ISDFS)*, Jun. 2020, doi: https://doi.org/10.1109/isdfs49300.2020.9116360.

[11] T.-A. N. Abdali, R. Hassan, A. H. M. Aman, and Q. N. Nguyen, "Fog Computing Advancement: Concept, Architecture, Applications, Advantages, and Open Issues," *IEEE Access*, vol. 9, pp. 75961–75980, 2021, doi: https://doi.org/10.1109/access.2021.3081770.

[12] A. Rayes and S. Salam, "The Things in IoT: Sensors and Actuators," *Internet of Things from Hype to Reality*, pp. 63–82, 2022, doi: https://doi.org/10.1007/978-3-030-90158-5_3.

[13] Y. K. Teoh, S. S. Gill, and A. K. Parlikad, "IoT and Fog Computing based Predictive Maintenance Model for Effective Asset Management in Industry 4.0 using Machine Learning," *IEEE Internet of Things Journal*, pp. 1–1, 2021, doi: https://doi.org/10.1109/jiot.2021.3050441.

[14] I. Martinez, A. S. Hafid, and A. Jarray, "Design, Resource Management and Evaluation of Fog Computing Systems: A Survey," *IEEE Internet of Things Journal*, pp. 1–1, 2020, doi: https://doi.org/10.1109/jiot.2020.3022699.

[15] U. Tadakamalla and D. A. Menasce, "Autonomic Resource Management for Fog Computing," *IEEE Transactions on Cloud Computing*, pp. 1–1, 2021, doi: https://doi.org/10.1109/tcc.2021.3064629.

[16] S. H. and N. V., "A Review on Fog Computing: Architecture, Fog with IoT, Algorithms and Research Challenges," *ICT Express*, vol. 7, no. 2, pp. 162–176, Jun. 2021, doi: https://doi.org/10.1016/j.icte.2021.05.004.

[17] V. Jain and B. Kumar, "Auction based cost-efficient resource allocation by utilizing blockchain in fog computing," *Transactions on Emerging Telecommunications Technologies*, Feb. 2022, doi: https://doi.org/10.1002/ett.4469.

[18] M. K. Hussein and M. H. Mousa, "Efficient Task Offloading for IoT-Based Applications in Fog Computing Using Ant Colony Optimization," *IEEE Access*, vol. 8, pp. 37191–37201, 2020, doi: https://doi.org/10.1109/access.2020.2975741.

[19] O.-K. Shahryari, H. Pedram, V. Khajehvand, and M. D. TakhtFooladi, "Energy and task completion time trade-off for task offloading in fog-enabled IoT networks," *Pervasive and Mobile Computing*, vol. 74, p. 101395, Jul. 2021, doi: https://doi.org/10.1016/j.pmcj.2021.101395.

[20] F. H Azizi, S., M. Shojafar, F. Ahmadiazar, and R. Tafazolli, " PGA: a priority-aware genetic algorithm for task scheduling in heterogeneous fog-cloud computing,"

ISSN: 2312-8135 | Print ISSN: 1992-0652

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Conference on Computer Communications Workshops (INFOCOM WKSHPS), IEEE, May. 2021, doi: https://doi.org/10.1109/infocomwkshps51825.2021.9484436.

[21] S. A. Alsaidy, A. D. Abbood, and M. A. Sahib, "Heuristic initialization of PSO task scheduling algorithm in cloud computing," *Journal of King Saud University - Computer and Information Sciences*, Nov. 2020, doi: https://doi.org/10.1016/j.jksuci.2020.11.002.

[22] D. Rahbari, "Analyzing Meta-Heuristic Algorithms for Task Scheduling in a Fog-Based IoT Application," *Algorithms*, vol. 15, no. 11, p. 397, Oct. 2022, doi: https://doi.org/10.3390/a15110397.

[23] H. Tariq Ibrahim, W. Jalil Mazher, and E. Mahmood Jassim, "Modified Harris Hawks optimizer for feature selection and support vector machine kernels," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 29, no. 2, p. 942, Feb. 2023, doi: https://doi.org/10.11591/ijeecs.v29.i2.pp942-953.

[24] V. Seethalakshmi, V. Govindasamy, and V. Akila, "Hybrid gradient descent spider monkey optimization (HGDSMO) algorithm for efficient resource scheduling for big data processing in heterogenous environment," *Journal of Big Data*, vol. 7, no. 1, Jul. 2020, doi: https://doi.org/10.1186/s40537-020-00321-w.

[25] N. Potu, C. Jatoth, and P. Parvataneni, "Optimizing resource scheduling based on extended particle swarm optimization in fog computing environments," *Concurrency and Computation: Practice and Experience*, Jan. 2021, doi: https://doi.org/10.1002/cpe.6163.

[26] T. M. Shami, S. Mirjalili, Y. Al-Eryani, K. Daoudi, S. Izadi, and L. Abualigah, "Velocity pausing particle swarm optimization: a novel variant for global optimization," *Neural Computing and Applications*, Jan. 2023, doi: https://doi.org/10.1007/s00521-022-08179-0.

[27] E. G. Radhika and G. Sudha Sadasivam, "A review on prediction based autoscaling techniques for heterogeneous applications in cloud environment," *Materials Today: Proceedings*, vol. 45, pp. 2793–2800, 2021, doi: https://doi.org/10.1016/j.matpr.2020.11.789.

[28] E. G. Radhika and G. Sudha Sadasivam, "A review on prediction based autoscaling techniques for heterogeneous applications in cloud environment," *Materials Today: Proceedings*, vol. 45, pp. 2793–2800, 2021, doi: https://doi.org/10.1016/j.matpr.2020.11.789.

[29] C. Desebrock and C. Spence, "The Self-Prioritization Effect: Self-referential processing in movement highlights modulation at multiple stages," *Attention, Perception, & Psychophysics*, Apr. 2021, doi: https://doi.org/10.3758/s13414-021-02295-0.

[30] G. S. S. Chalapathi, V. Chamola, A. Vaish, and R. Buyya, "Industrial Internet of Things (IIoT) Applications of Edge and Fog Computing: A Review and Future Directions," *Fog/Edge Computing For Security, Privacy, and Applications*, pp. 293–325, 2021, doi: https://doi.org/10.1007/978-3-030-57328-7_12.

ISSN: 2312-8135 | Print ISSN: 1992-0652

info@journalofbabylon.com | jub@itnet.uobabylon.edu.iq | www.journalofbabylon.com

[31] C. Fohry, M. Bungart, and J. Posner, “Fault Tolerance Schemes for Global Load Balancing in X10,” *Scalable Computing: Practice and Experience*, vol. 16, no. 2, Jun. 2015, doi: https://doi.org/10.12694/scpe.v16i2.1088.

[32] J. B. Jr., B. Costa, L. R. Carvalho, M. J. F. Rosa, and A. Araujo, “Computational Resource Allocation in Fog Computing: A Comprehensive Survey,” *ACM Computing Surveys*, Mar. 2023, doi: https://doi.org/10.1145/3586181.

[33] R. K. Dhanaraj, K. Lalitha, S. Anitha, S. Khaitan, P. Gupta, and M. K. Goyal, “Hybrid and dynamic clustering based data aggregation and routing for wireless sensor networks,” *Journal of Intelligent & Fuzzy Systems*, vol. 40, no. 6, pp. 10751–10765, Jun. 2021, doi: https://doi.org/10.3233/jifs-201756.

[34] F. Jazayeri, A. Shahidinejad, and M. Ghobaei-Arani, “Autonomous computation offloading and auto-scaling the in the mobile fog computing: a deep reinforcement learning-based approach,” *Journal of Ambient Intelligence and Humanized Computing*, Sep. 2020, doi: https://doi.org/10.1007/s12652-020-02561-3.

[35] W. WANG, Y. PEI, S.-H. WANG, J. MANUEL GORRZ, and Y.-D. ZHANG, “PSTCNN: Explainable COVID-19 diagnosis using PSO-guided self-tuning CNN,” *BIOCELL*, vol. 47, no. 2, pp. 373–384, 2023, doi: https://doi.org/10.32604/biocell.2023.025905.

[36] K. L. Devi and S. Valli, “Multi-objective heuristics algorithm for dynamic resource scheduling in the cloud computing environment,” *The Journal of Supercomputing*, vol. 77, no. 8, pp. 8252–8280, Jan. 2021, doi: https://doi.org/10.1007/s11227-020-03606-2.

[37] M. Gill and D. Singh, “A comprehensive study of simulation frameworks and research directions in fog computing,” *Computer Science Review*, vol. 40, p. 100391, May 2021, doi: https://doi.org/10.1016/j.cosrev.2021.100391.

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الخلاصة

المقدمة:

في السنوات الأخيرة ، أدى الاستخدام المتزايد لتطبيق خادم الضباب المحمول إلى توليد كميات كبيرة من البيانات من أنواع مختلفة ، مثل الصور والمستندات والوسائط المتعددة والملفات الأخرى. المشكلة هي من الصعب إدارة حجم البيانات المستخدمة في حوسبة الضباب والتحكم فيه ، كما أن حوسبة خادم الضباب تعاني من مشاكل في زمن الوصول وتخصيص الموارد واللياقة. للتغلب على هذه المشاكل ، تم استخدام حوسبة خادم الضباب ؛ يتكون من عقدة ضباب مركزية وخمسة خوادم ومجموعة من العقد المتنقلة لكل حاله دراسة .

طرق العمل:

متطلبات تنفيذ خوارزمية الكشف عن مجريات الأمور ، ومعايير كفاءة تطبيق Harris hawks ، والخوارزمية الهجينة: الخوارزمية الهجينة المقترحة بناءً على خوارزمية دمج Harris hawks ، وخوارزمية PSO الاستكشافية.

الاستنتاجات:

اوضحت نتائج النظام المقترح ان إجمالي زمن الوصول لـ PSO هو 223.629 ثانية ، HHO هو 167.722 ثانية ، وانخفاض زمن الوصول مع Hybrid إلى 140.943 ثانية. إلى جانب ذلك ، يبلغ إجمالي أوقات الاستجابة 253.019 مللي ثانية و 215.066 و 170.357 لكل من PSO و HHO و Hybrid على التوالي. بالإضافة إلى ذلك ، يبلغ متوسط إجمالي معدل فقدان الحزمة 31.131 و 27.287 و 16.853 لأجهزة PSO و HHO و Hybrid على التوالي.

الكلمات المفتاحية:

شبكة الضباب الموزعة ، تخصيص الموارد المختلطة ، HHO ، شبكة الهاتف المحمول ، الكشف عن مجريات الأمور.