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# Hybrid Meta-Heuristics Based Task Scheduling Algorithm for Energy Efficiency in Fog Computing

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## ABSTRACT

*Task scheduling in fog computing is one of the areas where researchers are having challenges as the demand grows for the use of Internet of Things (IoT) to access cloud computing resources. Many resource scheduling and optimization algorithms were used by many researchers in fog computing; some used single techniques while others used combined schemes to achieve dynamic scheduling in fog computing, many optimization techniques are reassessed based on deterministic and meta-heuristics to find out solution to scheduling problem in fog computing. This paper proposes Hybrid Meta-Heuristics Optimization Algorithm (HMOA) for energy efficient task scheduling in fog computing, the study combines Particle Swarm Optimization (PSO) Meta-heuristicsand deterministic Spanning Tree (SPT) to achieve task scheduling with the intension of eliminating the drawbacks of the two algorithms when used separately, the PSO is used to schedule user task requests among fog devices, while hybrid MPSO-SPT will be used to perform resource allocation and resource management in the fog computing environment. The study proposed to implement the algorithms using iFogSim in the future work such that performance of the algorithms will be evaluated, assessed and compared with other state of art scheduling and resource management algorithms.*

**Keywords:** Algorithms, Deterministic, Fog Computer, Task Scheduling, Meta-heuristics.

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## 1.0 INTRODUCTION

Fog Computing (FC) is a Cloud Computing layer which extends cloud services to the edge layer or to the end user computing with the intension of optimal service provisioning and faster processing capabilities among the end users, it is not the intension of FC to replace cloud computing capability, but is to provide faster accessibility of the cloud services which includes; storage, processing and computation to the end users [1].

With the increase in demand of cloud resources, task scheduling is one of the greatest challenge and area of interest among researchers in the field of cloud computing, it is generally known that the main function of cloud computing is resources provisioning, therefore many strategies of resource scheduling and optimization methods were used by many researchers in the area [2].

According to Aliyu, et al., [3]. Task scheduling can be classified and categorised based on real time, cloud services, workflow, or can be static or dynamic scheduling. Many dynamic scheduling techniques have been envesaged based on metaheuristics and deterministic to resolve scheduling prolems. Related research can be observed in (Li, Liu, Wu, & Li, 2019; Matrouk & Alatoun, 2021) and etc.Relavant cited works Verma, Bhardwaj, & Yadav, (2016) discused task allocation and scheduling techniques in Fog computing. Amancio da Silva, Asamooning, Orrillo, Sofia, & Mendes, (2020) presented data placement algorithms in fog

environment which further stated virtual machine selection and virtual machine allocation can be combined to optimise task scheduling that will be assigned to Cloud, therby efficient allocation of resource modules in the fog networks. Deteministic method is a technique of problem solving which follows a trigent sequence of defined procedure in solving a solution to a task which sometime are categorised as inconclusive/inaccurate, as a result of traping in to the local minium[2].

The concept of Meta-heuristics algorithms are set of problem solving method in which are desinged to find, select, or generate a heuristic that can produce a significantly better result to an optimization problem with few iterations. This algorithm provide better result through exploration and exploitation specifically with very limited computational effort or non complete information which is applicable to wide number of problems for task scheduling in fog computing. The following are examples of meta-heuristics algorithms; Particle Swarm Optimization (PSO), Cuckoo Search (CS), Cat Swarm Optimization (CSO), genetic algorithm (GA) and so on. These algorithms have been used and reasonablyperformed better in optimizing task scheduling and cloud service providers throughput in the area of minimizing makespan, balancing load and scalability by providing shortest optimal results within shortest period [3].

The main purpose of this study is to propose a framework for an energy efficient task scheduling algorithm based on hybrid meta-heuristics optimization in fog computing environment with the intension of reducing energy consumption, improving lacency and reducing execution time in fog computing.

The paper is organized based on the following sections; section I presented the introduction of the paper which includes general terms and background about fog computing, section II presented the layers of fog computing which includes the general architecture of fog computing, section III presented the literatures that are related to fog computing with regards to task scheduling, section IV presented the methodology of the proposed system design which include the system architecture and the various parameters required for the development of the proposed system and finally section V presented the conclusion and future directions of the research.

### 1.1 The Fog Computing Architecture

FC architecture can be categorized into three level tiers for the provision of cloud services to the end users.Tier 1 level is the level that integrates IoT devices that is the field level which accomodates sensors and actuators. This level serve as data sources, the devices here, distributes and capture data to the next tier level. Tier 2 (FOG) in this level, IoT devices are integrated and labelled as fod nodes [4]. Processing and gathering of information including translating communication protocols and help in data decimination to other part of network is here in the IoT gatways and hubs, this level includes other devices like access points and routers. Communication in fog nodes are arranged in hierarchical way and is possible between parent-child pair in the hierarchy. Since these devices are in edges of the network, they are normaly positioned in the customers domain, fog nodes are characterised with limited resources.Tier 3 (CLOUD) devices in this level are generally having significantly higher amount of resources. These they make up for example, virtual machines in data centers [4].

Computation and processing of data is generally occurs in all of the three Tier levels therfore comsuming a lot of resources like energy, CPU, memory and network capacity. Scheduling algorithms can play an important role in supporting distribution of services, data and applications to specified level or devices, and fog layer.

## 2.0 REVIEW OF RELATED WORK

Resource scheduling in cloud computing is an NP-hard (Nondeterministic Polynomial time) problem. To solve this problem, various resource scheduling algorithms are proposed to solve the problem by different researchers[5].



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Pradeep & Jacob, (2018) proposed a hybridization of cuckoo search and gravitational search algorithm (CGSA) for task scheduling. The purpose of the design was to exploit the merits of both cuckoo search (CS) and gravitational search algorithms (GSA) while avoiding their drawbacks. The performance of the algorithm was analyzed based on the different evaluation measures. The algorithms like GSA, CS, Particle swarm optimization (PSO), and genetic algorithm (GA) were used as a comparative analysis, the proposed model outperform the other methods based on the results presented.

Ghasemi & Hanani, (2019)proposed a new scheduling algorithm for workflows in the cloud environment using Cuckoo Optimization Algorithm (COA). The aims of the proposed algorithm was to reduce the processing and transmission costs as well as maintaining a desirable load balance among the processing resources. The proposed algorithm was implemented in MATLAB and its performance was compared with Cat Swarm Optimization (CSO). The results of the comparisons showed that the proposed algorithm was superior to CSO in discovering optimal solutions**.**

Pham, Man, Tri, Thai, & Huh, (2017) proposed a scheduling algorithm called Cost-Make span aware Scheduling heuristic whose major objective was to achieve a balance between the performance of application execution and the mandatory cost for the use of cloud resources. Additionally, they use an efficient task reassignment strategy based on the critical path of the directed acyclic graph modeling the applications was also proposed to refine the output schedules of the Cost-Make-span aware Scheduling algorithm to satisfy the user-defined deadline constraints or quality of service of the system. The study also verified the proposal by extensive simulations, and the experimental results show that their scheduling approach was more cost-effective and achieves better performance compared to other algorithms.

Spanning Tree have been used by many researchers in improving the convergence rate of heuristic algorithms as observed in Aliyu, Murali, Gital, & Boukari, (2020) in their research, they proposed ant colony optimization population based and deterministic spanning tree ACO-SPT for task sheduling in cloud computing, their proposed algorithmachieved a faster convergence with loop free with least make span time based on their simulated results, and their result outperforms other algorithms in terms of load balancing and proposed future work in assessing the algorithm performance in multi-tier environment and software Defined Network (SDN). However their work is limited to resource management in cloud without extending fog or edge computing.

Rafique *et al* [15].Proposed a nature inspired task scheduling algorithm in fog computing, they modeled and proposed a novel bio-inspired hybrid algorithm (NBIHA) which is a hybrid of modified particle swarm optimization (MPSO) and modified cat swarm optimization (MCSO). In their proposed scheme, the MPSO was used to schedule the tasks among fog devices and the hybrid of the MPSO and MCSO was used to manage resources at the fog device level. In the proposed approach, the resources were assigned and managed on the basis of the demand of incoming requests. The main objective of their proposed work was to reduce the average response time and to optimize resource utilization by efficiently scheduling the tasks and managing the fog resources available, their proposed model outperformed other related research in terms of optimal resource utilization and energy saving.

## 3.0 METHODOLOGY

The proposed research focuses on improving the work of Rafique *et al* [15]. by considering communication cost between cloud and fog collaboration, latency in fog, this is because the algorithm used in their model exhibit some nature of slowness in the exploration and exploitation in the search space, therefore this research will introduce Spanning Tree (SPT) algorithm which is one of the fastest deterministic algorithms as task scheduling in fog computing is generally dynamic in nature [6].

Thisresearch proposes a Hybrid Meta-heuristics Optimization algorithm (HMOA) for task scheduling in fog computing environment, with the goal to design energy efficient fog resource services by optimizing Particle Swarm Optimization using one



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of the optimization algorithms which is Modified Cat Swarm Optimization (MCSO) algorithm and injecting Spanning Tree (SPT) deterministic Algorithm in order to improve the convergence rate.

### 3.1 Problem formulation

The aim of this proposed system is to design an energy efficient task scheduling system in fog computing environment which is focused on load balancing and resource management. In this system, tasks are being described as methods that define user's service demand which can be in the form of mobile user, web user, or internet users. User tasks or requests$st_u\{t_1, t_2, t_3, t_4, \ldots\ldots, t_n\}$ and available fog devices $fd_j$ $\{fd_1, fd_2, fd_3, fd_4, \ldots\ldots fd_k\}$ are used to schedule these tasks and cloud resources. Our propose system will use MPSO for task scheduling and load balancing by using best fit cloud and fog devices for request processing, when tasks are being scheduled, the average response time of the fog devices will be found based on the given equation;

$$AVTime = t_2[\sum_{x=1}^{k} \mathrm{FD(x)}] - t_1[\sum_{x=1}^{k} \mathrm{FD(x)}] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

Best fit of the fog device can be obtained by finding the *fitness value* based on the given equation *ii* and the equation can be used to calculate the resource demand of a given task.

$$FValue = \frac{(R)\sum_{FD=0}^{k} \mathrm{FD(j)}}{\sum_{x=1}^{n} (\mathrm{RD})} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

### 3.2 Limitation of the Existing System

The existing system in which this research intended to build upon is called Novel Bio-Inspired Hybrid Algorithm (NBIHA) by Rafique, Shah, Islam , Khan, & Maple, (2019) which is a hybrid of Modified Particle Swarm Optimization (MPSO) and Modified Cat Swarm Optimization (MCSO) in their approach they use MCSO to manage resources where *bestfitres* are compared for future demand of task, while the MPSO algorithm was used for task scheduling and load balancing among the fog nodes, this model combines two meta-heuristic algorithm to achieve their research goals, but these heuristics they have their known drawbacks of slow convergence and crossover in the search space of prompts the introduction of deterministic Spanning Tree (SPT) algorithm to improve the search space and improve the convergence rate.

### 3.3 Proposed Framework

The proposed research work intend to schedule the tasks which are arriving at the cloudlets of the fog for execution are having the dissimilar types and sizes, types in the sense that mobile and static fog nodes. In this research work, the task will be given as the input, and it will be managed and directed to arrive into the cloudlet. This research work will use Modified Particle Swarm Optimization Algorithm (MPSO) to quickly distribute tasks to Task scheduler efficiently. These tasks are gathered and formed into task queues.

The fog environment has variety of resources such as CPU, bandwidth and memory and those algorithms are addressed by the proposed algorithm using Hybrid Meta-Heuristics Optimization algorithm. In this algorithm, the task will be taken from the task queue in order to execute it, the Spanning Tree (SPT) Algorithm will be used for load balancing between the fog nodes. After that, it checks the status of the fog node whether a mobile fog node or static fog node, in this sense they will be categorized as homogeneous i.e all static fog nodes and heterogeneous i.e mobile and static fog nodes, if there are homogeneous fog (static fog) devices present, then the MPSO algorithm will be used to allocate resources and execute tasks. For, heterogeneous fog devices (Mobile and static), this research will use Hybrid Meta-heuristics Optimization Algorithm (HMOA) which the combination of MPSO, MCSO and SPT to distribute tasks to fog devices and execute them accordingly. In this way, the proposed framework is



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expected to perform better for energy efficient task scheduling in fog computing for both homogeneous and heterogeneous fog nodes with improved latency [6].

### 3.3.1 Hybrid Meta-heuristics Optimization Algorithm (HMOA)

The main purpose of this proposed scheduling algorithm is to find optimal schedules for executing task in the fog environment. The main idea of this proposed algorithm is to use Modified Cat Swarm Optimization (MCSO) algorithm and Modified Particle Swarm Optimization (MPSO) to solve the problem of task scheduling by injecting Spanning Tree (SPT) Algorithm in order to improve the convergence speed of exploration and exploitation in the search space. The optimization criteria in the proposed algorithm is to address the shortcomings observed by the MPSO and MCSO algorithms when used, as both of them are heuristic algorithms and they have a problem of crossover when handling search space, therefore this algorithm is the combination of Hybrid MPSO and SPT to achieve resource management in fog computing and subsequent sending the tasks to cloud for further processingYang, [18]. As shown in figure 3.1.

PSO and CSO are members of meta-heuristics algorithm that follows the behaviour of particle and cat movements respectively. According to Tian & Shi, [8]. PSO and CSO has been used in different areas for solving scheduling problems, the algorithms performed extremely good in solving the problems in those fields, these algorithms still require some improvements in dealing with transition loops which are being observed to have longer convergence time.

### 3.3.2 Modified Particle Swarm Optimization (MPSO)

For the most part, Modified Particle Swarm Optimization (MPSO) is a populace based streamlining procedure, which is inspired by the practices of fish tutoring or flying creatures running. In MPSO, a populace is known as a swarm, and every part in it is known as a molecule and is also a potential answer for the enhancement error and amid the advancement, the pursuit bearing of one molecule is dictated by its very own past best molecule and the worldwide premier molecule found by all particles till today. Let $N$ be the swarm measure. Every molecule $i$ ($1 \leq i \leq N$) contains two vectors, speed ($V$), position ($X$). At every cycle, every molecule in the swarm refreshes its speed and position as pursues

$$Vi,j(t+1) = w.Vi,j(t)+c1.r1.(pbesti,j-Xi,j(t))+c2.r2.(gbestj-Xi,j(t))Xi(t+1) \ldots\ldots\ldots 3$$

$$= (t)+Vi(t+1) \qquad \ldots\ldots\ldots\ldots 4$$

Where $Xi$ and $Vi$ represent the position and speed vectors of the $i$th molecule, individually. $p$best $i$ speaks to the past best molecule of the $i$th molecule and $g$best is the worldwide best molecule identified by all particles till now. $r1$ and $r2$ are two autonomously created arbitrary numbers having the scope of [0, 1]. $w$ is a parameter called idleness weight, $c1$ and $c2$ are termed as quickening coefficients [7], since task scheduling in fog computing is a nondeterministic NP-hard problem, the standard MPSO will be used with both global best and individual best. The individual best is used for increasing diversity to obtain a quality solution, therefore, it is compulsory to use the individual best in order to solve highly nonlinear and multimodal problems [8].

### 3.3.3 Modified Cat Swarm Optimization Algorithm (MCSO)

The cat swarm optimization algorithm is a heuristic optimization methodology that has an evolutionary approach in finding and exploration of optimized solutions. The cat swarm optimization algorithm is inspired by the amazing tracing and resting behavior of cats. Cats sometimes seems to be lazy and spend most of its time resting, but throughout its resting period the cats are very much aware of what is happening around them. So the cats are intelligently observing constantly the surrounding and deliberately when they see their target, they start moving toward it quickly. So the Cat Swarm Optimization algorithm is modelled based on these two techniques of *seeking* and *tracing* modes.



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The MCSO in this algorithm, the mutation operator are combined as a local search procedure with CSO algorithm to obtain better solutions in the area of the global best. This mode is then used in optimizing the feature selection and parameters of the search space [9]

### 3.3.4 Spanning Tree (SPT)

Spanning Tree (SPT) Algorithm is a member of deterministic algorithms which are used for finding an optimal path in a search space through graph means of visiting nodes and therefore the Spanning Tree is inform of graph and its subset which is having all the nodes connected with possible number of arcs. Generally, the spanning tree has no loops or cycles and cannot be disconnected [2]. However it is good in handling problems that require alternative routes in decision making especially task scheduling. The loops in the transition operators that may cause relative influence will be eliminated by the Improved SPT in the set $G = (N, M)$. The function of the Spanning Tree here is to stop all redundant paths in cloud user request for job that may cause loop allowing convergence delay, this will allow existence of single logical path between all destinations in the fog devices. In the event where users request is intentionally denied from leaving or entering a path, the path will be termed as blocked path.

### 3.3.5 Convergence factor

Consider; $\lim_{t\to\infty} Makespan\ (t) = \lim_{t\to\infty} \sum_{j}^{m} Execution\ time\ task\ \ (T_i)$ ... ... ... ... ... ... ... ... ... ... 5

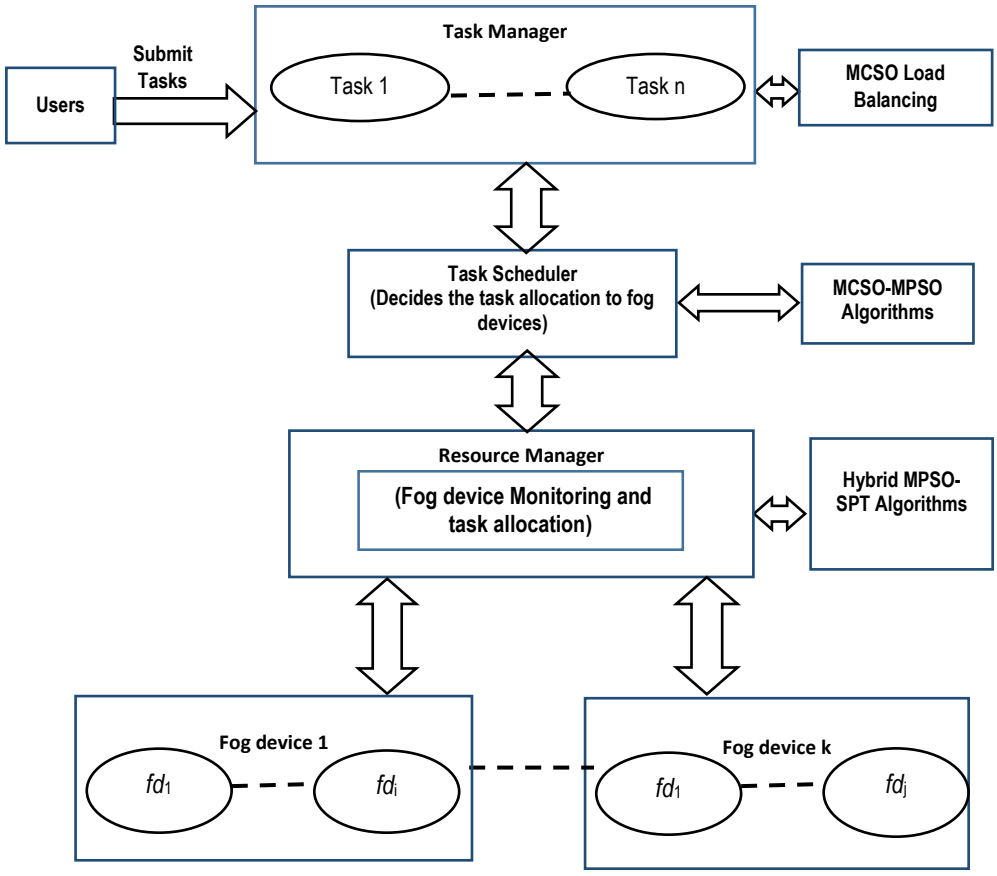


**Figure 3.1: Proposed system**

### 3.4 System Architecture

The proposed system in this paper, is intended to consider cloud-fog system which include fog nodes and cloud processing nodes. Our proposed system consists of three layers; client module, scheduler, and fog devices and cloud data centers, in the proposed system all user tasks and request are received by the scheduler, this schedule layer performs task scheduling and optimized by the



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optimization algorithm to obtain the best resource match for jobs based on the memory and CPU requirement of the tasks. MCSO will be used to schedule the task by finding global best (GB) for load balancing then hybrid MPSO-SPT algorithm for fog device monitoring and task allocation as resource manager based on fitness function.

There are many simulators that are available for evaluating fog computing research and assess the performance, but this research experiment is intended to use iFogSim simulator as a platform for simulating the proposed model. iFogSim is high performance toolkit to model and simulate the networks of Edge Computing, Internet of Things and Fog Computing. iFogSim integrates the resource management techniques which can be further customized as per the research area. The simulation with iFogSim works in association with the CloudSim. CloudSim is a widely used library for the simulation of cloud based environment and resource management. The layer of CloudSim exists to handle the events between the components of Fog Computing using iFogSim [1].

### 3.5 Expected Outcome

Proposed algorithm when implemented will produce an energy efficient task scheduling algorithm with improved latency and shorter execution time in fog computing.

## 4.0 CONCLUSION

Hybrid Meta-heuristics scheduling algorithm for energy efficiency in fog computing is proposed in this study as a research direction, the study intended to combine two heuristics algorithms and deterministic algorithm to achieve task scheduling in fog computing with shorter execution time, reduced latency and reduced energy consumption. The study proposed MPSO and MCSO for task allocation and virtual machine allocation between fog nodes and the user task or request, and hybridization of MPSO and SPT for task scheduling and resource allocation and management in collaboration between fog and cloud computing. The hybridization is to reduce the drawbacks of the heuristics or deterministic algorithms when used separately.

Future work will try to implement the algorithms in iFogsim and look at the performance of the algorithms, then evaluate the algorithms with other state of the art resource management and task scheduling algorithms in fog computing environment.

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