Energy efficient resource scheduling in fog computing

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Abstract*— Fog Computing paradigm extends the cloud computing technology to the edge of the network. The basic concept is kind of similar to cloud computing and supports virtualizations as well. It is very useful in healthcare, intelligent transportation systems and smart cities. Optimal resource scheduling is an important topic in fog computing virtualization. The resource scheduling procedure is an NP-complete problem where the time needed to locate the solution varies by the size of the problem. There are various computation-based performance metrics use in scheduling procedure such as energy consumption and execution cost. Optimal resource scheduling of tasks in fog computing can be classified as heuristic, swarm intelligence and hybrid task scheduling approaches. The heuristic task scheduling algorithms deliver ease to schedule the task and deliver the best possible solutions, but it doesn't guarantee the optimal result. The swarm intelligence approaches can handle massive search space to discover better optimal solution for task scheduling problem within reasonable time. Smart healthcare application model is implemented and simulated in iFogSim simulator tool which is used to test and select the technique to introduce a Whale Optimization swarm intelligence algorithm. Swarm intelligence algorithm is compared with several heuristic algorithms (RR, SJF) and PSO meta-heuristic algorithm. The results show that proposed algorithm improved the average energy consumption of 4.47% and cost 62.07% relative to the RR, SJF algorithms and energy consumption of 4.50% and cost 60.91% relative to the PSO algorithm.

Keywords: Fog computing, Tasks Scheduling, Energy management, Meta-heuristic, iFogSim

I. INTRODUCTION

A. Background

Fog computing[1][2][3] becomes popular because cloud computing is not enough to deal with the large amount of data generated by increasing number of connected Internet-of-Things (IoT) devices. Fog computing plays a significant role in minimizing the service delivery latency of different IoT-enabled systems and relaxing the network from dealing with huge amount of data to be sent to Cloud[4] datacenters, Fog nodes are not resource enriched. So, cloud and fog has to work together to make the work more successful. In this paper we are going to give an idea of a solution how to do energy efficient resource management for fog computing[5][6][7]. Resource management in Fog computing is incredibly sophisticated because it engages important range of numerous and resource constraint Fog nodes to satisfy process demand of IoT-enabled systems in distributed manner.

Meta-heuristic algorithm[8] is an advanced procedure designed to find or generate a good solution which is sufficient enough to solve an optimization problem in the cloud or fog environment. These type of algorithms are known as algorithms which gives exact solution which is guaranteed to the optimization problem under incomplete information or limited capacity in the system. Unlike heuristic algorithms[9], meta-heuristic algorithms don't ignore problems and they don't focus on efficient solution. They focus on the problem to be solved first. Meta-heuristics provide set of solutions by taking few assumptions about the optimization problems and those solutions can be used for various problems. These algorithms are able to find good solutions with less computational effort.

B.Motivation

When the fog devices are connected to datacenters and gateway nodes, these fog devices have to process data as well as store data. It happens all the time because fog devices have to support real time data transferring. In that case, network usage is high and there is a cost for this process. Since, these devices consume lots of energy, the cost of this execution process and network usage is also high. When the applications get more complex, those applications consume more energy and it takes more cost and network usage. Therefore, it's necessary to have a way to handle these too much waste of energy, cost and network usage. This research is focusing on analyzing the architectures of fog applications and the way energy consumes in these applications. During the analyze, the

parameters which affects the energy consumption and cost of execution are also analyzed. The motivation of this study is to finding a better to reduce the waste of energy, cost and network usage in fog environment.

Resource scheduling and allocating resources is important to maximize the use of these resources and the satisfaction of the end users. Resource scheduling[10] is the NP-hard issues in fog computing. Fog computing additionally offers a lot of flexibility to the overall technology because of its n-tier design. The purpose of this research is to find a meta-heuristic algorithm and implement it in iFogSim[11] simulation tool. For that, a smart health care application will be developed and simulated in iFogSim. Then, two heuristic algorithms Round Robin[12] and Shortest Job First[13] will be implemented in the Smart health care application. Then, these algorithms will be implemented in VR Game application and DCNS application. Finally, energy consumption of all algorithms will be compared.

C. Problem Statement and Research Questions

Energy management is required in fog environment. In this research, problem statement was how to manage energy efficiently in fog computing environment. This has been retrieved from following research questions.

RQ1 - How to do energy efficient task scheduling in fog environment?

RQ2 - How to solve NP-hard problem with task scheduling in fog environment?

RQ3 - How to implement meta-heuristic algorithms in fog environment?

RQ4 - What kind of objectives can be used for energy management?

RQ5 - What are the simulation tools for fog computing?

D. Research Objectives and Goals

The main objective of this research is to implement efficient task scheduling methods in fog computing environment to minimize energy consumption and cost. This main objective is achieved by focusing on achieving some sub objectives. First, researcher wanted to implement efficient task scheduling methods in fog computing to minimize cost and energy consumption. For that, it was needed to propose novel meta-heuristics algorithm to solve NP hard task scheduling problem in fog computing environment. To implement an algorithm, researcher needed to simulate a smart healthcare application in fog computing. Finally, as the evaluation of this research, it was required to evaluate the performance of the new WOA algorithm with other meta-heuristics and heuristics algorithms.

II. METHODOLOGY

A. Whale Optimization Algorithm

In this research, it provides a Whale Optimization Algorithm (WOA)[14] for resource allocation in order to manage energy. The Whale Optimization algorithm is a method for solving both constrained and unconstrained optimization problems that is based on natural selection, the process that drives biological evolution. Here, there is a fog node between administrator node and the user. When the user requests a service from the cloud, fog nodes send the request to administrator. Then, the administrator decomposes tasks and execute the algorithm to manage resources such as cost, storage, energy and so on.

In iFogSim, researchers are given already implemented two applications. They are VRGameFog and DCNSFog. When these applications are executed, it gives the output as energy consumption, Cost, network usage and so on. When these applications are studied, it is found that, there are number of sensors, actuators and other IoT devices are defined as variables in different packages in simulator. Further, there are classes for fog devices, tuples and so on.

1) Case Study 1: VRGameFog

VRGameFog[15] application is a game between two users that involves increased brain-computer interaction. The EEG headsets are connected to the smartphone. EEG headset sends the real-time signals to the gateway and calculates the brain state of the user. Application model has three functions. The consumer module receives raw EEG signals and sends those to concentration calculator and display modules. The concentration calculator module gets the sensed EEG signal values and calculates them. The coordinator module detects the game between players in distributed positions.

2) Case Study 2: DCNSFog

This case study is based on a monitoring system of cameras in areas of healthcare, transportation, Security and so on. The requirements of the system should be low-latency communication, handling massive data, and heavy long-term processing. In that case study, object tracker module tracks objects and then calculates a most suitable PTZ configuration.

3) Case Study 3: Smart Healthcare

In addition to the applications already developed, for developing this energy management algorithm, a smart healthcare application solution will be implemented in iFogSim. In that implementation, energy consumption of each fog device will be measured and total energy consumption will be calculated. Then, Whale Optimization algorithm[16] will be executed to reduce the energy consumed by fog devices. For healthcare solution, hand held or body connected IoT[17][18][19] devices for example; pulse oximeter, ECG monitor, smart watches and so on receive health details of the patients and through a Client application module. The IoT devices[20] are normally connected with smart phones. In this situation, smart phone act as the application gateway node. These nodes are for pre-processing data which are sensed by IoT devices.

B. Implementation

To create the application, following steps are hoped to be followed.

1. Create FogDevice object and define n-tire hierarchical Fog environment
2. Create Sensor object with different sensing interval and transmission of a par-ticular number of Tuples
3. Model mobility of and form cluster of the Fog devices
4. Define Application object for the discussing IoT-enabled healthcare application
5. Create ApplicationModule object with different requirements
6. Deal with additional requirements and deadline expectations of the ApplicationModule objects
7. Implement WOA to manage energy which was calculated in fog nodes
8. Connect those fog nodes with application gateway nodes

As the author mentioned before, the simulation environment of this research is iFogSim. After the application is created, next step was to implement algorithms in the application. Therefore, first of all, Round Robin application is implemented all three applications VRGame, DCNSFog and Smart Healthcare. Then, energy consumption and the cost of execution values are measured by running those applications. Then, SJF is also implemented in all three applications and got the output values by running the applications.
Now, heuristic algorithms are analyzed with task scheduling in three applications in iFogSim. Then, as the next step, meta heuristic algorithms are to be implemented. Therefore, PSO algorithm is implemented and energy consumption and cost values are received as outputs from all three applications. Now, moving to the main objective of this research, WOA is implemented in all three applications and got the results same as before. In this data collecting process, different parameters for each application are changed and analyzed the changes of the output results. As example, in DCNSFog application, number of areas and number of cameras per area are changed three times and analyzed the result. Then, same as before, in VR game application, number of departments and number of mobiles per department are changed and then, results are analyzed. Finally, in Smart healthcare application, number of gateways and number of end devices per gateway are changed and analyzed the output.
After analyzing the outputs, the results of the heuristic algorithms and meta-heuristic algorithms are compared. After that study, the results of PSO and WOA are compared. While comparing the results of PSO and WOA, the number of tasks are changed five times and analyzed the results and checked what algorithm is better for task scheduling.

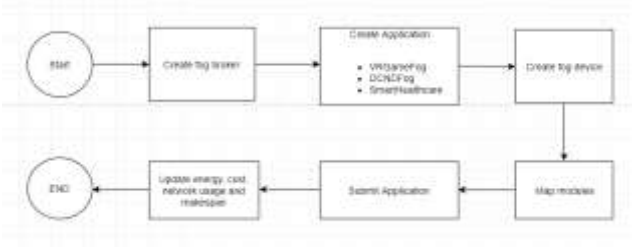

Figure 1: Way of implementing algorithm in an application

When the algorithms were implemented in iFogSim, a broker class was created extending DatacenterBroker class. In that class, number of VMs allocated is defined. Further, some of the methods are overridden in that class which are defined in DatacenterBroker class. In main class of the application, VMs, fog devices are created and mobility of fog devices and more characteristics are defined. Then, the module mapping is performed and after it is done application is submitted. Then, the energy consumption, network usage, cost and makespan values are updated.
After gathering the data from all the applications using all algorithms and by changing parameters, those data are compared each other. First, meta-heuristic algorithms are compared to heuristic algorithms and then, the results of the two meta-heuristic algorithms PSO and WOA are compared. Using these results, WOA will be proved as a better algorithm for task scheduling in fog environment.

III. Results

First of all, researcher implemented Round Robin, SJF, PSO and Whale Optimization algorithms in DCNS fog application and analyzed the energy consumption values and cost of execution values. When these results are analyzed, for further investigation, the number of areas and the number of cameras per area are changed and re-analyzed the results.

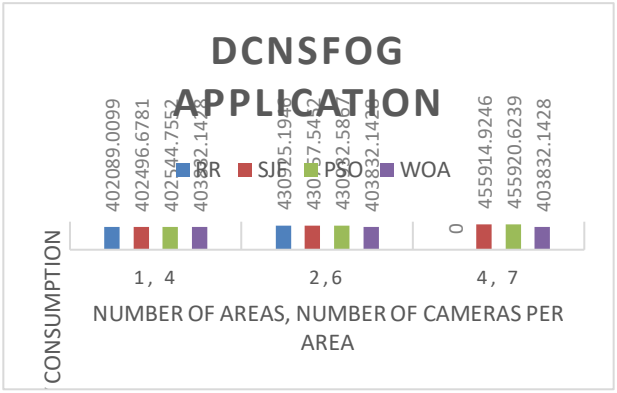

Figure 2: Energy consumption of DCNS fog application

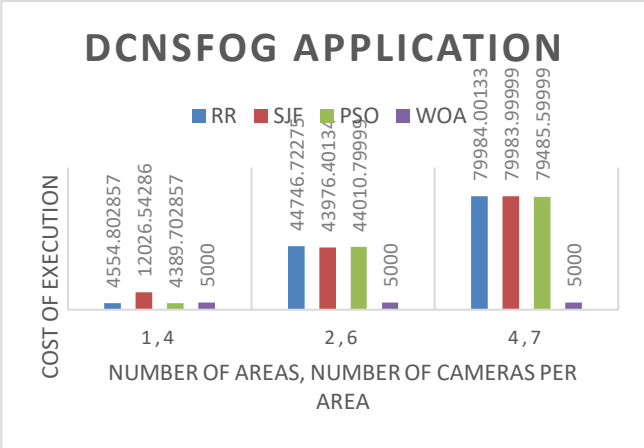

Figure 3: Cost of execution of DCNS fog application

Then the researcher implemented these algorithms for VR game application as well and got the results as following. For further investigation, number of departments and the number of mobiles for each department are changed several times and re-analyzed the results of energy consumption and cost of execution.

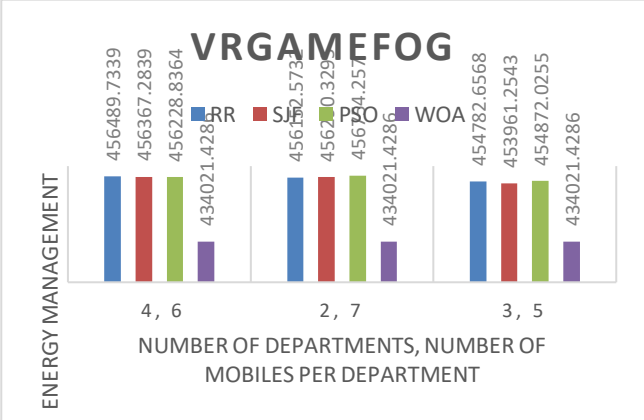

FIGURE 4: ENERGY CONSUMPTION OF VR GAME FOG APPLICATION

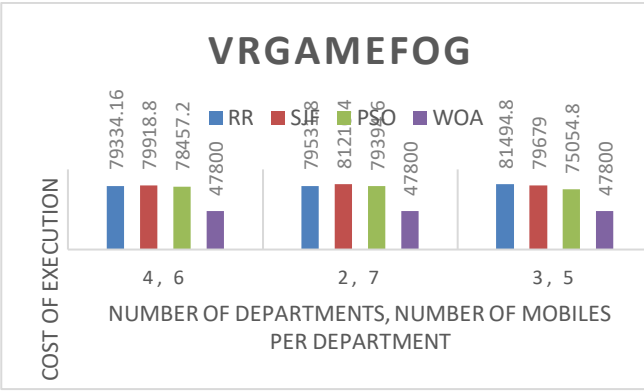

Figure 5: Cost of execution of VR game fog application

For cost as well, WOA has got less value considerably than other algorithms.

Finally, the main part of this research which is Smart Healthcare application is simulated in iFogSim and those four algorithms are implemented in that application. For further analysis, number of gateways and number of end devices per gateway are changed several times and analyzed the results of energy consumption and cost of execution again.

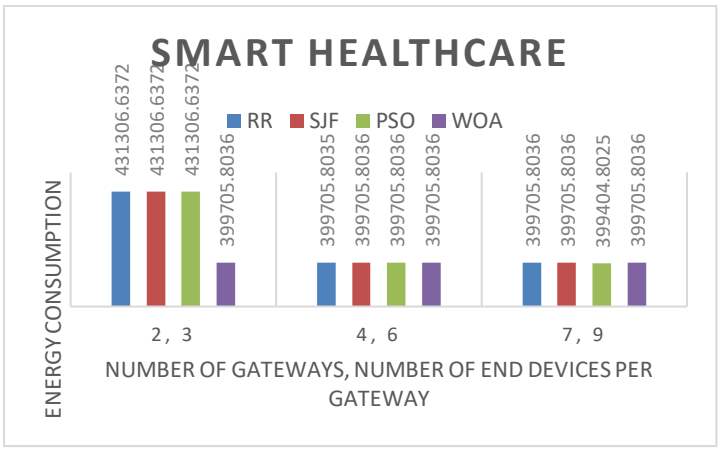

Figure 6: Energy consumption in smart healthcare application

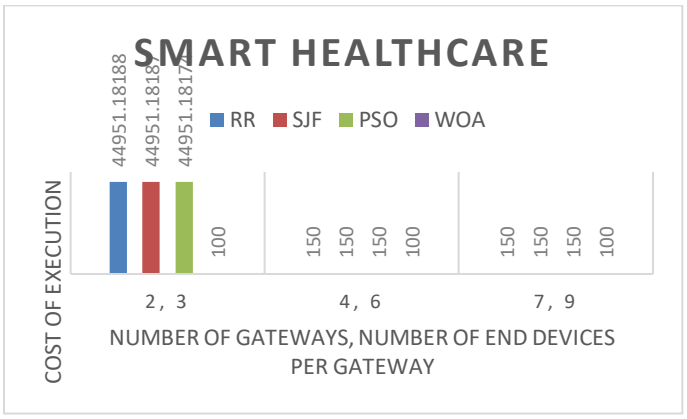

Figure 7: Cost of execution in smart healthcare application

After these algorithms are finished comparing by changing those parameters, researcher studied the changing of energy consumption and cost of execution according to number of tasks in meta-heuristic algorithms PSO and WOA. Therefore, number of tasks is changed five times and analyzed the results of energy consumption and cost of execution.

First, DCNS fog application is analyzed with number of tasks.

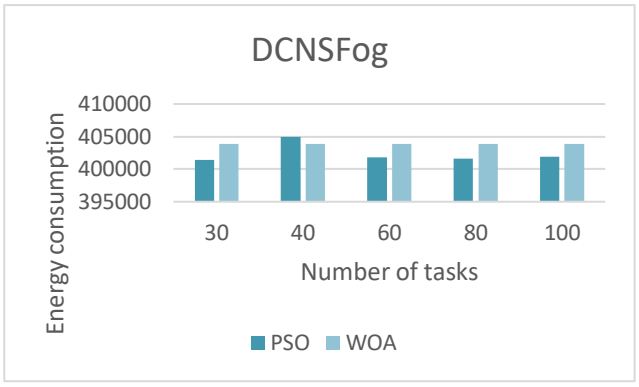

Figure 8: Energy consumption of DCNS fog application

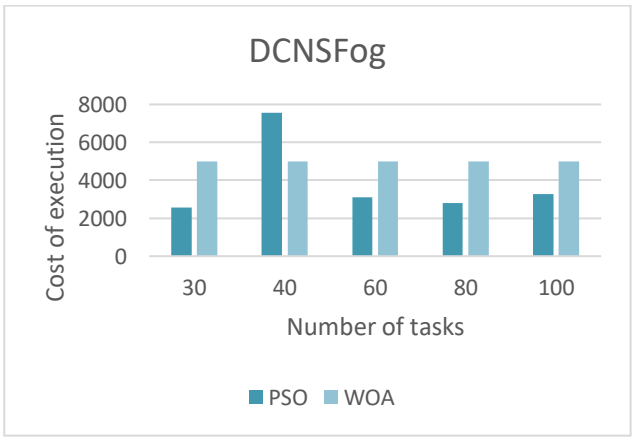

Figure 9: Cost of execution of DCNS fog application

Secondly, VRGameFog application is tested with meta-heuristic algorithms by changing number of tasks.

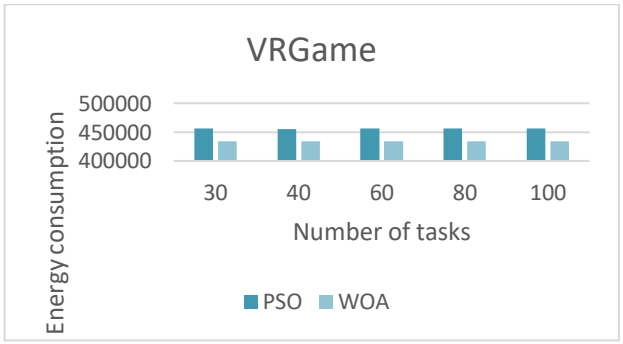

Figure 10: Energy Consumption in VR game fog application

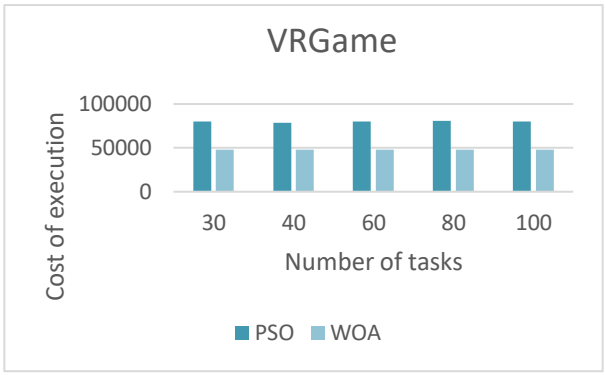

Figure 11: Cost of execution in VR game fog

Finally, Smart Healthcare application is tested with meta-heuristic algorithms by changing number of tasks and analyzed the results of energy consumption and cost of execution.

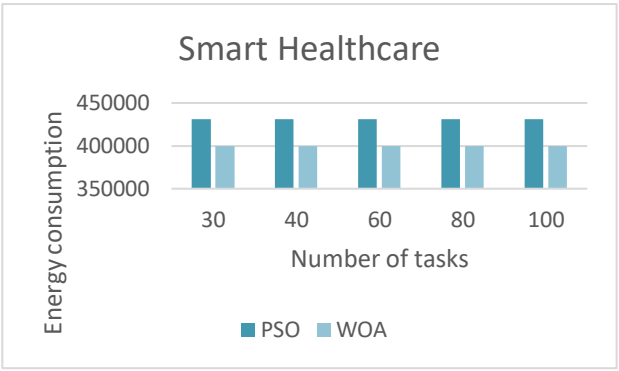

Figure 12: Energy Consumption of smart healthcare application

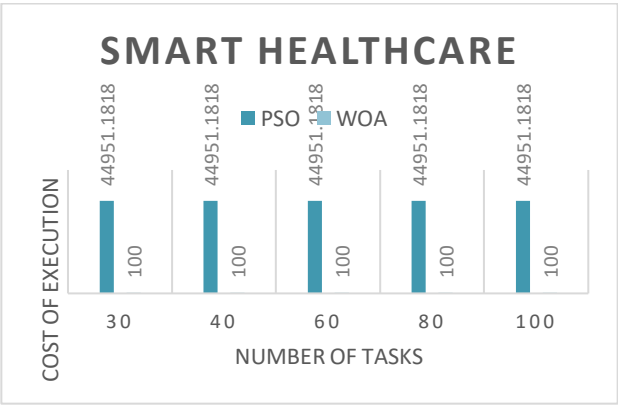

Figure 13: Cost of execution of smart healthcare application

These are the results of energy consumption and cost of execution in heuristic and meta-heuristic algorithms all three applications. All the results are stored and compared each other under different circumstances.

IV. Discussion and Conclusion

This research focused on implementing a new solution which would help energy management. For that meta-heuristic Whale Optimization algorithm was implemented in applications in fog environment. As it was expected, it gave a better solution than other algorithms such as SJF, RR and PSO. Since, implementing it with real IoT devices would be very costly, it was simulated using iFogSim simulation tool. iFogSim consists two applications named VRGameFog and DCNSFog. In addition to these applications, a smart healthcare application was developed and simulated in iFogSim. All the heuristic and meta heuristic algorithms were implemented in these three applications and ran test cases several times and got the average values of energy consumption and cost of execution in the fog environment. This WOA algorithm was developed by the researcher and analyzed the results. When it came to the analysing of results, all the results were compared each other by running algorithms several times by changing the parameters like number of tasks, cameras, gateways and so on. Then the results were diagrammed and analysed. When that investigation was done, it was able to come to a conclusion that meta-heuristic algorithms schedule tasks better than heuristic algorithms. According to the results, it gave the idea that Whale Optimization algorithm is better with tasks scheduling than Particle Swarm Optimization algorithm when meta-heuristic algorithms were compared.

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