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Article

Novel Dynamic Scaling Algorithm for Energy Efficient Cloud Computing

M. Vinoth Kumar[1], K. Venkatachalam[2], Mehedi Masud[3] and Mohamed Abouhawwash[4,5,*]

[1]Department of Computer Science and Engineering, Anna University, University College of Engineering Dindigul, Dindigul, 624622, India
[2]Department of Applied Cybernetics, Faculty of Science, University of Hradec Králové, Hradec Králové, 50003, Czech Republic
[3]Department of Computer Science, College of Computers and Information Technology, Taif University, Taif, 21944, Saudi Arabia
[4]Department of Mathematics, Faculty of Science, Mansoura University, Mansoura, 35516, Egypt
[5]Department of Computational Mathematics Science, and Engineering (CMSE), Michigan State University, East Lansing, MI, 48824, USA
*Corresponding Author: Mohamed Abouhawwash. Email: abouhaww@msu.edu
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Abstract: Huge data processing applications are stored efficiently using cloud computing platform. Few technologies like edge computing, Internet of Things (IoT) model helps cloud computing framework for executing data with less energy and latencies for better infrastructure. Recently researches focused on providing excellent services to cloud computing users. Also, cloud-based services are highly developed over IT field. Energy a level varies based on the cloud setup like speed, memory, service capability and bandwidth. The user job requirements are varied based its nature. The process of identifying efficient energy resources for the user job is main aim of this research work. Initially IoT, Edge devices capture the job and process to help cloud infrastructure. Data transferring process is a Non-deterministic Polynomial (NP) hard problem which can be easily supported by technologies like IoT and Edge computing. Main issue is, tremendous increase of data over the cloud causes difficult to manage consumption of energy. In this research work server clouds with edge devices and centralized cloud servers are combined to work for providing efficient energy consumption. Here, in this paper we implement novel dynamic speed scaling (NDS) algorithm. The CPU workload is first computed using NDS algorithm for incoming application. The less energy computation is achieved using energy internet of things (EIoT). Fine methodology called speed processor scaling, helps to consume less energy and less computation price. High energy consumption of processor is due to high computation speed. likewise, less energy is consumed during less processor computation speed. This technique is building in NDS algorithm and computed in Edge devices for less energy consumption. The result evaluation proves that proposed technique consumes only 10 s for data computation when compared to other existing techniques.

Keywords: Cloud computing; edge computing; IoT; energy; dynamic speed scaling algorithm; EIoT

1 Introduction

Usage of IoT devices widely for information computing like sharing, storing, processing etc. makes edge devices more important. Data Storing and processing of huge applications uses cloud computing as a best infrastructure. While more and more devices are being connected—we are talking about billions of units—imagine the amount of energy they consume. Moving artificial intelligence (AI)/machine learning (ML) to the edge means to focus is on custom designs that must successfully meet the critical requirements of low power use with high performance. Energy efficient ML algorithms take less processing power, run fewer CPU cycles and consume less memory; this enables us to run our algorithms on tinier devices that never before had the capacity to run machine learning on the edge. A slightly more energy efficient ML algorithm saves battery, CPU cycles, etc., which means we can run on smaller things. While it saves energy it also contributes to a development of more sustainable devices—and less CO_2 emissions.

The smart devices like mobile phones, Bluetooth's, wearable smart devices perform internetworking using emerging IoT devices [1,2]. At present, sensors, radio frequency identification (RFID) embedded with smart devices and connected to network forms mobile computing more popular. Health care applications, businesses, hotel management uses IoT more determinately [3,4]. Measuring of noise over the network is very difficult task. So nowadays high mobile applications improves it service quality by measuring energy, time, location, image capturing [5]. The real time data are sensed using the devices and processed by IoT and mobile based applications [6,7]. Further efficiency of devices is calculated using how less energy require to process for computing the data. If the devices have more computation capacity it consume more energy, time and memory for processing [8,9]. When the mobile devices consume more energy, it will abbreviate battery life and leads to emit greenhouse gases.

Cloud computing is considered as burgeoning method to overcome the limitation of the resources for mobile devices. This computing infrastructure helps mobile based applications to offload the data in cloud centralized server [10]. A cloud manager executes the on-demand resources for requested mobile applications. Above process helps to reduce the time of execution and energy consumption of smart IoT devices. This helps to increase life of battery and reduce time. Another problem addressed is, due to offloading data continuously, produce congestion in the network. Further WAN is used to connect the mobile devices leads to high data latency. so it is important to address the cloud offloading time of data in the network especially in intensive networks [11,12]. Edge computing makes small servers (data centers) to transmit data with minimum resources , access points and base station using edge based data radio network [13]. The process of communicating in cloudlets to local mobile devices via LAN reduces the data latency, bandwidth and offloading time efficiently [14]. Sometime Edge computing offloads data from both clouds as well as cloudlet server.

1.1 Motivation

Energy consumption is the major problem in every environment. Not only in cloud computing, it also big issues in small data processing in CPU. More energy consumption makes more power consumption, less data loading in more time and more bandwidth. The battery life is very less while consuming more power during processing. This makes huge data processing very difficult in maintenance of resources in cloud computing infrastructure. Our proposed article uses NDS algorithm to track the performance of CPU, processor based on input data. Our output is evaluated with existing algorithms.

1.2 Paper Contributions

Our research mainly focused on energy saving concept in EIoT for efficient cloud computing process:

- First, we focus on where the energy is consumed more in edge nodes in the mobile devices.

- Cloud-edge process with IoT is termed as multi objective problems.
- Here we check every edge node where the energy is wasted and where to process the next data.
- NDS algorithm is implemented to for scheduling the data process by consuming less energy.

Then the results are compared with varies energy saving algorithms for comprehensive evaluation process.

Further this article is organized as follows: Section 2 describes related work. The proposed implementation is described in Section 3. Section 4 describes the result evaluation. Finally, Section 5 concludes the work with future directions.

2 Related Work

Present information development makes big data age for every human being. Due to demand s of intelligent data processing, intelligent data terminals are required to process the data efficiently IoT have increased its usage and attracted more due to inventions of smart devices information process. Problem of reducing the IoT loss in every life cycle is achieved through analyzing the data efficiently by mining rules and characteristics on IoT. The advanced precision mathematical technique has to be enhanced in the present cloud IoT model to upgrade the traditional IoT methods. Application limitations are high knowledge in technical field and low precision. Recently IoT has more perfect data collection techniques in huge areas. Messages which are undiscovered will be collected by IoT databases. But it has concerns, when using traditional IoT analyzing methodology. Traditional IoT techniques are very difficult to summarize the IoT content and messages. This background uses knowledge discovery process, machine learning algorithms, data management and mining techniques for data management. Large capacity of data are handled using data mining techniques. This technique also capable of handling potential data and essential messages.

Expert knowledge on the domain is not necessary for data mining applications to identify the necessary information. This mining process proves it achievement in various fields. In depth study on data mining process to build the analysis model mainly based on grouping and clustering data. The clustering data in IoT applications is main method in data analysis strategy. Next, association-based rule mining method in data mining technology used to analyze an efficiency and effectiveness of IoT. Some software technologies are used to analyze theoretically about IoT data through mining strategy. Various communications like wired, wireless uses IoT to transmit and collect data from sensors by online process, early warning system, businesses by mobile terminals [15].

Markov decision making process used in making decision regarding the offloading of the data in the cloud [16]. The performance of the system and usage of powers are machine in cloud is applied with numerous queuing models in [17–19], for computing efficiently. Data offloading can be done on incoming tasks based on decision algorithms to offload data in local cloud or remote cloud through WLAN or cellular connectivity.

Total cost of Amazon server maintenance is estimated as 52% in which energy related estimation is 41% for consuming the power, cooling infrastructure etc. [20]. Advisor on global policy at Sweden of WWF suggested various IT solutions for reducing the greenhouse gas emissions [21] like CO_2. Smart buildings, smart infrastructure, smart communications on businesses, commerce etc. are some IT based implementations for various solutions. In report [22] of energy based forecast results as 25% of energy saving by improving the cooling needs of server machine. Most IT networks is need of less energy consumption programmers. Mainly in cloud computing infrastructure is widely used application in 20th century for data communication and storage. Energy efficient virtualization method used in paper [23] remotely computes the cloud and improves the scalability of the resources.

The task dependency, transmission process, transfers condition like time, cost is considered to model the energy optimization problem using genetic algorithms. The performance of the system is evaluated for efficiency calculation [24]. A cloud software toolbox with libraries and service components used to develop a energy efficient infrastructure in stack of three layers. In this model reduce the consumption of power by deploying software in cloud [25]. Energy efficient methodology for Mobile device is proposed in [26], it improves the time of execution of mobile based applications cloudlet devices. Edge cloud-based framework using three layers for wireless resource scheduling of data offloading service computation is performed. This algorithm can save 80% of energy [27]. Cloud resources status is monitored by analyzing data obtained from tasks. At the right time target migration of data is consolidated before placement of data into the resources. It saves energy up to 21% on heavy load [28].

The energy and power efficiency of cloud physical and virtual machines is optimized in [29]. Here we study about different workloads affects the energy efficiency of the cloud computing system. Security of mobile cloud is proposed in novel offloading methodology. It combines techniques like secure hash algorithms (SHA), Advanced Encryption Standard (AES) and Diffi–Helman key transfer exchange technique. It provides high security to cloud when comparing with other types of algorithms [30]. Offloading algorithm provides less energy computation. The complex infrastructure like multi load parallel process in the area of cloud computing uses decoupling strategy in the virtualization [31]. Energy based resources allocation in distributed network improves the cloud computing process more efficiently. Consumption of energy and delay process in network is handled using NOVEL system design algorithm. It shows how better novel algorithm works to provide various simulation results [32]. Placing the virtual machines in the network is addressed using Swarm modified Salp algorithm. This algorithm computes the virtual machine placement in the network with less energy consumption and maximum utilization of resources. It also reduces cost of migration and violations.

The virtual machines allocated are directly proportional to used physical system [33–35]. This will provide less energy consumption. Randomly incoming tasks which are heterogeneous in mobile cloud architecture satisfies the QoS for reducing the consumption of energy [36,37]. Heterogeneous cloud computing infrastructure uses power aware scheduling methodology to consume less power. Swarm intelligence based artificial bee colony strategy is used in power consumption of cloud computing platform. Failed machines also will be under same requests. This means QoS is higher for this operation.

3 Proposed Methodology for Novel Dynamic Scaling on Edge Node Algorithm for EIOT

3.1 Problem Formulation

Edge computing is an emerging trend to bring computing and system monitoring activities that are related to the IoT devices. To address the issues in IoT based applications like network latencies, data processing and energy consumption, edge computing is the key to solve the issues. Edge computing focuses many advantages over the critical challenges on IoT environment such as edge devices security, agility of deployment, low latency and efficiency of cost and performance. AI based machine learning algorithms used to predict the future needs on IoT, to concentrate the possibilities to integrate the machine learning with IoT and edge computing in terms of energy saving.

In day today life, more IoT devices are in use. While more and more devices are connected, the energy consume by the devices are day by day increasing. To focus on low power usage with high performance, the machine learning algorithms are combined with edge computing that will focus on custom designs to meet the requirements successfully. An energy consumption algorithm on IoT with edge takes less processing power in terms of processor utilization and also consumes less memory. Due to the processor device scaling based on edge, our algorithms can be run on smaller devices.

The proposed framework is capable to process the data in edge node of the network. With the extension of the statements, the paper presents a novel dynamic scaling on edge node algorithm in edge computing frameworks for IoT environment. This paper also compared the proposed methodology with the existing energy consumption algorithms such as deep learning, Hoeffding Tree algorithm (HTA), dynamic Speed controller, Modified Best Fit Decreasing (MBFD) and LOAD to analyze the performance of the proposed work. The architecture for the proposed work is shown in Fig. 1.

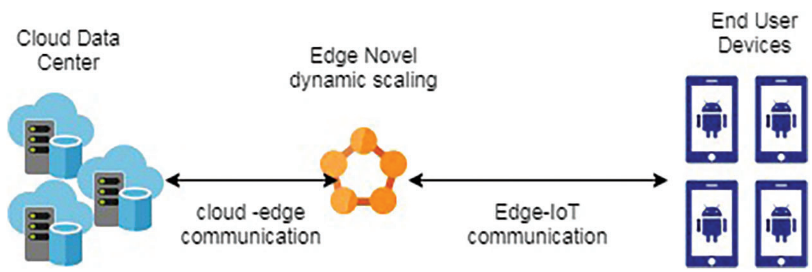

Figure 1: Proposed architecture for EIoT

3.2 Architecture

In edge computing, the edge node is present in between of the end user (IoT devices) and cloud. It is also termed as fog node. In our proposed work, the algorithm has been applied to utilize the cloud processor in less energy in terms of the edge node. As faster the workload, the energy will be saved. To balance the workload based on the proposed criteria, the speed of the cloud processor is changed according to the algorithm applied on the edge node.

In general, high processing will consume more energy while less processing job consume less energy. Hence, the proposed algorithm maintains two flags to monitor the cloud processor utilization. The flag1 to monitor the cloud processor utilization is high at the edge node and flag2 is to monitor the cloud processor utilization is low. Based on the flags, the cloud processor speed is increased or decreased. According to the workload, the speed of the cloud processor executes the instructions based on the edge node, so that the speed is altered. The workload is considered as areas set under the surveillance and monitoring of the possibilities. In this proposed work, the workload area is between the ranges 1 to 16.

3.3 Proposed Working Process and Algorithm

The proposed workflow stated in following steps,

i) Analyze the energy model of the algorithms—where energy is being utilized
ii) Updating the flag to check the change of cloud processor speed.
iii) Proposed article is implemented in terms of edge node in the cloud environment
iv) Testing is done for types of possible workload areas; lower and higher.
v) The proposed algorithm is compared with the existing energy efficient algorithms to analyze the performance.

To keep track of the utilization level of cloud processor is high or low, the amount of workload assigned to the EIoT application is monitored at each iteration. The flag value indicates the need to switch the cloud processor speed from high to low or low to high at the edge node. The maximum value of each flag is set to two iterations, which means if the amount of a workload is reached 2 iterations, then the cloud processor speed is changed. The importance of flag is to avoid the consequent cloud processor speed alterations. Here, the workload categories are limited to higher and lower in terms of area. The areas ranged from

1–8 are considered as lower and areas ranges from 9–16 are considered as higher. The lower workload area is allotted to flag1, and higher workload area is allotted to flag2.

According to the received flag value at the second iteration, the speed of the cloud processor will be altered and reaches final stage in terms of edge node. Here, if flag1 function receives value 2 as signal for functioning iteration 2, then the speed of cloud processor at the edge device decreases. In case the signal received indicates the flag2 then the speed of cloud processor at edge device would be increased. The algorithm for the proposed methodology Novel Dynamic Scaling on Edge Node (NDSEN) is,

Algorithm 1

Initialize: Procedure Energy_Saving_NDSEN (Flag1, flag2, t1, t2)

If areas >= 1 and areas <= 8

if flag1 = 2 then

$p(u) = k \times p_{low} + (1 - k) \times (p_{high} - p_{low}) \times u$

$energy = \int_{t2}^{t1} p(u(t))dt$

//Decrease the processor speed

End if

Else if areas >= 9 and areas <= 16

If flag2 = 2 then

$power(u) = k \times p_{high} + (1 - k) \times (p_{high} - p_{low}) \times u$

$energy = \int_{t2}^{t1} p(u(t))dt$

//The increase the processor speed

End if

End if

where,

Phigh–Maximum utilization of server in terms of power;

p_{low}–Minimum utilization of the sever interms of power;

K–Amount of power used by idle server;

u–Cloud processor utilization;

u(t)–CPU utilization;

t1–Start time of workload of the area;

t2–End time of the workload of the area;

In Fig. 2, the flow of our proposed NDSEN algorithm is depicted. The designing of proposed methodology of dynamic scaling on edge node can consume energy less than any other traditional IoT applications used by the authors in reference paper. In the proposed methodology, the cloud processor edge node speed is increased or decreased based on the workload area. So that the energy will be saved according to the speed of the cloud processor. Even though for maximum workload needs more energy our algorithm effectively performing the computation so that the speed increased to complete the task on time to save the energy.

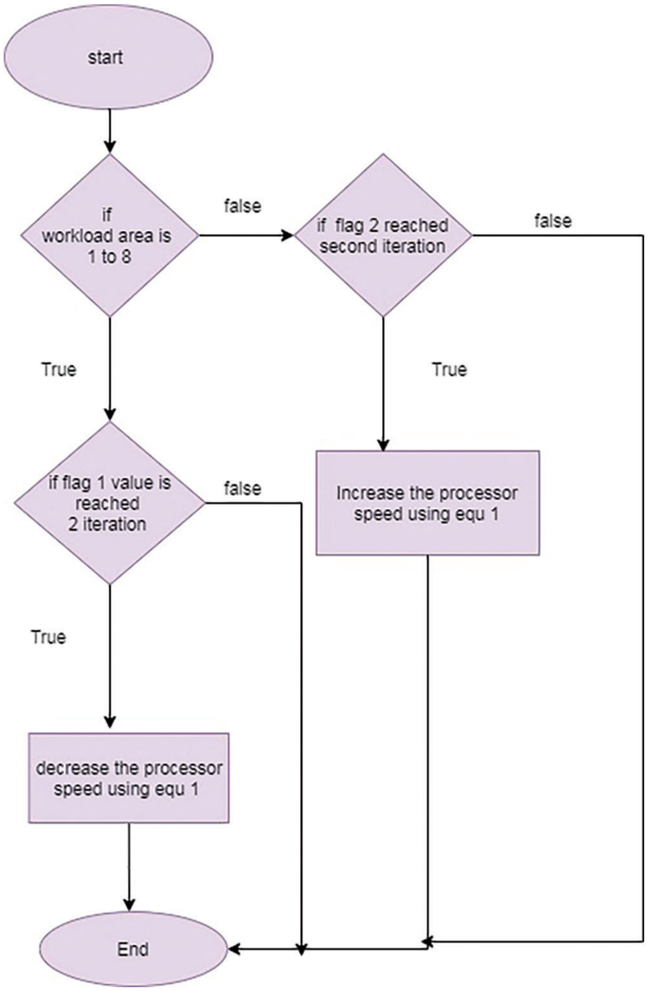

Figure 2: Flow chart of the novel dynamic scaling on edge node algorithm

3.4 Existing Energy Saving Algorithm

(i) **Hoeffding Trees**: Hoeffding Trees is a decision tree algorithm which use static hyper parameters for data to avoid the repetitive tasks since the repetitive tasks need more energy consumption. They proposed the solution that based on the characteristics of the data, the hyper parameters value will be changed. The proposed trees splitting criteria is based the energy used the splitting nodes. The reasonable accuracy node used the increasing energy whereas the rest of the nodes in the tree ran on less energy environment. These solutions of the proposed hoeffding trees reduce the energy level by only 20–40%. So, there is a need to develop better algorithm in terms of energy consumption.

(ii) **Deep learning algorithms**: Deep learning algorithms are based on neural network to solve complex problems. Due to the power of this networks to solve the complex problems like object recognition, it consumes major amount of energy. The existing method saves energy in terms of contributing methods like pruning and quantization. To remove the redundant connection in the neural networks, pruning used. This will reduce the memory access and computations. Quantization was used to reduce the energy by reducing the weights of the network with lower precision.

(iii) **Dynamic speed controller algorithm:** The processor speed controller is a recent methodology implemented by more research scholars for energy consumption. In this work, the energy saved based on the CPU speed. Based on the workload areas like higher, moderate, and lower, the speed can be increased or decreased in terms of the Counter variable. The workload on EIoT can be tracked by using dynamic speed controller which is placed on EIoT device by the IoT applications, in order to change the speed of the CPU.

(iv) **MBFD:** The term "Modified Best Fit Decreasing (MBFD)" uses SLA (Service Level Agreement) to assure the reduction of energy consumption at data centers. VM placement at initial stage is solved using bin packing strategy. Tasks have uncertainty in this process. This problem became main motivation for our proposed algorithm. Also, uncertainty in task makes few VM to host high provisions of applications whereas other VM use fewer resources to run. If cloud servers have unbalanced work, then it results in resources wastage and less performance.

(v) **LOAD:** The algorithm in—LOAD used to learn energy utilization automatically. It also considers SLA at VM's in cloud servers. This algorithm counts demands of users on resources and predicts the overload of hosts. It helps to reduce overloading at early stage. It stops idle hosts in demanding to save energy consumption at servers. The process of automatic learning detects the overloading and improves VM allocation to hosts by consolidating. It also monitors the hosts usage of CPU resources.

4 Result and Analysis

iFogSim in used to produce simulation for implementation of proposed methodology. It is considered as a dynamic platform for IoT based applications. In the cloud and edge computing platform iFogSim used to produce resource handling simulation and policy of scheduling applications. IoT networks receives data from sensors on network and processed by edge computing devices. These processed applications transfer the actuators sense of process to iFogSim. The CloudSim functionalities are combined with iFogSim architecture for basic simulations of events. Fig. 3 is used to depict energy consumption system. The consumption of energy increases by running system with high speed.

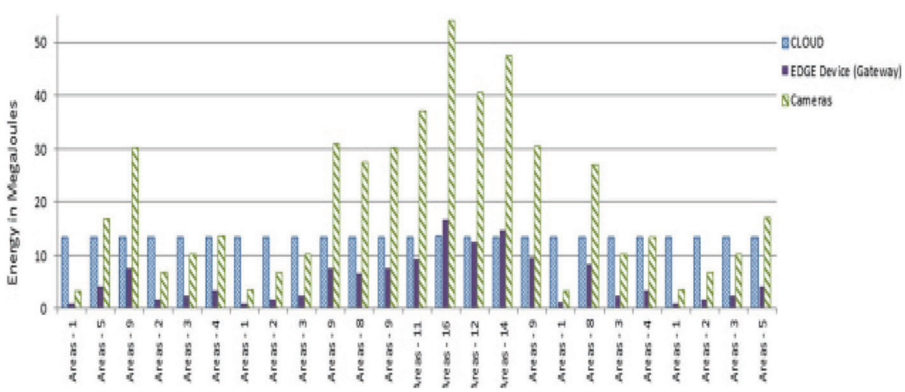

Figure 3: Simulation of energy consumption system

The inputs of proposed methodology are workload areas in the range of A1–A16. The corresponding cloud processor speed is either increased or decreased based on the flag function, which is shown in Tab. 1. Here the processor speed is changed after two iterations of each flag. Because constant change of the processor speed causes system inefficiency.

Table 1: Inputs towards the system response

Workload areas	A1	A9	A4	A11	A13	A7	A5	A14	A15	A16	A2	A3	A10	A6	A8	A12
Cloud Processor Speed (MIPS)	↓	↑	↓	↑	↑	↓	↓	↑	↑	↑	↓	↓	↑	↓	↓	↑

To analyze proposed NDSEN algorithm performance, the measures like Energy consumption in terms of Mega Joules, Network Usage in terms of Kilo Bytes, Execution Time in terms of Seconds and Loop Delay in terms of Seconds are compared with the existing Energy Saving algorithms such as Hoeffding Tree algorithm (EEA), dynamic Speed controller, MBFD and LOAD. The first measure energy consumption is calculated based on the computation complexity.

Computation complexity is one of the important metrics, which help the determination of the extent of effectiveness of the power consumption. In this research work, the energy of the proposed algorithm is determined using the power utilization of the cloud processor in terms of joules and time utilized for particular area as follows.

$$\text{Energy(Joules)} = \text{power utilization} * \text{time}$$

Tab. 2 represents the energy consumption of the energy efficiency algorithms. The equivalent chart is depicted in Fig. 4.

Table 2: Energy consumption

Energy efficiency algorithms	Energy
Hoeffding trees	130
Deep Learning algorithms	120
Dynamic speed controller	100
MBFD	180
LOAD	150
Proposed Novel dynamic scaling on edge node algorithm	80

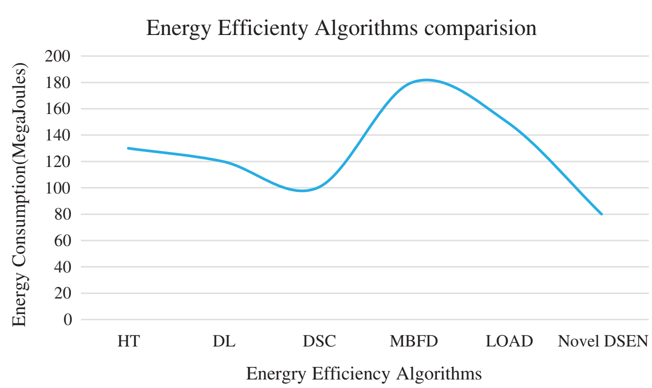

Figure 4: Energy consumption comparison of the energy efficient algorithms

From the Fig. 4, one can understand that our proposed Novel dynamic scaling on edge node algorithm consumes less energy of 80 J compared to the other existing energy saving algorithms on cloud such as Hoeffding Tress (130 MJ), DL (120 MJ), dynamic speed controller (100 MJ), MBFD (180 MJ) and LOAD (150 MJ) algorithms. Our proposed algorithm consumes less energy in terms of the speed scaling on edge node based on the flag values allotted to the input workload areas. The next to the proposed algorithm is Dynamic speed controller mechanism. Corresponding to the energy consumption comparison, the algorithms are compared in terms of network usage, time consumption and Loop delay for better analysis of the proposed algorithm. The Network Usage comparison is shown in Fig. 5.

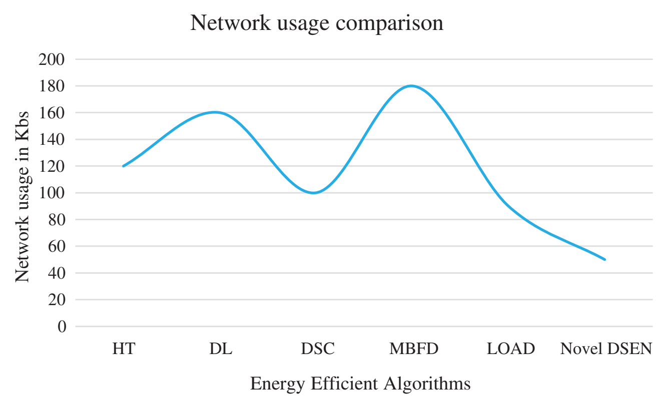

Figure 5: Network usage of the energy efficient algorithms

Fig. 5 shows that the proposed algorithm consumes knowingly lower network bandwidth of 50 kB under dynamic scaling of on the edge node compared to other existing algorithms such as Hoeffding Tress (120 kB), DL (160 kB), dynamic speed controller (100 kB), MBFD (180 kB) and LOAD (90 kB). The execution time shows the better result in attaining minimum time for processing the IoT applications. The Fig. 6. shows the execution time of the energy efficiency algorithms in terms of flag 2.

Fig. 6 shows the attain minimum time consumption of 10 s while using proposed algorithm compared to existing algorithms such as Hoeffding Tress (50 s), DL (30 s), dynamic speed controller (35 s), MBFD (55 s) and LOAD (45 s) algorithms.

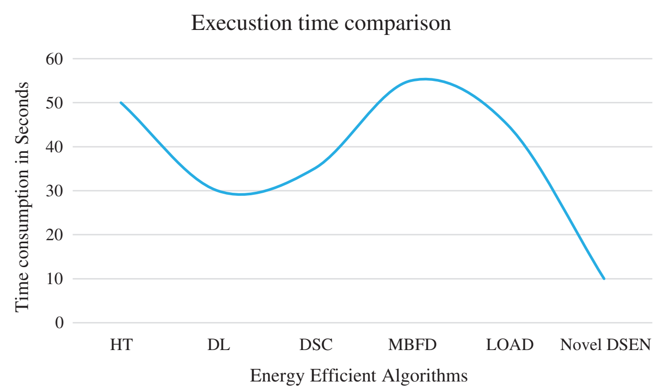

Figure 6: Execution time comparison of energy efficient algorithms

The Fig. 7 shows delay in the inner Loop of IoT application which is responsible for using better service quality in cloud computing-based edge devices.

From Fig. 7, one can understand that our proposed algorithm loop delay time is 2.5 s compared to the existing algorithms loop delay time such as Hoeffding Tress (9.4 s), DL (5 s), dynamic speed controller (4.6 s), MBFD (7.5 s) and LOAD (6.8 s). Next to the proposed novel dynamic scaling algorithm DSC is best. Hence, in all the cases in terms of consuming energy, using networks, Time of execution and delay at loop, our Proposed Novel Dynamic Scaling on Edge Node algorithm gives better result compared to the existing energy saving algorithms.

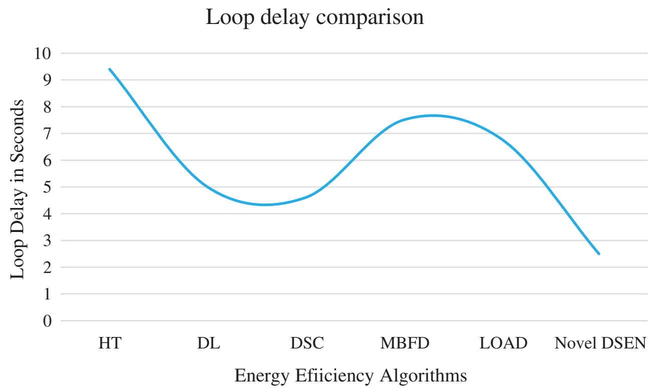

Figure 7: Loop delay comparison of the energy efficient algorithms

5 Conclusions

Future ICT mainly depends on energy consumption and power consumption. This process mainly saves the CO_2 emissions. The proposed strategy of novel dynamic scaling algorithms is implemented in this article. This research works mainly focus on the energy consumption in CPU and processor of the virtual machine. It identifies main energy consumption machine in the cloud computing network. Then the flags are used to monitor the energy of the respective system and what data to be processed based on its capacity. Large scale computer communications can achieve good energy saving plan by integrating the communication services based on needs. We have seen that large scale energy consumption networks have been proposed by this article. The output of the system is compared with various existing algorithms. The result obtained proves that novel dynamic scaling approach saves energy higher than older algorithms.

In future energy consumption algorithm with various services must be implemented. The Metaheuristic algorithm with AI can be also implemented for less energy consumption. Swarm intelligence and machine learning combine to give better results in future implementations.

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