Priya RM, S, Bhattacharya, S, Maddikunta, PKR, Somayaji, SRK, Lakshmanna, K, Kaluri, R, Hussien, A and Gadekallu, TR

Load Balancing of Energy Cloud using Wind Driven and Firefly Algorithms in Internet of Everything

Load Balancing of Energy Cloud using Wind Driven and Firefly Algorithms in Internet of Everything

Swarna Priya RM[a], Sweta Bhattacharya[a], Praveen Kumar Reddy Maddikunta[a], Siva Rama Krishnan Somayaji[a], Kuruva Lakshmanna[a], Rajesh Kaluri[a], Aseel Hussien[b], Thippa Reddy Gadekallu*[a]

[a]*School of Information Technology and Engineering, VIT - Vellore, Tamilnadu, India*
*Emails: swarnapriya.rm@vit.ac.in, sweta.b@vit.ac.in, praveenkumarreddy@vit.ac.in, siva.s@vit.ac.in, lakshman.kuruva@vit.ac.in, rajesh.kaluri@vit.ac.in, thippareddy.g@vit.ac.in**

[b]*Faculty of Engineering and Technology, School: Built Environment, Liverpool John Moores University, UK*
Email: a.hussien@ljmu.ac.uk

Abstract

The smart applications dominating the planet in the present day and age, have innovatively progressed to deploy Internet of Things (IoT) based systems and related infrastructures in all spectrums of life. Since, variety of applications are being developed using this IoT paradigm, there is an immense necessity for storing data, processing them to get meaningful information and render suitable services to the end-users. The "thing" in this decade is not only a smart sensor or a device; it can be any physical or household object, a smart device or a mobile. With the ever increasing rise in population and smart device usage in every sphere of life, when all of such "thing"s generates data, there is a chance of huge data traffic in the internet. This could be handled only by integrating "Internet of Everything (IoE)" paradigm with a completely diversified technology - Cloud Computing. In order to handle this heavy flow of data traffic and process the same to generate meaningful information, various services in the global environment are utilized. Hence the primary focus revolves in integrating these two diversified paradigm shifts to develop intelligent information processing systems. Energy Efficient Cloud Based Internet of Everything (EECloudIoE) architecture is proposed in this study, which acts as an initial step in integrating these two wide areas thereby providing valuable services to

the end users. The utilization of energy is optimized by clustering the various IoT network using Wind Driven Optimization Algorithm. Next, an optimized Cluster Head (CH) is chosen for each cluster, using Firefly Algorithm resulting in reduced data traffic in comparison to other non-clustering schemes. The proposed clustering of IoE is further compared with the widely used state of the art techniques like Artificial Bee Colony (ABC) algorithm, Genetic Algorithm (GA) and Adaptive Gravitational Search algorithm (AGSA). The results justify the superiority of the proposed methodology outperforming the existing approaches with an increased life-time and reduction in traffic.
Keywords: Green Communication, Cluster Heads, Energy Cloud, Internet of Everything (IoE), Wind Driven Algorithm, Firefly Algorithm.

---

1. Introduction

The enormous use of IoT technologies have revolutionised the way devices communicate with each other and human beings. The intelligence embedded in the IoT systems have contributed immensely to make human life more hospitable and comfortable. The developments of sensors, sensor networks and computational capabilities have enabled IoT to become the future of information technology and related applications. IoT provides a platform that allows embedded devices to be connected over the internet to ensure seamless collection and exchange of data. It also helps the devices to interact, collaborate and learn from experiences gathered, very similar to human beings [1].

The applications of IoT is prevalent in all domains of human life and are popularly used presently in smart home, wearable devices for health monitoring, smart farming, autonomous cars, smart retail etc. In cases of all these applications the basic framework of IoT application is deployed wherein the data acquired from the sensors are routed from various IoT network clusters and are sent to the cloud for processing and storage. The cloud analyses the data based on various intelligence algorithms and packages them as business intelligence for the user [1, 2].

Machine learning, data mining, deep learning and various analytics based technologies have been used in IoT frameworks to make technologies smarter, capable of predictions and classifications. The use of machine learning and deep learning approaches help to excavate novel, interesting and essential pattern pertaining to large datasets using innovative, traditional and hybrid algorithms [1, 2, 3].

Clustering is one such technique that helps in dividing objects that belong to similar groups. The training of data using clustering algorithms enables to get valuable insights from these data in order to predict there inclusions in an appropriate group. Clustering techniques thus often form nodes of a network into clusters and a cluster head is chosen based on the node activeness [1]. In case of network architecture, application of clustering technique enables energy efficient routing and assigns network topology administration to the cluster head. All these applications and framework often have scalability issues wherein IoT devices face hindrances to adapt to ever evolving changes in the environment thereby fail to meet newer user needs. In IoT applications such scalability challenges [2] of the IoT network have potential to be improved by aggregating the nodes of the IoT network into clusters and choosing an ambassador node, connected to the Internet assigned, to communicate on behalf of the other nodes. Such implementations help in enhancing system performance and also opens avenues for reengineering.

Some of the most industry preferred IoT cloud platforms are [3]: Microsoft Azure IoT Suite, Google Cloud's IoT Platform, IBM Watson IoT Platform, AWS IoT Platform and Cisco IoT Cloud Connect. These frameworks aid not only in storing the sensor data, but also enable the user to run machine learning algorithms to perceive the required information from the deployed IoT network. The IoT systems rely on data acquired from various types of sensors which have strict resource constraints.

Although IoT applications have opened up an era of convenience, but there are associated challenges relevant to power consumption, efficiency and reliability. It is important to realize that the smarter devices become, they tend to become less green. It is also difficult for smart devices to automatically save energy and technologies need to be designed to serve the same purpose. Hence, out of the aforementioned challenges pertaining to IoT, power consumption is a high prioritized challenge as identified by reputed scientists working on cloud based IoT applications. The observations elucidated from these scientific literatures point out the fact that, there exists a dire need for energy efficient frameworks for transferring the information to users and vice-versa [1, 2, 3]..

The present study proposes development of an energy efficient framework for accessing the information from IoE cloud network. With an objective to optimize the data efficiency of the sensors, Wind Driven Optimization algorithm is used to form cluster of related sensors. In order to select the right cluster head for these IoT clusters, a firefly optimization technique algorithm is deployed by using the metrics - distance, temperature, load, energy, cost function, alive nodes etc. This proposed energy optimized IoT network would contribute towards minimization of the traffic density to be stored in cloud. While processing the requests from the user end, an event aware node is used which aids in transferring the request seamlessly to the IoT network for processing of the required information

The unique contributions of the paper are:

1. Development of an energy efficient framework for accessing the information from IoE cloud network
2. Adaption of Wind Driven Optimization algorithm to form cluster of related sensors in the IoE framework
3. Application of firefly optimization algorithm to choose optimal cluster heads

The organization of the paper is as follows. Section 2 presents related work. Section 3 discusses briefly about the background algorithms used in this work. Section 4 describes proposed methodology. Section 5 highlights the results of experimentation and Section 6 incorporates the conclusion and points direction of future works.

2. Related Work

The dominant use of IoT applications has created immense research interest towards IoT and cloud computing technologies. The authors in [4] have discussed the unique characteristics of IoT based applications and how IoT portrays the role of interconnecting intelligent and self-sustained nodes, establishing a platform for seamless communication and collaboration among these nodes. IoT is a major resource for big data technologies which helps in the processing, storing and transferring of huge data across number of interconnected nodes in a form which can be easily understood and interpreted.

Cloud computing and related technologies like fog computing renders an extra hand to IoT based technology integrating storage, visualization, monitoring, and access of virtual resource infrastructures [5, 6]. Considering the huge data size and the number of heterogeneous nodes and networks to be seamlessly connected, development of energy efficient cloud based IoT applications becomes an absolute necessity. To fulfil such objective authors in [4] have developed an algorithm named as “multicloud IoT service composition (E2C2)” which helps to optimize the search and integration of minimum number of IoT services based on user requirements as well as considering the energy consumption aspects. The usage of minimum number of services for a particular requirement composition has enabled in significant reduction in the energy consumption and carbon footprints.

The application of IoT has its footprint across all spheres of human life. As an example, in the area of supply chain management, various researches have focused on deploying RFID based IoT technologies in smart factories and manufacturing industry [7]. IoT has also implemented in various levels of agriculture industry and relevant product chains. These applications basically collect, analyse and evaluate data pertinent to soil, atmospheric conditions, temperature, humidity, vibration, shock, biomass of plants and variables thereby enabling predictions relevant to product cultivation, demand, delivery and storage. It is obvious that convergence of sensor, energy, communication, computing, big data and visualization technologies are essential to create such level of IoT architecture [8].

Iot has gained immense momentum in research and industrial applications especially with the development of smart cities. The more intelligent and smart the devices have become, more they have deviated from being green [9]. Energy consumption cannot be automatically imbibed in these framework and hence devices need to be designed to ensure energy consumption is minimal. Also, when the energy is nearing to be drained out, devices should be designed to genrate automatic alerts to the provider to reduce occurences of disruption in services. Energy efficiency has thus become a major concern, ensuring ubiquitous monitoring, consistent and seamless communication. The authors in [10, 11] have implemented an IoT based energy management system using edge computation infrastructure in convergence with deep reinforcement learning (DRL). The unpredictability in energy supplies could be overcome using such DRL based scheduling scheme yielding better energy consumption at lower cost with even lower delays.

Wireless powered communication networks (WPCNs) based systems have been identified as the future direction in IoT applications. The authors in [12] have mentioned spectral and energy efficiency criteria as the primary focus in IoT technology where various energy-limited devices initially produce energy in the downlink and then transmit necessary information in the uplink. The authors in the paper have proposed the use of non-orthogonal multiple accesses (NOMA) for the improvement of spectral efficiency in fifth generation networks where concurrent transmissions could be allowed in the same spectrum deriving optimal time allocations. Any IoT architecture constitutes of a wide range of interconnected devices which have huge computational and storage capacities which are exposed to ransomware attackers. Hence monitoring of the power consumptions in the network becomes extremely important.

The authors in [13] have applied classification techniques namely K-Nearest

Neighbour, Neural Networks, Support Vector Machines (SVM), and Random Forest model to monitor the energy consumptions of the various applications in the network and segregate ransomware from safe applications. Authors in [14] have discussed the evolution of Low power wide area networks in IoT applications. The inference in LPWA networks is analysed in the paper for Sigfox and LoRaWAN in a large scale urban location and a comparative analysis of the networks are computed based on the occurrence percentage of inferences.

Also, in case of widespread geographical locations, sensor nodes are used to monitor physical events in a sensor networks. These nodes help to collect important data for a prolonged period of time from these locations but have issues pertaining to limited battery power. Hence deploying energy efficient systems using wireless sensor networks for gathering such information is an important operational requirement. The authors in [15] have implemented a "Low energy adaptive clustering hierarchy (LEACH)" protocol to enhance lifetime of networks applying clustering techniques. The increase in the energy variance in the nodes leads to load unbalancing thereby reducing stability period of the concerned nodes. The use of clustering helps basically to enhance stability, reduce variance in energy and make the systems more energy efficient. Narrow bandwidth is often a major reason for interruptions in a network resulting from creation of redundant data [16, 17].

The authors in [18] have proposed an "optimized clustering communication" protocol wherein an advanced algorithm is implemented for clustering in a sensor network. The choice of cluster head is done using an adaptation and heuristic function to find the next hops in the network. To further optimize and reduce energy consumption, controllable threshold parameters and variation coefficients are used to find the shortest paths in the network leading to efficient transmission of data in the network architecture. The primary measure to analyse efficiency of wireless sensor networks are its coverage and accuracy. In case of homogeneous and static wireless networks the task is quite simplified with the sensors having same features. But in case of heterogeneous networks, the task is quite cumbersome where each point in the network is under the coverage of multiple sensors having varied features. A generic globalised framework having multi-layer architecture is represented in [19] using adaptive hybrid forwarding scheme and mobile sink dividing it into concentric circular bands to collect data from all sensors in the network is considered to fulfil the objective of energy consumption.

One of the most common issues in wireless sensor network is a hotspot problem where nodes closer to sink tend to lose their energy at an accelerated rate in comparison to other nodes in the network. The authors in [20] have focused on eradication of the hotspot problem in heterogeneous wireless sensor networks using routing algorithm. The variation in energy for the nodes in the network depends on the selection of cluster heads in the network. The lifespan of the cluster heads with lower residual energy level gets increased due to irregular clustering. The application of next hop routing algorithm eliminates this residual energy issue and distance issues across the various nodes which enhances the efficiency of data transmission in a network.

Wind driven optimization techniques have been a popular choice for energy management of smart homes reducing consumption of energy and energy wastage. The authors in [21] have implemented hybrid approaches comprising of WDO and differential evolution algorithms with results evaluated for low and high dimensional cases to establish its superiority. The performance of load frequency controllers has become an important aspect of research in power systems. The authors in [21] have implemented Wind driven optimization algorithm which is an evolutionary algorithm gaining success in the tuning of load frequency controllers in power system domain.

Optimized selection of cluster heads for the refinement of routing is an approach adopted for energy consumption in wireless sensor networks. The authors in [22] have adopted a firefly algorithm motivated by energy efficient clustering protocol for wireless sensor networks. The cluster heads in the study were selected based on intensity value allocated using firefly algorithms. Thus, the clusters are formed based on the strength of intensity parameter of the cluster members under a cluster head. Due to the application of firefly algorithm, in case of densely populated network, the data transmissions between clusters happen within shorter distance leading to reduced energy consumption in comparison to LEACH and EOICHD based approaches.

3. Background

This section discusses about the preliminary definitions and concepts used in this work.

3.1. Internet of Things

Internet of Things is a system incorporating various computing devices, machines, human and non-human living beings assigned unique identifications termed as UIDs, which have the capability to transfer data over a network without any human or computational intervention [23]. IoT is the current industrial revolution which has changed the way different things interact with each other in the real world. Currently, IoT is considered as the most effective solution for business transactions in all industrial and domestic sectors namely hospitals, consumers, business industries and corporations. The reason behind this huge popularity of IoT based technologies in all these sectors lies in its ability to connect the various sensors and actuators involved in data collection that improves efficiency and productivity of any organization without much reliance on man power [24].

There exists wide spread applications of IoT and its use in effective host-to-host experiences for all the hospitals and clinics that are connected digitally ensuring complete security. The dominant applications of IoT can be visualized in Smart Home Surveillance, vehicle theft identification, Smart Cities etc. [25, 26, 27] that are based on IoT. Other applications worth highlighting would be its contribution in the increase in retailer based business. The retailers earlier were concerned about consumer data integrity which was achieved with the deployment of IoT. IoT has also enabled seamless connectivity among various devices, generating regular updates from the sensors in crucial real time applications pertinent to weather forecasting, waste management, fuel load monitoring etc [28]

Significant applications of IoT has been deployed in the manufacturing sector leading to energy optimization. IoT deployments have allowed controlling of energy consumption by monitoring the various functionalities and applications involved in domestic and commercial energy use without compromising on reliability. IoT provides optimized solutions for the efficient use of energy in all scales of organizations where wastage of energy has significant effect on business operations. IoT based systems are relatively lightweight and with the use of sensors technology an optimum level of security framework can be achieved which can defend issues like abrupt downtime, node failures, and communication disruptions [29].

IoT parameters which affect energy optimization of sensor nodes are primarily temperature, load, delay and distance. During the process of data collection from the sensors in an IoT based system, the system temperatures increase due to rise in energy consumption. Similarly, when there is an increase in the number of sensors, the proportional increase in load have huge impact on the energy optimization. In the IoT network, the devices can be added at any point of time which makes the network architecture extremely complex and large resulting in increase in system response time and delay due to heavy traffic in the network. Hence energy optimization becomes an extremely important area of research which would help to develop and deploy efficient and smart IoT applications.

3.2. Selection of Cluster Head

The CH of the Wireless Sensor Network (WSN) is usually chosen based on specific metrics such as size, delay and energy. In the proposed system, since the WSN is connected to IoT sensors, both load and temperature metrics of the devices need to be considered. The distance of the sensors to BS, the load of the sensors, the delay in transmitting the data, as well as the temperature of the devices, must be minimal and the energy of the sensors must be high [29].

3.3. Objective model

The objective model of the proposed work is on the basis of maximization function that is defined in Eqn. 1, Eqn. 2 and Eqn. 3. (β, γ) denotes the constant that has the fixed value of (0.9, 0.3) [30].

$$OM_1 = O_M^{ene} \frac{1}{O_M^{load}} + O_M^{ene} \frac{1}{O_M^{temp}} \tag{1}$$

$$OM_2 = \beta \frac{1}{O_M^{dist}} + (1 - \beta)\, OM_1 \tag{2}$$

$$OM_3 = \gamma OM_2 + (1 - \gamma) \frac{1}{O_M^{del}} \tag{3}$$

3.3.1. Distance Computation

Eqn. 4 Gives sensor nodes distance to the base station. The distance between the CH and base station is determined in Eqn. 5. Similarly, $O_M^{dist}(n)$ analyzes the distance between two (normal) sensor nodes in Eqn. 6. Here, the value of $O_M^{dist}(m)$ must be in the range 0 and 1.

$O_M^{dist}(m)$ is the distance between the sensor node and the CH which is given as.

$$O_M^{dist} = \frac{O_M^{dist}(m)}{O_M^{dist}(n)} \tag{4}$$

$$O_M^{dist}(m) = \sum_{p=1}^{N} \sum_{q=1}^{NCH} \left\| N_p^{normal} - CH^q \right\| + \left\| CH^q - B^I \right\| \tag{5}$$

$$O_M^{dist}(n) = \sum_{p=1}^{N} \sum_{q=1}^{NCH} \left\| N_p^{normal} - N_q^{normal} \right\| \tag{6}$$

3.3.2. Computation of Energy

Eqn. 7 evaluates the use of energy through IoT devices. In order to improve network performance, the energy should be maximum which is expressed in Eqn. 10,

ENE $\left(N_p^{normal}\right)$ denotes the energy of p^{th} normal node

ENE$\left(N_q^{normal}\right)$ specifies the energy of q^{th} normal node.

$$O_M^{ene} = \frac{O_M^{ene}\left(m\right)}{O_M^{ene}\left(n\right)} \tag{7}$$

$$O_M^{ene}\left(m\right) = \sum_{q=1}^{CH} nENE\left(q\right) \tag{8}$$

$$nENE\left(q\right) = \sum_{p=1,p\epsilon q}^{M^M} \left(1 - ENE\left(N^{normal}\right) * ENE(CH)\right); 1 \leqslant q < CH \tag{9}$$

$$O_M^{ene}\left(n\right) = CH * Max_{p=1}^{CH}\left(ENE\left(N_p^{normal}\right)\right) * Max_{q=1}^{CH}\left(ENE\left(N_q^{normal}\right)\right) \tag{10}$$

3.3.3. Delay Computation

Eqn. 11 is used to measure the delay experienced by IoT devices when transmitting data to the base station. The number of sensor nodes in all clusters must be small to eliminate delay.

$Max\left({}_{q=1}^{CH} CH^q\right)$ denotes the CH count in the network

N^N denotes the cumulative IoT sensors.

$$M_{del} = \frac{Max\left({}_{q=1}^{CH} CH^q\right)}{N^N} \tag{11}$$

3.3.4. Computation of Load and Temperature

The load and temperature of the sensor nodes are evaluated using Xively real-time IoT platform [31].

3.4. Wind-Driven Optimization (WDO) Algorithm

WDO is a recent meta-heuristic algorithm which conceptualizes the motion of air parcels in the wind based on Newton's second law [32]. This algorithm can be successfully implemented in multi-modal and multi-dimensional problems for implementing search domain constraints. In the velocity update equation, WDO uses additional terms when compared with similar PSO algorithms, which results in extra freedom and robustness for fine-tuning optimization. WDO performs well for both continuous and discrete parameters.

3.5. Firefly Algorithm

Firefly Algorithm (FA) [33] is a predominant algorithm among several bio-inspired algorithms for optimizing energy concerning the cluster heads of IoT. Firefly has been used in many applications like classification of medical datasets, dimensionality reduction, clustering etc [23, 34, 35, 30]. Firefly algorithms have been a popular choice of implementation in various fields of engineering achieving optimum efficiency and hence became an obvious choice in the present study as well. The algorithm is bioinspired wherein, each Firefly has an outstanding brightness and easily attracts the other fireflies in close proximity radiating light emited from the body. The mathematical equations followed in the FA algorithm are:

$$\alpha = \alpha_0 e^{-\gamma n^2} \tag{12}$$

$$a_p = a_p + \alpha_0 e^{-\gamma n_{pq}^2}(a_q - a_p) + \beta\epsilon_i \tag{13}$$

Where α_0 represents attraction at initial value $n = 0$ and the distance between any two fireflies (p, q) at a_p and a_q respectively and which is equivalent to $n_{pq} = a_p - a_q$ β and ϵ_i are the parameters of random movement parameters and vector for random values.

Inspired by the biological nature of any two fireflies as mentioned by a_p and a_q it is considered that p^{th} firefly gets attracted by the q^{th} firefly during a natural movement phenomenon. If $\alpha_0 = 0$, then it leads to a random walk. Also, ϵ_i indicates the process of randomization among the several fireflies which can be furtherly extended to the multiple scatterings like Levy flights which has an extreme variance and mean. Considering random walk and step length of Levy fly distribution, the equation is mentioned below as:

$$L(s, \lambda) = s^{-1+\lambda} \tag{14}$$

Where λ ranges from 0 *to* 2. Firefly algorithm has high convergence rate, and it is easy to find solution for complex problems with limited population, but it requires more control variables and iterations to complete the whole process. In the end the fireflies are ranked selecting the best ones in close proximity to one another.

Here firefly optimization algorithm is applied to select optimal solution. The firefly algorithm is illustrated below:

1. N no of solutions are randomly generated.

2. Fitness value is calculated using Eqn. 15.

$$M = F_{PCA} + c + O_P \tag{15}$$

Where M is the fitness value in the present work, F_{PCA} is features obtained by applying PCA, O_p is the objective function, c is the constant ranging between $[0, 1]$

3. Update the solutions using the following Eqn. 16.

$$F_i^{t+1} = F_i^t - \gamma_0^{xt} e^{-\beta C_a^2} (F_j^t - F_i^t) + \xi_t \psi_i^t \tag{16}$$

where F_i^{t+1} denotes updated i^{th}position, F_i^t denotes current i^{th} solution, F_j^t denotes current j^{th} solution which is the brighter fly, ξ_t denotes the randomization parameter, ψ_i^t is a vector of random number from Gaussion distribution at time t, γ_0^{xt}, β are the constants related to the attractiveness of the firefly.

4. N fitness values are generated for each of the iteration in firefly algorithm.

5. The optimal solutions are selected using fitness function.

6. The firefly algorithm terminates once all iterations are completed.

4. Proposed Methodology

Energy Efficient Cloud based Internet of Everything (EECloudIoE):

The model of the proposed EECloudIoE framework integrates the Internet of Everything with Cloud, providing real-time services as shown in Figure 1. It is composed of three different parts namely:

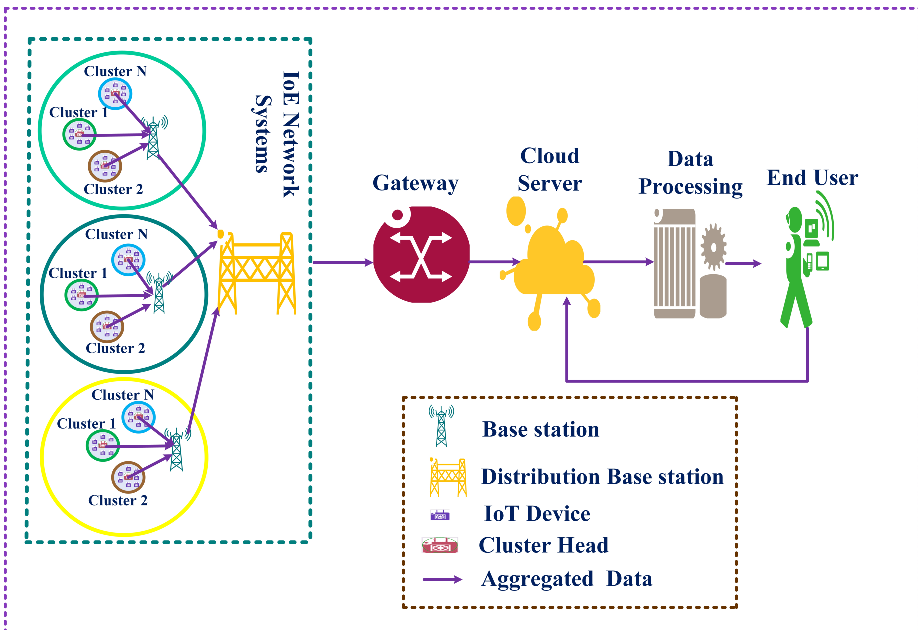

Figure 1: EECloudIoE Framework

1. The network of IoT networks termed as Internet of Everything (IoE)
2. Cloud Storage and data processing
3. End-User Services

4.1. Internet of Everything (IoE)

Internet of Things is the latest buzz word with wide applications in all spheres of life. As already mentioned, it is a paradigm where the word "Things" refers to any object in the global environment, which can either be a device that communicates or non-communicating or even a dumb object[36]. As an example, a leaf of a tree, a beverage bottle, a mobile, a sensor, a television, a table, or even a chair or any object can be part of this network. These objects or things can communicate over the internet. Hence it is referred as "Internet of Everything" in the present study. It is also apparent that in the forth coming years, apart from smart devices, massive traffic on the internet would be a resultant of household packets and related communication services dominating everyday human life. So there is a need for a network of IoE that are heterogeneous.

We know that the IoT networks are composed of various sensor nodes which work on limited battery power, limited storage, and processing capability. Hence the efficiency of the IoT network needs to be increased. The major challenge lies in increasing efficiency with optimized battery utilization. The architecture is designed in such a way that there is a varied network of things, which are heterogeneous. Each IoT network has some set of Sensor Nodes (SN) which communicate to their respective Base Station (BS).

Similar communications are performed by all the IoT networks to their respective base stations as well which further form Internet of Everything. The base stations of IoT networks are connected to a Distribution Base Station (DBS). The DBS communicates to the gateway. Each Sensor Node has initial energy, which is required to send and receive the data packets. In order to increase the lifetime of the sensor nodes, efficient use of energy is important. The objective of increasing life-time of the sensor nodes are achieved by aggregating the related sensor nodes into clusters using Wind Driven Optimization algorithm to form optimal number of clusters. Each cluster would identify a Cluster Head (CH) to which all the cluster members will communicate. The CH selection and optimizations are performed using the Firefly Algorithm. Energy-efficient CH selection is based on factors like distance, temperature, load, energy, cost function, alive nodes, etc. The CH sends the data to the corresponding base station. Similarly, all the IoT networks communicate to the base station and further to the DBS. The optimized clustering scheme and CH selection scheme is shown in Figure 2 below.

As depicted in the Figure 2, in the IoE network systems group of clusters are formed wherein each group consists of a cluster head and its related sensor nodes. These sensor nodes transfer data to their related cluster head and on behalf of the sensor nodes, the cluster head is accountable to transfer the information to the IoE Base station.

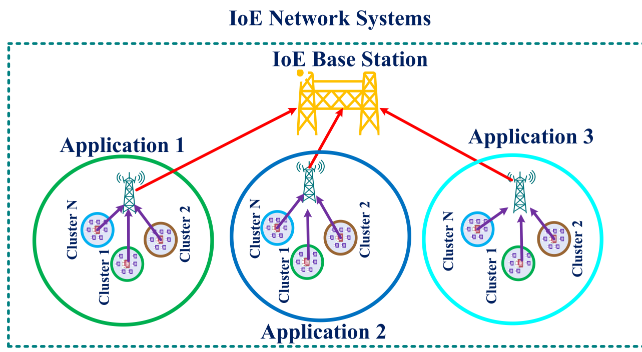

Figure 2: Optimized Clustering Scheme and CH Selection Scheme

4.2. Cloud Storage and Data Processing

The data collected from each IoE is transferred to the Gateway (GT) and then stored in the cloud. The IoT devices have minimal processing capability and energy due to which complex data processing cannot be done on-site. Hence the IoE needs to be integrated with the cloud, which can help in improvising the processing capabilities and analyse data in real-time. When IoE is integrated with cloud, real-time service could be provided extensively. Also, in the IoE networks, huge amount of structured and unstructured data are produced, which require enormous storage space, that could be provided by the cloud. Some of the issues faced by cloud computing and IoT are security [37], [38], load balancing [39, 40], energy consumption [41]. The energy-optimized IoT networks help in reducing the flow of packets, that is, to be stored in the cloud rather than all the IoT devices trying to float their data individually. Hence the traffic flow would also be optimized, thereby increasing the performance of the cloud service, as shown in Figure 3.

As depicted in Figure 3 there are various forms of smart IoT networks which collects and senses data from varied sources. These sensed data are trasferred to the nearby routers which further transfers the datapackets to the centralized energy cloud for storage.

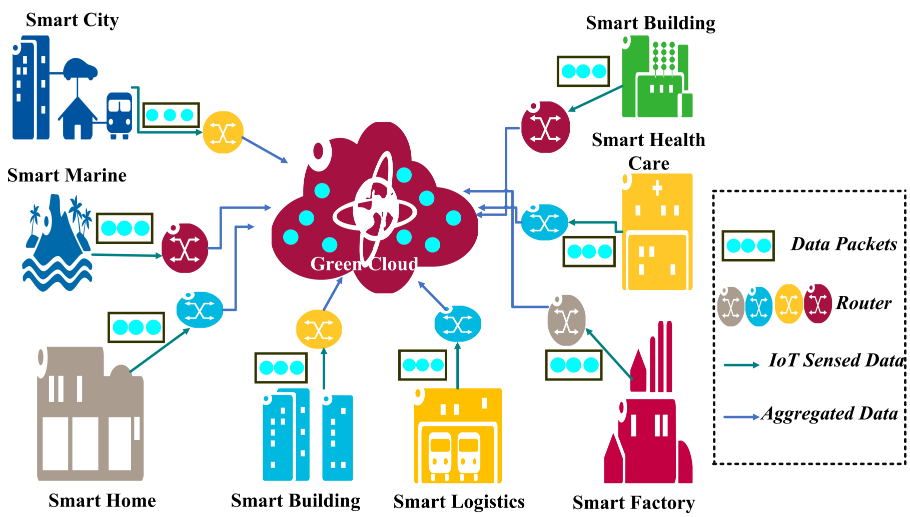

Figure 3: Cloud Storage and Data Processing

4.3. End-User Services

The End user may not be a human always but could also be a machine. Hence this architecture enables a machine to machine communication, as shown in Figure 4. When the end-user, like a server, in the vehicle monitoring system, healthcare domain, automotive sector, food sector, weather forecasting, etc. requests for the monitored and gathered data to the cloud, the service requested is served irrespective of the location of the request since all the gathered data are stored in the cloud. A node called Event Aware Node (EAWN) will forward the request to the DBS, which will further forward the request to the IoE network. Based on the event data requested, the request is served by connecting to the respective base station instead of contacting all the nearby base stations and IoT networks. The throughput and turnaround time hence will be significantly reduced due to such smart communication.

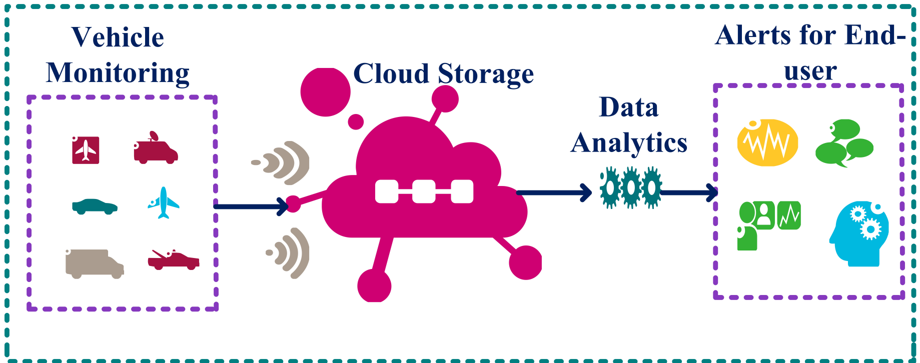

Figure 4: Machine to Machine Communication

5. Results and Discussion

The performance of the proposed model is evaluated and validated by simulating the environment in Matlab R2015a version. The size of the grid is assumed to be $500m * 500m$, and 500 data packets are transferred within the IoT network. The IoT network is simulated with 500 sensor nodes. The IoT network is considered to be having one Base Station (BS), which is placed at the center of the grid. Google Cloud Platform is used as cloud storage. The data from the Xively IoT platform [31] is used to measure the performance of the network. The 500 nodes in the IoT network are clustered into ten optimal clusters using the Wind-Driven Optimization Algorithm (WDO) and a single optimal cluster head (CH) is selected out of the members of each cluster formed using the FireFly Algorithm (FFA) based on the parameters namely load, temperature, energy, distance of sensor node from the BS and alive nodes at a particular iteration. The simulation results are discussed and represented for 3000 iterations. The results obtained are compared and analyzed with the existing state of art techniques, namely the Artificial Bee Colony Algorithm (ABC), Gravitational Search Algorithm (GSA) and Genetic Algorithm (GA).

5.1. Performance Evaluation of IoE

The performance of the overall IoE is evaluated by analyzing the individual performances of each IoT network. Hence, in the present study, simulation is done for a single IoT network, for simplified understanding of the behaviour of the network architecture. The analysis is performed four-fold based on various performance metrics namely - temperature of sensor nodes in the IoT network at each iteration, traffic load of the IoT network, residual energy at each iteration; and the number of alive nodes in the IoT network at each iteration.

5.1.1. Computation Analysis based on Temperature of IoT Network

The performance of the IoT network is evaluated based on the temperature generated by each sensor node in the IoT network. Initially, the temperature generated is meager for the entire network across all the approaches. When the iterations increase, it is evident from the graph given below in the Figure 5 that the temperature generated by the sensor nodes is lesser compared to the already available approaches. As shown in Figure 5, the temperature varies from 4.5^{o}C to 6^{o}C, which is lesser when compared to the others. The reduction in temperature is due to the optimal clustering and optimal CH selection in each round. A difference in temperature is observed after 1500 iterations.

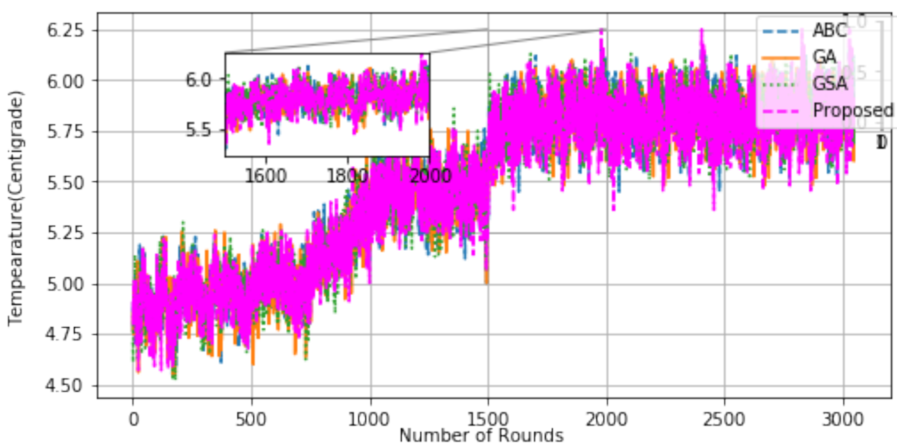

Figure 5: Temperature of IoT Network

5.1.2. Computation Analysis based on Residual Energy of IoT Network

During the simulation, the initial energy for every sensor node in the IoT network is assumed to be 1 Joule. When the number of iterations is increased and the data packets are transferred, for every transmission, some energy gets consumed by the sensor node. As the iterations increase, the energy is dissipated and the residual energy at each iteration reduces when the various approaches are used is shown in Figure 6. It is evident from the graph that the residual energy is higher at the end of 3000 iterations when the proposed methodology is used.

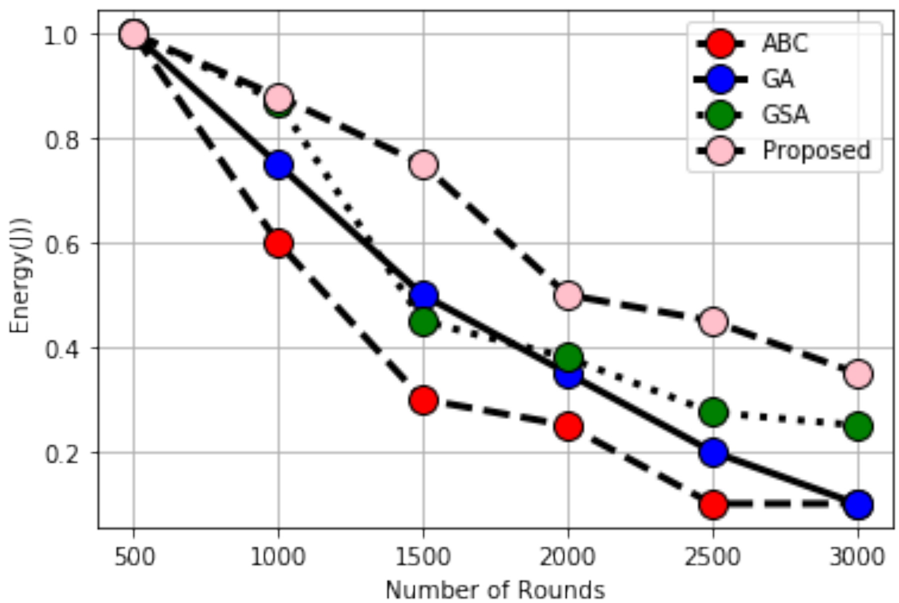

Figure 6: Residual Energy of IoT Network

5.1.3. Computation Analysis based on Number of Alive Nodes

When the simulation is run for 3000 iterations,the observation is such that during the initial 1500 rounds, all 500 nodes are alive across all the approaches. After 1500 rounds, the sensor nodes in the IoT network start dying one after the other. When the proposed model is used, approximately 30 nodes are alive at the end of 3000 rounds. However, all the nodes get dead before 2500 rounds of iterations in case of other approaches. Hence it is evident that the lifetime of the IoT network is increased as shown in the Figure 7 below:

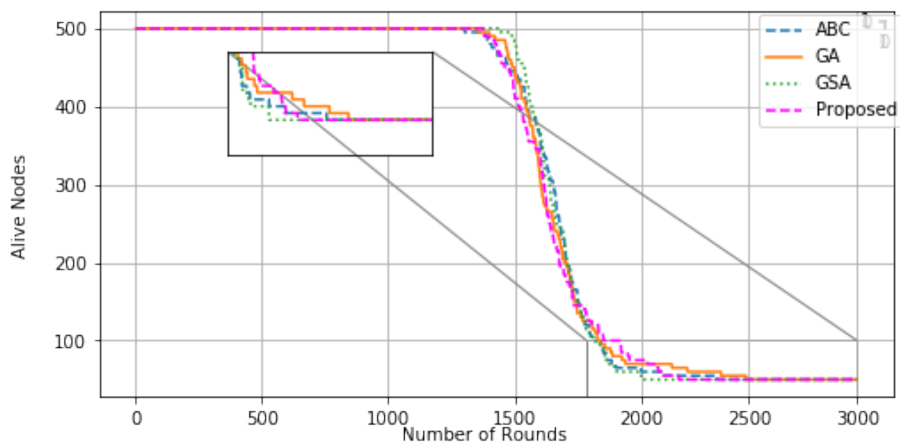

Figure 7: Number of Alive Nodes

5.1.4. Computation Analysis based on Load

The performance of the IoT network is analyzed based on the number of packets floated to the CH. When the packets are equally distributed and floated to the CH across the iterations, the load gets distributed and thereby reducing temperature generation. When the proposed model is used, the load on the CHs is reduced and evenly distributed ranging from 15 data packets to a maximum of 60 packets after 1500 iterations which is quite lesser compared to the other existing approaches as shown in Figure 8.

5.2. Performance of the Cloud-based on Load and traffic

The same approach is used when there are many IoT networks in each IoT network wherein the data packets from the clusters are aggregated and transmitted by the CH to the respective base station (BS). The data received at all the base stations are further transferred to the distribution base station, which get forwarded to the gateway. The gateway forwards the packets from the IoE

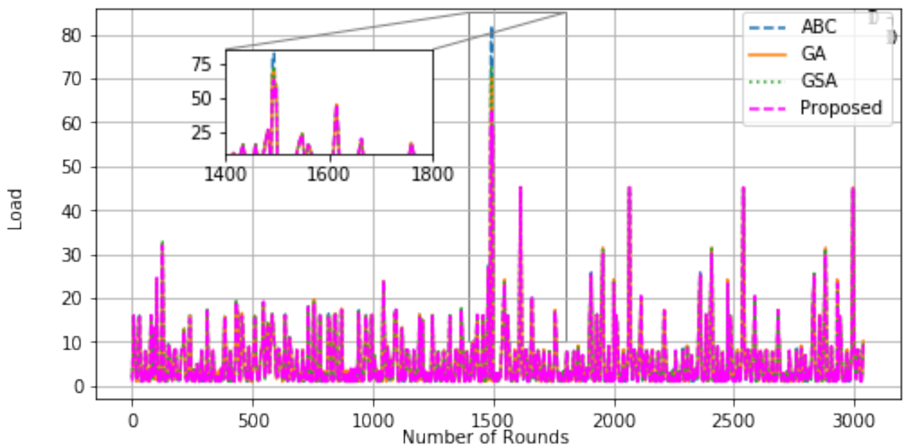

Figure 8: Load of the IoT Network

to the cloud for storage. As per the simulation, when the proposed model is used in the IoE, the data is aggregated, and the CH transmits the data packets to the BS. If the clustering-based methodology is not used, then each sensor node in the private IoT network will try to contact the BS and hence the load on the BS is higher compared to the proposed methodology. The number of packets reaching the cloud for storage also increases. The comparative analysis of the load of the cloud in terms of data packets reaching the storage in 3000 iterations for the traditional non clustered methodology and the proposed one is shown in Figure 9. It is evident that the load on the cloud is reduced and the resulting traffic as well. These reductions further reduce the requirement of storage space to store data in the cloud, coined as the term "Green Cloud" supporting energy optimization despite massive data generation from the IoE.

6. Conclusion

This research work focuses on developing a methodology for integrating the Internet of Everything (IoE) with the cloud efficiently. We have proposed a model named Energy Efficient Cloud-Based Internet of Everything (EECloudIoE) using Wind Driven Optimization and Firefly bio-inspired algo-

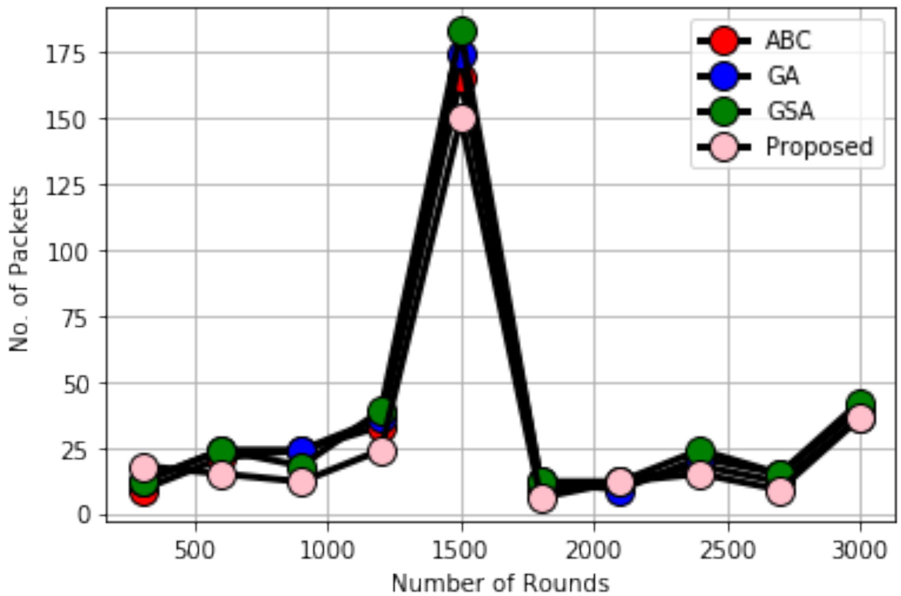

Figure 9: Load on Cloud

rithms. The sensor nodes in each IoT network are grouped into an optimal number of clusters using the Wind-Driven Optimization, and an optimal CH is chosen for each cluster using the Firefly algorithm. The CH selection is based on factors like temperature, energy, load, and alive nodes. The CH selection is optimized at each round, and thus the lifetime of the IoT network gets enhanced as justified by the results. The resuts reveal that the nodes in the proposed framework are alive even at the end of 3000 rounds. The number of packets which flood from all the IoT networks are stored in the cloud via the gateway. Since the optimization is performed at the cluster level in every IoT network of the IoE, the total load on the cloud is balanced and utilization of the space is optimal as significantly evident from the results. The decrease in load and increase in throughput enhances the performance of the cloud supporting energy optimization transforming the cloud to a "Green Cloud". The future focus would be to design an architecture for routing the packets based on context so that the throughput and request response time, could be optimized even further.

References

[1] K. Vijayalakshmi, P. Anandan, A multi objective tabu particle swarm optimization for effective cluster head selection in wsn, Cluster computing 22 (5) (2019) 12275–12282.

[2] Y. Sung, S. Lee, M. Lee, A multi-hop clustering mechanism for scalable iot networks, Sensors 18 (4) (2018) 961.

[3] P. P. Ray, A survey of iot cloud platforms, Future Computing and Informatics Journal 1 (1-2) (2016) 35–46.

[4] T. Baker, M. Asim, H. Tawfik, B. Aldawsari, R. Buyya, An energy-aware service composition algorithm for multiple cloud-based iot applications, Journal of Network and Computer Applications 89 (2017) 96–108.

[5] N. Thilagavathi, D. D. Dharani, R. Sasilekha, V. Suruliandi, V. R. Uthariaraj, Energy efficient load balancing in cloud data center using clustering technique, International Journal of Intelligent Information Technologies (IJIIT) 15 (1) (2019) 84–100.

[6] M. Ghobaei-Arani, A. Souri, A. A. Rahmanian, Resource management approaches in fog computing: a comprehensive review, Journal of Grid Computing (2019) 1–42.

[7] M. Ben-Daya, E. Hassini, Z. Bahroun, Internet of things and supply chain management: a literature review, International Journal of Production Research 57 (15-16) (2019) 4719–4742.

[8] J. M. Talavera, L. E. Tobón, J. A. Gómez, M. A. Culman, J. M. Aranda, D. T. Parra, L. A. Quiroz, A. Hoyos, L. E. Garreta, Review of iot applications in agro-industrial and environmental fields, Computers and Electronics in Agriculture 142 (2017) 283–297.

[9] A. Souri, A. Hussien, M. Hoseyninezhad, M. Norouzi, A systematic review of iot communication strategies for an efficient smart environment, Transactions on Emerging Telecommunications Technologies (2019) e3736.

[10] Y. Liu, C. Yang, L. Jiang, S. Xie, Y. Zhang, Intelligent edge computing for iot-based energy management in smart cities, IEEE Network 33 (2) (2019) 111–117.

[11] D. Patel, R. K. Gupta, R. Pateriya, Energy-aware prediction-based load balancing approach with vm migration for the cloud environment, in: Data, Engineering and Applications, Springer, 2019, pp. 59–74.

[12] S. Lee, M. Bae, H. Kim, Future of iot networks: A survey, Applied Sciences 7 (10) (2017) 1072.

[13] A. Azmoodeh, A. Dehghantanha, M. Conti, K.-K. R. Choo, Detecting crypto-ransomware in iot networks based on energy consumption footprint, Journal of Ambient Intelligence and Humanized Computing 9 (4) (2018) 1141–1152.

[14] B. Vejlgaard, M. Lauridsen, H. Nguyen, I. Z. Kovács, P. Mogensen, M. Sorensen, Interference impact on coverage and capacity for low power wide area iot networks, in: 2017 IEEE Wireless Communications and Networking Conference (WCNC), IEEE, 2017, pp. 1–6.

[15] N. Mittal, U. Singh, B. S. Sohi, A stable energy efficient clustering protocol for wireless sensor networks, Wireless Networks 23 (6) (2017) 1809–1821.

[16] A. S. Al-Zubaidi, B. M. Mahmmod, S. H. Abdulhussain, D. Al-Jumaeily, Re-evaluation of the stable improved leach routing protocol for wireless sensor network, in: Proceedings of the International Conference on Information and Communication Technology, 2019, pp. 96–101.

[17] V. R. M. Sarobin, L. A. Thomas, Improved leach algorithm for energy efficient clustering of wireless sensor network (wsn), International Journal of Technology 7 (1) (2016) 50–60.

[18] Z. Sun, X. Xing, T. Wang, Z. Lv, B. Yan, An optimized clustering communication protocol based on intelligent computing in information-centric internet of things, IEEE Access 7 (2019) 28238–28249.

[19] H. M. Ammari, A unified framework for k-coverage and data collection in heterogeneous wireless sensor networks, Journal of Parallel and Distributed Computing 89 (C) (2016) 37–49.

[20] Y. Zhang, W. Xiong, D. Han, W. Chen, J. Wang, Routing algorithm with uneven clustering for energy heterogeneous wireless sensor networks, Journal of Sensors 2016.

[21] H. Haes Alhelou, M. E. Hamedani Golshan, M. Hajiakbari Fini, Wind driven optimization algorithm application to load frequency control in interconnected power systems considering grc and gdb nonlinearities, Electric Power Components and Systems 46 (11-12) (2018) 1223–1238.

[22] A. M. Bongale, C. Nirmala, Firefly algorithm inspired energy aware clustering protocol for wireless sensor network, International Journal of Communication Networks and Distributed Systems 23 (3) (2019) 380–411.

[23] M. P. K. Reddy, M. R. Babu, A hybrid cluster head selection model for internet of things, Cluster Computing (2017) 1–13.

[24] M. Praveen Kumar Reddy, M. Rajasekhara Babu, Energy efficient cluster head selection for internet of things, New Review of Information Networking 22 (1) (2017) 54–70.

[25] G. T. Reddy, R. Kaluri, P. K. Reddy, K. Lakshmanna, S. Koppu, D. S. Rajput, A novel approach for home surveillance system using iot adaptive security, Available at SSRN 3356525.

[26] M. Eswar Kumar, G. Thippa Reddy, K. Sudheer, M. Reddy, R. Kaluri, D. Singh Rajput, K. Lakshmanna, Vehicle theft identification and intimation using gsm & iot, in: Materials Science and Engineering Conference Series, Vol. 263, 2017, p. 042062.

[27] Y. Singh, S. Bhattacharya, B. Singh, Iot: Framework for smart city.

[28] P. K. R. Maddikunta, R. B. Madda, Energy aware cluster head selection for maximizing lifetime improvement in internet of things, International Journal of Grid and High Performance Computing (IJGHPC) 9 (4) (2017) 71–91.

[29] M. P. K. Reddy, M. R. Babu, Implementing self adaptiveness in whale optimization for cluster head section in internet of things, Cluster Computing (2018) 1–12.

[30] G. T. Reddy, N. Khare, An efficient system for heart disease prediction using hybrid ofbat with rule-based fuzzy logic model, Journal of Circuits, Systems and Computers 26 (04) (2017) 1750061.

[31] Xively, Xively IoT Platform, https://xively.com/ (2019).

[32] Z. Bayraktar, M. Komurcu, D. H. Werner, Wind driven optimization (wdo): A novel nature-inspired optimization algorithm and its application to electromagnetics, in: 2010 IEEE Antennas and Propagation Society International Symposium, IEEE, 2010, pp. 1–4.

[33] X.-S. Yang, et al., Firefly algorithm, Nature-inspired metaheuristic algorithms 20 (2008) 79–90.

[34] G. Thippa Reddy, N. Khare, Ffbat-optimized rule based fuzzy logic classifier for diabetes, in: International Journal of Engineering Research in Africa, Vol. 24, Trans Tech Publ, 2016, pp. 137–152.

[35] G. T. Reddy, N. Khare, Heart disease classification system using optimised fuzzy rule based algorithm, International Journal of Biomedical Engineering and Technology 27 (3) (2018) 183–202.

[36] T. Baker, E. Ugljanin, N. Faci, M. Sellami, Z. Maamar, E. Kajan, Everything as a resource: Foundations and illustration through internet-of-things, Computers in Industry 94 (2018) 62–74.

[37] G. Thippa Reddy, K. Sudheer, K. Rajesh, K. Lakshmanna, Employing data mining on highly secured private clouds for implementing a security-asa-service framework, Journal of Theoretical and Applied Information Technology 59 (2) (2014) 317–326.

[38] T. Baker, M. Asim, Á. MacDermott, F. Iqbal, F. Kamoun, B. Shah, O. Alfandi, M. Hammoudeh, A secure fog-based platform for scada-based iot critical infrastructure, Software: Practice and Experience.

[39] M. Al-Khafajiy, T. Baker, A. Waraich, D. Al-Jumeily, A. Hussain, Iot-fog optimal workload via fog offloading, in: 2018 IEEE/ACM International Conference on Utility and Cloud Computing Companion (UCC Companion), IEEE, 2018, pp. 359–364.

[40] M. Al-khafajiy, T. Baker, H. Al-Libawy, Z. Maamar, M. Aloqaily, Y. Jararweh, Improving fog computing performance via fog-2-fog collaboration, Future Generation Computer Systems 100 (2019) 266–280.

[41] I. Al Ridhawi, M. Aloqaily, Y. Kotb, Y. Jaraweh, T. Baker, A profitable and energy-efficient cooperative fog solution for iot services, IEEE Transactions on Industrial Informatics.