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FAULT TOLERANCE BASED NOVEL ENERGY OPTIMIZATION TECHNIQUE FOR IoT SENSOR NODE MODELLING

Julie mary T[1], Bhuvaneswari A[2]
[1]Assistant Professor, [2]Associate Professor
PG & Research Department of Computer Science
Cauvery College for Women (Autonomous), [Affiliated to Bharathidasan University]
Tiruchirappalli, Tamil Nadu, India
[1]juliemary.ca@cauverycollege.ac.in, [2]bhuvaneswari.it@cauverycollege.ac.in

ABSTRACT

The Internet of Things(IoT) is one of the highly influencing and promising technologies of today's world, consisting of sensor devices. The internet smoothly changes from an internet of people towards an Internet of Things(IoT),which allows different things and objects to connect wirelessly. Things and objects are grouped into IoT subgroups in the IoT system, which are called clusters, and each cluster is controlled by a central authority and checked by the broker's help. A concept of keeping backup data is used to increase the lifespan of IoT subgroups by avoiding re-clustering overhead for smooth transmission of packets and increasing availability concerns. A novel approach is used for the selection of cluster head/broker and backup nodes simultaneously. Cluster head and Backup Storage Point node (BSP) remain the same unless and until the residual power of the broker/cluster head is greater than the threshold energy. A novel Energy Efficient Message scheduling algorithm EAAFTMS (An Energy-Aware Available and Fault-Tolerant System with Message Scheduling in IoT) is incorporated at broker node for smooth transmission of messages. To overcome this issue, several routing approaches have been presented in recent years. Nonetheless, the extension of the network lifetime in light of the sensor capabilities remains an open subject. In this research, a CUCKOO-ANN based optimization technique is applied to obtain a more efficient and dependable energy efficient solution in IoT-WSN. The proposed method uses time constraints to minimize the distance between sources and sink with the objective of a low-cost path. Using the property of CUCKOO method for solving nonlinear problem and utilizing the ANN parallel handling capability, this method is formulated. The resented model holds significant promise since it reduces average execution time, has a high potential for enhancing data centre energy efficiency, and can effectively meet customer service level agreements. By considering the mobility of the nodes, the technique outperformed with an efficiency of 98% compared with other methods.

Keywords : IoT, WSN, Fault Tolerance, Energy Efficiency, Node Modelling

Introduction

Sensor nodes serve as the main backbone in wireless sensor networks (WSNs), which are

among the most common wireless communication networks. In terms of sensor designs, WSNs can have either homogeneous or heterogeneous sensors, with numbers ranging from hundreds to thousands. Most WSNs are tailored to a specific use case, and their sensor nodes typically offer fundamental functions including sensing, processing, computation, and communication. The communication is mostly done with neighboring nodes using radio.
Wireless sensor networks (WSNs) based on the Internet of Things (IoT) have recently opened up a new exciting arena for novel and new sorts of applications. The small and active sensor nodes are the basic structure of WSNs that monitor their surroundings, analyses data (in few cases), and send/receive refine/processed data to/from other neighboring sensor nodes. In the centralized network, these sensing nodes are spread across the defined area connecting base node with sink node. In centralized networks, the sink collects sensor data for end-user use. In certain situations, the sink can also send network pol to sensor nodes to activate them. Figure 1 depicts the basic general architecture of the WSNs encountered in this investigation. The message is sent from the source sensor to the sink sensor via the most efficient way feasible, which includes the use of other random sensors.

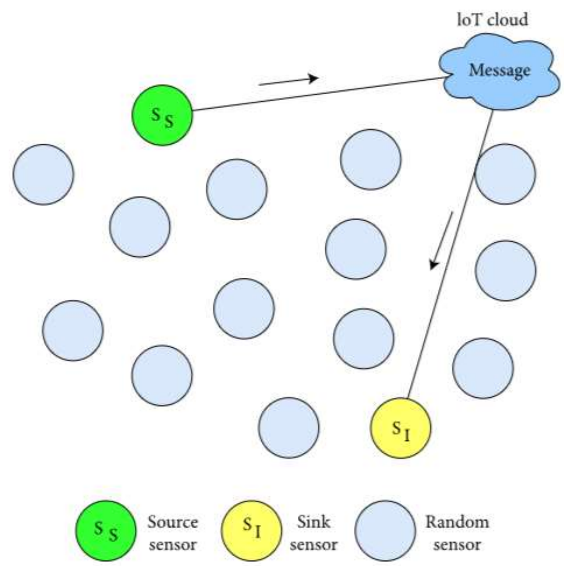

Figure 1: IoT – WSN Acrhiteecture

Related Work
According to Statista [1], the estimated rise in install-based IoT devices is more than 31 billion up to 2020 and more than one billion US dollars are being spent annually on Internet of Things projects. According to International Data Corporation (IDC) [2], IoT spending will increase from $698.6 billion to $1.3 trillion from 2015 to 2019, thus estimating a 17% compound annual growth rate (CAGR).
A typical wireless sensor network consists of sensor nodes, a broker and a base station (usually termed as sink nodes). All types of nodes have varying resource capabilities. Sensor nodes come with limited range, storage, processing and energy capabilities[3]. Base stations receive all the messages sent by the broker and due to this, the base station comes with more storage, processing power and consumes more energy than other sensor nodes. Hence, exhibiting more

alarming heat waves. [4] In a recent study, there are more than four billion base stations, each base station consumes approximately 25MWh/year which is 80% of the overall wireless network energy consumption. To overcome this alarming situation the world is stepping forward towards green IoT systems.WSN is used for a variety of applications to help a human being to monitor surroundings, chase a target, track health records and assist in many other monitoring and prevention measures [5]–[10]. A framework for WSN is presented which integrates two routing protocol algorithms. These two algorithms are using the Energy Balanced Clustering algorithm to maximize fault tolerance of WSN. It is using the mechanism of automatically selecting base station and cluster head, based on power and energy load balancing, with the help of an organizer node. Furthermore, in case of any fault in the cluster head, the organizer is selecting a new one. In this manner, this framework is maximizing the lifetime and energy handling of WSN. This approach is termed as Energy Balanced with Fault Tolerance Capability (EEBFTC) protocol [11]. It proposes an energy-efficient approach for WSN which is based on centroids of nodes, called Energy Efficient Centroid based Routing Protocol (EECRP). It considers three parts for EECRP: a novel approach for distributed cluster creation, other approaches for cluster familiarization and then spinning the cluster head based on centroids for equal energy workload dispersal and to minimize the energy usage. In EECRP, the lingering energy of nodes is used to determine centroid position [12]. Virtualization in WSN also needs to optimize fault tolerance capability and in various other networks IoT applications designed to provide services. To maximize fault tolerance and to minimize communication time, the author is using a non-dominated sorting-based genetic algorithm [13]. The research was done to adopt a suitable framework to maximize fault tolerance. Fault can be in nodes or data transmission between them, the framework is used to detect fault and method to recover fault in nodes and communication between nodes. The framework is used to maximize fault tolerance and network lifetime. When network lifetime increases, it means network communication increases which also increases the energy consumption of the network [14]. [15] Presented the detailed fault-tolerant scheme for wireless sensor networks. As sensor nodes are usually placed in open access environments, malicious activities are invited from outside and inside the network. In a cluster of sensor nodes, there is one node with more storage, processing and power elected as cluster head. There are also some backup nodes which are called spare cluster heads. It presented the strategy for the election of a spare cluster head to take charge of the cluster head, in case the cluster head dies. The spare cluster head which is placed at a minimal distance from the cluster head will immediately become a cluster head if all the messages sent by sensor nodes are not received by the sink node. The message is divided into three parts: the first part is heartbeat (HB) sent by the sender node to cluster head and the second part consists of a summary which contains the heartbeat of all nearby nodes to make sure that they are alive and not in a dead state. The third part contains the actual data sent by the sensor node. It presented efficient reliable working of the wireless sensor network. Another limitation in this proposed fault tolerance scheme is the presented algorithm may exhaust high energy due to extensive message packets and time. [16] Presented an algorithm for fluent message transmission between the sensor node and broker node by using the shortest processing time first algorithm in a wireless sensor network to avoid collision and minimize waiting time. Wireless sensor networks consist of N number of sensor nodes that sense the message from their surroundings and send those messages to the broker. The broker node is responsible for aggregation and transmits the received messages to the sink node. The paper presented the fault-tolerant scheme for efficient message transmission considering node failure in the Internet of Things systems. It deals with a fault in the sensor node only and uses the backup scheme. Whenever sensor node failure occurs, the node itself recovers the fault and if self-recovery doesn't happen then that sensor node is replaced with the backup sensor node considering the minimal distance for replacement. The proposed approach is energy efficient but deals only with the fault in the sensor node and with no consideration for fault in the broker node or sink node. [17] Routing protocols for efficient data transmission and communication within wireless sensor networks and also the fault tolerance issues faced in routing protocols. It provides a detailed analysis of different routing protocols. According to [18] wireless sensor networks are facing limitations in storage, resources, power and range. Different routing protocols face different fault tolerance challenges as described in [19]. Although, it provided a detailed comparison of different routing protocols and possible faults and their possible countermeasure.

S. Suguna Devi et al [21], has proposed Trilateral Location based Maximum Weighted Directive Spanning Tree for Optimal Routing in IoV. The proposed TLIMWDST technique consists of two major phases, namely location identification and optimal path identification to improve the reliability of data transmission from source vehicle to destination vehicle. In the first phase, the location of the neighboring vehicles is identified by applying a trilateration technique. The author identified after the location identification, an optimal route path between the source and destination is identified using Maximum Weighted Directive Spanning Tree (MWDST) through the intermediate nodes.

[22] S. Suguna Devi et al has implemented a Quantile Regressive Fish Swarm Optimized Deep Convolutional Neural Learning for Reliable Data Transmission In IoV. The author introduced reliable data transmission with minimum end to end delay in IoV. The Deep Convolutional Neural Learning uses multiple layers such as one input layer, three hidden layers, and one output layer for vehicle location identification and optimal route path discovery. The different node characteristics of vehicle nodes are analyzed in the hidden layers using the quantile regression function. Depends on the regression analysis, the neighboring node is identified with minimal time. To improve the throughput and reduce the packet loss rate, the artificial fish swarm optimization technique is applied to choose the best route among the population based on the fitness function.

Problem Formulation for Energy Module

The goal of this research is to reduce and conserve energy in WSNs. CUCKOO search is used in the initial phase to construct static clusters to reduce the use of energy sensor nodes. According to [20], the radio model used is the most commonly used assumptions, and models in sensor network simulation and analysis are listed below.

Nodes are spread in a 2-dimensional space at random in a uniform distribution, and all sensors are aware of the location of the Base Station (BS). Depending on the distance to the receiver, the nodes can transmit at different power levels. The nodes have no idea where they are. If the transmit power level is known, the nodes may estimate the approximate distance using the received signal intensity, and communication between nodes is not affected by multipath fading. Here, a network operating model based on rounds is used, similar to that of LEACH and HEED [34, 35]. A clustering phase precedes the data collection phase in each round.

$$E_{ms} = \left\{l\, E_{\mathrm{eng}} + E_a \bullet d^2\right\} \text{ for } 0 \le d \le d_l, \tag{1}$$

$$E_{ms} = \left\{l\, E_{\mathrm{eng}} + E_a \bullet d^4\right\} \textit{ for } d \ge d_l. \tag{2}$$

Proposed CUCKOO-ANN Optimization Modeling for IoT-WSN

The energy consumption of IoT-WSN depends on the distance and the message bit. To have the efficient system CUCKOO-ANN based model is proposed as shown in Figure 2. The CUCKOO search has three stage as described below:(1)*Stage 1*. Random placement of eggs(2)*Stage 2*. The finest nest having good quality of eggs is selected and carried over for next generation(3)*Stage 3*. Probability of getting discovered by the host bird nest

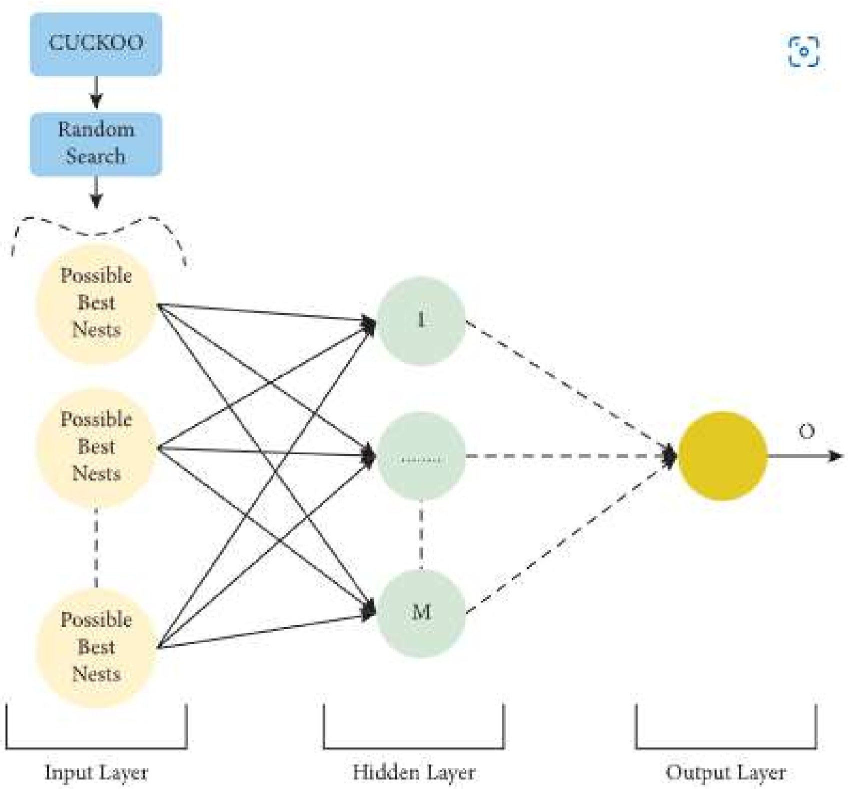

Figure 2 Proposed CUCKOO-ANN basic diagram.

Taking into account these three stages of CUCKOO search, it increases the system effectiveness for global optimizations by maintaining a balance between global random walk and local random walk. The output of CUCKOO search regarding to possible best nests is used as input for the ANN. The output of ANN is the best efficient path having the lowest cost in terms of path from source to sink leads to energy efficient system.

Proposed CUCKOO Search Modeling for Possible Best Nests

The aim of the CUCKOO search in IoT-WSN is to find all the best possible path to send the message from the source sensor to the sink sensor by using the random sensors present in the vicinity. This is achieved using the nature of the CUCKOO which lay eggs in the range of 2-10, which can be used as lower and upper limit of egg dedication to each CUCKOO involved. The second habit is they try to lay eggs at maximum distance from their source habitat. The flow chart in Figure shows the use of CUCKOO search for finding the best possible route from source sensors to base/sink sensor.

Proposed ANN Modeling for Possible Best Solution

The best possible nodes are identified by the CUCKOO search in the previous section. Using the best nodes and possibility of best path is used as input for the ANN model. In this model, the best 3 possible input is considered from CUCKOO search. A total of 30 hidden layer neurons is used to get the best output. The steps required to get the best solution consist of low cost, and low energy use using ANN is given below:

Step 1. Find the best possible routes using the fittest sensor nodes.

Step 2. Which route has minimum number of sensor nodes involvement.

Step 3. Train the neural network for minimum cost leads to minimum energy consumption.

Step 4. If simulation round over stop, otherwise simulate for possible solution.

Step 5. Compute the performance of the different parameters required.

Simulation Results

The following result is obtained from the proposed CUCKOO-ANN method. The simulation parameters required for the proposed method are given in Table 1. First, the IoT-WSN is placed in two-dimension coordinates as shown in the simulation (Figure 4). The green color indicates the sensor with their sensor number. The CUCKOO search gives the fitness parameters for different rounds of simulation. Figure shows the last 10 best fitness parameters of simulation. The range of fitness parameters are well in ranged for best results.

Table 1: Simulation environment

Parameters	Value
Area	800 m ∗800 m
No. of sensors	80
Initial energy	4 Watts
Data packet size	2 Mb/sec
No. of rounds	200
Motion coefficient (constant)	20
No. of possible nest	80
No. of CUCKOOs	5
Max. No. of CUCKOOs	20
No. of eggs in each nest	2
Radius coefficient (constant)	0.05
Cuckoo population variation	1*e*-10

Energy Consumption:

Each device receiving and transmitting energy consumption is computed. The node is randomly located with initial energy. If sensor transmits the packets or sensor receives a data packet from base-station, the node consumes some energy. Energy model in all sensor nodes transmission the radio transmission performing the power control. For reaching fault tolerance status, the node having minimum energy. For a given time, sufficient energy for Energy Transmit (Et) and energy for Energy Receiving (Er).

$$EC = E_r + (Dist * PS * E_t) \quad (3)$$

EC is the Energy Consumption of a device in J; Dist is the distance between two devices measured in meter, and PS is the Packet Size in Kb. Et is the energy transmit to the packet. And Er is energy receiving to the packet

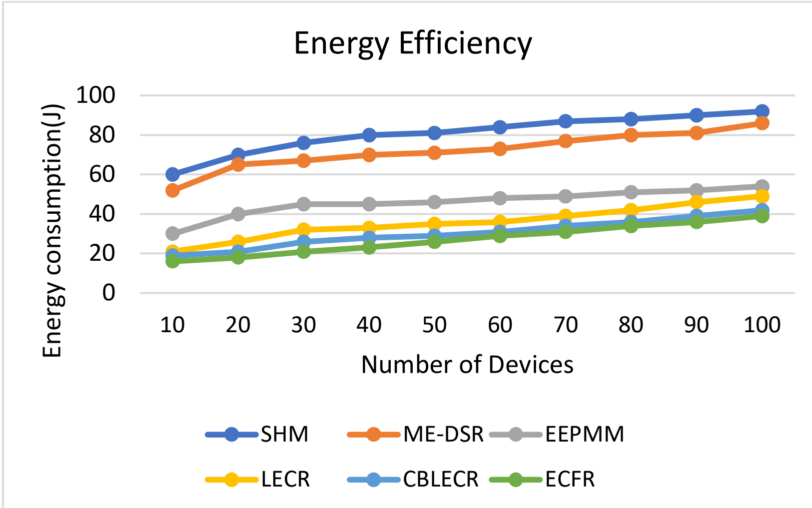

Figure 3: Comparison of Number of devices Vs Energy Consumption

From Figure 3, it inferred that the overall energy consumption is minimum by applying the EAAFTMS algorithm. Because the EAAFTMS algorithm used fault-tolerant routing and , it helps to minimize the devices energy consumption.

Network Lifetime:

Network Lifetime is one of the essential performance measurements defined as the time from the beginning to the first node failure due to battery power exhaustion shown in Eq (4)

$$NL = FI - NS \quad (4)$$

NL = Network lifetime, FI = Network finished time

NS = network startedtime

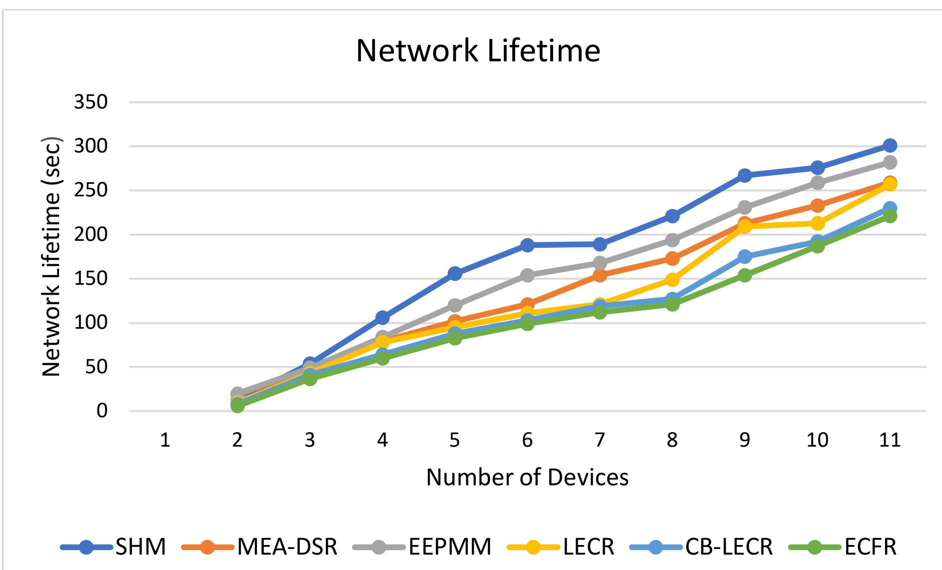

Figure 4: Comparison of Number of devices Vs Network comparison

Figure 4, it is inferred that the overall network lifetime increased by applying the EAAFTMS algorithm. This is because the selection of clustering based on a less energy consumption route and fault tolerant route using CUCKOO search regarding to possible best nests is used as input for the ANN. So reduces the network energy consumption achieves to increase the network lifetime in the IoT.

Throughput:

Throughput is a measure of how many units of data can transmit in a given amount of time. The unit of throughput is kilobits/seconds.

$$\text{Throughput} = \frac{No\ of\ data\ packet\ transmitted}{unit\ time} \quad (5)$$

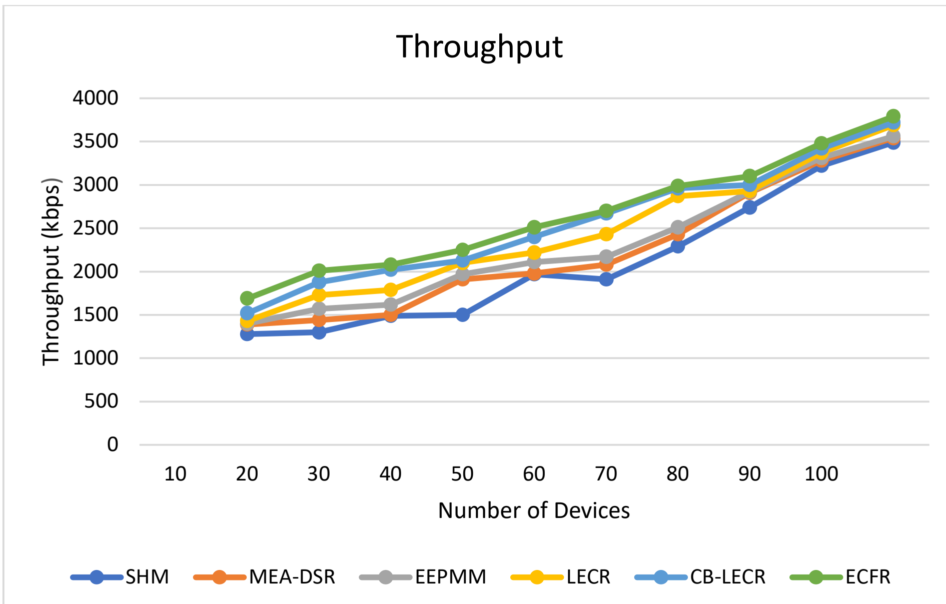

Figure 5 : Comparison of Number of devices Vs Throughput

The proposed ANN algorithm selects the optimal route between a source device to BS based on maintaining a balance between global random walk and local random walk. This helps to minimize the unwanted traffic congestion while routing the data packets, which leads to enhancement in network throughput. Higher network throughput achieves less transmission to IoT.

End To End Delay:

It is the amount of time it takes to reach the destination. The end-To-End delay computation formula is shown in Eq. (6).

End to end Delay = Data packet received time - Data packet sent time

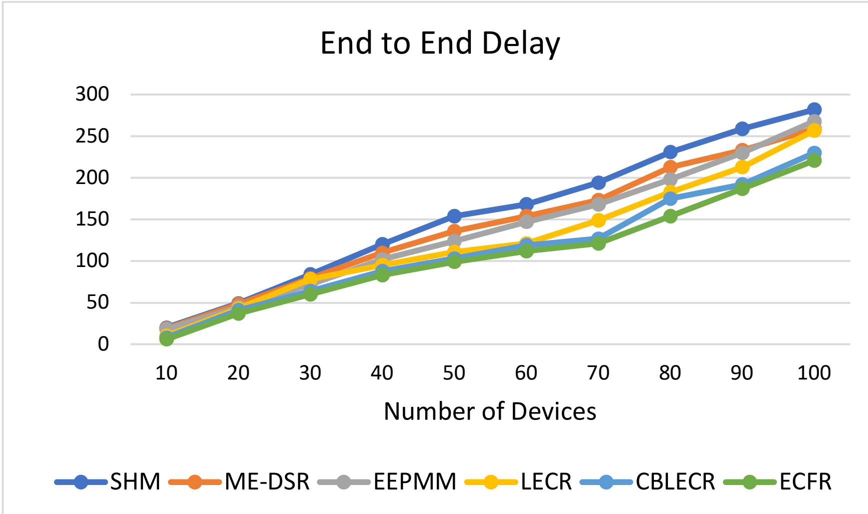

Figure 6: Comparison of Number of devices Vs End to End Delay

The graph inferred compare the number of devices and end to end delay. The proposed ANN algorithm selects the fault-tolerant route with less number of hop counts is selected to transmit the data packets from the source to BS, resulting in minimizing the delay.

From the simulation results, it can be concluded that the proposed CUCKOO-ANN technique is the most suitable for IoT-WSN in terms of energy efficiency. The CUCKOO optimization plays a vital role in selecting the best sensors for message transfer, and the ANN module helps the system obtain the best suitable path for message transfer from source to base sensors. By combing these two features, the overall cost of the system decreases, which directly indicates the superiority of the model with respect to other models discussed in the literature review. Although the technique is better than other existing technique but for large size network, the method needs more computation space and fast processor.

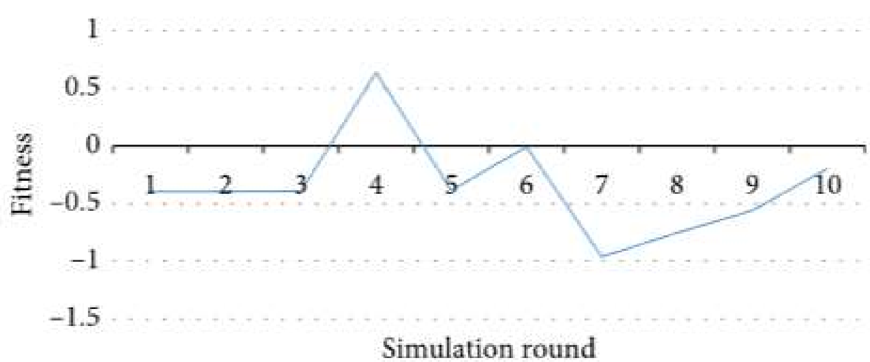

Figure Best fitness for last 10 rounds of simulation.

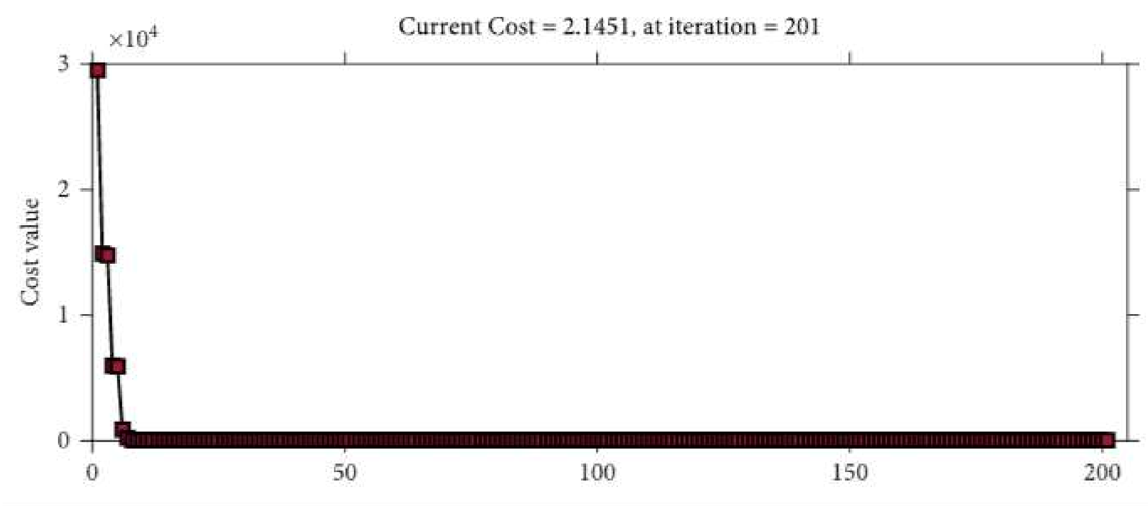

Figure 7: Best cost simulation round

For future work, keeping security and efficiency as key points in the block chain can be a useful tool for future IoT-WSN routing and safety. The following are possible future goals for using block chain:(i)Improving network performance(ii)Minimizing the random deployment cost(iii)Enhancing the security of sensors

Conclusion

IoT-WSNs are commonly installed in dense clusters in certain fields to monitor required parameter values. Any wireless sensor network's main goal is to extend the network's overall lifetime as much as feasible. As a result, energy efficiency is a critical parameter for every sensor network, and any effective management must emphasize it. In this research paper, a novel CUCKOO-ANN based optimization technique is used to achieve a more efficient and reliable energy efficient solution. First, the CUCKOO method finds the suitable/possible nodes which can help for fast message transfer. Then, the ANN system finds out all the possible paths and then chooses the three best paths, those having the smallest number of nodes, and calculates the cost of the possible routes.

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