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Energy Optimization Using Reptile Search in Wireless Sensor Networks

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ABSTRACT

Energy saving in wireless sensor networks (WSNs) is a critical problem for diversity of applications. Data aggregation between sensor nodes is huge unless a suitable sensor data flow management is adopted. Clustering the sensor nodes is considered an effective solution to this problem. Each cluster should have a controller denoted as a cluster head (CH) and a number of nodes located within its supervision area. Clustering demonstrated an effective result in forming the network into a linked hierarchy. Thus, balancing the load distribution in WSNs to make efficient use of the available energy sources and reducing the traffic transmission can be achieved. In solving this problem we need to find the optimal distribution of sensors and CHs; thus, we can increase the network lifetime while minimizing the energy consumption. In this paper, a Reptile Search Algorithm (RSA) for preserving location privacy and congestion avoidance with less delay guaranteed is proposed. With this routing technique, the complete sensor field is divided into different subdivisions and each subdivision elects a target area by computing its transmission distance. The backbone of the dynamic routing protocol consists of a virtual ring called bell nodes and a radial line called tentacle nodes employs more nodes to construct the network. The amount of radial line and radius of the virtual ring in a network are conjointly determined to ease the communication path from the node to sink. The radial line paths are routed directionally and bell nodes are routed with angular directions probabilistically. From the routing path, the tentacle nodes collect the data to dynamic sink which will assure that the information is going to be collected with less delay and attacker cannot guess their positions. The experimental results show that the proposed RSA method accomplishes enhanced performance in terms of energy consumption, packet delivery delay and lifetime.

Keywords: Wireless sensor network, clustering algorithms, Reptile Search Algorithm

I. INTRODUCTION

A wireless sensor network (WSN) is a network with a collection of sensor nodes communicating with each other using radio signals with the objective to sense, monitor, and explain some phenomena. WSNs have found many applications in industry, science, health care, transportation, civil infrastructure, and security. They were used in diverse applications including habitat and environmental monitoring [1], visual surveillance for automatic object detection such as real-time traffic monitoring and vehicle parking control [2], intrusion detection [3], and noise pollution monitoring [4]. WSNs suffer many challenges. Some of these challenges include network protocol [5], coverage problems [6], data gathering and distribution [7], energy management [8], fault detection [9], and security [10]. A typical WSN consists of number of sensor nodes (i.e. nodes) [11]. The number of sensor nodes could be from a few nodes up to several thousand based on the size of the coverage area. Each node is normally connected with other nodes in the network so that they can exchange data about various events that could happen in an environment. Each node normally consists of several components such as a radio transceiver and microcontroller. An electronic circuit is also part of the sensor node [12]. This circuit is responsible for managing the energy source during deployment and transmission.

A WSN is similar to any network with an adopted topology. Some examples of the WSN topologies are the star network and the multihop wireless mesh network. The propagation technique for data flow between the nodes could be routing or flooding [13]. A survey of the state-of-the-art routing techniques in WSNs can be found in [14]. An example of WSN architecture can be seen in Figure 1. The main components of a WSN were described in [15].

This paper is organized as follows: The overall introduction of mobile sink based routing protocols is described in Section 1. In Section 2, the related work is reviewed. Section 3, exhibits the proposed routing network model scheme and reveals the proposed framework. Similarly, the performance evaluation and simulation results are provided in Section 4. Lastly, the conclusion of our work is concluded in Section 5.

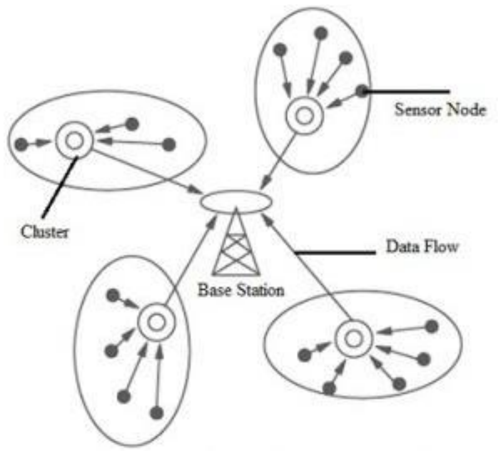

Figure 1.WSN architecture

II. METHODS AND MATERIAL

Several works have been discussed earlier in terms of energy-aware routing, congestion avoidance, and privacy-based routing approaches to improve the network performance of the WSN. Clustering-based routing is an efficient way to control energy utilization, decrease delay, and improves the scalability of nodes. In such algorithms, the selection of appropriate CH reduces the burden of data transfer to the sink node and maintains the energy of the nodes.

An Energy-Efficient Cluster-based Dynamic Routes Adjustment method that optimize the routing path to the extent the location of the sink. Here, the circular field are situated in a location of nodes with two mobile sinks [16]. After the selection of CH, the member nodes gather the data from the field and share it with the cluster in single or multi-hop depending upon the distance between them. The routes are adjusted according to the underlying area of the sink. When the sink moves to a new location, the CH close to the sink shares the current position of the sink to all the remaining CHs. Once the residual energy of CH drops down, the threshold limit reclustering is done. This technique extends the network lifetime.

A routing protocol called Rendezvous-based Routing Protocol (RRP) [17] that address the energy consumption and latency problems in WSN. In this technique, the network is appropriated into a cross-area called Rendezvous region. A tree-like structure is framed in the cross area by backbone nodes to cover the limits. These nodes are responsible to transmit the data packet from the source to the sink. At the point, when the sink is moved to a new location, a gateway node shares the information with the backbone nodes via intermediate nodes. This method has an advantage of reduced control packet overhead, high packet delivery ratio, less delay, and increased network lifetime. However, the protocol is not reliable for numerous sink nodes.

SL Protection protocol based on Dynamic Routing that prevents the network area against security dropping attacks [18]. This protocol is based on Dynamic Routing that can perform cyclic, greedy and direct routing patterns. In cyclic routing, the CH stores the original data and forwards dummy packet in a clockwise and anticlockwise direction to confuse the adversary. Directed routing generates multiple paths from source to the sink to resist backtracking attack by the adversary. This strategy is more efficient in terms of delay, lifetime, energy consumption, and security.

Sensible computing [19] devices by constantly interacting nearby wireless devices are redefined as Wireless as a Sensor (WaaS) architecture. In this, a different kind of wireless transceivers causes unexpected battery reduction problem. To solve these issues, a sensor fusion core utilizes the energy with the relation of WaaS based smartphone architecture. Furthermore, this architecture represents a duty cycle determination algorithm that assures the needed applications of Quality of Service (QoS) and responsible to minimize the energy consumption. The wireless transceivers of Bluetooth and Radio Frequency Identification (RFID) sensors can be simulated on a Moto X tested for both algorithm and architecture respectively. Since the depicted results extend the battery life compared with smartphone devices. Though, the performance of QoS still needs to be improved when scheduling it together.

A review of communication based state-of-art methods in which the computation tasks such as user status preserving, environment, navigation, Artificial Intelligence (AI), robust communication and human robot interface for mobile healthcare robots [20]. In this, the demand for these tasks categorizes the ability of a certain type healthcare robot over the network usages. The alternative of a healthcare robot consists of two classes. They are core and edge functionalities. Several frequent communication would be processed with delay sensitive tasks like autonomous moving, health receiver status recognition and user interaction without connection to centers. This work pointed out the list of tasks used for several functionalities to develop the progress toward robots with the help of wireless communications.

An energy efficient routing algorithm named as Enhanced PEGASIS to avoid the hot spot issue in between the nodes. For this purpose, the EPEGASIS approach comprises of four aspects. First, the data transmission distance will be determined to ease the energy among the optical communication [21]. After that, a mobile sink strategy is designed to reduce the transmission distance of each splitted areas and a fixed threshold value is used to defend the dying nodes. Next, the communication range of the sensor node area will be adjusted according to the mobile sink node distance. Hence, this approach will have short communication distance to reach close to the sink and achieves less energy consumption and high network lifetime during transmission [22].

A non-uniform clustering method in which it combines the PEGASIS and Hamilton loop algorithm to avoid the energy hole issue and balance the resource overhead in the network. In this, the combined approach mitigates the load transmission of nodes through the mechanism of single hop and multi-hop in the neighbourhood of BS. Moreover, the Mobile Agent (MA) [23] is used in the Hamilton loop that is responsible for collecting the data packets from the CH to the loop. Therefore, the mixture approach decreases the complete network expenditure and solves the energy hole problem. The simulation result of this approach has better energy saving and low transmission latency [24].

A routing based clustering method which attends intelligent clustering method based on machine learning called Affinity Propagation based Self-Adaptive (APSA) clustering [25] to solve the issues of irregular circulation of CH and balancing the energy consumption. In this, the AP combines with the K-medoid to attain more reasonable clustering routine [26]. Firstly, the AP utilizes to search the initial number of cluster centers and identify the CHs for K-medoids. After that, the network topology formation is adapted to partition the entire network by the number of rounds (iteration) into clusters using modified K-medoids. Hence, the clustering based routing method effectively reduces the data transmission distance and offer load balanced routing of the network in terms of network lifetime and energy consumption [27].

Trajectory Scheduling technique based on Coverage Rate for Multiple mobile sinks (TSCR-M) to avoid high energy consumption over long distance network areas [28]. For this purpose, a new location based method is introduced to select the parking position areas with ideal coverage rate using the combination of mutation operator and Reptile Search Algorithm. This algorithm deliberates the sensors coverage rate of overlapped areas. Next, the trajectory is scheduled for multiple sinks in which the multi-path scheduling determines the moving path position efficiently using Reptile Search Algorithm [29]. Thus, the scheduling based mobile sink

III.PROPOSED METHODOLOGY

In this section, we introduce the Reptile Search algorithm to avoid congestion and traffic analysis attack in the wireless network. Here, we divide the network by adopting the structure of the approach and classify the sensors as bell nodes and tentacle nodes. The bell nodes are formed at the midpoint in the form of a ring and the tentacle nodes are spread across the network radially from the center. The bell nodes collect the data from the target area and transmit it to the sink through the tentacle nodes which assures the transmitted data of other tentacle nodes confuse the attacker and cannot arrive at the path locations.

This makes it possible for the member nodes to communicate sink with less number of hops compared with the existing routing methods. They keep themselves near the path by pushing their bell nodes. They also keep the top of the nodes appropriately level within the area, so their tentacle nodes are pointed out. This ensures that the bottom of the bell nodes covers as much area as possible, so it can collect more information. Hence, this protocol has a short path to reach the endpoint. Also, the RSA mitigates the issues of congestion, traffic analysis attack and stays up with the current situation of the sink.

This section highlights the attacker model, network model and network assumptions of the Reptile Search approach.

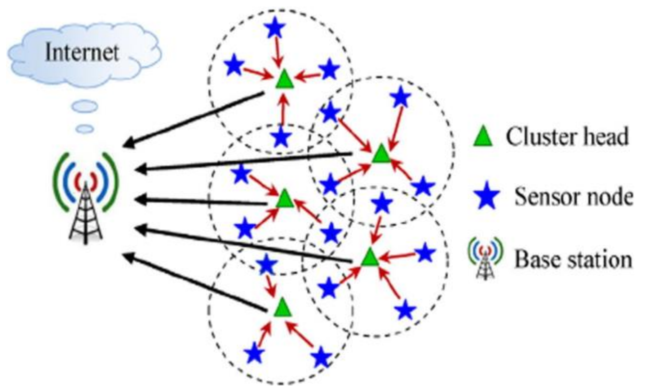

Figure 2 Clustering environment of wireless sensor network.

3.1 Reptile search algorithm (RSA)

RSA is a new nature-inspired metaheuristic algorithm developed by Abualigah et al. [30]. It simulates the hunting behavior of crocodiles. Encircling, which is accomplished by belly walking or high walking, and hunting, which is accomplished by hunting cooperation or hunting coordination, are the two major crocodile behaviors implemented in RSA. Its search mechanisms are unique compared with other algorithms. RSA contains a single process developed to update solutions based on four mechanisms.

The following subsection describes the main steps of RSA:

3.1.1. Initialization

RSA initializes the search through random determination of n search agents by Eq. (1)

$x_{ik} = rd \times (U_{BB} - L_{BB}) + L_{BB}, k \in \{1,2,\ldots,n\}$ (1)

where rd is a random value, L_{BB} and U_{BB} are the lower and upper bounds.

3.1.2. Exploration phase

The exploration phase presents the exploratory behavior of RSA. Crocodiles have two motions according to the encircling behavior: high walking and belly walking. Crocodile motions, unlike hunting, make it difficult for them to approach a victim. Consequently, the exploratory search uncovers a large amount of data. Furthermore, during this phase, the exploration mechanisms (high and belly walking) are activated to aid in investigating the search process through vast and dispersed inquiry.

$$X_{i,k}(t+1) = \begin{cases} \text{Best}_k\,(t) \times -\eta_{(i,k)}(t) \times \beta - R_{(i,k)}(t) \times rd, & t \le T_m/4 \\ \text{Best}_{\,k}(t) \times x_{(r1,k)} \times ES(t) \times rd, & t \le 2T_m/4 \,\&\, t > T_m/4 \end{cases} \quad (2)$$

where $\text{Best}_k\,(t)$ denotes the k_{th} position in the optimal solution, rd indicates a random number of $[0,1]$, t denotes the index of current iteration, whereas T_m indicates the maximum iterations number. The parameter β is utilized to control the performance of exploration. $\eta_{(i,k)}$ identifies the hunting operator of the k_{th} position in the i_{th} solution that is calculated by Eq. (3). Additionally, $R_{(i,k)}$ denotes the reduce function, which is used to decrease the search region and is calculated by Eq. (4),

$$\eta_{(i,k)} = \text{Best}_k\,(t) \times P_{(i,k)} \quad (3)$$

$$R_{(i,k)} = \frac{\text{Best}_k\,(t) - x_{(r2,k)}}{\text{Best}_k\,(t) + \varepsilon} \quad (4)$$

where, ε denotes a small value whereas r_2 denotes a random number in $[1, N]$. Moreover, the evolutionary sense $ES(t)$ that is defined in Eq. (5) represents the probability ratio, which decreased from 2 to -2 over the iterations, and it is identified as:

$$ES(t) = 2 \times r_3 \times (1 - 1/T_m) \quad (5)$$

where, r_3 denotes a random number belongs to -1 and 1 whereas $P_{(i,k)}$ refers percentage difference between both the k_{th} value for the best and current solution, that defined using Eq. (6).

$$P_{(i,k)} = \alpha + \frac{x_{(i,k)} - M(x_i)}{\text{Best}_{\,k} \times (UB_k - LB_k) + \varepsilon} \quad (6)$$

where, $M(x_i)$ stands for the average solution defined by Eq. (7).

$$M_{(i,k)} = \frac{1}{n}\sum_{k=1}^{n} x_{(i,k)} \tag{7}$$

3.1.3. Exploitation phase

The exploitative nature of RSA is demonstrated in this stage. During foraging, crocodiles undergo two processes: coordination and cooperation. These processes denote different intensified methods that commit to the exploitation search and are defined in Eq. (8).

$$X_{(i,k)} = \begin{cases} \text{Best}_k\ (t) \times P_{(i,k)} \times rd & t \leq 3\frac{T_m}{4} \& T_m > 2\frac{T_m}{4} \\ \text{Best}_k\ (t) - \eta_{(i,k)}(t) \times \varepsilon - R_{(i,k)}(t) \times rd & t \leq T_m \& t > 3\frac{T_m}{4} \end{cases} \tag{8}$$

To conclude, RSA starts by producing a random list of candidate solutions within specified permissible boundaries. The RSA's search mechanisms analyze the probable positions of the near-optimal answer during the recurrence trajectory. Each solution substitutes its locations from the optimal solution. The two primary methods used in the search process are exploration and exploitation, based on four different methodologies. Exploration consists of two different walking strategies: (1) high walking, and (2) belly walking. While hunting cooperation and coordination are examples of exploitation.

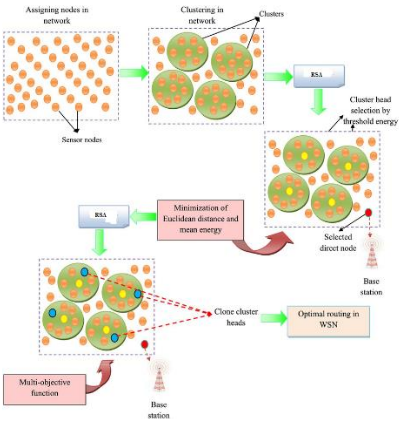

Figure 3 Network energy optimization and intelligent routing in wireless sensor network (WSN)

3.2 The proposed mRSA algorithm

This section provides the proposed mRSA algorithm in detail. mRSA [31] is actually proposed to enhance search efficiency and avoid the limitations of the original RSA. The primary objective of using RUN is to use its operator, the ESQ mechanism, to boost the performance of RSA. To be more explicit, the steps of the original RSA are executed as usual, and then, the ESQ mechanism is utilized to avoid getting stuck on the local optima in RSA and enhance its performance.

3.2.1. Shortcomings of RSA

The original RSA has four steps that replicate crocodile behavior: high walking, belly walking, hunting coordination, and hunting cooperation. When these strategies are applied randomly to solutions, the resultant solutions may diverge; however, in some optimization scenarios, RSA becomes stuck in subregions, particularly in complicated and high-dimensional problems. Although each solution updates its location based on the previous one, this slows down the convergence and cannot effectively cover solutions of search space, making RSA converge prematurely. Thus, the hybrid technique may enhance the convergence rate and prevent it from becoming stuck on the local optimum. Therefore, mRSA was proposed to address these limitations. The ESQ mechanism was used to keep away from the local optimal solutions and increase the convergence speed because it updates the solution following a robust strategy.

3.2.2. Initialization stage of $mRSA$

Like the original RSA and other metaheuristic algorithms, mRSA begins the initialization process by a set of N search agents initialized randomly; each agent is of a dimension (Dim) within the search space, which is bounded by lower and upper bounds U_{bb} and L_{bb}, as indicated in Eq. (1).

2.3. The fitness evaluation phase of mRSA

mRSA evaluates the best fitness solution (BestFitt (x)) of each solution. Then, the solution that has the optimal fitness is considered the optimal solution (optimal position)(X_{best}), which is used to update positions.

2.4. Updating phase of $mRSA$

In this phase, updating the current population of mRSA is divided into two parts, as presented in Eq.. If the solutions belong to the first part, they will be updated by RSA, as described by Eqs. (2) to (8). Meanwhile, solutions that belong to the second half work on solutions received from the previous phase and aim to significantly update these solutions depending on the ESQ mechanism [33], which assists in avoiding local minimum. The second half is executed according to a specific condition (rand < 0.5) where rand indicates a random value between 0 and 1.

$$X(t+1) = \begin{cases} X_{ESQ}(t) \text{ using the } ESQ, & \text{if (rand } < 0.5) \\ X_{\text{best}}(t) \text{ using the basic } RSA \text{ update rules}, & \text{otherwise} \end{cases} \quad (9)$$

3.2.5. Termination criteria of $mRSA$

The terminal criteria are checked; if they are achieved, the solution search is stopped because the best solution so far is found. The pseudocode of mRSA is presented in Algorithm 2. Moreover, Fig. 1 shows a flowchart of mRSA.

IV. RESULTS AND DISCUSSION

From the research methodologies presented above, the routing of packets is made efficiently that avoids congestion and enhances the energy consumption of the system.

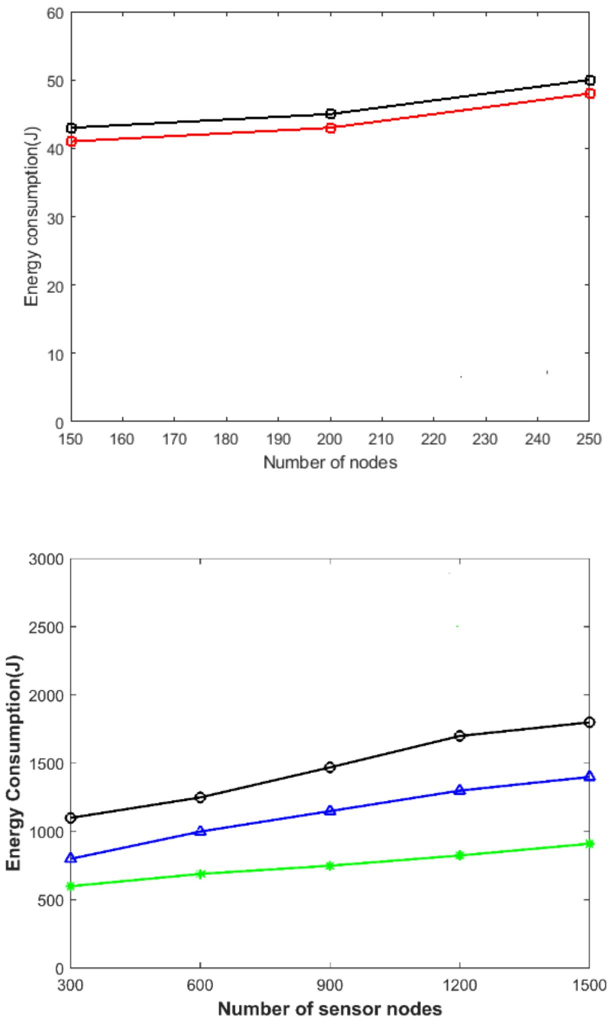

Figure 4 : Performance of energy consumption

The analysis of the proposed methodologies is made in terms of throughput, energy, delay, packet delivery ratio, and network lifetime. Figure 4 shows the energy consumption analysis for 250 and 1500 sensor nodes between the proposed (DHRGP, JDRP) and existing approaches. In Figure 3 a), the result shows the CGRP model (Agrawal *et al.* 2018) consumes more energy of 48 Joules while comparing to the DHRGP approach. Also, in Figure 3.b), for the total energy of 3000J for 1500 nodes, the reduction of energy consumption is achieved by JDRP than the other two existing approaches.

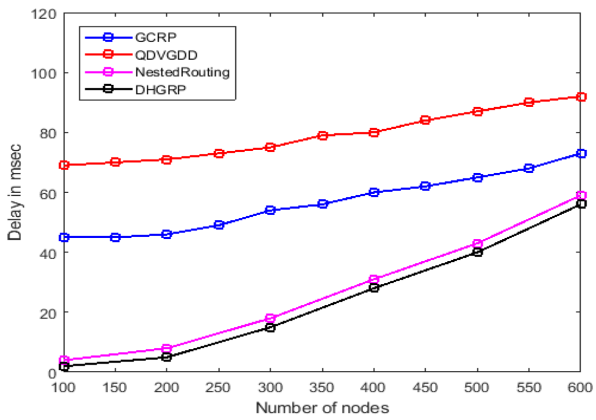

Figure 5: Delay analysis

Figure 5 shows the comparison of delay between the proposed approaches to the existing techniques. In this, the hop count increases the delay of 70, 45ms however the nested routing [14] results are nearer to the proposed technique but for the increasing number of nodes, the proposed technique achieves a better result with less delay.

Figure 5 shows the performance of the throughput evaluation. Here, in Figure 5a), technique achieves the maximum throughput of 330 bits/sec than the model and hence achieves better energy consumption with the efficient hexagonal grid routing In Figure 5b), the RSA achieves higher throughput for the increasing number of sink compared to the starfish routing technique.

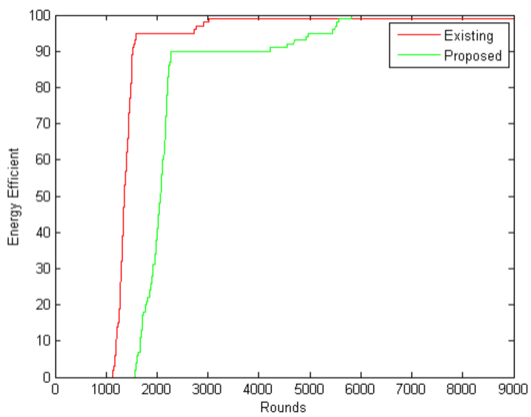

Figure 6 Total remaining energy vs. number of rounds

Figure 6 illustrates the RSA metric to determine the success rate of received packets at the sink node. In this, when the sensor node increases, the packet tends to increases that result in low RSA in the existing techniques but our proposed techniques achieve a better delivery ratio due to better routing strategy.

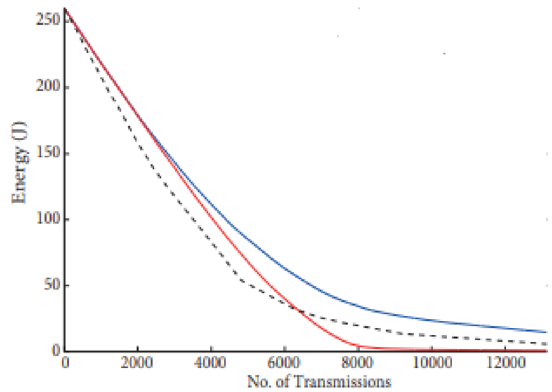

Figure 7. Total remaining energy vs. number of transmissions

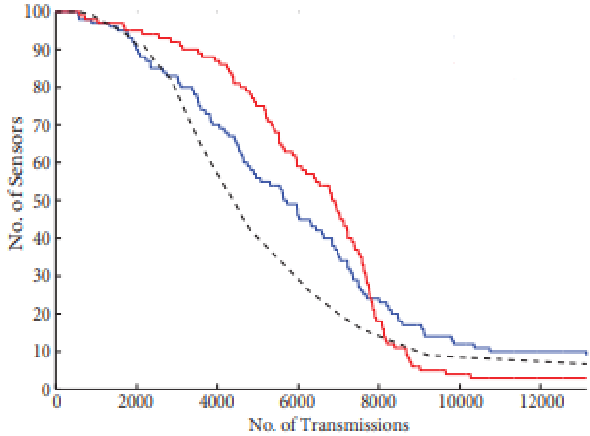

Figure 8. Total number of live sensor nodes vs. number of transmissions

V. CONCLUSION

In this research, an energy optimization method with secure routing for IoT heterogeneous WSN applications is proposed. This secure as well as reliable routing protocol gathers data about neighbor nodes at BS, and generates the key and energy-efficient multipath for every node. CHs help in data aggregation and forward them to BS, which continuously monitors nodes for residual energy to choose some new paths and CHs. Routing is a major constraint in the day to day applications of WSN. Also, other factors such as energy consumption, network lifetime, and delay constraints affect the systematic working of the system. Hence, efficient routing protocol is essential for routing data packets in the network. Several systems in the same concern do not consider the energy factors and some nodes drain off their entire energy at a shorter duration resulting in a reduced lifetime. Furthermore, location privacy is under threat in several applications due to the absence of suitable protocols and techniques to retain its privacy. Hence, WSN needs improved routing, location privacy, reduced energy consumption and delay factors in the future so as to provide better comfort to the life of the people.

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