

Extending lifetime of heterogeneous wireless sensor networks using spider monkey optimization routing protocol

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ABSTRACT

The nodes of wireless sensor networks (WSN) are severely restricted in terms of computing capabilities, limited communications, and limited power supplies, as it is difficult or impossible to replace or recharge the sensor battery. Consequently, the energy of nodes is one of the most important resources to consider when designing of WSNs. So, most of the routing protocols in WSNs are to assure the saving of energy as a significant aim for improvement. Nevertheless, just providing power is not sufficient to extend the lifetime of WSN. Where unbalance energy depletion in WSNs is a challenging issue often leading to splits the network and reduces its lifetime, also retrogression of its performance. This paper, therefore, uses a powerful routing protocol named spider monkey optimization routing protocol (SMORP) to generate an optimal data routing of the pathway for heterogeneous WSNs (HWSNs). SMORP, here, can compute the best way from a sensor to the sink through the cluster head, inside the intra-cluster, and the inter-cluster respectively. For this purpose and the organization of heterogeneous nodes, this paper uses the clustering partition. The simulation results revealed that SMORP significantly improves in terms of data latency reduction, stabilizing depletion of energy, and maximizing the network lifetime for HWSNs.

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1. INTRODUCTION

For economic and technological causes, the most accessible remote sensor gadgets available today are very restrictive regarding computational, memory, energy, and communication capacities. Typically the most cause why most of the researches on wireless sensor systems (WSNs) have focused on the plan of vitality- and computationally-efficient algorithms and protocols, and the application space has been confined to plain data-oriented observing and announcing applications [1]-[3]. In this regard, WSN takes a significant task to increase the spread of networks with smart devices. WSNs offer a large application assortment, including monitoring of the environment, medical treatment, the response of emergency, and exploration of outer space [3], [4].

A huge sensor number is diffused in a wide area in the sensor network with each sensor that can collect or monitor data from the neighboring environment and passing information to the sink to reach the user remotely via technologies of varied communication [5], [6]. In these networks, nodes of sensors are generally operated by cheap, small batteries for long-term survival, as it is difficult or even impossible to perform a replacement or recharge of the sensor battery. Consequently, the depletion of energy is an

important factor to consider when designing WSNs. At times, improving network energy is more complicated because it reduces energy depletion and extends the lifetime. By raising awareness of energy in every aspect of design and operation, energy can be improved [3]-[7].

One way to use the scarcity of energy incompetent, computational, and communication resources is for dividing the WSN into several clusters. The cluster head (CH) works, as a collection point, to aggregate all data collected in one cluster [8], [9]. As protocols of clustering routing, in [8], [10]-[11], are depending upon the nodes grouping into clusters to treat some of the shortcomings in protocols of flat routing, we can talk about efficiency and scalability. The principal concept behind routing of clustering is that nodes of the sensor only directly communicate with a node of leader inside their cluster, usually referred to as CH. These CHs, specific within heterogeneous WSNs, that may be devices of more powerful and less energy-restricted than “regular” nodes of the sensor, are thereafter in charge of disseminating the data of the sensor to the sink. This way is the most efficient decrease the energy and communication burdens for nodes of the sensor, whereas CHs will face more important traffic than regular nodes of the sensor [9].

Consequently, the expending will by fewer resources through the minimizing quantity of the data which is indeed transferred to the sink by the CH. Also, the clustering ways have suggested treating unbalance energy depletion (UED) trouble inside WSNs. In networks of the exemplary sensor, the pattern of many-to-one traffic is predominant, i.e., oversize nodes of sensors are sending data to the sink. So, the sensors near the sink take charge of forwarding the data from all over the network to the sink, this depleting their energy quickly due to enormous traffic overhead near the sink. The low lifetime of those imperative sensors significantly decreases the lifetime of the network [12]. This paper, therefore, addresses the problem of unbalanced energy depletion in heterogeneous WSNs (HWSNs) which leads to prolonging its lifetime.

Two sensor types have been included in HWSN: Standard resource-powered sensors (N-sensors) and some others as high-resource CHs. N-sensors execute the task of sensing and send the info to their CH. In turn, the CH enacts aggregation of data from N-sensors that belong to an equivalent cluster and delivers the info to the sink. This paper proposes to use the clustering partition method [8] to arrange the nodes of the heterogeneous sensor. This clustering method is particularly useful for helping CH to identify the N sensors on its cluster and for identifying their CH on the N-sensors. After the organization of the sensors, a powerful routing protocol named spider monkey optimization routing protocol (SMORP) [13] is used to seek out the difficulty of maximizing the network lifetime and balancing the depletion of energy. It uses to settle on the optimal path of routing for HWSNs, for both inter-cluster and intra-cluster, via favoring three routing metrics of the node (highest remaining energy inside the node, the minimal hops number, and minimal traffic within the node).

This paper organizes as follows. The related works have been discussed in Section 2. Section 3 shows the heterogeneous sensors organization. Next, the proposed approach of HWSNs is presented in Section 4. This is followed by Section 5 that describes the simulation results. Section 6 is found to sum up this work.

2. RELATED WORKS

Generically, in WSNs, the major challenge is how to develop routing protocols to significantly extend the lifetime. This challenge, therefore, has attracted the consideration of researchers right now. Some of the studies that related to developing the routing protocols to prolong the WSNs lifetime are giving as follow:

A novel way has been suggested by Lin *et al.* [14] for dynamical HWSN networks with nodes of energy harvest to expand the total life of the network. This way is named a harmony search algorithm with multiple populations and local search (HSAML) algorithm that can discover the maximal nodes number that covers each part of all nodes so that all aims can be observed through this node. In [15], Zhang and Chen suggested a model of the dynamical network for HWSN networks named (DHWSNs). The model is depending upon the dynamical energy heterogeneousness idea to give adding additional nodes into the network. Also, within the framework of this model, Zhang and Chen have developed a clustering-dependent adaptive way to show how a mass header sensor can be enhanced. This aggregation way has improved the life of the model and heightened HWSN data transmitting packs. In [16], there is a hybrid schema in HWSNs to fully set the depletion of power for nodes of the sensor and outdo the throttle problem nearby the sink by modifying the connection load. For avoiding a bottleneck, the sink moves to a new place when sensors nearer to the sink are of low power (the portable sink). Also, the Hilbert curve method [17] has been used by this paper to extend network life by aggregating HWSNs node.

Pandey and Vishwakarma [18] presented a modern clustering strategy for HWSNs. An effective path regarding the power of energy utilization is used in this method for choosing a head of cluster nodes, sensor nodes degree, and leftover energy. Moreover, the approach of chaining is utilized to accumulate and transmit the information parcel. Dutt *et al.* [19] have suggested excluding using clustering schema named

Dispersed Energy-Efficiency Clustering (DEEC). This schema is suggested to move forward the network lifetime by versatile the limits of cluster head determination in HWSNs. The work in [20] seemed to heterogeneous nodes of the sensor with arbitrary varieties within the information making rate (traffic) to perform practical clustering-depended HWSNs. A routing procedure named Traffic and Energy Aware Routing (TEAR) is suggested to move forward the cluster heads' choice by looking at the traffic along with the node with its level of energy. Wang and Hong in [12] suggested an unused algorithm named energy-efficient topology control (EETC) which was utilized to choose the heads of the cluster in HWSNs. In this suggested, after building the clusters, Wang and Hong have utilized breadth-first search (BFS) to discover the routing way intra-cluster (i.e. from the cluster of sensor part to the head of the cluster). Other than that, they have made the shortest way to urge the routing way inter-cluster (i.e. from the head of the cluster to sink).

In [21], the researchers suggest a protocol of an enhanced balanced energy-efficient network-integrated super-heterogeneous (E-BEENISH) routing. E-BEENISH is proposed to analyze the communication power of clusters inside HWSNs. It is dependent upon the adjusted electing probabilities of each node of the sensor to end up the head of the cluster concurring to the leftover power and the length measure from the node to the sink. Madhavi and Madheswaran [9] have displayed an unused region-based energy-conscious sink movement (RESM) to make strides in the HWSNs lifetime. In this work, the topographic area is partitioned into a few of the egalitarian locales, each locale divide into a few of the clusters. The locales division saves energy for the sensor nodes' short-distance communication. Also, Madhavi and Madheswaran have utilized the stable election protocol (SEP) to minify the general size of energy that went through in each locale for the randomized re-selecting of the head node of the cluster. Alshawi *et al* [8] have created a protocol of energy-efficient named fuzzy chessboard clustering and artificial been colony routing method (FCC-ABCRM). It suggested outdoing the blockage case and fathoms the UED issue in HWSNs. Fuzzy dstar-lite which is a routing protocol used to produce the best information routing for HWSNs is recommended by Alshawi *et all*. [22]. Moreover, this protocol can reuse the element method to save energy usage that is reasonably propagated across network nodes.

3. ORGANIZATION HWSNs UNDER CLUSTERING PARTITION

This section shows the organization of the sensors of HWSN under the clustering partition method [8]-[22] idea. N-sensors are went to means the essential sensors and CHs are employed to point the cluster heads. It's supposed which CH and N-sensors recognize their places and none of them can simultaneously receive and send the info.

3.1. Deployment Sensors

In a HWSN, a huge number of typical sensors (N-sensors) must be randomly deployed in the field. So, the N-sensors here are going to be erratically spread within the topographic region in HWSN. The network also contains several sensor nodes that have high resources to be suitable to act as CHs. Therefore, the CH here must be diffused carefully to ensure that all N sensors are secure and can be interconnected with at least one CH.

3.2. Clustering partition

N-sensors must be partition into clusters. This is named cluster partition and was utilized in homogenous WSNs [23], [24] and HWSNs [8]-[22] too. In HWSN, it utilizes to notify the CH that N-sensors belong in its cluster and to notify N-sensors to that cluster they belong to. Therefore, clusters are composed around CHs.

Under this clustering concept, CHs broadcast messages which contain their place depending upon their IDs. The CH containing the smallest ID will become first. Then, as per the strength of the signal received, each of the N-sensors makes a list of CHs it has heard from where the bigger signal strength turns into first. Thereafter, each N-sensor will recognize that CH might belong and will select CH at the top of the list as its favored CH. Next, CH begins finding which N-sensors must be inside its cluster. The procedure is identical for every cluster. Figure 1 shows a flowchart of the clustering partition algorithm for HWSNs.

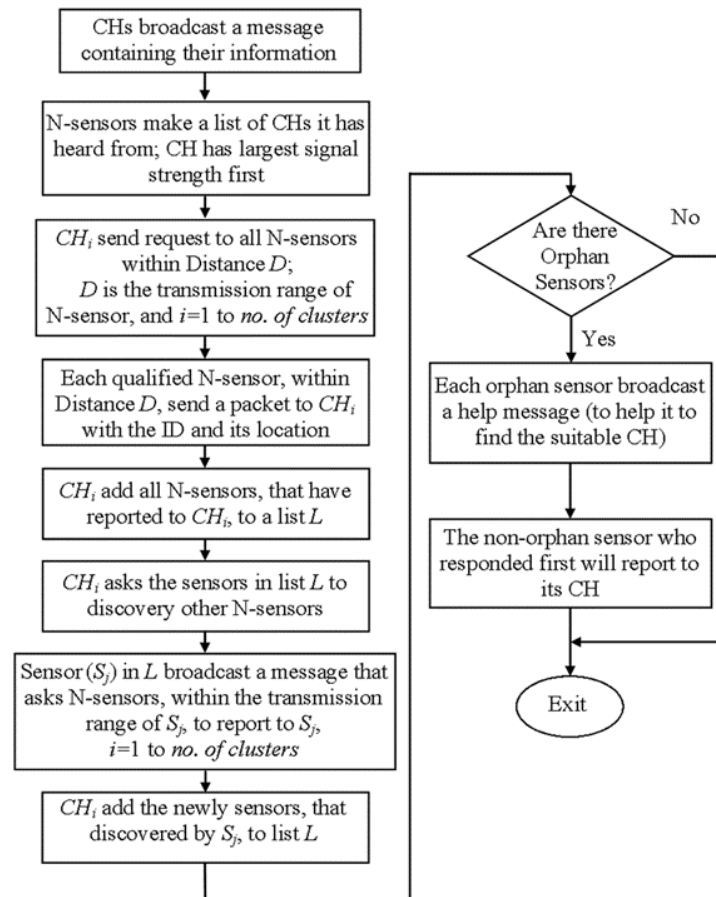


Figure 1. Flow-chart of the clustering partition algorithm for HWSNs

4. SPIDER MONKEY OPTIMIZATION ROUTING PROTOCOL (SMORP) FOR HWSNs

The lifetime of the network is one of the substantial challenges of the WSN. Notwithstanding, within the protocol of routing proposed at the time that any node of the sensor (whether N-sensor or CH) depletes its energy the info-communications amongst various N-sensors and therefore their CH will break the connection also the aforesaid will happen amongst the CH and the sink. This generally gives rise to scarcity within the lifetime of WSN. Where the lifetime of every sensor within WSN depending upon enervation of power, it's the most affair to preserve the residual power in those sensors which provides rise to expand the mixture lifetime of the network to the maximum amount as possible. Thus, this paper utilizes an energy-sufficient routing protocol named (SMORP)[13] to expand the HWSNs lifetime via constraining the value of energy amongst the node's communication paths (in both inter-cluster and intra-cluster), also to outdo the UED problem that's occurred in the HWSNs.

In this paper, firstly the clustering partition is employed to arrange the heterogeneous sensors under the clustering concepts (each cluster owns a CH within the role of leader and owns a number of the N-sensors within the role of members). Within the following time, the protocol proposed is employed to accumulate the simplest pathway of routing from N-sensor to its CH and from a CH into the sink, in sequential, via considering a number of the standards of routing and balancing them (that is to mention residual power of the battery, shortest path of routing, and therefore the minimal load of traffic). The paper supposes: i) the range of transmission and the initial power of batteries are identical in all N-sensors; ii) each N-sensor knows its place also knows its CH and its neighbors; iii) the range of transmission and the initial power of batteries are identical in all CHs; and iv) each CH knows its place also has knowledge its neighbors that is to say the other CHs and the sink's place. As per arrange HWSN, the method proposed of routing is carried out two times in inter-cluster and intra-cluster, in the same manner in sequential. The flowchart of the SMORP in HWSN is shown in Figure 2.

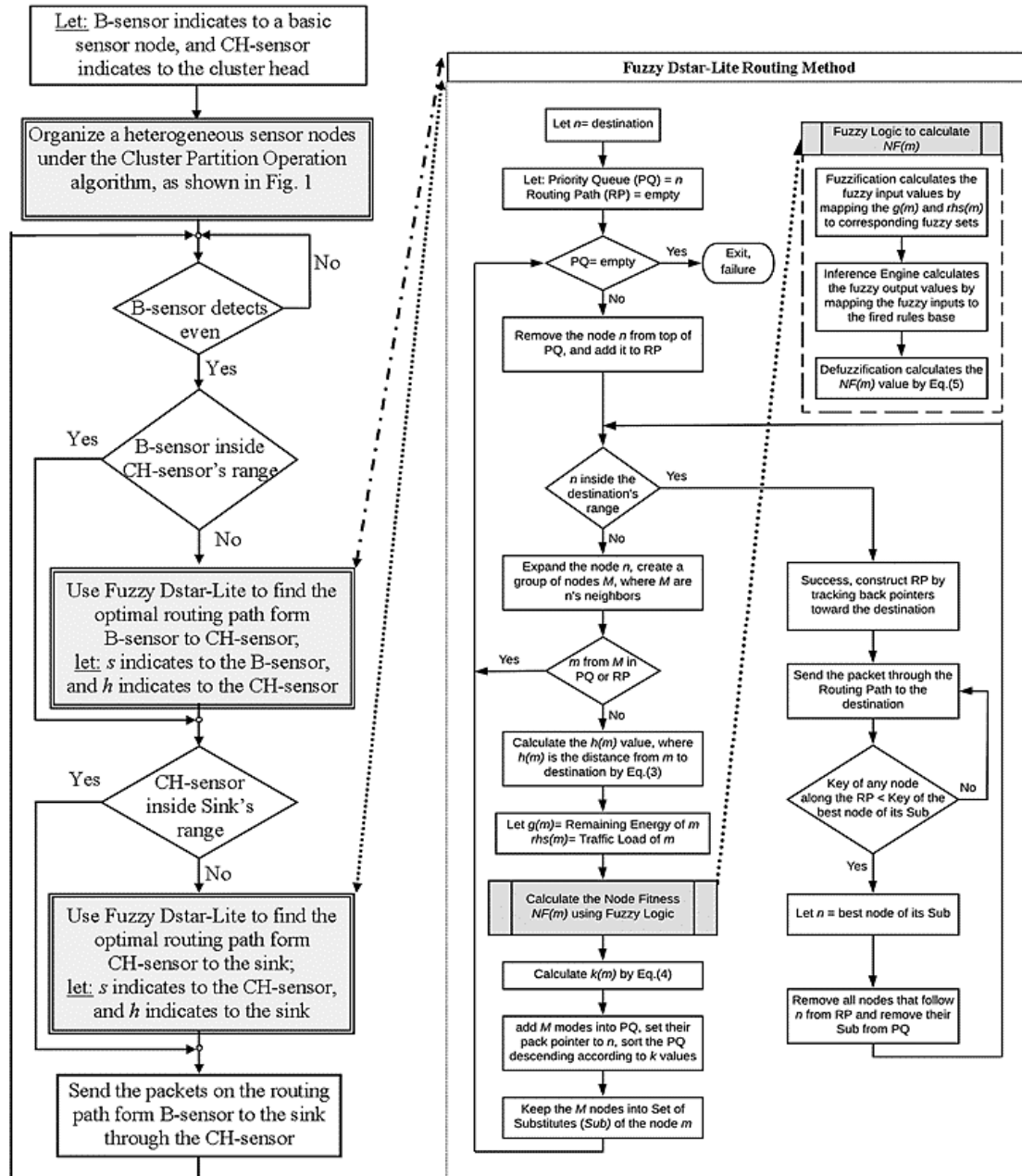


Figure 2. SMORP flow-chart for HWSNs

5. PERFORMANCE EVALUATION

Extending the lifetime of the described HWSN can be attained by prolonging the time passed till the death of the first and last sensor for both N-sensor and CH sensor. So, the performance of our proposed in HWSNs was evaluated by comparing it with the chessboard clustering (CC) method [11] in the case of utilizing the same routing metrics and the same environment. In both models, the death of the first node is used much more than (first/last) criteria, since the first node death impacts the main function of the WSNs which is sensing.

5.1. Simulation setup

We have been considered the average remaining energy of the network, numbers of dead nodes, running times, and the number of transmission hops as comparison factors to show the efficiency of our proposed protocol in terms of uniform energy consumption and extending the network lifetime. This

subsection shows the parameters that must be set up in the network to mimic the real-world network as possible. As demonstrated in Table 1 for the two approaches, we considered a heterogeneous network where (1000) N-sensors and (36) CHs are deployed randomly over a square topographical area with (300 m × 300 m) dimensions.

The N-sensors are organized around CHs using the clustering partition method. Both approaches run out of (2000) transmission rounds and they are done used the primary radio model described in [25]. In each round, equal (2 k) bytes of packet length were generated by both approaches. Also, there is just one data sink located at (0 m, 150 m) and all N-sensors and CHs have equivalent initial energy of (0.5 J) and (2.5 J) with a sensed transmission of (20 m) and (80 m) correspondingly. The traffic load on each N-sensor will be generated randomly with a range value of [0...10]. It is also altered in the [0...50] range in each CH sensor.

Table 1. Simulation parameters

Parameter	Value
Topographical area (meters)	300 m x 300 m
Sink location (meters)	(0, 150)
Control packet length	2k
No. of transmission packets (rounds)	2×10^3
No. of nodes	1000
Limit of transmission distance	20 m
Initial energy	0.5 J
E_{elec}	50 nJ/bit
E_{amp}	100 pJ/bit/m ²
Max. traffic in node's queue	10
No. of nodes	36
Limit of transmission distance	80 m
Initial energy	2.5 J
E_{elec}	100 nJ/bit
E_{amp}	200 pJ/bit/m ²
Max. traffic in node's queue	50

5.2. Simulation results

For the area of fixed routing, the transmission packets are represented by the ratio of live nodes by utilizing the two approaches for both N-sensors and CHs shown in Figure 3 and Figure 4, respectively. Since the first objective of our approach is to avoid energy holes near the CH, the suggested method achieved a better result in such a factor than the CC approach. So the suggested method usually raises the number of alive nodes of the whole network. The network lifetime achieved by the proposed method is about 25% greater than that gained through the CC approach.

The different time intervals associated with the primary dead node computed using the two approaches within the area of fixed routing are shown in Table 2. The time for the primary node to die within the suggested method is far longer than the time for the primary node to die within the CC approach. Therefore, from Figures 3, 4, and Table 2, the proposed approach exceeds the CC approach for energy depletion balancing and network lifetime maximization.

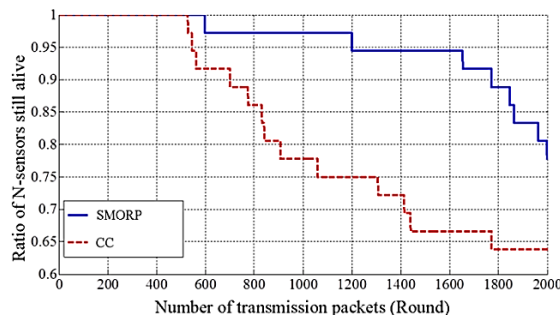


Figure 3. N-sensors ratio still alive per the rounds

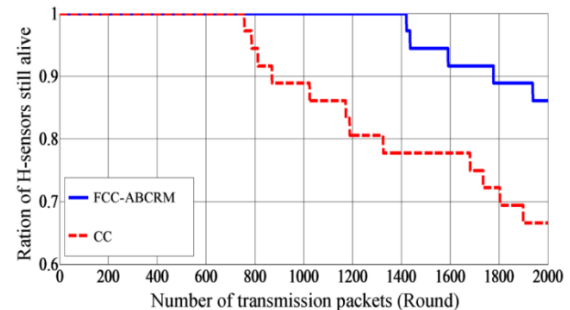


Figure 4. CH-sensors ratio still alive per the rounds

Figure 5 shows the percentage residual power of N-sensor nodes as transmission rounds depending on the two methods within the area fixed routing. Due to the higher routing number, the proposed approach achieves a better performance than the CC approach. As a result, N-sensors have less initial energy than CHs

and also N-sensors consume slightly less energy than CHs to exchange data. On the other hand, Figure 6 displays the ratio of residual energy for CHs nodes as a function of transmission rounds depending on the suggested method and the CC method. Therefore, from Figures 5 and 6, it's clear that realizing the depletion of energy and maximizing network lifetime is administered by the method suggested better than the CC approach.

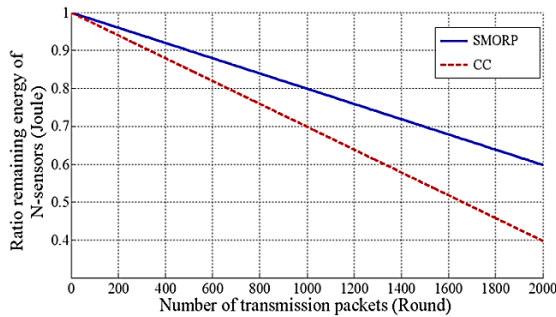


Figure 5. The remaining N-sensors energy ratio depends on transmission rounds

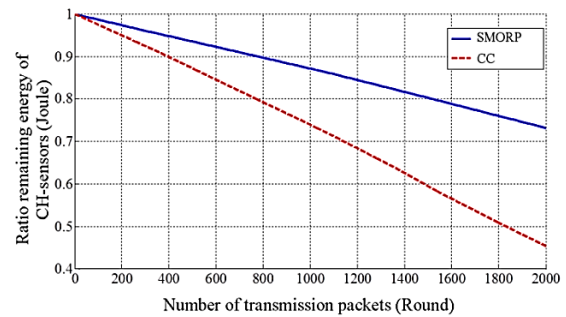


Figure 6. The remaining CHs energy ratio depends on transmission rounds

Table 2 Number of rounds with the first dead node

Approaches	CC	SMORP
A lifetime of the first dead N-sensor (Rounds)	529	589
A lifetime of the first dead CH-sensor (Rounds)	757	790

The delay caused within the data packet transmission is likewise the main parameter for specific applications. Figure 7 shows a simulation time comparison between the two approaches within the static routing region. So, when comparing the suggested model to the CC method, the first one shows the shortest delay time. Furthermore, the low end-to-end delay has been achieved by the proposed method which shows in Figure 8. A shorter delay of time shows energy savings and efficient information transfer. This means that data packets routed in various paths are broken down to the node using multipath routing to avoid network congestion and extend the network lifetime.

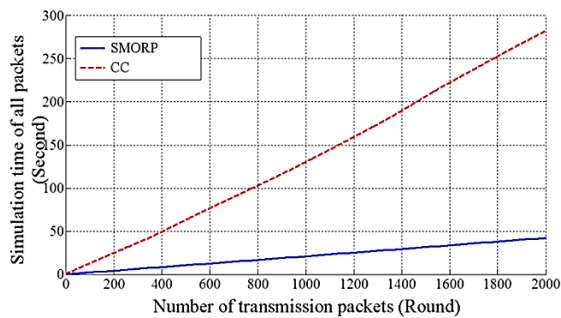


Figure 7. Data transmission delay depends on transmission rounds

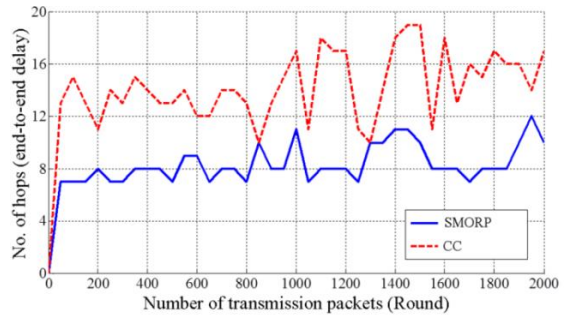


Figure 8. The number of hops depends on transmission rounds

6. CONCLUSION

The larger number of the works within the literature, about heterogeneous WSNs, affirmed energy savings as a significant optimization aim. Nonetheless, UED is a habitual drawback in the WSNs caused by many-to-one traffic patterns and multi-hop routing among sensors. This UED squandering can remarkably scale back network lifetime. Therefore, the researchers in this paper utilize the SMORP to hunt out the optimum path of routing for the heterogeneous WSNs, for both intra-cluster and inter-cluster. For this, the clustering partition methodology is used to organize the HWSNs. The efficacy of our suggestion is evaluated




and compared with the CC approach. Simulation results have shown that the lifetime of the network gained by the suggested may be multiplied by about 25% more than that got by the CC.

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