Multi Driven EDT Clustering for Wireless Chemical Sensor Network

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Research Article

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Abstract

WCSN is one of the most important research areas in the terrestrial networking field due to its wide range of applications. One of the most difficult challenges is expanding the overall running time without attaching any new batteries or hardware. Using a novel method called EDT (Energy, Distance, Time) driven strategy, this paper proposes a clustering algorithm to solve the problems of the hotspot as well as reduce battery energy loss. The CH rotation method was then described in detail. In this paper, will introduce a new function called SCH (Substitute cluster head), which has replaced CH. The main objectives of this research are to improve energy reliability and network lifetime. Finally, the presented EDT approach can be comparable to current algorithms, where LEACH's network lifetime is 15.4 %, DECSA's is 23.2 %, and NEAP's is 11.4 %, but our proposed EDT methodology extends network lifetime by 40% as well as decreases energy usage by 7% as compared to LEACH when determining the SCH.

1. Introduction

The Wireless Chemical Sensor network (WCSN) is used to sense tiny chemicals present in the surrounding circumstances. It collects the information about the chemicals from the neighborhood environment and then process & transmits the details to remote devices usually by radio communication [1]. The sensor node has a potential to sense, computation, and also communicate along with limited energy. Most of the SN (Sensor Nodes) is used in difficult areas which are out of human access. The necessity of WCSN gained huge application in military, assassin detecting, environmental monitoring, and medical measurements and so on. Battery operated intelligent WCSN depletes energy very quickly compared to other wireless sensor network scenarios. [2] Near Cluster Head (CH) receives more data from other sensor nodes compared to other CH due to large amount of sensed information. This near Cluster Head (CH) depletes energy very quickly compared to other CH which induces hotspot problem, and also before the data transmission process Data Deduplication (DD) occurs. Where DD can eliminate the duplicate copies of same data and save only one copy which can reduce the storage of the network, so which can improve the energy efficiency. The major research challenge behind WCSN is how can extending the overall working time without introducing any extra batteries or any other hardware device [3]. To overcome these flaws mentioned above, a multi drive clustering algorithm based on EDT (Energy, Distance, Time) strategy for WCSN is proposed in this paper. In this algorithm, sensor nodes are systematically arranged into clusters which consist of Cluster Heads and Cluster Members, here chief (CM) collects the data and send it to the cluster head. There are various advantages of clustering in WCSN such as conflict avoidance, delay reduction and also better network communication. [5] The main quality of CH in clustering algorithm introduces new optimization paradigm strategies for upgrade or extended the network working time by saving the energies of each individual sensor. This paper adopts, Cluster Head (CH) rotation algorithm for choosing the CH based on EDT driven strategy [6].

The major contribution of this proposed work is as following steps,

- **Step 1**: First, a new technique called EDT powered strategy based on clustering algorithm is used to solve the "hotspot" problem and reduce battery energy depletion.
- **Step 2**: This paper presented a novel function called Substitute Cluster Head (SCH), which is used in place of the current main Cluster Head.
- **Step 3**: Data Deduplication (DD), which eliminates redundant copies of the same data and saves just one copy, is the third contribution. Data Deduplication is significant because it reduces the quantity of sensed data that may be sent through the network or BS.

The rest of this paper is presented as follows: the section II will be discussed about literature survey works and proposed algorithm is presented in section III. And its result and simulation are presented in Sect. 4. Finally, this paper concludes in section V and some future scope points are included in section VI.

2. Literature Survey

Various approaches have been used in past decades to improve energy quality and maximize WCSN life. In this section, this paper addressed the relevant work reviews of this multi-driven clustering algorithm focused on the EDT strategy.

Quan Wang et al. presented a report on the advantages of clustering and CS-based methods in 2019. To minimize data associated problems such as spatial and temporal similarity, the clustering approach was combined with compressive sensing (CS-scheme). The energy-efficient compressive sensing routing algorithm will help you save money and extend the life of your network. Aside from that, cluster size and CH distribution is discussed in order to improve energy efficiency. The “Hot Spot Problem,” which causes early network lifetime wind-up, is a flaw in this report.

In 2019, Fakhrosadat Fanian, Marjan Kuchaki Rafsanjani., proposed a paper on cluster-based routing protocols with a small non-rechargeable battery was proposed for precise research. The purpose of this paper is to provide perspective, to compare strategies and ethics, regardless of any criteria, in terms of procedure. The current survey does not analyze any methods or protocols from a formal perspective

In 2012, Champake Mendis et al., Proposed a paper about chemical sensor tracers. At the productive level, all wireless chemical sensors are constantly residual and resulting in considerable energy consumption. This article explores the impact of conceptual communication and grid constellation performance of WCSN in epidemiologically based dynamic sensor implementation protocols. If number of sensors increases it would face some challenging task such as mathematical modeling, computer simulation and parameter optimization.

J. P. Barbot et al. reviewed on cluster hierarchical sparse signals in the context of BCS in 2012. This experiment was carried out in order to determine the utility of the proposed algorithm. In this article, we propose a new algorithm for retrieving ordered sparse signals from clusters using both sparse prior and cluster prior techniques. These algorithms do not need any manual parameters, unlike current Clustered

Sparsity Model recovery algorithms. This approach solves the problem in reverse – without understanding the cluster size or number of clusters present.

A report on different methods of compressive sensing strategies was presented by P. Venkat Rao and Ch. Balaswamy in 2018. From a small number of linear scales, CS can be used to renovate the signals in WSN. Their compression ratio and energy consumption reduction are spectacular, according to test reports. Various techniques are used to improve the use of the CS approach, but it also has many shortcomings and flaws. It is important to improve the efficiency of compressive sensing techniques in order to mitigate the shortcomings of current approaches.

Dr. Prachi Maheshwari and colleagues explored how to reduce total energy demand and maximize network lifetime in 2020. Cluster heads in this paper use the butterfly optimization algorithm to optimize a set of nodes. ACO points out the path between CH and BS. The proposed method's output is evaluated using AN (alive nodes), DN (dead nodes), power consumption, and PS collected data packets.

Won woo Lee et al. proposed a survey in 2020 on a novel wireless-powered chemical sensing device based on energy-harvesting met materials operating at microwave frequencies. Wireless chemical sensing was achieved using the proposed sensor device as a single wave source with no external power source. Miniaturized wireless sensor devices, including biochemical and dielectric environmental inventors, are the product of the findings. To solve both of these flaws, energy harvesting met material seems to be a promising platform.

This work uses a modern technique named EDT (Energy, Distance, Time) that is based on clustering algorithm to resolve the shortcomings of hotspot problem as well as energy depleting batteries. Substitute Cluster Head (SCH) is a modern function that allows the current Cluster Head (CH) to hand off all duties to the replacement in the event of an energy outage. Both energy efficiency as well as network running time is considered in this paper without the use of any additional batteries or hardware components.

3. Proposed Method

The suggested method's main aim is to improve energy quality and extend the network's running time in the WCSN [7]. The Multi-driven Clustering Algorithm (MCA) for WCSN has been introduced in this section, which is based on the EDT (Energy, Distance and Time) Strategy. Cluster creation, CH (Cluster Head) collection, as well as replacement CH is all part of the cluster setup process. [8] Overall, the proposed approach is based on an EDT (Energy, Distance, Time) guided strategy that uses the Cluster Head Rotation Algorithm. Furthermore, the compressive sensing (CS) scheme has been combined with the clustering algorithm. [9] Energy efficiency decreases with Fs (Sampling Frequency) so Compressive Sensing method is used to prolong the overall working time. Once the Base Station (BS) gets the specification values such as n, ε, k, and s, It determines the best optimal solution for cluster at each layer according to the Eq. (1)

$$C_{opt=}1/2s\,(2n-1)\,\epsilon^2 \times 22/7\,\left(-1/\epsilon^2{}_n\right) + P\ (1)$$

Eventually, CH choosing the best optimal solution according to the it layers of Cluster Head. Now the Base station reports all the optimal information about CH to all the participating nodes in broadcast form. When the BS transmits the information to participating SN it calculates the R_{E-D} and it remembered. [11] Then the participating nodes send the (HELLO) packets which contain cluster ID and NR_{E-D} (Node Residual Energy to distance). [12] The SN compare RE values with the collected message (HELLO) if the rate was smaller, it forwarded the HELLO packets to the neighbor node. Or else, it rejected the HELLO message and created the latest CH selection packet. In Fig. 1 given below, it shows the cluster head selection in WCSN.

Once completed the above steps, redo the steps till the clusters are joined with neighbor node. [13–14] Sometimes base station does not transmit HELLO packets to the sensor node, so it chosen itself as a secluded cluster head. After completing each round, CH compared with R_{E-D}if the residual energy value is smaller, then the present cluster head handover all responsibilities to the Substitute Cluster Head (SCH). In this way rotation conducts between CH and SCH. [16] Afterwards SCH collects the information from cluster head, it will be announced to the entire cluster member (CM). So, it went back to the next cluster formation phase.

In cluster setup phase it consists of SCH [17]. Significantly, which node has second highest rate of residual energy to distance were chosen as the SCH by the current CH. The R_{E-D} and ID of the Substitute CH are stored in current CH's memory. However, the Substitute CH (SCH) announced its role by the current Cluster Head via uncast [18]. CH selection concept is based on if two nodes have same energy level, then the node which have higher number of neighboring nodes is selected as CH [19].

3.1 CH Rotation Strategy

The sink flooded hello packet messages directly to all participating nodes based on this flow diagram. The Received Signal Strength Indicator (RSSI) will measure the SN distance from the base station after the HELLO message has been received. [20] Energy, Distance, and Time (EDT) driven strategy is one type of CH rotation strategy. The TDRE technique can be used to evaluate the WCSN network's energy use. In the other hand, determining the rotation time for each round is complicated. [21] There will be periodic Cluster Head rotation if the rotating time is short and there will be little effect on determining the energy consumption if the rotating time is long. Up to the minimum range, the effect of the TDRE loop may be monitored. [22–23] Data transmission would require less and less energy as the residual energy of the CHs was reduced. The CHs' energy would soon surpass the energy barrier, causing the entire network to crumble into a continuous choice of rotation, with only little sensitivity to transmitting energy [24]. As energy efficiency deteriorates, an effective energy gateway is needed to reduce energy usage as well as extend network life.

(Where, NR_E = Node Residual Energy; B-NR_E = Base Station to Node RE; RNR_E = Required Node to RE; RNS_d = require Node to Sink distance; RNS_t = Required Node to Sink time; TDRE = Threshold Differential Residual Energy; TNSD = Threshold Node to Sink Distance; TNST = Threshold Node to Sink Time)

From the Fig. 2, If the actual NR_E is higher than the $B\text{-}NR_{E,}$ then it will check TDRE for all nodes (Threshold Differential Residual Energy) if any cluster node has highest energy than the required node to R_E, so it will take Substitute Cluster Head (SCH) as a CH and changeover the role of the CH to the substitutes (SCH). Then Data Deduplication (DD) process occur which can delete the extra copies of same data and send only one data to the particular sink, afterwards data transmission process occurs easily [25]. If the rate was smaller, it forwarded the HELLO packets to the neighbor node. Or else, it rejected the HELLO message and created the latest CH selection packet.

If all the participating node has same energy level (for example each node have1J difference) it is difficult to get a CH, so check TNSD (Threshold Node to Sink Distance) for all nodes, one of the cluster nodes is very nearest to the sink when compared with required node to sink distance. If the above condition is accepted, it eliminates the duplicate copies of same data and it consist only one copy which reduces the storage cost. After that Data transmission will occurs where SN transmits to the BS by "hop-by-hop" method.

The energy efficiency gradually reduces when the network's durability is lower. At lower-state, TNST (Threshold Node to Sink Time) can achieve high energy efficiency. At initial stage, both TDRE and TNSD is used in some cases it doesn't find the substitute CH; finally, it checks TNST for all nodes. If TNST is higher than node to sink time, t transmits 'n' rounds of data to the participating sensor nodes else it rejected the message and again created a new CH selection packet. The energy can be defined as

$$\mathrm{e} = \frac{\epsilon_{\mathrm{steady}}}{\epsilon_{\mathrm{steady}} + \epsilon_{\mathrm{setup}}}$$

2

Where 'e' is Energy efficiency;ϵ_{steady} is used to sense and transmits the data; $\epsilon_{setup}$is used to select the cluster head and for cluster formation. Let us consider there are *n* rounds of data transmission in TNST. Then the energy efficiency of TDRE is calculated by the Eq. (3)

$$\mathrm{E}_{\mathrm{TDRE}} = \frac{\mathrm{n}\left(\epsilon_{\mathrm{CH}} + \epsilon_{\mathrm{CM}}\right)}{\epsilon_{\mathrm{setup}} + \mathrm{n}\left(\epsilon_{\mathrm{CH}} + \epsilon_{\mathrm{CM}}\right)}; \epsilon_{\mathrm{steady}} = \mathrm{n}\left(\epsilon_{\mathrm{CH}} + \epsilon_{\mathrm{CM}}\right)$$

3

Where,ϵ_{CH}energy consumption of main CHs in each round data transmission,ϵ_{CM} is energy consumption of CMs and vice CHs in each round data transmission. In the TDRE technique, if the residual energy of the main CH goes below a threshold, the whole network will be rotated. The threshold is shown in formula $\lambda = c.\, R_{E_i}$ where 0 < c < 1.

The energy efficiency of the TDRE is calculated by Eq.(3)$\phi = \frac{(1-c)R_{E_i}}{\epsilon_{CH}}$; where $\phi$is number of rounds of data transmission.If TDRE is not used, it is replaced by TNSD or TNST by the Eq. (4)

$$\frac{\mathrm{n}\left(\epsilon_{\mathrm{CH}}+\epsilon_{\mathrm{CM}}\right)}{\epsilon_{\mathrm{setup}}+\mathrm{n}\left(\epsilon_{\mathrm{CH}}+\epsilon_{\mathrm{CM}}\right)}=\frac{\phi\left(\epsilon_{\mathrm{CH}}+\epsilon_{\mathrm{CM}}\right)}{\epsilon_{\mathrm{setup}}+\mathrm{n}\left(\epsilon_{\mathrm{CH}}+\epsilon_{\mathrm{CM}}\right)}$$

4

When TNST (Threshold Node to Sink Time) is below required node to sink time, the system discarded all packets and goes to cluster setup phase is shown in the Fig. 3. After the cluster formation, the CH calculates the ratio of R_{E-D} and remembered it very well. If actual participating sensor node residual energy is higher, this proposed method presented a new strategy is called EDT strategy (Energy, Distance, and Time). From this new strategy, if the present cluster head gets reduced its energy, so CH needed a backup so in this method, present CH will be changed by SCH (Substitute Cluster Head) based on EDT.

Pseudo code For Multi Drive Edit Strategy

sink broadcast opt_ CH & opt _CH $_{dist}$ to all sensor nodes

for each node SN_i do

calculate R_{E-D}

receives HELLO packets (C_id &N R_{E-D})

compare R_{E-D} with HP (N R_{E-D})

while SN_i, TDRE0

SN_i receives HP (C_id &N R_{E-D})

end

end

if (NR > B-NR)

check for TDRE

if (TDRE > RNR_E)

it will take substitute as CH

else if

it check with TNSD

if (TNSD > RNS_d)

eliminate the duplicated copies

compute data transmission

end

end

end

end

else

check TNST for all nodes

if (TNST > RNS_t)

data deduplication occurs before data transmission

end

end

4. Result And Discussions

MATLAB is used to implement various simulation experiments in our work. In terms of network working time, throughput, as well as participating sensor nodes, our proposed algorithm is compared to the Clustering algorithms LEACH, DECSA, and NEAP. The hierarchy routing protocol LEACH (Low Energy Adaptive Clustering Hierarchy) is used in the WCSN to extend the network's running time. In order to minimize energy demand, it used cluster-based routing. DECSA is based on a classic clustering routing algorithm that takes into account both node distances as well as RE. It strengthens both the CH collection and cluster forming processes. In contrast to LEACH, NEAP performs better in terms of CH selection and forms an adaptive power-efficient as well as clustering hierarchy. The main goal of our proposed solution is to extend the life of wireless chemical sensor networks by lowering the amount of energy used to create and maintain cluster heads. The values obtained from the matlab simulator are shown in Fig. 4. The findings of this simulation are focused on clustering techniques.

The Fig. 5 shows the simulation of all clustering operation using EDT driven technique. Fig (a)&(b) shows participating chemical sensor nodes where the sensor nodes drop data packet messages due to buffer overflow so Cluster Node (CN) takes the alternate path to the BS. In fig (c) member nodes of cluster 2, 3, 4 sends the data packets to BS through cluster head (CH). In fig. (d): node 3 has highest energy efficiency so it is elected as a cluster head therefore now node 3 can transmits data packets to the BS. In fig. (d)& fig. (f) Besides, new node gives join request to the CH for authenticate key however CH provides authentication to the new node, then the new node becomes authenticated sensor node of cluster1.

The network life is very crucial predictor for quality evaluation of energy efficiency. Network working time is compared with three existing algorithm LEACH, DECSA, NEAP as shown in the Fig. 6. The simulations were carried out with constant number of sensor nodes. The suggested approach was contrasted with the current algorithm, like LEACH, DECSA, NEAP to check the benefit of the proposed paper. From the Fig. 6 it shows that LEACH, DECSA, NEAP gets lowest simulation time due to redundant data and unbalanced energy. But our proposed method consists of clustering technology. Therefore, redundant data and energy balance are adopted. At some point, our proposed method is strengthened and their lifespan is longer than the existing algorithm. It is proved that our EDT method gives better results and extended 40% of the network life time by using EDT strategy.

Here throughput comparison is shown in the Fig. 7. It is specified as number of data packets (HELLO messages) is successfully reached the BS. The figure shows the simulation results which were compared with the existing algorithm. LEACH received lowest data packets moreover for 2000 rounds but DECSA and NEAP are getting increased for first 600 rounds due to large number of redundant data after that dead nodes are appeared in it so data packets are begin to reduced, but our proposed method adopts EDT clustering strategy so the cluster formation are more reasonable and energy efficiency is balanced. Finally, our proposed method has received large amount of data packets at the base station more than LEACH, DECSA, NEAP.

Figure 8 depicts the typical node RE's comparative performance. The proposed method's average node is greater than the current algorithm, as can be shown. In LEACH, DECSA, and NEAP, the typical node RE begins to lose its initial energy after 400 rounds. However, as opposed to other current algorithms, our proposed solution has more advantages after 1100 rounds. As a result, the average node residual energy efficiency of our proposed system is higher.

As opposed to the other two algorithms, the LEACH algorithm saves energy, but our proposed solution gains more energy than the current algorithms, as seen in Fig. 9. DECSA has the smallest sensor nodes at 150, while LEACH and NEAP have 300 and 250 SN, respectively. In comparison to all current algorithms, the proposed approach has the most participating sensor nodes, which extends the WCSN's lifetime. Finally, compared to the existing LEACH, DECSA, NEAP algorithm, our suggested solution conserves 40% more resources and extends network running time by 40%. Furthermore, it increases transmission capability, SN lifetime and RE average node. As a result, our suggested solution is seen to be an effective routing algorithm.

5. Conclusion

Energy limitation was one of the key challenges for a long time, facing the conventional WCSNs. The "Hot Spot Problem" causes early end to the existence of the network. The transmission used for the rotation of CHs often leads to a loss of energy. In addition, the Cluster Head replacement and the rotating system were suggested to reduce the energy loss during the CH rotation. However, the optimal cluster size, the optimal cluster head distribution was suggested to further improving energy efficiency. This approach is felicitous to a wide variety of algorithms which used EDT (Energy, Distance, Time) strategy-based cluster head rotation process. Our simulation results revealed that EDT technique beats the existing benchmark algorithms such as LEACH, DECSA and NEAP. The proposed method achieves our pricipal goal of expanding the life of the network by 40% compared to other works and also number of data packets sends to the base statio increased up to 25%. To the authors knowledge, such a study has not been completed to date. The simulation findings have shown that the EDT strategy can successfully increase energy efficiency and extends network working time.

6. Future Scope

For future works, data aggregation will be used, where data will be aggregated and compressed depending on the compressive sensing technique at each node. There have been no articles aimed at optimizing WCSN's energy quality, as far as we know. In addition, the EDT solution can also be paired with the CS theory to reduce the energy consumption resulting from the data-correlated problem and also overall data's get even more tightly secure.

Declarations

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Conflict of interest/Competing interests

This paper has no conflict of interest for publishing

Ethics approval

The Research guide reviewed and ethically approved this manuscript for publishing in Wireless Personal Communication journal.

Consent to participate

The participants are Abin John Joseph, Dr. R. Asaletha

Consent for publication

The author was agreed to publish this research work in Wireless Personal Communication journal.

Availability of data and materials

Not applicable

Code availability

Not applicable

Authors' contributions

Conceptualization, investigation: Abin John Joseph, Dr. R. Asaletha

Writing—original draft preparation: Abin John Joseph,

Writing—review and editing: Abin John Joseph, Dr. R. Asaletha

All authors have read and agreed to the published version of the manuscript.

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Figures

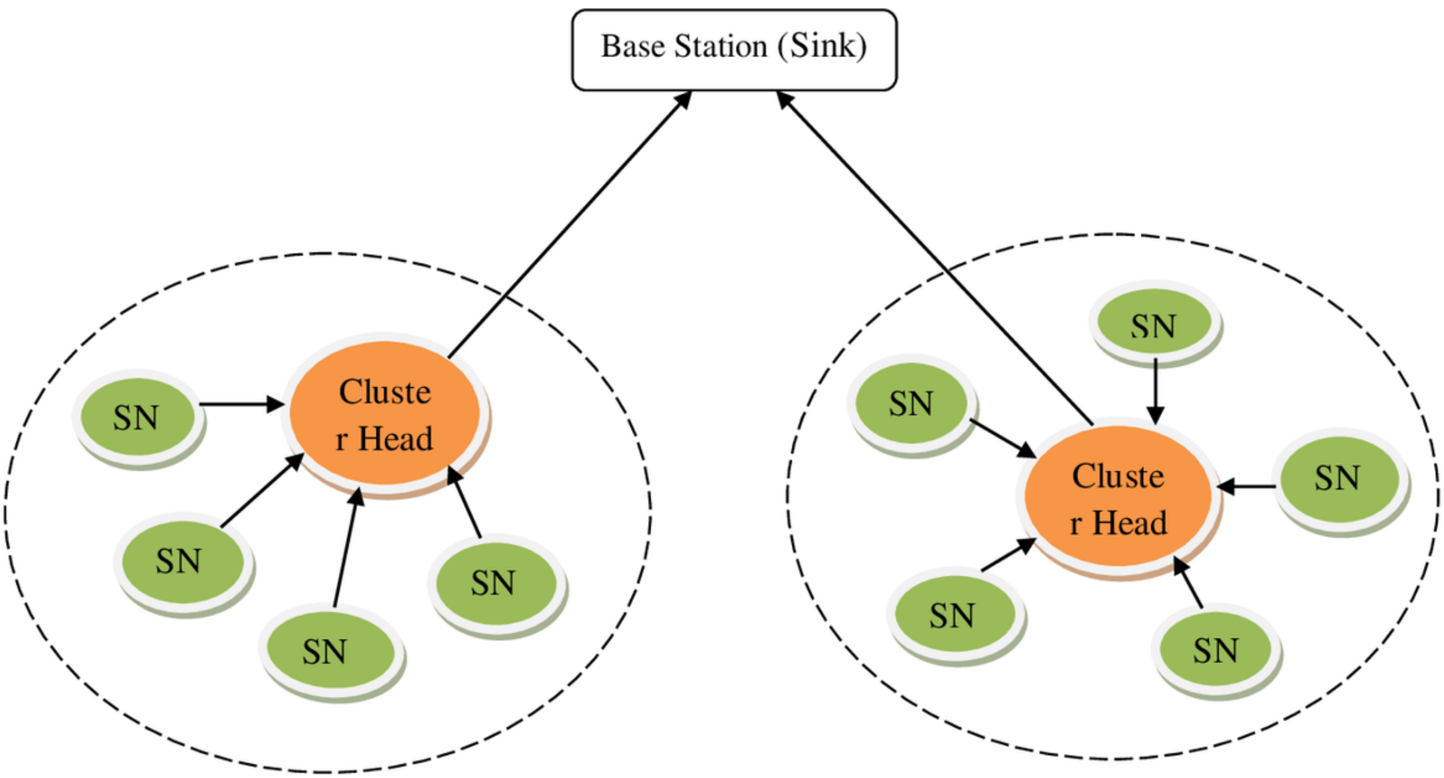

Figure 1

Cluster Head selection in WCSN

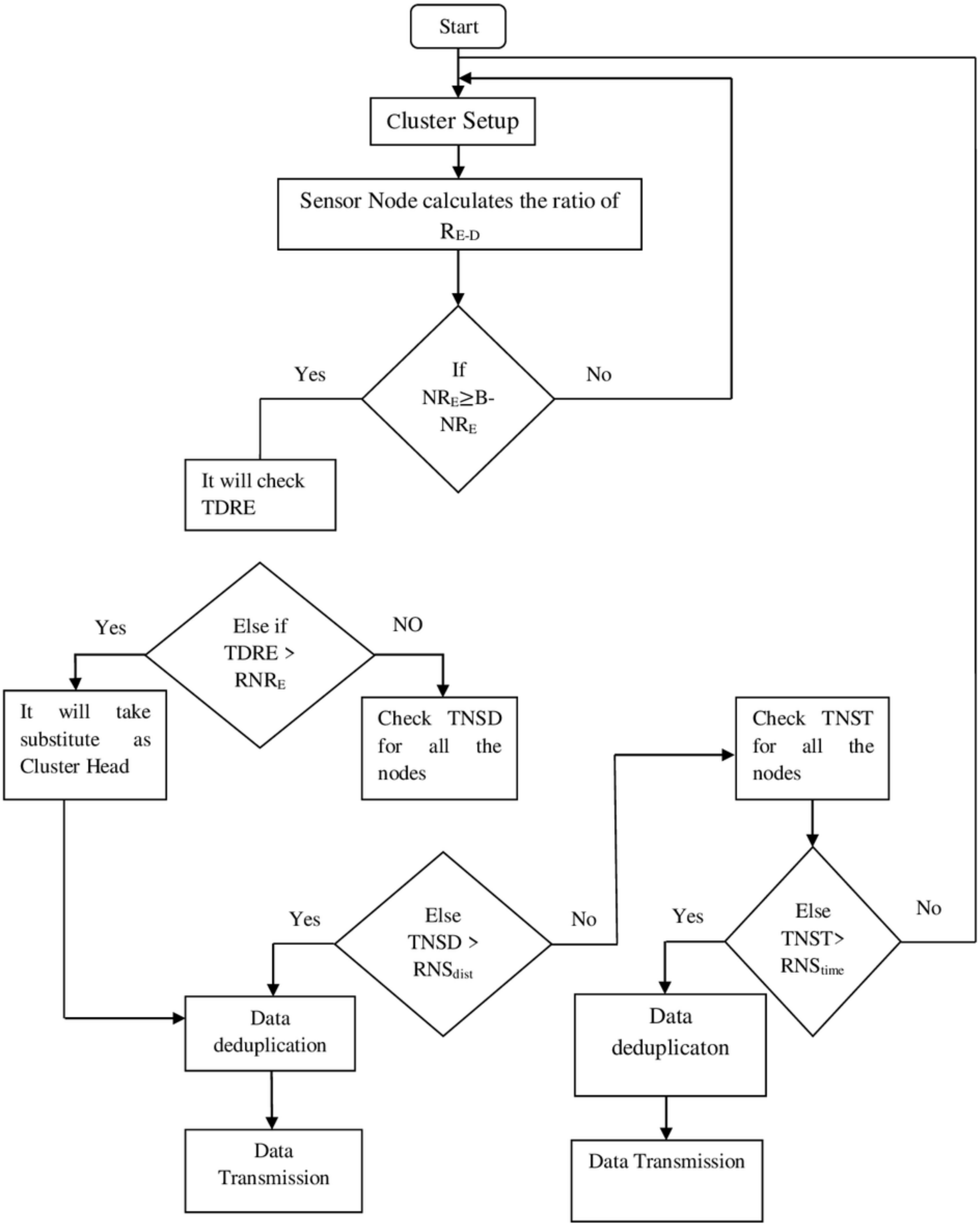

Figure 2

Flow diagram of proposed method (Based on EDT strategy)

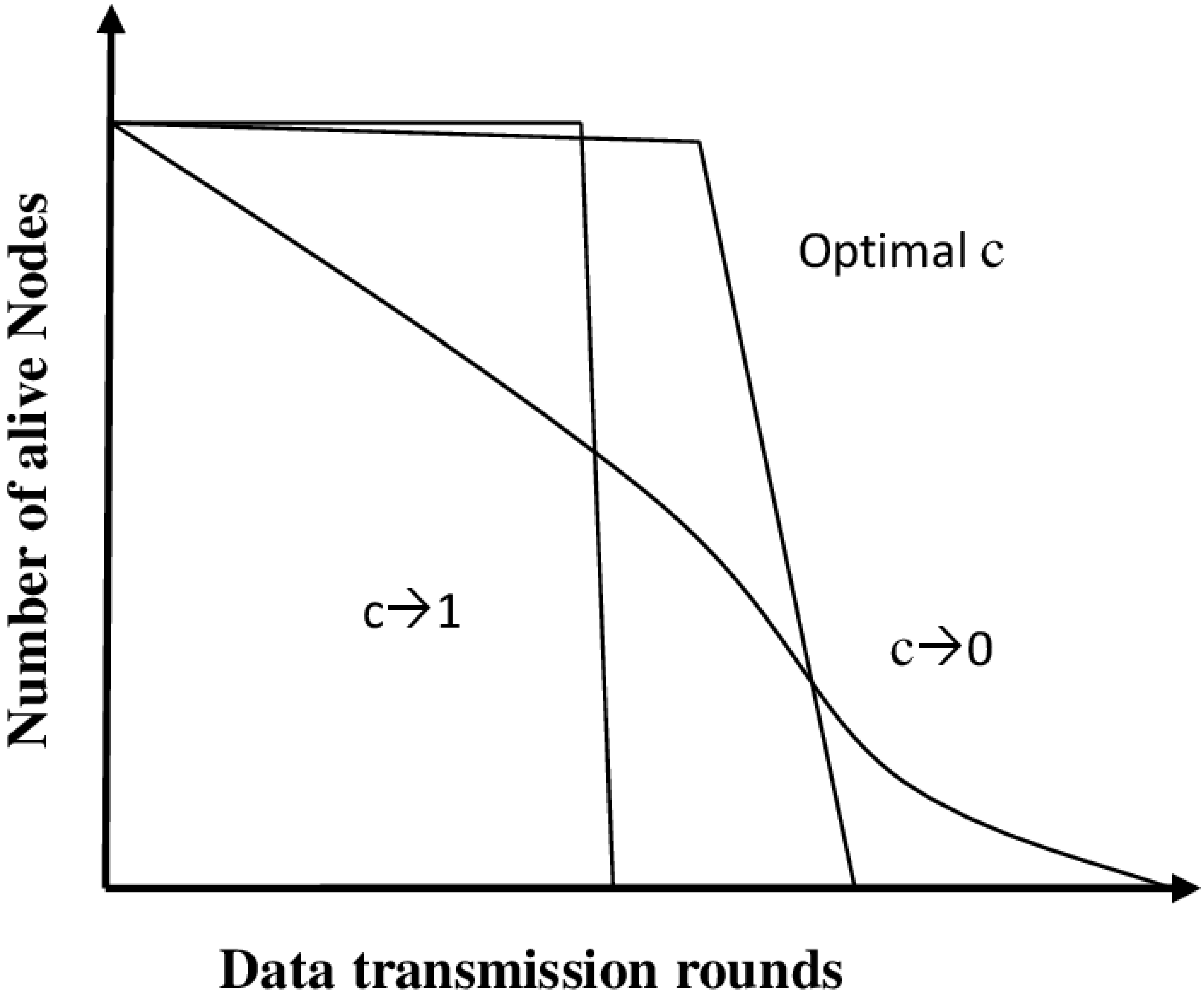

Figure 3

Lifetime of WCSN with respect to C

```
5.539583: d: 282.066343, Pr: 1.558912e-09
5.539583: d: 289.029806, Pr: 1.484701e-09
5.539583: d: 302.061605, Pr: 1.359356e-09
5.539583: d: 312.893756, Pr: 1.266865e-09
5.539583: d: 319.514089, Pr: 1.214910e-09
5.539583: d: 461.078783, Pr: 5.834102e-10
5.539583: d: 469.205970, Pr: 5.633745e-10
5.539583: d: 474.140925, Pr: 5.517081e-10
5.539584: d: 551.166124, Pr: 4.082811e-10
5.539584: d: 575.383177, Pr: 3.746364e-10
5.539584: d: 592.291635, Pr: 3.535518e-10
5.539584: d: 629.001038, Pr: 3.134884e-10
5.539584: d: 657.772977, Pr: 2.866634e-10
5.539584: d: 667.357767, Pr: 2.784882e-10
5.539584: d: 724.700421, Pr: 2.361605e-10
5.539584: d: 738.030250, Pr: 2.277068e-10
5.539584: d: 742.077836, Pr: 2.252295e-10
5.539585: d: 791.648165, Pr: 1.979064e-10
5.539585: d: 807.401066, Pr: 1.902592e-10
5.539585: d: 904.105702, Pr: 1.517350e-10
5.539585: d: 904.105702, Pr: 1.517350e-10
5.539585: d: 904.105702, Pr: 1.517350e-10
5.539585: d: 904.105702, Pr: 1.517350e-10
5.539585: d: 904.105702, Pr: 1.517350e-10
```

Figure 4

The values obtained from the simulator

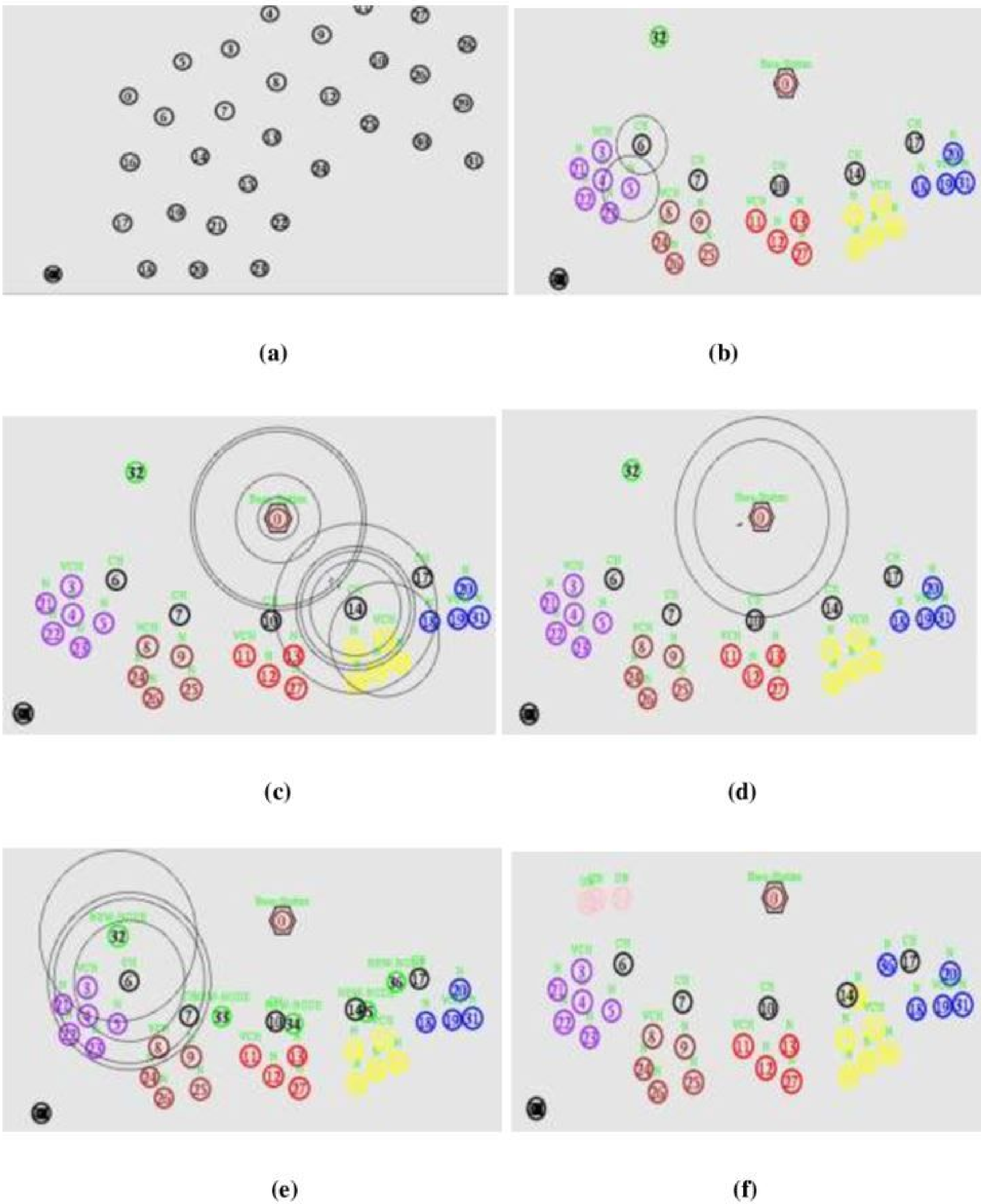

Figure 5

(a) Chemical sensor nodes, (b) CH and virtual CH formation, (c) SN sends data packets to base station through CH, (d) Node 3 has highest energy so selected as a CH, (e) Formation of new node, (f) New node becomes authenticated SN

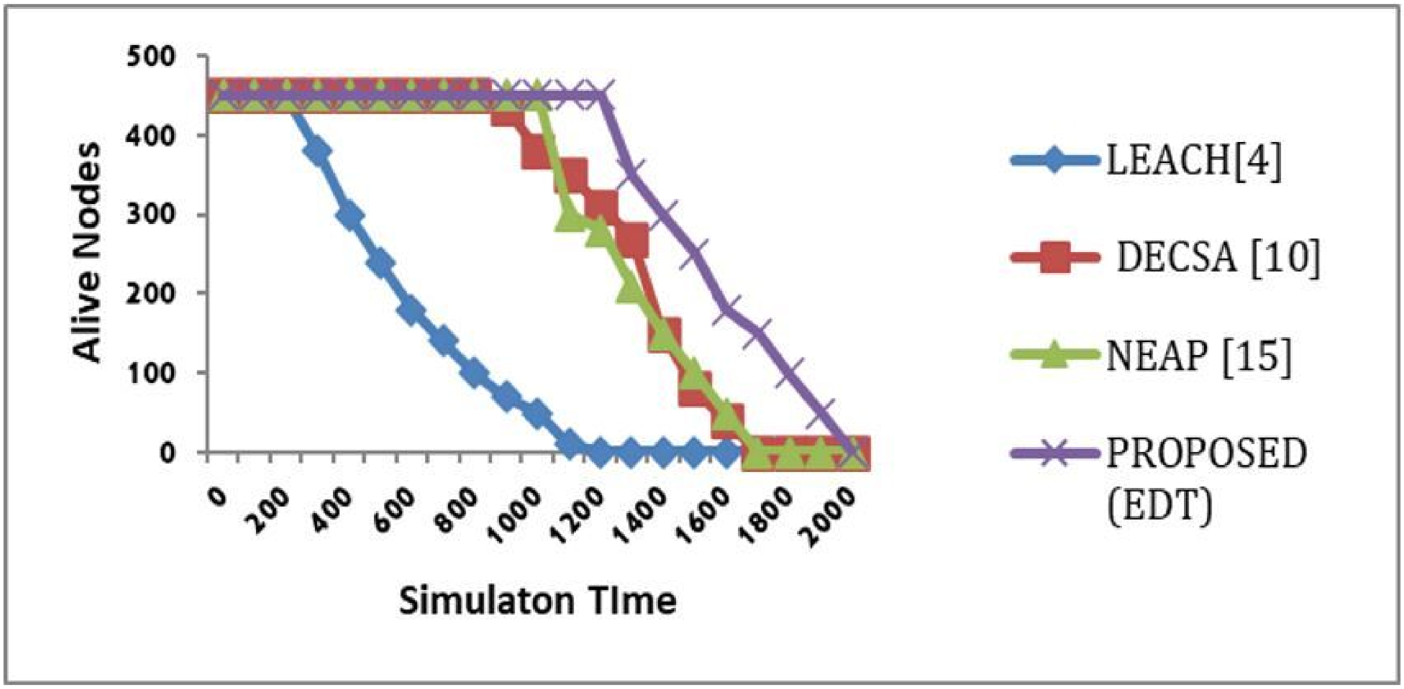

Figure 6

Network Lifetime

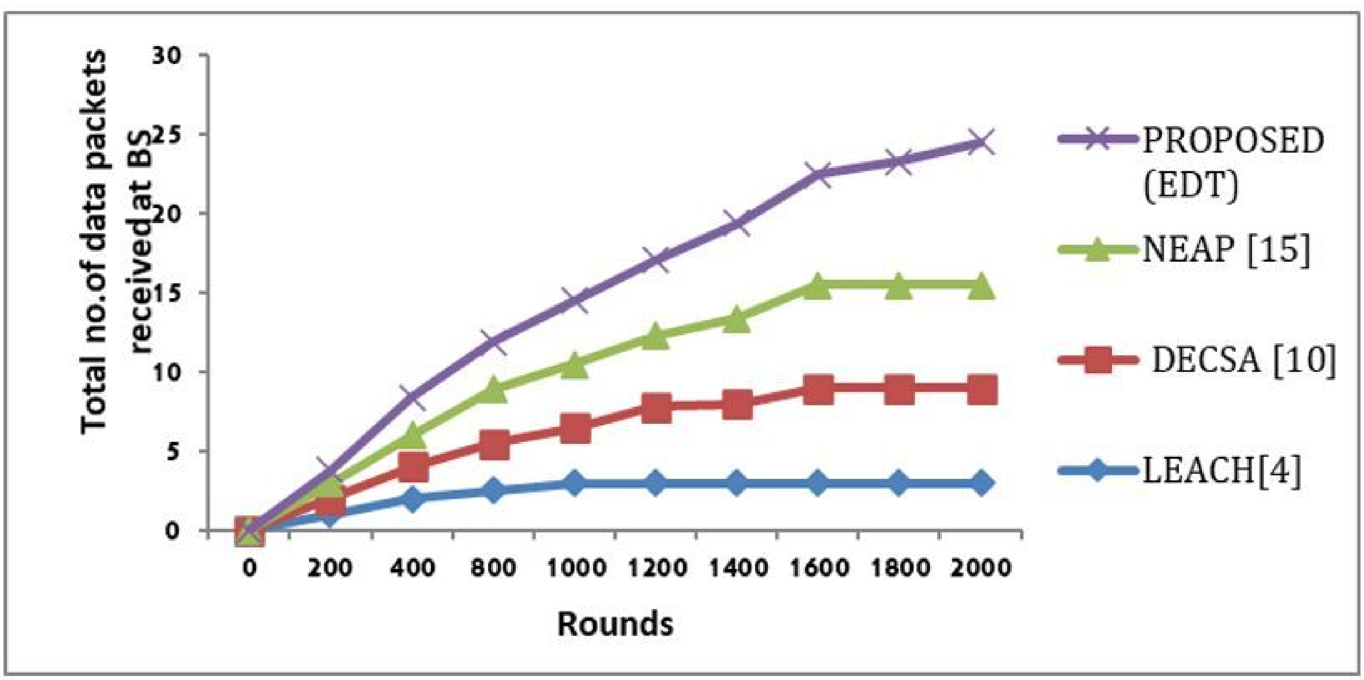

Figure 7

Throughput

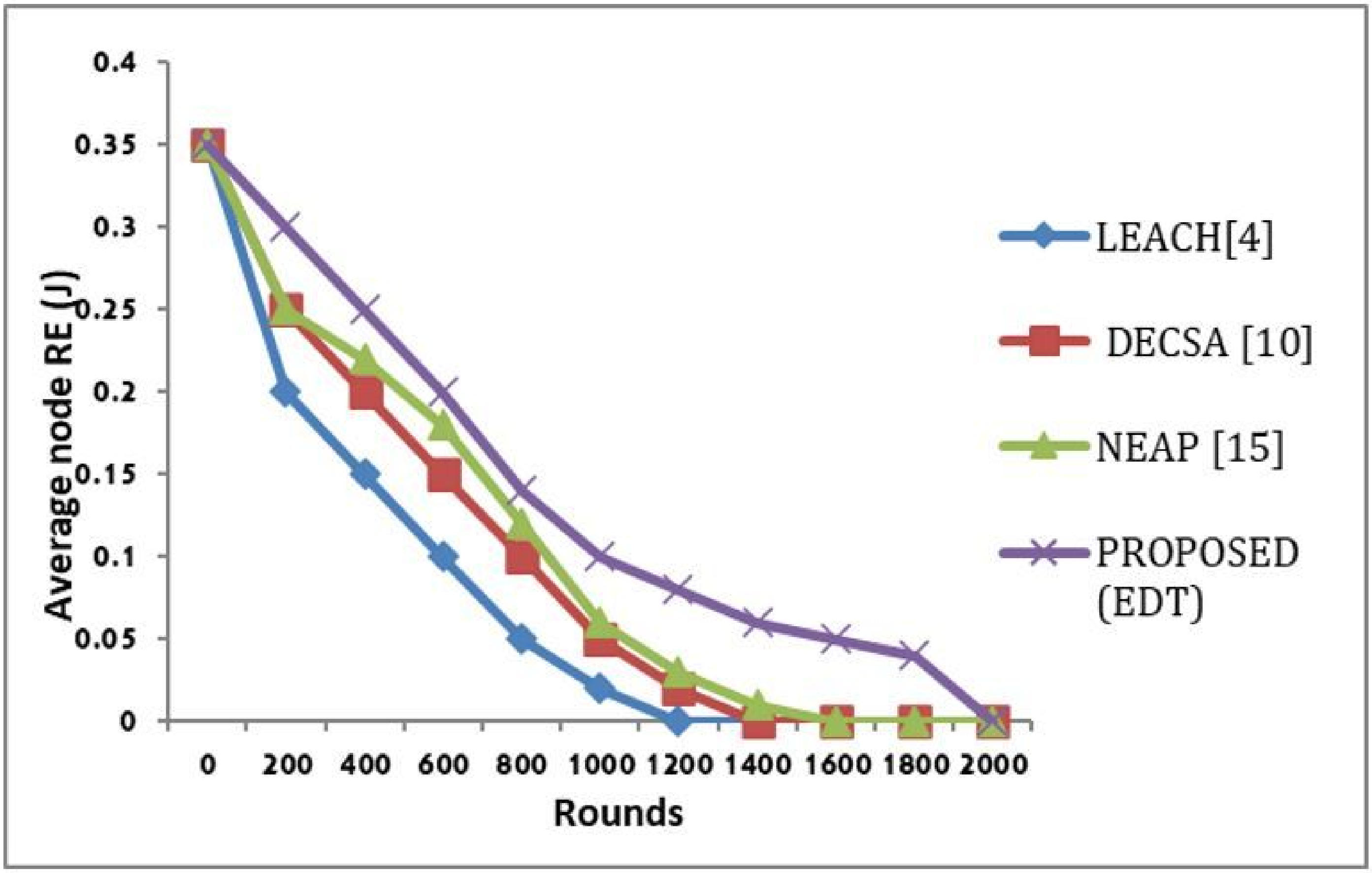

Figure 8

Average node RE

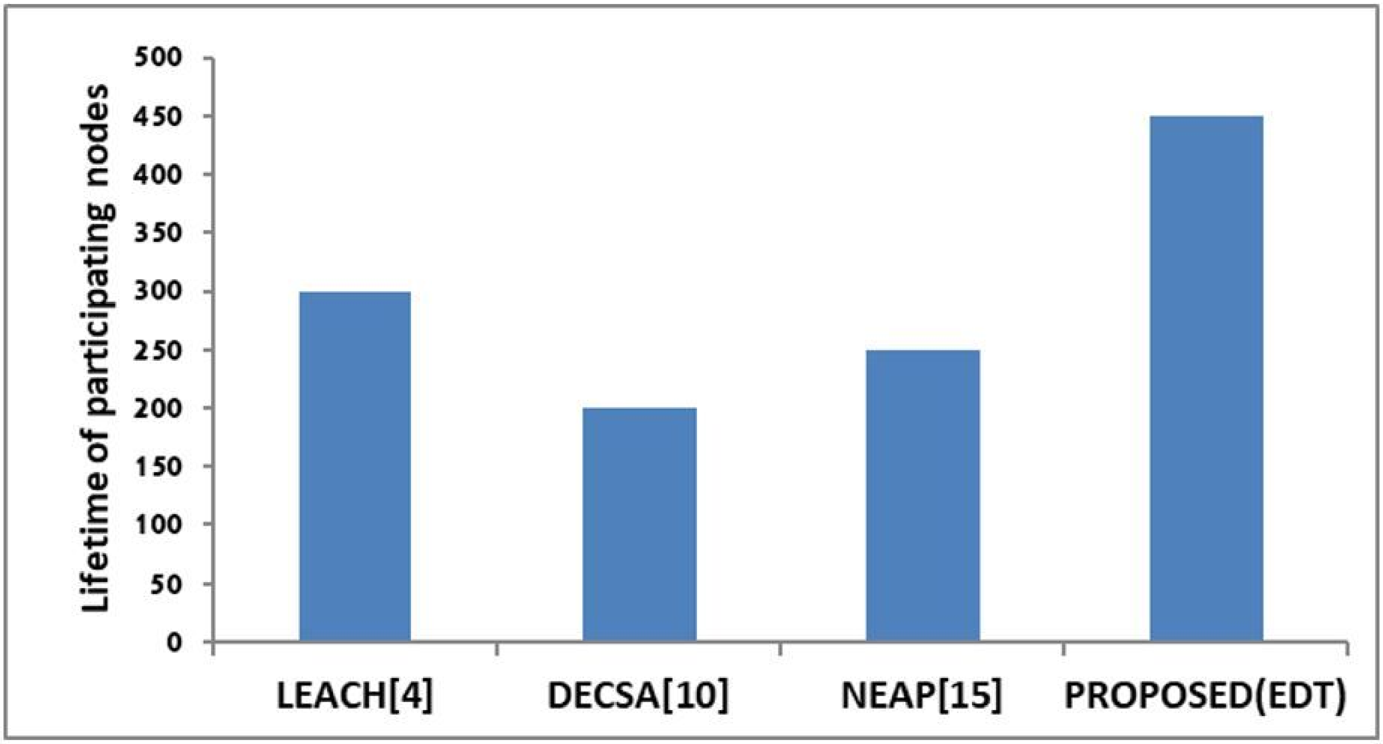

Figure 9

Lifetime of sensor nodes