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Energy Level Estimated Reactive Clustering Routing Protocol in Wireless Sensor Network

Saraswati Bhargava[1*], Manoj Lipton[2], Himanshu Yadav[3]

[1,2,3]Dept. of Computer Science & Engineering, Radharaman Institute of Technology & Science, Bhopal, India

Corresponding author: sarasbhargava@gmail.com

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***Abstract*—** The challenging task of wireless sensor network is to increase the lifetime of the network as they are equipped with critical battery power. Many protocols were proposed to efficiently use the battery power to extend the lifetime of the wireless sensor network. For optimizing the battery power of the sensor network, various energy efficient routing strategies are applied. In this paper, we studied and reviewed popular routing protocols LEACH, DEEC, DDEEC, EDEEC and EDDEEC as they use their own algorithm for energy efficiency. They use probability based cluster head selection, as a result, the nodes having low battery power may be selected as cluster head and the nodes having high battery power may not be selected as cluster head. This creates unbalancing condition in wireless sensor network for network lifetime enhancement point of view. Also, there are no observation on current energy level of the sensor nodes. To address this limitation, we proposed energy level estimated reactive clustering routing (ELERCR) algorithm in wireless sensor network which uses the concepts of energy level observation of nodes of cluster head selection. ELERCR uses ratio of current energy to initial energy for selection of cluster head in wireless sensor network. Simulation result shows that performance of our protocol gives significant energy efficiency and more network lifetime compared to other protocols.

***Keywords*—**Wireless Sensor Networks, Clustering, Energy Efficiency, Stable Election, Network Lifetime,.

I. INTRODUCTION

The sensor is basically an electromechanical device which senses or measures a physical property, stores and converts it into a signal then which can be collected or read out by a user or observer. Modern sensors are tiny electromechanical devices they are modern MEMS (Micro Electronics Mechanical Sys- tem) [1]. Modern advanced technologies in microelectronic mechanical systems (MEMS) [1][2] and wireless communication technologies have developed low-cost, low-power, small sized, multi-functional and bi-directional smart sensor nodes in a wireless sensor network. Sensor usually sense the physical conditions like light, motion, vibration, temperature, sound, moisture, magnetic fields, electrical fields, gravity, humidity, pressure, radiation and other physical aspects and parameters of the external environment [3].

Wireless sensor network (WSN) is individual the group of wireless network which belongs to ad-hoc networks. Sensor networks are composed of nodes, since these sensor nodes are furnished with the smart sensors. Nodes of wireless sensor networks in the planted area, are a lesser category of mobile than the ad-hoc networks so the mobility in the case of ad-hoc is some more. A wireless sensor network (WSN) is basically spatially distributed autonomous sensors to monitor the environmental or the physical conditions such as humidity, temperature, sound, radiation, pressure, etc. and to cooperatively pass their data values through the network to its main location [4]. Today's modern networks are usually bi-directional, they have the ability to control the activity of the sensing node. The modern development of wireless sensor networks was originally motivated by military applications such as in battlefield surveillance, today this type of networks is widely used in many industrial, commercial and consumer applications, such as automation control, industrial process monitoring and control, agriculture, machine or instrument health monitoring, and so on [5].

In the network, each such sensor network device has basically several parts such as a radio transceiver with an internal antenna or connection to a micro-controller, an external antenna, an electronic circuit for interfacing with the sensors and a power source, usually a main battery backup or an embedded form of energy harvesting. The sensed data records from all sensors are sent to gateway sensor node or base station from where user or observer can receive data records as shown in Figure 1.

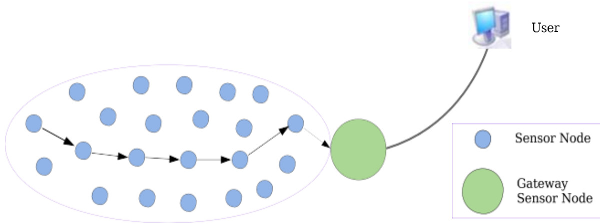

Fig. 1. Wireless Sensor Network.

II. RELATED WORK

There exists a considerable research effort for the development of routing protocols in wireless sensor networks (WSNs). The development of these protocols is based on the particular application needs and the architecture of the network. However, there are several factors that should be taken into consideration when developing routing protocols for WSNs. Energy efficiency is the most important among these factors, since it directly affects the lifetime of the network. There have been a few efforts in the literature pursuing energy efficiency in WSNs.

A. LEACH (Low Energy Adaptive Clustering Hierarchy)

LEACH [6] was proposed by **Wendy B. Heinzelman** in "An application-specific protocol architecture for wireless microsensor networks" for wireless sensor network.

LEACH [6] is basically a proactive routing protocol. The proactive routing protocols continuously try to send up-to-date sensed data to the base station in the wireless sensor network. This has as advantage that network connection time is fast, because when the first data packet is sent then routing information data is already available. A main disadvantage of proactive protocols is that they continuously use resources to communicate routing information, even when there is no traffic. In a network hundreds and thousands of sensor nodes dispersed randomly for even distribution of work load among nodes. These nodes sense data, transmit it to their associated cluster heads (CHs) which first receive, aggregate it and then send its data packets to the Base Station (BS) [6].

Low Energy Adaptive Clustering Hierarchy (LEACH) [6] is usually a TDMA - based MAC protocol and which is integrated with concept of clustering and a simply routing protocol in wireless sensor networks (WSNs). The goal of the LEACH strategy is to considerably lower the energy consumption which is required to create and keep maintain the clusters in order to increase and improve the network life time of a wireless sensor network. LEACH [6] is usually a hierarchical routing protocol in which most sensor nodes transmit data packets to the cluster heads, and the cluster heads usually aggregate it in memory unit and compress this data and simply forward it to the associated base station or sink. Each node generally uses a stochastic algorithm at each round for determining whether it will next become a cluster head in that round. LEACH [6] usually assumes that each sensing node has a transmission radio powerful more enough to directly approach the base station or its nearest cluster head (CH), but by using this transmission radio at full power all the time would waste energy [6].

All the sensor nodes deployed in an environment are homogeneous and constrained in limited battery power. To distribute the burden or work among nodes, an improve network life clusters are formed. The sensor node devices are made to become CHs on turns. Nodes randomly elect themselves as CHs and it is done in a way that each node becomes CH once in the time period of $\frac{1}{P}$ round. CHs selection is done on probabilistic basis, each sensor node generates a random number r inclusive of 0 and 1, if the generated value is less than this threshold computed by formula given in Equation 1, and then this node becomes CH.

$$T_N = \begin{cases} \dfrac{P}{1 - P\left[r \bmod \frac{1}{P}\right]}, & if\ n \in G, \\ 0 & Otherwise \end{cases} \qquad (1)$$

where,

$T_N = Threshold$

P = *Desired change (probability) of being Cluster Head (CH)*

r = *Current round number*

G = *Set of nodes which are not became CH in* $\frac{1}{P}$ *round*

Usually by using this threshold value, each sensing node will be a CH in $\frac{1}{P}$ round thus probability remaining nodes are CH must be increased since there are fewer nodes that are eligible to become CH. All nodes that are not cluster heads usually communicate with the cluster head in a TDMA (Time Division Multiple Access) fashion, and according to a schedule created by the cluster head. They usually do this strategy using the minimum energy required to reach the cluster head, and only require to keep the switch on their radios during their time slot interval. LEACH strategy also uses CDMA scheme so that each cluster in a network uses a different set of CDMA codes, to minimize the interference between the clusters [6].

Advantages of LEACH:

- LEACH [6] strategy is completely distributed, it reduces energy consumption 4 to 8 times lower in case where packets are relayed in multi-hop transmission, and at last, all the nodes in the network die at about the same time due to LEACH fair distribution of CH role.

- In LEACH method [6], usually the control information from the base station is not required for sensor nodes.
- LEACH reduces 7 to 8 times low overall energy dissipation as compared to direct transmissions and minimum transmission energy routing.
- In a completely distributed sensor network, the sensing nodes do not require any knowledge of global network.

Limitation of LEACH:

- LEACH [6] is basically not ideal for a large geographical region or areas.
- LEACH protocol generally offers no guarantee at all on the placement of the cluster head nodes.

B. During the set-up phase of LEACH, each node sends information about its current location and energy level to the base station (BS).

- Normally the clusters are formed by such that total sum of squared distances between all the non-cluster head sensing nodes and its closest cluster head is minimized.
- LEACH's cluster formation algorithm will end up by assigning more cluster member nodes A. This could make cluster head nodes a quickly running out of energy.

B. DEEC (Distributed Energy-Efficient Clustering)

DEEC [7] was proposed by Li Qing, Qingxin Zhu, Mingwen Wang in "Design of a distributed energy-efficient clustering algorithm for heterogeneous wireless sensor networks". DEEC [7] is a distributed energy-efficient clustering algorithm for heterogeneous wireless sensor networks which is based on clustering, when the cluster-heads are elected by a probability based on the ratio between residual energy of each node and the average energy of the network. The round number of the rotating epoch for each node is different according to its initial and residual energy. DEEC adapt the rotating epoch of each node to its energy [7]. The nodes with high initial and residual energy will have more chances to be the cluster-heads than the low-energy nodes.Thus DEEC can prolong the network lifetime, especially the stability period, by heterogeneous aware clustering algorithm [7]. This choice penalizes always the advanced nodes, specially when their residual energy deplete and become in the range of the normal nodes. In this situation, the advanced nodes die quickly than the others [7].

DEEC uses the initial and residual energy level of the nodes to select the cluster-heads. To avoid that each node needs to know the global knowledge of the networks, DEEC estimates the ideal value of network life-time, which is use to compute the reference energy that each node should expend during a round [7].

C. DDEEC (Developed Distributed Energy Efficient Clustering)

DDEEC [8] was proposed by **B. Elbhiri and R. Saadane and S. El fldhi and D. Aboutajdine** in "Developed Dis- tributed Energy-Efficient Clustering (DDEEC) for heteroge- neous wireless sensor networks". DDEEC [8] is based on DEEC [7] scheme, where all nodes use the initial and residual energy level to define the cluster heads. To evade that each node needs to have the global knowledge of the networks, DEEC [7] and DDEEC [8] estimate the ideal value of network lifetime, which is used to compute the reference energy that each node should expend during each n round. In this section, we consider a network with N nodes, which are uniformly dispersed within an $M \times M$ square region. The network is organized into a clustering hierarchy, and the cluster-heads col- lect measurements information from cluster nodes and transmit the aggregated data to the base station directly. Moreover, we suppose that the network topology is fixed and no-varying on time. It is assumed that the base station is located at the center [8]. Furthermore, this condition show a two-level heterogeneous network, where we have two categories of nodes, a mN advanced nodes with initial energy $E_0(1+a)$ and $a(1-m)N$ normal nodes, where the initial energy is equal to E_0. The total initial energy of the heterogeneous networks is given by:

$$E_{total} = N(1-m)E_0 + NmE_0(1+a) = NE_0(1+am) \quad (2)$$

1) Radio Model of DDEEC: On the first, for the purpose of this protocol it uses similar energy model and analysis as proposed in DEEC [7]. According to the radio energy dissipation model and in order to achieve an acceptable Signal- to-Noise Ratio (SNR) in transmitting an L - *bit* message over a distance d, the energy expended by the radio is given by:

$$E_{TX}(L.d) = \begin{cases} LE_{elect} + L\epsilon_{fs}d^2, & if\ d < d_0 \\ LE_{elect} + L\epsilon_{mp}d^2, & if\ d \geq d_0 \end{cases} \quad (3)$$

where E_{elec} is the energy dissipated per bit to run the transmit- ter (E_{TX}) or the receiver circuit (E_{RX}). The E_{elec} depends

on many factors such as the digital coding, the modulation, the filtering, and the spreading of the signal. E_{fs} and E_{mp} depend on the transmitter amplifier model used, and d is the distance between the sender and the receiver. For the experiments described here, both the free space (d^2 power loss) and the multi path fading (d^4 power loss) channel models were used, depending on the distance between the transmitter and the receiver. If the distance is less than a threshold, the free space (fs) model is used; otherwise, the multi path (mp) model is used. we have fixed the value of do like on DEEC at $d_0 = 70$.

D. EDEEC (Enhanced Distributed Energy Efficient Clustering)

EDEEC [9] was proposed by **P. Saini and A. K. Sharma** in "E-DEEC- Enhanced Distributed Energy Efficient Clustering scheme for heterogeneous WSN". EDEEC [9] adds heterogeneity in the network by introducing the super nodes having energy more than normal and advanced nodes and respective probabilities. EDEEC [9] has better performance as compared to DEEC in terms of parameters used. It extends the lifetime and stability of the network. EDEEC [9] for three types of nodes in prolonging the lifetime and stability of the network. Hence, it increases the heterogeneity and energy level of the network. Simulation results show that EDEEC [9] performs better than SEP with more stability and effective messages.

1) EDEEC Network Model: Sensor network is used with N nodes in MXM network field as shown in **??**. There are three types of sensor nodes. They are normal nodes, advanced nodes and super nodes [9]. Let m be the fraction of the total number of nodes N, and m_o is the percentage of the total number of nodes which are equipped with b times more energy than the normal nodes, called as super nodes, the number is $N.m.m_0$. The rest $N.m.(1 - m_0)$ nodes are equipped with a times more energy than the normal nodes; called as advanced nodes and remaining $N(1 - m)$ as normal nodes [9]. The total initial energy of the three-level heterogeneous networks is given by Equation 4:

$$E_{total} = N.E_0.(1 + m(a + m_0.b)) \qquad (4)$$

Therefore, the three-level heterogeneous networks have $m.(a + m_0b)$ times more energy or it means that the total energy of the system is increased by a factor of $(1 + m.(a + m_0.b))$.

2) Properties of EDEEC Network: In the network model described in previous section some assumptions have been made for the sensor nodes as well as for the network. Hence the assumptions and properties of the network and sensor nodes are:

- Sensor Nodes are uniformly randomly deployed in the network. There is one Base Station which is located at the centre of the sensing field.
- Nodes always have the data to send to the base station.
- Nodes are location-unaware, i.e. not equipped with GPS-capable antennae.
- All nodes have similar capabilities in terms of processing and communication and of equal significance. This motivates the need for extending the lifetime of every sensor.

Sensor nodes have heterogeneity in terms of energy and different energy levels. All nodes have different initial energy, some nodes are equipped with more energy than the normal nodes [9].

E. EDDEEC (Enhanced Developed Distributed Energy Efficient Clustering)

EDDEEC [10] was proposed by **Nadeem Javaid and Muhammad Babar Rasheed and Muhammad Imran and Mohsen Guizani and Zahoor Ali Khan and Turki Ali Alghamdi and Manzoor Ilahi** in "An energy-efficient distributed clustering algorithm for heterogeneous WSNs". Heterogeneous WSNs may contain two, three, or multi types of nodes with respect to their energy levels and termed as two, three, or multi-level heterogeneous WSNs, respectively. EDDEEC [10] considers three-level heterogeneous network that contains three different energy levels of nodes: normal, advanced, and super. Normal nodes have E_0 energy. Advanced nodes of fraction m have a times more energy than normal nodes, i.e., $E_0(1 + a)$. Whereas, super nodes of fraction m_0 have b times more energy than the normal ones, it means, $E_0(1 + b)$. As N is the number of nodes in the network, then Nmm_0, $Nm(1 - m_0)$, and $N(1 - m)$ are the numbers of super, advanced, and normal nodes in the network, respectively. The total initial energy of super nodes in WSN is as follows:

$$E_{super} = Nmm_0E_0(1 + b) \qquad (5)$$

The total initial energy of advanced nodes is as follows:

$$E_{advanced} = Nm(1 - m_0)E_0(1 + a) \qquad (6)$$

Similarly, the total initial energy of normal nodes in the network is calculated as follows:

$$E_{normal} = N(1 - m)E_0 \qquad (7)$$

The total initial energy of three-level heterogeneous WSNs is therefore calculated as:

$$E_{total} = E_{super} + E_{advanced} + E_{normal} \qquad (8)$$

$$E_{total} = NE_0(1 + m(a + m_0b)) \qquad (9)$$

The three-level heterogeneous WSN has $m(a + m_0b)$ times more energy as compared to the homogeneous WSN [10]. A homogeneous WSN also turns into heterogeneous after some rounds due to unequal energy consumption of nodes. CH nodes consume more energy, as compared to member nodes. After some rounds, the energy level of all nodes becomes different, as compared to each other. Therefore, a protocol which handles heterogeneity is more important than the homogeneous protocol [10].

III. PROPOSED APPROACH

In this section, a new proposed protocol ELERCR (energy level estimated reactive clustering routing) in Wireless Sensor Network is discussed which is based on energy level evaluation as well as three levels of node heterogeneity and threshold estimation. Cluster head (CH) selection is based on energy level of nodes in the proposed protocol ELERCR unlike LEACH [6], DEEC [7], DDEEC [8], EDEEC [9] and EDDEEC [10] as cluster head is selected on probability bases.

Clustering method provides an efficient and effective way to increase the network lifetime of a WSN. The clustering algorithms discussed in literature review basically utilize two techniques, first the selection of a cluster head (CH) with more residual energy and second the rotation of cluster heads (CHs) on the probability basis periodically, for an equal distribution of energy consumption among sensor nodes in each cluster and enhance the lifetime of the WSN. To forward data packets to the base station, cluster heads usually cooperate with other cluster heads, the cluster heads is selected basically on the probability bases and high residual energy node may not be selected as cluster head (CH) and low residual energy node may be selected as cluster head (CH).

To address this problem, an ELERCR (energy level estimated reactive clustering routing) protocol in wireless sensor network is proposed which is based on residual energy level estimation of sensor nodes as well as it combines the best feature EDDEEC [10] protocol and also provides mechanism for periodical data packet gathering in WSN.

A. Formation of Cluster

In Wireless Sensor Network, all sensor nodes are grouped into many clusters and one cluster head is selected in each group of cluster [11]. All sensor nodes sense their environment and the sensed values are transmitted to their associated cluster heads (CHs) and finally the collected sensed data packets are transmitted to the base station (BS) [12].

Clustering provides an efficient and effective way to enhance the lifetime of a wireless sensor network [11]. The clustering algorithms discussed in previous section usually utilize two techniques, selection of cluster heads with more residual energy and rotating cluster heads (CHs) on the probability basis periodically, for distribution of energy consumption among sensor nodes in each cluster and enhance the network lifetime. When cluster heads cooperate with other cluster heads to forward their data packets to the base station, usually the cluster heads nearer to the sink or base station of the network are loaded with high data packet transmission traffic and it tend to discharge or die early, leaving remaining region of the network uncovered and causing network partition [11].

For cluster formation in the WSN, the base station (BS) broadcasts a signal at a fixed energy level. Each node in the network computes its approximate distance from base station based on received signal strength. It provides the sensor nodes to estimate the proper power strength level to communicate with base station. Clusters are produced by this clustering formula given below in Equation 10.

$$R_{ci} = \left(1 - c\frac{d_i - d_{min}}{d_{max} - d_{min}}\right) R_{max} \tag{10}$$

where,

R_{ci} = The range of radius in the network for cluster formation, d_{max} = Maximum distance from sensor node to base station, d_{min} = Minimum distance from sensor node to base station, d_i = Distance from node i to base station in WSN,

c = Weighted factor (value is between 0 to 1),

R_{max} = Maximum competition radius.

The competition radius of the sensor node is estimated by d_i. If d_i is bigger, then R_{ci} will be smaller. The diameter of the cluster in the WSN dominated by node i is represented by the Equation 11.

$$R_a = 2R_{ci} \tag{11}$$

B. ELERCR (Proposed Algorithm)

ELERCR (energy level estimated reactive clustering routing) in Wireless Sensor Network is the proposed algorithm. The proposed algorithm implements the idea of probabilities for CHs selection based on initial and residual energy of nodes as well as the average energy of the network. The average energy of r^{th} round from is given by Equation 12:

$$E_a(r) = \frac{1}{N} E_{total} \left(1 - \frac{r}{R}\right) \tag{12}$$

R = the total rounds during the network lifetime. It is calculated by the Equation 13.

$$R = \frac{E_{total}}{E_{round}} \tag{13}$$

where E_{round} is the energy dissipated in a network during a single round and is calculated by Equation 14:

$$E_{round} = K\left(2NE_{elect} + NE_{DA} + l\epsilon_{mp}d_{toBS}^4 + N\epsilon_{fs}d_{toCH}^4\right) \quad (14)$$

where,

K = The number of clusters,

E_{DA} = The data aggregation energy cost expended by CH,

$d_{to\ BS}$ = The average distance between the CH and the BS,
$d_{to\ CH}$ = The average distance between cluster members and the CH.

Now $d_{to\ BS}$ and $d_{to\ CH}$ can be calculated as Equation 15 and Equation 16:

$$d_{toBS} = 0.765\frac{M}{2} \quad (15)$$

$$d_{toCH} = \frac{M}{\sqrt{2\pi K}} \quad (16)$$

By taking the derivative of Eround with respect to K and equating to zero, we can find the optimal number of clusters k_{opt} and is calculated by Equation 17:

$$k_{opt} = \frac{\sqrt{N}}{\sqrt{2\pi}}\sqrt{\frac{\epsilon_{sf}}{\epsilon_{mp}}}\frac{M}{d_{toBS}^2} \quad (17)$$

At the start of each round, nodes decide on the basis of threshold whether to become CHs or not. The value of threshold is calculated by Equation 18:

$$Th(S_i) = \begin{cases} \dfrac{P_i}{1 - P_i\left(mod\left(r, \dfrac{1}{P_i}\right)\right)}, & if\ S_i \in G, \\ 0 & otherwise \end{cases} \quad (18)$$

where G is the set of nodes eligible to become CHs for round r and p is the desired probability of the CH. In real scenarios, WSNs have more than two types of heterogeneity. Therefore, in ELERCR, we use the concept of three-level heterogeneity and characterize the nodes as: normal, advanced, and super. The probability for three types of nodes given by ELERCR is given below:

$$P_i = \begin{cases} \dfrac{P_{opt}E_i(r)}{(1 + m(a + m_o b))E_a(r)} \times \dfrac{E_{res}}{E_o} & if\ S_i\ is\ the\ normal\ node, \\ \dfrac{P_{opt}(1+a)E_i(r)}{(1 + m(a + m_o b))E_a(r)} \times \dfrac{E_{res}}{E_o} & if\ S_i\ is\ the\ intermediate\ node \\ \dfrac{P_{opt}(1+b)E_i(r)}{(1 + m(a + m_o b))E_a(r)} \times \dfrac{E_{res}}{E_o} & if\ S_i\ is\ the\ advanced\ node \end{cases} \quad (19)$$

Equation 19 primarily illustrates the difference between DEEC [7], DDEEC [8], EDDEEC [10] and proposed protocol EL- ERCR by defining probabilities for CH selection as DEEC, DDEEC, EDEEC and EDDEEC use probability based cluster head (CH) selection, however, the proposed protocol uses energy levels by using the ratio of E_0 (initial energy) to E_{res} (residual energy). It is the modification of the existing EDDEEC protocol. The objective of this expression is to balance the energy consumption between nodes such that the stability period and network lifetime are increased. However, soon after few rounds, super and advanced nodes might have the same residual energy as that of the normal. At this point, DEEC punishes advanced nodes, ELERCR punishes advanced as well as super nodes and ELERCR is only effective for repeatedly selecting the CH.

C. Work Flow of Proposed Method

The Figure 2 represents the overall work flow of our proposed method. The proposed work flow can be expressed as the following pseudo-code.

Algorithm of ELERCR:

Deploy the sensor nodes randomly across the network area.
for all sensor nodes ***do*** $i = 1$ to n, $S(i) = (X_i, Y_i)$
Randomly establish the sensor nodes.
end for
Calculate $E_{current}$ and $E_{initial}$ along with P and r.
Elect the cluster heads (CHs) based on $T(n)$.
Form the clusters, using elected CH.
for every cluster
Transmit the sensed data to the CH.
CH forwards it to the sink node.
end for

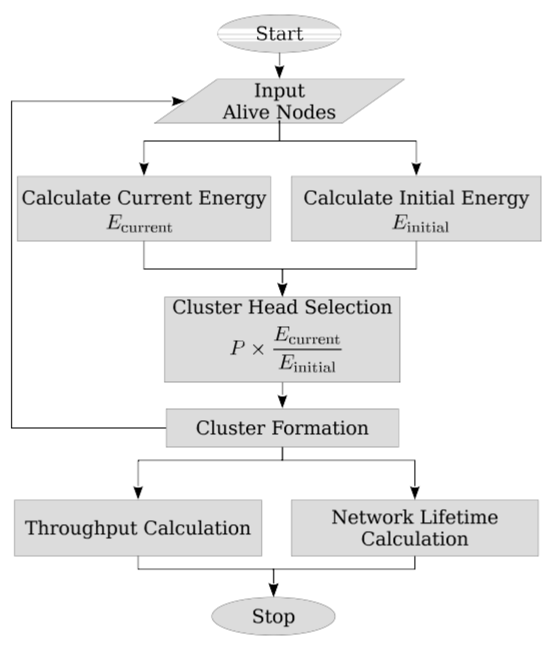

Fig. 2. Work Flow of Proposed Method

IV. SIMULATION RESULTS

MATLAB as a simulator is used for this implementation and performance evaluation of the proposed protocol ELERCR. The purpose of estimating simulations is to compare the per- formance of ELERCR with DEEC [7], DDEEC [8], EDEEC [9] and EDDEEC [10] protocols on the basis of energy consumption, lifetime of the sensor network and throughput. Performance attributes used in this MATLAB simulations are as follows:

1) The number of alive nodes during each round, also called as "Network Lifetime".
2) The number of packets sent from cluster heads to the base station, also called "Throughput".

For simulation of DEEC [7], DDEEC [8], EDEEC [9] and EDDEEC [10], some initial parameter values are taken as well as the same parameter values for this proposed protocol ELERCR. In this section, we present the simulation results for DEEC [7], DDEEC [8], EDEEC [9] and EDDEEC [10]: three-level and multi-level heterogeneous WSNs using MATLAB. WSN consists of $N = 100$ nodes which are randomly deployed in a field of dimension $100\ m \times 100\ m$ with a centrally located BS. For simplicity, we consider that all nodes are either fixed or micro-mobile and ignore the energy loss due to collision and interference between signals of different nodes. The performance metrics used for the evaluation of the protocols are: stability period, network lifetime, and number of packets sent to the BS.

- **Stability Period:** By stability period, we mean the round number at which first node dies or the number of rounds from network initialization till the death of first node.
- **Network Lifetime:** By network lifetime, we mean the round number at which all nodes die or the number of rounds from network initialization till the death of all nodes.
- **Number of packets sent to BS:** By this metric, we mean the total number of packets that are directly sent to BS either from CHs or non-CH nodes.

The parameters used in simulations are given in Table I. Results along with discussions are provided in the following subsections. These are considering that initially the WSN consists of 200 sensor nodes, all sensor nodes are placed randomly in a region and a base station (BS) is located at the outside of that region.

TABLE I. INITIAL PARAMETER SETTINGS

Parameters	Values
E_0	0.60 *Joule*
E_{elect}	60 *nJoule/bits*
L	400 *bits*
ϵ_{fs}	15 *nJoule/bits/m*^{2}
ϵ_{mp}	0.0015 *pJoule/bits/m*^{4}
E_{DA}	6 *nJoule/bits/signal*

For MATLAB simulation, some parameters are initialized like E_0 as $0.60\ Joule$, E_{elect} as $60\ Joule$, L as $400\ bits$, E_{fs} as $15\ nJoule/bits/m^2$ and E_{mp} as $0.0015\ pJoule/bits/m^4$. On the next MATLAB simulation, the parameters setting are changed to different values.

A. Simulation

Result metrics used in the simulations are based on the following:

1) Number of the alive nodes during each round (network lifetime).
2) Number of packets sent from the cluster heads (CHs) to the base station (throughput).

B. Result Analysis of Nodes Alive Per Round (Network Life- time)

In Figure 3, DEEC protocol is shown as the black curve, DDEEC protocol is shown as the red curve, EDEEC protocol is shown as dashed blue curve, EDDEEC is shown as magenta curve and the proposed protocol ELERCR is shown in Figure 3 as dashed dark blue curve. The graph of Figure 3 for DEEC [7], DDEEC [8], EDEEC [9] and EDDEEC [10] represents the graph of nodes alive during each round (network lifetime). Again the proposed protocol ELERCR performs better as compared to other protocol as shown in the graph.

C. Result Analysis of Throughput

The graph of Figure 4 plots the data packets send to the base station (BS) or throughput. Again the same colored curve are used for DEEC [7], DDEEC [8], EDEEC [9] and EDDEEC

[10] protocols. For performance evaluation of ELERCR in MATLAB, the same initial parameter values are considered and the next parameter values as used in DEEC [7], DDEEC [8], EDEEC [9] and EDDEEC [10]. As shown in Figure 4, the proposed protocol ELERCR presents maximum throughput as compared to these protocols.

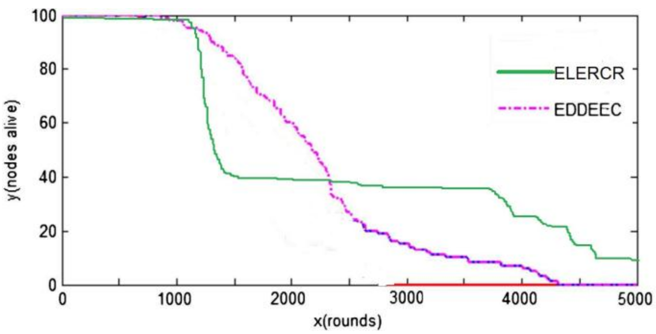

Fig. 3. Network Lifetime of EDDEEC and Proposed Protocol ELERCR

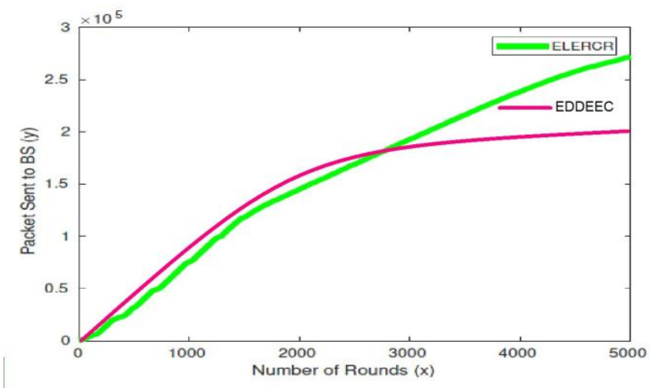

Fig. 4. Throughput of EDDEEC and Proposed Protocol ELERCR

V. CONCLUSION AND FUTURE SCOPE

Presently there were so many algorithms protocols proposed for energy efficient routing to enhance the lifetime of the whole wireless sensor network. The modern routing protocols DEEC, DDEEC, EDEEC and EDDEEC use their own algorithm for energy efficiency.

In this paper, "ELERCR (energy level estimated reactive clustering routing) protocol in Wireless Sensor Network" as a reactive network routing protocol are proposed with con- sidering three different levels of sensor node heterogeneity. ELERCR combines the best features of EDDEEC protocol and energy level evaluation method. Due to the concept of energy level based cluster head selection, hard and soft threshold value, three levels of node heterogeneity and being reactive routing network protocol ELERCR produces increase in energy efficiency, enhanced lifetime of network and also maximum throughput as shown in the simulation result. In comparison with DEEC, DDEEC, EDEEC and EDDEEC with the proposed strategy of ELERCR, it can be concluded that the protocol ELERCR will perform well in small as well as large geographical networks and best suited for time critical applications.

However, ELERCR is not suitable where frequent infor- mation is received from wireless sensor network. The future direction will be to overcome this limitation in this protocol. Finally, in future, the concept and implementation of the mobile base station can be introduced in ELERCR to perform the next level of advanced technology of wireless sensor network due to three levels of heterogeneity and being reactive routing network protocol, so it produces increased level in energy efficiency and enhanced network lifetime..

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