ISSN: 2350-0328

International Journal of AdvancedResearch in Science, Engineering and Technology

Vol. 5, Issue 12, December 2018

A Novel Energy Aware Clustering for Multilevel Heterogeneous Wireless Sensor Networks

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ABSTRACT: In Wireless Sensor Network, the proper energy utilization is the main issue for designing the protocol because sensor nodes have limited battery backup. There are many modern protocols which increase the lifetime of the wireless sensor network by efficiently using battery power of the sensor node. In this paper, we propose Energy Dissemination Clustering for Mobile Sink Based Heterogeneous Wireless Sensor Networks. We analyze and compare the performance and results of modern protocols like LEACH, SEP, ESEP, TEEN and EDDEEC with proposed work. The simulation result shows that performance and throughput of our proposed work gives the effective and significant energy efficiency as well as more network lifetime compared to other protocols.

KEYWORDS: Wireless Sensor Networks, Clustering, Energy Efficiency, Stable Election, Network Lifetime.

I. INTRODUCTION

Wireless sensor networks (WSNs) [1][2] are group of sensor nodes that sense the environment and send the data to the users. Each sensor node in WSN is an electromechanical observing device. The microelectronic mechanical systems (MEMS) is a new developed technology today, MEMS with wireless transmission technologies have developed small sized, low-energy and low-cost multifunctional smart sensor nodes in a wireless sensor network (WSN) [9][10]. For monitoring physical and environmental conditions such as temperature, humidity, radiation, sound, vibration, motion, light and pressure the sensor nodes cooperate together to collect environmental information and data.

Earlier, the developments, application and usage of wireless sensor networks were initiated by military such as battlefield surveillance; today the modern sensor [9][10] networks are bi-directional and have self-controlling ability. Modern sensor networks are used in many industrial, commercial and consumer applications, such as industrial process control and monitoring, instrument health monitoring, healthcare applications, traffic control system, home automation and so on.

The WSN [1] consists of hundreds to thousands sensor nodes, where each sensor node is connected to several sensor external antenna, a microcontroller, an electronic circuit for interfacing to the sensors and a power source, typically a battery or an embedded form of energy source. The cost of sensor nodes may vary, according to the type, size, functionality, applications and complexity of the individual sensor nodes. The cost of the multifunctional sensor is usually higher than the normal single functional sensor node. Size and cost limitations on sensor nodes result in corresponding limits on resources such as power backup, memory, computational speed, processing speed, durability, efficiency, accuracy and communications bandwidth.

The network layout and topology of the WSNs may differ from a simple star network to an advanced multi-hop wireless mesh and hybrid network. The information propagation technique among the multiple hops of the sensor network may be routing or flooding. To resolve the scalability and expandability issues the cluster based techniques and protocols have been originally proposed for the wire line networks. Now, the cluster based protocols are used in WSNs to minimize the energy consumption [3]. Once WSN is deployed, then the power backup or replacement of sensor nodes are not possible practically. Therefore, WSN must operate without human manipulation or involvement so our main focus is to enhance the lifetime of the network in any way and for this purpose many protocols and techniques were introduced and proposed.

ISSN: 2350-0328

International Journal of AdvancedResearch in Science, Engineering and Technology

Vol. 5, Issue 12, December 2018

II. BACKGROUND

In this paper we reviewed, explored and analyzed some modern energy efficient protocols [19] like LEACH, SEP, ESEP, TEEN and TSEP.

A. LEACH (Low Energy Adaptive Clustering Hierarchy)

LEACH [4] is a proactive and cluster based routing protocol. In LEACH clustering reduces the energy consumption in sensor nodes. In a wireless sensor network, to distribute the load evenly among all sensor nodes the hundreds and thousands of sensor nodes are dispersed randomly. These sensor nodes continuously sense data, transmit it to their associated cluster heads (CHs) which receive, aggregate and send this data packets to the Base Station (BS) or sink. In LEACH, all the sensor nodes deployed in the environment are homogeneous and each node has limited battery power. To distribute the work load amon ters are formed. In this network, each sensor node is mad t itself as a CH (cluster head) and this process is done in a f 1/ round. Once a node becomes cluster head (CH) then a t a chance to become a CH. The cluster heads (CHs) sele ode generates a random number in the rage of 0 and 1, if g uation given below [4], and then that node becomes a CH.

$$T_N = \begin{cases} \dfrac{P}{1 - P\left[r.mod\dfrac{1}{P}\right]} & if\ n \in G \\ 0 & otherwise \end{cases}$$

$$T_N = \begin{cases} \dfrac{P}{1 - P\left[r.mod\dfrac{1}{P}\right]} & if\ n \in G \\ 0 & otherwise \end{cases}$$

where,

TN = Threshold

P = Probability or change of node to become a CH r = Current round number

G = Set of nodes which are not became a CH in 1/P round. By using this threshold value, each sensor node will become a CH in 1/P rounds, thus probability of becoming CH among remaining nodes must be increased, and however there are some nodes that are eligible to become CH.

Advantages of LEACH:

The strategy of LEACH [4] protocol is completely distributed, it minimizes energy consumption 4 to 8 times lower in case of multi-hop data packets transmission.

All the sensor nodes in the network die at about the same time due to even distribution of CH work in LEACH protocol.

The control information from base station is not required for sensor nodes in LEACH [4] protocol.

LEACH [4][6] minimizes 7 to 8 times low overall energy consumption as compared to direct transmission and minimum transmission energy (MTE) [6] routing protocol.

Sensor nodes do not require knowledge of global network or identification in completely distributed wireless sensor network.

Limitation of LEACH:

Nodes have different energy level, but CH is selected unreasonably.

The performance of LEACH protocol is not ideal for large geographical areas.

B. SEP (Stable Election Protocol)

SEP [7] protocol is an improvement and enhancement of LEACH [4] protocol which uses clustering based routing strategy based on the node heterogeneity of the sensor node in the networks. In this protocol and technique, some of the sensor nodes have high energy they are referred to as the advanced nodes and the probability of the advanced nodes to become CHs is more as compared to the normal nodes and the normal nodes have lower energy as compared to the new nodes in the network. SEP strategy uses a shared method to select a CH in WSNs. It is heterogeneity-aware protocol and CH selection probabilities of nodes are weighted by initial energy of each node compared to the other nodes in WSN. So basically, SEP protocol is based on two levels of node difference as normal nodes and advanced nodes.

Let, m is the fraction of total number of nodes n, which are deployed with α times more energy than the others nodes.

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 5, Issue 12, December 2018

These powerful nodes are as advanced nodes.
The remaining (1 − m) × n nodes are as normal nodes.
Probability of normal nodes to become CHs is calculated as

$$P_{nor} = \frac{P_{opt}}{1+m.\alpha}$$

- Probability of advanced nodes to become CHs is calculated as

$$P_{adv} = \frac{P_{opt}}{1+m.\alpha}(1+\alpha)$$

Popt is the optimal probability of each node to become CH in the network. In SEP [7][8] strategy, selection of CH is done randomly on probability basis for each node. Sensor nodes endlessly sense data and transmit it to their related CH and CH transmit that data it to the sink or base station (BS). This system can be further improved by increasing the value of or P . Due to advance nodes with two level of node heterogeneity, SEP [7] strategy results in high stable time period, high network lifetime and high throughput.
Advantage of SEP:

Any identification or global knowledge of energy of sensor node is not required in SEP [7] technique at each selection round of cluster head.

Limitations of SEP:

The cluster head (CH) selection among sensor nodes are not dynamic, which results that nodes that are far away from the powerful nodes will die first.

C. ESEP (Enhanced Stable Election Protocol)

ESEP [7][11] is improvement and enhancement of SEP technique. Three types of sensor nodes are considered in ESEP method, as normal, advance and intermediate nodes on the basis of their power levels. The purpose of ESEP is to build a self-configured WSN which enhances network lifetime and stability period. Each sensor node in a network, continuously sense environment and transmits data to their associated CH, whereas, CH aggregates data to reduce data redundancy and sends that data to base station. In ESEP, advance nodes are some of total nodes having additional energy as in SEP. Intermediate nodes are those nodes having extra energy greater than normal nodes but less than advance nodes, and normal nodes are the remaining nodes. In ESEP, CHs are selected on probability based method for each type of node.

Advantage of ESEP:

Due to three levels of diverse in ESEP [7][11], the energy saving advantage is little enhanced as compared to SEP. The limitation of ESEP is same as SEP.

III. PROPOSED WORK

In this section we a Novel Energy Aware Clustering for Multilevel Heterogeneous Wireless Sensor Network which is based on energy level calculation as well as three levels of node heterogeneity and threshold estimation. Cluster head (CH) selection is based on energy level of nodes in our proposed work unlike LEACH, SEP, ESEP, TEEN and TSEP as cluster head is selected on probability bases.

Clustering method [17] 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 cluster head (CH) with more residual energy and second the rotation of cluster heads (CHs) on the probability basis periodically, for 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 cooperate with other cluster heads, on the probability bases the cluster heads is selected 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, a method which is based on residual energy level estimation of sensor nodes as well as it

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 5, Issue 12, December 2018

combines the best feature TSEP protocol and also provides mechanism for periodical data packet gathering in WSN.

For cluster formation [16] in the WSN, the base station (BS) broadcasts a signal at a fixed energy level. Each node in the network calculates its estimated distance from base station depends on received signal strength. It provides the sensor nodes

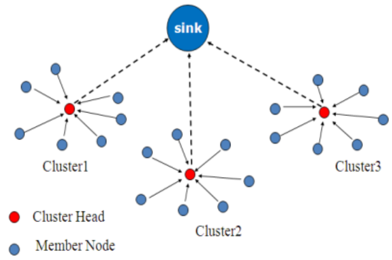


Figure 2.1 Clustering in Wireless Sensor Network [10]

station [16]. Clusters [16][17] are produced by this clustering formula given below.

$$R_{di} = \left(1 - c\frac{dbi - dbmin}{dbmax - dbmin}\right) Rmax$$

Rdi = the range of radius in the network for cluster formation,
dbmax = maximum distance from sensor node to base station,
dbmin = minimum distance from sensor node to base station,
dbi = distance from node i to base station in WSN,
c = weighted factor (value is between 0 to 1), Rmax = maximum competition radius.

$$R_{di} = \left(1 - c\frac{dbi - dbmin}{dbmax - dbmin}\right) Rmax$$

The competition radius of the sensor node is estimated by dbi. If dbi is bigger, then Rbi will be smaller. The diameter of the cluster in the WSN dominated by node bi is

$$R_{a=} 2R_{bi}$$

Cluster heads formation of the network:

$$R_{di} = \left(1 - c\frac{dbi - dbmin}{dbmax - dbmin}\right) Rmax$$

After cluster formation depends on the distance from the base station, cluster head selection process will be conducted. Before cluster head selection, sensor nodes are classified according to the energy levels in the network. As we know the transmission of data used more energy than sensing so data transmission is done only when a specific threshold limit is exceeded and it has three levels of node heterogeneity. For three levels of node heterogeneity [20], sensor nodes with different energy levels are:
1) Advanced Nodes
2) Intermediate Nodes
3) Normal Nodes

Advance nodes are some of total nodes which contain extra energy (advance nodes have power greater than all other nodes). Intermediate nodes are those nodes it have extra energy greater than normal nodes and less energy than advance nodes, while normal nodes are the remaining nodes. Energy method of proposed work, we consider following:
Energy of normal nodes = E_0
Energy for advance nodes Eadv = E_a (1 + α) Energy for intermediate nodes Eint = E_i (1+α)
where,

$$\mu = \frac{\alpha}{2}$$

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 5, Issue 12, December 2018

α_e = factor for advanced nodes which have α_e times more energy than ordinary nodes.

$$P_{nor} = \frac{P_{opt}}{1 + m.\alpha + b.\mu}$$

The entire energy of normal nodes = n.b $(1+\alpha_e)$
The entire energy of advance nodes = n.E_0e (1 - m - b.n)
The entire energy of intermediate nodes = n.m.E_{0e} $(1+\alpha)$

Energy of all the nodes = n.E_0(1 – m – b.n) + n.m.$E_0(1+\alpha)$ + n.b$(1+\mu)$ = n.$E_0(1+m.\alpha+b.\mu)$
n = total number of sensor nodes,
m = proportion of advanced nodes,
b = proportion of intermediate nodes,
Optimal probability of ordinary nodes to be selected as cluster head (CH) is evaluated by this equation:

$$P_{int} = \frac{P_{opt}}{1 + m.\alpha + b.\mu}(1 + \mu)$$

Optimal probability for modern nodes to be selected as cluster head (CH) is evaluated by this equation:

$$P_{adv} = \frac{P_{opt}}{1 + m.\alpha + b.\mu}(1 + \alpha)$$

Popt = Optimal Probability.

For cluster head (CH) selection in our proposed work, we improved over TSEP method. We have taken threshold levels as the parameters for consideration. Each node generates a random number between 0 and 1, if generated value is less than this threshold then that node become a cluster head (CH).

The threshold levels for normal nodes are estimated as

$$T_{nor} = \begin{cases} \dfrac{P_{nor}}{1 - P_{nor}\left[r.mod\dfrac{1}{P_{nor}}\right]} \times \dfrac{E_{current}}{E_{initial}} & if\ P_{nor} \in G' \\ 0 & otherwise \end{cases}$$

G' = Set of those normal nodes that have not became cluster head in earlier round.
$E_{current}$ = Remaining energy of the node at current time. $E_{initial}$ = Remaining energy of the node at beginning time.
The threshold levels for intermediate nodes are calculated as

G'' = Set of those intermediate nodes that have not became cluster head in earlier round.
The threshold levels for advanced nodes are evaluate as

$$T_{int} = \begin{cases} \dfrac{P_{int}}{1 - P_{int}\left[r.mod\dfrac{1}{P_{int}}\right]} \times \dfrac{E_{current}}{E_{initial}} & if\ P_{int} \in G'' \\ 0 & otherwise \end{cases}$$

G''' = S G''' = Set of these advanced nodes that haven't became cluster head in previous spherical.
Here is modification and improvement in our proposed work by estimating the quantitative relation of energy levels of

ISSN: 2350-0328

International Journal of AdvancedResearch in Science, Engineering and Technology

Vol. 5, Issue 12, December 2018

node at current time to energy of node at initial time.

Total average types of cluster heads per spherical = =
n(1 – m – b)Pnor + n.b.Pint + n.m.Padv = n.Popt

$$T_{adv} = \begin{cases} \dfrac{P_{adv}}{1 - P_{adv}\left[r.\,mod\,\dfrac{1}{P_{adv}}\right]} \times \dfrac{E_{current}}{E_{initial}} & if\ P_{adv} \in G''' \\ 0 & otherwise \end{cases}$$

The proposed work has better aspect of energy dissipation and improved lifetime of the WSN and this refinement due to node diversity and ratio of current energy to initial energy of the nodes.

Functioning of network:

The starting of each round, node to node cluster head (CH) selection take place. At the time of cluster setup, the cluster head (CH) transmits the following parameters [18]:

Report Time: The time period through which each sensor node successfully transmits the reports.

Attributes: The set of substantial parameters about which information data is being sent.

Hard Threshold: The upper bound of the value for the sensed attribute beyond which the nodes switch over their transmitter on and send reports to their cluster head.

Soft Threshold: The lowest limit of the attributes value below which the nodes switch over their transmitters on and transmit data to their respective cluster head (CH).

All sensor nodes continuously sense their region continuously. As the parameters value from attributes equals or exceeds hard threshold, transmitter is turned on and the data packets are transmitted to their cluster heads (CHs), however this is for the first time when hard threshold condition true. The sensed parameter value is stored by the sensor node is called the “Sensed Value”. The next time, sensor nodes transmit data if the sensed value equals or exceeds the upper limit of the hard threshold or if currently sensed value and the previously sensed value equals or exceeds the limit of soft threshold value. So, by estimating hard threshold and soft threshold, the frequent data packet transmissions can be reduced, as the data transmission will only take place when sensed value equals or exceeds the hard threshold [18]. Further data transmissions is taken place by soft threshold, as it minimize transmissions when there is a small changes in value. Some of important functions and features of our proposed work is summarized below:

1. This work is applicable in time critical applications in which data is sent to the user almost instantaneously.
2. Sensor nodes regularly keep on sensing but data transmission is not continuous as data transmission consumes more energy than sensing and processing, so energy consumption is much less than that of other networks.
3. When the new luster head formed, the threshold value is evaluate by ratio of current energy to initial energy of the sensor node, so it is a better strategy for cluster head selection in my work and values of hard threshold, soft threshold, report time and attributes are transmitted, so user can predict the occurrence of sensed values and parameters according to applications.
4. The parameter value can be varied by the area depending on applications and requirement, as attribute values are broadcasted at the time of cluster head changes.
5. As we use ratio of current residual energy to initial residual energy so it balances the energy consumption among sensor nodes and enhances the network lifetime.

IV. SIMULATION AND PERFORMANCE EVALUATION

We used MATLAB as a simulator for our implementation and performance evaluation of our proposed work. Our purpose of estimating simulations is to compare the performance of proposed work with SEP, ESEP, LEACH, TEEN and TSEP protocols on the basis of energy consumption, lifetime of the sensor network and throughput.

Performance attributes used in our MATLAB simulations are as follows:

1. The number of existing nodes during each round.
2. The number of expired nodes during each round.

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 5, Issue 12, December 2018

3. The number of packets received to base station from cluster head, (throughput).

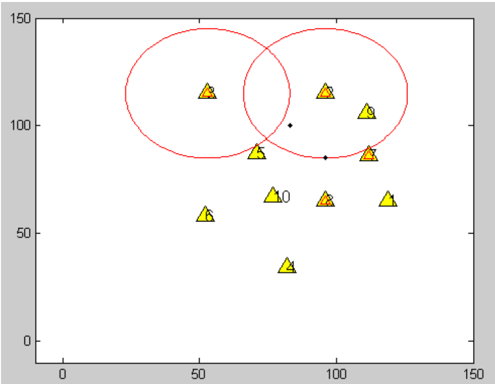
For simulation of LEACH, SEP, ESEP, TEEN and TSEP, we have taken some initial parameter values as well as the same parameter values for our proposed work.

Table 1: Initial Parameter Settings

Parameters	*Values*
$E_{initial}$	0.60 Joule
$E_{current}$	0.55 Joule
P_{opt}	0.10
α	1.30
n	200
m	0.20
b	0.80
E_0	0.60 Joule

We are considering that initially our 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.

For MATLAB simulation, we initialized some parameters like Einitial as 0.60 Joule, Ecurrent as 0.55 Joule, Popt as 0.1, α as 1, n as 200, m as 0.20, b as 0.80 and E0 as 0.60 Joule.



On the next MATLAB simulation, we changed the parameters setting to different values. Figure 1 draw graph of nodes dead during each round. In figure 1, LEACH protocol is shown as the green curve, SEP protocol is shown as the red curve, ESEP protocol is shown as the cyan curve, TEEN protocol is shown as the magenta curve, TSEP is shown as blue curve and our proposed work protocol is shown as dashed blue curve. As shown in the figure 1 our proposed work has better performance as sensor nodes dies later as compared to other protocol.

In figure 2, same colored curves have been used as in figure 1 for LEACH, SEP, ESEP, TEEN, TSEP and my work. The diagram of The limitation of my work is that if threshold value is not reached, the base station will not receive any information or data from sensor network and even all the sensor nodes of the network become dead, system will be unknown about this limitations. So, this work is not useful for those types of applications where a sensed data is required frequently and continuously.

Comparison of the graph of nodes dead during each round. Again our proposed work performs better as compared to other protocol as shown in the graph. The graph plotted for nodes alive during each round of my work is shown as again dashed blue curve in figure 2. The graph of figure 3 plots the data packets send to the base station or throughput. As shown in figure 2, the graph plotted for nodes alive during each round, This curve shows that our proposed work performs better than LEACH, SEP, ESEP, TEEN and TSEP as more nodes alive after each rounds as compared to all protocols.

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 5, Issue 12, December 2018

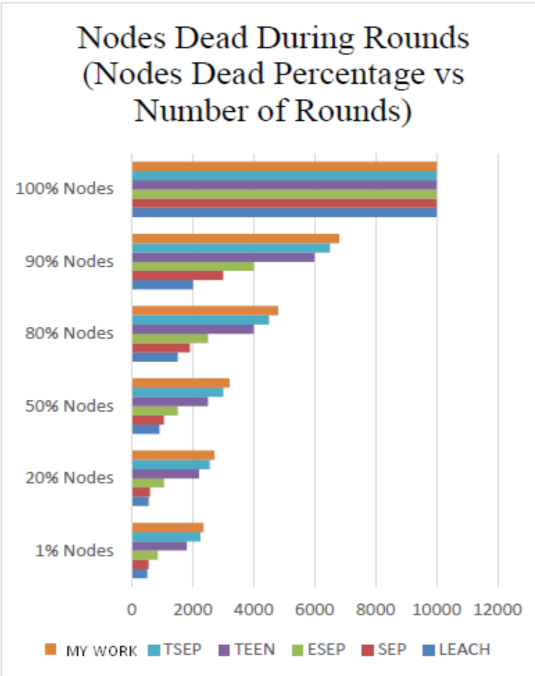


Figure 4.2: Nodes dead during each round

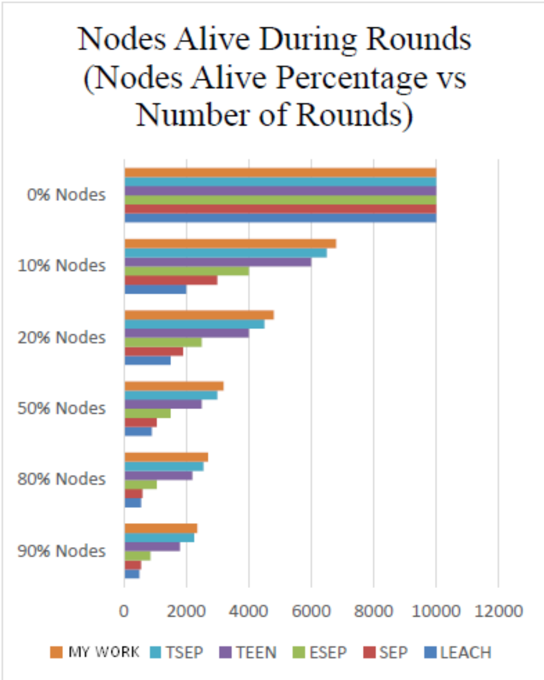
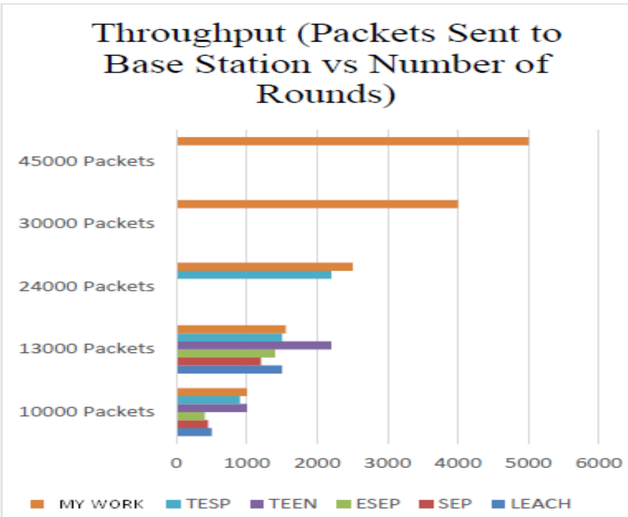


Figure 4.3 : Nodes alive during each round



In our MATLAB simulation, we considered the same parameter setting to compare our work with LEACH, SEP, ESEP, TEEN and TSEP. The throughput of our work as the graph of data packet sent to the base station is around double as compared to TSEP, as shown in figure 3 which is better than LEACH, SEP, ESEP, TEEN and TSEP. The curve of throughput shows our proposed work sends more data packets to the base station (around 50 % more) as compared to other protocols discussed above. After comparison of proposed work with LEACH, SEP, ESEP, TEEN and TSEP, we evaluated that using our proposed work, better energy efficiency, increase network lifetime and maximum throughput. Again the same colored curve are used for LEACH, SEP, ESEP, TEEN, TSEP and proposed work. For performance evaluation of proposed work in MATLAB, we considered the same initial parameter values and the next parameter values as used in LEACH, SEP, ESEP, TEEN and TSEP. As shown in figure 1, the graph plotted for nodes dead during each round in this work, curve shows that our proposed work performs better than LEACH, SEP, ESEP,TEEN and TSEP as less nodes die after each rounds as compared to these protocols.

V. CONCLUSION AND FUTURE WORK

In this paper, the proposed work as a reactive network routing method with three different levels of node heterogeneity. This work combines the best features of TSEP and energy level estimation 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 method produces increase in energy efficiency, enhanced lifetime of network and maximum throughput as shown in the simulation result. In comparison with SEP, LEACH, ESEP, TEEN and TSEP it can be concluded that this work will perform well in small as well as large geographical networks and best suited for time critical applications. However this work is not suitable where frequent information is received from wireless sensor network. Our future direction will be to overcome limitation in this work. Finally, in future, the concept and implementation of mobile base station can be introduced in this work to perform the next level of technology of wireless sensor network.

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