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Performance Evaluation of Routing Protocols in Heterogeneous WSN by using Performance Metrics

Garima Singh
M.E. Student: Department of Computer Science and Eng.
NITTTR Chandigarh
Chandigarh, India
e-mail: singh1garima2@gmail.com

Rakesh Kumar
Assistant Professor: Department of Computer Science and Eng.
NITTTR Chandigarh
Chandigarh, India
e-mail: raakeshdhiman@gmail.com

***Abstract*—**Wireless Sensor Network (WSN) suffers from the biggest stumbling block of limited energy resources of sensor nodes in achieving the network longevity. The energy preservation can be done only if the communication among the nodes or the routing among the nodes is an energy efficient. The cluster based routing in heterogeneous WSN brings energy balancing in the network. In this paper, the reactive protocols i.e., Threshold-sensitive Stable Election Protocol (TSEP), Distance-Based Residual Energy-Efficient Stable Election Protocol (DRESEP) and A stable energy efficient clustering protocol (SEECP) are taken into consideration for their performance evaluation. The performance metrics on the basis of which the protocols are evaluated include viz., stability period, network lifetime and network's remaining energy. These protocols are reactive and work according to the event detection. Simulation results show that protocol SEEC is having more stability as compared to DRESEP and TSEP protocols however network lifetime of DRESEP is much higher than the SEECP and TSEP protocols. These protocols are highly stable and applicable for time constrained applications.

Keywords-*Heterogeneous Wireless Sensor Network, DRESEP, SEECP, TSEP, energy efficient routing*

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I. INTRODUCTION

In the past few years there have been large advancement in wireless sensor networks because of the reduction in development costs and betterment in hardware manufacturing. Basically, a wireless sensor network consists of a large number of nodes deployed over a specific area where the environment or the surrounding has to be monitored[1]. A sensor node generally comprises of sensors, actuators, memory, a processor and communicating transceiver.

These wireless nodes follow communication through a wireless medium. This wireless medium can be of radio frequencies, infrared or any other medium, in fact even with no wired connection. The task of node deployment is done in random pattern so that they can communicate among themselves to frame an ad-hoc network[2]. When a node is at much farther distance from the other nodes, then node follow the intermediate node to pass on the data to the farthest node or to the Base Station.

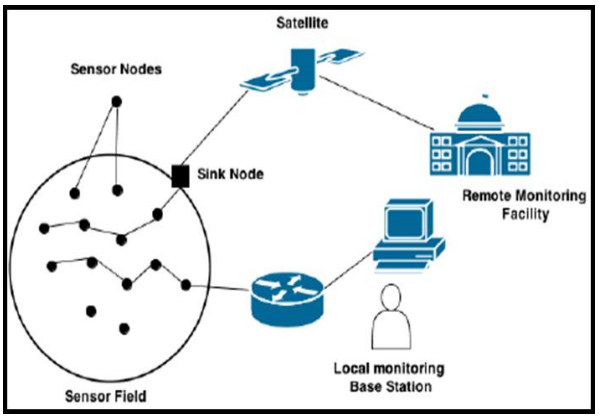

Fig. 1 Architecture of Wireless Sensor Network [1]

WSN comprises of various sensors such as seismic, humidity, temperature, infrared, magnetic, vibrational sensors. These sensors basically monitor various attributes like temperature, humidity, pressure, soil moisture and vibration etc. It is to be noted that WSN applications can be classified into two main categories [3].

a. Continuous Monitoring: In this, the applications include health care monitoring, environmental monitoring that may focus on temperature, humidity, flood detection and seismic and structural monitoring etc.
b. Tracking: These applications include tracking different individuals like animals, any objects and they basically categorize the particular applications into different sectors of human life.

Routing is very essential for the battery preservation of sensor nodes. If the network is to be made energy efficient data aggregation, nodes are partitioned into a number of groups which are called as clusters [4][5].

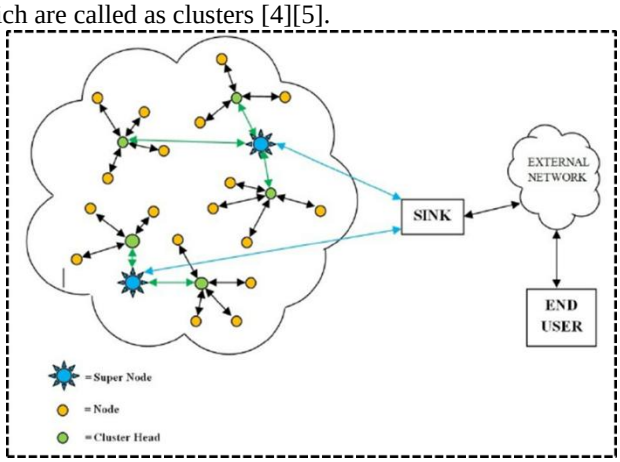

Fig. 2 Clustering in WSN [4]

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There is one cluster head which is selected for the supervision of data collection task in each cluster as shown in Fig. 2. It then forwards the collected data to the Base Station. This clustering scheme leads to the enhancement of the life time of network by avoiding unbalancing of energy load in the whole network. LEACH [6], TEEN[7] DSEP[8]were the protocols which followed clustering approach for the data forwarding. PEGASIS [9]although worked in hierarchy manner, but it made the chain for the data forwarding.

In this paper, the reactive heterogeneous protocols are taken into consideration.

The organization of the remaining work is as follows. Section 2 represents the related work and section 3 represents the problem definition and characteristics comparison. Section 4 discusses the results and simulation. Thereafter, conclusion and future scope is presented. Then the reference listing is performed.

II. Related Work

The heterogeneous mode of network has proven to be the most essential mode as far as enhancing the network lifetime is concerned. The main emphasis in the energy heterogeneous network has been the Cluster Head selection[10]. There have been various strategies in the heterogeneous network which aim to improve the network lifetime and more importantly the stability period of network by exploiting various ways through which CH can be selected. The energy heterogeneity started from the two levels introduced by the SEP protocol[11]. It incorporated two types of sensor nodes; normal and advanced nodes, but working on only two energy level heterogeneous network. Gradually the research work was focused on the amendments in the probabilistic and threshold formulae for the CH selection.

Where SEP worked on only two energy level heterogeneity but it failed for multi-level. The CH selection was not efficient. The CH selection in DEEC[12] was incorporated with the residual energy factor introduced in the threshold formula. It faced the penalization effect for higher energy nodes for being selected as CH frequently.

In EEHC[13], the three level energy nodes were taken and it followed the energy factor based CH selection.

Thereafter the penalization at three energy levels was avoided by EDDEEC[14] protocol. However, the protocol was deprived of any distance factor that could have been incorporated to the energy effective CH selection.

BEENISH [15]worked at four level of energy heterogeneity but still faced the penalization for the frequent selection of high energy nodes as CH.

Paola G. et al.[16]presented a novel technique that organize the advanced nodes and helps in the selection of CHs in WSNs. The proposed protocol i.e. Prolong SEP (P-SEP) used two energy level nodes; normal and advanced nodes. It treats every node equally for the selection of CHs i.e. the probability of CH selection among all the nodes is same. It is observed that the proposed protocol outperforms the traditional schemes. The protocols TSEP [17] , DRESEP [18] and SEECP [19] has outperformed various heterogeneous protocols these are discussed below.

III. HETEROGENEOUS PROTOCOLS; TSEP; DRESEP AND SEECP

This section discusses about the reactive protocols, TSEP, DRESEP and SEECP protocols.

A. TSEP

It is the first heterogeneous protocol that works in the similar way as of Threshold Sensitive Energy Efficient sensor Network protocol (TEEN). However, TEEN worked for homogeneous network, TSEP is made to work in heterogeneous network. TSEP works on the threshold concept and they are defined as follows.

Hard Threshold (HT):It is the value of an attribute beyond which the data will be transmitted to the CH. The moment sensed value gets greater than threshold value, the transmitter is turned on and information is sent to CH.

Soft Threshold (ST):After crossing the hard threshold value, the next transmission will occur only if the sensed value gets higher than soft threshold.

B. DRESEP

Nitin Mittal et al. [18] considered the residual energy and distance from BS for CH selection.

a) It is fully distributed and doesn't require global knowledge of network.
b) It is scalable due to multi hop communication as shown in Fig.3.

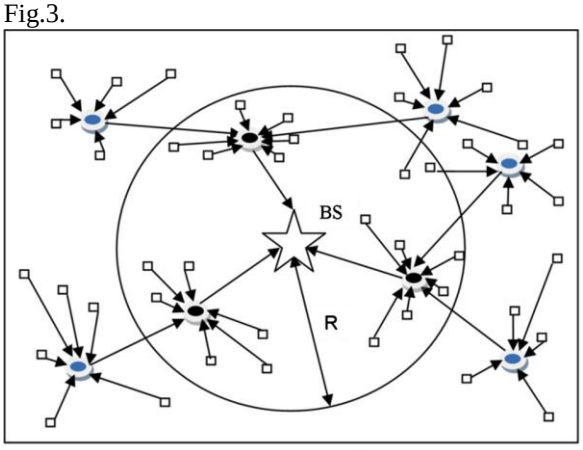

Fig. 3 Scenario for dual hop communication

c) However, Stability period is reduced due to the fact that low energy node may become CH.
d) It employs weighted election probability for CH selection, so normal node may die first thereby reducing network lifetime. The high energy variance of nodes in DRESEP leads to improper CH selection thereby reducing stability period.

The CH selection of the proposed protocol follows following equations (1-8).

$$D(i) = \sqrt{(D_x(i) - Sink_x)^2 + (D_y(i) - Sink_y)^2} \quad (1)$$

$$Davg = \left(\frac{1}{n}\right) \times \left(\sqrt{(D_x(i) - D_x(j))^2 + (D_y(i) - D_y(j))^2}\right) \quad (2)$$

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$$P_N = \frac{P}{(1+m\alpha+m0\beta)} \quad (3)$$

$$P_{IN} = \frac{P(1+\beta)}{(1+m\alpha+m0\beta)} \quad (4)$$

$$P_{AN} = \frac{P(1+\alpha)}{(1+m\alpha+m0\beta)} \quad (5)$$

$$T(n_N) = \left\{ \frac{P_N}{1-P_N\left(r\bmod \frac{1}{P_N}\right)} \frac{D_{avg}}{D_{BS}} \times \left[\frac{E_{CNT}}{E_{MAX}} + (r_s \operatorname{div} \frac{1}{P_N})\left(1 - \frac{E_{CNT}}{E_{MAX}}\right] \right\} \quad (6)$$

$$T(I_N) = \left\{ \frac{P_{IN}}{1-P_{IN}\left(r\bmod \frac{1}{P_{IN}}\right)} \frac{D_{avg}}{D_{BS}} \times \left[\frac{E_{CNT}}{E_{MAX}} + (r_s \operatorname{div} \frac{1}{P_N})(1 - \right.$$

ECNTEMAX (7)

$$T(A_N) = \left\{ \frac{P_{AN}}{1-P_{AN}\left(r\bmod \frac{1}{P_{AN}}\right)} \frac{D_{avg}}{D_{BS}} \times \left[\frac{E_{CNT}}{E_{MAX}} + (r_s \operatorname{div} \frac{1}{P_N})(1 - \right.$$

ECNTEMAX (8)

In equations (1-8) the probabilities for normal node, intermediate node and advanced node is shown by P_N, P_{IN}, P_{AN} respectively. The threshold formula for normal node, intermediate node and advanced node is shown by $T(n_N)$, $T(I_N)$, $T(A_N)$ respectively.

These threshold values are compared with the random number, if for a node random number is less than threshold value generated, a node is selected as Cluster Head otherwise node is a normal node.

C. SEEECP

Nitin Mittal et al. [19]explored deterministic model for CH selection as compared to threshold based selection in other protocols thereby reducing the uncertainties in CH selection. It focused onfollowing factors.

a) It uses multi hop communication by determining radius R for the region by using geometric theory.
b) No. of CHs are already predefined with 5% of the total nodes.
c) CH selection is entirely based on the residual energy, which is inefficient approach. The other factors like Distance and Node Density are not considered.
d) There is no such mechanism being considered to determine whether the CH located outside R should calculate its distance first from the relay CH and BS before sending data to anyone of them. Rather, it is being made to send data to relay CH irrespective of its distance.
e) The radius R is calculated based on geometric theory and it doesn't consider the random deployment of nodes making it energy efficient.

The protocols follow the two phases operation. These include setup phase and steady state phase as shown in Fig. 3. Set up phase includes deployment of nodes and cluster formation. Steady state phase includes data transmission for inter cluster and intra cluster communication. Energy of node is checked after each round; the network is said to be dead when all the nodes are dead.

IV. SIMULATION RESULTS

The network is simulated in MATLAB Software version 2016. There are different performance metrics on which the performance of protocols is evaluated. These include stability period, network lifetime and networks remaining energy. Stability period of SEECP, DRESEP and TSEP is found to be 685, 337 and 246 rounds respectively as shown in Fig.4.

The stability period of SEECP is higher due to the fixed number of CHs involved. Moreover, the dual hop communication involved is made efficient by defining circular radius on some particular parameters.

The stability period of SEECP is 106% higher than the DRESEP protocol.

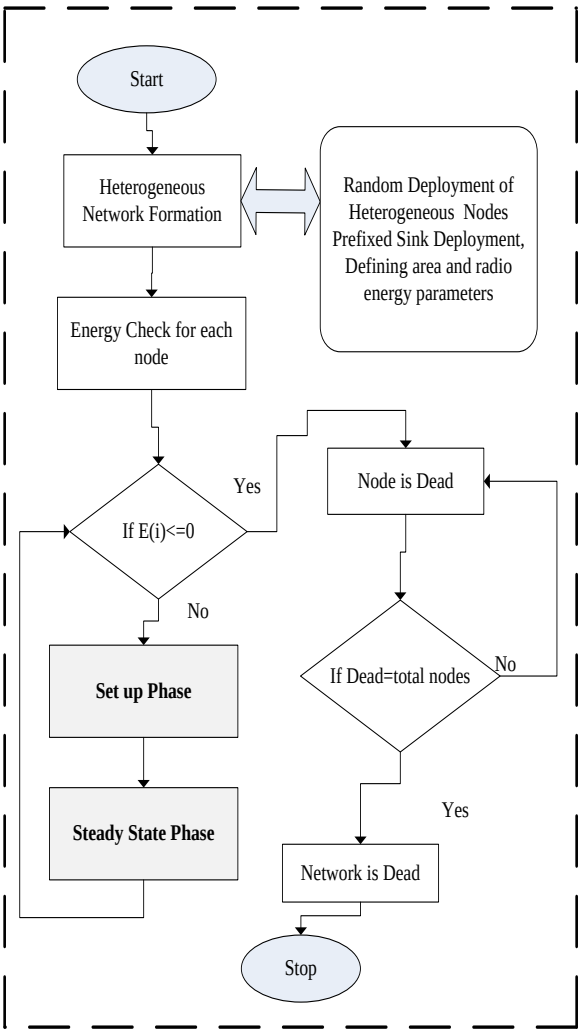

Fig. 3. Flow chart for the network scenarios in heterogeneous protocols

The graph of dead nodes vs rounds is shown in Fig. 5, and it is observed that network lifetime for SEECP, DRESEP and TSEP at 725, 1519 and 1258 rounds respectively.

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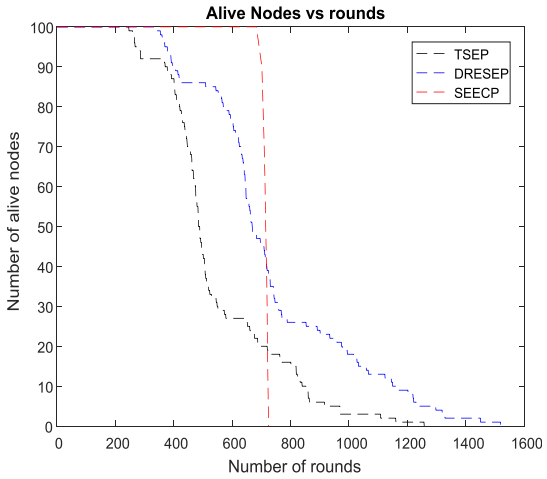

Fig. 4. Alive Nodes vs rounds

It can be observed from the Fig. 5 that more number of rounds are covered as the network operates. In case of SEECP, all nodes are dead at one particular value of round that indicates the load balancing by SEECP protocol.
Moreover, the less number of dead nodes are there in case of DRESEP and TSEP protocols at the end of transmission, it is due to the energy efficient CH selection.

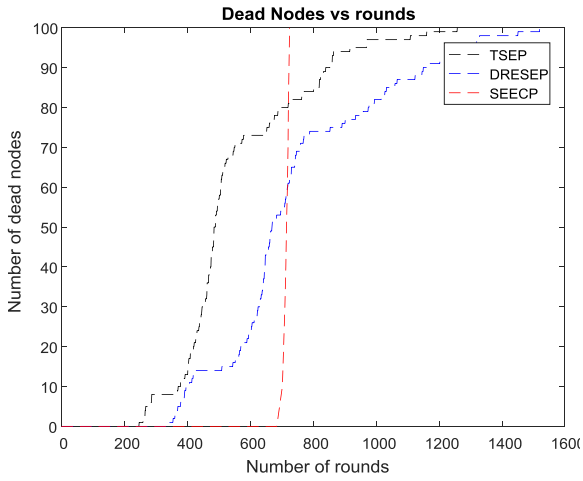

Fig. 5. Dead Nodes vs rounds

The networks remaining energy is observed to cover more number of rounds in SEECP as comparison to the DRESEP and TSEP protocols. However, at the end of rounds, the protocol DRESEP covers more number of rounds as compared to the TSEP protocols.

V. CONCLUSION AND FUTURE SCOPE

In this paper, the performance comparison of reactive heterogeneous protocols i.e., TSEP, DRESEP and SEECP is done. The protocols are compared by using different performance metrics. These metrics are stability period, half dead node and network lifetime.It is observed through the simulation in MATLAB that the protocol SEECP has highest stability period whereas, the protocol DRESEP has highest network lifetime among three protocols. The network lifetime of DRESEP is higher due to its energy efficient CH selection.

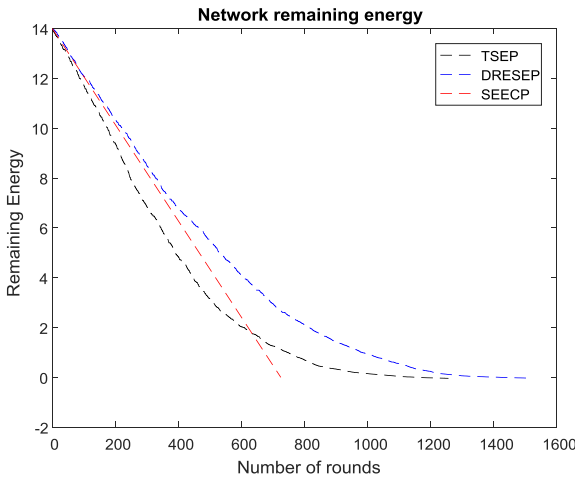

Fig. 6. Network's remaining vs rounds

Whereas, the higher stability period is achieved in case of SEECP due to the fixed number of CHs in the network in case of SEECP. In future, the proposed protocol can be further improved by energy efficient selection of circular radius. Moreover, the sink mobility can be introduced to enhance data throughput in the network.

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