Shortest Distance On-demand Stable Election Protocol

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Research Article

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Shortest Distance On-demand Stable Election Protocol

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Abstract

In current era Wireless Sensor Networks (WSNs) play a vital part in every field of day to day life. This is one of the most popular network technologies for the Internet of Things (IoT). Power efficiency and stability constraint is considered as impediment in the further development of the IoT. One of the efficient solutions is effective routing techniques. This paper proposes an effective cluster based, threshold sensitive routing technique Shortest Distance On-demand Stable Election Protocol (SDOSEP) for IoT based heterogeneous wireless sensor networks. As data transmission between nodes with different routes is one of the most costly operation that affect the performance of the network. This technique chooses cluster head on the basis of total energy of network and selects shortest weighted path for data transmission. The proposed approach exceeds the network lifetime, stability, instability and throughput of the network with existing baseline techniques.

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1. INTRODUCTION

The wireless sensor network assembles of specialized sensor devices with a communications network for monitoring, gathering and recording conditions at different locations [1]. WSN consists of different tiny sensing nodes, which has different sensing units, having a range of sensors to sense and gather the data from the sensing field or external environment, one processing unit to process the gathered data, and wireless transmitter and receiver unit for network communication. Sensor monitors and records the physical conditions of the environment which is further sent to base station (sink), where data is collated and analyzed. The sensing nodes may be either mobile or fixed in the sensing field.

In wireless sensor network, networks are labeled into two categories [1,2]: homogeneous and heterogeneous. Homogeneous WSN consist of similar energy levels of node, while heterogeneous WSN have different energy levels of sensor nodes. Sensor node's energy is supplied by an inbuilt battery, so it has limited capacity. Realistically it is almost impossible to replace or recharge the sensing node's batteries once deployed. Some of the energy of sensor nodes is utilized during monitoring and channeling of data from nodes to base station. So the energy consumption [3, 10] and stability is one of the main constraints and challenge in the wireless sensor network. To prolong the network lifetime and stability different routing protocols for WSN have been proposed. In network routing protocols, three mechanisms direct transmission, multi hop routing and clustering are implemented. In the direct transmission, the remotely located nodes straightly transmits the data to the base station, so in this mechanism the nodes which are situated at farther distance from the base station, dies earlier, whereas in case of multi hop routing the sensor nodes redirects data to base station using multiple stop, therefore sensor nodes which lies in proximity to the base station die first than those nodes which are situated far away from the base station. The third one, clustering is most widely used and relevant mechanism for data aggregation [6] and its transmission from sensing node to base station to save the energy of sensing nodes. The clustering mechanism consists, cluster head selection, and data transmission in three phases. In cluster head selection phase, probability and threshold value is calculated for proper cluster head election procedure. After election of cluster head, it simply broadcast an advertisement to other nodes to form a cluster. After that, nodes disseminate their sensed value to the cluster heads, and these cluster heads redirects that aggregated value or data to the base station.

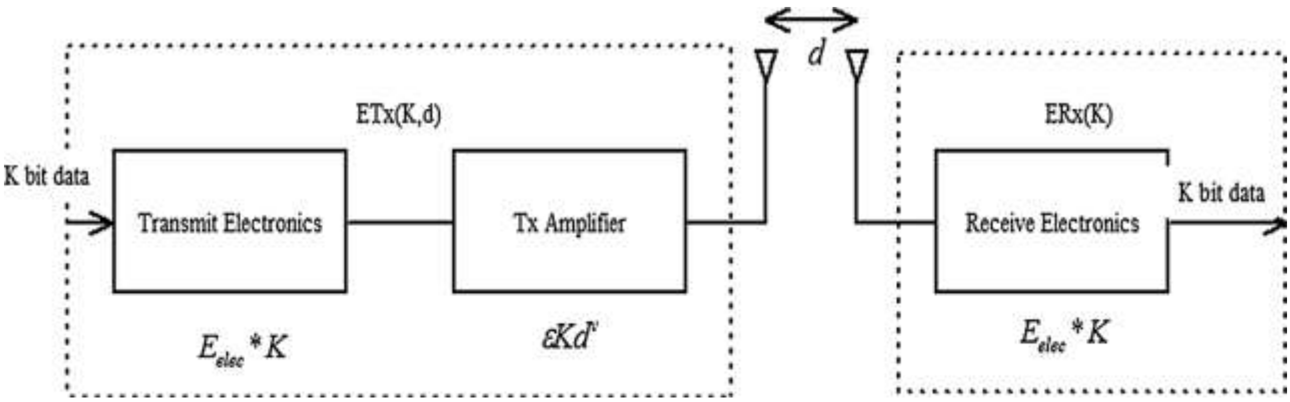

Fig. 1 Radio energy dissipation model

The sensing nodes contain a battery having a limited lifetime, so now a day energy conservation and stability plays a very major role and key challenge for wireless sensor network. The maximum energy is consumed during the transmission of data into the network; this also affects the stability of the network. Fig 1, shows the radio energy dissipation model, it describes the energy expanded by the network to transfer K bit message over a distance d, which is compounded by:

$$E_{Tx} = \begin{cases} K.E_{elec} + K.E_{fs} * d^2 \; if \; d < d_0 \\ K.E_{elec} + K.E_{amp} * d^4 \; if \; d \geq d_0 \end{cases} \tag{1}$$

Where, E_{elec} is energy dissipated per bit to run the transmitter or the receiver and d_0 denotes threshold distance and calculated as:

$$d_0 = \sqrt{\frac{E_{fs}}{E_{amp}}} \tag{2}$$

Here two different radio models: E_{fs} (free space model) and E_{amp} (the multi path fading channel model) are utilized for transmission. The distance between the transmitter and receiver is denoted by d. If the value of d is lower than d_o, free space model (E_{fs}) is considered for use, otherwise multipath fading channel (E_{amp}) is utilized. The energy dissipated is denoted by E_{Rx} , for receiving K bits and calculated as:

$$\mathrm{E_{Rx}(K) = K.\,E_{elec}} \tag{3}$$

In routing protocols, proper election of cluster head and well transmission of data over network can reduces the energy utilization and enhances the lifetime and stability period of the sensor network. The direct transmission and multi hop mechanisms does not guarantee a well distribution of energy [11] load of nodes. Under both cases due to improper distribution of energy load, a part of the sensing area will not be monitored. So the solution for this problem was Low Energy Adaptive Clustering Hierarchy (LEACH), that guarantees the proper distribution of energy [12] load throughout the sensing area. In this protocol, cluster heads are elected dynamically depending on the election probability value. LEACH [2] is a homogeneous reactive routing protocol, and not as successful for heterogeneous wireless sensor network. So for heterogeneous network different routing protocols was implemented. Stable Election Protocol (SEP) is the first reactive routing protocol for heterogeneous WSNs that also improve the network performance in the manner of stability [2,9] and lifetime [10,11] of the network. In this protocol the cluster head is also chosen on the basis of election probability, which is well suited for heterogeneous networks.

In this paper, a stability aware protocol SDOSEP is proposed, in which four parameters are considered i.e. lifetime, stability, instability [6,13] and throughput [16] of the sensor network. Lifetime is total time until the death of last node, stability period is time interval from the start of network until the death of first node, and instability period is the time interval between the death of first node to until the death of last node. Throughput of the network is the rate in which the number of packet is transmitted to the base station. In SDOSEP, the behavior of protocol is investigated on the basis of above four parameters, and it is observed that, proposed protocol outperforms in comparison to other protocols.

The rest of paper is described into six sections. In section 2, a survey on entity cluster based routing protocols and its relation with proposed protocol is discussed. In section 3, the proposed approach is introduced. Section 4, describes the simulation results in detail. Conclusion of the proposed approach SDOSEP is presented in section 5. Future work is discussed in section 6.

2. CLSTER BASED -ROUTING PROTOCOLS

2.1 Stable Election Protocol (SEP)

Smaragdakis et al. [3] proposed stable election protocol (SEP) for heterogeneous wireless sensor network. It is a reactive routing protocol, with two types of nodes normal and advance having different initial energy. The advance nodes contains (1+α) time greater initial energy than normal nodes. In stable election protocol, the sensor nodes are distributed regularly over the sensing area, and the dimension of the field is fixed. Cluster head election depends on the weighted election probability. Initially any node can be elected as cluster head, and then according to the remaining energy of node cluster head is elected. So the advance nodes have more probability to become a cluster heads more often than normal nodes.

2.2 Threshold Sensitive Energy Efficient Routing Network Protocol (TEEN)

TEEN [4] is a reactive routing protocol for heterogeneous wireless sensor network, mainly used for time critical applications. This protocol also used election probability to elect cluster head in any epoch. Nodes continuously sense the data, but send the data to the base station only if there is any change occurs in the field. The foundation of this protocol is set on two major threshold values, hard threshold and soft threshold. The first criteria for transmitting the data to cluster head by node is decided to be when the value of sensed data is equal or greater than hard threshold. And for the second criteria they transit data if there is a change between the sensed values and previously saved value at which transmission was done is greater than or equal to soft threshold. Hence network lifetime and stability is improved.

2.3 Threshold sensitive Stable Election Protocol (TSEP)

This protocol [5] for WSNs comes with an advantage of low energy dissipation which happens because of presence of energy heterogeneity. The protocol is reactive routing in nature in which nodes react only when the change in data is severe otherwise nodes keep on sensing the data continuously. The sensing nodes are maintained at three levels of heterogeneity which comprises normal nodes, intermediate nodes and advanced nodes. The change of cluster is performed at the beginning of every round and selection of cluster head is both hard and soft threshold based. Hard threshold signifies the ultimate range of sensed data beyond which the transmitter will definitely redirect the data whereas soft threshold is least sensed value for the same purpose.

2.4. Enhance Threshold Sensitive Stable Election Protocol (ETSSEP)

Shekhar et al. [6] proposed ETSSEP with three energy levels for heterogeneous WSNs. It is cluster dependent reactive routing protocol, in which the criteria for electing cluster head is based on the ratio of residual energy, average energy and optimal number of clusters per round. The threshold value is adjusted in that manner that the node with highest energy level becomes cluster heads during current rounds.

3. PROPOSED WORK

The proposed approach for this chapter is SOSEP. It is a clustering based reactive routing protocol with three level of heterogeneity. SDOSEP consist of three types of nodes with different levels of energy. These nodes are: advance nodes, intermediate nodes and normal nodes. First type of node is advance nodes which contains greater initial energy than remaining nodes in the network and a fraction of node that contains less energy than advance nodes and higher energy than normal nodes are called intermediate nodes, while the remaining are called normal nodes. An advance node contains α times more energy than normal nodes, intermediate nodes contains β times more energy than normal nodes, and we assume $\beta = \frac{\alpha}{2}$. In SOSEP the energy distribution of different category of nodes is calculated as:

For normal node

$$E_{nrm} = n. b. (1 + \beta) \tag{4}$$

For intermediate node

$$E_{int} = n. (1 - m - bn). E_0 \tag{5}$$

For advance node

$$E_{adv} = n. m(1 + \alpha). E_0 \tag{6}$$

Total energy for whole network is calculated as:

$$E_{total} = n.(1 - m - bn).E_0 + n.m(1 + \alpha).E_0 + n.b.(1 + \beta)$$
$$= n.E_0(1 + m.\alpha + b.\beta) \quad (7)$$

In the above equations m is the fraction of advance nodes and b is the fraction of intermediate nodes of total number of nodes.

The probability is calculated dynamically for election of cluster head in current epoch. The probability depends on the total energy of node during current round. Probability of all three types of nodes to be a cluster head in current round is calculated according to the equation presented below:

For normal node

$$P_{nrm} = \frac{P_{opt}}{1 + m.\alpha + b.\beta} \quad (8)$$

For intermediate node

$$P_{int} = \frac{P_{opt}}{1 + m.\alpha + b.\beta} \quad (9)$$

For advance node

$$P_{adv} = \frac{P_{opt}(1+\alpha)}{1+m.\alpha+b.\beta} \quad (10)$$

Where m and b, denotes the proportion of advance and intermediate nodes to the total number of nodes n.

In the proposed SDOSEP, every time the distance between cluster head and base station is determined before routing sensed data and minimum weighted path is selected for transmission. Distance is calculated as:

$$d = \sqrt{(n(r) - n(r+1))^2} \quad (11)$$

Energy is consumed by the network for data transmission, aggregation and processing. In a particular round the amount of energy dissipated by the network is denoted by E_{round} and calculated as follows :

$$E_{round} = K(2NE_{elec} + NE_{DA} + kE_{amp}d^4{}_{toBS} + NE_{fs}d^2{}_{toCH}) \quad (12)$$

In this equation 14, K is data size in bits, E_{DA} is energy abraded for data aggregation, k is number of clusters, d_{toBS} is average distance among cluster head and base station, and d_{toCH} is the average distance between sensor nodes to cluster heads. In equation 13 and 14, the average distance between cluster head to base station, and node to cluster head is computed.

$$d_{toBS} = 0.765\frac{M}{2} \quad (13)$$

$$d_{toCH} = \frac{M}{\sqrt{2\pi k}} \quad (14)$$

In this protocol, at first sensor nodes are deployed with equal amount of energy. So, initially any node can be a cluster head with a calculated probability. Further the cluster head election depends on the total energy of node in a particular round in current epoch. Those nodes which are cluster heads for the current round cannot be elected as cluster head in the same epoch.

Every time nodes select shortest path to redirect the sensed data to the cluster head. Cluster head will dispatch the sensed value only if there is a change in the information. After cluster head selection, threshold is calculated. Each node generate a random number that lies between 0 and 1, and generated number is compared with threshold value, if threshold value is bigger than the node will be selected as cluster head for present round. In SDOSEP, threshold is modified based on the total energy level of node in current round with a certain epoch for election of cluster head. Because of shortest path selection for data transmission and proper distribution of total energy to nods per round gives the more stability, instability, network lifetime and throughput to SDOSEP.

SIMULATION AND RESULTS

To evaluate the performance of SDOSEP with the other related routing protocols, we use MATLAB 2018 simulation environment. The simulation is performed in the network, where we set 100*100 m field area. Initially each sensor node consist equal amount of energy. The base station is positioned in the middle of the sensing field. The protocol is analyzed, in terms of stability period, instability period, network lifetime and throughput. We have compared simulation result with other reactive routing, cluster-based, heterogeneous network protocols TSEP and ETSSEP. In this simulation we use the following parameters which are shown in Table 1.

Table 1 Parameters used for simulation

Parameter	Value
Network field	100x100
Number of nodes	25-400
Initial energy (E_0)	0.5 J
Message size	4000 bits
E_{elec}	50nJ/bit
E_{fs}	10nJ/bit/m^2
E_{amp}	0.0013 pJ/bit/signal
E_{DA}	5 nJ/bit/signal
P_{opt}	0.1
A	2
M	0.1

In simulation, initial energy of each node is adjusted to 0.5 J, message size is 4000 bits. The energy dissipated (E_{elec}) to run transmitter and receiver is 50 nJ/bit, E_{fs} and E_{amp} are the free space and multipath fading channel whose value is 10nJ/bit/m2 and 0.0013 pJ/bit/m2 respectively. 5nJ/bit/signal energy is consumed for data aggregation, P_{opt} is the optimal probability to be a cluster head for present round and m denotes the fraction of advance nodes having additional amount of energy.

From the analysis of the result, we found that SDOSEP prolongs the stability, instability period, lifetime and throughput of the entire network. Figure 2 and 5 shows number of alive nodes during rounds, it describes that number of nodes die slowly in proposed protocol in comparison to TSEP and ETSSEP. In TESP, ETSSEP and SDOSEP the first node die at round 1527, 3058 and 7087 respectively. This denotes stability of the network, and it is observed that SDOSEP improves the stability period by 131.75% in comparison to ETSSEP and more than thrice in comparison to TSEP. Figure 3 and 6, describes number of dead nodes during rounds, it clearly shows that in TSEP, ETSSEP and SDOSEP, all node dies at round 4238, 7865 and 14830 respectively. After examining the data we clearly observe the network lifetime in SDOSEP is far better than TSEP and ETSSEP.

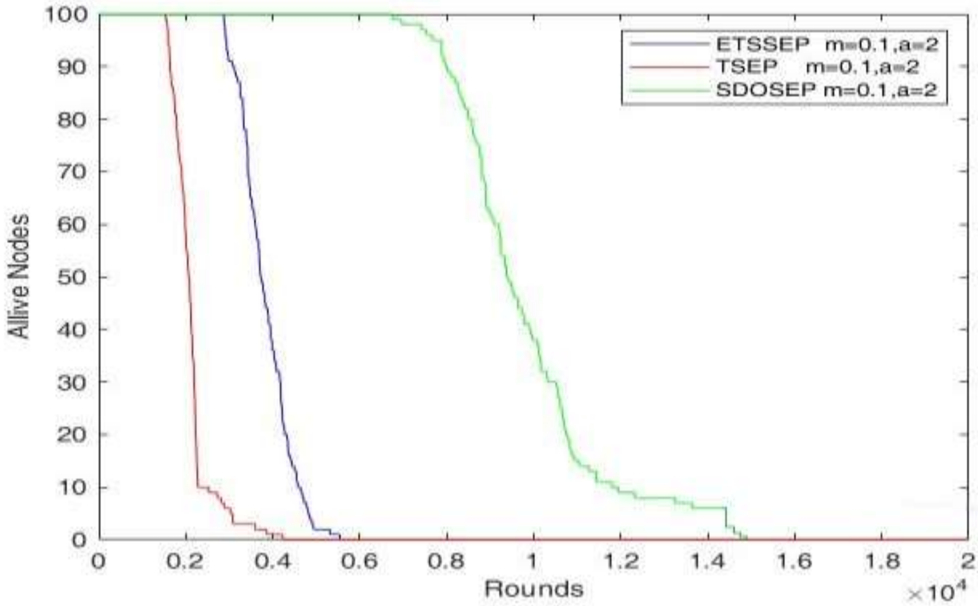

Fig. 2 Number of Alive nodes during rounds

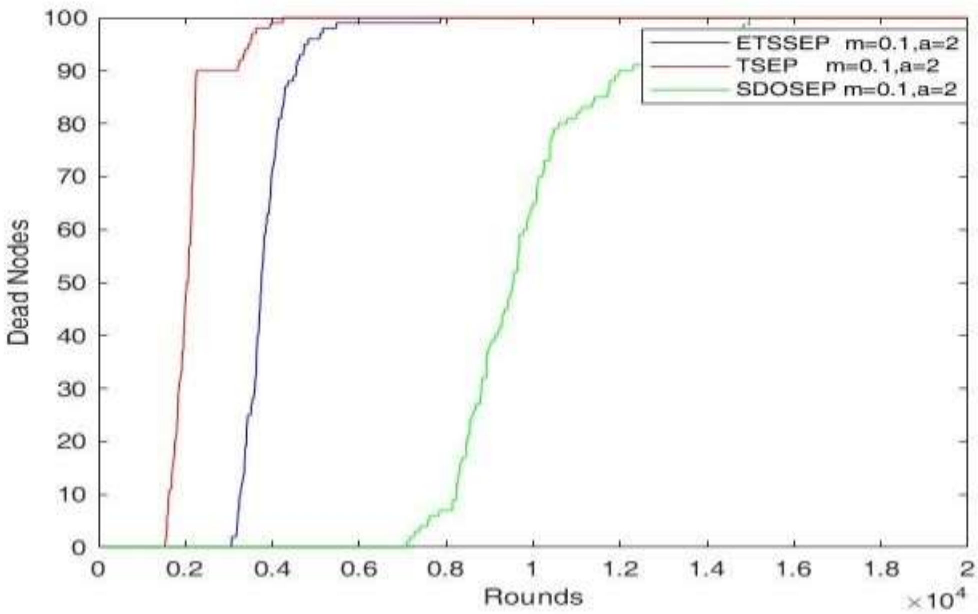

Fig. 3 Number of dead nodes during rounds

Figure 4 and 8 describes the throughput of different protocols, throughput is the packet sent to base station. In TSEP, ETSSEP and SDOSEP Number of packets transmitted to base station are 47072, 51788 and 212089 respectively.

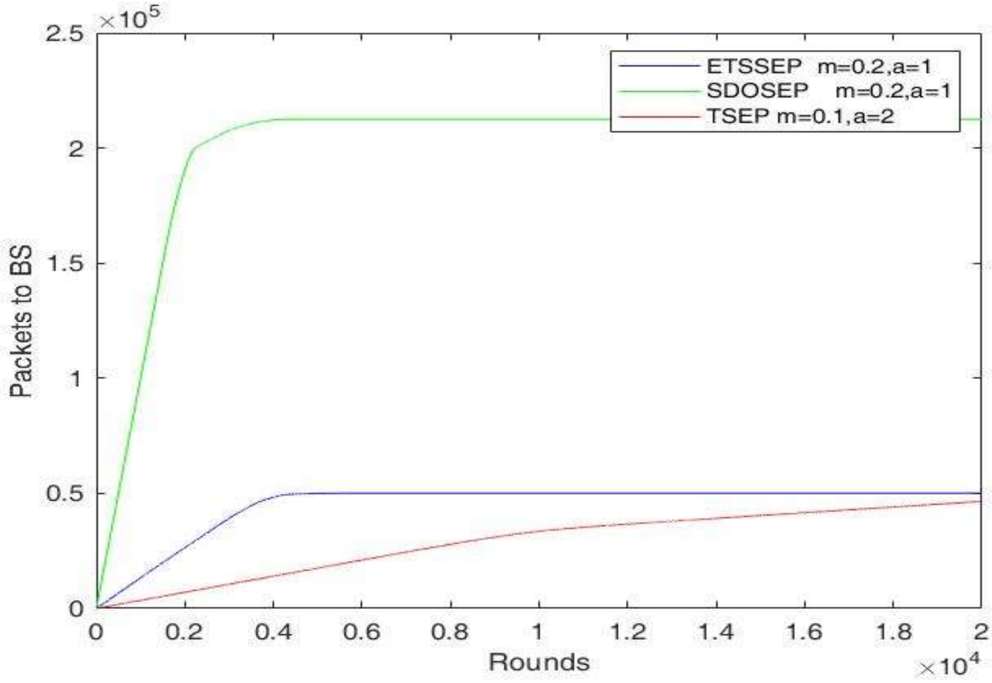

Fig. 4 Throughput of the protocol

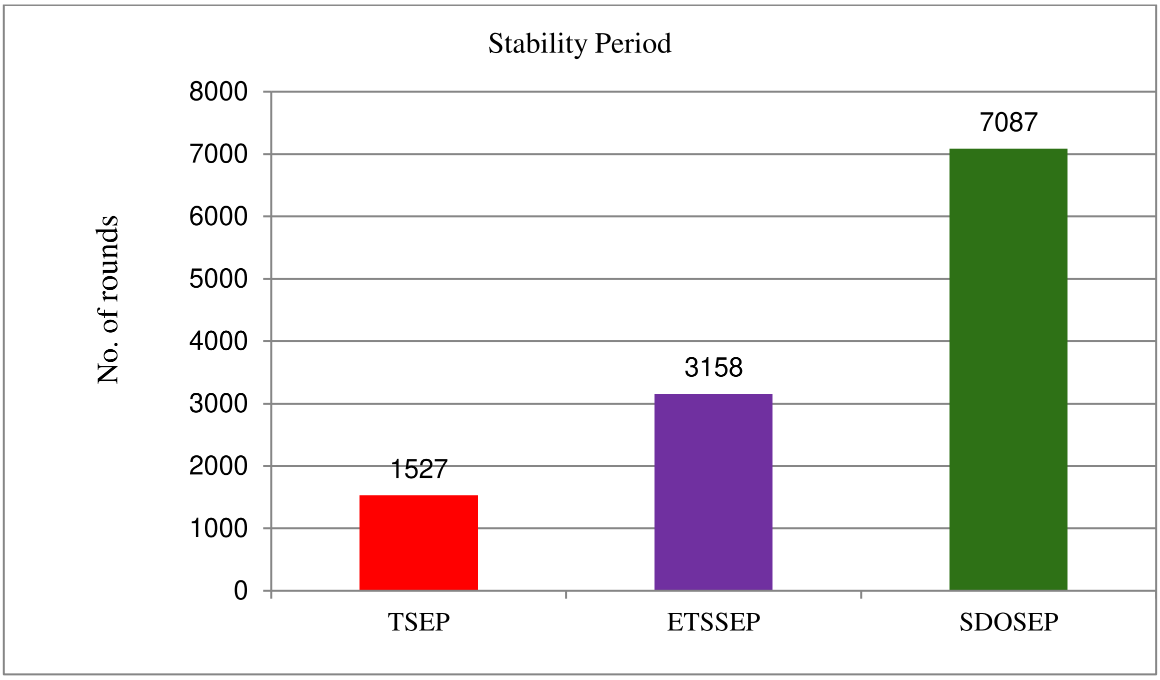

Fig. 5 Stability period versus number of rounds

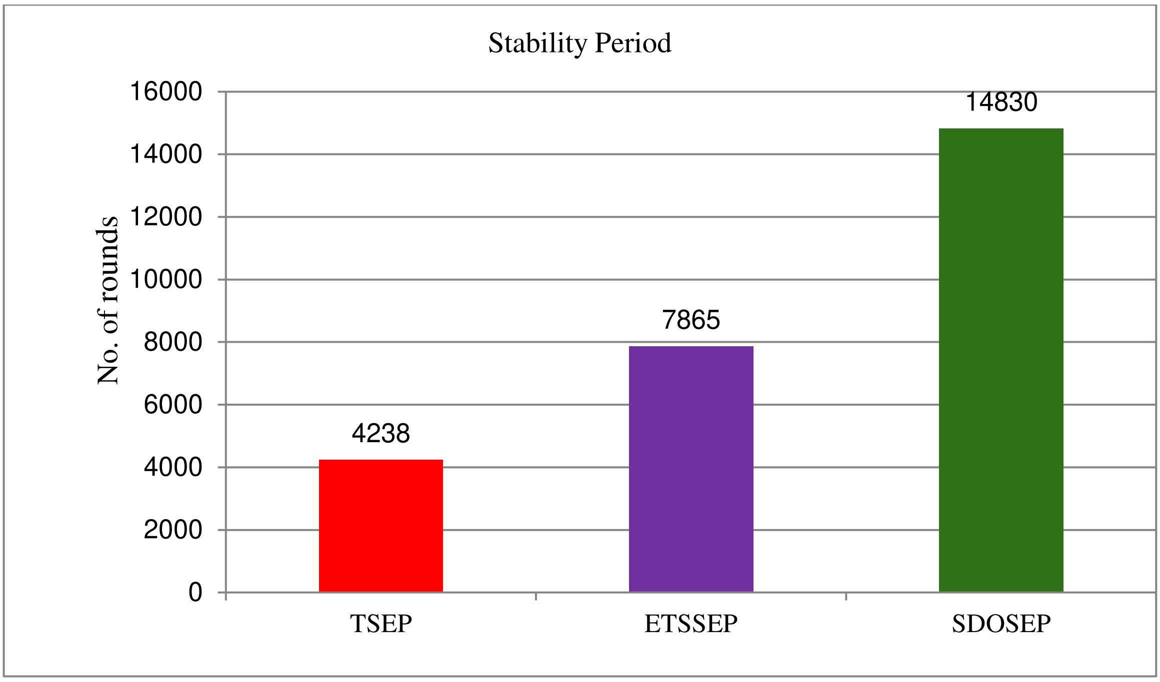

Fig. 6 Network life time versus number of rounds

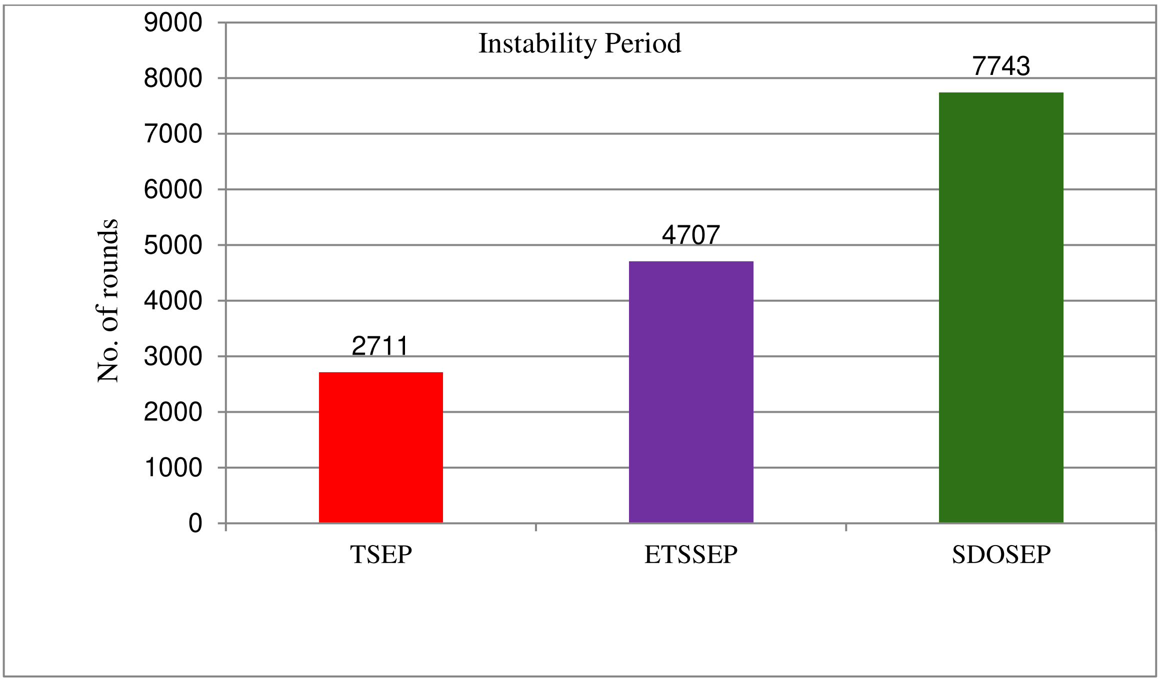

Fig. 7 Instability period versus number of rounds

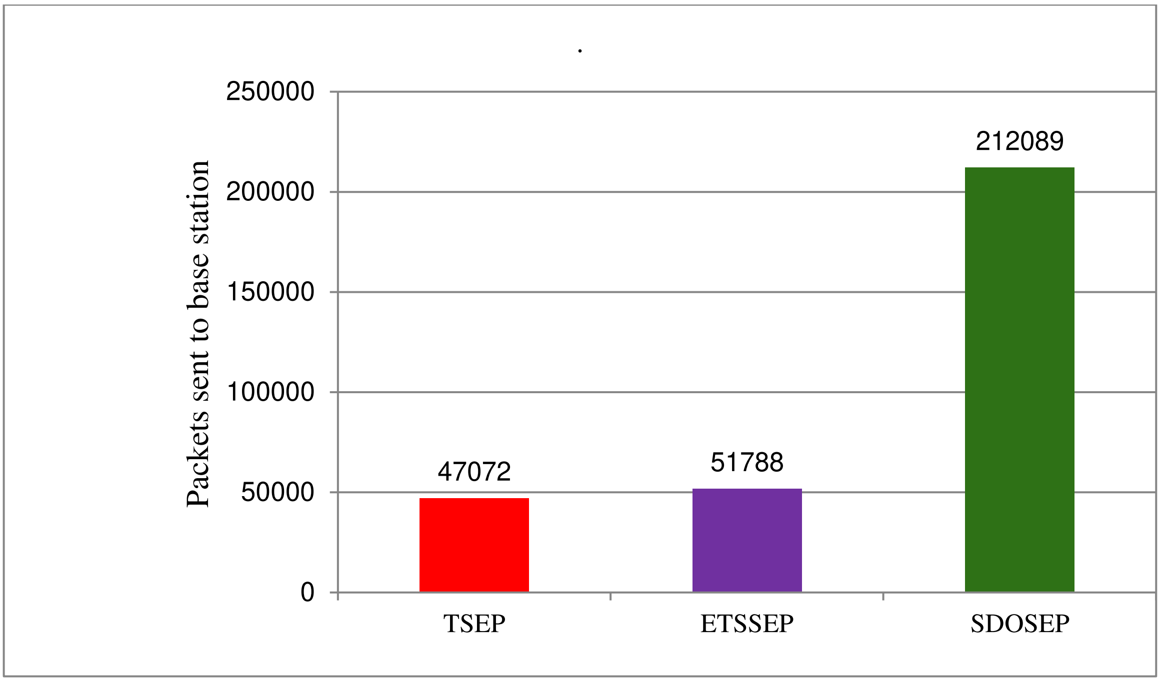

Fig. 8 Throughput of the network

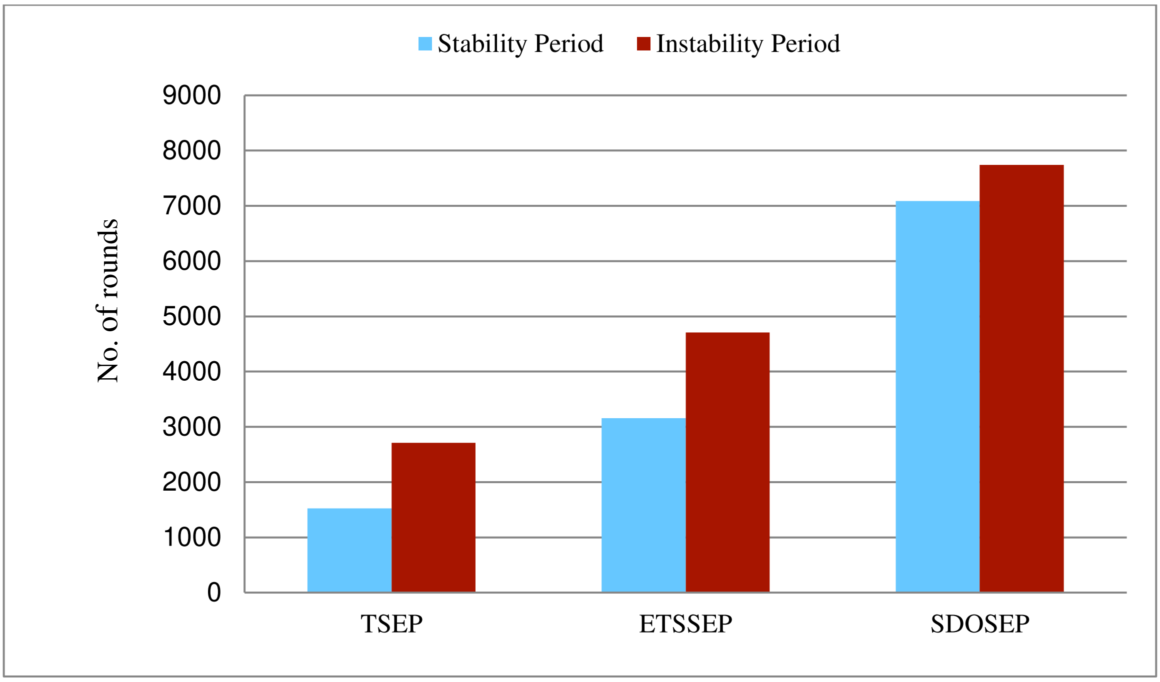

Fig. 9 Stability versus Instability period

Figure 9 shows the comparison of stability and instability period of different protocols and clearly specifies that SDOSEP performs better than TSEP and ETSSEP in all parameters that are stability, instability, network lifetime and throughput.

CONCLUSION

In SDOSEP we considered three levels of heterogeneity of nodes, where cluster head is elected in accordance with the probability in which the nodes with more energy level have greater chances to be a cluster head. Stability period, network lifetime, instability period and throughput are four parameters are considered to assess the performance of the proposed method with other routing protocols.

Protocol	Stability	Instability	Lifetime	Throughput
TSEP	1527	2711	4238	47072
ETSSEP	3158	4707	7865	51788
SDOSEP	7087	7743	14830	212089

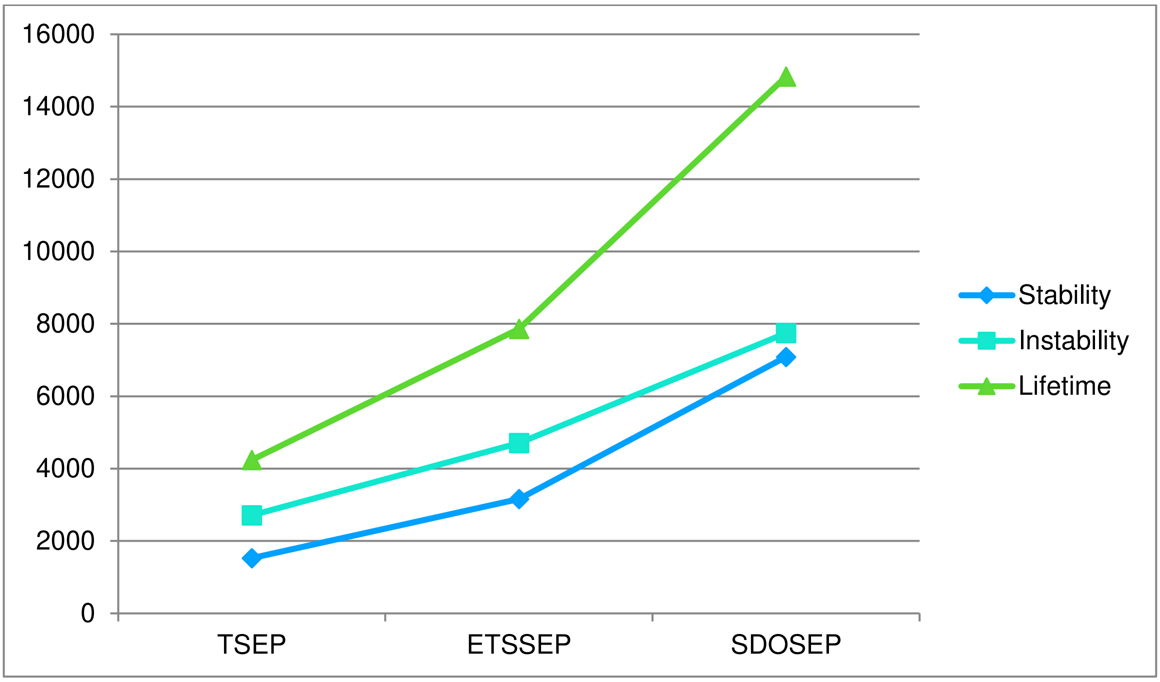

Fig. 10 Comparative analysis of protocols

Figure 10 shows in SDOSEP, stability of the network is upgraded by more than once over ETSSEP and more than thrice over TSEP. Overall lifetime is upgraded by 64.49% over ETSSEP and more than thrice over TSEP. The instability period is also improved in comparison to ETSSEP and TSEP. Throughput of the network is improved more than twice and thrice in comparison to ETSSEP and TSEP respectively.

Declarations

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Conflicts of interest/Competing interests: Shekhar Kumar and Kamika Chaudhary have no conflict of intrest.

Availability of data and material: Data is available within the article.

Code availability: The code is available from the corresponding author on reasonable request.

Author's contributions: Shekhar Kumar developed the theoretical formalism, performed the analytic calculations and performed the numerical simulations. Both Shekhar Kumar and Kamika Chaudhary contributed to the final version of the manuscript

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