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Performance analysis of various hierarchical routing protocols using spatial correlation

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ABSTRACT

In Wireless Sensor Networks (WSNs), the most significant task is to gather the data from the sensor nodes available in specific region available in event sensing field. The nodes in WSNs are energy constrained. To enhance the lifetime of WSNs, energy efficient protocols are needed. Spatial Correlation based Low Energy Adaptive Clustering Hierarchy (SCLEACH), Spatial Correlation based Power-efficient Gathering in Sensor Information Systems (SCPEGASIS), Spatial Correlation based Threshold Sensitive Energy Efficient Sensor Network Protocol (SCTEEN) are well-designed solutions to rectify this problem. These protocols minimize the overall dissipation by means of individual sensor nodes located in the network. Spatial correlation based Hierarchical Routing Protocols (SCHRP) adapt clustering concept and enhance the energy efficiency and the performance of over all network. The Performance of SCHRP model is compared with existing LEACH and PEGASIS, TEEN protocols and results have been taken for various parameters such as End-to-End delay, Packet drop, Packet delivery ratio, Throughput, Energy Efficiency and Energy Consumption. The proposed SCLEACH has 6.35% higher energy efficiency than the existing LEACH protocol. The impact of the proposed protocols are evaluated using various parameters and compared with k-d tree algorithm. The importance of spatial correlation based routing concept is analyzed with respect to k-d tree algorithm and the simulation results have been taken using Network Simulator tool.

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1. Introduction

Hierarchical Routing Protocols (HRP) provide substantial energy savings in WSNs. In HRP, each cluster is assigned with Cluster Head (CH) node elected by the member (sensor nodes) of the clusters. CH will act as a leader of the cluster and performs the task such as data collection from sensor nodes available in the cluster, data aggregation and data transmission to the Base Station (BS) [3]. Total energy consumption of the network is greatly reduced by prioritizing and scheduling each task. This leads to maximization of the network lifetime due to the reduced energy consumption. Network traffic is greatly reduced by cluster based routing protocols towards the destination node [16]. Due to the factors such as cluster configuration and maintenance, the overhead is introduced in the hierarchical based cluster. Cluster based protocols performed well compared to flat network topologies for large-scale WSNs specifically in tree topology based clusters [7]. The implementation phase of WSNs includes vast challenges in implementation. The key attributes considered for the design aspect of clusters in WSNs are data aggregation, selection of cluster heads and clusters, synchronization of real-time operation, real time operation, cost of clustering, repair mechanisms, Quality of Service (QoS).

To improve the scalability and efficiency, hierarchical or cluster-based routing is proposed for WSNs. In WSNs, hierarchical routing techniques is used to enhance energy efficiency and hence prolong the network lifetime [17]. Reservation-based scheduling, collision avoidance, data aggregation by cluster head, uniform energy dissipation, fair allocation of channel and lower latency are some of the characteristics of hierarchical based routing protocol. Network structure based routing and Protocol operation based routing are the classifications of WSNs routing. SCHRP is considered in the proposed work.

In Section 2, Related Work has been discussed. In Section 3, LEACH, PEGASIS, TEEN Protocols have been shown with necessary diagrams and its functionality also discussed. In Section 4, proposed model is elaborated in detail. Simulation results have been discussed with necessary parameter values in Section 5. In Section 6, Conclusion and Future work have been discussed.

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2. Related work

The authors discussed a taxonomy of different attributes of clustering schemes for WSNs [2]. The attributes are classified into three types such as cluster properties, cluster head capability, clustering process. The objective of network clustering are load balancing, fault tolerance, increased connectivity and reduced delay, minimal cluster count and maximal network longevity. Different types of clustering algorithms are also discussed in this paper. Each clustering method is highlighted with its strength and weakness. Spatial correlation based clustering approach is not discussed in detail.

Authors proposed Energy Efficient Hierarchical Clustering Algorithm for Wireless Sensor Network (EEHCA) [4]. EEHCA balances energy in all nodes in WSNs and maximizes the lifetime of the network by reducing the energy consumption. During inter-cluster transmission, energy is distributed among the clusters in EEHCA algorithm. EEHCA algorithm outperforms LEACH and Hybrid Energy-Efficient Distributed clustering (HEED) algorithms. For large scale sensor networks, inter cluster communication needs to be improved. Therefore design of directional antenna and location unaware protocol for many applications should be improved.

Hybrid approach (H-LEACH) is proposed with fixed no of clusters [5]. In this method, the clusters are fixed and cluster heads are chosen dynamically. The approach shows an improved performance that is duly supported by the simulation.

The authors proposed k-d tree algorithm for partitioning of data structure available in WSNs space into clusters [9]. For the formation of cluster, the values such as jitter, delay and throughput are considered. Comparison is made between kd tree algorithm Vs LEACH, LEACH-C algorithms and indorsing the results through simulation.

The survey of routing techniques in WSNs is proposed [8]. Comparison between hierarchical routing and flat based routing is discussed. Comparison between Sensor Protocols for Information via Negotiation (SPIN), LEACH, Directed Diffusion protocols are also discussed. Node mobility, time and location synchronization, localization, tiered architecture exploitation of redundancy for routing protocols are not discussed elaborately.

A New energy efficient cluster based routing protocols for WSNs is proposed [10]. Centralized clustering approach is adapted to select the cluster heads. To select the CHs, representative path is also generated. For inter-cluster and intra-cluster communication, multi-hop routing protocol is proposed. Algorithm for cluster management and the different routing protocols are compared. Private data aggregation scheme with energy efficient routing protocol has not been discussed in detail.

Cluster based routing protocols for large scale WSNs is initiated [12]. Comparison of different cluster based routing based protocols according to QoS metrics are also considered. QoS considered for the analysis are energy, delay and bandwidth. The protocols considered for the analysis are LEACH, CBHRP, MH-LEACH and LEATCH. Among the protocols CBHRP produce best result.

Hierarchical routing protocol developed for Mobile WSNs (MWSNs) is proposed [15]. Based on the survey on hierarchical protocols, the classification was completed. Classification is performed based on routing approach, control manner, mobile element, mobility pattern, network architecture, clustering attributes, protocol operation, path establishment, communication paradigm, energy model, protocol objectives. Comparison between the protocols had been completed with respect to delay, network size, energy-efficiency, and scalability.

The survey of hierarchical routing protocols with advantages and disadvantages are proposed [19]. Categories and Working of each protocol along with working are also discussed in detail.

The concept of K-medoids algorithm to calculate the optimal medoids between sensor nodes is proposed [20]. The selection of appropriate cluster heads by balancing network load among the clusters, energy efficiency can be improved and network lifetime is extended effectively.

Clustering routing protocols for WSNs is proposed [21]. Advantages and applications of clustering scheme for WSNs are highlighted. Classifications of different routing protocols in WSNs is tabulated with respect to the characteristics of the cluster. Node mobility and topology changes in WSNs is not discussed in detail. When the network scale increases automatically, redundant information level also increases. Redundancy affects the reliability of the network. Trade-off between reliability and redundancy in information are not concentrated in detail.

Various hierarchical routing protocols such as cluster based and chain based routing protocols is discussed [23]. The influence of network topology on the performance of cluster based and chain based routing protocol is analyzed. Chain based hierarchical routing protocols result in longer lifetime and better results towards energy efficiency than cluster based routing protocols.

A new routing protocol that provides QoS in terms of delay and energy consumption [25]. The network is organized in clusters supervised by CHs (Cluster-Heads), elected according to important metrics, namely the energy capability, the riches of connectivity, which is used to select the CH with high node density [22], and the accessibility degree regarding all the actuators. The latter metric is the distance in number of hops of sensor nodes relative to the actuator nodes. This metric enhances more the network reliability by reducing the communication delay when alerting the actuator nodes, and hence, reducing the energy consumption.

In this paper, Spatial Correlation based LEACH (SCLEACH) and Spatial Correlation based PEGASIS (SCPEGASIS), Spatial Correlation based TEEN protocols (SCTEEN) have been considered. Based on the residual energy the election process of CH in each round is opted. Therefore CH concept is adapted in the proposed system. Using High Energy First (HEF) algorithm, Cluster Heads (CH) are elected for each round. Therefore spatial correlation based hierarchical routing methods achieve better results towards energy efficiency.

3. Existing hierarchical routing protocols

Existing Hierarchical Routing Protocols such as LEACH, PEGASIS, TEEN protocols are considered for the comparative analysis with the proposed system.

3.1. LEACH protocol

LEACH is the conventional routing protocol used in many applications of WSNs [24]. LEACH adopts distributed clustering algorithm for WSNs. In a homogenous medium, BS is fixed [6]. The lifetime of WSNs is improved by means of cluster-head rotation mechanism, data aggregation, and data fusion technologies. In Fig. 1, dark circle represents cluster head. Other circle represents sensor nodes in the each cluster. The network has collection of nodes which are responsible to form a cluster and each cluster has one Cluster Head (CH).

Set up and steady are the two phase involved in LEAECH protocol operation. Cluster heads are chosen in set up phase. LEACH uses cluster-head rotation, elects the cluster head randomly among the clusters after certain number of rounds [14].

3.2. PEGASIS protocol

PEGASIS is a near optimal chain-based protocol. The nodes can communicate with their neighbor and transmitting the information to BS [12]. Therefore it reduces the amount of energy spent

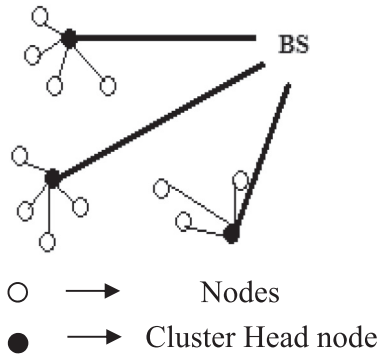


Fig. 1. LEACH Protocol Model.

per round. Each round, the BS receives information from the head node. PEGASIS forms a chain among the sensor nodes such that each node receives data from a neighbor and transmits it to it.

BS will receive the gathered data which is transferred from each node and it leads to form fused data [12]. A model for PEGASIS protocol is shown in Fig. 2.

Chain construction is done initially and gathering of data is done next in a PEGASIS protocol [18]. When a node is dead, to bypass the dead node the chain is reconstructed.

3.3. TEEN protocol

TEEN protocol is a threshold sensitive energy efficient sensor network protocol. Hierarchical clustering and data centric protocols are used to make TEEN protocols. It is used in time critical applications. It responds to immediate change in attributes observed in WSNs. Formation of cluster head is the first step and then cluster heads forward two threshold values to the nodes in cluster head. Two threshold values such as hard and soft threshold are useful for effective operation of TEEN protocol [1]. Hard threshold represents sensed attribute values. When a node senses the hard threshold value then it reports the hard threshold value to CH through transmitter. Small change in sensed attribute is defined as soft threshold. It triggers the node to transmit and report the sensed data. Message propagation is accomplished by CH. This protocol is not suitable for updating the periodic measurements to sink. BS is unable to identify the active nodes from failure nodes. The operation of TEEN protocol is explained in Fig. 3.

4. Proposed model

Many possible ways are there to reduce the energy wastage and energy consumption in WSNs. Two ways are commonly available for solving this issue. One way is using required number of nodes

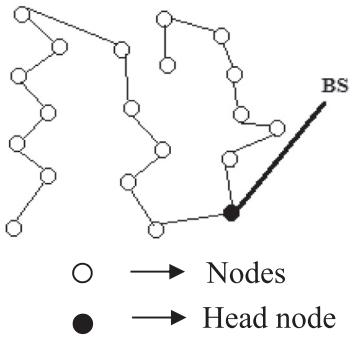


Fig. 2. PEGASIS Model.

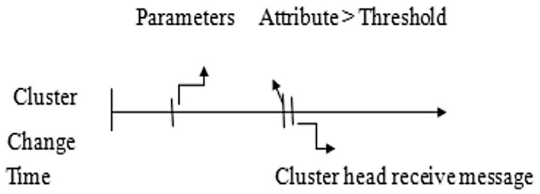


Fig. 3. TEEN Protocol – Operation.

to be active to make the network redundant free and also to reduce traffic inside the network. It leads to the decrease the effect of packet forward delay and packet collision. Second way is to make few sensor nodes into sleep mode and assigning the balance nodes for sensing, communication task.

In this paper, SCLEACH and SCPEGASIS, SCTEEN are considered for the analysis. A model for WSNs is shown in Fig. 4. Sensor nodes are deployed randomly in WSNs field.

4.1. Spatial correlation in WSNs

In the concept of Spatial Correlation region, the set of sensor nodes from each region send the report which are similar in nature through the CH to sink or Base Station. Instead of sending multiple copies of redundant information, it is enough to send single report from each region [13]. In sensor field, if any event is occurred then the regions which are very nearer to that event started to detect the event information through the nodes available in it. Every nodes in those regions are started to send their own sensed data which are highly correlated in nature to sink. This type of transmission is considered as redundant transmission in WSNs.

Minimization of redundant data transmission leads to maximization of network life time. Designing efficient MAC protocol improves network lifetime. Fig. 5 shows the correlation region.

In Fig. 5, Set 1 is considered with total number of nodes. It is identified as the correlation region. Nodes involved in the operation of correlation region and correlation radius are calculated. For each node, the current position, neighbor node position and sink node values are stored. The highest residual energy of the representative nodes depends on distance, Correlation, coefficient and covariance function. The nodes available in set 1 will start to collect the data when an event occurs and reporting about the event with sink node through representative node's of the region. Redundant data transmission from each region to sink and the lost data between the nodes are also considered for the analysis. It is enough to send a single report to sink from each region to avoid redundant report through the respective representative nodes. SCLEACH, SCPEGASIS and SCTEEN protocols are used to route the data to destination node. If the residual energy of the representative node is zero or very low then the nodes with peak residual

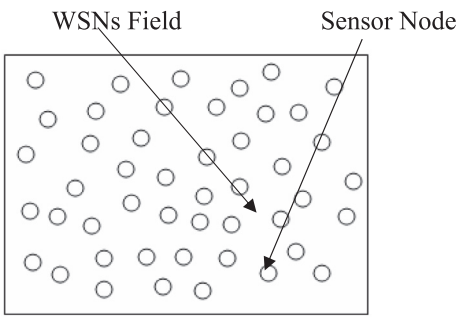


Fig. 4. Model for Wireless Sensor Networks.

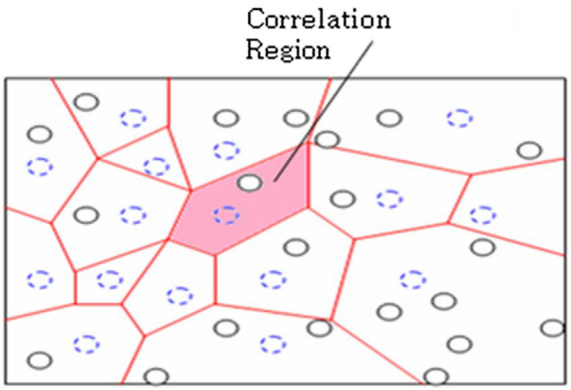


Fig. 5. Correlation Region.

energy is considered as representative node for next event. The nodes will move to sleep mode when they are not involved in transmission process. Same procedure is repeated when next event occurs in WSNs field.

Figs. 6 and 7 shows the structure of routing at two different instances of time. At first instance, the nodes in the correlation region (region with pink color) senses the event and reports to BS through representative nodes.

At the second instance, based on the residual energy of representative node and relaying node, the position is changed. When an event occurs in WSNs field, it is detected by the nodes in the correlation region. Based on the HEF algorithm, the node with highest residual energy is elected as the representative node. The other nodes in the correlation region sense the event and send a report to its corresponding region's representative node. If two nodes are having same energy level during the representative node election process, tie occurs to elect the representative node and the ID of the node is considered. Only one representative node is available in each group. If the energy level of the representative node reduces to very low value, then election process starts again, based on high residual energy of the nodes in the group. When correlation region is identified, representative nodes are elected and only that nodes collect the data and report it to BS [11].

Fig. 8 shows the pseudocode for the proposed method. Initially all the necessary parameter values are assigned and when an event is occurred in WSNs sensing field, the corresponding event area's distance and correlation radius, weight values, covariance function are calculated. Missing data between two sets are also calculated using the formula. Then SCLEACH is applied to WSNs to direct the data from CH to sink. Later replace SCLEACH by SCPEGASIS and do the routing procedure. SCPEGASIS is replaced by SCTEEN in the next round. If the residual energy is low then the node with peak residual energy is assigned as next representative node of the

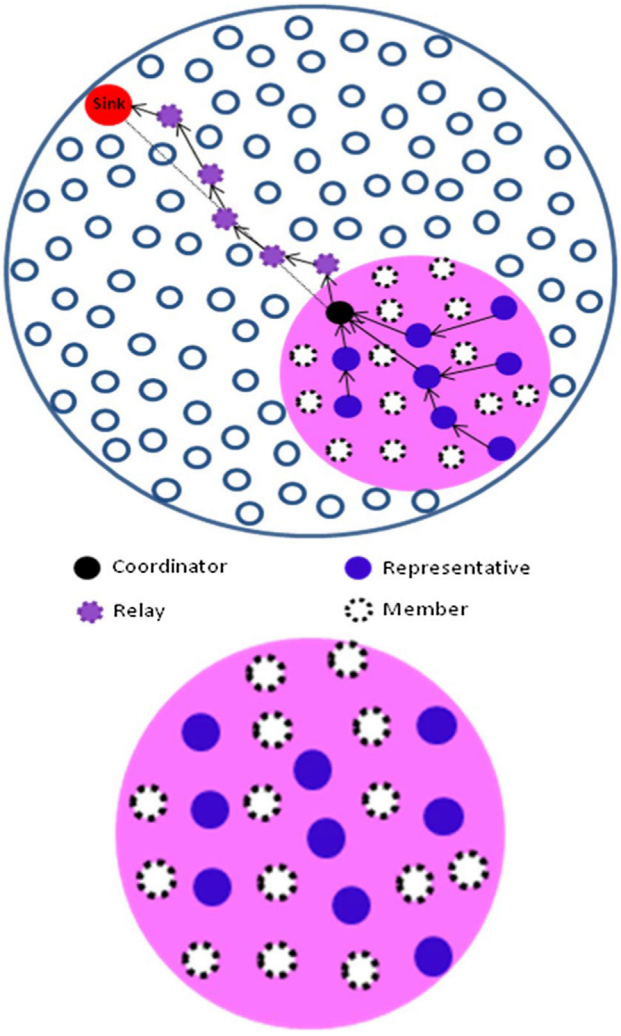


Fig. 6. Structure of routing at First Instance.

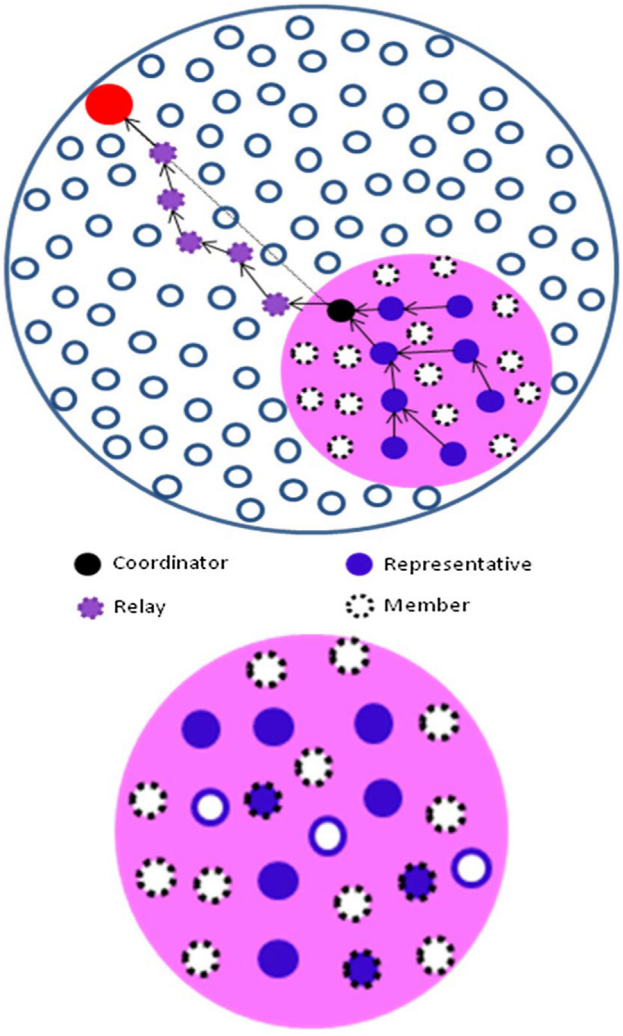


Fig. 7. Structure of routing at Second Instance.

/* Performance Analysis of Various Hierarchical Routing Protocols Using Spatial Correlation Concept*/

Step 1: Assign A1 for Set 1 and C for Correlation of the node;

Step 2: Assign Di value for distance and Rep for representative nodes;

Step 3: Assign Rrh for highest residual energy of the representative node;

Step 4: Assign a2 for variance, PE for Power Exponential model and g1 , g2 to control C & Di;

Step 5: Assign CorrR for Correlation radius of A1and CV for Covariance function of A1;

Step 6: Assign ttBn for transmission period of the nodes in set A1(Mn);

Step 7: Assign tsBn for sleep time period ;

Step 8 : Assign tNBn for next transmission time;

Step 9: While (Occurrence of event)

{

Estimate Mn, Rn1, CR1of A1;

Note and save the position of sink, neighbor of A1;

Estimate weight w.r.t Sink,

$W(Bn, Sk) = Rrhn / Di(Bn, Sk)$;

M2 is neighbor of M1 when (M1,M2) < CR1;

Check Rrh of representative nodes in S1;

Estimate $Di1{,}2 = Cx1 - Cx2$;

Estimate $CorrR1{,}2 = E[x1, x2] / a2$;

Estimate $CvPE\ (Di) = e(-Di/g1)g2$;

Collect a single report if redundant report is identified and send to Rn1;

Put on SCLEACH to route the data from Rep to Sink;

Substitute SCLEACH by SCPEGASIS and do route;

Substitute SCPEGASIS by SCTEEN and do route

Check the Rrhn of Rep;

Check $Rrh = low$, if the condition is satisfied then replace the node with $Rrh = high$;

Node is in tsBn when $ttBn < tsBn < tNBn$;

}

Nodes sense the next event and repeat the same procedure;

}

Fig. 8. Pseudocode for the Proposed Method.

corresponding region. Check any event is occurred after the completion of first event then repeat the same procedure for second event also.

5. Simulation results

Network Simulator (NS2) tool is used for simulation of proposed work. In the proposed work, Spatial Correlation based LEACH (SCLEACH), Spatial Correlation based PEGASIS (SCPEGASIS), Spatial Correlation based TEEN (SCTEEN) protocols are considered. All the three protocols are compared with existing hierarchical routing protocols such as LEACH, PEGASIS, TEEN protocols with respect to five different output parameters. In the proposed work, the simulation time is set for 100 ms. The Figures show the simulations at 20 ms and 100 ms. Details of simulation parameters have been shown in Table 1.

For the simulation purpose, 1500 × 1500 network size is considered with 100 number of nodes and spatial correlation radius value of 100 m. 512 bytes of packet length is considered with 100 J of initial energy along with 2.4 GHz range of bandwidth, 250 kbps of data rate and 2mW of transmission power and 1 mW of receiving power, 0.01 microwatts of idle and sleep power. For the proposed system, Tree and Chain, Cluster based topologies are considered for the analysis.

Five output parameters considered for this proposed work are end-to-end delay, packet drop, packet delivery ratio, throughput, energy efficiency, energy consumption. All the parameter analysis is carried out at 20 ms and 100 ms. Each parameter plot consists of existing and proposed protocols. For the Existing system, LEACH and PEGASIS, TEEN protocols are considered. SCLEACH, SCPEGASIS, SCTEEN are considered as proposed system.

SCHRP model doesn't take much time to analyse the performance of the network and also to calculate the parameters. SCHRP model takes less time to measure the parameters of the network. Therefore SCHRP model is considered as one of the best model for the analysis of various parameters.

5.1. End-to-end delay

Fig. 9 is the plot between time Vs end-to-end delay for the proposed SCLEACH, SCPEGASIS, SCTEEN protocols and the existing LEACH, PEGASIS, TEEN protocols. All the simulations are carried out at 100 ms.

The proposed SCLEACH has 0.11 ms which is lesser than the existing LEACH protocol. LEACH protocol has the rotation CH in random manner whereas the proposed SCLEACH avoids this and considers spatial correlation technique.

In the proposed SCPEGASIS, end-to-end delay of 0.41 ms which is lesser than the existing PEGASIS protocol. Since PEGASIS protocol has the CH node which sends the fused data to the BS per round. The proposed SCPEGASIS avoids this by selecting CH based on its highest residual energy.

At 100 ms, the proposed SCTEEN has an end-to-end delay of 0.39 ms which is lesser than the existing protocol. This is because

Table 1
Input Parameters used for Simulation.

S.No	Parameters	Values
1.	Network Size	1500 X 1500
2.	Total no of nodes	100
3.	Spatial Correlation Radius	100 m
4.	Packet Length	512 bytes
5.	Initial Energy	100 Joules
6.	Bandwidth	2.4 GHz
7.	Data Rate	250 kbps
8.	Tx Power	2 mW
9.	Rx Power	1 mW
10.	Idle Power	0.01 microwatts
11.	Sleep Power	0.01 microwatts
12.	Topology	Tree, Chain, Cluster

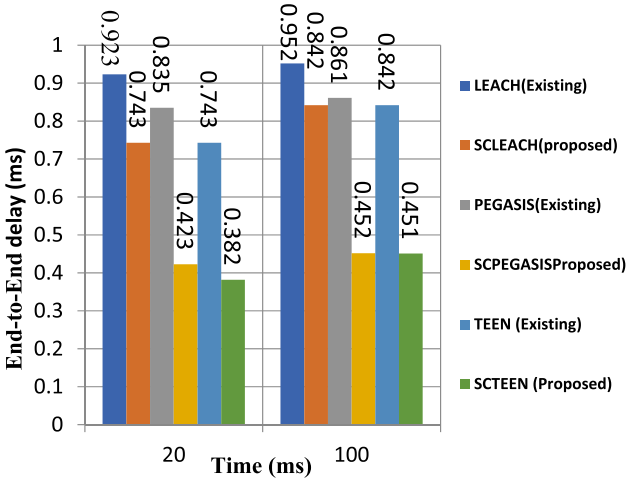


Fig. 9. Time Vs End-to-End delay.

TEEN protocol has two different threshold values to forward to its node in the cluster through CH. This process takes time and it is reduced by exploiting spatial correlation concept in the proposed SCTEEN.

On an average, SCLEACH has 14% which is low value of end-to-end delay than the LEACH protocol. SCPEGASIS has 48.5% which is lesser end-to-end delay than the PEGASIS protocol and SCTEEN has 53% which is lower value of end-to-end delay compared to TEEN protocol.

5.2. Packet drop

Fig. 10 is the plot between time Vs packet drop for the proposed SCLEACH, SCPEGASIS, SCTEEN protocols and the existing LEACH, PEGASIS, TEEN protocols. All the simulations are carried out at 100 ms.

The proposed SCLEACH drops 120 packets lesser than the existing LEACH protocol. This is because LEACH protocol has to maintain two different phases such as set up phase and steady state phase. Therefore LEACH drops more number of packets than SCLEACH. SCLEACH adapts spatial correlation technique which is useful to collect the single report about the event from the correlation region.

The proposed SCPEGASIS drops 50 packets which is lesser than the existing PEGASIS protocol as PEGASIS protocol has gathered data which moves and gets fused whereas in SCPEGASIS, spatial correlation regulates redundant data transmission by forwarding the filtered data packets to sink node.

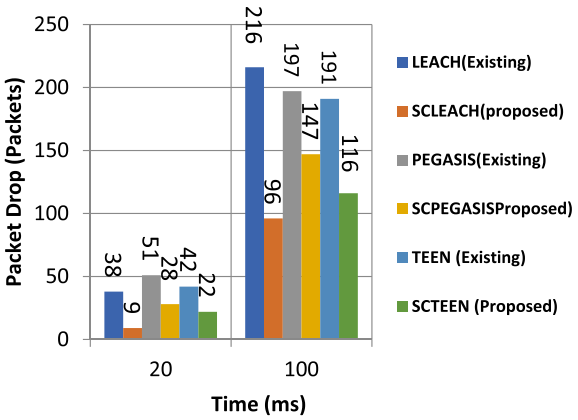


Fig. 10. Time Vs Packet Drop.

The proposed SCTEEN drops 75 packets which is lesser than the existing TEEN protocol as TEEN protocol is not suitable for periodic reports whereas in SCTEEN protocol due to spatial correlation periodic reports are updated at sink node through the representative nodes.

On an average, SCLEACH has 61.7% which is lesser packet drop value than LEACH protocol. SCPEGASIS has 25.70% lesser packet drop value than PEGASIS protocol and SCTEEN has 35.99% lesser packet drop value than TEEN protocol.

5.3. Packet delivery ratio

Fig. 11 is the plot of time Vs packet delivery ratio for the proposed SCLEACH, SCPEGASIS, SCTEEN protocols and the existing LEACH, PEGASIS, TEEN protocols. All the simulations are carried out at 100 ms.

The proposed SCLEACH has 0.6% which is higher packet delivery ratio than the existing LEACH protocol as LEACH protocol has high value of transmitting distance therefore packet delivery ratio is very less when compared with SCLEACH. In SCLEACH, two different MAC protocols are designed to achieve good results and it adapts spatial correlation technique which is useful to collect the single report about the event from the correlation region.

The proposed SCPEGASIS shows 2.33% packet delivery ratio which is higher than the existing PEGASIS protocol. This is because PEGASIS protocol has gathered data which moves and gets fused whereas in SCPEGASIS, Spatial correlation regulates the data transmission and gathered data is delivered at the sink node by forwarding the prioritization of data.

The proposed SCTEEN shows 0.61% packet delivery ratio which is higher than the existing TEEN protocol. This is because SCTEEN protocol has the ability to switch on its transmitter to transmit the single report collected by the cluster head in each correlation region. Therefore packet delivery ratio is better than TEEN protocol.

On an average, SCLEACH has 1.89% which is higher packet delivery ratio than LEACH protocol. SCPEGASIS has 2.33% which is higher packet delivery ratio compared to PEGASIS protocol and SCTEEN has 0.43% higher packet delivery ratio compared to TEEN protocol.

5.4. Throughput

Time Vs throughput plot is shown in Fig. 12 for the proposed SCLEACH, SCPEGASIS, SCTEEN protocols and the existing LEACH, PEGASIS, TEEN protocols. All the simulations are carried out at 100 ms.

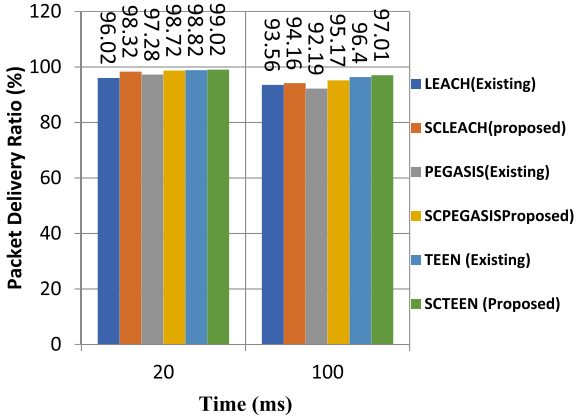


Fig. 11. Time Vs Packet Delivery Ratio.

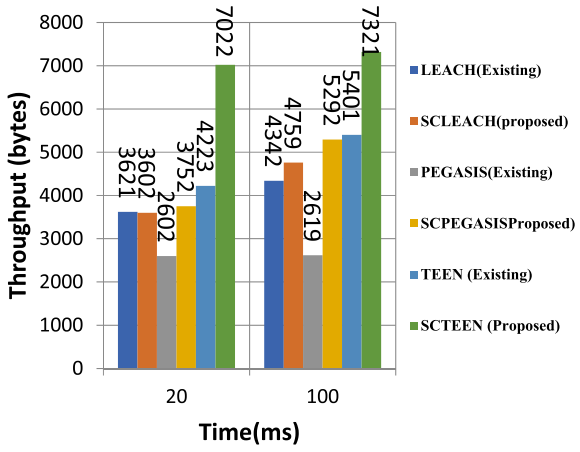


Fig. 12. Time Vs Throughput.

SCLEACH has 417 bytes which is higher value of throughput than the existing LEACH protocol as SCLEACH protocol has spatial correlation based data aggregation and data fusion methods to improve the lifetime of the network.

SCPEGASIS has 2673 bytes which is higher value of throughput than the existing PEGASIS protocol. This is because SCPEGASIS protocol has the ability to alter the route when the node dies in the chain along with spatial correlation method. Therefore correlation between the nodes is easily identified and routing is performed with higher throughput.

SCTEEN has 2232 bytes which is higher throughput value than the existing TEEN protocol. This is because TEEN protocol works only on demand. The sensed data is transmitted whereas in SCTEEN protocol, the sensed report reaches sink node periodically.

On an average, SCLEACH has 4.6% which is higher value of throughput value than that of LEACH protocol. SCPEGASIS has 39.76% which is higher throughput value than that of PEGASIS protocol and SCTEEN has 30.96% which is higher throughput value than that of with TEEN protocol.

5.5. Energy efficiency

Fig. 13 is the plot between time Vs energy efficiency for the proposed SCLEACH, SCPEGASIS, SCTEEN protocols and the existing LEACH, PEGASIS, TEEN protocols. Initial energy is set to 100 Joules. All the simulations are carried out at 100 ms.

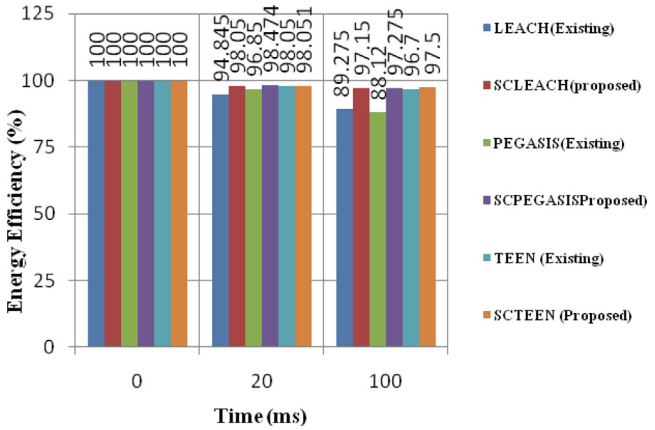


Fig. 13. Time Vs Energy Efficiency.

SCLEACH has 7.9 Joules higher energy efficiency value than the existing LEACH protocol. This is because SCLEACH protocol has the direct communication with nodes and cluster heads, BS along with spatial correlation. Therefore energy consumption is reduced significantly.

SCPEGASIS has 9.11 Joules which is higher energy efficiency value than the existing PEGASIS protocol. This is because SCPEGASIS protocol has the ability to choose the sensor node randomly from the chain and transmits the aggregated data to BS along with spatial correlation. Therefore energy consumption is reduced in each round.

SCTEEN has 0.8 Joules which is higher energy efficiency value than the existing TEEN protocol. This is because SCTEEN protocol regulates the transmission based on demand and redundant reports are filtered in before each transmission from cluster head to BS. Therefore SCTEEN controls the data transmission to get better energy efficiency.

On an average, SCLEACH has 6.35% energy efficiency which is high value than LEACH protocol. SCPEGASIS has 4.18% energy efficiency which is high value than PEGASIS protocol and SCTEEN has 0.03% energy efficiency which is high value than TEEN protocol.

Fig. 14 is the plot of time Vs energy consumption for the proposed SCLEACH, SCPEGASIS, SCTEEN protocols and the existing LEACH, PEGASIS, TEEN protocols. From the above Figs. 9–14, it is observed that the proposed routing protocols performs better than the existing protocols.

Fig. 15 shows that time Vs Energy consumption of k-d tree algorithm, SCLEACH, SCPEGASIS, SCTEEN algorithms. k-d algorithm consumes much energy than that of spatial correlation based protocols because it uses partitioning of given WSNs field into various regions. Therefore each cluster partition needs much energy than the proposed spatial correlation based hierarchical routing protocols.

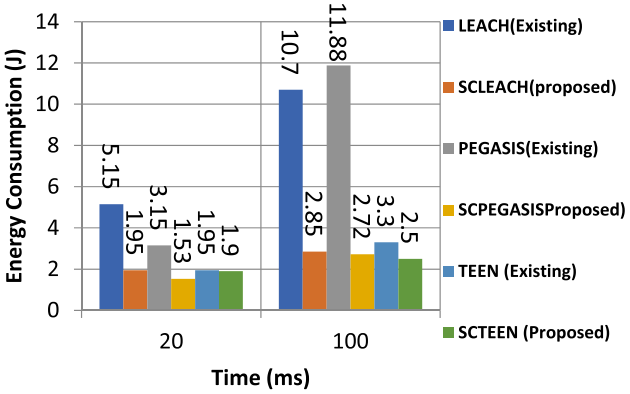


Fig. 14. Time Vs Energy Consumption.

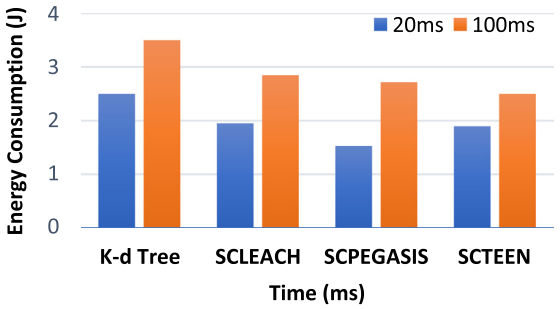


Fig. 15. Time Vs Energy Consumption for Comparison of Protocols.

6. Conclusion and future work

Performance analysis of various hierarchical routing protocols using spatial correlation method is proposed in this paper. LEACH and PEGASIS, TEEN protocols are implemented using spatial correlation concept and the performance of three protocols is analyzed. The redundant data are controlled by deactivating the redundant nodes. Various parameters are taken into account for various sets of wireless sensor nodes and also for different simulation conditions. SCTEEN and SCPEGASIS protocols give better results in energy efficiency than LEACH, PEGASIS, TEEN protocols. The proposed SCLEACH, SCPEGASIS, SCTEEN exhibit an average improvement of about 6% higher energy efficiency than the existing hierarchical routing protocols. Proposed protocols have been compared with k-d tree algorithm and the performance analysis with respect to energy consumption is considered. Than the proposed protocols, the k-d algorithm consumes much energy for its efficient working in WSNs field. SCHRP model has few limitations. When the cluster node density or nodes density is increased it is very difficult to analyze the performance of the proposed model. Individual node or cluster node's energy is the main factor that decides the lifetime of the entire network. Due to idle listening, some of the nodes may have reduced energy level which are not useful for efficient operation of the WSNs.

In future, SCHRP model can be compared with LEACH-C, CBHRP, MH-LEACH protocols. Cluster node density will be increased to certain level and the same analysis will be carried out. SCHRP model can be compared with Power optimization routing techniques. The proposed SCHRP method can also be compared with single valued neutrosophic graph for WSNs in future. The theory and applications of neutrosophic methods will also be considered for further analysis.

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