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A Stable and Energy Efficient Zone based Cooperative Routing Protocol for Wireless Sensor Network

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Abstract

Background/Objectives: In the current work, a new zone based and energy-efficient cooperative routing protocol is presented by equally distributes the load of network among all nodes by establishing zones; separation of zones depends on the directions that address some of the requirements of Wireless Sensor Networks (WSNs).**Methods/Statistical Analysis**: Based on the analysis, cooperative communication improves the reliability and can be made the network topology more energy-efficient and stable. Reduction in the Transmission Time (TT) from source to destination by using Cluster Coordinates (CCOs) in inter-cluster and relay nodes in intra-cluster communication helps to prolong the network lifetime. The primary problem with existing solutions is the location of the Base Station (BS) increases transmission load upon Cluster Head (CH) which is nearby to the BS, so cluster depletes energy earlier as compared to others. **Findings:**The performance of proposed protocol is tested for dead nodes, alive nodes and packet send to BS. In homogeneous scenario, the results reveal that proposed Zone based Cooperative Routing Protocol (ZCRP) performs better in terms of energy-efficiency and stability as compared to Chain based Cooperative Routing Protocol (CBCCP), Low Energy Adaptive Clustering Hierarchy (LEACH) and Stable Electron Protocol (SEP). **Application/Improvements:**Based on the performance of ZCRP, this can be beneficial for those real time applications where data delivered on time is essential like Border surveillance, healthcare systems and many others.

Keywords: Base Station (BS), ClusterCoordinates (CCOs), Cluster Head (CH), Transmission Time (TT), Wireless Sensor Networks (WSNs)

1. Introduction

Because of the unbelievable growth in wireless technologies, WSN act as an interface between communication society and physical world. Moreover, WSN is considered as an admirable tool beneficial for various applications like disaster management, health secure systems and so on. WSN consist the autonomous nodes (capable for self-managing and self-healing) which are deployed in the field to make a communication scheme in the decentralized manner and form a multi-hop network. The WSN has unpredictable and unique features as compared to other networks but it also has some limitations like limited battery life, consumes more power that's why called as energy-constrained network[1].A huge deployment of sensor nodes results in the high transmission packet overhead that leads to more energy wastage. For designing a WSN, clustering has been adopted that provide benefits to minimize the energy consumption per unit data transmission. Clustering minimizes the communication between nodes and BS and it offers for proper energy utilization as well as load balancing. In Figure 1, instead of direct communication between source and destination the cooperative relay nodes (6,1) are accomplished for data forwarding because transmission range is large enough.

In clustering sensor networks, the various energy-efficiency issues have been examined when sensor nodes start collaborating while transmitting and reception of

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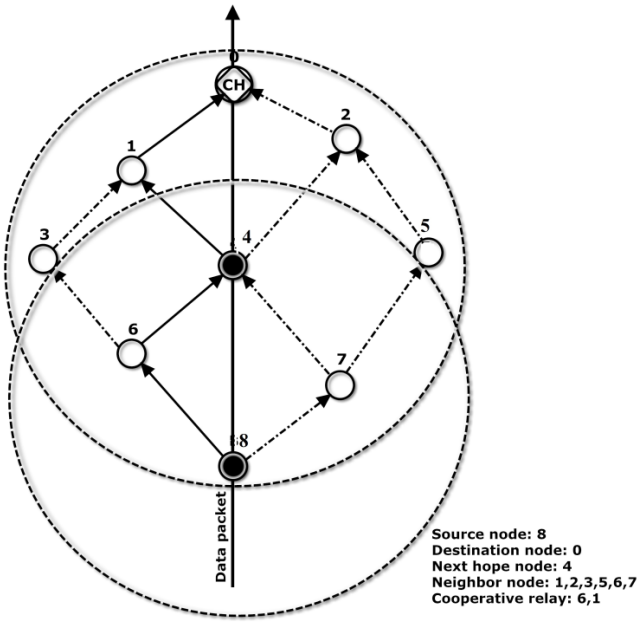

Figure1. Cooperative communication transmission

the signals. But on the other hand if the distance between the clusters is large enough then this scheme shows the remarkable performance by reducing the energy consumption in network even the collaboration among sensor nodes is being considered[2]. Our vision is on the main issues considered in WSN i.e. the management of an energy and reliability in data delivery. When signal follows the different paths to reach at the destination in presence of propagation like humidity, environmental conditions then there would be the chances of multipath interference that can lead to multipath fading[3]. Because of the multipath fading an increasing distance from CH to BS can further lead to path loss exponent. To avoid the fading, an energy efficient strategy i.e. cooperative communication has achieved the significant attention for providing the spatial diversity. With the help of spatial diversity techniques, the multiple nodes participating in network can collaborate among themselves to achieve the reduction in transmitting power and this strategy named as cooperative communication scheme. Cooperative communication beam forming helps to make the network more stable because in this each node has to transmit the data and always act as cooperative node for the others. In this, nodes having the single antenna extract some of the benefits of Multiple Input Multiple Output (MIMO) system. It means single antenna mobile user creates a virtual MIMO system by utilizing their antenna in an efficient way to achieve the high transmission rate.Another specific challenge related to WSN is topology control, it is beneficial for the WSN implementation but because of its complexity it may lead to the undesired results. So that the connectivity and coverage is very important terms to keep in mind while designing the topology control mechanisms[4].

In an existing cooperative communication scheme, the bottleneck problem occurs when complete data is transmitted to node which is nearby to the BS. At that time the nearest node overloads with data of all under beneath clusters and depletes energy earlier as compared to other ones and can also affect the routing path to sink. Energy of last cluster depletes earlier that cause the complete network disconnection in some era. Hence the network will be exhaust and minimize the stability period also.

Another problem: the whole network is treated as single network zone, so the packets coming from clusters which are far from BS travelled more that can cause the multipath fading.But in our ZCRP approach, sub cluster head (relay) are used to minimize the total data transmission time by aggregating data from nodes and further forwards to destination so that the load of network will be partially divided among all nodes. It is assumed that BS has a constant power supply with no energy constraint. The advantage of using relay's in cooperative communication is to increase the reliability of network by selecting an appropriate route between nodes and speed-up the communication. The relaying scheme is not fixed; it may be selective or incremental. In fixed relaying the nodes which can be considered as relay are always aggregate data from its neighboring nodes and forwards the received data to destination after processing on it. Spectral efficiency is increased by using an incremental relaying because it helps in saving the channel resources. In this a short feedback from destination to source indicates the success or failure of send data. In selective relaying the two phases are introduced; relay nodes can only forward the received data to destination either source can retransmit the data to destination. For this purpose, a fixed threshold value is set up, if Signal to NoiseRatio(SNR) of source to relay node link is large than threshold value then relay nodes forward the data otherwise source retransmits the data to its respective destination.

As we compare the single sub-cluster head approach with the multi-node cooperative communication; find out that single relay doesn't need cooperation beam-forming and in this only an optimized "relay" will be selected

among all of them for data transmission[2]. It neither makes the network overhead.

1.1 Objective

- To improve the energy efficiency and load balancing of conventional cooperative scheme by using zone based communication network
- The selected sub-cluster head (relay nodes) are in transmission range of CH so communication is considered to be half duplex
- To recommend the new transmission algorithm
- To reduce the transmission time as well as minimize the multipath fading

Cooperative communication scheme is single relay but it can be multi-relay. The relaying cooperative scheme exists with an optimal selection of packet size. As we compare the direct communication strategy with relay cooperative communication; it extends the source to destination hop length by increasing the number of hops between source and destination[5]. Because of the increasing number of hops the load of an entire network is balanced among various nodes which will make a protocol more energy efficient and stable.

In traditional schemes, it is assumed that relaying cooperative scheme wastes the channel resources. Moreover, this scheme doesn't utilize the resources in an efficient manner and it is not adapted to the available resources[6]. The orthogonal channels as well as additional resources both are required for communication purpose in case if relaying is not essential for transmission. But the purpose of an incremental relay scheme is to secure the available resources. Due to the broadcast nature of wireless networks, it relies on some fact that if SNR ratio of the transmission link is sufficiently high then it assumes the success of direct transmission between source and destination. In case if SNR ratio is low, the Non-acknowledgment from destination ensures that relaying is essential and starts transmitting the data. This scheme will make an accurate utilization of resources.

In[7] analyzed the results of two cooperative protocols Amplify and Forward protocol (AF) which employs with analog relaying and Decode and Forward protocol (DF). The comparison results show that in case if relay is nearby to source node then both protocols have similar results. If relay is moving towards destination or far away from source, then analog relaying is beneficial for network.

In[8] proposed an effective communication scheme having a single relay for the energy constrained WSN. Single relay selection is very much easier to implement because only an appropriate node is selected as 'relay' for signal transmitting which reduces the cooperation overhead. The numerical results confirmed that network lifetime of cooperative communication is large than direct communication as the cooperative communication is transmitted three times more packets.

In[9] studied on various Topology issues like Topology awareness and Topology control in WSN which can adversely effect on network lifetime. A specific Topology control protocol is a key to preserve energy, increase network lifetime and reduce the radio interference in energy constrained networks. The various routing schemes are discussed- 'Flat' in which all nodes available in the network having same level of energy. 'Hierarchical' in which the nodes with low energy are used to sense the environment only and nodes with high energy are used for transmitting the data. 'Location aware' in which each node knows about the exact location of others.

In[10] a new protocol named as Cooperative Power and Energy Efficient (COPE) has been proposed and results derived from the simulation proved that number of dead nodes is decreased after each round, that's why it provides a good throughput. At the end, the proposed approach compared with non-cooperative approaches LEACH and Power Efficient Gathering in Sensor Information System (PEGASIS) on basis of some parameters like Packet Delivery Ratio (PDR), throughput.

In[11] analyzed the performance of cooperative transmission scheme where nodes in particular cluster act as 'relay' and forwards the received data to nearby cluster. But in this scheme only those sensor nodes will be allowed in cooperative cooperation which can decode the data efficiently as per the requirement of network. The analysis of proposed scheme is based on Packet Error Rate (PER) and numerical results proved that we can improve inter and intra cluster communication more significantly by optimally balancing the energy levels in a network for the transmission purpose.

In[12] compared the two different schemes direct communication and Incremental Relay Cooperation (IRC) that are taking into account on effect of PER. Simulation results proved that IRC scheme will make the network more energy efficient significantly as well as communication reliability can be improved because hop counts will be incremented continuously from source to destination.

However, by taking multi-relay communication reliability may be improved but it's not favorable in terms of energy efficiency.

In[13] cooperative communication is presented for energy conservation and also describes some benefits over the non-cooperative communication schemes. The nodes participating in a network coordinates among them and shared their resources to enhance the spatial diversity and network's quality.

In[14] proposed CBCCP for Wireless Sensor Networks in which one CH aggregates data and transmit to the next cluster, second level CH further transmits and this process continues until the complete data has been transmitted to the BS. CCO is being used for inter-cluster communication and relay nodes with in particular cluster. In this way, it helps to reduce the total transmission time for transmitting packets as well as more energy efficient using multi hop data aggregation. The Simulation results of proposed scheme compared with traditional protocols and find out that CBCCP consumes six times less energy.

In[15]surveyed on the performance of static and dynamic clustering on basis of some distribution schemes for sensor nodes like binomial distribution, random node distribution. Enhanced Energy Efficient Protocol with Static Clustering (EEEPSC) depicts best results over LEACH (dynamic clustering) because its main objective is to reduce intra-cluster communication and also proved that uniform distribution of nodes increases the network lifetime as well.

In[16] made a systematic classification of solutions include mobile relay based scheme, mobile sink based scheme, data driven and duty cycling scheme for energy conserving and network lifetime is adopted. The suitable techniques have been devoted for less energy consumption because data acquisition cost can't be neglected.

In[17] proposed a clustering scheme in which network is organized in an efficient way for having equal cluster members in each cluster. This protocol outperforms over PEGASIS in terms of energy efficiency and stability.

In[18] proposed a new scheme 'LEACH-C' for load balanced among an entire network in which only BS decides the clusters in the network. It extends the network lifetime because all nodes consume equal amount of energy.

2. Multi-hop system analysis

For the convenience of readers, Table 1 presents the various network parameters and Table 2 depicts some of the notations used in this paper.

Table 1. Simulation parameters

PARAMETERS	VALUES
Network size	800*800
Base station	At the center of four zones
Packet size	4000 bits
Nodes	800
T* Transmission energy	50nj/bit
R*Reception energy	50nj/bit
Initial energy of Node	0.5j/node

Table 2. Notation parameters

E_a	Energy consumption for data aggregation
N_N	Total number of nodes
Sc_b	Radius of sub cluster head
E_T	Energy consumption for transmission
E_R	Energy consumption for reception
n	Neighboring nodes
E_{CT}	Energy transmission for cooperative transmission
P_C	Packet error rate for transmission
d_k	Distance
K	Path loss exponent
N_{CH}	Number of CH
D	Total distance from source to destination
Pr	Packet error rate for cooperative reception
n_{cn}	Nos. of neighboring nodes participate in cooperative transmission
E_{CCO}	Energy consumption by Cluster Coordinates
E_{CC}	Total energy consumption by network

2.1 Cooperative Communication Protocols

Cooperative routing helps to reduce power consumption and delay in transmission purpose also. An appropriate selection of relay for data transfer in an efficient manner is the most challenging issue in field of cooperative communication and the effective communication among the nodes will make network more energy efficient. There are two cooperative communication protocols have been discussed in this paper:

1. Amplify and Forward protocol in which relay node firstly receives the signal from source tries to amplify it and forward to its destination. It is totally based on principle of amplifying repeaters.
2. Decode and forward protocol in which relay retrieves the signal from the source. After that convert the

signal in form of bits then decode and modulate it. At the end it forwards to its respective destination and this relaying protocol was introduced by Thomas M. Cove et. Al.

3. Compress and Forward protocol was basically designed to get diversity benefits in which source already decode the data before sending to the relay node. Relay has further transmitted the data in compressed form to destination.

2.2 System Model

In ZCRP approach, two nodes while communicating uses the same transmission power so that links are symmetric and each node is aware about the location of other nodes in network. The specific aim is that each node has capability to communicate with its CH by minimum energy utilization. CH and CCO must use the efficient path while transmitting the data and node which are participating in cooperative communication can be a CH, CCO and sub cluster head (relay node) during clustering time.

In the monitoring area, transmission and reception among nodes is main reason of energy consumption that is being restricted the network's stability and lifetime too. To meet the objectives ZCRP approach is initializing by dividing the complete network into four zones on basis of directions i.e. North-East zone, East-South zone, South-West zone and West-North zone. This network is set up with fixed dimension (800*800m) in which 0 to 400m for 1st zone, 400m to 800m for 2nd zone on y-axis and same is for x-axis. In Figure 2area of particular zone like North-South zone is divided into sub-areas (clusters) and further each cluster is divided into sub-areas from which sub cluster head (inter-cluster communication) is elected to aggregate the data from its neighboring nodes. The CH is elected from each cluster and its responsibility of CH to receive data from sub cluster head and further transmits to next cluster. The receiving node in next cluster called as CCO (intra-cluster communication) and for each cluster there would be one CCO in next cluster and its responsibility of CCO to receive data of its CH. The last CH in particular zone be called as Relay Cluster Head (RCH) which is responsible to aggregate data from its cluster as well as from all CCO and directly transmits to BS. This data transmission process continues until the complete data has been received by BS. There is an increment in CCO at every cluster; let us suppose there are five clusters in one zone then at 5th cluster there will be four CCO for under beneath clusters. But no CCO is required at first

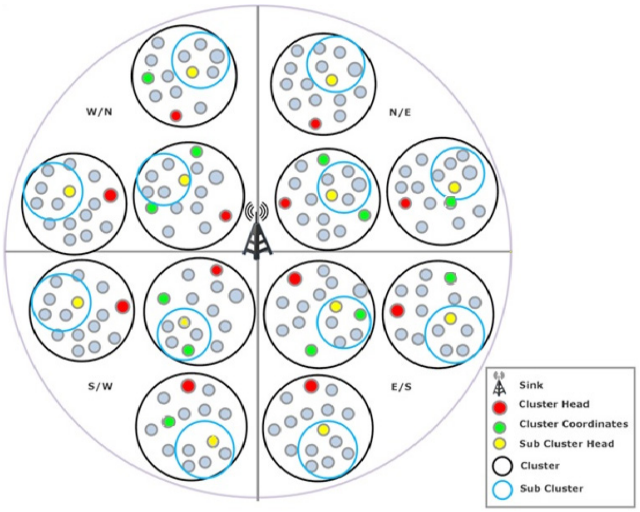

Figure 2. Proposed scenario.

cluster. In this way, load is balanced among all the nodes which are participating in cooperative communication and hence will make the network more energy-efficient.

2.2.1 *Why Static Nodes are Taken?*

No doubt mobile nodes are good but sometime nodes can move from one cluster to other because of the mobility feature, it can affect the clustering of a network and these nodes deplete energy very fast as compared to static nodes.

2.2.2 *Why We Put Dimensions for Each Zone?*

Sometimes in case of non-dimensional area, two or three sensor nodes are come under the range of different clusters then extra processing is required to check the location of all nodes. That's why static clustering with fixed dimensions is introducing so that no problems will occur.

The operation of ZCRP is broken up into iterations where each iteration consists various phases for data transmission.

- **Set-up Phase-** In beginning of this phase, cluster formation is described and nodes are deployed with same energy level. Random probability is generated by each node and for election of CH and CCO we have to compare the energy level of nodes with threshold value i.e. 0.1J. The nodes which are apart from CH depletes their energy earlier as compared to others; so we are introducing a new approach 'ZCRP' having sub cluster head and CCO for minimizing the data transmission.

This type of network flows for a very long term duration and hence increase the stability and network lifetime as well

- **Data Transfer Phase**- After the cluster formation, sub cluster head (relay node) is randomly selected from its respective CH and then starts transmitting the data. CH further transmits the received data to its CCO which exists at next cluster. In this way, the data from all zones received by BS in very less transmission time
- **Steady State Phase**- The two tasks are performed in this last phase i.e. sensing environment and transmission of data. It's necessary to keep the nodes alive till end of transmission because life of single node depends upon the energy utilized in transmitting data. How much energy is utilized by network is depend upon packet size and distance traveled by nodes. We can't reduce the size of packet but to minimize the distance from source to destination; Zone Based Approach is proposed to reduce multi path fading[Figure3].

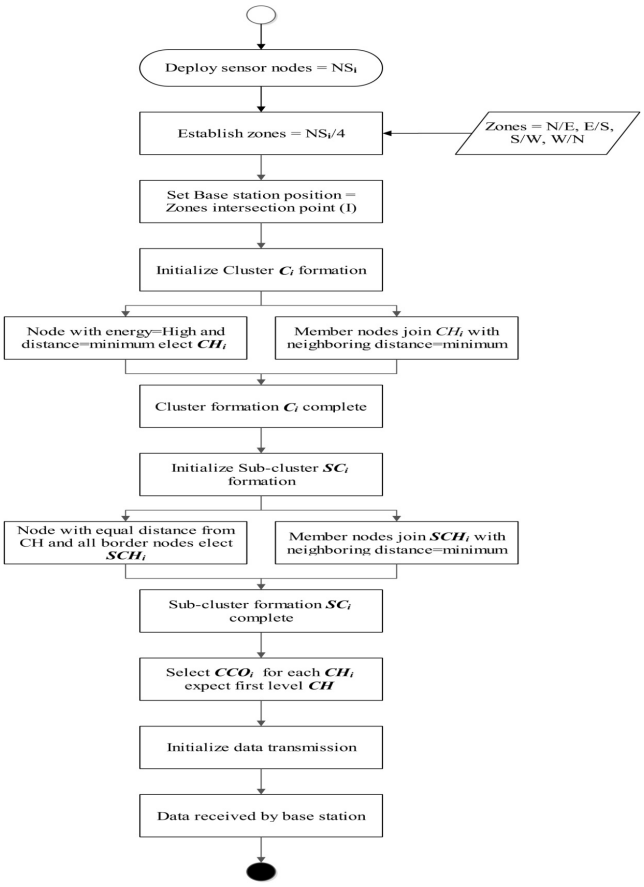

Figure 3. Flow chart for data transmission in ZCRP approach.

2.3 Clustering Attributes

The network is equally divided into four zones and each of them consist 200 nodes. In a Zone, approximately 5 static clusters are formed in which node are being elected as CH which has energy 0.1J $<E_{ch}<=$ 0.5J and minimum distance from the BS. In the next phase after sorting, selected CH's arranged in a descending order and then we can specify the CH which is far from BS is rank-1 in the network and so on. This strategy is made so that number of CCO in respective cluster is clearly defined. During first iteration CH is randomly selected, but re-election algorithm is applied in which node is elected as CH but only if that node was not acted as CH previously.

In an existing solution, the comparison can be made in residual energy of all the nodes and after that the node left with highest energy is being elected as CH. This scheme required an extra processing and increase complexity. In proposed approach for re-election process we only compared energy of node with threshold value (0.1J). There is no comparison of residual energy among nodes. So there would be less chances of complexity in ZCRP.

2.4 Energy Consumption in ZCRP

The radius of sub cluster head is Sc_b and energy consumed by sub cluster head to aggregate data from its neighboring nodes.

$$E_a (N_N, S^k b_b) = E_T (n^{cn}, S^k b_b, 1). E_R \quad (1)$$

As we know the total transmission distance (D) from source to destination in much more than radius of sub cluster head. The numbers of nodes come under respective sub cluster head are treated as: -

$$(\pi Sb^2_b)\ \rho = N_N (Sb_b) \quad (2)$$

For cooperative transmission, the energy consumed by sub cluster head for transmitting packets to its CH and energy consumed for reception of data by CH as well: -

$$E_{CT} = E_T (n^{cn}, P_c, d^k) * E_R \quad (3)$$

In next phase, energy consumed by CCO to receive data from its under beneath CH and forwards to next CH: -

$$E_{CCO} = (N_{CH}, d^k, P_r) = E_T \{N_{CH}, d^k) * E_R (P_r) \quad (4)$$

Eventually, energy consumption can be derived as:-

$$E_{CC} = E_a(N_N, S^k b_b) + E_{CCO} (N_{CH}, P_{r)} + E_{CT} (n^{cn}, P_c) \quad (5)$$

To reduce the total data transmission time, it's necessary that clustering time T_C is less than total operational time $ $T_{O.}$

3. Performance Evaluation

In this section, we present the simulation results of our proposed scheme ZCRP to show the benefits for various applications on MATLAB. All the four protocols are compared on basis of energy-efficiency, transmission time and network lifetime to show the stability and effectiveness of ZCRP approach from Figures 4 to 6.

In Figure 4, alive node is presented over 12000 rounds and find out that in LEACH not a single node is alive after 3200 rounds and after 3800 rounds in SEP. In CBCCP, after 5000 rounds no node is alive but in ZCRP 10 nodes are still alive up to 10000 rounds that will help to improve the network's reliability.

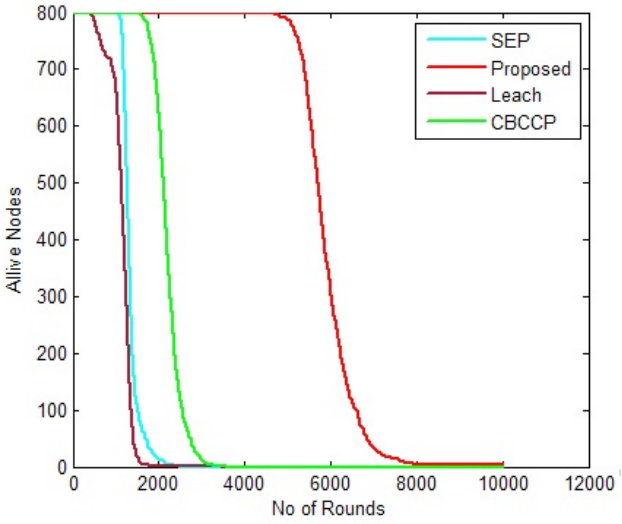

Figure 4. Alive nodes versus no of rounds.

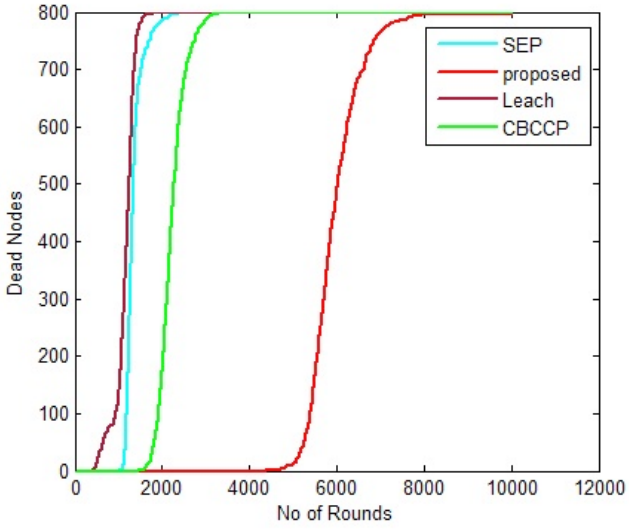

Figure 5. Dead nodes versus no of rounds.

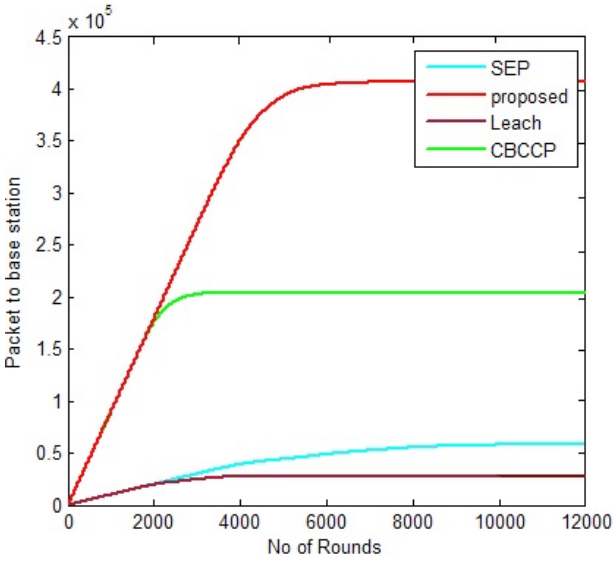

Figure 6. Packets send to BS versus rounds.

Figure 5, in 1000 rounds 98 nodes are dead in LEACH and 78 in SEP. In case of CBCCP, only 70 nodes are dead in 2000 rounds. In ZCRP not a single node is dead till 4000 rounds. In Figure. 6 ZCRP transmitted $4*10^5$ packets to the BS in 5000 rounds and CBCCP transmitted $2*10^5$ packets in 2000 rounds. So, ZCRP proved itself as an energy efficient and optimal approach over comparative approach.

Table 3 distinguishes the various clustering based routing protocols in terms of energy, data aggregation and so on. We find out that ZCRP leads in all above mentioned terms and it is proved to be the most energy-efficient approach. CBCCP also shows the good performance in energy efficiency aspect and this scheme has good QOS metric as compared to LEACH and SEP.

4. Conclusion

The protocol named as ZCRP is presented in this paper for WSN, where the complete network is equally divided into four zones for an equal distribution of network's load. A special attention has been devoted to enhance the network lifetime by reduction in total transmission time as well as distance from source to destination. We analyzed that this approach is useful to reduce the energy consumption per packet. Simulation results confirmed that ZCRP scheme shows the remarkable performance over CBCCP and other non-cooperative techniques LEACH, SEP in which direct communication scheme follows. We

Table 3. Comparison of routing protocols

Routing Protocol	Classification	Data Aggregation	QOS	Energy	Scalability	Power Usage
LEACH	Hierarchical/ Node centric	Yes	No	Energy Efficient& Consumption	Fair	Maximum
SEP	Hierarchical	No	No	High than LEACH	Limited	Limited
CBCCP	Hierarchical	Yes	Yes	Energy Efficient	Fair	Limited
ZCRP	Data Centric	Yes	Yes	Energy Efficient	Good	Minimum

show that how energy consumption by network can be reducing via relay nodes and CCO and it plays a representative role for speed up the network's communication. This cooperative communication scheme is a promising next research direction in which each zone has its own BS to make the protocol more energy preservative.

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