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Study on Co-operative Communication for Energy Efficient Routing in Wireless Sensor Network

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Abstract: ***Wireless Sensor Network (WSN) is a network of various nodes, which get connected with each other whenever they are deployed. The communication among nodes has been one of the major factors for the draining the energy of nodes. That is the reason, routing between sensor nodes becomes significant. In this paper, the one of the modes of routing is studied which incorporates co-operative communication among sensor nodes. The co-operative communication forms virtual MIMO (Multi Input Multi Output) structure which helps in enhancing the reliability and network lifetime of WSN. This paper contributes the summarizing the significant research work being done in the routing protocols following co-operative communication in WSN.***

Keywords: Co-operative communication, MIMO, energy efficient routing, Wireless Sensor Networ

1. Introduction

A wireless sensor network (WSN) comprises of hundreds to several thousand low-power multi-functional sensor nodes, doing work in an unattended environment, and having sensing, computation and communication capabilities. WSNs have managed to establish the connection between the physical world, the computing world and human society. WSN consists of a large number of tiny sensor nodes distributed over a large area with one or more powerful sinks or base stations (BSs) collecting information from these sensor nodes All sensor nodes have limited power supply and have the capabilities of information sensing, data processing and wireless communication.

A. Co-operative Communication

In recent years, many techniques have been proposed for improving the energy efficiency in energy-constrained and distributed WSNs. Among these techniques, the multiple inputs, multiple output (MIMO) techniques have been considered as one of the effective ways to save energy. The MIMO technique includes space-time coding scheme. It has layered space-time architectures. It has the potential to enhance channel capacity and reduce transmission energy consumption particularly in fading channels. These are also capable of providing high system performance without additional transmission power and bandwidth. Co-operative communication provides other various major advantages such as spatial diversity and data throughput.

In this scenario of WSN, due to the small size and limited energy of sensor nodes it becomes difficult to implement MIMO and to support multiple transmitters and receivers. Co-operative communication helps in the creation of Virtual MIMO in a WSN. A cluster of single-antenna sensor nodes can cooperate to form a virtual antenna array (VAA) to achieve virtual MIMO communication with proper timing and frequency synchronization between constituent nodes of the VAA. Virtual MIMO can realize the advantages of true MIMO techniques for WSN. It helps in enabling the single antenna wireless sensor node to perform in a multiuser environment. It is achieved with the help of sensor nodes sharing their antenna to achieve transmission diversity. Since all the benefits of MIMO of Co-operative communication are availed, it can be termed as Co-operative MIMO (C-MIMO) or Virtual MIMO (V-MIMO).

a) *Virtual MISO:* In WSN, MISO is formed when the multiple inputs are fed to the one of the cluster entities that may be a co-operative node, cluster head or any cluster node of another cluster.
b) *Virtual MIMO:* It is formed when the multiple inputs are fed to the multiple entities of a cluster. So the multiple outputs are generated and fed to the other multiple entities. Since WSN came into existence, the one of the prominent focus has been on the energy saving while carrying data transmission in the network. In order to achieve energy efficiency in data transmission the concept of cooperative MIMO has been adopted due to its significant contribution in load balancing in the network.

B. *Pitfalls of co-operative MIMO communication*

It is observed from the brief literature review that co-operative communication is really significant in improving the Quality of Service (QoS) parameters, while dealing with different routing techniques. However, following are the observed pitfalls of co-operative MIMO communication in wireless sensor network.

1) *Complexity in the network:* With the incorporation of cooperative communication and employing a virtual MIMO structure in WSN adds too much complexity in the network. As compared to the traditional clustering, the cooperative communication requires the synchronization in time scheduling for assigning the slots for the members of clusters and among them who are involved in inter-cluster communication. So there is a tradeoff between the energy efficiency required in the network and in the complexity that is added up due to a virtual MIMO structure built into the network.
2) *Delay-constrained application:* The schemes based on the cooperative communication become ineffective in dealing with the delay-constrained applications. It is due to the multi-hop data transmission within the cluster and

increased number of levels for sending the data to the base station (BS) through various inter-cluster communications.

3) *Energy cost added in the process of data aggregation:* When the network is incorporated with the cooperative communication, then each cluster head over an area will receive similar data packets or we can say redundant data. Consequently, it increases the cost of energy consumption over that area. However, this increase in the energy consumption could be overcome by enhanced network lifetime by achieving the load balancing in the network.
4) *Not suitable for large area application:* When the cooperative communication is involved in the intra cluster as well as in inter cluster communication, the nodes which are nearest to the sink are supposed to relay data from the farthest nodes which leads to the Hotspot problem. So with an increase in the area of the network, the effective distance of a node from the base station (BS) increases. This causes the heavy burden on the nodes nearest to the base station. Therefore, the cooperative communication becomes more suitable for small area applications.
5) *Increased number of overheads:* When co-operative communication is introduced into the network, the selection of various parameters like co-operative nodes, cluster heads, transmitter node, receiver node, are taken into consideration. The re-selection of these parameters in each round requires too many overheads for the declaration of the selected node to play a role in any of the above-mentioned parameters.

2. Related Work

Wenqing Cheng et al. in [1] proposed an optimization model to find the optimum number of cooperative nodes, clusters and transmission rates. Simulation results show that tremendous energy saving is possible with judicious choice of designed protocol parameters even considering the local circuit energy cost and STBC training overhead. They propose a cooperative MISO transmission scheme based on LEACH and analyze the end-to-end transmission energy consumption. To minimize the network energy consumption, they develop an optimization model to find the optimum communication parameter. Simulation results show that their proposed cooperative transmission scheme can lead to large scale energy saving compared with the LEACH.

J. Vidhya et al. in [2] proposed MIMO system which is evaluated in terms of energy efficiency and reliability. Simulation results show that tremendous energy savings can be achieved by adopting cooperative MIMO scheme among the clusters. The proposed cooperative MIMO scheme prolongs the network lifetime with 75% of nodes remaining alive when compared to LEACH protocol. A cluster-based cooperative MIMO scheme for multi-hop WSN has been explored and the performance of the system is evaluated to minimize the energy consumption and increase the lifetime of sensor nodes. The simulation results reveal that the LEACH protocol consumes more energy and has shorter lifetime of 7000 rounds due to the adverse channel fading effects.

Md. Abdullah-al MAMUN et al. in [3] proposed HACC, a heterogeneous-aware cooperative clustered scheme for wireless sensor networks based on weighted election probabilities of each node to become a cluster head according to its residual energy. Then they propose a simple modification in the clustering algorithm to exploit virtual MIMO based cooperative transmission. In place of selecting a single cluster head at network layer, we proposed multiple cluster heads in each cluster to obtain a full diversity gain over long distance communication without sacrificing transmission data rate, and established virtual MIMO based cooperative transmission.

Yongming Qin et al. in [4] LEACH (EE-LEACH) protocol and cooperative MIMO. EE-LEACH is an improved LEACH algorithm, in which the network is partitioned to sectors with equal angle for avoiding the distribution non-uniformity of cluster heads. For comparisons, LEACH, EE-LEACH, the simple cooperative scheme with LEACH and MIMO (LEACH-MIMO), and EE-LEACH-MIMO scheme are simulated. The result shows that EE-LEACH-MIMO scheme can well balance the network load, save energy and prolong the network lifetime. In the paper, they put forward EE-LEACH-MIMO scheme, which integrates MIMO technology into LEACH algorithm, and consider the location and the residual energy of each node when cluster heads for clustering and cooperative nodes for MIMO system are selected.

Vibhav Kumar Sachan et al. in [5] considerd the cases for fixed rate as well as variable rate constellation. Further, they investigate the impact of distance and long range distances on the choice of MIMO, MISO, SIMO, and SISO. They assume that the transmitters and receivers for each cluster are selected in offline and then the optimized constellation size is adapted for the cluster. Our results shows that the proposed MIMO based communication architecture can offer substantial energy savings in wireless sensors network provided that the system is designed judiciously for e.g. careful consideration of transmission distance requirements.

Neeraj Tiwari et al. in [6] proposed a new virtual MIMO communications architecture for energy-limited wireless sensor networks. They have provided analytical methods to obtain the energy consumption values for such virtual MIMO communications architecture based sensor networks taking into account transmission, circuit and additional training energy requirements. Their results show that even with extra energy over-head requirements, virtual MIMO-based techniques can offer substantial energy and delay efficiencies in wireless sensor networks provided the system is designed judiciously. These include careful consideration of transmission distance requirements and rate optimization.

Li Wang et al. in [7] considerd a clustered wireless sensor network where sensors are randomly distributed within a circle area with the only cluster head in the center. After the cluster head broadcasts source message to nearby sensor nodes, those neighboring nodes which have successfully decoded the message may help relay data for the head to the destination using space time block coding (STBC) scheme to form a virtual multi-input multi-output (MIMO) system. They first analyze the average outage performance and

overall energy consumption including transmission energy and the circuit energy. Then they present a transmission scheme to maximize system throughput as well as its performance dependence on data rate and power allocation decisions.

P. Naga Malleswari et al. in [8] proposed a cluster-based virtual multiple-input multiple-output (MIMO) communication scheme for energy-constrained wireless sensor networks. They investigate virtual MIMO for fixed and variable rates. They propose energy efficient routing space-time block coding (STBC) based virtual MIMO technique is incorporated into low-energy adaptive clustering hierarchy (LEACH). In the proposed scheme, instead of using cluster members as cooperative nodes, multiple cluster heads cooperate to form virtual antenna array so that STBC based MIMO technique can be implemented to achieve transmission energy savings. Compared to MIMO, Virtual MIMO provides more efficiency, simulation results show that the proposed scheme can provide efficient energy without any break in the sensor network, especially in situations where the sink is far from the sensor area.

Jianpo Li et al. in [9] proposed a new energy balance routing algorithm which has the following three improvements over the conventional LEACH algorithm. Firstly, they propose a new cluster head selection scheme by taking into consideration the remaining energy and the most recent energy consumption of the nodes and the entire network. Secondly, according to the ratio of remaining energy to distance, cooperative nodes are selected to form virtual MIMO structures. Thirdly, they construct a comprehensive energy consumption model, which can reflect more realistically the practical energy consumption.

Dr. P. Gnanasundari et al. in [10] proposed centralized scheduling is very helpful for top priority nodes for the usage of energy in efficient manner. To improve the performance of those continuous ant colony optimizations, the principles of evolutionary algorithm and artificial immune algorithm have been combined with the typical continuous Ant Colony Optimization, and the adaptive Cauchi mutation and thickness selection are used to operate the ant individual, so a new Immunized Ant Colony Optimization is proposed.

Li Fei et al. in [11] proposed a cooperative transmission strategy, where intermediate nodes participate in two cooperative multi input single-output (MISO) transmissions with the node at the previous hop and a selected node at the next hop, respectively. In this paper, a cooperative transmission strategy is proposed to mitigate energy hole problem by exploring the network energy balancing capability and improving energy efficiency simultaneously.

Pawan Singh Mehra et al. in [12] proposed a heterogeneity-based energy efficient clustering scheme for distant base station. In this protocol, cluster head selection is based on localized parameters of the node. The proposed work is simulated for two level and multilevel heterogeneous energy model. Simulation results validate the extended stability of proposed work. The proposed protocol remarkably outperforms SEP and DEEC. They describe the proposed work for heterogeneous wireless sensor network where base station is far away from base station. In this protocol, best candidate for cluster head is chosen keeping in mind the parameters that affect the energy of node to prolong the network lifetime. Proposed protocol performs remarkably well in two level as well as multilevel model.

Anjali Bharti et al. in [13] proposed enhanced energy efficient Leach (EEE-LEACH) routing algorithm reduces the energy consumption in the network by using MIMO technology and a shortest path algorithm which provides the shortest path for data transmission in fading channel.. The simulation results have proved that EEE–LEACH algorithm is more energy efficient than EE-LEACH-MIMO. The simulation results show that the proposed EEE– LEACH algorithm enhances the energy efficiency and lifetime of the sensor network by providing the shortest route for data transmission from member sensor nodes to the cluster head node in the cluster and from cluster head node to master head. MIMO technology is used for cooperatively transmitting information in the network, which reduces energy consumption in fading channel.

3. Conclusion

WSNs have various applications which are limited by only imagination of human beings. There have been various routing protocols aiming to enhance network lifetime. The one of the routing strategies, i.e. cooperative communication has been significantly imapactful. It doesn't only enhances the network lifetime, but also provides the reliability for data transmission to the base station. In the retrospective study of co-operative communication in WSN, it is found that virtual MIMO leads to the much better load balancing in the network. The selection of co-operative head and normal cluster heads, have been one of the important issues in implementing the virtual MIMO structure. It is observed that there is wide research gap that is to be fulfilled for selection of co-operative head and cluster head in co-operative communication.

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