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COOPERATIVE NODE SELECTION FOR VIRTUAL MIMO IN WIRELESS SENSOR NETWORKS

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Abstract - **Wireless Sensor Networks have wide range of applications and hence there is a great need to improve the performance. One of the major issue is to reduce the energy consumption by the sensor nodes as energy is the major constraint. Energy minimization now-a-days is a burning issue for remotely clustered wireless sensor networks. Wireless nodes typically operate with small batteries for which replacement, when required is very difficult and expensive. Thus, in order to increase the network lifetime, minimization of the energy consumption is a very important design consideration. Cooperative techniques need to be incorporated to avoid this problem. The proposed technique selects cooperative nodes in a network using a multi-criterion based algorithm and data is transmitted through multi-hop. Transmit power is reduced considerably through multi-hop communication thus the overall performance is enhanced. Through the proposed technique unnecessary transmissions by the non-cooperative nodes are avoided. The proposed scheme offers better performance in terms of bit-error-rate.**

Keywords- **Cooperative Nodes, Sensors, Clusters**

1. INTRODUCTION

A wireless sensor network (WSN) consists of autonomous sensors distributed spatially to cooperatively monitor environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants. The development of wireless sensor networks was motivated by military applications such as battlefield surveillance and is now used in many industrial and civilian application areas, including industrial process monitoring and control, machine health monitoring, environment and habitat monitoring, healthcare applications, home automation, and traffic control. These systems have unique characteristics and face many implementation challenges. Among all, the requirement of long operating life for a wireless sensor node under limited energy supply imposes the most severe design constraints. This calls for innovative design methodologies to address this rigorous requirement. The WSN is built of "nodes" – from a few to several hundreds or even thousands, where each node is connected to one (or sometimes several) sensors. Each such sensor network node has typically several parts: a radio transceiver with an internal antenna or connection to an external antenna, a microcontroller, an electronic circuit for interfacing with the sensors and an energy source, usually a battery or an embedded form of energy harvesting. A sensor node might vary in size from that of a shoebox down to the size of a grain of dust.

MIMO approach using alamouti code and node selection using distance criterion was proposed[1]. Low-cost and low-power sensor nodes forming Wireless Sensor Networks (WSN's) have become suitable for a wide range of applications during recent years. These networks, due to their special functional characteristics, demand the implementation of energy-aware techniques in all layers. Recently a MIMO – based structure has been proposed to offer enhanced energy savings in WSNs under certain circumstances. In this paper, a detailed analysis of the dissipated power during a sensor node's operation, to prove that as microelectronics develop the MIMO – based architecture will outperform the equivalent SISO structure for almost any case, in terms of energy efficiency. Moreover, introduce a simple Cooperative Node (CN) Selection algorithm to achieve additional energy gains in the MIMO approach along with enhanced network lifetime. The scalability of the algorithm on different channel conditions and varying network density, and the effect of the power dissipation analysis on its efficiency was examined. The drawback of this technique is that it considers only distance criteria for node selection. Sensor nodes in most cases operate on small batteries, which are difficult to replace, and thus have restricted sources of energy.

A technique that involves two paths (LOS & NLOS) and Received Signal Strength (RSS) was proposed [2].The paper presents an energy efficient selection of cooperative nodes with respect to their geographical location and the number of nodes participating in cooperative communications in wireless sensor networks. The cooperative communication in wireless sensor networks (WSN) gives us leverage to get the inherent advantages of its random node's locations and the direction of the data flow. Depending on the channel conditions and the transmission distances, the number of cooperative nodes is selected, that participate in an energy efficient transmission/reception. Simulation results show that increasing the cooperative receive diversity, decreases the energy consumption per bit in cooperative communications. The network backbone capacity can be increased by controlled displacement of antennas at base station at the expense of energy per bit. The drawback is that it is not very accurate as distance criteria has not been taken into consideration and since sensor networks are usually a low data rate networks, therefore low energy cooperative communication is opted.

A node selection scheme based on Received Signal Strength(RSS) was proposed[3]. In this paper, a cooperative localization algorithm for wireless sensor networks is presented. An RSS-based localization algorithm due to its lower complexity with respect to other ranging techniques such as TOA or AOA is used. Since the energy consumption is a key aspect in sensor networks, a node selection algorithm in order to avoid the use of all the nodes in the network for positioning purposes is proposed. Thus, a practical solution tailored to the strict requirements of sensor networks in terms of complexity, size and cost is derived. In particular, nodes in the network select the cooperating nodes by simply comparing their received RSS with a threshold. Simulation shows that the proposed scheme offers a good trade-off in terms of position accuracy vs. energy consumption. Furthermore, it does not imply any additional cost in size or complexity. The disadvantage of this technique is that the distance criteria has not been considered.

There are various location identifying modalities that has been studied for wireless networks, including time-of-arrival (TOA), angle of- arrival (AOA), and received-signal strength (RSS). Each has its own advantages and disadvantages. For example, radio-signal-based TOA estimations are not cost-effective because of timing and synchronization issues.AOA measurement requires a carefully calibrated antenna array, which is significantly expensive and complex. Fading characteristics of the signal makes RSS based measurements unreliable. Sensor networks have very different characteristics as compared with other wireless networks. Some of the unique characteristics, such as severe resource constraints, further complicate the design of reliable localization techniques, the RSS of radio signals can easily be measured in almost all existing wireless systems, which makes the RSS-based method a desirable alternative for miniature sensor nodes. Thus, the focus is on RSS-based techniques.

2. SYSTEM MODEL

A system of distributed sensors, can monitor an area and detect, identify, localize, and track an object for environmental monitoring, military applications, industrial automation, and traffic control. Distributed nodes in wireless networks are required to transmit to or receive from a remote location. Most often, the communication range is limited by the transmission power level of the individual network nodes since each node is usually operated by a battery. In this energy-constrained network, cooperative communication techniques can greatly increase the energy efficiency and range of communication. Through cooperative node selection the lifetime of the network can be enhanced remarkably. Since the sensor nodes operate on extremely low power for a long period of time, energy efficiency is a critical issue in wireless sensor networks. Sensor networks are typically organized in clusters or groups. One of the nodes in the cluster acts as an elected leader or cluster-head. The data in the cluster is collected and forwarded to the base station/s by the cluster-head. Thus cluster-head consumes more energy than the cluster-members. The clustering is driven by the minimization of energy for all the sensors. Once the clusters are formed and cluster header is set, cooperative nodes in each cluster is selected by the respective cluster headers. MIMO systems require less transmission energy than SISO systems. It is difficult to build multiple antennas on low-cost, small-sized sensor nodes. Hence, it is possible to implement MIMO techniques in WSN without physically having multiple antennas at the sensor nodes via cooperative communication techniques. Use of cooperative communication in WSN allow energy savings through spatial diversity gains. Cooperative nodes co-operate with each other at run time to send / receive data.

A. Architecture

The proposed model for communication between two nodes is shown in Figure 4.1. Communication within the same cluster is inter-cluster transmission and communication between different clusters is called intra-cluster transmission. Source transmits the data to its cluster header. The cluster header selects cooperative nodes in its cluster and transmits data to it. All these nodes collaboratively transmit data to the next cluster header. Cooperative nodes are selected by the cluster header and data is transmitted to it. This continues till the destination is reached.

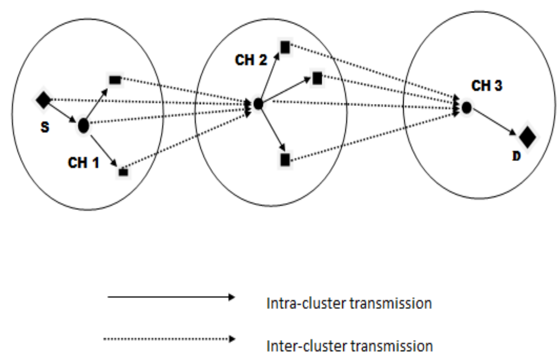


Figure 1 Architecture

B. Algorithm

The steps followed are,

1. Sensor nodes are deployed randomly.
2. Sensor nodes form a cluster based on any one of Cluster head protocol.
3. Cluster head is set.
4. If a node says S wants to transmit the data to the node D it sends the data to cluster head.
5. The cluster head find the path to D using routing algorithm. The routing algorithm gives the direction of data to D.
6. Co-operative nodes are selected based on the Multi-Criterion based algorithm.
7. Co-operative nodes receive the data.
8. Synchronization is applied to synchronize all the cooperative nodes because the nodes have to transmit collaboratively.
9. After synchronization the nodes sends the data to the next hop cluster head.
10. The steps 6 to 9 is repeated in the network until D receives the data.

C. Flowchart

Random placement of nodes is considered because sensor network deployment is random in nature most of the times. Cluster formation is done using the square of the distance between the nodes present in the network. Cluster Header is set. The nodes in the network join the nearest header and thus clusters are formed. Cooperative Node selection is done based on multi-criterion based algorithm.

D. Multi-Criterion Algorithm

Position accuracy is one of the vital characteristic of this algorithm. The node location is taken into consideration The criterion includes distance and Signal–to-Noise Ratio(SNR). Distance between the nodes are calculated. A threshold distance is fixed for comparison. The transmitting antenna height (h_t) and receiving antenna height (h_r) are used to calculate threshold distance. The calculated distance between nodes is compared with the threshold distance. If the distance calculated is less than the threshold distance, the nodes are found to satisfy the distance criterion of cooperative node selection.

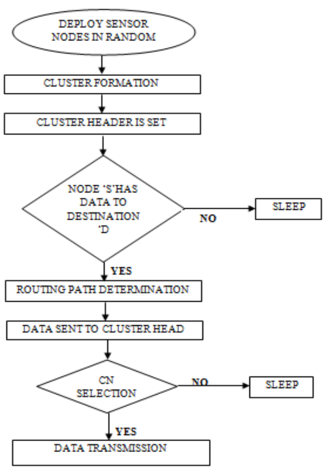
Threshold Distance (d_0) $=4\pi h_t h_r/\lambda$

$$d = \sqrt{((n_{ch}(x_i) - n(x_i))^2 + ((n_{ch}(y_i) - n(y_i))^2}$$

where, d-distance; $n_{ch}(x_i)$, $n_{ch}(y_i)$ – cluster header's position; $n(x_i)$, $n(y_i)$ - position of ith node ; i=1 to 100. Signal-to-Noise Ratio (SNR_i) between all nodes in the network is determined and the average Signal-to-Noise ratio (SNR_{th}) is calculated. The two parameters are compared. If the SNR of node is greater than the average SNR, the nodes are found to satisfy the SNR criterion.

$SNR_{th} = \sum SNR_i$ where i= number of nodes in the cluster. The nodes that satisfy both the criterion are termed as cooperative nodes. After the adoption of cooperative nodes for each cluster, the cluster head (CH) transmits the data to its cooperative nodes (CN). Then the CH and CN transmit the data to the next hop CH. The cluster head checks its cluster if the destination is present in its cluster. If yes data reaches the destination else data is transmitted to the next hop CH and so on.

3. SIMULATION



The simulation results were obtained using MATLAB.

Random placement of nodes is considered for deployment of nodes and position accuracy is maintained. Cluster header is set and cluster formation takes place. The sensor nodes are randomly placed, because the deployment of nodes in a practical situation is random. Here the random placement done in the area of 500 x 500 m^2. and the Cluster Heads i.e. 5,10,15,20,25,30,35,40,45,45 are set. Here ten clusters are formed. The connection between the Cluster head and their nodes in the cluster is based on the distance between them. Figure 5.1 shows the different Cluster heads and their corresponding clusters. The source node transmits data to its corresponding cluster head (CH).The CH transmits data to the next hop CH after having selected cooperative nodes in its cluster. There is intra-cluster transmission within the cluster between the header and its cooperative nodes. The routing table is checked to determine whether the destination node is present or not. The transmission continues till the destination is reached.

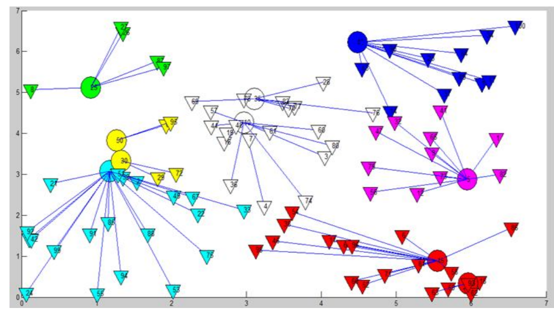


Figure 2 Cluster formation for 100 nodes

Fig 3 shows the routing taking place between the source node 1 and the destination node 18. Routing table is framed and the data reaches the destination through multi-hop. The routing table is checked for the destination before each hop.

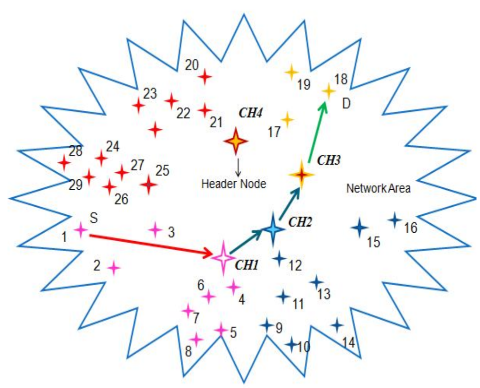


Figure 3 Sample Scenario

Table .1 Routing Table for Sample Scenario

S.No	Header Node ID	Neighbor Node Ids	Neighbor Header
1	CH1	1, 2, 3, 4, 5, 6, 7, 8	CH2
2	CH2	9, 10, 11, 12, 13, 14, 15, 16	CH3, CH1
3	CH3	17, 18, 19	CH2
4	CH4	20, 21, 22, 23, 24, 25, 26, 27, 28, 29	CH1

Here we consider four clusters with 5, 10, 15 and 20 as headers. Source node is 17 and destination node is 75.Source node 17 transmits data to its corresponding cluster head 5. Header node checks its routing table to find whether the destination node is present in its own cluster. Since 75 is not in the cluster the transmission continues to the next nearest cluster head 20. The transmission continues and finally the destination is reached.

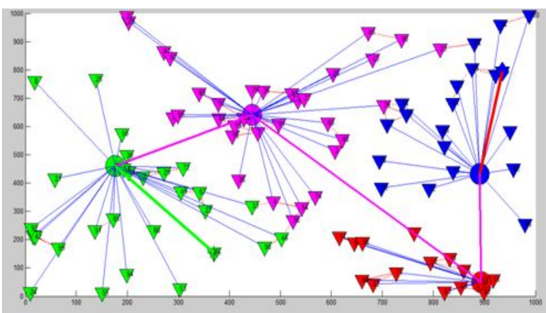


Figure. 4 Path (17-5-20-10-15-75)

4. RESULTS

The SNR – BER curve with and without cooperative node (CN) selection have been compared and it is observed from Fig 5 that better signal to noise ratio is obtained for the network with CN selection.

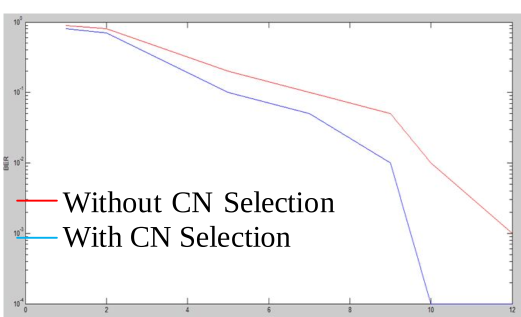


Figure.5 SNR Vs BER

Figure 6 depicts the reduction in the hop count as distance increases in cooperative and non cooperative node selection cases.

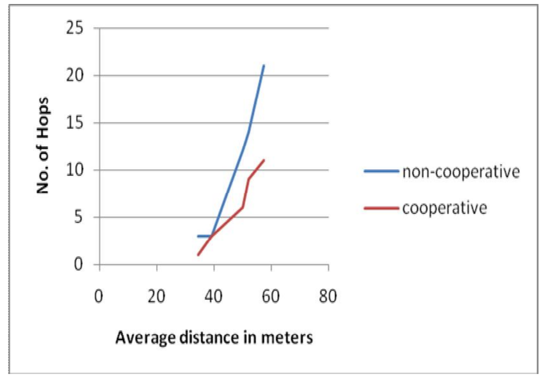


Figure.6 Average Distance Vs No. of Hops

6. CONCLUSION

The various concepts and methods to improve the performance of wireless sensor networks using cooperative node selection are reviewed. Bit-Error-Rate (BER) and power dissipation is reduced through multi-hop transmission. The network lifetime is enhanced as a result of cooperative node selection. The performance characteristics have been plotted and compared. In order to improve the signal to noise ratio of the received signal we have to implement the collaborative beamforming concepts in wireless sensor networks. To perform collaborative beamforming random array algorithms have to be implemented.

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