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New strategy of cooperative nodes selection for CMIMO-SM in Wireless Sensor Network

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***Abstract*—Recently, two techniques: Cooperative Multiple-input multiple output (CMIMO) and Spatial Modulation (SM) have been combined for energy-efficiency improvement, high data rate and low complexity transmission schemes. Nevertheless, CMIMO has a critical issue. It is that all nodes into cluster must keep their receivers on during cooperation phase which leads to dissipate a lot of energy. To overcome this shortcoming, we propose a strategy to select a set of nodes in the cluster as cooperative nodes instead of using all nodes of the cluster as cooperative nodes. In other words, we have to divide clusters to sections. Each section contains a number of sensor nodes which will be used in communication. By using this novel method, a large amount of energy consumption can be reduced. Simulation results show this significant savings.**

***Keywords*-Wireless Sensors Network; Cooperative Multiple Input Multiple Output; Spatial Modulation; Energy efficiency**

I. Introduction

Wireless sensor networks (WSNs) are composed of thousands of tiny and battery powered nodes that are deployed randomly over a geographical area. The critical issue for a credible deployment consists to how to reduce the energy consumption of nodes and maximize the network lifetime. Multiple-input multiple output (MIMO) is a proven technique to improve data throughput and reduce energy consumption of a wireless sensors network [1]. However, in WSN, sensor node is equipped only by one antenna due to its small physical size. For this reason, the Cooperative Multiple-input multiple output (CMIMO) approach [2] can dramatically reduce the total energy consumption. Furthermore, a new transmission approach named Spatial Modulation (SM) was proposed by Mesleh et al. [3, 4]. During each slot time, a single transmit antenna is activated. Hence, SM efficiently avoids Inter-Channel Interference (ICI) caused by multiple antennas. In [5], Yuyang Peng and Jaeho Choi had combined CMIMO with SM and results show the significant savings of energy consumption. To improve energy-efficiency based in this scheme "CMIMO-SM", we have proposed a new strategy to choose cooperative nodes inside cluster instead of use of all nodes of the cluster.

This paper is organized as follows. We present the related work in Section II then the system model in Section III. In section IV, we have detailed our proposed strategy of selecting cooperative nodes. Energy efficiency of our proposed scheme is presented in section V. Simulations setups and results are shown and discussed in section VI. Finally, section VII concludes the paper with insights for future researches in reducing energy consumption in WSN.

II. Related Work

In [1], for the first time, a CMIMO concept was proposed by Cui et al. for single hop transmission in WSN. It was shown that CMIMO can achieve real MIMO advantages in terms of energy efficient performance if the transmission distance is longer than the critical distance. In [5], the combination of CMIMO and SM shows important results for reducing energy consumption. In [7], the authors have demonstrate that based on transmission distance, the selection of the number of cooperative nodes at both transmitter and receiver sides reduces the energy consumption. As presented in [8], application of CMIMO technique in a WSN that is divided to clusters has major energy efficiency. In [9], the authors optimized energy consumption per unit transmit distance by selecting the number of cooperative nodes and the transmit energy consumption. In [10], MISO scheme based cooperative communication is proposed. This scheme is based on channel estimated selected nodes. Reference [12] presented two methods of selection of cooperative sensor nodes for each forwarding node over the path between source and destination based on the Dynamic Source Routing (DSR) algorithm. However, there is a limitation within the selection of a single cooperative sensor node for each forwarding node. This limitation is treated in [13]. Authors proposed a method that selects multiple cooperative sensor nodes based on "quality" and "angle" metrics criterion, which can select and order adequate cooperative nodes uniquely according to the criterion.

III. System Model

We adopt the same CMIMO-SM model depicted in [5, 11] with M_t transmit and M_r receive antennas. During a transmission period and since SM is used, only one transmit antenna is activated. Consequently, ICI can be efficiently avoided. In SM technique, as shown in Fig.1, information bits are split to two blocks. The first block is M-ary Quadrature Amplitude Modulation (MQAM)/ M-ary phase-shift keying (MPSK) symbol and the second one is the active transmit antenna. Each block contains $B_{SM} = \log_2(M_t) + \log_2(M)$ bits where $\log_2(M_t)$ bits select the transmit antenna of the signal, $\log_2(M)$ bits are mapped according to the spatial constellation point and M is the size of the complex signal-constellation diagram.

The CMIMO-SM process communication [5] is depicted in Fig.2. In fact, at transmitter, each sensor node broadcasts its information to the cooperative sensor nodes into the same cluster. When each cooperative node receives all information bits, the ready data is sent by one transmit antenna already chosen through the MIMO channel. At receiver, there is one destination node and M_r-1 nodes join the cooperating nodes in reception.

IV. Cooperative Nodes Selection

A. Criteria of selection

In the CMIMO technique, the main drawback is the local data transmission at both transmitter and receiver side. It costs additional energy in transmission due to the circuit consumption of nodes in cooperation and the overhead needed to support nodes cooperation. This extra energy is related to the number of cooperative sensor nodes and the local distance d_m separating two cooperating nodes at both transmitter and receiver sides.

To overcome the above drawback, we propose to use a number of nodes at the same cluster instead of using all available nodes as cooperative. To achieve this goal, we consider some important criteria. Assuming that the overall energy consumption depends essentially on inter sensor nodes distance into the cluster and geographical location of the sensor nodes. In fact, we are based on these parameters to construct a strategy for selecting optimal cooperative nodes.

B. Strategy of selection

The distance between sensor nodes into the same cluster is called the inter sensor distance d_m. More sensor nodes are closer to each other less is the energy consumption for local communication. The distance between transmit and receive clusters is d. Hence, the geographical location of sensors is an important factor that influences the total energy consumption. This last one increases when d increases. Due to previously explained parameters, we propose to select a set of sensor nodes as cooperative nodes from the whole nodes in the same

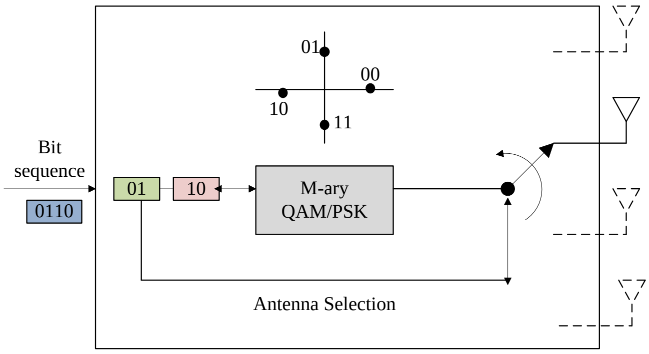

Fig. 1 Transmitter structure of Spatial Modulation

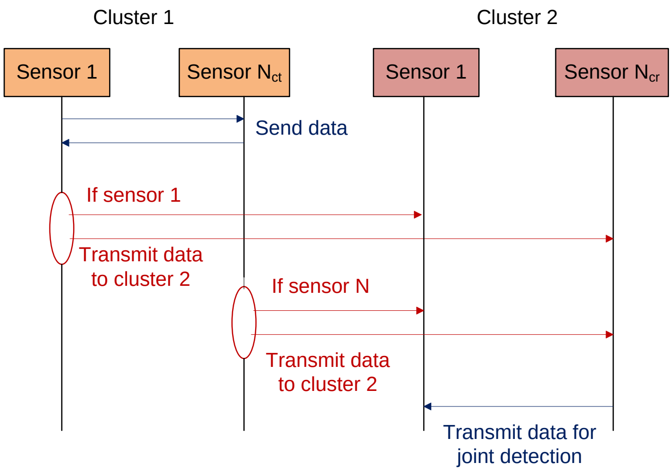

Fig. 2 Communication process of CMIMO-SM

cluster. In reality, after dividing the WSN in clusters, we need to divide also clusters in sections. The key idea of this strategy is to divide clusters in the network to a number of sections. Exactly, each cluster must have eight uniform sections starting from the center of the cluster. Each section contains a number of nodes N_c that will cooperate if needed as shown in Fig.3. The choice of cooperative nodes to use from transmitter cluster depends on the receiver cluster. In fact, in transmitter side we must know the geographical information about the receive cluster. Based in this information, we can choose the adequate section in other words the cooperative nodes in transmitter side. Then, in receiver cluster, we use the section which contains the receiver node.

This distribution allows sensor nodes in close proximity and also the closest nodes to the destination to cooperate in transmission. In this manner, the number of cooperative node and local distance dm are reduced consequently the energy of data exchange inside cluster. Indeed the choice of cooperative nodes depends also on the location of receive cluster. We must select the closest section of the transmit cluster. Thereby, the long haul distance is also reduced. For the novel SM mapper, the sequence of bits to send is divided into two subgroups $\log_2(M)$ and $\log_2(N_{ct})$.

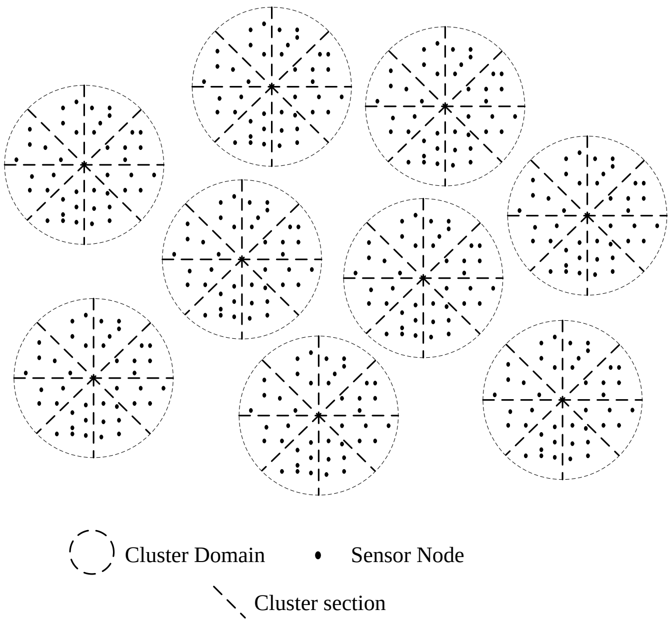

Fig. 3 Proposed clustering section in WSN

These results imply minimizing of the total energy consumption as shown in simulation results in section V.

V. ENERGY MODEL

We consider the same energy model of [2], the total energy consumption per bit is given by:

$$E_{bt} = \frac{P_{PA} + P_c}{R_b} \tag{1}$$

Note that P_{pa} is the power consumption of all the power amplifiers and P_c is the power consumption of all the circuit blocks and calculates as follows:

$$P_{PA} = (1+\alpha)\overline{E}_b R_b \frac{(4\pi d)^2}{G_t G_r \lambda^2} M_l N_f \tag{2}$$

where $\overline{E}_b$: energy per bit required at the receiver for a given Bit Error Rate requirement, R_b : Bit rate, d : distance between source and destination node, G_r : Receiver antenna gain, G_t : Transmitter antenna gain, λ : Carrier wavelength, M_l : link margin, $N_f=N_r/N_0$: Receiver noise (N_0 : single sided thermal noise Power Spectral Density (PSD) at room temperature and its value is −171 dBm/Hz and N_r : Power Spectral Density of the total effective noise at the receiver input).

Note also that: $\alpha=\xi/\eta -1$ with $\xi= 3(M^{1/2}-1)/ (M^{1/2}+1)$ is the Peak-to-Average Ratio and η is the drain efficiency of the RF power amplifier for MQAM.

$$P_c = M_t (P_{DAC} + P_{mix} + P_{filt}) + 2P_{syn} + M_r (P_{LNA} + P_{mix} + P_{IFA} + P_{filr} + P_{ADC}) \tag{3}$$

Note that:

P_{DAC} and P_{ADC} are the power consumption of Digital to Analog Converter and Analog to Digital Converter respectively.

P_{filt} and P_{filr} are the power consumption of active filters at transmitter and receiver respectively.

P_{syn}, P_{mix}, P_{IFA} and P_{LNA} are respectively the power consumption of the frequency synthesizer, mixer, Intermediate Frequency Amplifier (IFA) and Low Noise Amplifier (LNA). The values of P_{ADC}, P_{IFA}, and P_{DAC} are calculated in the same way as in [6].

According to (1) and (2), the total energy consumption per bit can be rewritten as:

$$E_{bt} = (1+\alpha)\overline{E}_b R_b \frac{(4\pi d)^2}{G_t G_r \lambda^2} M_l N_f + \frac{P_c}{R_b} \tag{4}$$

From [5], the total energy consumption per bit for CMIMO-SM is calculated as follows:

$$E_{btcsm} = E_l + E_{lh} \tag{5}$$

Where E_l and E_{lh} are the local and long haul energy consumption respectively. E_{lh} is calculated according to (4):

$$E_{lh} = (1+\alpha)\overline{E}_b R_b \frac{(4\pi d)^2}{G_t G_r \lambda^2} M_l N_f + \frac{P_c}{R_b} \tag{6}$$

Where d is the long haul distance between transmit and receive clusters.

And E_l is expressed below:

$$E_l = \frac{\sum_{i=1}^{Nct} N_i E_i^t + \sum_{j=1}^{N_{cr}-1} E_j^r \sum_{i=1}^{N_{ct}} N_i}{\sum_{i=1}^{N_{ct}} N_i} \tag{7}$$

Note that N_i is the number of transmit bits, N_{ct} is the number of selected cooperative nodes in transmitter side, E_i^t is the data exchange energy in transmitter cluster and E_j^r is the data collection for joint detection in receiver cluster.

After combining (5), (6) and (7), the final expression of the total energy consumption per bit for CMIMO-SM is:

$$E_{btcsm} = \frac{\sum_{i=1}^{Nct} N_i E_i^t + E_{lh} \sum_{i=1}^{N_{ct}} N_i + \sum_{j=1}^{N_{cr}-1} E_j^r \sum_{i=1}^{N_{ct}} N_i}{\sum_{i=1}^{N_{ct}} N_i} \tag{8}$$

VI. SIMULATION RESULTS

In this section, we perform simulation in MATLAB tool to evaluate the proposed scheme. We assume that each sensor node has Ni= 20kb to transmit. The rest of parameters is below : G_tG_r = 5 dBi ; M_l =40dB; N_0 = -171 dBm/Hz; f_r=2,5 GHz; N_f=10 dB; λ=0,12 m; η=0,35; P_{syn}=50 mW; P_{mix}=30 mW; P_{LNA}=20 mW; $P_{filt}=P_{filr}$=2,5 mW; P_{IFA}=3 mW; P_{DAC}=6,698 mW; P_{ADC}=15,437 mW; E_{da}=5 nJ/bits/signals; L_c=8; n_t=10; f_{cor}=1 MHz; l_0=50 µm; L_{min}=0,5 µm; $n_1=n_2$=10; B=10 kHz; C_p=1 pF; β=1; V_{dd}=3V

The energy consumption per bit comparisons for 2bits, 3 bits, and 4 bits systems between CMIMO-SM-8-Sections and CMIMO-SM are depicted in Figures 4, 5, and 6, respectively.

From above plots, we see that the proposed CMIMO-SM beats CMIMO due to the advanced transmission scheme. Also, for both systems, as the transmission distance increases, energy consumption per bit increases. Moreover, for both systems, the energy consumption per bit decreases as the transmission rate increases from 2 bits/s/Hz to 4 bits/s/Hz. This can be explained by the reason that circuit power working in a shorter time will bring lower energy.

Let's now present the simulation results of proposed scheme CMIMO-SM-8-Sections.

Comparisons for 2 bits, 3 bits, and 4 bits systems in terms of energy consumption per bit between CMIMO-SM and the CMIMO-SM-8-Sections are presented respectively in Fig. 4, Fig. 5 and Fig. 6.

We can see from these plots that the proposed scheme beats the CMIMO-SM approach in saving energy consumption. Therefore, with sectoring the cluster to eight sections, in other term choosing an optimal set of cooperating sensor nodes, results confirm that the total energy consumption is minimized and also the choice of dividing cluster to eight sections and not to four sections.

VII. CONCLUSION

In our paper, we have proposed an improvement of CMIMO-SM scheme in order to reduce the total energy consumption and prolong the lifetime of the network. This scheme is based on selection a number of cooperative nodes instead of using all sensor nodes of the cluster as cooperative nodes. By observation of simulation results, our goal is achieved and when using our proposed strategy, energy is minimized compared with the CMIMO-SM approach.

Later, we will investigate in routing protocol with using the proposed scheme in this paper to optimize furthermore the total energy consumption in wireless sensors network.

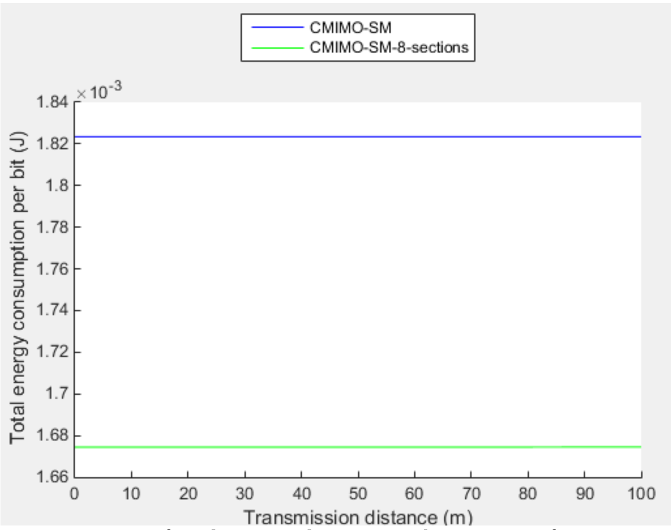

Fig. 4 Variation of total consumed energy per bit in terms of transmission distance d, Cluster divided in 8 sections, 2bits transmission

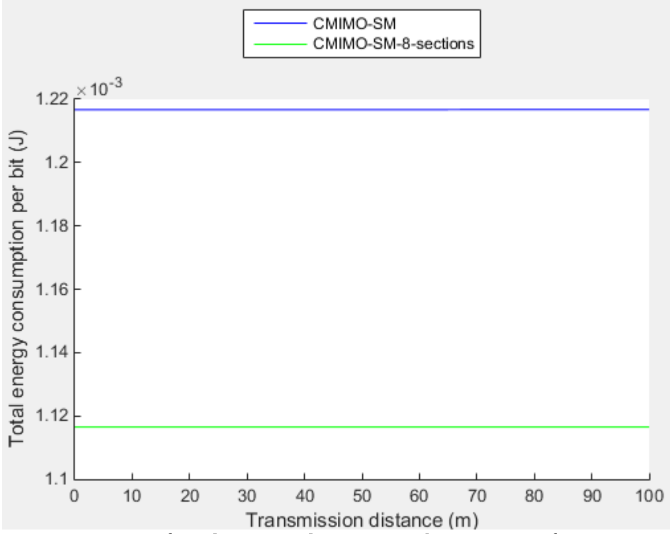

Fig. 5 Variation of total consumed energy per bit in terms of transmission distance d, Cluster divided in 8 sections, 3bits transmission

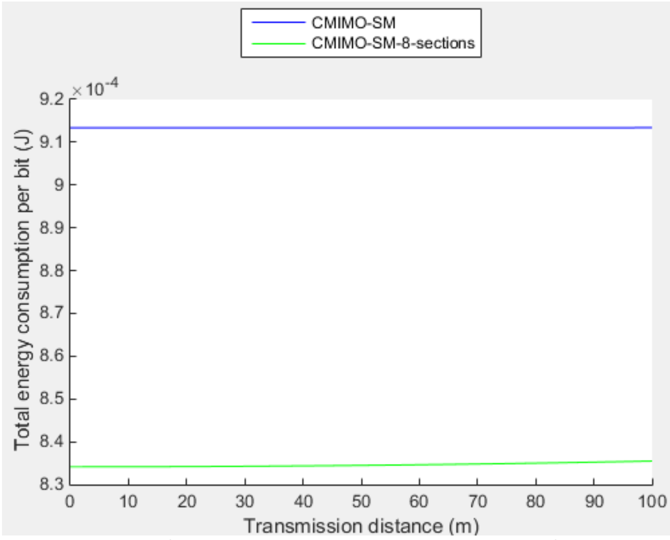

Fig. 6 Variation of total consumed energy per bit in terms of transmission distance d, Cluster divided in 8 sections, 4bits transmission

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