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# An enhanced CMIMO-SM scheme based on cooperative nodes selection in Wireless Sensor Networks

Wided Abidi[#1], Tahar Ezzedine[#2]

[#] *University of Tunis El Manar (UTM)*
*National Engineering School of Tunis (ENIT)*
*Communications Systems Laboratory (SysCom)*
*Tunis, Tunisia*
[1]abidiwided@gmail.com
[2]taharezz@gmail.com

***Abstract*— The main issue for the wireless sensor networks (WSNs)is the energy constraints. Sensor nodes are powered with batteries which are limited resources. In addition, they are usually deployed randomly which makes hard to replace or recharge its batteries. A cooperative multiple input multiple output spatial modulation (CMIMO-SM) technique is developed to reduce the energy consumption of WSN. But in CMIMO and during cooperation phase all nodes into cluster must keep their receivers on which increases the energy consumed by nodes. In this paper, we propose a new algorithm to select the cooperative nodes. In this algorithm, the sensor nodes are grouped into clusters and each cluster is divided to eight sections. Each section contains the set of cooperative nodes. Thus, the number of cooperative nodes is 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

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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. PROPOSED COOPERATIVE NODES SELECTION ALGORITHM

### A. System Model

Our system consists of $M_t$ transmit and $M_r$ receive antennas. Sensor nodes of the network are organized into clusters. We consider the same CMIMO-SM [5, 11] model depicted in Fig.2. At the transmitter, cooperative sensor nodes into the cluster communicate and broadcast their data between each other. Thus, each node has data from all sensor nodes into the cluster. This is called the local communication. Then, since spatial modulation technique is used, data are sent by the only activated transmit antenna already chosen through the MIMO channel, as shown in Fig.1. This phase is the long haul communication. In fact, with SM, the bits sequence to transmit is 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. At the receiver, there is one destination node and $M_r$-1 nodes join the cooperating nodes in reception.

### B. Cooperative nodes selection process

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 separating two cooperating nodes at both transmitter and receiver sides. To overcome the above drawback, we propose to reduce the number of cooperative nodes into the cluster and hence reduce the number of awaken nodes which decrease the energy consumption.

Since the overall energy consumption depends essentially on inter sensor nodes distance into the cluster and geographical location of the sensor nodes, our algorithm is based on these two factors to select the optimal cooperative nodes. The key idea is to divide clusters in the network to a number of sections. Each cluster has 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.

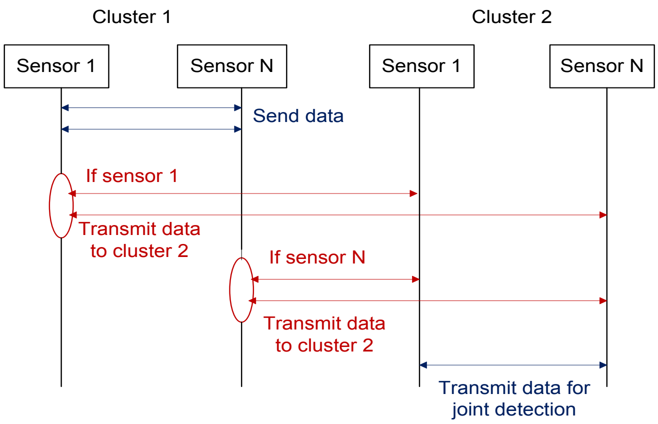

Fig. 1 Communication process of CMIMO-SM

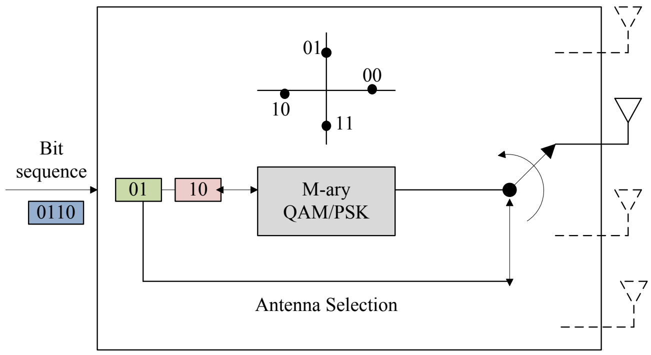

Fig. 2 Transmitter structure of Spatial Modulation

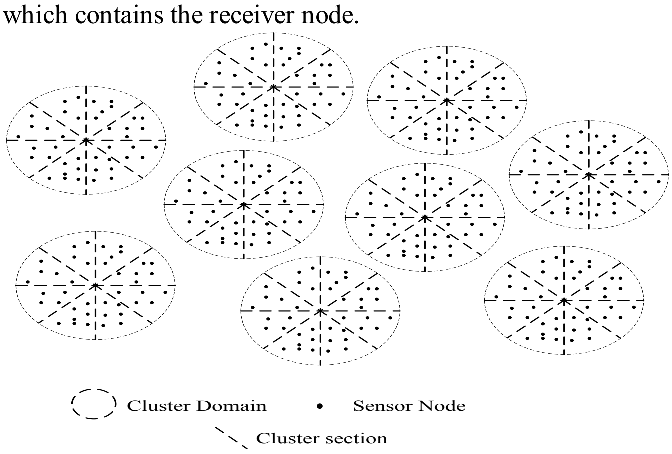

Fig. 3 Proposed clustering section in WSN

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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 $\log_2(N_{ct})$. These results imply minimizing of the total energy consumption as shown in simulation results in section IV.

*C. Energy Model*

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

$$E_{bt} = \frac{P_{pa} + P_c}{R_b} \qquad (1)$$

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:

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

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.

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

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:

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

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

$$E_{btcsm} = E_l + E_{lh} \qquad (5)$$

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

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

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

And $E_l$ is expressed below:

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

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:

$$E_{bt,csm} = \frac{\sum_{i=1}^{N_{ct}} N_i E_i^t + E_{lh}\sum_{i=1}^{N_{ct}} N_i + \sum_{j=1}^{N_{cr}-1} E_j^r \sum_{i=1}^{N_{ct}} N_i}{\sum_{i=1}^{N_{ct}} N_i} \qquad (8)$$

## IV. 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.

First we present results of simulation when the cluster is only divided to 4 sections CMIMO-SM-4-Sections. Fig. 4, Fig.5 and Fig.6 show the comparisons of simulation results for 2 bits, 3 bits, and 4 bits systems between CMIMO-SM and the CMIMO-SM-4-Sections. From plots, the CMIMO-SM-4-Sections approach consumes more energy than the conventional CMIMO-SM. Therefore, the division of the cluster to four sections increases the energy consumption of the network. Hence, this algorithm is eliminated.

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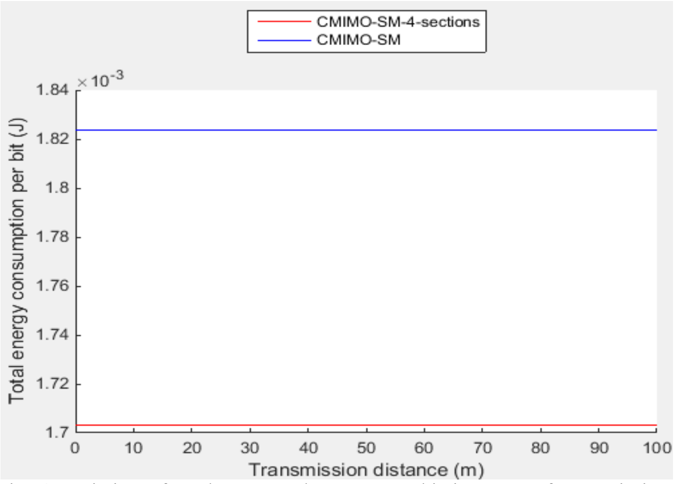


Fig. 4 Variation of total consumed energy per bit in terms of transmission distance d, Cluster divided in 8 sections, 2bits transmission

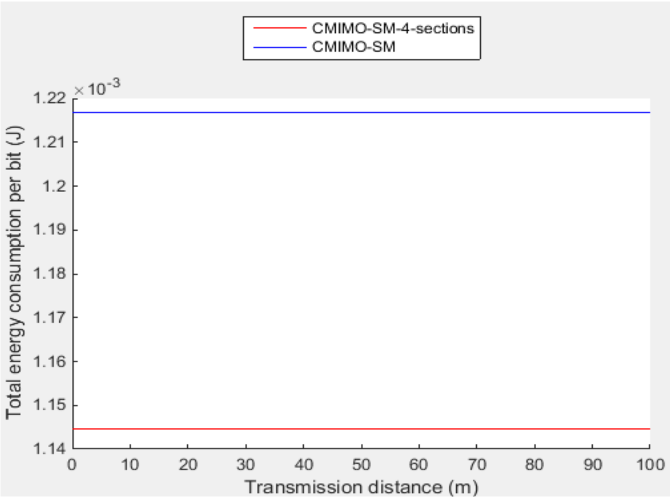


Fig. 5 Variation of total consumed energy per bit in terms of transmission distance d, Cluster divided in 8 sections, 3bits transmission

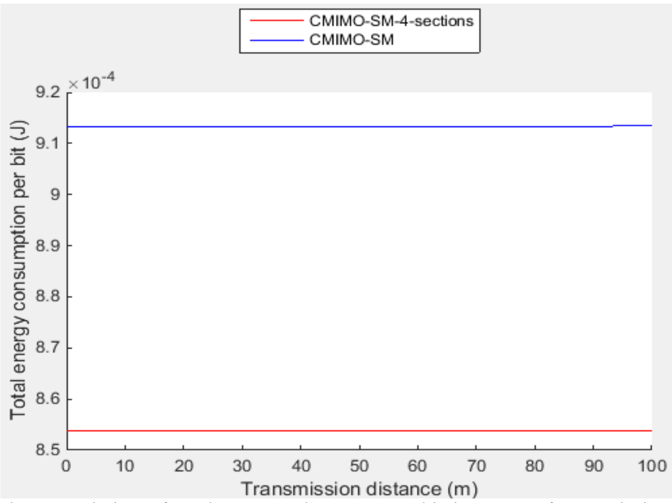


Fig. 6 Variation of total consumed energy per bit in terms of transmission distance d, Cluster divided in 8 sections, 4bits transmission

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 Fig. 7, Fig. 8 and Fig. 9, respectively. From above plots, we see that the enhanced 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.

Therefore, with sectoring the cluster to eight sections and choosing an optimal set of cooperating sensor nodes, the total energy consumption is minimized and the lifetime of the network is prolonged.

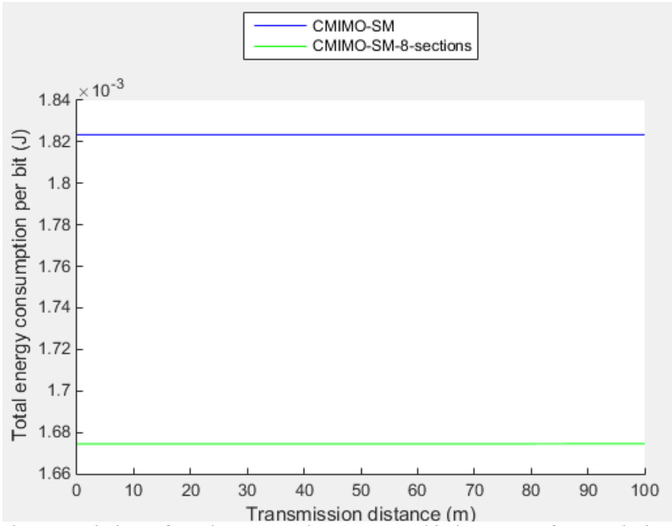


Fig. 7 Variation of total consumed energy per bit in terms of transmission distance d, Cluster divided in 8 sections, 2bits transmission

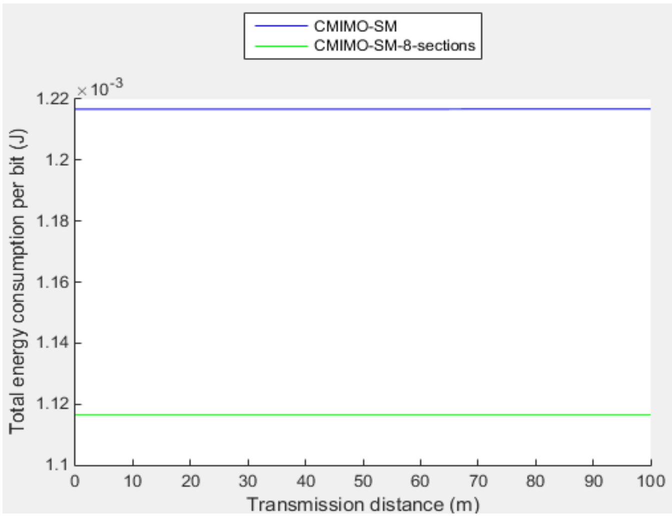


Fig. 8 Variation of total consumed energy per bit in terms of transmission distance d, Cluster divided in 8 sections, 3bits transmission

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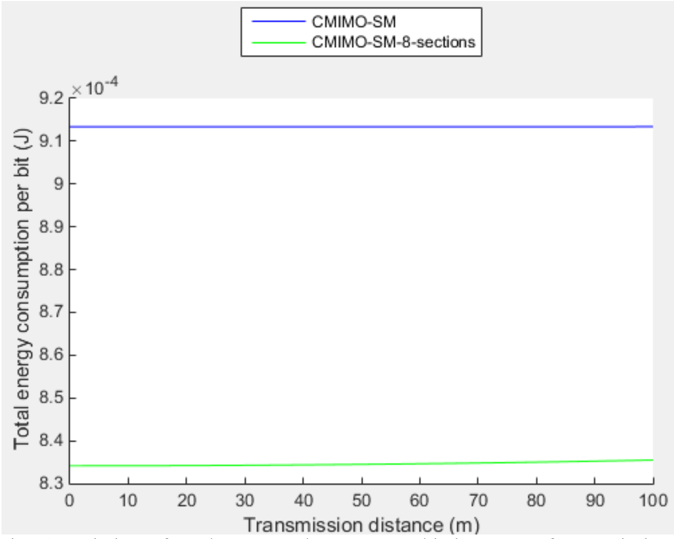


Fig. 6 Variation of total consumed energy per bit in terms of transmission distance d, Cluster divided in 8 sections, 4bits transmission

## V. CONCLUSION

In this paper, we have proposed an enhanced CMIMO-SM scheme based on a new strategy to select the cooperative nodes. This scheme aims to select a number of cooperative nodes instead of using all sensor nodes of the cluster as cooperative nodes. As a result, the number of awaken nodes is reduced and hence the energy consumption is minimized and the lifetime of the network is prolonged. The simulation results confirm our approach which beat CMIMO-SM approach.

Later, we will research in the way of selection of the activated transmit antenna in spatial modulation technique. The objective is to select the appropriate antenna which has the sufficient energy to transmit data.

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