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Reducing Energy Consumption in WSN Based on MIMO and IOT Environment

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Abstract:

Lately, many researchers have focused on improving communication systems in Wireless Sensor Networks WSNs. However, energy consumption was the most important factor to be decreased to make the network much efficient. Therefore, many techniques have been studied in this field such as Cooperative Multi-input-Multi-output MIMO. In this paper, we have suggested a new transmission technique to minimize the power consumption in WSN, considering a Cooperative MIMO at the transmission side and a Data Gathering Node DGN in the reception side by the use of well-known Internet Of Things IOT environment. Various models of prior well-known techniques have been compared with our proposed scenario.

Keywords — **WSN, MIMO, Cooperative MIMO, IOT, Energy Efficiency.**

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I. INTRODUCTION

Wireless Sensor Network WSN is a technology consists of a large number of sensing nodes scattered in the environment which are low powered, efficient and small sized that sense, compute and connect with each other to send the sensed data to one or more collecting sink nodes using Internet, UMTS or other infrastructure networks [1]. Although each node is small sized and powered by small batteries, those batteries may not be able to be replaced or to be recharged. So that energy consumption is considered one of the most important constraint in such network. Multi-input-Multi-output MIMO, or multiple antenna, communication is one of the techniques that has gained considerable importance in wireless systems during recent years [2]. However, MIMO can't be implemented directly to WSN because of its small size which often requires it to be equipped with single-antenna so we tend to use the Cooperative MIMO in such network. WSN is considered as a part of Internet of Things IOT environment which contains various types of devices. These devices could be used as distributed transmit and/or receive entities allowing massive distributed multiple-input multiple-output MIMO systems to be implemented [3]. Among many possible scenarios, while the energy consumption in physical layer plays an important role in which a transmission energy consumption is the dominant part for medium and long range transmission [4]. We mainly focus on studying a new suggested transmission technique to decrease the power consumption in WSN and comparing it with different models of well-known transmission techniques using MATLAB simulator. The reminder of this paper is organized as follows: In section II we talk about MIMO, Cooperative MIMO systems and we reviews the IOT technique and its environment which will be needed in our proposed scenario. Section III mainly describes the system model and the comparisons. Finally, conclusion is presented in section V.

II. RELATED WORK

A. MIMO in Wireless Sensor Networks

Multiantenna systems have been studied intensively in recent years due to their potential to dramatically increase the channel capacity in fading channels [5]. MIMO systems can support higher data rates under the same transmit power budget and bit-error-rate performance requirements as a single-input single-output (SISO) system. An alternative view is that for the same throughput requirement, MIMO systems require less transmission energy than SISO systems [6]. However, direct implementation of MIMO technique to WSN is impractical because of small sized sensor nodes which can't be equipped with more than one antenna. Fortunately, if we allow individual single-antenna nodes to cooperate on information transmission and/or reception, a cooperative MIMO system can be constructed such that energy-efficient MIMO schemes can be deployed [6].

B. Energy Consumption Model in Cooperative MIMO :

The energy efficiency of MIMO transmission is particularly useful for Wireless Sensor Network (WSN) where the energy consumption is the most important constraint [4]. The Cooperative MIMO transmission from source node S to destination node D over a transmission distance d is composed of three phases [5] :

1) ***Local data exchange:*** When a source node S has data to be sent to destination node D, it sends its data to (N-1) neighboring nodes over a transmission distance d_m in order to form a MIMO transmission.
2) ***Cooperative MIMO transmission:*** After receiving the data from the source node, N cooperating nodes transmit the data to M cooperating receive nodes forming MIMO transmission by using Space Time Block Coding STBC technique.
3) ***Cooperative reception:*** The cooperative nodes firstly receive the MIMO modulated symbols and then retransmit it over d_m distance to the destination node D sequentially.

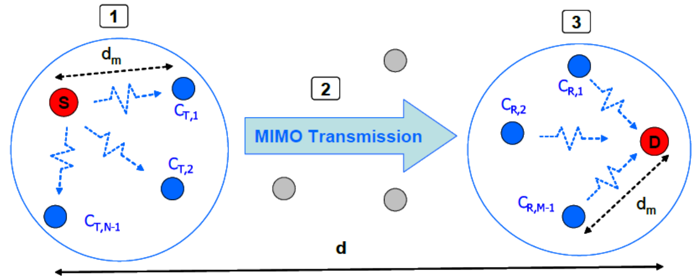

Fig. 1 Cooperative MIMO Technique

Assuming that the source node S has N_b bits of data to be sent to the destination node D, it has to exchange its data with the N-1 neighbour nodes over a d_m distance in cooperative techniques. However, the total energy consumption consist of the transmission power P_{pa} of the power amplifier and the circuit power P_c of all RF circuit blocks. with a path-loss factor K, P_{pa} depends on the output transmission power P_{out} and can be written as

$$P_{out} = \bar{E}_b R_b \times \frac{(4\pi d)^K}{G_T G_R \lambda^2} M_l N_f$$

where $\bar{E}_b$ is the mean required energy per bit for ensuring a given error rate requirement, R_b is the bit rate, d is the transmission distance. G_T and G_R are the transmission and reception antenna gain, λ is the carrier wave length, M_l is the link margin, N_f is the receiver noise figure defined as $N_f = M_n/N_0$ with $N_0 = -174\ dB_m/Hz$ single-side thermal noise Power Spectral Density (PSD) and M_n is the PSD of the total effective noise at receiver input [7].

$\bar{E}_b$ can be calculated depending on the needed SNR and Bit error rate. Finally, we can calculate P_{pa} as : $P_{pa} = (1+\alpha)P_{out}$, where $\alpha = \frac{\varepsilon}{\eta} - 1$ with ε the drain efficiency of the RF power amplifier and η the Peak to-Average Ratio (PAR) which depends on the modulation scheme and the associated constellation size [7].

The total circuit power consumption of N transmit and M receive antennas is given by:

$$P_C \approx N\left(P_{DAC} + P_{mix} + P_{filt} + P_{syn}\right) + M(P_{LNA} + P_{mix} + P_{IFA} + P_{filr} + P_{ADC} + P_{syn})$$

where $P_{DAC}, P_{mix}, P_{LNA}, P_{IFA}, P_{filt}, P_{filr}, P_{ADC}, P_{syn}$ stand respectively for the power consumption values of the digital-to-analog converter, the mixer, the low noise amplifier, the intermediate frequency amplifier, the active filter at the transmitter and receiver, the analog-to-digital converter and the frequency synthesizer whose values are presented in [7].

The total energy consumption per bit E_{bt} for non-cooperative MIMO can be obtained as

$$E_{bt} = (P_{pa} + P_C)/R_b$$

Then, the total energy consumption can be calculated as $E_{tot} = E_{bt}N_b$

To calculate the needed power consumption of cooperative MIMO, we can calculate the energy consumption per bit of Local Data Exchange phase $E_{pb_{coop}Tx}$ based on energy consumption model for non-cooperative system. Therefore, the extra power consumption at transmission side E_{coopTx} can be written as $E_{coopTx} = N_b E_{pb_{coop}Tx}$

After receiving N_b bits from S, *N-1* cooperative transmission nodes and S will encode and modulate the information to the *QPSK STBC* symbols and then transmit simultaneously to the destination node (or multi-destination nodes) over a MIMO Rayleigh fading channel [4].

At the reception side, *M-1* cooperative receive nodes firstly receive the MIMO encoded symbols, quantize one STBC symbol to N_{sb} bits and then retransmit their quantized bits respectively to the destination node D using *uncoded 16-QAM* modulation [4]. We can calculate the energy consumption per bit for this cooperative reception phase $E_{pb_{coop}Rx}$ by using non-cooperative energy model for a *SISO 16-QAM* transmission with distance $d=d_m$ [4]. Total energy consumption of this phase can be written as

$$E_{coopRx} = N_{sb}(M-1)N_b E_{pb_{coop}Rx}$$

Finally, the total consumed power of cooperative technique can be calculated as

$$E_{total} = E_{coopTx} + (P_{pa} + P_C) + E_{coopRx}$$

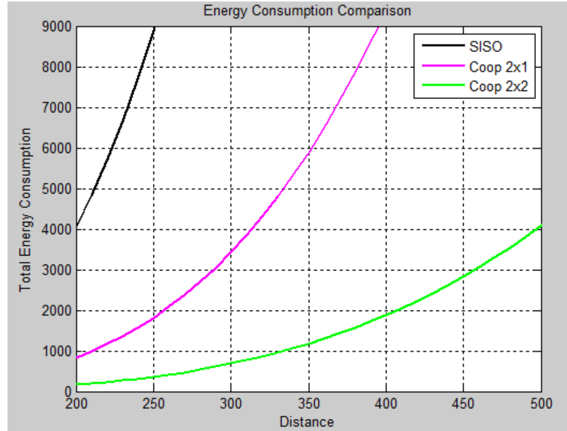

Fig. 2 Energy Consumption Comparison between SISO, traditional Coop Miso 2x1 & Coop MIMO 2x2 systems for $BER = 10^{-5}$

Fig.2 shows the power consumption comparison between SISO, traditional Cooperative MISO 2x1 and Cooperative MIMO 2x2. It's clear that Cooperative MIMO 2x2 outperforms both SISO and Cooperative MISO 2x1 at short and long distances. We can notice that at distance *d=250m*, SISO system needs to consume about E_{SISO}*=9 kJ*, cooperative MISO 2x1 consumes $E_{CoopMISO}$*=1.9 kJ* while cooperative MIMO 2x2 consumes only $E_{CoopMIMO}$*=0.25 kJ.*

III. SYSTME MODEL

We have proposed two different transmission techniques in order to minimize the total power consumption in wireless sensor networks, by the use of IOT environment and associate it with the Cooperative MIMO technique.

C. Simulation Environment

We've suggested a wireless sensor network consisting of two transmitting sensor nodes, forming virtual MIMO system by cooperating with each other at the transmission side, where Space Time Block Coding STBC technique is used. These nodes have a set of bits of data to be sent to a destination node DGN by taking advantage of the scattered nodes in the Internet of Things environment.

We have assumed that the transmission is perfect from the geographically distributed IOT nodes to the final destination node DGN, in order to benefit from the equation of the developed Maximum Likelihood ML detector for this environment, which was developed in previous works. With the assumption that the fusion center can access the full knowledge of h_k and y_k for all k; where k is the number of the IOT scattered nodes, $h_k$is the channel is the independent and identically distributed Rayleigh fading channel vector between the transmitter and the k-th receive node and y_k is the received signal at the k-th receive node, then the optimal receiver is given as: $\hat{X}_{opt} = argmin_{x' \in S^{N_t}} \left\| y - \sqrt{\frac{\rho}{N_t}} Hx' \right\|^2$

where H is the channel matrix, N_t is the number of transmitting antennas, ρ is the transmit SNR and S^{N_t} is the Cartesian product of S of order n [8].

We've worked on several scenarios for different previous systems in addition to our imposed system and then we compared the energy consumption of each of the studied models, assuming some of the considerations described as follows:

D. *Simulation Assumptions and Set Up*

Suppose that the source node S has *L=400* Bits of data that want to send to a *DGN* using *4QAM* modulation at calculated distances, with *p=10* training bits of each transmitting antenna where each block contains 500 symbols, the path loss coefficient is *K=3.5* and the required error rate is $BER = 10^{-5}$, assuming that distance is d_m= *10m* between cooperating nodes at the transmission side.

Assuming we have the following parameters:

TABLE I
NEEDED PARAMETERS

$f_c = 2.5$ GHz	$\eta = 0.35$
$G_t G_r = 5$ dBi	$\frac{N_0}{2} = -174$ dBm/Hz
$B = 10$ kHz	$\beta = 1$
$P_{mix} = 30.3$ mW	$P_{syn} = 50$ mW
$\bar{P}_b = 10^{-3}$	$T_s = \frac{1}{B}$
$P_{filt} = P_{filr} = 2.5$ mW	$P_{LNA} = 20$ mW
$N_f = 10$ dB	$M_L = 40$ dB

At the transmission side, sensor nodes cooperate with each other to form a virtual MIMO system to simultaneously transmits its data to the IOT geographically separated nodes, each receive node quantizes its received signal and forwards the quantized signal to the DGN which it tries to decode the sent data by investing the quantized incoming signals from the receive nodes and global channel information.

For practical purposes, we assume each receive node quantizes its received signal with one bit per real and imaginary part of the received signal to minimize the transmission overhead between the receive nodes and DGN [8].

We have assumed that the transmission between the IOT nodes and the DGN can be achieved in two different ways, as follows:

1) By using SISO technique. However, when modeling the supposed system on *MATLAB*, we've found that at distance *d = 250m* the total energy consumption is $E_{total} = 53.4375kJ$
2) By using Cooperative MISO. However, when modeling the supposed system on *MATLAB*, we've found that at the same distance E_{total} is $46.8753kJ$

E. *Simulation Results*

Fig.3 shows the total energy consumption of the traditional cooperative MISO 2x1, cooperative MIMO 2x2 systems and our two supposed transmission techniques, when using SISO technique at the transmission from IOT nodes to the DGN and when using the MISO technique for the same propose. It can be seen that at short transmission distances such as *d=250m*, the cooperative MISO technique is less energy-efficient than the cooperative MIMO and our supposed technique, the transmission energy saved by our supposed technique when using the cooperative MISO is greater than all of them and it outperforms the first suggested way, when SISO is used, but it still out performs the traditional cooperative MIMO and cooperative MISO.

On the other hand, at greater distances, such as d=900m, Fig.4 exhibits that using cooperative MISO technique at the second part of transmission in our supposed scenario where energy consumption is only $E_{total} = 210.62kJ$ is more energy-efficient than using the SISO strategy where $E_{total} = 2.51 \times 10^3 kJ$, according to the following table:

TABLE III
ENERGY CONSUMPTION COMPARISON(*KJ*)

SISO	Coop MISO 2x1	Coop MIMO 2x2
7.86×10^5	1.61×10^5	3.20×10^4

Therefore, it's better to implement the second suggested technique in wireless sensor networks due to its huge energy saving, while traditional cooperative MIMO 2x2 system is the less efficient of them all.

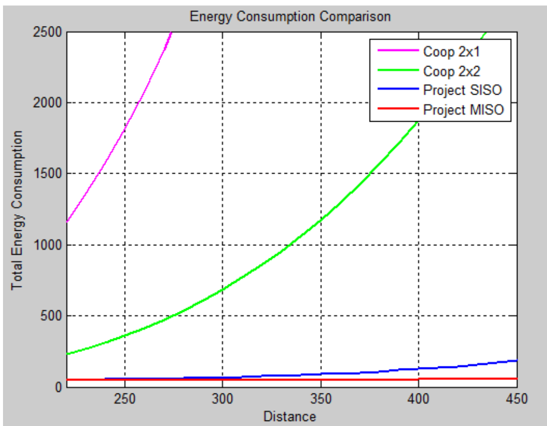

Fig. 3 Energy Consumption Comparison between Coop Miso 2x1, Coop MIMO 2x2 Techniques and our two supposed techniques for $BER = 10^{-5}$ and $N_t = 2$ and 15 IOT nodes

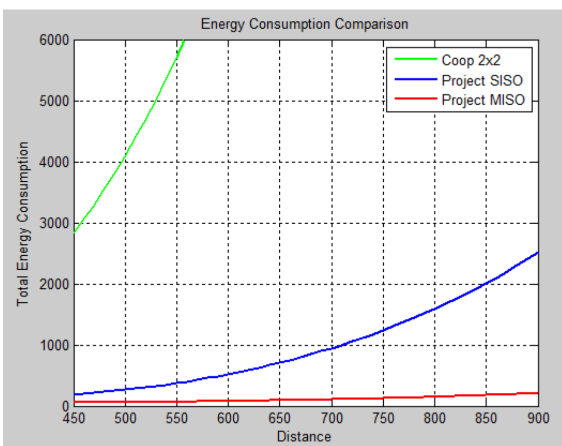

Fig. 4 Energy Consumption Comparison between traditional Cooperative MIMO 2x2 Technique and our two supposed techniques for $BER = 10^{-5}$ and $N_t = 2$ and 15 IOT nodes

IV. CONCLUSIONS

In this paper, we suggest a new transmission techniques to be used in WSN and we compare between our supposed techniques and other different traditional transmission techniques, it's really important to minimize the energy consumption in such networks due to applications that lasts for months or years where batteries of the sensors can't be replaced or recharged. So that, when implementing such network it is better to use this technique where there's a cooperation between sensor nodes at transmission side by the use of the IOT environment, where its wireless nodes play an important role in our scenario, using Cooperative MISO between them and the final destination DGN with less total energy consumption than any well-known traditional techniques.

ACKNOWLEDGMENT

As a future work, we plan to develop our supposed scenario and other transmission techniques in order to make the wireless sensor network much more efficient when it comes to energy consumption where batteries of sensors may not be able to be replaced or to be recharged.

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