# Performance Analysis of Different Diversity Schemes for Energy Efficient Wireless Sensor Networks

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## ABSTRACT
An energy-efficient communication schemes in wireless sensor networks (WSN) is highly desirable where energy consumption is constrained. In this paper, the mathematical model of energy consumption per bit in wireless sensor network using Cooperative MIMO is presented. Cooperative MIMO transmission and reception can simultaneously achieve the energy savings and the delay reduction over some distance ranges. Further, the best diversity scheme to minimize total energy consumption to send a given number of bits is analyzed. The simulation through MATLAB is carried out for various modulation techniques in Rayleigh fading channel.

## Keywords
Alamouti diversity schemes, Bit error rate (BER), Energy Efficiency, Rayleigh fading, Single-input-single-output (SISO), Single-input-multiple-output (SIMO), Multi-input-single-output (MISO), Multi-input-multi-output (MIMO), Modulation schemes, Wireless sensor network.

## 1. INTRODUCTION
To prolong the network life time is the main concern for the wireless sensor network, as the sensor nodes are powered by batteries energy consumption of each node is the main problem in the network. Therefore, sensor node lifetime shows strong dependence on battery life. In recent years, the ideas of wireless sensor network (WSNs) have gained world-wide consideration in Micro-Electro-Mechanical Systems (MEMS) technology facilitated the development of smart sensors by researchers [1]. Wireless sensor networks consist of sensor nodes with sensing and communication capabilities. Since fading environment and radio interference consumes major portion of battery power. To mitigate the effect of fading in wireless channel, multiple-input-multiple-output (MIMO) scheme is utilized for wireless sensor network [2], [3]. Multi-input-multi-output (MIMO) or multiple antenna communication is one of the techniques that have gained considerable importance in wireless system. Cooperative MIMO is a kind of MIMO technique where multiple inputs and outputs are formed via cooperation communication in a wireless sensor networks. The sensor cooperates with each other to form multiple-input-multiple-output configuration. Under the same bit-error-rate and throughput requirements, the diversity using multiple-input-multiple-output (MIMO) technique in a wireless network that required less transmit power than single-input-single-output (SISO) [4]. The simple transmit diversity schemes suggested by Alamouti [5] and space time coding suggested V. Tarokh et.al. [6] triggered research in this area.. Utilization of cooperative MIMO techniques to wireless sensor networks based on total energy consumption for data transmission from source node S to destination node D over a distance d, instead of SISO direct transmission which is inconvenient in long range, a cooperative MIMO transmission is shown in Fig.1, to reduce transmit energy.

Within local sensors, if the maximum separation is dm meter and for long-haul communication distance is d meter, as shown. At transmitter side, node S can cooperate with its neighbors and exchange its data. MIMO techniques are employed to transmit their data simultaneously to the destination node. At the receiver side, the cooperative neighbors of destination or relay node R and receive the MIMO modulated symbols and retransmit them to destination node R for joint MIMO signals combinations. An energy efficient communication technique is required so that energy consumption must be minimized while satisfying given throughput and delay requirements. Following energy-efficient diversity schemes for maximizing lifetime and to minimize energy consumption of wireless sensor networks are discussed in this paper. This paper is organized as follows. In section 2, Energy consumption in system model is calculated. In section 3, Energy efficiency of MIMO system for Alamouti code is discussed. In section 4, Modulation techniques are described. In section 5, Energy consumption is compared over various transmission distances for different diversity schemes. Finally, paper is concluded in section 6.

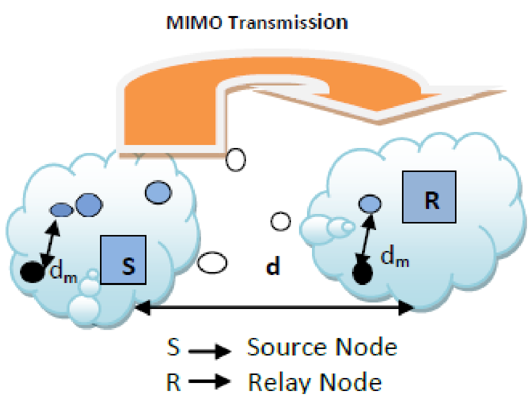


**Fig 1: Cooperative MIMO system for wireless Sensor Networks.**

## 2. SYSTEM MODEL
We considered the energy model in [7] with the same system parameter for energy estimation of cooperative MIMO system. We consider the total energy consumption; all signal

processing blocks at the transmitter and receiver are included in this model. The resulting signal paths on transmitter and receiver side are shown in Fig.2 and Fig. 3 respectively and we suppose that the frequency synthesizer is shared among all antenna paths. For SISO case, we have $M_t$=$M_r$=1.

Power consumption can be dividing into three domains: Sensing, communication and data processing. The total average power consumption e signal along the signal path can be divided into two main components: the power consumption of all power amplifiers $P_{PA}$ and power consumption of all other circuit blocks $P_C$. When channel experiences a $k_{th}$-power path loss $P_{PA}$ is depend on the transmit power Pout which can be calculated according to link budget relationship [7],

$$P_{out} \approx \left(\overline{E}_b R_b \times (4\pi)^2 d^k M_l N_f\right) \div \left(G_t G_r \lambda^2\right) \quad (1)$$

Where the average energy per bit required for a given BER specification is $\overline{E}_b$ , $R_b$ is the transmission bit rate, d is the transmission distance and $G_t$ , $G_r$ are the transmitter and receiver antenna gains respectively, λ is the carrier wavelength, $M_l$ is the link margin and other additive background noise, and $N_f$ is the receiver noise figure .

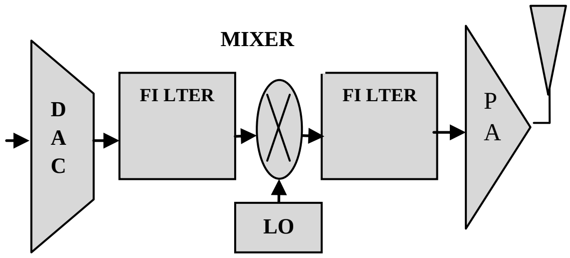


**Fig 2: Transmitter Block Diagram.**

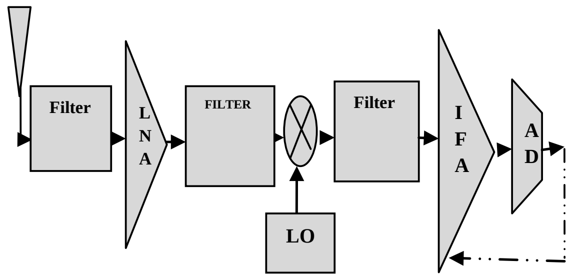


**Fig 3: Receiver Block Diagram.**

The power consumption of the power amplifiers a can be approximately calculated as

$$P_{PA} = (1+\alpha) P_{out} \quad (2)$$

Where α = (ξ-η) / η with η is the drain efficiency of the RF power amplifier [4] ξ is the peak to average ratio (PAR) [5] which depends on modulation scheme and associated constellation size. Assume M-array quadrature amplitude modulation scheme (MQAM) is considered. Then, $P_c$ in the total power consumption as

$$P_c \approx M_t\left(P_{DAC} + P_{mix} + P_{filt}\right) + \left(2P_{syn}\right) + M_r\left(P_{LNA} + P_{mix} + P_{IFA} + P_{filr} + P_{ADC}\right) \quad (3)$$

where $P_{DAC}$, $P_{mix}$, $P_{filt}$, $P_{sync}$ , $P_{LNA}$, $P_{IFA}$, $P_{filr}$ and $P_{ADC}$ are the power consumption values of D/A converters, the mixer, the active filters at the transmitter side, the frequency synthesizer, the low noise amplifier, the intermediate frequency amplifier, the active filters and A/D converters at the receiver side introduced in [8]. With equation (2) and (3) the energy consumption per bit for a general communication link can be formulated as

$$E_{bt} = \left(P_{PA} + P_c\right) / R_b \quad (4)$$

The total energy consumption is calculated by multiplying $E_{bt}$ by the number of bits to be transmitted.

## 3. DIFFERENT MIMO DIVERSITY SCHEMES

In WSNs Alamouti schemes are used to achieve diversity in the distributed Cooperative MIMO systems. Cooperative MIMO system in which individual single antenna nodes that cooperate to form multiple antenna transmitters or receivers. Therefore, achieving transmit and receive diversity distributive becomes the major design issue in the cooperative MIMO systems. For the simplicity we apply Alamouti schemes in the distributed cooperative MIMO in WSNs to achieve diversity. In Fig.4, the Alamouti code with two transmit antennas utilize two different symbols $S_1$ and $S_2$ that are transmitted simultaneously during first time slot from antenna 1 and 2 and another two coded symbols such as $-S_2^*$ and $S_1^*$ are transmitted during second time slot as proposed in [8].

$$s_1 = \left[s_1 s_2^*\right] \quad \text{and} \quad s_2 = \left[s_2 s_1^*\right]$$

**Table 1. Encoding and Transmission sequence for two branches transmit diversity schemes**

| Timeslot | Receive antenna 1 | Receive antenna 2 |
|---|---|---|
| Timeslot-I | $s_1$ | $s_2$ |
| Timeslot-II | $-s_2^*$ | $s_1^*$ |

MIMO system based on Alamouti scheme can achieve lower average probability error than SISO system in Rayleigh fading channel under same transmit energy budget due to diversity gain and array gain for multiple receiver antenna in [4]. Alamouti scheme for more than two transmit antennas and is known as Space-Time Block Codes (STBC) generalized in [6].

### 3.1 Alamouti 2×1 MISO System

The 2×1 MISO system Alamouti schemes, the channel matrix of 2×1 MISO systems can be written as H= $\left|h_1 h_2\right|$ and instantaneous received SNR is given by

$$\gamma_b = \left(\left(E_b \div N_o\right)\|H\|_F^2\right) \div M_t$$
$$M_t = 1,2,3..... \quad (5)$$

where $\|H\|_F^2$ is the Frebenius norm of the matrix H and probability distribution function (PDF) of $\|H\|_F^2$ can be determined according to the PDF of H given in [4].The average BER of a MIMO system using Alamouti schemes with MQAM is given by [9].

## 3.2 Alamouti 2×2 MIMO System

The channel matrix of 2×2 MIMO systems is given by

$$H = \begin{vmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{vmatrix} \qquad (6)$$

and the received instantaneous received SNR can be written as

$$\gamma_b = \left(\overline{E}_b \div 2N_o\right)\|H\|_F^2 \qquad (7)$$

The MIMO system offer higher diversity order and array gain over MISO system to achieve less transmission energy [4] under same performance requirement.

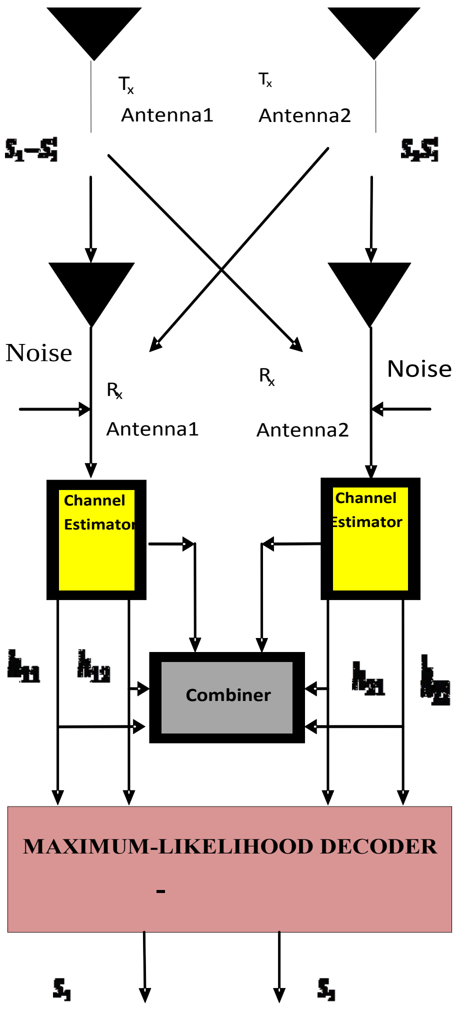


**Fig 4: MIMO system for Alamouti code.**

## 4. THEORITICAL ANALYSIS ENERGY EFFICIENT MODULATION TECHNIQUES

Energy saving is the significant issue in the wireless sensor networks. The optimal constellation sizes of modulation based on the transmission distance extend the superiority in terms of energy efficiency as proposed in [10]. Consequently, modulations techniques are required to transmit information over a communication channel are analyzed in this paper. The comparison of Bit-error rate performance for different modulation techniques over Rayleigh fading channel is presented. We found that M-QAM is the best modulation technique for combating fading in Rayleigh fading channel for wireless communication.

## 5. SIMULATION RESULTS

The scenario in which we assemble our simulation model is MATLAB. In this section simulation schemes are highlighted. We compare different diversity schemes for the performance improvement in Wireless sensor network (WSNs) i.e., (1×1) Single-input-single-output, (1×2) Single-input-multiple-output, (2×1) Multiple-input-single-output and (2×2) Multiple-input-multiple-output systems for Rayleigh fading channel. Modulation scheme M-ray Quadrature Amplitude Modulation (M-QAM) is used for study to increase the transmission rate and reduce circuit energy consumption. Then, we compare BER for Rayleigh fading with different modulation techniques.

**Table 2. Simulation parameters**

| Simulation parameters | Units | Values |
|---|---|---|
| Carrier frequency, ( $f_c$ ) | GHz | 2.5 |
| Bandwidth,(B) | KHz | 10 |
| Drain efficiency, (η) | | 0.35 |
| Link margin ($M_l$) | db | 40 |
| Antenna gains,( $G_t G_r$ ) | dbi | 5 |
| Power consumption by Intermediate frequency Amplifier ( $P_{IFA}$ ) | mw | 3 |
| Power consumption by Mixer, ( $P_{mix}$ ) | mw | 30.3 |
| Power consumption by filter, ( $P_{filt}$ ),( $P_{filr}$ ) | mw | 2.5 |
| Average bit error rate, ( $P_b$ ) | | $10^{-3}$ |
| Transmit Bit rate ,( $R_b$ ) | kbps | 250 |
| Power consumption by frequency synthesizer, ( $P_{syn}$ ) | mw | 50 |
| Receiver noise figure, ( $N_f$ ) | db | 10 |
| The single-sided thermal noise PSD, ($N_0$) | dbm/hz | -171 |

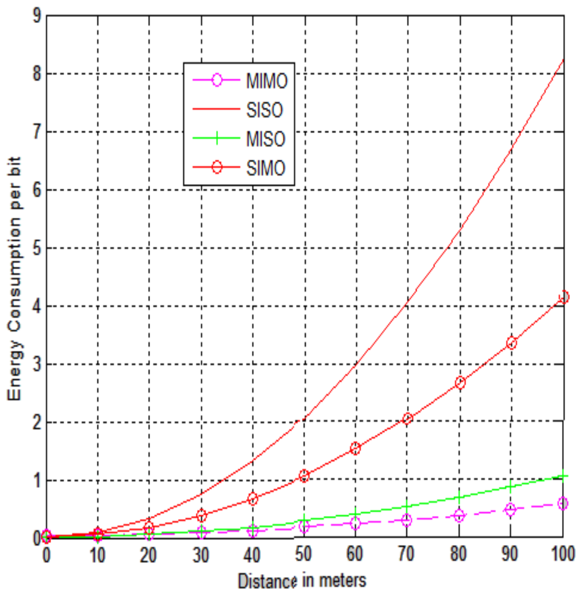


**Fig 5: Energy consumption per bit vs. Distance for 4 QAM in wireless sensor networks.**

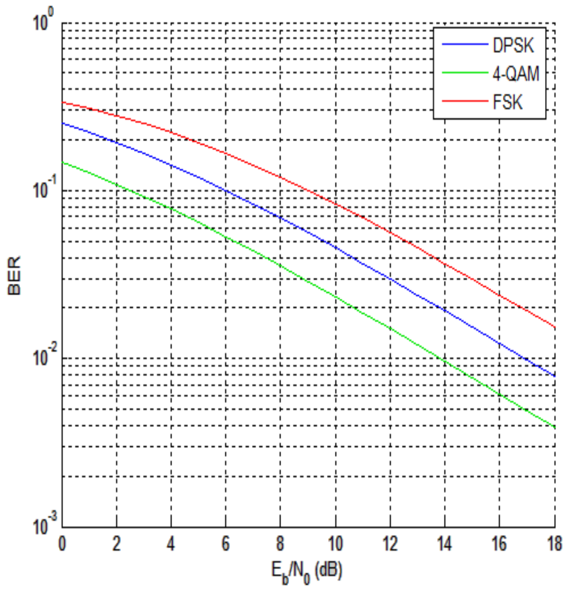


**Fig 6: The BER performance comparison of different modulation schemes in Rayleigh fading channel.**

In Figure.5, we examine energy consumption per bit with respect to the distance in meters for different diversity schemes like SISO (1×1), SIMO (1×2), MISO (2×1) and MIMO (2×2). Simulation results show that Alamouti scheme performs better for (2×2) MIMO in comparison to other diversity schemes. Energy consumption in SISO is higher as compared to other techniques for 4-QAM system. MIMO (2 x 2) System gives energy saving compares to SISO (1×1) system at a distance of 100 meter.

The Fig.6 illustrates the BER performance comparison plot between DPSK, FSK and 4-QAM modulation schemes. From the Fig. 6 it is found that in Rayleigh fading BER at $10^{-1}$, 4-QAM gives better performance of 3 dB as compared to DPSK and 6dB as compared to FSK. Thus, it is concluded that Quadrature Amplitude Modulation (4-QAM) modulation schemes is preferred for better BER performance when Rayleigh fading is present in wireless sensor networks.

## 6. CONCLUSION

Performance of different diversity techniques for MIMO wireless communication system in Rayleigh fading are analyzed through MATLAB simulation. With the analysis and simulation results proposed (2×2) MIMO scheme achieves a significant reduction in the overall energy consumption in WSNs. Alamouti scheme is simple and gives better performance as we increase number of receiver antennas. Total energy consumption has been evaluated with the help of system model. According to simulation results the multi-input-multi-output (MIMO) system can support higher data rates at the same transmission power and bit- error-rate (BER) requirements. MIMO system requires less transmission energy than SISO system. Comparison of different modulation schemes like DPSK, FSK, and 4-QAM using MATLAB presented. QAM gives the better performance in terms of BER as compared to other modulation schemes like DPSK, FSK shown in this paper.

## 7. REFERENCES

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