A Review of MIMO Technology for Wireless Sensor Network

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Abstract

Wireless sensor network becomes an attractive choice for number of applications because of their multifunctional nature like sensing, computing, and transmitting. But it contains a number of tiny sensor nodes which are operate on small batteries. So the energy consumption of wireless sensor network must be minimized. Also we want high throughput, spectral efficiency and diversity. For these reasons we analyze the efficient modulation schemes and transmission strategies to reduce the energy consumption that needed to transmit the number of bits. This paper Presents an overview of MIMO technique, energy model of MIMO technique and compares the energy consumption of different MIMO schemes.

1. Introduction

Wireless sensor network becomes a very hot research topic since last ten years. The building block of such an infrastructure is comprised of hundreds or thousands of small, low cost, low power, multifunctional devices which have the ability to sense, compute and communicate using short range transceivers known as sensor nodes. The interconnection of these nodes forming a network called wireless sensor network (WSN). The evolution of wireless communication and circuit technology has given rise to the development of an infrastructure consists of sensing, computational and communicating units that makes administrator capable to observe, measure and react to a phenomena in a particular environment. Advancement in recent hardware will allow more signal processing functionalities to be integrated in to a single chip. Also the cost of sensors will allow to have a network of hundreds or thousands of them , thereby enhancing the reliability and accuracy of data and the area coverage.

On the other side sensor nodes are powered by small batteries. The low cost, ease of deployment, ad hoc and multifunctional nature has exposed WSNs an attractive choice for numerous applications. But in reality, these networks are comprised of many small battery operated tiny sensor nodes with limited computation capabilities, memory, bandwidth, and hardware that results in resource constrained WSN. The resource constrained nature of WSN creates various challenges in its design and operations degrading its performance. On the other hand, varying numbers of applications having different constraints in their nature makes it further challenging for such resources constrained networks to attain application expectations.

The MIMO technique has been recently introduced in wireless sensor network. A tiny sensor nodes can be seen as multiple input multiple output (MIMO) system where a sensor nodes may be presented the role of a transmitting or receiving antenna of the MIMO structure. This structure will increase the energy gains for a wireless sensor network, depends on the distance between the transmitter and receiver side of the system. It is proved that above the some specific threshold distance MIMO system will be more energy efficient than SISO approach.

2. Basics of MIMO

2.1 System model of MIMO

An illustration of the MIMO channel can be seen in Figure 1.The MIMO system has Nt transmitting antennas and Nr receiving antennas. In order to describe the MIMO channel, we investigate the channel model at a certain time m. We denote the $N_t \times 1$ vector of transmit symbols as s[m] = [s_1. . . s_{Nt}]^T, and the received $N_r \times 1$ vector is

x[m] = H s[m] + v[m]...............................(1)

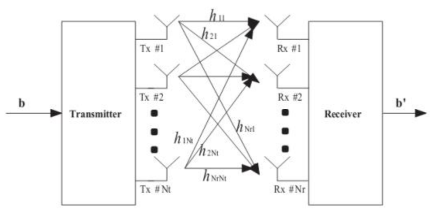

Figure-1 System model of MIMO channel

in(1), v[m] = [v_1 . . . v_{Nr}]^T represents white Gaussian noise, with variance of σ_n^2. The channel matrix **H** is

$$H = \begin{bmatrix} h_{11} & \cdots & h_{1Nt} \\ \vdots & \ddots & \vdots \\ h_{Nr1} & \cdots & h_{NrNt} \end{bmatrix} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(2)$$

Here h_{ij} represent the channel coefficient from transmitting antenna j to the receiving antenna i

2.1 Types of MIMO

2.2.1 Single input single output

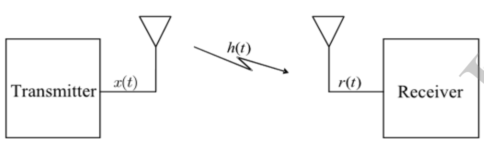

Figure-2 SISO system model

This type of configuration is the oldest known type of configuration. There is only a single antenna working as a transmitter and a single antenna working as a receiver.

2.2.2 Single input multiple output

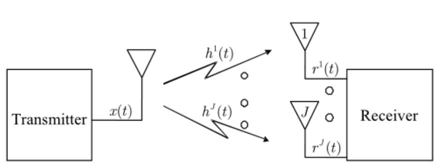

Figure-3 SIMO system model

There is one antenna to transmit and a couple of antennas in the receiver side.Figure-3 shows a basic diagram illustrating one-transmit and two-receive antennas system.

2.2.3 Multiple input single output

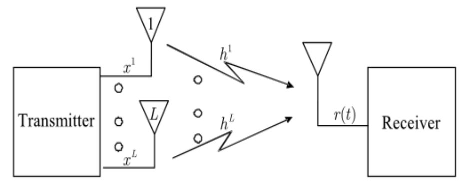

Figure-4 MISO system model

MISO is an antenna technology for wireless communications in which multiple antennas are used at the source (transmitter). The destination (receiver) has only one antenna. MISO is one of several forms of smart antenna technology.

2.2.4 Multiple input multiple output

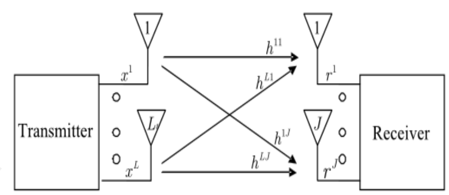

Figure-5 MIMO system model

Multiple-input and multiple-output, or MIMO is the use of multiple antennas at both the transmitter and receiver to improve communication performance. It is one of several forms of smart antenna technology

3. Energy model of MIMO

Energy consumption of mimo system will be divided into two main parts

1.Power consumption of all the power amplifiers P_{PA}

2.Power consumption of other circuit blocks P_C

The first term P_{PA} is dependent on the transmit power P_{out} , which is calculated from the link budget equation. when the channel experiences a square-law path loss, we have

$$P_{out} = \overline{E_b} R_b \times \frac{(4\pi d)^2}{G_t G_r \lambda^2} M_l N_f \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Where E_b represents required energy per bit for BER requirement, R_b represents a bit rate, d is distance between transmitter and receiver, G_t is transmitter antenna gain, G_r is receiver antenna gain, λ is carrier wavelength, M_l is the link margin compensating the hardware process variations and other additive background noise or interference, and N_f is the receiver noise figure defined as $N_f = (\frac{N_r}{N_0})$, where N_0 is the power spectral density of single sided thermal noise at room temperature and N_r is the power spectral density of total effective noise at the receiver input.The energy consumption of the power amplifiers can be approximated as

$$P_{PA} = (1+\alpha)P_{out} \quad \dots\dots\dots\dots\dots\dots\dots.. (4)$$

Where $\alpha = \left(\frac{\zeta}{\eta}\right) - 1$ with η is the drain efficiency of RF power amplifier and ζ is the peak to average ratio ,which is dependent on the modulation scheme and the associated constellation size.

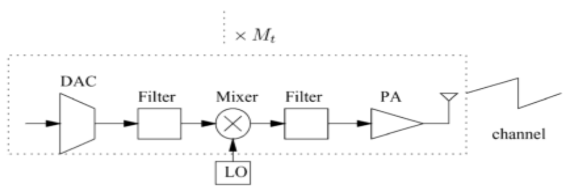

Figure-5 Transmitter circuit blocks

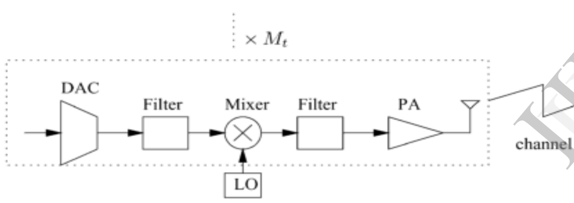

Figure-6 Receiver circuit blocks

The second term P_C in total energy consumption will be given by,

$$P_c \approx M_t\left(P_{DAC} + P_{mix} + P_{filt}\right) + 2P_{syn} + M_r\left(P_{LNA} + P_{mix} + P_{IFA} + P_{filr} + P_{ADC}\right) \quad \dots\dots\dots.. (5)$$

Where P_{DAC}, P_{mix}, P_{filt}, P_{filr}, P_{LNA}, P_{IFA}, P_{ADC} and P_{syn} are the power consumption values for the DAC, the mixer ,the active filters at transmitter side and active filters at receiver side, the low noise amplifier, the intermediate frequency amplifier, the ADC and the frequency synthesizer ,respectively. To estimates the values of P_{ADC}, P_{ADC}, P_{IFA} ,we use the model used in[6].Finally the total energy consumption per bit for a fixed rate system can be obtain by

$$E_{bt} = \frac{(P_{PA} + P_c)}{R_b} \quad \dots\dots\dots\dots\dots\dots\dots. (6)$$

The simulation parameters will be given in the below table-1

Table-1 Simulation Parameters

$f_c = 2.5\ GHZ$	$\eta = 0.35$
$G_t G_r = 5\ dBi$	$\sigma^2 = \frac{N_0}{2} = -174dBm/Hz$
B=10KHZ	β=1
P_{mix}=30.3 Mw	$P_{syn} = 50.0\ m\ W$
$\overline{P_b} = 10^{-3}$	$T_s = \frac{1}{B}$
$P_{filt} = P_{filr} = 2.5\ mW$	$P_{LNA} = 20\ mW$
$N_f = 10dB$	$M_l = 40\ dB$

4. Results

Here we compare four types of mimo technique SISO, MISO, SIMO, and MIMO with and without energy consumption at different distances

4.1 For SISO (1×1)

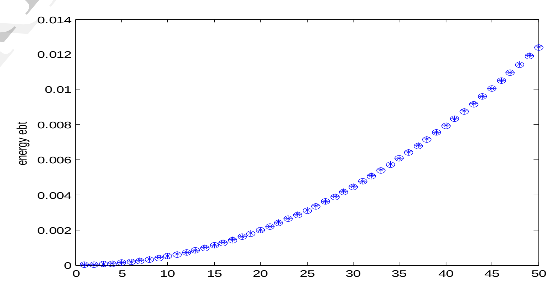

Figure-7 energy consumption with and without circuit consumption for SISO (1×1)

4.2 For MISO (2×1)

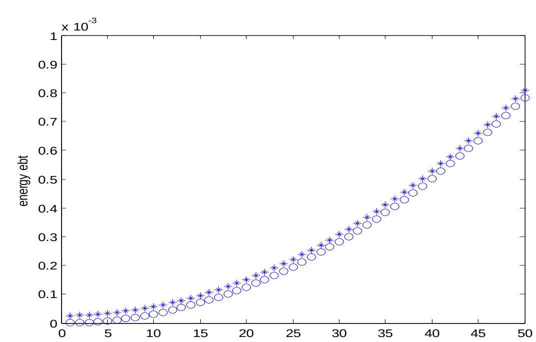

Figure-8 energy consumption with and without circuit consumption for MISO(2×1)

4.3 For SIMO (1×2)

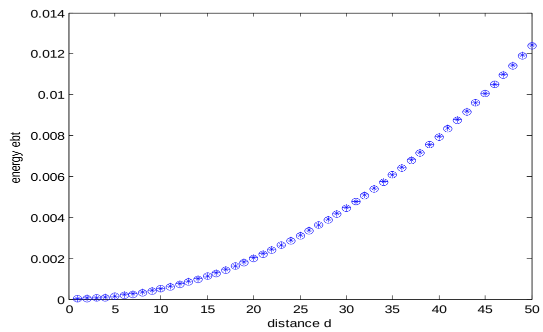

Figure-9 energy consumption with and without circuit consumption for SIMO(1×2)

4.4 For MIMO (2×2)

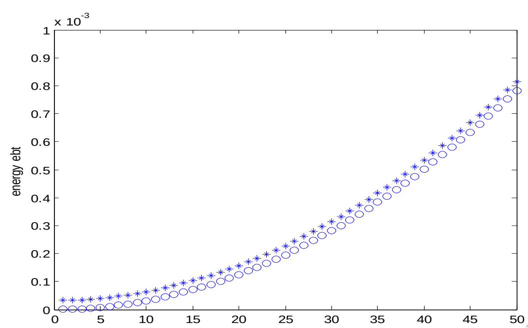

Figure-10 energy consumption with and without energy consumption for MIMO (2×2)

Energy consumption per bit in millijoule is given in the following tables

Table-2 Transmission energy per bit with circuit consumption

Distance(in m)	SISO(1×1)	SIMO(1×2)	MISO(2×1)	MIMO(2×2)
10	0.5	0.522	0.57	0.063
30	4.5	4.5	0.307	0.314
50	12.4	12.4	0.80	0.815

Table-3 Transmission energy per bit without circuit consumption

Distance(in m)	SISO(1×1)	SIMO(1×2)	MISO(2×1)	MIMO(2×2)
10	0.495	0.495	0.0379	0.03133
30	4.5	4.5	0.2820	0.2820
50	12.4	12.4	0.7523	0.7833

5. Conclusion

From the above results we have conclude that the technique of multiple input multiple output are more energy efficient than the other techniques. If we not consider the circuit energy consumption then the MIMO technique will be more energy efficient.

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