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Spatial Modulation in Cooperative Wireless Sensor Network

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***Abstract*—In recent years, Spatial Modulation (SM) has attracted much research interest due to its enhancement of spectral efficiency and reasonable system complexity. The basic idea for SM is that, at each time instant, only one antenna is active. The index of the active antenna becomes a resource for carrying information. Due to this, higher order modulation schemes suffers inherent throughput loss and poor spectrum utility. The implementation cost of MIMO system can be considerably by setting up a virtual MIMO, where the single antenna in each wireless node is used to establish a cooperative network for transmission of system. The constellation of the spatial modulated signal and its performance based on the symbol error rate is analyzed in this paper.**

***Index Terms*—MIMO system, spatial modulation, Cooperative communication**

I. INTRODUCTION

The use of multiple antennas at each transmitter and receiver sides [MIMO] has been shown to be an effective way to improve the capability and reliability of single antenna wireless system. MIMO increases complexity and also cost. Spatial Modulation (SM) could be a multiple-antenna transmission technique that may offer really low system complexity, improved information rates compared to Single-Input Single-Output (SISO) systems, and error performance even in related to channel environments. The essential plan of SM is an extension of 2 dimensional signal constellations (such as M-PSK or M-QAM) to a 3rd dimension that is the spatial (antenna) dimension. Improving the energy efficiency in wireless sensor networks (WSN) has attracted wide attention today. The multiple-input multiple-output (MIMO) technique has been evidenced for improving the energy efficiency, however it should not be possible in WSN that is owing to the size limitation of the sensor node. As a result, the cooperative multiple-input multiple-output (CMIMO) technique overcomes this constraint and shows a dramatically sensible performance. Wireless sensor network (WSN) has been one of the key techniques in several applications like environment monitoring, industrial management, so forth [17]. In a very typical WSN, the power supply of every sensor node is from its battery that is energy restricted and troublesome to charge. Minimizing the energy consumption to enhance the energy efficiency becomes another way to solve the energy constraint problem. Multiple-input multiple-output (MIMO) has been evidenced as a core technique to decrease the energy consumption of a wireless network [18]. However, in WSN, wireless sensor node is typically designed by single transceiver antenna to realize a single-input single-output (SISO) mechanism since the sensor node might not be ready to equip using multiple antennas owing to the little physical size. Consequently, it's troublesome to directly apply MIMO in WSN. Fortunately, the emergence of cooperative MIMO (CMIMO) [1, 2] brings the solution to unravel this transmission problem. CMIMO, generally noted as virtual MIMO, are able to do MIMO gains by use of collaboration among the single antennas embedded in every single node. Spatial modulation (SM) transmits the modulated symbol through a wireless channel by employing a corresponding antenna specified by the antenna index. Throughout the transmission, just one antenna is active whereas others are sleeping which might effectively avoid the inter channel interference (ICI).A new technique named CMIMO-SM is proposed that involves the joint utilization of cooperative MIMO and SM techniques in WSN for energy-efficiency improvement. CMIMO are able to do yield the MIMO advantages in terms of energy efficient performance if the transmission distance is longer than that of critical distance

II. RELATED WORK

In [1] CMIMO concept was proposed by Cui et al. for single hop transmission in WSN. A vertical Bell labs layered space-time (V-BLAST) based on virtual MIMO as proposed in [2], that considers the overhead demand. The authors of [3] mentioned the efficiency of cooperative transmission under space-time block code-encode (STBC) and also the synchronization needs. In [4], the authors have shown that the amount of cooperative nodes at transmission and

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reception sides is meant to be designated so as to reduce the energy consumption. The impact of cooperative transmitting area within the cluster was mentioned in [5]. CMIMO in a clustered WSN for energy efficiency was conferred in [6]. The routing design to achieve the benefits of CMIMO in energy saving is proposed in [7, 8]. In [9], the authors optimized energy consumption per unit transmit distance by choosing the amount of cooperative nodes and also the transmit energy consumption. The improvement of the cooperative transmission by single parameter selection of cooperative nodes is introduced in [10, 11]. In [12, 13], the CMIMO with information aggregation technique for energy efficient WSN was conferred. In WSN, data collected by the sensors has to be transmitted to the sink or destination. If the destination is far away, the transmission needs multi hop primarily based technique. Finding the optimum hop to profit CMIMO for achieving energy efficiency was investigated in [14, 15] and multi hop hybrid virtual MIMO for WSN was designed in [16]. However, none of those techniques take under consideration SM that is in a position to avoid ICI and improve spectral efficiency. In this proposed work it was intended to create a dynamic transmission manner of CMIMO with SM based technique for WSN.

III SYSTEM MODEL

In WSN within which every sensing element node provided with a single antenna for data transmission. Typically, local sensing element nodes within the cluster collect the information and transmit it to succeeding relay cluster if the destination is far away. CMIMO will create single node with single antenna achieve MIMO performance and SM will offer high spectral efficiency and avoid ICI. Thus, if it is needed to permit CMIMO and SM techniques to be used among multiple nodes, the joint performance are going to be obtained. In the proposed model, every sensing element node within the cluster includes a preassigned index using binary numbers to represent. Fig.3.1 illustrates the system model for the proposed work. So as to realize the MIMO perform for saving energy, the local data exchange is important. The data flow within the cluster is outlined as local transmission whereas the data delivering between 2 clusters is outlined as long-haul transmission. There are n_t nodes present in the transmitting side, where every sensing element node broadcasts its data to all or any another nodes within the cluster using different time slots at the initial stage. Once every n_r node receives all the another data bits, the data sequence is prepared to be transmitted through the wireless channel.

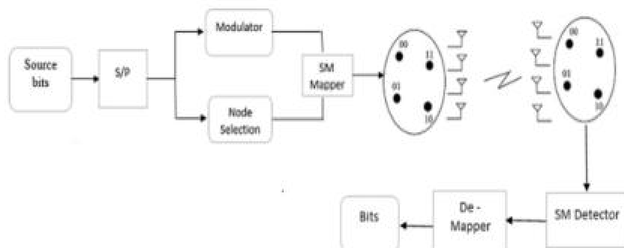

Fig 3.1 Cooperative MIMO network

For every time instant, the data sequence consists by the MQAM/MPSK modulated symbol part and antennas represented part. Only the MQAM/MPSK modulated symbols are transmitted and also the symbol represented by corresponding antenna as the hidden data are going to be detected at receiver. On the receiver side, one destination node and $n_r - 1$ nodes be a part of the cooperative reception.

A. NODE SELECTION

Power allocation in cooperative relaying Cooperation is offered in wireless networks, wherever the multiple nodes are helping one another by relaying transmission. Cooperative network consists of transmitter, receiver and n-number of relays. In cooperative communication, all the relays are useful to transmit the information from source to destination. The entire power during this system is equally divided to source and relays, such kind of power allocation is referred as equal power allocation (EPA). Power allocation in cooperative communication by knowing the channel gains is optimal power allocation (OPA). The optimum power allocation has many advantages for improve the system performance in terms of low SER, high throughput and low probability of error [24]. During this theme the system choose the best relay among the multiple relays and so allot power to the relay on assumption of mean channel gains [25]. In this, power allocation is done by 2 steps. In step-I, the power of source is balanced for overall network. In step-II, power allotted for selected relays equally [25]. The power allocation schemes are additional done by some soft computing techniques. Genetic algorithm (GA) for adaptive power allocation in cooperative communication is to attenuate the SER and outage probability. And this kind of power allocation is developed for relay selection [26]. During this kind of power allocation the soft computing techniques are

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optimized. Here the source power and relay power are taken as constraints for fitness function. Once evaluating the fitness function, the power of source and relay are assigned by optimum value. PSO (Particle Swarm Optimization) based power allocation additionally improves the system performance in terms of outage and SER. Unlike GA, PSO doesn't have any evolutionary process operations like, cross over and mutation. In PSO particles are updated themselves with the interior speed. It's simple to implement and it provides fast convergence to optimum solution. The PSO provides an algorithm to evaluate the fitness function for the system. PSO technique is based on moment of the swarm and therefore the reason behind using particle swarm optimization is, it's straightforward to implement and quick convergence for better optimum solution [27].

B. SPATIAL MODULATION

Spatial Modulation (SM) can be a novel mean of a novel means of transmitting information by means of the indices of the transmit antennas of a MIMO system additionally to the conventional M-ary signal constellations. In contrast to conventional MIMO schemes that rely either on spatial multiplexing to boost up the information rate or spatial diversity to improve the error performance, the multiple transmit antennas of a MIMO system are used for a special purpose in an SM. Specifically, there are 2 information carrying units in SM, indices of transmit antennas and M-ary constellation symbols. For every signal interval, a total of $\log_2(n_t) + \log_2(M)$ bits enter the transmitter of SM system, wherever n_t and n_r denote the number of transmit and receive antennas, respectively, and M is that the size of the considered signal constellation like M-ary Phase shift keying (M-PSK) or M-ary Quadrature Amplitude Modulation (M-QAM). The $\log_2(M)$ bits of the incoming bit sequence are used to modulate the phase and/or amplitude of a carrier signal, whereas the remaining $\log_2(n_t)$ bits of the incoming bit sequence are reserved for the selection of the index (I) of the active transmit antenna that performs the transmission of the corresponding modulated signal (s).

The receiver of the SM has 2 major tasks to accomplish: detection of the active transmit antenna for the decoding the index select bits and detection of the data symbol transmitted over the activated transmit antenna for the demodulation of the bits mapped to M-ary signal constellation. But, the optimum maximum likelihood (ML) detector of SM has got to build a joint search over all transmit antennas and constellation symbols to perform these 2 tasks. In alternative words, the maximum likelihood detector of the SM independently implements a classical single-input multiple-output (SIMO) maximum likelihood detector for all transmit antennas to find out the activated transmit antenna by comparing the minimum decision metrics $(m_1, m_2, \ldots, m_{n_t})$. On the other hand, the primitive suboptimal detector of SM deals with the 2 tasks one by one, that is, first, it determines the activated transmit antenna. Secondly, it finds the data symbol transmitted over this antenna. Therefore, the dimensions of the search space becomes $n_t \times M$ and $n_t + M$ for the maximum likelihood detector and suboptimal detector, respectively.

C. SM MAPPER

The low-complexity design and high spectral efficiency are simultaneously achieved by adopting the modulation and coded mechanisms in what follows (i)only one transmit antenna is activated for data transmission at any signal time instance. This permits SM to thoroughly avoid the ICI, to require no synchronization among the transmit antenna, and to need just one RF chain for data transmission. The multiple-antennas are used at the same time to transmit multiple data streams [19]. This permits SM to use a low-complexity single stream receiver design for optimal maximum likelihood (ML) decoding.

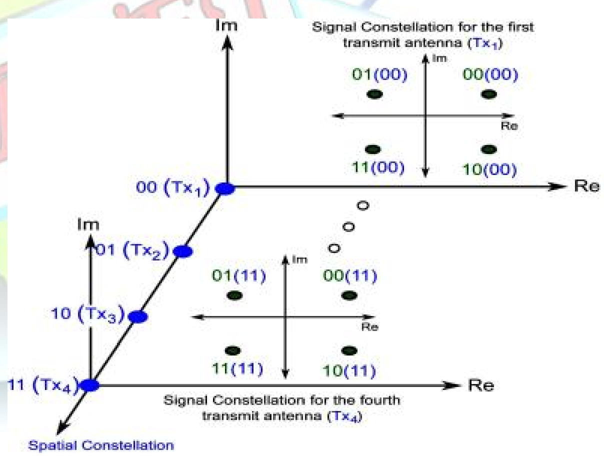

Fig 3.2 3D signal constellation

(ii) The spatial position of every transmit antenna within the antenna-array is employed as a source of data. This can be obtained by establishing a one-to-one mapping between every antenna index and a block of data bits to be transmitted, which ends up in a coding mechanism which will be known as transmit-antenna index coded

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modulation. This permits SM to attain a spatial multiplexing gain with regard to single-antenna systems since a part of the data is implicitly conveyed by the position of the transmit antenna[20,22]. Despite the fact that only 1 antenna is active, SM may also accomplish high data throughput. The two distinguishable features above create SM, aessentially new physical layer transmission technique which combines, in a very distinctive fashion, digital modulation, coding, and multiple-antenna to attain high data rates and low-complexity implementations. Fig. 3.2 shows the constellation of the modulated signal mapped to the transmitter selected using PSO algorithm. Specifically, the coding mechanism makes SM very different from Transmit-Antenna Selection (TAS) or Spatial Division Multiplexing (SDM) schemes. [19-21].

D. SM TRANSMITTER

At the transmitter, the bit stream emitted by a binary source is split into blocks containing $\log_2(n_t)+\log_2(M)$ bits every, with $\log_2(n_t)$ and $\log_2(M)$ being the amount of bits required to spot a transmit-antenna within the antenna-array and symbol within the signal-constellation diagram, respectively. Every block is then processed by a SM plotter, that splits each of them into 2 sub-blocks of $\log_2(n_t)$ and $\log_2(M)$ bits each.

The bits within the initial sub-block are used to choose the antenna that's switched-on for data transmission, whereas all other transmit-antenna are kept sleeping within the current signal time interval. The bits within the second sub-block are used to select a symbol within the signal-constellation diagram. If SSK modulation rather than SM is taken into account, each transmit-antenna, once switched on, can send precisely the same signal out, the information is, thus, encoded only within the position at intervals of the antenna-array.

E. MRC RECEIVER

In this methodology, the received signals at the receiver are combined linearly with a weighing factor chosen so properly that maximizes the SNR concerning both the phase and also the amplitude. This methodology exploits the information from both amplitude and phase of fading and therefore the performance is far higher, however complexity of implementation is high . In this methodology the signals from all the multiple nodes are weighted at the receiver by individual basis according to their voltage to noise power ratio and then combined. This Maximum Ration Combining (MRC) technique do the most effective performance by multiplying conjugated channel gain to every received signal. This assumes perfect CSI is known at the receiver [23].

$$y_d[n] = \sum_{i=1}^{k} h^*_{i,d} \cdot y_{i,d}[n]$$

IV. SIMULATION RESULTS

Simulation results is obtained using MATLAB tool . To find out the optimum path for effective transmission, the subsequent steps are executed. Initially the transmission for cooperative communication is done by using STTC methodology. For STTC method, M-PSK modulation technique is used. The Performance of the signal transmitted using Spatial modulation is analysed by using M-QAM With Increase Here QPSK is employed that has low bit error probability than other PSK modulation. AWGN noise that has zero mean value is added with input signal. Then the transmission in cooperative communication is executed by using spatial modulation. In SM, the input data stream is split into 2 vectors. Active transmitting antenna is found through vector. APM bit is modulated on both amplitude and phase.

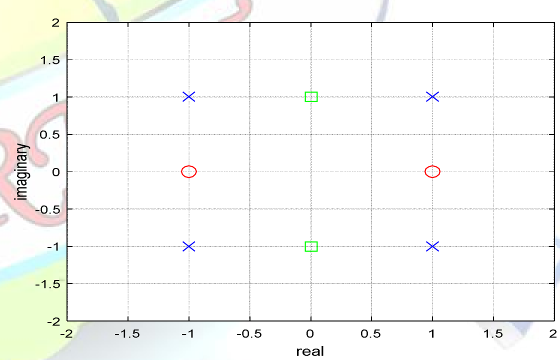

Fig 4.1 The crosses represent 4QAM and the circles (resp. squares) represent the BPSK0 (resp. BPSK1) signal constellation.

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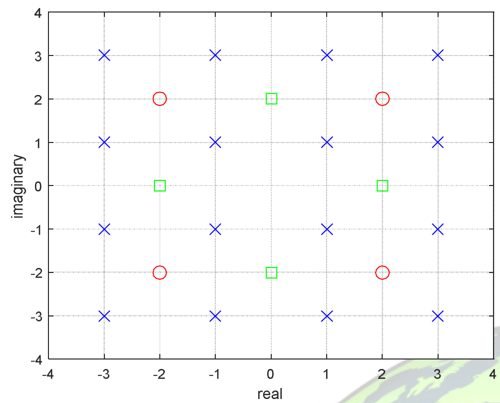

Fig. 4.2 The crosses represent 16QAM and the circles (resp. squares) represent the QPSK0 (resp. QPSK1) signal constellations.

For SM, QAM modulation is employed. By plotting the graph for SNR and BER of each STTC and SM, cooperative path of SM has low bit error rate than alternative techniques. SM-MIMO cooperative path is employed for transmission to achieve maximum throughput. [7] discussed about a method, Sensor network consists of low cost battery powered nodes which is limited in power. Hence power efficient methods are needed for data gathering and aggregation in order to achieve prolonged network life. However, there are several energy efficient routing protocols in the literature; quiet of them are centralized approaches, that is low energy conservation.

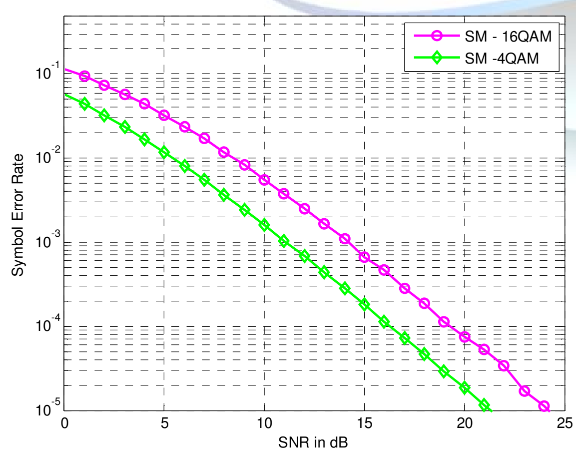

Fig 4.3 SER performance for SM in cooperative network (for 4 QAM and 16QAM)

V. CONCLUSION

Cooperative diversity has several advantages to extend the wireless communication system performance, in terms of lower SER (symbol error rate) and lower outage. Maximal ration combiner is employed to combine the multiple copies of the original message at the receiver. The performance has been analyzed for multi relay cases in Rayleigh fading channel. The SER performance analysis using single and multi-relay case with equal power allocation is analyzed. From the simulation results, it's determined that the system performance is improved, whenever the number of relays is increased. By this way the issues of wireless communication system like fading, shadowing and path-loss are reduced by using relay as a 3rd station. Thus the information is transmitted in the form of multiple copies of signals and it's combined at the receiver by using combining techniques.. The scope of future work is relay selection. In wireless environment, several relays are present it's necessary to select the relay from multiple relays to transmit the information from source to the destination and to use the enhanced spatial modulation.

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