# Energy Efficient MIMO Communication Technique – A Survey

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***Abstract-*** *Wireless communication systems can be divided into energy and power limited systems. Base stations are typically considered as power limited and mobile terminals as energy limited due to the limited capacity of batteries.Energy efficiency in wireless network is a rising concern for wireless operators to not only maintain effectiveness, but also to decrease the overall environment effects.We believe radio applications in sensor networks where the nodes operate on batteries so that energy consumption must be minimized while fulfilling given throughput and delay requirements.The total energy consumption are include both the transmission energy and the circuit energy consumption. The significant reasons for the use of MIMO techniques are: to increase the maximum data rate, to extend the coverage, and to serve a larger number of users. Wireless networks are gradually more considered as energy limited because the energy consumed by future networks is about to increase Cooperative communications is viewed as a mechanism for increasing the diversity order, robustness, fairness and energy efficiency of a wireless communication system.*

***Keywords-*** Multiple - input - multiple - output (MIMO), Energy efficiency, Cooperative MIMO

## I. INTRODUCTION

Multi-antenna systems have been studied intensively in recent years due to their potential to dramatically increase the channel capacity in fading channels. It has been shown that Multi-Input Multi-Output (MIMO) systems can support higher data rates under the same transmit power resources and bit-error-rate performance requirements as a Single-Input Single-Output (SISO) system. An another view is that for the same throughput requirement, MIMO systems require less transmission energy than SISO systems. Direct application of multi-antenna techniques to sensor networks is unreasonable due to the limited physical size of a sensor node which typically can only support a single antenna. We allow individual single-antenna nodes to cooperate on information transmission and/or reception, cooperative MIMO system can be constructed such that energy-efficient MIMO schemes can be deployed. In wireless communications, the objectives are to increase throughput and transmission quality. MIMO systems can take advantage of the inadequacy of a wireless channel , the multipath and turn it into advantage. In MIMO systems, random fading and multipath delay spread can be used to increase throughput. MIMO systems offer increase in capacity without the need to increase bandwidth or power.One obvious disadvantage of MIMO is that they contain more antennas: MIMO increases complexity, volume, and hardware costs of the system compared to SISO. MIMO system is not always useful knowing that channel conditions depend on the radio environment. When there is Line of Sight (LOS), higher LOS strength at receive will effect in better performance and capacity in SISO system, while in MIMO systems capacity is reduced with higher LOS strength. This is because strong contributions from LOS lead to higher relationship among antennas, which reduces the advantage of using MIMO system.

The energy consumption of simple MIMO systems and compare the value with that of reference SISO systems under same throughput and BER requirement. The energy efficiency is compared over various transmission distances. In the traditional approach, the multihop transmission techniques are used to reduce the transmission energy consumption by dividing the long transmission channel into multiple short transmissions. The cooperative relay technique can exploit the spatial and temporal diversity gains to reduce the path loss effect in wireless channels. The result is that system performance is improved or less energy is needed for data transmission. Relay techniques are known as simple energy-efficient way of extending the transmission range due to their simplicity and their performance for wireless transmissions over fading channels.

## II. OFDM OVERVIEW[6]

The IEEE 802.16 standard supports multiple physical condition due to its modular nature. The 802.16e OFDMA PHY is based on Orthogonal Frequency Division Multiple Access (OFDMA) modulation, which includes OFDM modulation and subcarrier allocation. OFDM belongs to a family of transmission schemes called multicarrier modulation, which is based on the idea of dividing given high-bit-rate data stream into several parallel lower bit-rate streams and modulating each stream on separate carriers, called subcarriers, or tones. OFDM is spectrally efficient version of multicarrier modulation, where the subcarriers are selected such that they all are orthogonal to one another over the symbol duration.

### III. BASICS OF MIMOCOMMUNICATION

The unstable growth of Multiple Input Multiple Output (MIMO) systems has permitted for high data rate and wide variety of applications. Some of the technologies which rely on these systems are IEEE 802.11, Third Generation (3G) and Long Term Evolution (LTE)ones. Recent advances in wireless communication systems have contribute to the design of multi-user scenarios with MIMO communication. These communication systems are referred as multi-user MIMOs. MIMO system model is showing in Figure 1. We present a communication system with $N_T$transmit antennas and $N_R$ receive antennas.

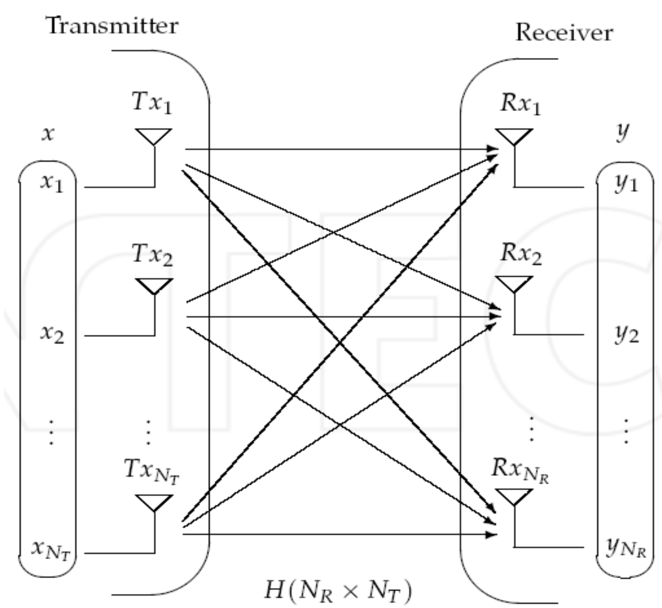


Figure 1- MIMO system model

Now, MIMO system is implemented in many advanced technologies such as various standard proposals for the Fourth Generation (4G) of wireless communication systems and LTE. MIMO technology was shown to boost the communication system capacity and to enhance the reliability of the communication link since it uses several diversity schemes beyond the spatial diversity.

### III. MIMO COMMUNICATION TECHNIQUES

**(A) SISO Multihop Techniques:**

The most simple cooperation system are the multihop SISO transmission, as shown in Figure.2 Instead of the transmission over long distance from source node S to destination node D, a message from source node S at a junction can be transmitted through multiple cooperation nodes to destination node D. Multihop transmission can considerably save the transmission energy consumption with the cost of more circuit energy consumption.

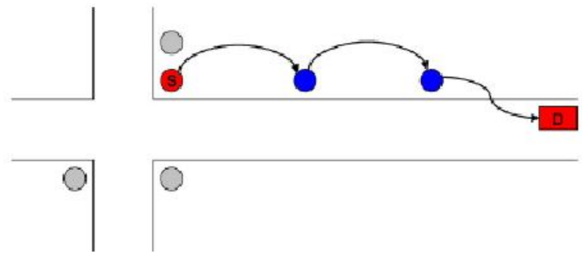


Figure 1. Multihop SISO transmission between source and a destination[1]

**(B) Cooperative SIMO Techniques**[2]

SIMO Transmission Technique consists only one antenna consider at a source and multiple antenna at a destination point for signal transmit and receive respectively. If the signals received on these antennas have on average the same amplitude, then they can be added coherently to produce an N increase in the signal power. On the other hand, there are N sets of noise that are added incoherently and result in an N-fold increase in the noise power. Compared with SISO system, the capacity of SIMO and MISO system shows improvement. The increase in capacity is due to the spatial diversity which reduces fading and SNR improvement. However, the SNR improvement is limited, since the SNR is increasing inside the log function.

**(C) Cooperative MISO Techniques[2]**

MISO Transmission Technique is consist multiple antenna at source side and only one antenna consider at destination point for signal transmit and receive respectively. However, in the presence of transmission errors, the performance of the cooperative MISO technique decreases, leading to the increase of transmission energy consumption. The cooperative MISO technique characteristically needs two or greater than two transmission phases for data exchange and MISO transmission phases. The transmission delay of the cooperative MISO technique is small, so it is usefull to reduce total energy consumption.

**(D) Cooperative Relay Techniques**

The traditional model for the relay diversity technique with one relay node, as shown in Figure. 3, consists of source node S, a destination node D, and a relay node R. The relay transmission from S to D can be performed by two-time slot transmission. In the first time slot, signal is transmitted by the source S to the destination node D and the relay node R at the same time. In the second time slot, the relay node retransmits the information earlier received.

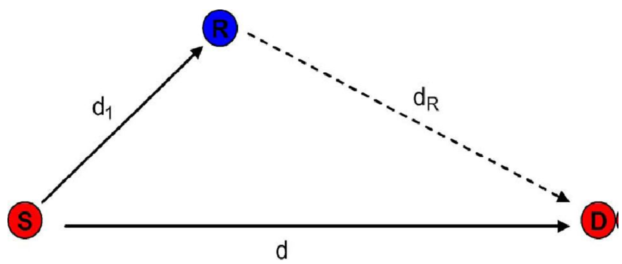


Figure: 3-Three-terminal relay diversity scheme[1]

At node D, the receiver combines received signals by using a diversity combination technique, e.g., maximum-ratio combination (MRC) or equalgain combination (EGC), before symbol detection. In relay cooperative networks, the received signal comes from different independent fading channels, so that the possibility of deep fading is minimized. This diversity gain helps decrease the error rate or the transmission power for the same required error rate. Relay techniques can be classified according to their forwarding strategy. There are three main methods for the relay node to transmit the received frame to the destination node: (1) amplify and forward;(2) decode and forward;(3) re-encode and forward.

**(E) Cooperative MIMO Technique**

The MIMO technique can exploit diversity gain of the space–time coding technique to increase the system performance or to reduce the transmission consumption for the same bit-error-rate (BER) requirement. The principle of cooperative MIMO transmission using STBCs was presented in, As illustrated in Figure 4, the cooperative MIMO transmission (with *N* cooperative transmissions and *M* cooperative reception nodes) from source node S to destination node D over a transmission distance *d* is composed of the following three phases:(1) local data exchange;(2) cooperative MIMO transmission; (3) cooperative reception.

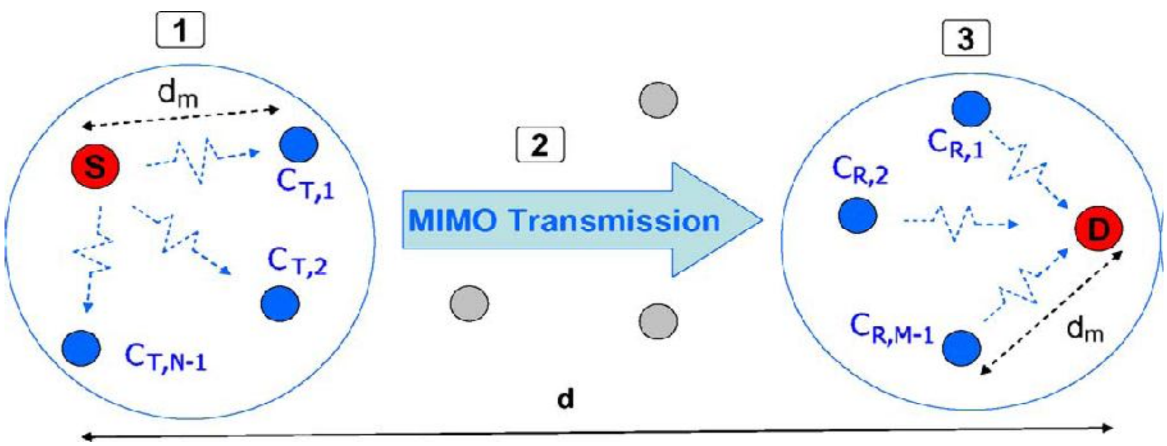


Figure: 4-Cooperative MIMO transmission scheme[1]

In the local data exchange at the transmission side, the source node S must cooperate with its neighbors and exchange its data to perform MIMO transmission in the next phase. Node S can transmit the transmission bits to the other *N* − 1 cooperative transmission nodes. The distance between cooperating nodes *dm* is usually much smaller than transmission distance *d*. In the cooperative MIMO transmission phase, after *N* – 1 neighbor nodes have received the data from source node S, *N* cooperative transmission nodes will modulate and encode their received bits to the quaternary phase-shift keying (QPSK) STBC symbols and then simultaneously transmit to the multi destination nodes similar to traditional MIMO systems (each cooperative node plays the role of one antenna of the MIMO system). Finally, in the cooperative reception phase at the reception side, cooperative neighbor nodes of destination node D receive the MIMO modulated symbols and then sequentially retransmit them to destination node D for joint MIMO signal combination and data decoding. In a cooperative MIMO system, the decoder at destination node D requires the analog value of received signals at all cooperative nodes for the space–time combination. So, each cooperative node must transmit its received value through a wireless channel to destination node D. One of the following three cooperative reception techniques can be used for this retransmission procedure as:(1) quantization;(2) combine and forward; (3) forward and combine.

**(F) Multihop Cooperative MIMO Transmission:**

For a long distance communication, the cooperative MIMO technique with the number of transmit and receive nodes greater than 2 has energy consumption advantages, but this scenario cannot always be employed because of the lack of available nodes at the junctions. In this condition, a multihop technique using cooperative MIMO for each transmission hop is a suitable solution. As an example, for a communication between Cooperative nodes with a distance greater some desired distance shown in Figure-5, two cooperate nodes in the middle of the transmission line can be cooperate together to perform a multihop cooperative MIMO transmission.

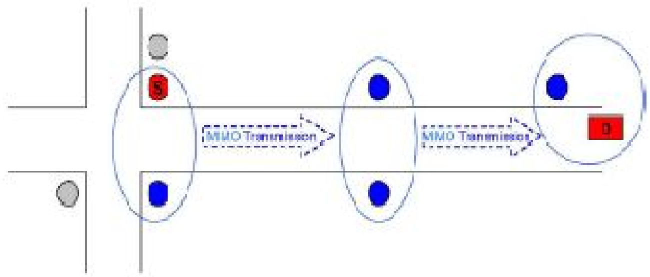


Figure- 5. Multihop cooperative MIMO transmission between the source and destination[1]

## IV. ENERGY EFFICIENCY OF COOPERATIVE STRATEGIES

Assume the cooperative MIMO transmission is with M sending nodes and N receiving nodes, including source node and destination node respectively. The energy consumed for an unsuccessful transmission attempt is

$$\begin{aligned} Eu_{coop} &= E_{mrts} + E_{mcts} + 2E_{rrts} \\ &+ (M-1)E_{scts} + (N-1)E_{scts} \\ &+ E_{br} + E_{data} + (N-1)E_{col} \end{aligned}$$

For a successful attempt is,

$$\begin{aligned} Es_{coop} &= E_{mrts} + E_{mcts} + 2E_{rrts} \\ &+ (M-1)E_{scts} + (N-1)E_{scts} \\ &+ E_{br} + E_{data} + (N-1)E_{col} + E_{ack} \end{aligned}$$

The energy Emrts, Emcts, Eack are the energy consumption of sending MIMO RTS, MIMO CTS and ACK. The MIMO RTS (MRTS) and CTS (MCTS) messages are control messages between source and destination and require higher transmission power for such long distance transmission. Errts and Escts are energy consumption of sending recruiting RTS (RRTS) and sequential CTS (SCTS) to form sending group and receiving group, respectively. The recruiting RTS (RRTS) and sequential CTS (SCTS) are control messages between source and destination and their neighbors. Compared to the MIMO RTS and CTS, the recruiting RTS (RRTS) and sequential CTS (SCTS) can be transmitted with less power due to short-distance transmission. Ecol is the energy consumed by data collection in the third phase. In the receiving group, each helping node will transmit its signal back to the destination with energy Ecol. And there are N−1 helping nodes in receiving group, without the destination node. Ebr is the energy consumption of broadcasting data to helping nodes in sending group. Edata is the energy consumption for data transmission between sending group and receiving group. To make the comparison reasonable, we assume there are the same amount of information bits and the same energy consumption Edata in point-to-point transmission and cooperative MIMO transmission. Similarly, the total energy for one-hop transmission in cooperative MIMO system is

$$E = \frac{P_e}{1-P_e} Eu_{coop} + Es_{coop}$$

where Pe is the packet error probability for cooperative MIMO transmission, which can be derived from the bit error rate results in previous section.

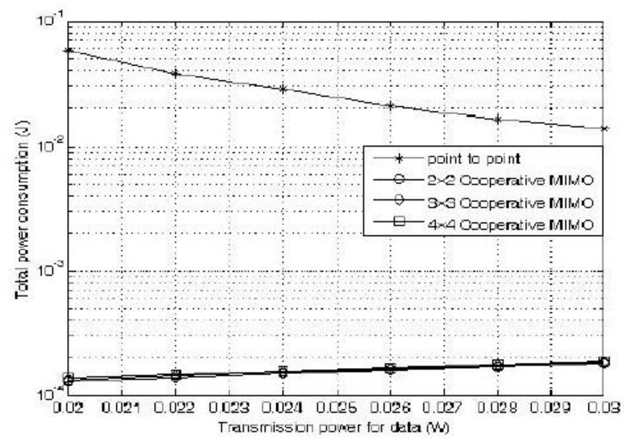


Figure:6- Energy consumption in cooperative MIMO system is muchless than it in point-to-point (SISO) transmission[1]

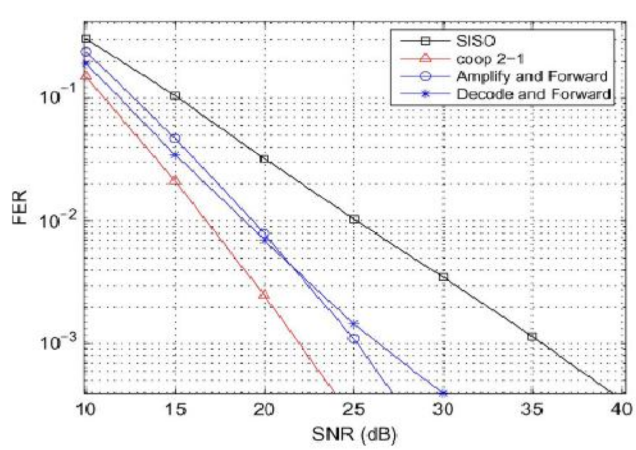


Figure- 7. FER of the relay technique versus the cooperative MISO technique with two transmission nodes[1]

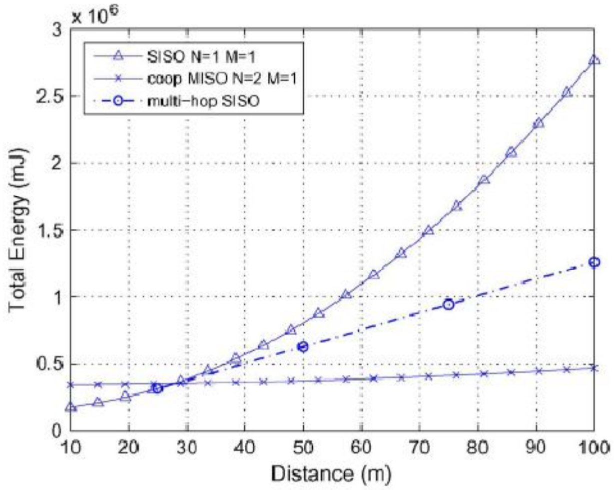


Figure-8. Energy consumption of SISO versus the cooperative MISO technique with two transmission nodes[1]

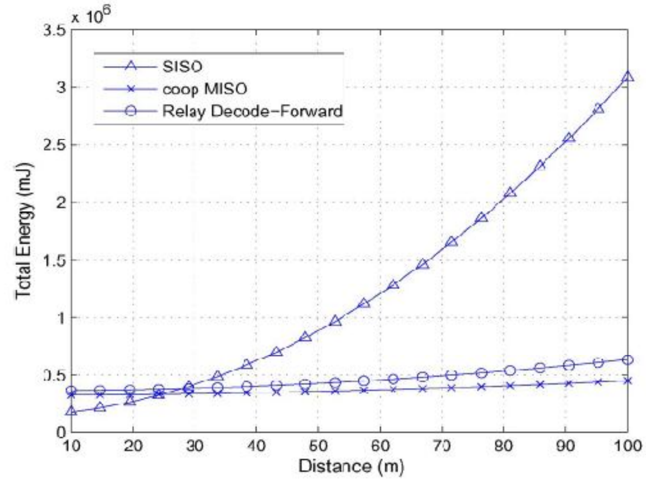


Figure-9. Energy consumption of the relay technique versus the cooperative MIMO technique with two transmission nodes[1]

## V. SUMMARY TABLE

In this summary table, we include above various techniques performance evalutation and figure no.-6,7,8,9 results analysis.

| Sr.NO. | Techniques | Comparisons |
|---|---|---|
| 1 | SISO Multihop Techniques | SISO is better than all of MIMO technique for small transmission distance, but at large transmission distance it is not good for energy efficiency. |
| 2 | Cooperative SIMO Techniques | SIMO is better than SISO for medium range of transmission, but large transmission distance is not good as MISO and MIMO for energy efficiency. |
| 3 | Cooperative MISO Techniques | MISO is better than SISO.SIMO and Relay techniques, but it is not good than MIMO. The energy consumption of the cooperative MIMO 2–2 using the forward-and-combine cooperative reception technique is always smaller than the cooperative MISO 4–1 consumption and smaller than the cooperative MISO 3–1 consumption for large distance. |
| 4 | Cooperative Relay Techniques | In relay cooperative networks, the received signal comes from different independent fading channels so that the probability of deep fading is minimized. The performance of the relay techniques is limited by the decoding process at the relay nodes. The error bit that occurs at the relay node cannot always be corrected at the destination node. However, with the same diversity gain, the performance of relay is always lower than MISO space–time coding techniques. |
| 5 | Cooperative MIMO Technique | The cooperative MIMO technique is an energy-efficient cooperative technique for medium- and long-range transmissions. The cooperative MIMO technique exploits the diversity gain of the MIMO space–time coding technique in distributed wireless networks to reduce the transmission energy consumption. Depending on the system topology and the transmission distance, the optimal selection of transmit and receive nodes number can be chosen to minimize the total energy consumption. |
| 6 | Multihop Cooperative MIMO Transmission | For a long distance communication, the cooperative MIMO technique with the number of transmit and receive nodes greater than 2 has energy consumption advantages , but this scenario cannot always be employed because of the lack of available nodes at the junctions. In this condition, a multihop technique using cooperative MIMO for each transmission hop is a suitable solution. |

Table-1 summary of various cooperative Techniques

## VI. CONCLUSION

Cooperative techniques are exploiting the transmission diversity gain to increase the performance or reduce the transmission energy consumption of the system. The cooperative MISO and MIMO techniques are more energy efficient than the SISO and traditional multihop SISO techniques for medium and long-range transmissions Cooperative relay techniques provide attractive benefits for wireless distributed systems when the temporal and spatial diversity can be exploited to reduce the transmission energy consumption. Relay techniques are more efficient than the SISO technique but are at rest less efficient than the cooperative MISO techniques in terms of energy consumption. The performance of the relay techniques are not as good as the cooperative MISO techniques for the same SNR. However, the relay techniques are not affected by the unsynchronized transmission scheme. When the transmission synchronization error becomes significant, the performance of the relay techniques is better than the performance of the cooperative MISO, leading to better energy efficiency. Multihop Cooperative MIMO technique is more suitable than Cooperative MIMO and Relay technique in large transmission distance for energy efficient.

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