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ENERGY EFFICIENT COOPERATIVE COMMUNICATION MIMO FOR WIRELESS COMMUNICATIONS

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Abstract: For energy limited, distributed and cooperative wireless sensor networks, an energy efficient virtual multiple input multiple output (MIMO) based communications architecture is proposed. The energy and delay efficiencies of the pro-posed MIMO-based communications scheme are derived using analytical techniques while assuming a space time block coding (STBC) for the MIMO system. In this paper, an energy-efficient cooperative MIMO (multiple-input multiple-output) wireless communications system is proposed for distributed, energy-constrained, and cooperative WSNs (wireless sensor networks). Using the concept of cooperative MIMO communications, the energy efficiency and increased capacity of the MIMO system is achieved. The system and channel propagation parameters are most important factors which affects the efficiency of the proposed cooperative MIMO communications. A virtual MIMO system is formed by dynamically selecting the source node and cooperative nodes. The concept of virtual MIMO is used to provide significant energy and delay efficiencies with proper selection of system parameters. The scheme, called MIHOP (Made It Happen On Purpose), combines cluster-based virtual MIMO and multihop technologies. The multihop mode is employed in data transmission. Here the related sensors are located within a specific number of hops from the sink, and the virtual MIMO mode is used for transmitting data from the remaining sensor nodes. The comparison of the energy consumption of different transmission schemes was performed and propose an algorithm for determining the optimal hop count in MIHOP. The controllable mobile sink reduces the energy consumed in sensor transmission is also adopted for data collection. This project combines both MIMO with multi point relay set. MIMO technology takes the advantage of a radio wave phenomenon called multipath where transmitting the information to other objects.

Keywords: Mesh Topology, Multipoint Relay, Stateless Multicast Protocol, Virtual MIMO, Wireless Sensor Networks.

I.INTRODICTION

The leading and efficient promising technology for the future generation wireless communications is MIMO (multiple-input multiple-output); due to its potentiality to increase the channel link capacity without requiring the additional power and to efficiently use the available spectrum [1-3]. The concept of The MIMO technology has been adopted by cutting-edge and emerging mobile wireless network standards such as Wi- MAX, 802.11n, and LTE. In MIMO technology higher communication reliability or higher data rate can be effectively achieved by using the multiple antennas at both transmitter side and at receiver side and the channel boosting is achieved by suppressing the correlation among all communication links. Therefore several multiple communication link are present between all active antennae elements and causes to increases the consumption of power and it is particularly problematic for short range wireless communications. Therefore increasing the efficiency of energy for the transmission of data becomes an important challenging issue for the design of MIMO WSN (wireless sensor Networks).Data packet error and the severe fading in the communication channel are two important factors which have great impact on energy efficiency and transmission reliability of MIMO WSNs [1]. Therefore an imperative design concept is required for wireless sensor networks to achieve efficient robustness and to minimize the energy consumption.

Recently several researches has done and recently shown that by efficiently using the broadcast nature of wireless channel link medium and the sensor node's spatial distribution, the collaboration of several individual multiple nodes will improve the reliability of MIMO WSN system and effectively decreases the more power requirements. This type of strategy is known as *cooperative MIMO communication.* Generally there are two kinds of cooperative communications are broadly available.

1. Multiple-relay based
2. Single-relay based.

The Multiple-relay based cooperative MIMO communications is formed using the concept of *distributed beam forming or distributed space-time coding* [3], [4]. Therefore the complexity in the formation of former is higher than Single relay based. Therefore it is used to apply Single-relay based cooperative MIMO communication concept to resource constrained WSNs.

Basically in classical transmission i.e. non-cooperative or direct transmission, No any other neighbouring nodes are involved except source and destination nodes while transferring the nodes. In direct transmission, all the remaining nodes except source and destination nodes are keep in sleep mode for saving the energy consumption but greatly affects the reliability and consumptions of MIMO WSN system.

II. Virtual MIMO Communications Architecture

For effective design of proposed system we assume that a narrow band communication link with flat fading to comunicate wireless sensor networks [3]. And in this paper we choose STBC (Space Time Block Codes) or Alamouti scheme to provide the considered generalizations to more than 2 transmit antennas [3]. By using the concert of sensor cooperation it is easy to build a *virtual MIMO communication system architecture.* And a virtual V-BLAST based scheme for WSNs was given in [4].Therefore we propose an efficient wireless sensor network system model as discussed below…

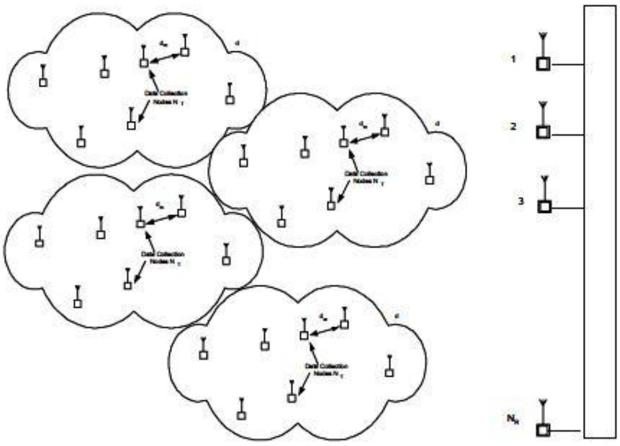


Fig 1: A Virtual MIMO Communications Based WSN

The most common elements for ditributed WSNs are *lead sensor nodes or antennas* and *data collection nodes or antennas* (here each antenna termed as node, as see in fig 1). Particularly this type of system model is very helpful for employing the energy efficiency of the systems which provide distributed coding and signal processing. The proposed system model comprises of *Data-Collection sensors* at lower-end over a wireless communication link with *Data-Gathering Nodes (DGNs)* at higher-end. The data gathering sensors works as a lead node or lead sensor or fusion centre. Here the collection sensors are modelled as strictly energy constraint node sensors, where as DGN is not. The name itself the data collection nodes are used to collect the information on physical phenomenon of interest. The collected from collection nodes is then transformed to the *Data-Gathering Nodes (DGNs)* to implement the cooperative processing over a wireless communication link.
Therefore the proposed virtual MIMO-based communications can be implemented as follows:
Intially, assume that much amount of data will be present at data collection nodes to sent to the *DGNs (Data-Gathering Nodes).* Here each individual data collection antenna element broadcasts their data to every other individual antenna elementin the set by using multiple access techniques. This process is
termed as the *local distribution at* the transmitter side.
Therefore at the end of the process of local communications each individual data collection nodes have information from each and every sensor nodes. For achieving the efficient and robust communication among all these sensors or antennas
Space - Time Block Code (STBC) is implemented. Whenever the STBC scheme is implemented each space time code symbol is assumed to be sent by specific individual transmit antenna to the DGN. This process is known as *Long haul Communication.*
To peform the process of local distribution and long haul communications the DGN is assumed to have larger physical dimensions, which enables multiple receiver antenna capability without energy constraints. This assumption allows realization of true MIMO.

III. LOCAL DISTRIBUTION AND LONG-HAUL TRANSMISSION

Figure 2 illustrares the poposed system model. We assume that source node has the abilility to build a cooperative MIMO system by effectively cooperating with its neighbour antenna elements or sensors. All the antenna elements or sensors including source assumed as single antenna elements and the destination node is assumed with large number of antenna elements.

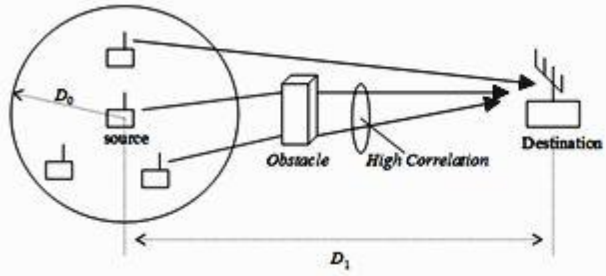


Fig 2: System model of proposed method

For the illustartion of proposed scheme we supposes that the source has a information of L0 bits to sent to the destination. Using our proposed scheme the main objective is to implement cooperation MIMO. As discussed above in the process of implementing cooperation MIMO there are two important sequential processes are present known as Local Distribution and Long-Haul Transmission.

A. Process of Local Distribution

In the process of local distribution assume that N nodes are used to perform cooperation. Briefly, in this process the the total information of L0 bits is divided into N individual unique sub-streams, and transmits these N individual sub streams to the N selected cooperative nodes such that each unique cooperative node will has one distinct unique sub stream. In this process the TDMA scheme id implemented to distribute the information. In the process of local distribution the energy consumption is very important factor in order to complete the process successfully. Therefore the required energy for the process of local distribution to each cooperative node is the summation of transmission consumption energy and circuit energy consumption [3, 14]. Consider that source node has i L bits to transmit cooperative node '*i*'. And assume that QAM scheme is used for modulation and demodulation of packetized information. We know than QAM signal consists of in phase and Quadrature phase components and the probability of error of QAM signal is:

$$SER = 1 - (1 - SER_I)(1 - SER_Q)$$

SERI and SERQ are the probabilities of symbol error rates of in phase and quadrature phase components of QAM signal respectively. Therefore the Symbol Error Rate (SER) of signal is

$$SER \approx 4Q\left(\sqrt{\frac{3\zeta}{M_o -}}\right)$$

ζ is the corresponding SNR for the transmission to node *i*, and ζ is defined as

$$\zeta = \frac{\alpha_i P_i^{(1)}}{N_0}$$

α_i is known as channel gain and (1) Pi is defined as transmission power per symbol. N0 is noise power.
Therefore the total (1) Pi to node 'i' is defined as:

$$P_i^{(1)} = \frac{(M_0 - 1).N_0}{3\alpha_i} \times \left[Q^{-1}\left(\frac{SER_t}{4}\right)\right]^2$$

Similarly assume that, for the transmission of each symbol the consumed circuit power is constant and it is Pc for all the nodes. Therefore the total energy consumption in the process of localization for transmitting total 0 L bits is).

$$E_{tot}^{(1)} = \sum_{i=1}^{N}\left(\frac{T_s L_i}{b_0} \times \left[P_c + P_i^{(1)}\right] \times I(i)\right)$$

L_i/b_o is defined as the number of symbols in the Packet.

Here one very interesting note is that, when node 'i' the source node itself then there is no power consumption and automatically some delay is introduced for local distribution. Therefore we define I (i) as the indicator function
I (i) = 0, when 'i' is source node.
1, when node 'i' is not the source node.
The total delay introduced in the process of local distribution with fixed symbol duration Ts of N cooperative nodes is

$$T_{tot}^{(1)} = \sum_{i=1}^{N} \frac{L_i}{b_o} \times T_s \times I(i)$$

B. Long Haul Transmission Optimization
In this process all the selected 'N' cooperative nodes will communicate together and implement a virtual MIMO system with destination node. In this stage the total power required for the transmission of information from all cooperative nodes is must be less than or equal to PT and the total bit rate is bT Therefore

$$b_T = \log_2\left(\prod_{i=1}^{N}\left[\frac{6P_i.\left|R_{i,i}\right|^2}{d_0^2} + 1\right]\right)$$

$$P_T = \max_{\{P_i\}}\left\{\prod_{i=1}^{N} 6P_i.\left|R_{i,i}\right|^2\right\}$$

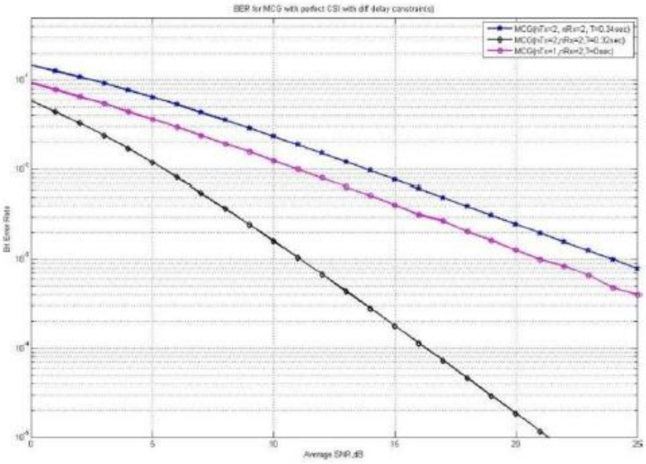
Whenever the total power PT distributed to all the cooperative nodes then the maximization of optimization problem is successfully achieved and amount of total required power is varies depending on the number of cooperative nodes.

IV. COOPERATIVE NODE SELECTION

The selection of cooperative nodes is very important task while dealing with the concept of cooperative MIMO. This selection is depends on the availability of the Channel State Information (CSI) at the source. The information of CSI at transmitter describes the combined effect of signal propagation and decay in power with distance.
Channel state information:
The Channel-State Information (CSI), available at both transmitter and receiver will greatly effects the capacity of MIMO system. Generally pilot signals are combined within all transmission signals from the transmitter to accurately measure the CSI at receiver. In frequency duplexed systems, the CSI must be conveyed through feedback, since in those systems the uplink and downlinks are separated in terms of frequency. Where as in time-duplexed systems, the uplink anddown links are invertible to each other as long as the synchronous time of the fading process overcomes the duplex time. Thus, the transmitter may have access to reliable CSI at low and moderate levels of mobility.

V. SUMULIATION AND PERFORMACE ANALYSIS

In this session the results for the proposed method is discussed clearly with the help of simulation results using MATLAB.



As we know that whenever there is no delay exists, then the performance of the system is best for ever for any condition. But it is impossible to implement a practical system with no delay constraint. In above figure we represent the performance of the MCG algorithm with no delay. As discussed already the performance of the system degrades as per the changes in delay constraints. Since we are proposing a cooperative scheme of MIMO, the performance of the system will definitely depends on all the individual performances of the cooperative antenna elements at that time of instant.

So definitely the cooperative MIMO never chooses the best set of nodes in all instances, therefore we never achieves best results in all time for same type of conditions. As shown in figure 3 whenever the delay changes 0.32 to 0.34 seconds, correspondingly the system performance also changes. Therefore it is clear that the performance of an individual MIMO system not better than our proposed cooperative MIMO concept, since the delay constraints are changes as per requirement.

As we discussed already the performance of the proposed system depends on the availability of CSI. To achieve efficient cooperative node selection the channel state information is most important factor.

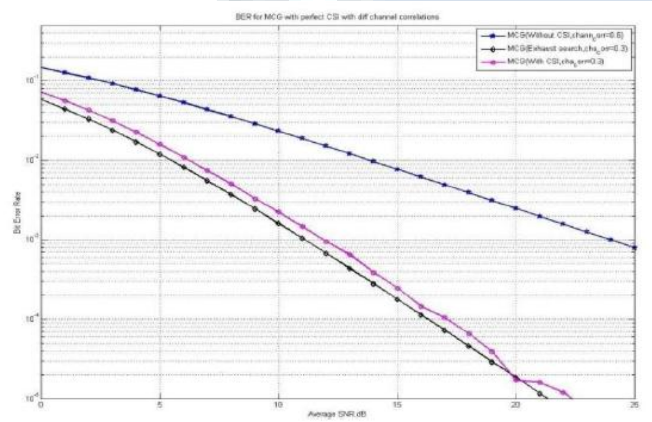


Fig 5: Simulation results for performance comparison between MCG with perfect CSI, MCG w/o CSI As shown in above figure, the MIMO will achieve the best performance only when perfect CSI is available. Figure 5 represents the performance comparison of proposed system with respect to availability of CSI. S from the simulation results our proposed method is best suitable with CSI only than exhaustive search and without CSI cases.

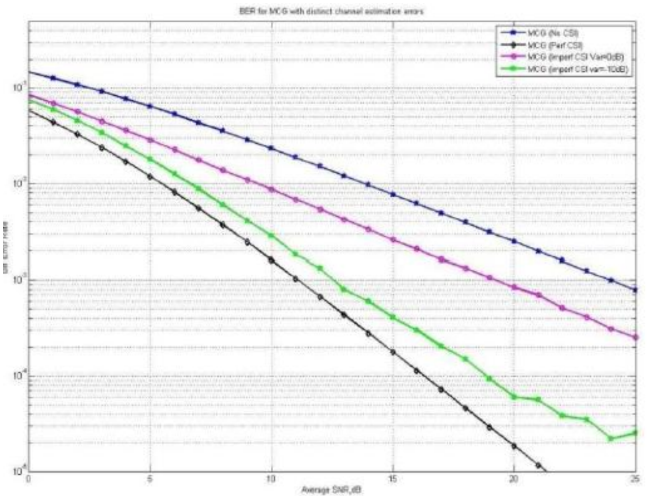


Fig 8: Comparison of MCG with distinct channel estimation

Figure 8 represents the performance comparison of proposed method with different CSI cases. Initially, the channel estimation error is assumed as Gaussian random variable with zero mean. From our simulation results it is clear that the performance of the cooperative system completely depends on the CSI.

From the above figure, the best performance results will achieves only when perfect CSI is available and worse results will obtain when there is no CSI. And as per the channel model and availability of channel information the performance of *cooperative MIMO* will changes as shown in figure.

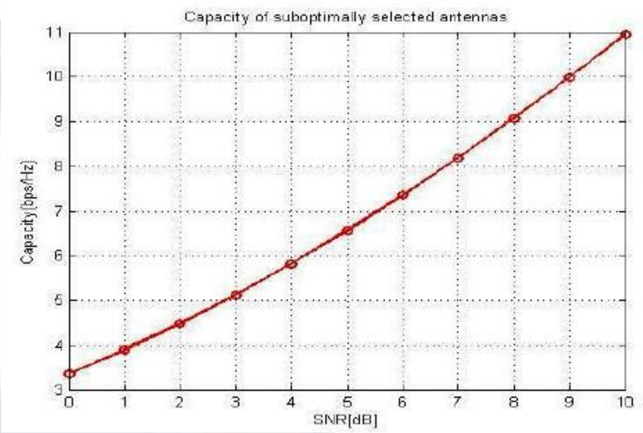


Fig 9: Performance of MIMO Capacity Vs. SNR

As discussed already in previous theoretical discussions whenever the delivery delay is low then SNR will automatically increases, which describes the good communication process. Here the delivery delay is greatly reduced by increasing the capacity of MIMO channel. Figure9 represents the performance analysis of MIMO Capacity Vs SNR, which shows that the increment in SNR will causes to increment in Capacity.

VII. CONCLUSIONS

Using this paper we effectively discuss the cooperative ad hoc MIMO network. And we investigate the process of node cooperation in the formation of virtual MIMO. Then, we quantified the energy consumption and delay incurred during the local distribution stage, and jointly combined the local distribution stage and the long haul transmission stage. Finally, the subset of cooperative nodes participating in the virtual MIMO communication is chosen by considering the overall system constraints and the power level and data rate for each selected cooperative node are adaptively assigned in order to optimize the system performance.

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