Performance of Co-operative Relay for Multicast Multi-Hop Networks Using Virtual MIMO .

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***Abstract* – Multicasting is a bandwidth conservation technology that can utilize the resources very efficiently, reduces the traffic volume and improves the network capacity by simultaneously delivering a single stream of information to more than one intended receivers. Wireless medium is inherently multicast in nature and this property can be exploited with virtual MIMO. The improvement in BER can be achieved with multicasting over multi-hop wireless networks. The network will also be more energy efficient .The BER performance and energy consumption of two-hop networks with STBC has been simulated in this paper. These performance curves will be helpful in many ways, i.e., the selection of number of antennas on the receiver, the selection of the number of intermediate nodes (relay stations) and the selection of modulation and coding schemes to achieve a desirable BER performance. The multicast multi-hop virtual MIMO configuration is proposed for video streaming applications for Long Term Evolution (LTE) 3G wireless networks.**

***Index terms* –** Multicasting, video Streaming, virtual MIMO, and multi-hop.

I. INTRODUCTION

Through the evolution of next generation wireless networks the key technology of multi-hop wireless networks is becoming more important to provide better services. These types of networks are dynamically self-organized and self-configured, with the nodes in the network automatically establishing and maintaining multi-hop connectivity among themselves. This feature brings the advantages of low up-front cost and easy network maintenance, robustness and reliable service coverage to the next generation wireless networks [1][2].

Multi-hop networks are not only significant for wireless ad-hoc and sensor networks but also it is equally important for the next generation cellular networks. As the terminal power is very limited, so the co-operation between terminals is required to transmit the data to the next hop with minimum consumption of energy. The co-operation between different nodes has paved the way for virtual MIMO and the space-time coding schemes. Recently, the virtual MIMO configuration has been exploited for multi-hop co-operative networks which can provide better spatial diversity and higher system capacity. Fortunately, the densely populated nodes can jointly act as a multi-antenna array through interchange of messages.

The proposed scheme is a special form of co-operative MIMO scheme used for multicasting in multi-hop networks. In our scheme there is no need to exchange the data from the co-operative nodes .In the first hop the sender cluster head (CH) transmits the data to the next cluster. For a pair scheduling scheme we have assumed that the CH has the information about the channel state information (CSI) of the nodes co-operating with CH for the next hop transmission. This pair scheduling scheme is different from Nortel pair scheduling schemes presented in [3][4], i.e., random pair scheduling (RPS) and determinant pair scheduling (DPS) [3] [4] and recently proposed adaptive determinant pair scheduling (ADPS) [5]. At the receiver side, there is no co-operation between the receiving nodes. Practically it happens rarely that more than one intended receiver lies in the range of 10 meters and request the same video streaming application. However the number of antenna on the receiver may vary from one to three. This can be adaptive based upon the BER performance curves presented in this paper.

This proposed multi-hop virtual MIMO based co-operative scheme will not only support multicasting but also helpful for the development of adaptive cross-layer design for real-time applications. In this way real time applications can take the advantage of MIMO and its coding schemes, co-operation between the neighboring nodes, and multicast nature of the wireless medium.

In this paper we consider the clustered environment in which two clusters A and B are formed using the LEACH protocol and use time division multiplexing between different multicast sessions. The performance for a single multicast session has been evaluated and hence considered no interference. The CH in cluster A multicasts the data to the nodes in the adjacent cluster B. As the nodes are densely populated so that the three nodes including the cluster head in the cluster B can receive the signals with reasonable strength. The CH B using the pair scheduling scheme based on known CSI and received signal strength, has selected nodes I_2 and I_3. This scenario is helpful for uniform energy consumption throughout the network.

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The remainder of the paper is organized as follows, Section II elaborates on the system model, the energy consumption per bit of the multicast scheme is calculated in Section III, and Section IV describes the simulation results and finally conclusions are drawn in Section V.

II. SYSTEM MODEL

A set of nodes are distributed in such a way that the cluster head (CH) and a set of receiver are located in the two adjacent clusters. It is assumed that all the nodes have equal power and are located as shown in Figure1. We assume that the route is already determined by some routing algorithms that optimize certain characteristics of the network such as load balancing. Each node operates in three modes: transmit, receive and sleep modes, where it transmits, receives, and turns off the circuits to save energy, respectively. The bit sequence received at each relay is first detected and then re-modulated for transmission to the destination node. Note that all the detected bits are forwarded even if some of them are in errors. Such a strategy is different from the traditional decode-and-forward (DF) strategy used in relay channels, where error free decoding is assumed at the relays. This strategy is called as the detection-and-forward (DTF) strategy proposed in [6], while we still call the underlying channel as a relay channel.

In this paper, the use of multiple relay is introduced instead of a single relay. This is firstly due to the wireless multicast property and it also avoids the superfluous energy consumption of the single relay. The Time scheduling is used within the cluster and a single multicast session is transmitted over a single time slot. All the multicast sessions are time scheduled and it is assumed there is no interference between different multicast sessions. There is a trade-off between network capacity and interference. By considering multiple multicast sessions over the same time slot the network capacity can be increased at the expense of enhanced interference. The selection of relay in cluster B is based upon known CSI. The CH in Cluster A (T) wants to communicate with the set of receivers (R_1, R_2, R_3) in cluster B through three intermediate nodes CH B (I_1), I_2 and I_3. For pair scheduling, it was considered that the two intermediate nodes are selected to co-operate with the I_1 on the base of known CSI. In this simulation the distances between the intermediate nodes I_1 , I_2 and I_3 is less than 10 meters .The node positions are given in the Section V. We consider the following four distinct cases for Raleigh flat fading channels with AWGN noise.

Case A – *SISO*

The conventional SISO transmission from the transmitter CH A to a single receiver R_1 via the intermediate node (relay station) CH B using QAM-16 modulation.

Case B – *Virtual MISO*

In the first hop, it is the conventional transmission from a CH A to the three intermediate nodes including the CH B of the adjacent cluster. In the second hop, these three nodes virtually behave as the multiple input antenna array and forms a virtual MISO with the single antenna on the receiver R_1.

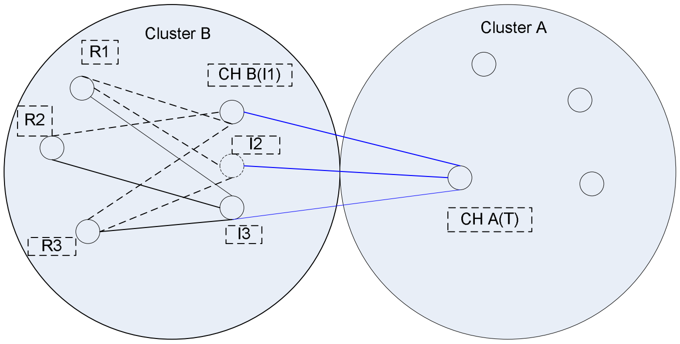

Figure 1. A transmitter in cluster A multicasting to the set of receivers in cluster B

Case C – *Virtual MIMO*

In the first hop, it is the conventional transmission from a CH A to the three intermediate nodes including the CH B of the adjacent cluster. In the second hop, these three nodes virtually behave as a multiple input antenna array and forms a virtual MIMO with the three antennas on the receiver R_1. On the receiver side Maximum Ratio combining (MRC) is adopted.

Case D – *Virtual MIMO with STBC.*

In the first hop, it is the conventional transmission from a CH A to the two intermediate nodes including the CH B of the adjacent cluster. In the second hop, these two nodes virtually behave as a multiple input antenna array and forms a virtual MIMO with the two antennas on the receiver R_1. To incorporate space-time block codes (STBCs), the 2x2 virtual MIMO system is considered. On the receiver side maximum likelihood (ML) decoding is used.

III. ENERGY CONSUMPTION

In the system model discussed in the previous section, the energy consumption is divided between two hops. In the first hop , CH A (T) transmits the same signal at time t_1 to the next three intermediate nodes CH B (I_1), I_2 and I_3 .It is similar to the traditional SISO transmission. In the second hop, the detected signal at three intermediate nodes is transmitted to the intended receivers. The receiver R_1, out of three receivers, forms virtual MISO configuration with a single antenna and forms a virtual MIMO configuration with three antennas. The energy calculation for this configuration is proceeded as follows.

The total power consumption of typical RF transmission system can be segregated as the transmission power P_{PA} of the power amplifier and the circuit power $P_{tx\text{-}elect}$ of all the RF circuit blocks . P_{PA} is dependent on the transmit power P_{out} . If the channel follows l-law path loss, it can be calculated as follows.

$$P_{out} = \overline{E_b} R_b d^l K \tag{1}$$

where K is a constant depends upon transmit and receive antenna gains, carrier frequency, link margin and power spectral density (PSD) of the total effective noise at receiver input [7],[8]. $\overline{E_b}$ is average received bit energy, R_b is transmission rate in bits per second and 'd' is the transmission distance. The transmission distance for the first hop is $d_{average} = d_1 + d_2 + d_3 \approx d_1$ and for the second hop $d_{average} = d_4 + d_5 + d_6 \approx d_4$ as the three intermediate nodes lie in the range of 10 meters. P_{PA} can be approximated as ;

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

where $\alpha = \xi / \eta - 1$ with ξ being the drain efficiency of the RF power amplifier and η being the peak to average ratio which depends on the modulation scheme and the associated constellation size. Therefore the total transmission power is given by

$$P_{TRANS\_Total} = P_{PA} + P_{tx\_elect}$$

and the transmission energy per bit can be approximated as

$$E_{TRANS} = E_b d^l K (1+\alpha) + P_{tx\_elect} / R_b . \tag{3}$$

At the receiver side the total power consumption P_{rx_elect} is due to the RF receive circuit blocks. Hence the energy per bit at the receiver node is given by

$$E_{RCV} = P_{rx\_elect} / R_b$$

As in our scheme we have considered the multicasting and it is assumed that the very little energy is consumed in the selection of intermediate nodes and there is no exchange of data between the co-operative intermediate nodes.

The first hop transmission is based on the SISO system using MQAM and the probability of bit error is given by

$$P_b = \frac{2(M-1)}{M.\log_2 M} Q\left(\sqrt{\frac{6E_{avg}}{(M^2-1)N_o}}\right) \tag{4}$$

For a specified bit error rate we can find the average bit energy consumed for the first hop.

Consider a MIMO system consisting Mr receive antenna and M_t transmit antennas. The bit energy is computed in (3). If we denote channel matrix by H, the received SNR can be computed as follows.

$$\gamma_b = \frac{\|H\|^2}{M_t} . \frac{E_{TRANS}}{N_o} = \frac{E_{TRANS}}{2M_t N_o} \chi^2_{2M_t M_r}$$

where $\chi^2_{2M_t M_r}$ is a chi-squared random variable with degree of freedom $2M_t M_r$ .The bit error rate for MQAM is given by

$$\overline{P_b} = \varepsilon_H \left\{ \frac{4}{b}\left(1 - \frac{1}{2^{b/2}}\right) Q\left(\sqrt{\frac{3b\gamma_b}{2^b - 1}}\right)\right\} \tag{5}$$

For a given probability of bit error rate we can find the bit energy consumption for a MIMO system. The total energy consumption for Case B is equal to the sum of energy consumed in SISO transmission (hop 1) and the virtual MISO (hop2) averaged by three for a single receiver and in the same way it can be calculated for case C .

IV. SIMULATION RESULTS

Ten nodes are located at the positions described on XY Plane having an area of 250 square meters. The coordinates of the ten nodes are given as {(20,110) , (30,140) , (50,90) , (60,130) , (150,155) , (146,151) , (150,161) , (190,140) , (200,160) , (210,90) }. The first four nodes are in cluster A and the next six nodes are located in cluster B. CH A, CH B , I_2, I_3, R_1, R_2, R_3 are located at (60,130) to (210,90) correspondingly on the XY plane. The following simulation parameters are used;

TABLE I
Simulation Parameters.

No.	Parameters	Numerical values
1	Carrier frequency	2.5 GHz
2	Symbol Rate	256000
3	Modulation Type	QAM-16
4	Coding Scheme	Case A – C : with STBC Case D : STBC
5	Number of frames	100
6	Symbols per Frame	Case A – C : 250 Case D : 100
7	Eb/N0	5-15 dB
8	Channel Type	AWGN, Raleigh fading.
9	Noise Power	-174dBm/Hz (3. 981x10^{-13})
10	Antenna Gain (Tx , Rx)	5 dBi
11	*l* path loss factor	2

In Figure 2, the bit error rate performance of the first three cases has been considered. At low E_b/N_o, the BER performance of virtual MIMO is much better as compared to virtual MISO and SISO. In Figure 3, the BER performance of virtual MIMO (2x2) with STBC (ML decoding) and without STBC (MRC-4) has been compared. We have considered the 100symbols/frame in this case. These curves can be beneficial for the selection of optimum number of intermediate nodes and the optimum number of receive antennas at the receiver to achieve the desired E_b/N_o. For a very low E_b/N_o the STBC can be used and however a very little improvement is achieved with STBC for high E_b/N_o. It was also observed that the BER of MIMO with STBC is lower than MIMO without STBC when the E_b/N_o is more than 8 with 1000 bits/frame (250 symbols/frame). In Figure 4, the energy consumption per bit versus the BER curve is plotted. The traditional multi-hop

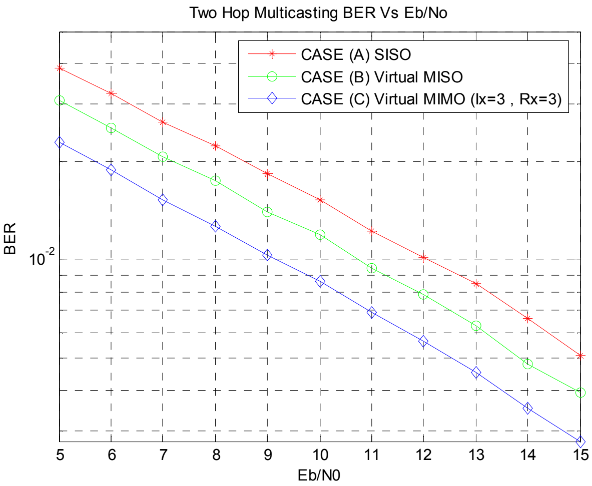

Figure 2: BER performance for two hop networks.

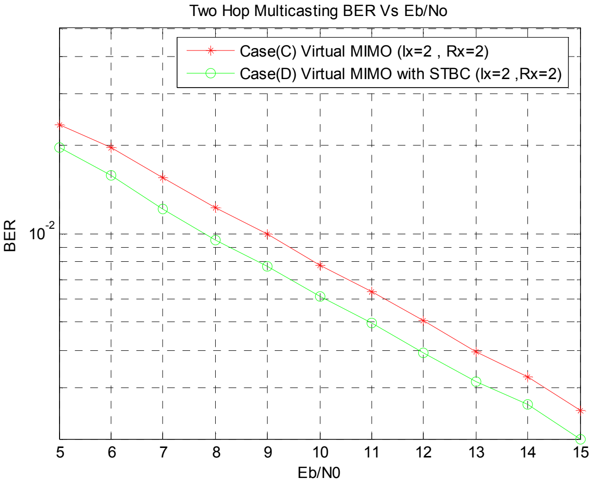

Figure 3: BER performance with STBC.

SISO transmission Case A has been compared with energy consumption per bit derived in previous section for Case B and Case C. The first hop transmission energy consumption is constant for all the three cases. So only the energy consumption of the second hop is shown in the plot.

V. CONCLUSION AND FUTURE WORK

A co-operative virtual MIMO scheme is proposed in this paper for multicast applications. The BER performance curves for two hop multicasting using virtual MIMO has been plotted and the energy consumption of this new multicast based co-operative scheme is compared with the traditional SISO multi-hop transmission. However it is not required to consider the interference between each multicast session in a different time slot but the interference model will be required for transmission of more than one multicast session over a single time slot to improve the network capacity. The simulation test-bed developed in this paper will be useful for the development of cross-layer models designed for multicast applications using co-operative virtual MIMO.

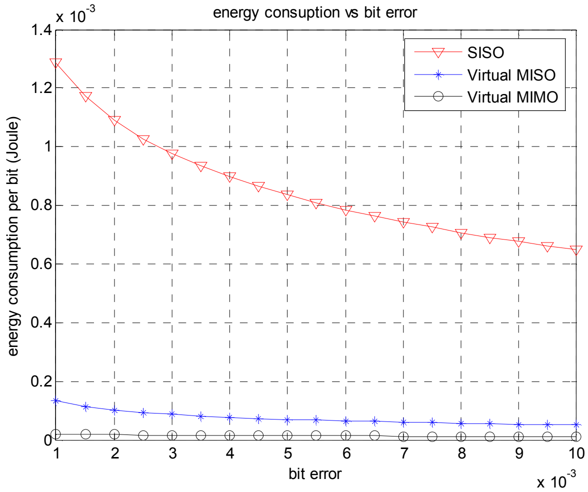

Figure 4: Energy consumption for multicasting in two hop Virtual MIMO.

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