Energy Efficient Link Adaptive Multiuser MIMO system with MRT precoding and Limited feedback

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Abstract— Since a large amount of energy is used at the base station of cellular system, how to use energy in an efficient way is the topic of interest of most of the researcher. In this paper, we proposed a algorithm of link adaptive energy saving scheme for multiuser MIMO system. The scheme improves energy efficiency of Multiuser MIMO system with limited feedback. Proposed scheme feedbacks transmit power, which will increase the energy efficiency of Multiuser MIMO system with the help of MRT precoding and limited feedback. Although adaptation of MRT precoding reduces the energy efficiency of Multiuser MIMO system, but it is still good in comparison with other traditional and energy efficient link adaptive methods. Graphs are plotted for comparison of energy efficiency and transmit power for various energy saving schemes of for single user and multiuser MIMO system

Keywords— *Energy Efficiency; Multiuser MIMO system; Transmit power feedback; Link adaptive energy saving scheme*

I. INTRODUCTION

The demand of information is increasing day by day. One of the surveys about the information flow on mobile reveals that global mobile data traffic will be 49 exabytes monthly and half a zettabyte annually by 2021. Mobile IP traffic will be 20 percent of total data traffic by 2021. The number of mobile-connected devices per capita will reach 1.5 by 2021 [1]. As 80 percentage of the energy consumption in cellular system is done at base station site [2]. Therefore various papers tried to improve energy efficiency of base station network. The paper [3] described the use sleep mode for improving the energy efficiency of cellular network. The paper [3] further demonstrates that even with the development of highly energy-efficient hardware, a holistic approach incorporating system level techniques is essential to achieving maximum energy efficiency. The paper [4] attempt to find an adaptive cell zooming method to reduce the energy consumption of base stations. The increase in size of cell was formulated as an optimization problem with consideration of varying traffic patterns and interference, as well as the service availability of the whole area. As for as author's knowledge is concern a few paper discussed link level energy efficient schemes for LTE/LTE advanced. In traditional link adaptive scheme, once the transmission power is decided it will never change, during entire transmission time. Apart from this, parameters such a RI (Rank Indicators), CQI (Channel quality indicators) and PMI (Precoding matrix Indicator) are selected in such a way to maximize transmission rate.

In Paper [5] mentioned an energy efficient link adaptation scheme combining the traditional link adaptation with power control in a direct way. The scheme introduces transmit power as a new feedback parameter and calculates the optimal parameters which maximize the BS's EE while meeting the system's block error rate (BLER) constraint for the current channel state. The paper [6], in order to reduce adjustment frequency of transmission power, introduces a semi-static power control scheme the scheme proves better in improving energy efficiency. Both the papers [5][6] worked on single user MIMO system. In our work, we have proposed a scheme for improved semi-static power control schemes for multiuser MIMO system. Our schemes will work in system of limited feedback and under MRT precoding. The rest of the paper is organized as follows. In Section II, we present the system model and define the EE maximization problem. Next, we describe the energy efficient link adaptation and semi-static power control scheme in Section III and IV respectively. Simulation & Results are given in Section V. Finally Section VI concludes the paper.

II. SYSTEM MODEL

In link adaptive Multiuser MIMO system with limited feedback, System model described as in paper [7]

Let us assume that a base station has N numbers of antennas and sends signal to K number of users $U_1, U_2..........U_k$ each of the receiver equipped with $M_1, M_2..............M_k$ antennas.

The transmitted signal matrix $x_{N\times M_k}$ is expressed as the sum of signals intended to users $U_1, U_2..........U_k$:

$$x = \sum_{k=1}^{K} \sum_{l=1}^{M_k} X_{k,l} \qquad (1)$$

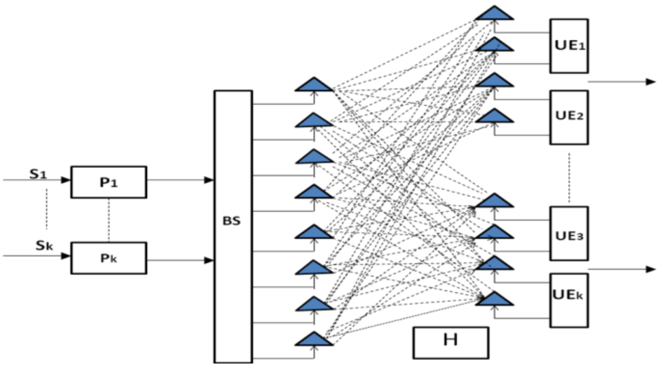

Figure1: Multiuser MIMO system

The channel matrix between user U_k ; $k = 1, 2, ...K$ and the base station is denoted by $H_{M_k \times N}$. At each user, received signal vector of dimension, $k = 1........K$ is given by:

$$Y_k = H_{\mathbf{k}}.x + n_k ;\quad k = 1, 2, ...K \qquad (2)$$

n_k , $k = 1, 2, ...K$ is an additive noise signal of size $M_k \times 1$.
eq. 2 can also be written as:

$$Y_k = H_k \cdot X_k + \sum_{i=1, i \neq k}^{K} H_k X_i + n_k ; k = 1, 2.......K \qquad (3)$$

The second term of the sum in equation (3) represents the multiuser interference (MUI) coming from multiple users.

$$MUI = \sum_{i \neq k}^{K} H_k X_i \qquad (4)$$

Block diagonalization using SVD removes the second term of the equations but it cannot remove interference among the antennas of the user itself. With help of Maximum ration transmission technique this interference also removes. Means MRT supports perfect beam forming which need perfect CSI information at transmitter. SVD is applied second time to remove inter antennas interference of the user itself [7].

When MRT precoding is applied with limited feedback [7], For K user having Mk antennas sum rate capacity (bps/Hz) for multiuser MIMO with B bit feedback is given by

$$R_{MU-MIMO}(b, B) \approx \sum_{k=1}^{K} \sum_{l=1}^{M_k} \log_2 \left(1 + (1-\eta_b)\gamma_{k,l} N_t \left(1 - 2^{-\frac{B}{N_t - 1}} \right) \right) \quad \text{for low } \gamma_{k,M_k} \qquad (5)$$

$$R_{MU-MIMO}(b, B) \approx \sum_{k=1}^{K} \sum_{l=1}^{M_k} \log_2 \left(\frac{1}{\eta_{b,k,l}} \right) \quad \text{for large } \gamma_{k,M_k} \qquad (6)$$

Where real and quadrature component of signal are separately quantized and

$$\eta_b = \frac{E\left[\left| \bar{\bar{y}}_k - \bar{y}_k \right|^2 \right]}{E\left[\bar{y}_k \right]} \text{ for } b = 4bit \text{ ADC precision} \qquad (7)$$

.
SIQNR ratio of the received signal is given by

$$SIQNR = \frac{(1-\eta_b)^2 \left[\left| \phi_{k,M_k} \right|^2 \frac{P_t}{KM_k} \right]}{(1-\eta_b)^2 \sigma_{n,M_k}^2 + \sigma_Q^2} = \frac{(1-\eta_b) \left[\left| \phi_{k,M_k} \right|^2 \gamma_{M_k} \right]}{1 + \eta_b \left[\left| \phi_{k,M_k} \right|^2 \gamma_{M_k} \right]} \qquad (8)$$

A. Channel Vector Quantization (CVQ) estimation

For downlink transmission in a multiuser multiple-input multiple-output (MIMO) communication system, quantized Channel State Information (CSI) is fed back to the base station in an uplink channel of finite rate. The quantized CSI is obtained via Channel Vector Quantization (CVQ) of the so-called composite channel vector, i.e., the product of the channel matrix and an estimation of the receive filter, which cannot be computed exactly at the stage of quantization because of its dependency on the finally chosen precoder. Here, the state-of-the-art approach estimates the receive filter and quantize the composite channel vector such that its Euclidean distance to the estimated composite channel vector is minimized. With the help of quantized composite channel vector codebook index is calculated. Finally, each user feeds back the corresponding codebook index to the base station using B bits. In addition to this directional information, the user provides a channel Quality Indicator (CQI), i.e., Scaled SINR approximation including a rough estimate of the interference caused by the quantization error.

III. FEEDBACK OF POWER

A. ENERGY EFFICIENT LINK ADAPTATION

The proposed scheme is the modification of the scheme mentioned in the paper [6]. The proposed scheme includes two methods of feedbacks, first one called energy efficient link adaptation scheme to improve BS's EE while meeting the systems' BLER constraint. In addition to this, to reduce the transmit power adjustment frequency; a new scheme called Semi-static power control will be investigated. Energy efficient link adaptation scheme: The scheme combines power control with traditional SE centered link adaptation in a direct way. Firstly, the user estimates the channel gain and determines the optimal CQV and codebook index and power satisfying equation then these parameters are feed back to BS through the feedback channel. Finally, the BS adjusts its transmission mode based on these parameters (with the assumption that each transmission layer is transmitting one transmission code at an instant). The key to the scheme is to find out the optimal parameters which maximize the BS' EE while serving the system with BLER constraints.

$$Max\ EE = \sum_{j=1}^{l} \frac{(1 - BLER_j)}{t_s P_{total}} . L_j \quad (9)$$

Where l is the number of transmission codewords determined by the codebook index, which is find out from composite channel vector. L_j represents the transmit block size of the j^{th} transmission codeword. t_s is equal to one milliseconds and represents the duration of one transmission time interval (TTI) in LTE. P_{total} is the total energy consumption of the BS (assuming a single user system). $BLER_{target}$ is the BLER constraint which is determined by the application. Usually, we choose $BLER_{target}$=0.1.

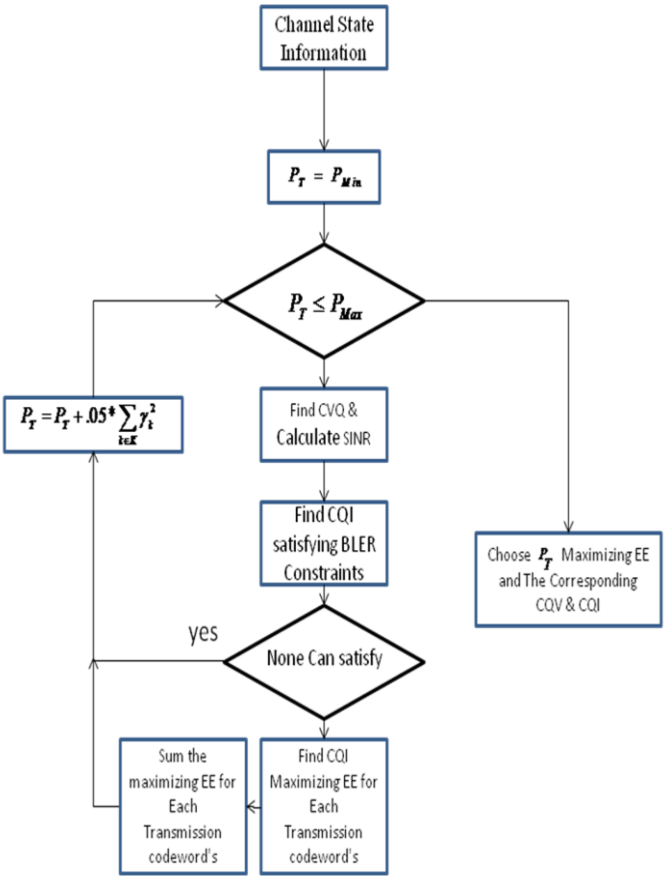

Figure 2: Proposed Working of Feedback with Link Adaptive power Control algorithm and Semi-SPower Control Algorithm.

The protocol for the feedback system is given as:

- The user estimates the channel gain with the assistance of known transmitted pilot symbols. The possible transmit power has range from Pmin to Pmax. . The step size is not fixed but varies in square of some multiple of respective SNR of specific user. Here, Pmin and Pmax will be set according to experimental result.
- Sorting all transmit power levels in an incresing order. For each transmit power level, according to channel quality, the user finds out the optimal CQV and channel quality index with CQI (effective AWGN SNR). Initially, we assume that transmit power is always shared equally among all the transmission codewords. In formula of EE it is clear that denominator does not affect EE, but value of EE is determined by numerators. That is to find out the CQV and CQI based on maximizing the system' throughput.
- After determining the CQV and CQI, for each transmission codeword, the user need to predict the BLER of all the CQIs and finds the CQIs meeting the BLER constraints.
- If none of the available CQIs satisfies the BLER constraint for any one of the transmission code word (Which implies that the transmit power is too low for the current channel quality to satisfy the system's BLER Constraint), the next transmit power level (which is 0.05 multiple of square of effective SNR of that channel plus pervious transmit power) will be considered. Following Equation is applied for this

$$P_T = P_T + 0.05 * \sum_{k \in K} \gamma_k^2 \quad (10)$$

- In this way obtain the EE corresponding to these CQIs based on the definition of EE. Then find out the optimum CQI which maximizes the EE for each transmission codeword' for each user.
- As only one transmission code is transmitted for each user Then total the transmit power is the sum of with the maximum value EE for each user and the corresponding CQV & CQI as feedback parameter.

B. SEMI-STATIC POWER CONTROL SCHEME

The Semi Static Power control scheme ensures that BS cannot adjust its power too frequently [6]. The paper [8] modify Semi power control scheme to suit LTE downlink transmission so as to control the transmit power adjustment frequency. The scheme defines relative EE difference D as

$$D = \frac{\xi_{opt} - \xi}{\xi_{opt}} \quad (11)$$

Where ξ is the EE derived from the last transmission, ξ_{opt} is the maximum EE derived from the current transmission. In this scheme, a timer is used to record the time is denoted as T. T_{min} represents the minimal trigger interval. A predefined EE difference threshold is set to be Δ .If D $\ge \Delta$ and T $> T_{min}$ satisfied at the same time or only T $> T_{max}$ is satisfied, the user will feed the optimal transmit power back to the BS. Otherwise, the BS will maintain its current transmit power unchanged. Note that when the BS adjusts the transmit power, the timer must be reset.
The proposed system use one of all these feedback methods to improve the spectral efficiency as well as the energy efficiency the system.

IV. SIMULATIONS AND RESULTS

LTE simulation tool available in mat lab is used for simulation. Power is allocated uniform for other precoding algorithm while for MRT. it is allocated as per feedback information. We employ the path loss model

of Okumura-Hata in [9] without considering the shadow fading and use improved Jakes Doppler model in [10]. Each transmit-receive (Tx-Rx) antenna pair is assumed to experience independent fading.

At the receiver, each antenna is worked as MISO link and after recovery of main beamfromed signal with MRT block diagonalization, we adopt the simple decision making device for detection. Both the feedback period and the feedback delay are one TTI, which means that the feedback parameters derived from the current TTI are used for transmission in the next TTI.

TABLE I. SIMULATION PARAMETERS

Parameters	Value
Carrier Frequency	2.4Ghz
Bandwidth	1.4Mhz
Number of Transmit antenna	8
Number of receivers	4
Number of antennas in receiver	2
Channel Estimation	Ideal
Power conversion efficiency η	40%
Dynamic circuit power	6W
Static Power	6W
Minimum trigger interval T_{Min}	5ms
Maximum trigger interval T_{max}	50ms
EE difference threshold Δ	0.2

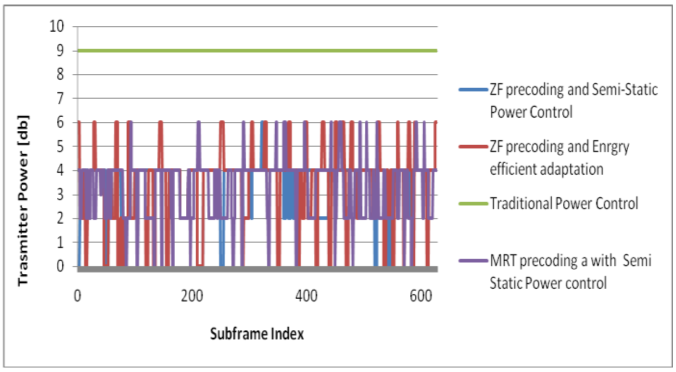

Figure3: Transmit power for single user MIMO system for various subframe indices.

Fig.3 shows transmit power for single user scenario, the Traditional Power Control Algorithm provides a constant power of 9 db at all subframe indices; instead, modern link adaptation algorithms adapt the power per subframe basis. Fig.3 also describes that Zero force precoding with Energy efficient link adaptation varies power somewhat between 2 to 4 db while Zero force precoding with semi-static power control algorithm confine power strictly between 2 to 4 db. The MRT precoding with Semi static power control algorithm requires slightly higher transmitter power compare to (2.4 to 4.2 db).

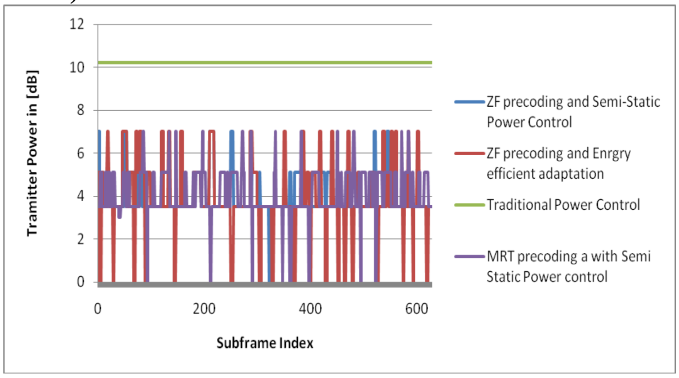

Figure 4: Transmit power for Multiuser MIMO system for various subframe indices

Fig.4 shows Transmit power for multiuser scenario, the Traditional Power Control Algorithm provides a constant power of 10 db at all subframe indices; instead, modern link adaptation algorithms adapt the power per subframe basis. Fig. 4 also describes that Zero force precoding with Energy efficient link adaptation varies power somewhat between 3.7 to 5 db while Zero force precoding with semi-static power control algorithm confine power strictly between 3.7 to 5 db. The MRT precoding with Semi static power control algorithm requires slightly higher transmitter power compare to (3.75 to 5.2 db), of course; semi-static power control algorithm reduces the instantaneous power transitions.

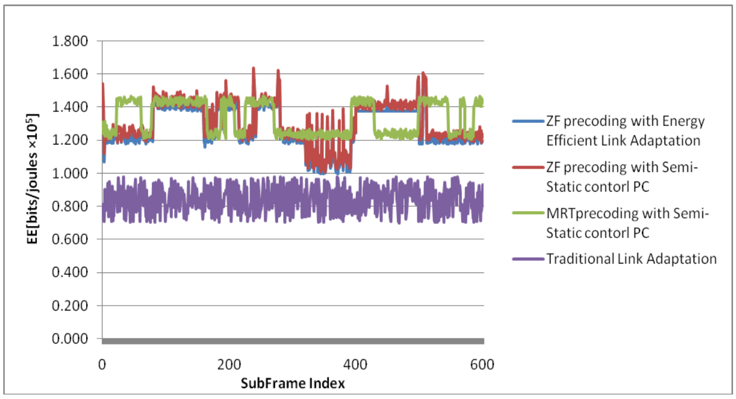

Figure 5: Energy Efficiency for single user MIMO system for various subframe indices

Fig. 5 shows for energy efficiency of single user scenario, the Traditional Power Control algorithm provides average efficiency of 9 × 10^5 bits/joules on the average at all subframe indices. Fig. 5 also describes that energy efficiency of Zero force precoding with Energy efficient link adaptation varies somewhat between 1..05 to 1.45 × 10^5 bits/joules while Zero force precoding with semi-static power control algorithm confine energy efficiency between 1..05 to 1.45 × 10^5 bits/joules . The MRT precoding with Semi static power control algorithm requires slightly higher transmitter power compare to (1.25 to 1.45× 10^5 bits/joules).

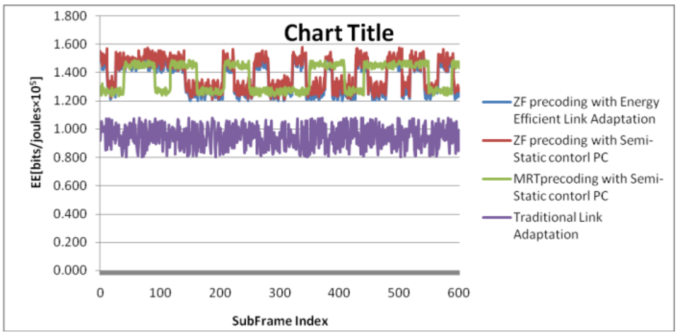

Figure 6: Energy Efficiency for Multiuser MIMO system for various subframe indices

Fig. 6 shows for energy efficiency of Multiuser scenario, the Traditional Power Control algorithm provides average efficiency of 9.5 × 10^5 bits/joules on the average at all subframe indices. Fig. 6 also describes that energy efficiency of Zero force precoding with Energy efficient link adaptation varies somewhat between 1.28 to 1.55 × 10^5 bits/joules while Zero force precoding with semi-static power control algorithm confine energy efficiency between 1.28 to 1.55 × 10^5 bits/joules. The MRT precoding with Semi static power control algorithm requires slightly higher transmitter power compare to (1.28 to 1.47× 10^5 bits/joules).

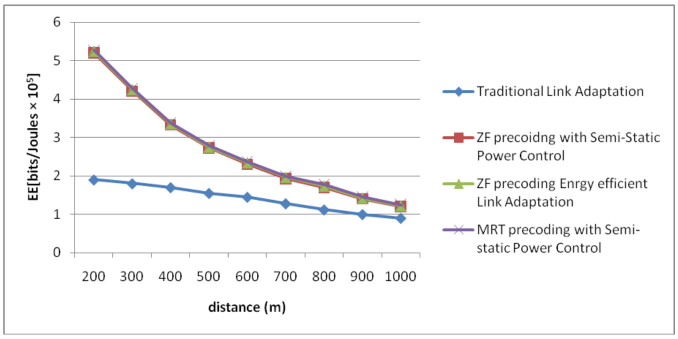

Figure 7: Energy Efficiency for single user MIMO system for various distances

Figure 7 shows that the enrgy efficincy for single user senario with the distance, the enrgy efficiency of traditional link adaptation algorithm is 2 × 10^5 bits/joules at 200 m distance and reduces to 0.9 × 10^5 bits/joules at 1 Km distance. Zero force precoding with energy efficiency link adaptation algorithm has energy efficiency of 5.2 × 10^5 bits/joules at 200 m distance and reduces to 1.2 × 10^5 bits/joules at a distance of 1 Km. Zero force precoding with Semi-static power control algorithm has similar behavior as Zero force precoding with energy efficiency link adaptation algorithm. MRT precoding with Semi-static power control has energy efficiency of 5.25 × 10^5 bits/joules at 200 m distance and reduces to 1.25×10^5 bits/joules at a distance of 1 Km.

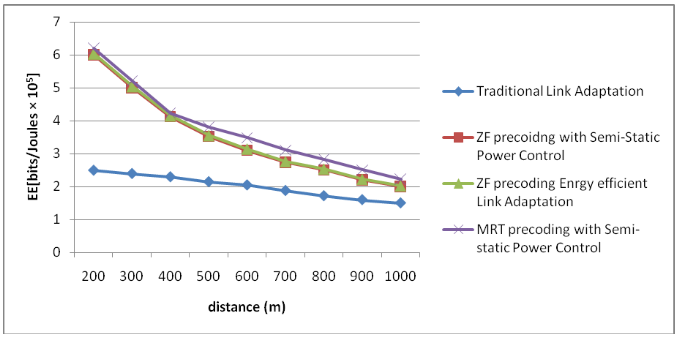

Figure8: Energy Efficiency for Multiuser MIMO system for various distances.

Fig. 8 shows that the enrgy efficincy for Multiuser user senario with the distance, the enrgy efficiency of traditional link adaptation algorithm is 2.5 × 10^5 bits/joules at 200 m distance and reduces to 1.5 × 10^5 bits/joules at 1 Km distance. Zero force precoding with energy efficiency link adaptation algorithm has energy efficiency of 6.1 × 10^5 bits/joules at 200 m distance and reduces to 2 × 10^5 bits/joules at a distance of 1 Km. Zero force precoding with Semi-static power control algorithm has similar behavior as Zero force precoding with energy efficiency link adaptation algorithm. MRT precoding with Semi-static power control has energy efficiency of 6.2 × 10^5 bits/joules at 200 m distance and reduces slowly as compare to zero force precoding algorithms and reaches to 2.1 × 10^5 bits/joules at a distance of 1 Km.

V. CONCLUSION

The various simulation results above shows that MRT precoding with semistatic power control algoritm shows comparable results with other enrgy efficient algoritm that's why we can apply it for multiuser senario in place of other algoritms. MRT precoding with semistatic power control algoritm shows better results for enrgy efficiency with the distance in comparision with other algoritms. Also with the use MRT percoding we can achieve better Sum rate capacity under limited feedback [11] than other precoding shemes. Hence we can achieve good enrgy efficiency at good sum rate capacity and less use of uplink resources.

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