Binary Switch for Hybrid Beam Formers in Massive Mimo

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Abstract—Massive MIMO refers to an idea of equipping BS with large number of transmit and receive antennas so that it can serves a very large number of users simultaneously.The Massive MIMO plays an important role in achieving higher spectral efficiency and reliability of the system.Massive MIMO systems are capable of achieving higher spatial multiplexing gain so that a huge amount of information can be transmitted which will be the requirement of 5G. One of the main challenge of Massive MIMO is its hardware complexity due to large number of RF chains, phase shifters and switches when hybrid beam formers are used in the system.A solution is to reduce the no: of phase shifters and switches by pairing the antenna elements.Binary switching is the method of pairing two antenna elements and this will connected to a single RF chain.In this approach,Proposing new structures for hybrid beam formers to reduce the power consumption of the phase shifter network.

Keywords*—Massive MIMO, Spatial multiplexing,Beam forming,spectral efficiency, RF chain, Binary switching*

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I. INTRODUCTION

MULTIPLE-INPUTMULTIPLE-OUTPUT (MIMO) technologycan significantly improve the capacity and reliability of wireless systems . The massive MIMO term refers to a scenario that the number of the antennas at the base station is much larger than the number of the user equipment. The purpose of this technology is to scale up the benefitsof conventional MIMO systems and act as an enabler for more energy and spectral efficient, secure and robust systems With massive MIMO, antennas has been simultaneously serving many tens of terminals in the same time-frequency resource[4]. Large spatial multiplexing gains can beachieved, and transmit energy-efficiency can be improved[5].massive MIMO is an enabler for the development of future broadband networks which will be energy-efficient,secure, and robust, and will use thespectrum efficiently[7].

One of the critical challenge of Massive MIMO is its system complexity due to large number of RF chains. As the number of antennas grows,RF chains will also increases which will causes higher system complexity and hardware energy consumption may significantly increase. Therefore, it will adversely affects the overall energy-efficiency of massive MIMO[7]. An effective solution is to pair the antennaelements and thereafter performing the antenna selection. By using large number of antennas with a fewer RF chains, Antenna selection will exploits large degree of spatial freedom.This technology relies on phase-coherent but computationally very simple processingof signals from all the antennas at the base station. In fact, The Massive MIMO system is a novel MU-MIMO architecture, which scales up MIMO by using antenna arrays at the base station with a large number of antennas, serving a multiplicity of single-antenna terminals. In the hard selection, the RF chains are connected to the antennas by a network of switches. The drawback of this approach is that large beamforming gains cannot be achieved as only a small fraction of the antennas are used. In the soft antenna selection, also known as hybrid beamforming, the RF chains and the antennas are connected through a network of phase shifters[3]. Such architectures have lower cost and power consumption compared to digital beamformers and they achieve a higher spectral efficiency compared to hard selection. When the base station has CSI of the users, then it can apply beamforming techniques to improve the spectral and energy efficiencies of the system. It is noted that the performance of the beamformers relies on the properties of the MIMO channel. In other words, depending on the channel behavior, a new beamformer design may be requiredInSec.II involves the description of different switching methods and in Sec. III we describe the system model and present the antenna pairing with in a sub-connected structure of massive MIMO. Then inSec. IV we present performance comparison of proposed sub-connected structure with an existing soft-selection based

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structure, and makecomparisons. Summary and conclusion are given in Sec. V

II.SOFT ANTENNA SELECTION IN MASSIVE MIMO

In general, beamforming is defined as a type of spatial filtering technique to exploit the spatial properties of the signals from multiple sensors. For example, by manipulating the phase and amplitude of the signals from each sensor, beamforming can be performed such that the signals from a desired direction are added constructively or deconstructively. In this thesis, beamforming term is often used as a technique at both the transmitter and receiver to increase the received SNR.

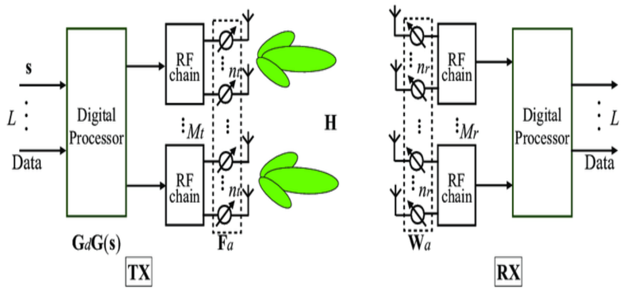

Fig.1. Massive MIMO system with hybrid-beam formers

In conventional MIMO systems, each antenna element is connected to the baseband processor. This requires a dedicated mixer, analog-to-digital converter (ADC) or digital- to-analog converter (DAC), filters and amplifiers per antenna. The series of the components that connect the antennas to the baseband are called radio frequency (RF) chains. Hence, pre-coding and combining can be performed at the baseband by digital beamforming techniques where there is a full control over the phase and amplitude of the signals at/from each antenna element. As the number of the antenna elements at the transceiver goes large, higher diversity and multiplexing gains are achievable and the channel matrix tends to have favorable conditions.hybrid beamforming for the point-to-point MIMO systems will be investigated. In this scenario, which is also called single-user MIMO, both transmitter and the receiver are equipped with a hybrid beamformer. In general, the capacity of MIMO channels is achieved when the transmitter and receiver have full channel state information (CSI), and both of them are equipped with a fully-digital system. However, this requires a dedicated RF chain per antenna element. Digital beamforming, where each antenna element is equipped with a dedicated RF chain, can provide a higher degree of freedom to improve the system performance. Due to the complexity of mixed signal circuits and high level of power consumption, however, the implementation of a large number of RF chains can become very expensive. Alternatively, analog beamformers can be implemented with a single RF chain and a phased array antenna[1].

In order to reduce the number of the RF chains in MIMO systems with large arrays, hard and soft antenna selection techniques are proposed. In the hard selection, the RF chains are connected to the antennas by a network of switches. Depending on the performance metric, e.g. maximizing the spectral efficiency, the best set of antennas are selected. The optimum performance is achieved by exhaustive search over different combination of the selected antennas. However, this is a combinatorial optimization problem and it imposes a high computational complexity In the soft antenna selection, the RF chains and the antennas are connected through a network of phase shifters. Through beam forming techniques with in a sub-connected structure, it is possible to reduce the interference ,signaling overhead and channel estimation delay and there by increases the SNR at each intended users. Moreover a soft selection based structure is more efficient than hard selection. In soft selection ,The no :of RF chains are significantly lower. Some massive MIMO structures are fully connected. But, the fabrication of fully-connected structures are difficult due to required no: of RF paths as well as high power consumption in the beam former. The sub-connected structures are more suitable for practical applications. One of the soft selection based structure is shown here in fig1. Even though this sub-connected structures of massive MIMO offers certain advantages, the complexity due to large no: of phase shifters and switches is still an unavoidable issue. This may leads to complex structure, insertion losses and higher power consumption. So, here proposing a new sub-connected structure by incorporating sub-array pairing .For a pair of antenna, single switches and phase shifters are needed. So the no: of switches and phase shifters are equal to half of total no: of antennas. A linear array is splits up in to four sub-arrays and pairing is carried out with in this four sub-arrays.

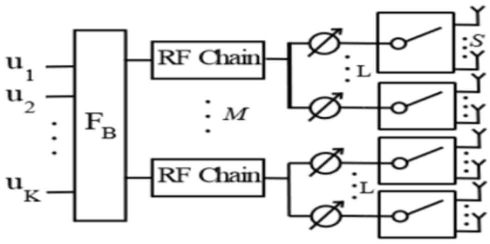

Fig.2.Sub-connected structure with hybrid beam-formers

III.SYSTEM MODEL FOR SUB-CONNECTED STRUCTURE AND ANTENNA SWITCHING

Here we describe the system model of proposed system, and then present the pairing criteria's based on convex optimization.

A. System model

Consider a K-user downlink massive MIMO scenario.As shown in Fig, the base station has M RF chains and N antennas, and serves K single-antenna users in the same time-frequency resource. Assume perfect channel state information (CSI) at thebasestation[1]

In massive MIMO systems, it has been shown that linear pre-coders such as zero-forcing (ZF) can achieve a close to optimal performance

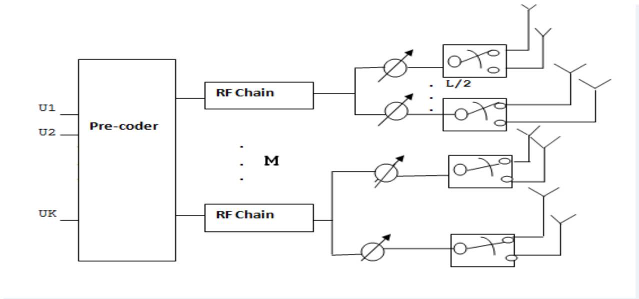

Fig.3.System model for proposed structure

A linear array of 128 antenna elements will be considered at the transmitting end over the band width 2.6 GHz. and the array is splits up in to four sub arrays and the elements of first two sub-arrays and then second two sub-arrays will be paired. With binary switching, two antennas are connected with one RF chains through a binary switch, thus the antenna selection has lower degrees of freedom. There are different configurations of binary switching, depending on which two antennas are paired, see Fig. Let us assume that the i_{th} antenna and the $(i+1)_{th}$ antenna are paired[2]. With the binary switching network, the optimization problem can be written as the optimization problem can be written as,

Maximize $\frac{1}{L}\sum_{i=1}^{L} log2\ det(\ \mathrm{I}+\frac{\rho}{N}H_l\ \Delta\ H_l^H\ )$

Subject toΔ_i , $\Delta_i^{'}\in\{0, 1\}$

$\Delta_i + \Delta_i^{'}$=1

By pairing, the no: of phase shifters and switches will reduces to half.ie,64 phase shifters and switches will be required for the entire system. The resultant channel matrix after pairing will be applied to existing structure and the performance are derived according to the singular values of channel matrix. Here an ZF pre-coder is used at the base band and the performance is evaluated in terms of ZF sum rate. ZF sum rate is given by,

$$R_{sub} = log_2(\det(I_k+\frac{P}{T_{sub}\,\sigma_z^2}\mathrm{H}F_{sub}\,F_{sub}^H\,H^H))$$

P is the power allocation matrix where power is equally allocated to all four users.T_{sub} is the power normalization factor,I_k is an identity matrix. H is the channel matrix ,σ_z^2 is the variance of noise vector. F_{sub} is the beam forming matrix

IV.PERFORMANCE EVALUATION AND RESULTSDISCUSSION

With the measured channel data, we apply pairing, in LOS propagation scenario where four users are closely located. Here in existing structure,64 antenna elements will be selected from 128 antenna elements and for the proposed structure 64 elements will be active after pairing

We first pay attention to the LOS scenario where four users are closely located as shown in Fig. 4

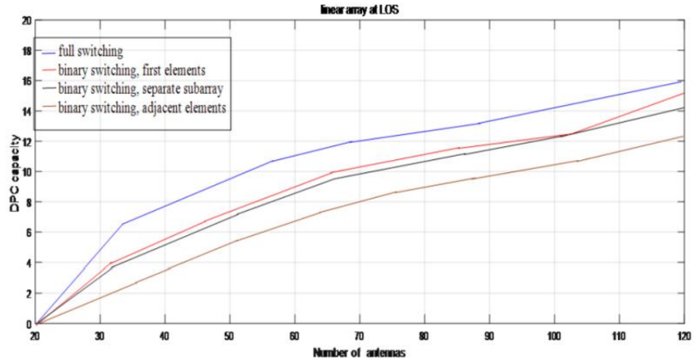

Fig.4. Performance comparison of linear array(DPC capacity Vs no:of antennas) at LOS Condition

From the graph ,it can be understood that the full switching gives better performance compared to binary switching. However, The separate sub array pairing also shows higher performance than other binary switching schemes. Adjacent element pairing shows poor performance than other schemes. This is because of less spatial correlation among antenna elements and hence interference will be higher[2].

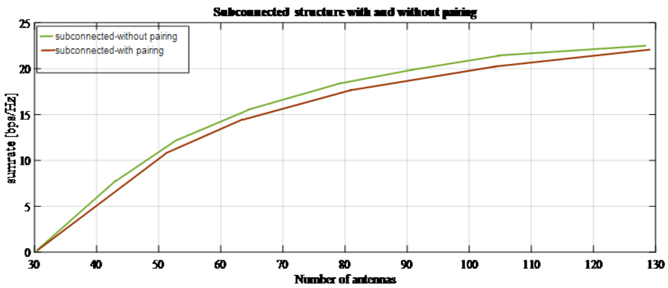

Fig.5. Performance comparison of existing and proposed structure (Sum rate Vs No:of antennas) at LOS Condition

From the simulation results, it can be understood that the sum rate for proposed structure closes to existing structure going to larger no: of antennas. So, it will be hopeful that the proposed structure will exhibits improved performance for larger arrays .For 128 antenna elements ,the no:of phase shifters and switches are reduced to half.ie,64.So the proposed system will expect to offer low cost. This because of the fact that implementation of massive MIMO with hybrid beam formers is an expensive procedure. So by reducing phase shifters and switches in hybrid beam formers, we can expect that much reduction in the system cost. and it also provides greater degree of freedom for each antennas and components in the system. This will helps to avoid insertion losses due to coupling of the circuits. Moreover, the expense of phase shifters ,They have high power consumption. It was reported that phase shifters and switches at 2.4 GHz consumes almost 28.8-152mW and 0-15mW respectievely. So, for larger arrays that much power will be consumed. Hence ,the proposed structure will be a better solution in future.

V.CONCLUSION

In this paper we have analyzed a simplified and sub-connected for hybrid beam-formers in massive MIMO. The presented technique could reduce the complexity of system due to large no: of phase shifters and switches in massive MIMO. A substantial number of phase shifters and switches in transceivers will incurs a significant performance loss.So that we go for a simpler solution called binary switching in which the pairing of antennas will provide the no:of components one half of antennas. The sub-connected structure will be preferred in practice. So, by adopting this proposed structure with pairing can be a better solution to the issues such as higher cost, complexity, high power consumption and losses.

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