Robust & Efficient Power Management Technique For MIMO Network Interfaces

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***Abstract*— In this paper we proposes a new methodology called as *"Antenna Management"* , which provides a high degree of efficient use of power and power management in high speed wireless networks and high data rate mobile wireless systems. This technique is particularly very usefully in the case of MIMO network interfaces, which contains a number of components and as well as RF chains. The objective of this project is to efficiently manage the available power among the large number of antennas in MIMO systems, and also satisfies all the requirements of MIMO like bit error rate, data rate, minimize energy per bit etc..In this paper we provide a systematic procedure to validate the energy efficiency and benefits of proposed method i.e. *Antenna Management.* Finally using this paper we provide a great solution for Power requirements by efficiently and effectively managing the all active antennas in MIMO systems.**

***Key Terms*—Power management, MIMO, Antenna management, Energy per Bit**

I. INTRODUCTION

In antenna communications the concept of MIMO systems (Multiple-Input Multiple-Output) are greatest extension and development. Improving spectral capacity is today's greatest requirement while dealing with wireless communications. This requirement is greatly answered by using the concept of MIMO (Multiple-Input Multiple-Output). The multiple-input multiple-output systems are enables to increase the spectral efficiency for a given transmit power. Over single-antenna-to-single-antenna (SISO) communication MIMO systems provide a number of advantages. Especially the sensitivity to fading is reduced by the *spatial Diversity* by providing multiple spatial paths. And for high spectral-efficiency communication the power requirements are significantly reduced by avoiding the compressive region of the information-theoretic capacity bound. The spectral *efficiency* is defined as the total number of information bits /second/Hz transmitted from one array to the other.

MIMO technology achieves the multipath behaviour by using multiple antennas at transmitter side and as well as receiver side and by providing *Spatial Diversity* to dramatically increase the channel capacity. By using the spatial diversity MIMOs are able to allow multiple antennas to send and receive multiple spatial streams at the same time.

The two main basic formats of MIMO are:

Spatial diversity: Spatial diversity used in this narrower sense often refers to transmit and receive diversity. These two methodologies are used to provide improvements in the signal to noise ratio and they are characterized by improving the reliability of the system with respect to the various forms of fading.

Spatial multiplexing: For providing higher data rate capacity by utilizing different paths to carry additional traffic i.e. increasing the data throughput capability the concept of *spatial multiplexing* is used.

However, By using the multiple antennas at transmitter side and at receiver side simultaneously and due to existence of multiple RF chains the circuit power consumption increases exponentially which becomes as severe problem in short-range communication scenarios like 802.11-based WLAN etc.

Therefore to address the power management problem in MIMO we proposes a systematic methodology called as antenna management methodology, which determines the number of antennas and transmit power for each antenna dynamically. This proposed antenna management scheme satisfies all the requirements of MIMO systems like BER, data rate, SNR etc. to guarantee the required data rate each data bit is transmitted with *minimum energy per bit* and *minimum energy per bit* is defined as required minimum energy per each individual bit to travel from transmitter to receiver.

The remaining paper is organized as, section II clearly explains about the system model of MIMO system and briefly explains about wireless channel model. MIMO channel model. In section III the originating idea behind this project i.e. the system capacity and MIMO power is discussed and the solutions for all the queries raised in this section clearly answered in following section i.e.in section IV. The simulation results of this project explained in section V.

II. SYSTEM MODEL

In this section we explain about the complete architecture of MIMO system which contains a complete description about the MIMO link, MIMO capacity, MIMO Link architecture etc...

Fig 1 represents block diagram of the MIMO system with RF channels.

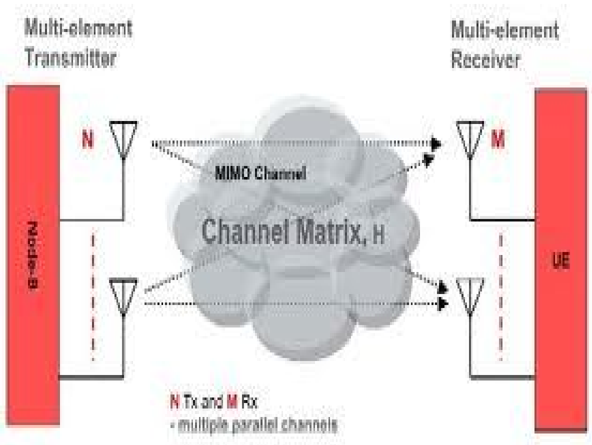

Fig. 1. A MIMO link with a transmitter and a receiver, each with RF chains and antennas

We first provide a basic model for the wireless – SISO (Single Input Single Output) channel after that, we provide the capacity of MIMO channels and then discuss the benefits of using MIMO architecture.

The Wireless Channel:

Here we discuss about the basic model of wireless channel clearly. Traditionally the wireless channel is designed as

$$y = x + n$$

x is input symbol for the channel and it is complex number, referred to as *symbol*, with two bits of information. 'x' can take up to four different values according to the mapping.

$$00 \rightarrow x = -\sqrt{E_S} - j\sqrt{E_S}$$
$$01 \rightarrow x = -\sqrt{E_S} + j\sqrt{E_S}$$
$$10 \rightarrow x = \sqrt{E_S} - j\sqrt{E_S}$$
$$11 \rightarrow x = \sqrt{E_S} + j\sqrt{E_S}$$

The probability of 'x' is equal in all cases.
'n' is defined as the channel noise component. The main reason of 'n" is due to the thermal noise induced by different parts of the receiver. *N* is modelled as a zero mean, complex Gaussian random variable with variance σ^2 per dimension, i.e., the real part of *n* and the imaginary part of *n* are zero mean, statistically independent Gaussian random variables with variance σ^2

$$E(n) = 0$$
$$E|n|^2 = E(nn^*) = 2\sigma^2$$

Signal to Noise Ratio of the Channel is, formulated as

$$SNR = \frac{E|x|^2}{E|n|^2} = \frac{E_s}{\sigma^2}$$

In the other hand, At the receiver side receiver observes the channel's output y from the transmitter and decides Which symbol, out of the four possible ones, was sent as discussed above.

In wireless communication fading is a most common element through entire communication process. The receiving symbol at the receiver is defined as

$$Y = h\,x + n$$

h is fading constant. And *h* is modelled as a complex Gaussian random variable with zero mean and variance is 0.5 per dimension.
Therefore the channel SNR is

$$SNR(h) = \frac{E|hx|^2}{E|n|^2} = SNR|h|^2$$

MIMO Channel Model

Consider N_R active receiving antennas and N_t active transmitting antennas as shown in figure 2.

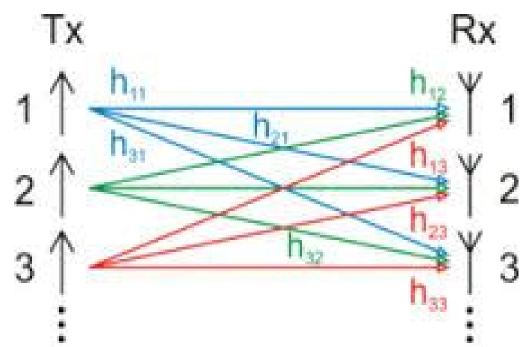

Fig 2: Channel Model of the MIMO system

The channel model can be described as

$$H(t) = \sqrt{\frac{k(t)}{K(t)+1} H_{LOS}(t) + \frac{k(t)}{K(t)+1} H_{NLOS}(t)}$$

$H_{LOS}(t)$ denotes the line-of-sight (LOS) component and $H_{NLOS}(t)$ non-line-of-sight (NLOS) component of the channel, respectively. And k(t) is the *Ricean* factor that indicates the propagation condition of the channel.

III. MIMO SYSTEMS CAPACITY

The MIMO system capacity is defined as total bits per second per total number of active channels [4]. Generally the capacity of the system is nothing but the maximum throughput of the system while maintaining the lowest probability of the error.
The capacity of the wire line Single Input Single Output channel is given by [6]

$$C_{siso} = log_2(1+\frac{E|x|^2}{E|n|^2}) = log_2(1+ p/2\sigma^2)$$

Where P is the transmission power

$$P = E|x|^2$$

Therefore from the above equation it is clear that for the wire line SISO channel, the capacity will be increased only if the transmission power 'P' is increased. But this is not the case for wireless MIMO channels. The capacity of the wireless MIMO channel is

$$C_{MIMO} = log_2 \det(1 + p/2\sigma^2 \frac{1}{M} Q)$$

Where

$$P = \sum_{j=1} E|x_y|^2$$

P is the total transmission power radiating from the all active transmitting antennas at transmitter side.
Therefore it is clear that higher transmit power 'P' or large number of active antennas at both the sides i.e. at transmitter side and receiver side can increases the channel capacity 'C'.
However, these both possible ways will increase power consumption of the transceiver [12]. The efficient solution for this problem is designing a large *Ricean Factor*, so that the sub-channels are highly correlated and under these circumstances it may not be energy efficient to employ a large number of active antennas.

MIMO Power Model

Generally a MIMO link is a combination of active transmitter antenna and an active receiver antenna. Therefore the power consumption of a MIMO link P_{MIMO} is combination of power consumption at transmitter antenna $P_{Transmit}$ and as well as the power consumption at receiver antenna $P_{Receive}$

$$P_{MIMO} = P_{Transmit} + P_{Receive}$$

$P_{Transmi}$ is the combined effect of al the power consumed by all power amplifiers P_{PA} and circuit elements $P_{Circuit\_T}$

$$P_{Transmit} = P_{PA} + P_{Circuit\_T}$$

Assume that identical power amplifiers are used in all RF chains so that P_{PA} depends on total transmitting power P_{TX} .

$$P_{PA} = \frac{P_{Tx}}{\eta(P_{TX})}$$

η : Drain efficiency of the power amplifier.

$P_{Circuit\_T}$ Can be divided into that contributed by each active transmit RF chain, $P_{RFChaint\_T}$, and that by the circuit shared by all active transmit RF chains, P_{Share_T} .

Therefore

$$P_{Transmit} = \frac{P_{Tx}}{\eta(P_{TX})} + N_T P_{RFChain\_T} + P_{Share\_t}$$

N_T is the number of active antennas in the transmitter.
Similarly, Power consumption at receiver is formulated as $P_{Receive}$

$$P_{Receive} = N_R P_{Rfchain\_T} + P_{Share\_R}$$

$P_{RF\_Chain\_R}$ is power consumed by each receive RF chain and P_{Share_R} is shared receive circuit power consumption.

Therefore from all the above discussion, the capacity of MIMO system will increases by increasing the power only. In this paper we achieve the increased capacity of MIMO system by efficiently managing all the active antennas in MIMO transceiver and active RF chains by using *Antenna Management* Scheme.

IV. ANTENNA MANAGEMENT SCHEME

The main objective presents behind the scheme of antenna management is to provide efficient solution for the power management in MIMO systems**.**
Antenna management scheme consists of "Pre-built mapping techniques" and "Efficient Antenna Selection technique".
Pre-built mapping technique is used to calculate the optimal transmitting power P_{TX_OPT} and efficient antenna selection techniques are used to calculate the optimal antenna configuration ω_{OPT} .

Pre-Built Mapping

Pre-Built Mapping is a systematic procedure to calculate the optimal transmit power. In this procedure, with different combinations of N_R and N_T and their corresponding channel matrix we can calculate the different transmitting powers delivered from the transmitter. While performing this procedure approximate transmitted power level P_{TX_Approx} also calculated. By repeating this process for hundreds of different RF communication links exists between active receiving antennas and transmitting antennas P_{TX_Approx} are calculated.

Then by considering the systematic mean of all approximated values of we can find out the optimum transmitted power P_{TX_OPT}

Efficient Antenna Selection

In this procedure a systematic procedure has to be followed as: At the given combination of active transmitting antennas and receiving antennas the minimum bit energy rate is calculated. And it is apparent that given fixed N_R and N_T , minimizing E_b is equivalent to maximizing R since P is constant. Therefore we perform this procedure of finding ω_{OPT} into several multiple steps where each step can be solved by existing antenna selection algorithms, e.g. [10].

V. Simulation Results and analysis

The objective of this project mainly concentrates to increase the capacity of the MIMO system under given power constraint by efficiently managing the power using proposed *"Antenna Management"* technique. In this context we analyse the results in a sequential manner as discussed below.

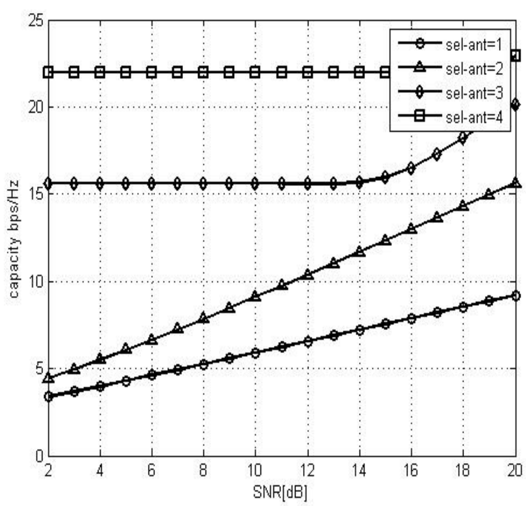

Fig3: Performance comparison of MIMO system

Figure 3 represents the comparison among 4 different combinations of single MIMO systems i.e. the capacity of MIMO system is compared when antenna selection increases linearly by 1 (like 1, 2, 3 and 4). Obviously as discussed in above sections the carrying capacity of MIMO system increases whenever the number of active antennas increases as shown in figure 3. Similar results are shown simulatically in figure 4 as shown below.

Here we have to find out an important point is that the capacity of MIMO increases as antennas increases but the problem is that the power requirement also increases linearly as number of antennas increases.

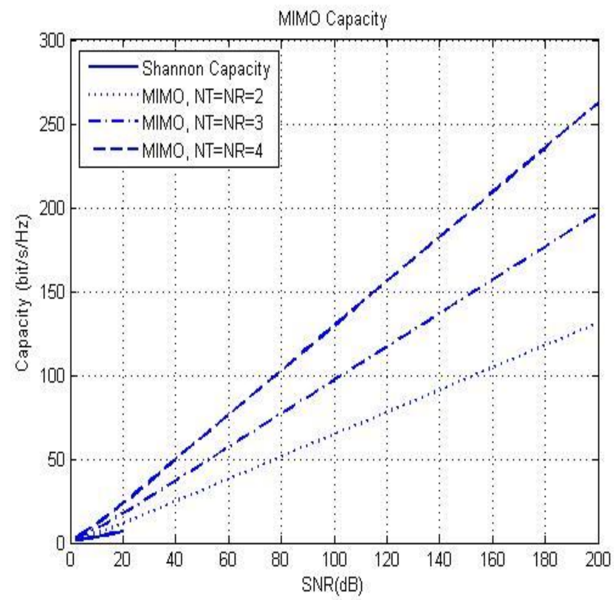

Fig 4: Performance comparison of MIMO system (Simulation results)

Figure 4 clearly represents that the capacity of a MIMO system gradually increases as the number of active antennas increases.

Therefore using proposed method i.e. *Antenna Management* technique we can efficiently manage the all active antenna under all power constrains.

Fig 5 represents the different noise levels present in different MIMO communication links.

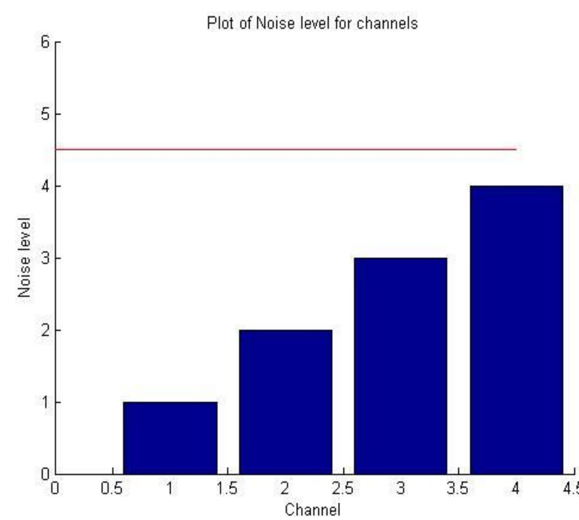

Fig 5: Noise Levels in MIMO Channels

The allocation of power levels are depends on the current levels of the noise channels which are un-able to pre calculate in real world applications. For our convenience the different levels of noise in different communication channels are pre fixed as shown in below figure. Here the allocated nose level occupies some extent of MIMO link and remaining part of the communication link is occupied by antenna power as shown in figure 6.

Below figure shows the power level occupation in MIMO communication link. In MIMO communication links most of the space is occupied by Noise and remaining are occupied by the power levels as shown in figure 6

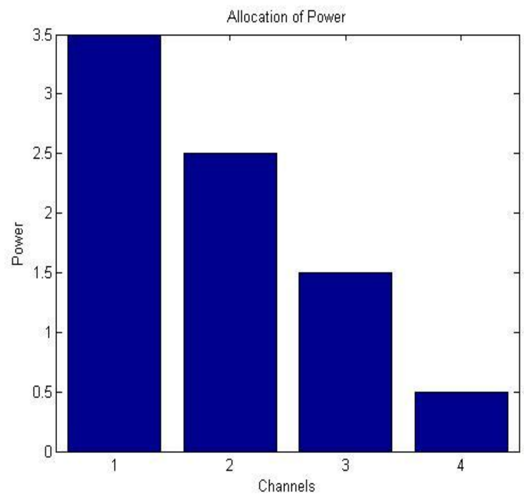

Fig 6: Power Levels in MIMO Channels

After considering all the above situations and effectively applying the proposed scheme the complete results for proposed method are shown in below figure 7.

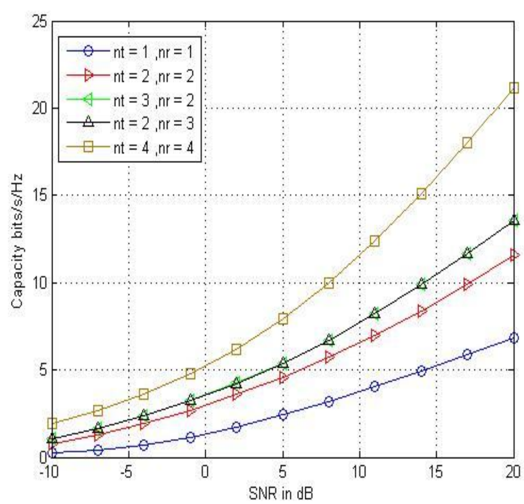

Fig 7: Increased data rate of MIMO system

Figure 7 shows the results for MIMO system for different combinations of antennas under proposed scheme considerations. From the above results we clearly analyses that the capacity of the MIMO system increases gradually by increasing the number of active antennas linearly, without increasing the input power levels which is efficiently achieved by using proposed method only. By using this schema i.e. *Antenna Management* we show that by efficiently managing the power we can increases the capacity of MIMO system.

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