A Novel Power Reduction Scheme for MimoNetwork Interface

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ABSTRACT

Most power consuming components of the mobile system are high speed wireless network interface. This is particularly true for multiple-input multiple-output network interface which uses a multiple number of RF chains simultaneously. In this paper, we introduce an antenna management technique, a novel power reduction scheme for MIMO network interface on mobile systems. The main idea is to reduce some antennas and some RF chain to improve the capacity and reduce circuit power. Antenna management adaptively optimizes the transmit power and antenna configuration is ordered to achieve the minimum energy per bit under a given data rate constraints. The antenna selection algorithm efficiently solves the problem of minimizing energy per bit and uses MIMO-based WLAN standard, IEEE 802.11n as the operating protocol. The evaluation is based on MATLAB simulation. The results show the front end of the MIMO network interface can achieve a 7% system reliability, the power reduction on one-end energy per bit and two-end energy per bit method will be compare with static MIMO configuration.

General Terms

Algorithm, measurement, performance, theory.

Keywords

Multiple-input-multiple-output (MIMO), RF chain, antenna management, energy per bit.

1. INTRODUCTION

The next generation wireless broadband communication multiple-input-multiple–output (MIMO) technologies, are significantly considered as an innovating method to improve link capacity with lower usage of spectrum or transmit power [1] - [3]. WiMAX, LTE and 802.11n are the leading and current mobile standards. The multiple antenna in MIMO system can be split into two different ways, one is to improve channel reliability and better antenna diversity and another one is to simultaneously use multiple number of antennas at the transmitting and receiving section. Due to multiple number of RF active chains the circuit power consumption is significantly higher in MIMO network interface, especially on transmitting section. This technological barrier is practically happening in MIMO systems, particularly on thermally constrained and battery mobile system.

The increased rate of circuit power consumption is mainly problematic for short range communication scenario such as 802.11n-based WLAN standard where circuit power is more often compared to transmit power to a network interface. The goal of an antenna management is to achieve the optimal tradeoff between the power consumption and data rate. That means choosing the optimal number of antennas and an optimal number of RF chains to minimize energy consumption per transmitted data. To address the power challenge, we introduce a novel power reduction method for MIMO network interface on mobile system called antenna management. Antenna management significantly determines, every each number of active antennas would have a separate transmit power. The key factor behind the power reduction scheme of MIMO network interface is the mobility of a mobile system, very high speed wireless networks that offer the best quality-of-service (QoS) and the range-capability in non-line-of-sight (NLOS) environment. This MIMO technology has been designed to improve the data rate and channel capacity to offer (Qos) by offering the diversity gain in communication link.

We make the following key contributions in this work.

- In this work we provide both algorithm and MATLAB-based Simulation, the antenna management algorithm would efficiently solve the problem of energy per bit minimization.
- We analyze the energy per bit MIMO as a function of antenna configuration and transmit power, significantly formulate an optimization problem towards its energy per bit minimization at single end and both ends.
- We offer both a one - ended and two - ended power reduction scheme for MIMO network interface with suitable between a mobile user end and access point while the other operates between two mobile users.

We evaluate the antenna management with a MATLAB-based simulation of 4x4 MIMO network interface. We show the effectiveness of antenna management with simulation, the system reliability should be 7% in 4x4 MIMO system and antenna management can achieve one-end and two-end power consumption of front end MIMO network interface compared to the static MIMO method with all antenna active.

The rest of the paper is organized as follows. Section 2 provides antenna selection in MIMO systems. Section 3 and 4 provides background work of MIMO technology and discuss related works, respectively. Section 5 provides simulation based evaluation and section 6 concludes the paper.

2. BACKGROUND

We first provide the background work for the MIMO technology and particularly, we are interested in spatial multiplexing MIMO. To increase the spatial streams by multiple antennas that would increase the link data rate. The increased data rate of a 300Mbps under an 20 MHz, it can be adopted by 802.11n WLAN link.

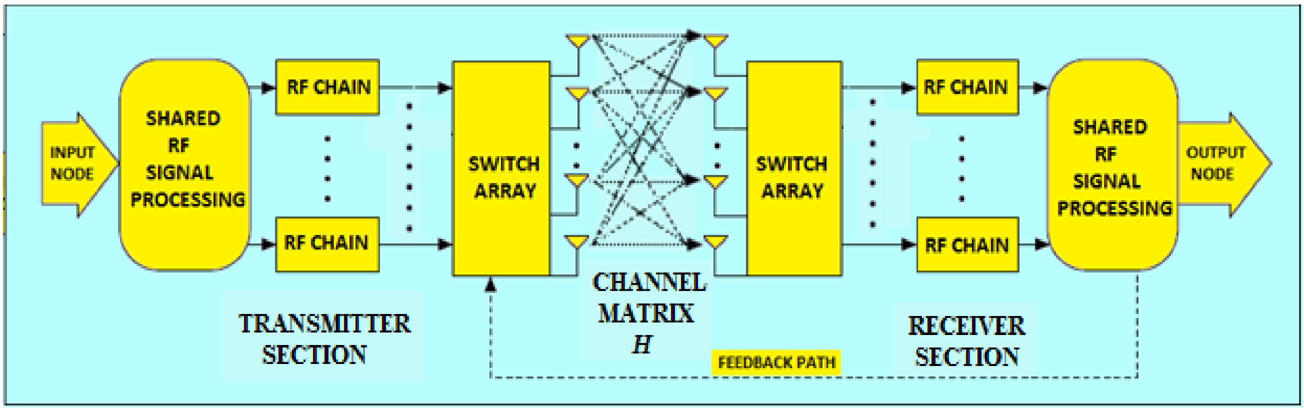

Fig 1: A MIMO link with feedback path.

2.1 MIMO Link Architecture

Fig. 1 illustrates an architecture of MIMO link with a pair of transmitter and receiver respectively, and each pair of transmitting antenna and receive antenna would form the sub channel between the transmitter and receiver, it can work in a half -duplex manner. A MIMO transceiver can allow an excess number of passive antennas than RF chains and it employ the antenna selection method [5] [6]. At the transmitter end, each active RF chain would send out an individual data stream supplied through baseband to the optimal subset of antennas.

2.2 MIMO Channel Model

The MIMO channel can be determined by an N_T x N_R complex matrix H as illustrated in fig 1. The N_T denotes number of active antennas in transmitting section and a N_R denotes number of active antennas in receiving section the channel model can be used by IEEE 802.11n [7]

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

In the model, $H_{NLOS}(t)$ and $H_{LOS}(t)$ denotes the non-line-of-sight (NLOS) component and line-of-sight (LOS) component of the channel, respectively. The value $K(t)$ indicates the Ricean k factor for fading distribution of the channel, by varying this $K(t)$ Fading distributions. For example, k = ∞ model the Ricean fading channel and k = 0 models the Rayleigh fading channel, respectively. The time, t, indicates the dynamic over time of the channel, and the change in $H_{NLOS}(t)$, $H_{LOS}(t)$ and $K(t)$ it can yield channel variation and this model path loss of each sub-channel is being normalized. We explained in other words, that the given fixed distance between the transmitter section and receiver section that, the fluctuation happens due to small-scale node.

2.3 Power Model For MIMO System

A MIMO link consists of transmitter section and receiver section, the power consumption of the transmitter, $P_{transmit}$, and that the receiver, $P_{receiver}$, therefore both initialized as a MIMO link, P_{MIMO},

$$P_{MIMO} = P_{Transmit\_T} + P_{Receive\_R} \quad (2)$$

For all antennas and RF chains,we assume an identical power amplifier P_{PA} that totally depends on total transmit power P_{TX}. Therefore, we determine $P_{transmit}$ as

$$\text{Ptransmit} = \frac{P_{TX}}{\eta(P_{TX})} N_T P_{RF_{chain_T}} + P_{shared\_T}, \quad (3)$$

Where NT represents the number of active antennas in the transmitter section and the power amplifier of the drain efficiency η is full depending on the transmit power.
Similarly, we represent P_{Recive} as

$$P_{Receive} = N_R P_{RF\_chain\_R} + P_{Shared\_R}, \quad (4)$$

Where $P_{RF\_Chain\_R}$ and P_{Shared_R} represents power consumed by the RF receive chain respectively.

3. RELATED WORK

Next we discuss existing work related to an antenna management in three different directions. First, we compare this method with MIMO capacity maximization. Second, we show that the antenna management can consider as Rate adaption in MIMO systems. Finally, we compare antenna management with other energy efficient MIMO system.

3.1 Capacity Maximization In MIMO System

To improve the capacity of the MIMO link we approach MIMO capacity maximization with a multiple number of RF chains and antennas in both transmitter and receiver section. To minimize the energy per bit minimization by selecting the optimal number of antennas in MIMO systems. By employing multiple number of RF chains and multiple number of antennas to maximize the antenna selection and maximize the capacity [5], [6], [10], [11]. Another important approach for MIMO capacity improvement is to implement optimal power for each transmit antenna it optimally optimizes the RF chains and activating multiple number antennas at the same time [7], [11], [12].

3.2 Data Rate Adaption

Signal-to-noise ratio realization as being regarded as rate adaption technique for MIMO link in antenna management.The idea of this technique is to understand the current channel condition to approach the capacity [14], [16]. Similarly by changing the number of antennas it will alter the data rate to estimate the channel capacity.

3.3 MIMO Energy-Efficient System Design

In this section we discuss the energy-efficiency of MIMO system design with an IEEE 802.11n MIMO - based WLAN

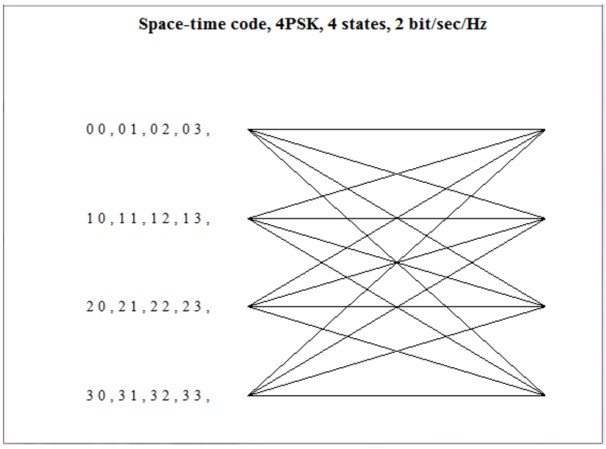

Fig. 2. A transition path of 4x4 MIMO system.

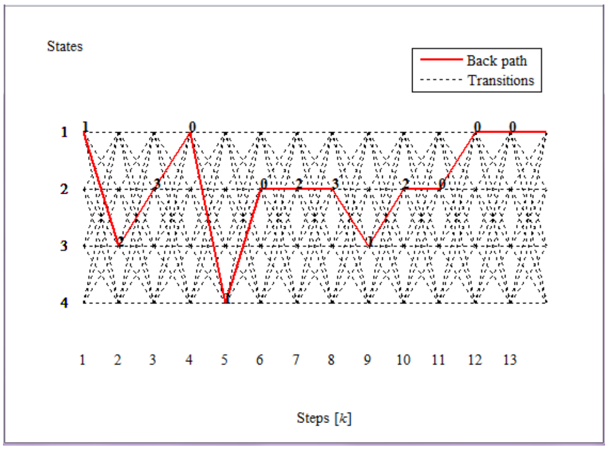

Fig. 3. A feedback path for 4x4 MIMO system.

standard as the operating protocol. In that we have two observations regarding power consumption and the data rate supported by the function of antennas in both the section. At the mobile end to improve the transmit rate we use two or more transmit antenna according to the load utilization at the bait stations, by choosing the better mode.using multiple number of RF chains and antennas its make the MIMO system more energy-efficient in MIMO system.

4. ANTENNA SELECTION

In multiple-antenna systems, also known as multiple-input-multiple output radio system it can improve reliability and capacity of radio communication. Moreover, the multiple antennas are associated with multiple RF chain in terms of size, power and hardware requirement. And this antenna selection method is low-complexity low-cost alternative to capture many of the advantages in MIMO systems. This signalling process can be improved by two different methods those are spatial multiplexing and diversity methods those techniques are known as antenna selection in MIMO systems. In the following, we present an overview of antenna selection in MIMO systems with multiple antennas at transmitting and receiving section with a feedback path from the receiver end to transmitter end. The antenna selection method is mainly used to reduce the hardware system complexity in MIMO systems and effectiveness of antenna selection is reduced by frequency selectivity.

4.1 Spatial Multiplexing And Capacity

Fig. 1 illustrates a representative of the multiple - antenna system with the transmitter and receiver antenna. And the channel matrix would mentioned as a complex valued matrix. We assume a fading block in which the channel can be Ricean or Rayleigh and system experience the additive Gaussian noise at the receive antenna section. Assuming the equal power transmission from the antenna, the capacity as the function of channel matrix H is

$$C = logdet\left(I + \frac{\rho}{N_T}\widetilde{H}^{\dagger}\widetilde{H}\right) \qquad (5)$$

Where ρ is the receiver SNR and the above expression is being maximized the identity channel matrix are represented as hermitian of Ĥ, for a spatial multiplexing, different set of data streams is transmitted from multiple antennas. Similar to this diversity case each number of antennas is being associated with is own channel matrix, and $\widetilde{H}^{\dagger}$ is the hermitian of $\widetilde{H}$[5]. The capacity under the channel capacity is defined as the average of the maximum value of the information between the transmitted end and the receiver end, The other method of a channel capacity is outage capacity.without this outage capacity,the channel remains constant under the transmission signal.further the MIMO channel is possible by diagonalizing the product matrix $\widetilde{H}\widetilde{H}^{\dagger}$ by singular value decomposition or eigenvalue decomposition.

4.2 Transmit / Receive Antenna Selection

The Muliple-Input-Multiple-Output channel capacity has been optimized based on the assumption of all transmitting antennas and receiving antenna are operating at the same time. In the spatial multiplexing to maximizing capacity, they have many similarities with transmit and receive antenna selection the main difference, is in transmitter selection, a feedback path must be exist to inform the transmitter which antenna to select. Next, the signal is sent over a flat-fading channel, and we denote that N_R x N_T matrix of the channel is denoted as H. The output of the channel is being disturbed by additive white Gaussian noise, which is independent to assume all the receiving antenna selection. The fading at the different antenna element is to be identically distributed through Rayleigh fading channel and Ricean fading channel. The fading channel is assumed to be frequency flat, the coherence bandwidth of the signal is apparently larger than transmission bandwidth.

We assume that the receiving section as a perfect knowledge of the channel, for the transmitter, we will analyze both the cases where the transmitter has no channel knowledge. Then each channel realization is being associated with a capacity value the capacity becomes a random variable, and described by cumulative distributive function (cdf).

The input and output relationship can be written as

$$\vec{y} = \underline{H}\vec{s} + \vec{n} = \vec{x} + \vec{n} \qquad (6)$$

Where $\vec{n}$ is noise vector and $\vec{s}$ is transmit signal.

In this section an overview of MIMO systems with antenna selection is described. Either the transmitter section, the receiver section, or both use the signal from a subset of available antennas, it remains the diversity degree is been compared to the full complexity for space time coded system and complete channel capacity, channel estimation errors did not affect the channel capacity moreover the antenna selection process would reduce the hardware complexity in MIMO system and improve the system reliability by 7% in 4X4 MIMO system.

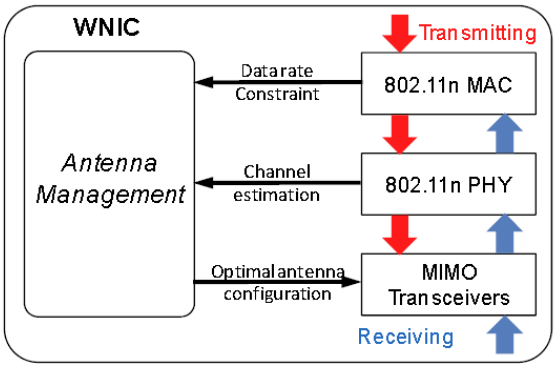

Fig . 4. Implementation of antenna management inside the 802.11n WNIC.

5. SIMULATION-BASED EVALUATION

In this section, we employ a MATLAB-based simulation to evaluate the energy per bit reduction in antenna management under different channels, we use two identical MIMO link like 802.11n transceiver has a multiple number of RF chains and antennas.we are using two types of traffic patterns, namely continuous traffic and intermittent traffic to represent different types of frame arrival rate.For continuous traffic, we analyze that upper layer would always arrive at maximum high rate that transmitter are always engaged in both transmitting and receiving section.In intermittent traffic pattern the most of the time transceivers are in idle mode it happen between successive frames, and the distribution of inter-frame interval can be arbitrary and it represents the application which generate a lower data rate and sparse traffic. The data rate constraint can be represented by the application, the idle period may change the structure of MIMO energy per bit minimization so that the antenna management is still valid in intermittent traffic. For both intermittent and continuous traffic, we explore five scenarios for evaluation using different synthetic channels by using Ricean factor K which equals 0,1,10,100 respectively to represent the various types of fading distribution, all those channels are assumed to be reciprocal with an 20 MHz bandwidth.

5.1 Simulation Results

We use a static configuration with all the antennas are active at the both ends comparing the energy efficiency with an antenna management, first we show the simulation results under continuous traffic and then under intermittent traffic.

5.1.1 Continuous Traffic

The energy per bit reduction by one-ended and two-ended antenna management, respectively. And the two-ended and one-ended antenna management will achieve the energy per bit reduction, to offer an average performance antenna management consider random K as variable.This technique reduces energy per bit reduction for channels with smaller K. And we will employ four different data rate constraints for comparison: 50Mbps, 100Mbps, 200Mbps, 300Mbps, respectively.

5.1.2 Intermittent Traffic

We then employ antenna management under an intermittent traffic, while most of the observations for the continuous traffic can be similarly used in the intermittent traffic,for recalling the frames in intermittent traffic, we use successive frames between the fixed intervals.Therefore, by using some antennas to extend active transmitting or receiving can result in shorter idle time.When the data rate constraint is low the both transmitter and receiver spend little time in the traffic sparse by antenna management technique improves little bit efficiency which is different from as continuous traffic.

6. CONCLUSION

In this paper, we presented a novel power reduction scheme for antenna management, to maximize the energy per bit efficiency in MIMO network interface on mobile systems. And this technique will adaptively optimize the antenna configuration and transmit power to maximize energy efficiency in single end and both ends of the communication link and, to achieve the minimum energy per bit under a given data rate constraint. Our evaluation of using MATLAB-based simulation demonstrate, 7% of achievement in system reliability on antenna selection process, one-end energy per bit reduction and two-end energy per bit reduction can be achieveble, the simulation results will be under the continuous traffic and intermittent traffic.

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