ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com
International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 3, Special Issue 2, March 2016

JUDICIOUS ANTENNA MANAGEMENT FOR POWER OPTIMIZATION IN MIMO SYSTEMS

M.SOWMIYA,M.E.,
Assistant professor
Department of Electronics and communication Engineering
Bharathiyar Institute of Engineering for Women
Tamil Nadu, India.
r.sowmiyaya@gmail.com

ABSTRACT
Designing very high speed wireless links that offer good quality-of-service and range capability in non-line-of-sight environments with low power consumption, constitutes a significant research and engineering challenge. High-speed wireless network interfaces are among the most power-hungry components on mobile systems. This is particularly true for multiple-input-multiple-output (MIMO) network interfaces which use multiple RF chains simultaneously .In this project, we present a novel power management solution for MIMO network interfaces on mobile system, called antenna management. The idea is to intelligently disable a subset of antenna and their RF chains to reduce circuit power consumption, when the capacity improvement of using a large number of antennas is small. An antenna management judiciously determines the number of active antennas to minimize energy per bit while satisfying the data rate requirement. This work provides both theoretical framework and system design of antenna management. We first present an algorithm that efficiently solves the problem of minimizing energy per bit and, then offer its 802.11n compliant system designs. We employ both MATLAB-based simulation and hardware prototype-based experiment to validate the energy efficiency benefit of antenna management..

Keyword- Antenna management,MIMO,Power management, Energy per bit

I. INTRODUCTION

Multiple-Input Multiple-Output (MIMO) technology is a wireless technology that uses multiple transmitters and receivers to transfer more data at the same time. Wireless products with 802.11n support MIMO. This is part of the technology that allows 802.11n to reach much higher speeds than products without 802.11n.The antennas at each end of the communications circuit are combined to minimize errors and optimize data speed.

The key idea of MIMO is to simultaneously use multiple antennas1 at both the transmitter and receiver. By properly leveraging the multiple propagation paths between the transmitter and receiver, i.e. suppressing the correlation between different paths, a MIMO link can significantly boost channel capacity, yielding either higher data rate or higher communication reliability. However, the simultaneous use of multiple antennas significantly increases the circuit power consumption of the MIMO network interface, due to multiple active RF chains. The circuit power increase is particularly problematic for short-range communication scenarios such as 802.11-based WLAN where circuit power is often more than comparable to transmit power. Existing work on MIMO mainly focus on improving the channel quality e.g. link data rate, given the transmit power budget; little published work has considered the dual problem of reducing power consumption including circuit power under a data rate constraint.

To address the power challenge, our solution is a novel power management mechanism, called *antenna management,* which dynamically determines the number of antennas and transmit power for each antenna. Antenna management delivers each data bit with minimum energy consumption, or achieves *minimum energy per bit*, while guaranteeing the

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com
International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 3, Special Issue 2, March 2016

required data rate. Antenna management leverages the mobility of mobile systems.

II .*Design Of Antenna Management*

We provide both algorithm and system designs of antenna management. Our system design of antenna management is 802. 11n-compliant.We offer both one-ended and two-ended designs where the former is suitable for a MIMO link between a mobile node and an access point while the latter for that between two mobile nodes.

A. *Algorithmic Design Of Antenna Management*

Antenna management leverages two key techniques to tackle the above challenges.

First, it identifies P_{TX-OPT} with mappings built offline. For each pair of N_T and N_R , antenna management employs multiple mappings to cope with large-scale channel fading introduced by significant movement of the mobile node.

Second, for a small number of antennas, antenna management enumerates all the antenna configurations to find ω_{OPT} , i.e., the optimal $N_{T,}N_R$ and the optimal subset of antennas; for a large number of antennas, it leverages existing antenna selection algorithms. The overall algorithm is summarized in Algorithm and we next describe the two techniques.

ALGORITHM: *ANTENNA MANAGEMENT*

Input: channel matrix H, minimum data rate constraint R_{min}

Output: optimal transmit power $P_{TX\_opt,}$ optimal antenna configuration ω_{opt}

```
E_b,min = +∞
for 1 ≤ n_t ≤ N_T, 1 ≤ n_r ≤ N_R
    identify H(n_t,n_r) using antenna selection algorithms
    P_TX = P_TX(n_t,n_r,R_min) using the pre – built mapping
    E_b = E_b(P_TX,n_t,n_r)
    if E_b < E_b,min
        E_b,min = E_b, P_TX_opt = P_TX, ω_opt = ω
    end
end
return P_TX_opt , ,ω_opt
```

B.*System Design Of Antenna Management*

We next provide the system design of antenna management. We choose the MIMO-based WLAN standard, IEEE 802.11n, as the operating protocol due to its commercial availability.

1) *Mimo-based 802.11n*

802.11n supports MIMO with up to four RF chains integrated in the MIMO network interface. More than one passive antenna can be attached to each RF chain to enable antenna selection. Each RF chain together with its selected passive antenna is responsible for sending a spatial stream.

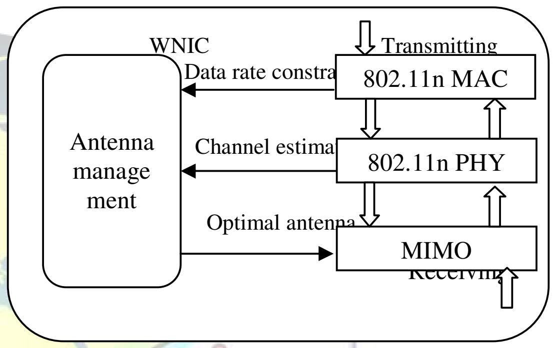

Fig1. Implementation of antenna management inside 802.11n WNIC

A single frame from MAC can be broken up and multiplexed across multiple spatial streams and then reassembled at the receiver. The number of spatial streams, or active antennas, is allowed to be dynamic. The PLCP header specifies this number so that the receiver can correctly decode the original signals.

2) Design Overview

We present two 802.11n-compliant designs of antenna management. The first design is one-ended targeting the mobile node in a legacy 802.11 network. The mobile node only considers its own energy efficiency. The second design is two-ended, with antenna management at both ends to minimize energy per bit for the MIMO link. It is desirable when both ends are energy constrained, e.g., two mobile nodes in an 802.11 ad-hoc network. Both designs intend antenna management to be implemented inside the MIMO WNIC, as illustrated by Fig 1.

i) *One-Ended Antenna Management*

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com
International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 3, Special Issue 2, March 2016

Next we present the unique design principles of one-ended antenna management and target two-ended management

One-ended antenna management leverages open-loop channel estimation. It is triggered when the MIMO transceiver receives a frame in the receive mode. The default configuration of the receive mode has all antennas active, which is essential for the transceiver to use open-loop channel estimation. The transceiver then leverages the estimated channel matrix to obtain the achievable data rate, gets the optimal transmit power for each antenna configuration, and then identifies the one with minimum energy per bit.

The open-loop channel estimation is effective because of the acknowledgement mechanism intrinsic to 802.11: a receiver immediately sends back an ACK frame to the transmitter to acknowledge the reception of a data frame, which provides the transmitter a free opportunity to estimate the channel. Moreover, 802.11 provides a carrier sensing mechanism with the RTS/CTS frame exchange before data frame transmission. While RTS/CTS is only used for large data frames, it guarantees the effectiveness of open-loop channel estimation, especially for non-continuous transmission where a long interval may exist between the last ACK frame and the current data frame. Christo Ananth et al. [11] discussed about Improved Particle Swarm Optimization. The fuzzy filter based on particle swarm optimization is used to remove the high density image impulse noise, which occur during the transmission, data acquisition and processing. The proposed system has a fuzzy filter which has the parallel fuzzy inference mechanism, fuzzy mean process, and a fuzzy composition process. In particular, by using no-reference Q metric, the particle swarm optimization learning is sufficient to optimize the parameter necessitated by the particle swarm optimization based fuzzy filter, therefore the proposed fuzzy filter can cope with particle situation where the assumption of existence of "ground-truth" reference does not hold. The merging of the particle swarm optimization with the fuzzy filter helps to build an auto tuning mechanism for the fuzzy filter without any prior knowledge regarding the noise and the true image. Thus the reference measures are not need for removing the noise and in restoring the image. The final output image (Restored image) confirm that the fuzzy filter based on particle swarm optimization attain the excellent quality of restored images in term of peak signal-to-noise ratio, mean absolute error and mean square error even when the noise rate is above 0.5 and without having any reference measures.

ii) Two-Ended Antenna Management

Two-ended antenna management leverages closed-loop channel estimation, but does not incur additional frame transmission due to two key reasons. First, since each data frame actually grants the receiver a free opportunity to estimate H using the training symbols in the PLCP preamble, no extra training frames from the transmitter are needed. While all transmit and receive antennas need to be active to deliver the training symbols, the resultant energy overhead is negligible since the training symbols are much shorter compared to the frame body. Second, the receiver only needs to send back the optimal antenna configuration instead of H to the transmitter. Once the transmitter knows ω_{opt} , it can easily find the optimal transmit power $P_{TX\text{-}opt}$ using the pre-built mapping. Since ω_{opt} can be encoded as indexes, e.g., a 4 × 4 MIMO link has 256 possible configurations and can be uniquely represented by 8 bits, it is allowed to be included in the ACK frame sent immediately after the data frame.

III. SIMULATION-BASED EVALUATION

In this section, we use a MATLAB-based simulation to evaluate antenna management under synthetic channels.

A. *MATLAB Simulation Setup*

We employ MATLAB to simulate a MIMO link that includes two identical 802.11n-like transceivers, denoted as Node 1 and Node 2. Each transceiver has four RF chains and antennas, in accordance to 802.11n. We use two traffic patterns, namely continuous traffic and intermittent traffic, to represent different frame arrival rates. For the continuous traffic we assume that frames from upper layers arrive at an extremely high rate so that transceivers are always engaged in active transmitting or receiving, i.e., idle period never appears.

Intermittent traffic, in contrast, may introduce considerably long idle period between successive frames, during which the transceiver enters idle mode. Intermittent traffic represents applications which generate sparse traffic and relatively a lower data rate, such as VoIP.

For both continuous and intermittent traffic, we explore five scenarios for evaluation using synthetic channel. For the first four scenarios we use a constant *Ricean* factor K which equals 0, 1, 10, 100

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com
International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 3, Special Issue 2, March 2016

respectively, to represent different fading distributions; for the last scenario we assume K is random.

B. *Simulation Results*

We use a static configuration with all antennas active all the time for both ends, i.e. a static 4x4 MIMO link, as the baseline to compare energy efficiency with antenna management. For two-ended management we measure the average energy per bit of the MIMO link for 1000 successive data frames, with the first 500 frames transmitted by Node 1 and the second 500 frames transmitted by Node 2. For one-ended management only Node 1 implements antenna management which transmits 1000 data frames to and receives ACK frames from Node 2. Instead of energy per bit of the MIMO link, we measure that of Node 1 only.

1) Continuous Traffic

We first evaluate the performance of antenna management under continuous traffic. Fig. 2 (a) and (b) shows the MIMO energy per bit reduction by two-ended and one-ended antenna management, respectively.

We employ four different data rate constraints for comparison: 0Mbps, 100Mbps, 200Mbps and 300M bps. We make several key observations from Fig. 2 (a) and (b).

First, the energy per bit achieved by antenna management is always no larger than that of the static configuration. Considering the scenario with a random K as the one where antenna management offers average performance, 13% and 21% energy per bit reduction can be achieved for two-ended and oneended management, respectively. Since one-ended management only considers the energy per bit of a single end and the other end is supposed to use all antennas, the amount of energy per bit reduction can be potentially higher than that of twoended management. Second, when the data rate constraint increases, the energy per bit reduction by antenna management is shrinking.

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com
International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 3, Special Issue 2, March 2016

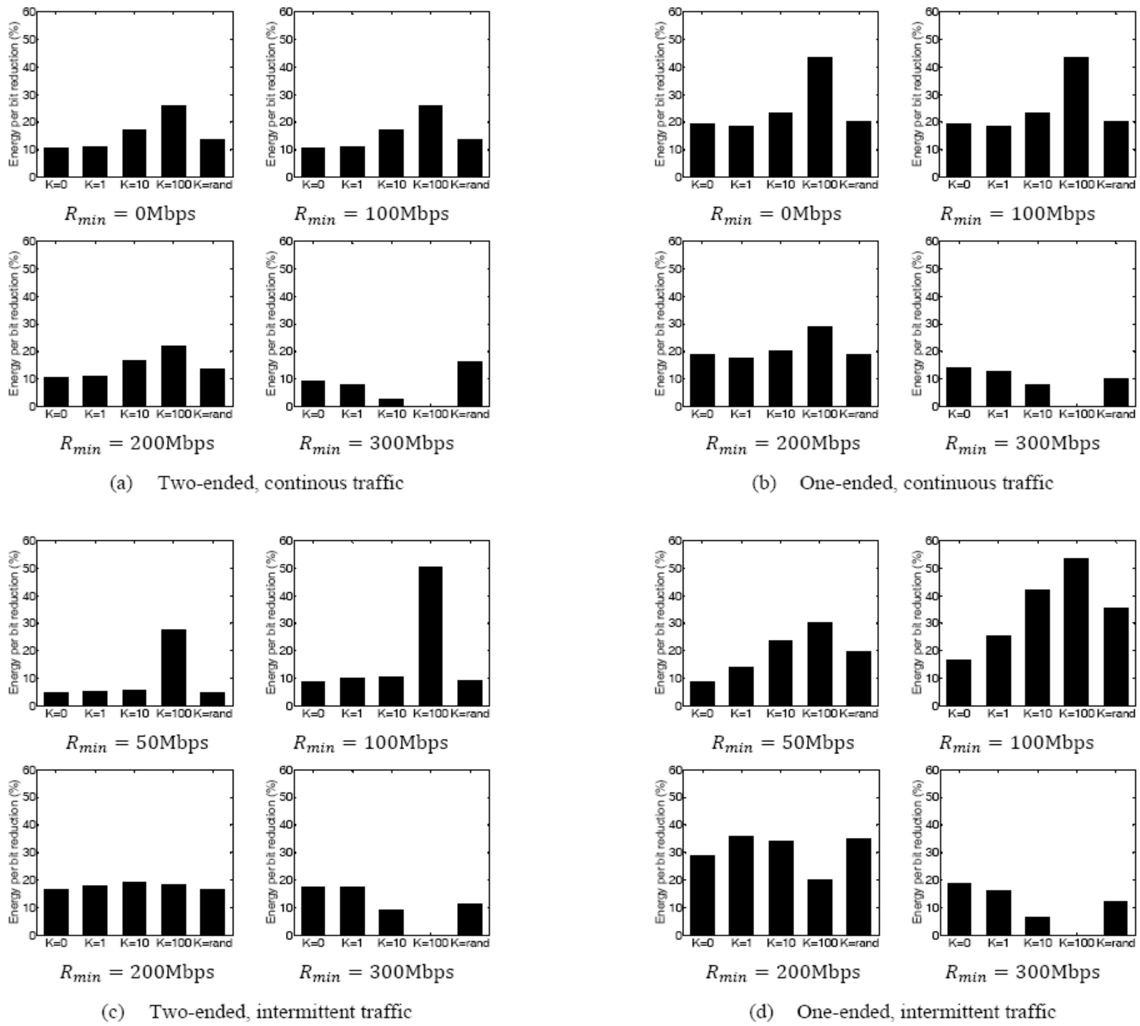

Fig. 2. MIMO energy per bit reduction by antenna management

This is because higher data rate requires more active antennas so that the optimal configuration given by antenna management gradually approaches the static one as data rate constraint increases. Third, under a relatively low data rate constraint, e.g., less than 200Mbps, when the LOS path is more dominant with a larger K, antenna management becomes more effective. This is because under channels with large K, adding more antennas brings marginal capacity improvement while incurs fixed additional power expense. Therefore, the static configuration using all antennas can be very inefficient. On the other hand, under high data rate constraint, the conclusion is on the contrary. That is, antenna management reduces energy per bit more for channels with smaller K. It can be explained by the fact that using the same number of antennas, a channel with smaller K is able to yield higher channel capacity so that more likely to meet the data rate constraint.

2) Intermittent Traffic

We then assess antenna management under intermittent traffic.

As shown in Fig. 2 (c) and (d), while most observations for the continuous traffic can be similarly extended to the intermittent traffic, there are indeed unique characteristics for the latter. First, the peak energy per bit reduction for intermittent traffic is higher than that for continuous traffic. For example, under a random K, 18% and 34% average energy per bit can be reduced by two-ended and one-ended management under intermittent traffic, in contrast to 13% and 21% under continuous traffic. This is because antenna management under intermittent traffic also reduces energy consumption during the idle period. Recall that for intermittent traffic we assume fixed intervals between successive frames. Therefore, using fewer antennas to extend active transmitting or receiving duration can result in shorter idle period thereby less idle energy consumption. Second, under intermittent traffic there exists certain data rate constraint under which antenna management is most effective, e.g. R_{min}=200Mbps for two-ended management and R_{min}=100Mbps for one-ended management. Again, this is due to the consideration of idle energy. When the data rate constraint is low, i.e., the traffic is sparse, both transceivers spend very little time in transmitting or receiving. Therefore, the transmitting and receiving optimization by antenna management improves efficiency very little which is different from continuous traffic. For very high data rate constraint intermittent traffic indicates similar results as continuous traffic does. We must note that many have addressed the energy efficiency of the idle period. Such work is complementary to antenna management.

CONCLUSION

We presented a power-saving mechanism, *antenna management*, to maximize the energy efficiency of the MIMO network interface on mobile systems. Antenna management adaptively optimizes the transmit power and antenna configuration in order to achieve the minimum energy per bit under a given data rate constraint.

We showed that antenna management can be realized with little change to the 802.11n protocol to maximize the energy efficiency of a single end or both ends of a MIMO link. Our evaluation using both MATLAB-based simulation and prototype based experiment demonstrated that antenna management on average can achieve 13% two-end energy per bit reduction and 21% one-end energy per bit reduction.

REFERENCES

[1] A. J. Paulraj, D. A. Gore, R. U. Nabar, and H. Bolcskei, "An overview of MIMO communications - A key to gigabit wireless," *IEEE Proc.,* vol. 92, pp. 198-218, Feb 2004.

[2] D. Gesbert, M. Shafi, D.-s. Shiu, P. J. Smith, and A. Naguib, "From theory to practice: an overview of MIMO space-time coded wireless systems," *IEEE Journal on Selected Areas in Communications,* vol. 21, pp. 281-302, 2003.

[3] L. Zheng and D. N. C. Tse, "Diversity and multiplexing: a fundamental tradeoff in multiple-antenna channels," *IEEE Trans. Information Theory,* vol. 49, pp. 1073-1096, 2003.

[4] S. Sanayei and A. Nosratinia, "Antenna selection in MIMO systems," *IEEE Communications,* vol. 42, pp. 68-73, Oct 2004.

[5] A. F. Molisch and M. Z. Win, "MIMO systems with antenna selection," *IEEE Microwave Magazine,* vol. 5, pp. 46-56, 2004.

[6] V. Erceg, L. Schumacher, P. Kyritsi, A. Molisch, and D. S. Baum, "TGn channel models," in *IEEE document 802.11-03/940r2*, 2004.

[7] T. Yoo and A. Goldsmith, "Capacity and power allocation for fading MIMO channels with channel estimation error," *IEEE Trans. Information Theory,* vol. 52, pp. 2203-2214, 2006.

[8] S. G. Cui, A. J. Goldsmith, and A. Bahai, Energy-efficiency of MIMO and cooperative MIMO techniques in sensor networks," *IEEE Journal on Selected Areas in Communications,* vol. 22, pp. 1089-1098, Aug 2004.

[9] R. W. Heath, Jr. and A. Paulraj, "Antenna selection for spatial multiplexing systems based on minimum error rate," in *Proc. IEEE Int. Conf. Communications (ICC)*, 2001, pp. 2276-2280 vol.7.

[10] A. F. Molisch, M. Z. Win, and J. H. Winters, "Capacity of MIMO systems with antenna selection," in *Proc. IEEE Int. Conf. Communications (ICC)*, 2001, pp. 570-574 vol.2.

[11] Christo Ananth, Vivek.T, Selvakumar.S., Sakthi Kannan.S., Sankara Narayanan.D, "Impulse Noise Removal using Improved Particle Swarm Optimization", International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE), Volume 3, Issue 4, April 2014,pp 366-370

[12] E. Telatar, "Capacity of multi-antenna Gaussian channels," *European Trans. Telecommunications,* vol. 10, pp. 585-595, Nov-Dec 1999.

[13] G. Holland, N. Vaidya, and P. Bahl, "A rate-adaptive MAC protocol for multi-Hop wireless networks," in *Proc. Int. Conf. Mobile Computing and Networking (MobiCom)* Rome, Italy: ACM, 2001.

[14] B. Sadeghi, V. Kanodia, A. Sabharwal, and E. Knightly, "Opportunistic media access for multirate ad hoc networks," in *Proc. Int. Conf. Mobile Computing and Networking (MobiCom)* Atlanta, Georgia, USA: ACM,
2002.