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Power - Proficient Communications in MIMO Systems Based On Congestion Control

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Abstract— In this paper, we propose adaptive techniques for multiple input and multiple output (MIMO) systems, to solve the problem of energy efficient communications with delay constraint, where the energy efficiency is defined as the number of bits per second correctly received per power consumed.We first investigate the optimal multiple quadrature amplitude modulation (MQAM) constellation size for each transmission stream and the optimal packet size. By exploiting the intrinsic relationship among the constellation size, the packet size, the symbol error rate (SER) and delay, we propose an adaptive transmission mode for different delay demands. For the case of user's buffer overflow, we use the congestion control algorithm to schedule the average queue length, and maintain the optimal delay performance for energy efficiency. Simulations show that to maximize the energy efficiency and offer different Quality of Service (QoS) of delay simultaneously, the transmitter should adaptively choose the constellation size and the packet size as well as the transmission mode. In this framework, the tradeoff between energy efficiency and delay demand are well demonstrated.

Index Terms — Sensor network, MIMO, cooperative MIMO,energy efficiency.

I. INTRODUCTION

Recently, energy efficient communications in wireless networks have attracted much research attention. In communication theory, the throughput and the power are respectively the common measures of the benefit and the cost of a communication system, while the energy efficiency, expressed as the throughput per power, is to use the power as efficiently as possible. The packet size, the constellation size and the delay constraint are some key factors to influence the energy efficiency of a communication system [1], [2]. A large packet is susceptible to error which may cause retransmission, so as to affect the throughput [1] and the energy efficiency. On the other hand, when the packets generated from upper layer, they will be transmitted by the physical layer. Large constellation size of physical layer requires more power for transmission with particular symbol error probability, while small constellation size can reduce the transmit power. Thus, a specific modulation has impact on the energy efficiency. When the packet size, the constellation size and the symbol error rate (SER) are given, the packet delay can be derived. Then, under different delay constraints, different throughput and transmission power are required [2], which hence influences the energy efficiency. Motivated by these issues of energy efficiency, we try to find the optimal packet size and the optimal constellation size for energy efficient communications, and investigate the optimal energy efficiency for given delay constraints, which is a crosslayer optimization model. Cross-layer design based on energy and

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delay optimization in small-scale sensor networks are consideredin [3], [4], although multiple input and multiple output (MIMO) energy efficiency is not the main objective of these works. Similar cross-layer methodology can be applied. There exists several studies on the packet size optimization for wireless networks [5] which consider the maximization of energy efficiency subject to transmission power or data rates. In [7], [8], energy efficient packet size for sensor network has been studied. However, these works did not consider the inherent relation between the packet size and the delay aware energy efficiency. On the other hand, in [9], the authors use the convex-optimization method to study the optimal modulation that can minimize the energy consumption per bit under the delay constraint in multi-hop time division multiple access (TDMA) networks, but not considering different modulation sizes for each stream. In [10], the influence of the constellation size to the energy efficiency of a MIMO system has been shown, and it has been shown that the optimal constellation size can dramatically increase the energy efficiency. However, the influence of the constellation size to the power consumption of the MIMO streams has not been considered there, although the optimal power allocation for MIMO streams has been studied in [11]. On the other hand, MIMO systems are not always superior to the single input and multiple output (SIMO) systems due to different circuit power consumption [2]. Since multiple transmission antennas require multiple circuits (mixers, synthesizers, digital-to-analog converters, filters, etc). Hence the circuit power of MIMO transmission is higher than that of SIMO [10].

II. MOTIVATION AND RELATED WORK

The increasing demand for WSNs with long lifetime requires efficient management of the way in which the network resources are consumed. The network energy performance can be improved by employing MIMO communication technology, which uses multiple receiver and/or transmitter antennas to gain better spatial diversity and energy efficiency [2]. Several studies have explored the issue of energy efficiency in MIMO WSNs. In [4], the energy efficiency of non-cooperative, half-cooperative and cooperative MIMO systems are analyzed by considering the trade-off between spatial diversity and multiplexing gains. Their results show that the energy efficiency of MIMO systems is much higher than that of SISO. The energy trade-off between SISO and MIMO systems is also analyzed in [5]. They show that a MIMO transmission scheme performs better than SISO in terms of energy efficiency for long-range applications and vice versa for short-range applications. The protocols presented in [4] and [5] consider a fixed MIMO scheme for exchanging multiple packets between two sensors, regardless of their distance and battery level. However, for different energy levels, distances, and BERs, different MIMO schemes could maximize the network energy efficiency and, therefore , the system lifetime. In [8], the authors considered a MIMO-based wireless network in which the nodes are able to use different MIMO schemes, and presented a power-controlled channel access protocol to minimize the total power consumption. In this protocol, a suitable MIMO scheme is chosen among MIMO, MISO, SIMO, and SISO, based on the transmission distance and the transmission power. For every pair of nodes along a multihop communication path, they selected the MIMO scheme that minimizes the total energy consumption. However, for subsequent packet transmissions between two neighbor nodes, the protocol presented in [8] always selects the same MIMO scheme, disregarding the traffic load of a node and thus reducing the total system lifetime. It can be noticed that all these papers do not consider the system remaining energy while minimizing the total energy consumption. The proposed communication protocols, for a particular transmission distance and BER, always select the same MIMO scheme. Christo Ananth et al. [6] discussed about a method, End-to-end inference to diagnose and repair the data-forwarding failures, our optimization goal to minimize the faults at minimum expected cost of correcting all faulty nodes that cannot properly deliver data. First checking the nodes that has the least checking cost does not minimize the expected costin fault localization. We construct a potential function for identifying the candidate nodes, one of which should be first checked by an optimal strategy. We proposes efficient inferring approach to the node to be checked in large-scale networks**.**

Unlike previous work, we consider the energy trade-off between the transmitter and the receiver for different MIMO schemes and present an energy efficient model that dramatically increases the lifetime of both the transmitter and the receiver. By dynamically switching between the different MIMO schemes, namely MIMO, MISO, SIMO and SISO, our policies attain much longer system lifetime compared to wireless networks that select the MIMO scheme to be used based only on the transmission distance and on a BER threshold.

2.1 EXISTING SYSTEM

In Existing System, the multi-hop ad hoc networks most works are limited to the basic three-node relay scheme and single –antenna systems. These two limitations are interconnected and both are due to a limited theoretical understanding of the optimal power allocation structure in MIMO cooperative networks (MIMO-CN). So, capacity level is very low. Indeed, most of current works on wireless networks attempt to create, adapt, and manage a network on a maze of point-to-point non-cooperative wireless links. Such architectures can be seen as complex networks of simple links.

2.1.1 Disadvantages:

1. Low Network Capacity.

2. Communications are focused on physical layer issues, such as decreasing outage probability and increasing outage capacity, which are only link-wide metrics.

3. PROPOSED SYSTEM

In Proposed system we use Cooperative diversity. It is a cooperative multiple antenna technique for improving or maximizing total network channel capacities for any given set of bandwidths which exploits user diversity by decoding the combined signal of the relayed signal and the direct signal in wireless multi hop networks. A conventional single hop system uses direct transmission where a receiver decodes the information only based on the direct signal while regarding the relayed signal as interference, whereas the cooperative diversity considers the other signal as contribution.

3.1 Advantage

To make larger or more powerful; increase.

To add to, as by illustrations; make complete.

To produce amplification of: amplify an electrical signal.

To reduce the power consumption.

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3.2 SYSTEM IMPLEMENTATION

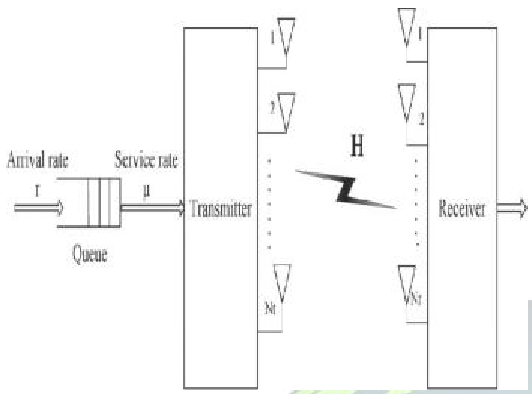

Fig 1. System Model

3.2.1 Relaying Strategies

In amplify-and-forward, the relay nodes simply boost the energy of the signal received from the sender and retransmit it to the receiver. In decode-and-forward, the relay nodes will perform physical-layer decoding and then forward the decoding result to the destinations. If multiple nodes are available for cooperation, their antennas can employ a space-time code in transmitting the relay signals. It is shown that cooperation at the physical layer can achieve full levels of diversity similar to a MIMO system, and hence can reduce the interference and increase the connectivity of wireless networks.

3.2.2 Cooperative Communications & Optimal Power allocation

Cooperative transmissions via a cooperative diversity occupying two consecutive slots. The destination combines the two signals from the source and the relay to decode the information. Cooperative communications are due to the increased understanding of the benefits of multiple antenna systems. Although multiple-input multiple-output (MIMO) systems have been widely acknowledged, it is difficult for some wireless mobile devices to support multiple antennas due to the size and cost constraints. Recent studies show that cooperative communications allow single antenna devices to work together to exploit the spatial diversity and reap the benefits of MIMO systems such as resistance to fading, high throughput, low transmitted power, and resilient networks.

3.2.3 Congestion Collapse

TCP sender's estimate of the number of data packets the network can accept for delivery without becoming congested. In the special case where the flow control limit (the socalled receiver window) is less than the congestion control limit (i.e., the congestion window), the former is considered a real bound for outstanding data packets. Although this is a formal definition of the real TCP rate bound, we will only consider the congestion window as a rate limiting factor, assuming that in most cases the processing rate of end-hosts is several orders of magnitude higher than the data transfer rate that the network can potentially offer. Additionally, we will compare different algorithms, focusing on the congestion window dynamics as a measure of the particular congestion control algorithm effectiveness

3.2.4 Congestion Control

Congestion control algorithm, the purpose of which is to reduce consumption of network resources in complex congestion situations. But this expectation rests on the assumption that congestion states, as deduced from each detected loss, are independent, and in the example above this does not hold true. All packet losses from the original data bundle (i.e., from those data packets

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outstanding at the moment of loss detection) have a high probability of being caused by a single congestion event. Thus, the second and third losses from the example above should be treated only as requests to retransmit data and not as congestion indicators.

Moreover, reducing the congestion window does not guarantee the instant release of network resources. All packets sent before the congestion window reduction are still in transit. Before the new congestion window size becomes effective, we should not apply any additional rate reduction policies. This can be interpreted as reducing the congestion window no more often than once per one-way propagation delay or approximately RTT/2

3.2.4.1 Algorithm 1 Congestion Control Algorithm

1: initialize the maximize transmission rate rs and the arrival

rate bound M;

2: **while** $Q(t) \geq Q0$ **do**

3: select the positive constant K;

4: **if** K

$Q(t)m \leq M$**then**

5: $r(t) = K$

$Q(t)m$;

6: **else**

7: $r(t) = M$;

8: **end if**

9: at the same time, compute the maximal service rate

$bRs\ ps/L$ from (29);

10: **if**$Q(t)rs \leq bRs\ ps$

L **then**

11: $\mu(t) = Q(t)rs$;

12: **else**

13: $\mu(t) = bRs\ ps$

L ;

14: **end if**

15: **end while**

In the congestion control algorithm, m and K are positive constants assuming that the utility function of user is $K\ r1-m\ 1-m$ when it transmits at rate r, and rs is the maximum transmission rate for the user at particular channel state [16]. Here we consider that the rate rs is constant.With the congestion control algorithm, the mean queue length can eventually reach stable, and the packet arrival rate with the service rate are scheduled by the controller, and we will see the convergence property of them in the simulation part. To accomplish optimal delay at the same μ, we can design an algorithm to reduce the mean queue length. We will see the superiority of energy efficiency in the next part.

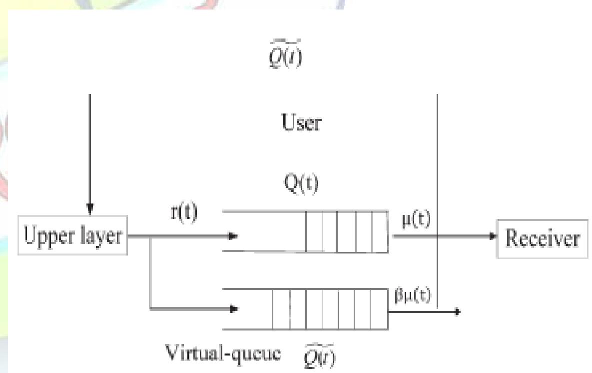

Fig. 2. Virtual queue model at the user.

Virtual Queue: By now, we have solved the problem of buffer overflow. In many cases, we want to make the delay below a certain value while keeping the energy efficiency. We can solve this problem by implementing the user's scheduler using virtual queue , which is shown in Figure, and can be described into three steps:

Step 1: For each flow i, the user maintains a counter called the virtual queue. The virtual queue

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of flow *i* will count the length of the virtual queue, and the arrival rate $r(t)$ of the virtual queue is as that of the flow *i*.

Step 2: The service rate $\mu(t)$ is always a fixed fraction $\beta < 1$ of the actual service rate $\mu i(t)$ of flow *i*, that is

$\mu(t)=\beta\mu i(t)$. However, the control signal which feedbacks to data generation source is the virtual queue length $\tilde{Q}i(t)$.

Step 3: When the virtual queue is evolved to the case of $\tilde{Q}i(t) \geq Q0$, the congestion control algorithm is scheduled.

So we can get the result that the virtual queue length $\tilde{Q}i(t)$ for flow *i* will always be larger than the actual queue length $Qi(t)$ for the reason of virtual service rate. The upper layer of the user will reduce its arrival rate *ri* before its actual queue being busy. So the congestion is virtual, making the stable queue length shorter. Choosing β close to 1, we can sacrifice throughput minimally, however, the queue-length can be dramatically reduced.

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Delay Analysis*:* Note that the total packet delay includes queueing delay and transmission delay. By the congestion control algorithm, we can reduce the average queue length, but the mean service rate for the user does not decrease significantly.

IV. CONCLUSION AND FUTURE WORKS

In this paper, we propose a cross-layer design model for the delay-aware energy efficiency. We first investigate the energy efficient communications with the effect of the constellation size in wireless physical layer. To achieve energy efficient communications, we optimize the constellation size for each stream, based on which, we study the delay aware energy efficiency for the upper layer service. We design the optimal packet size with the specific SER and derive the delay performance. By considering the circuit power consumption, we find the crossover point to select the energy efficient transmission mode between the optimal MIMO and the optimal SIMO for different delay-aware applications. In dealing with the user's buffer overflow from the burst service, we propose a congestion control with virtual queue algorithm to offset the influence, which can further enhance the energy efficiency in certain delay condition in comparison with that without virtual queue.

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