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Trasmission Protocol for Wireless Broadcast Channel -A Cooperative Strategy

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Abstract

Cooperative transmission protocols are proposed for wireless broadcast channels, a fundamental building block of wireless communication networks. The concepts of cognitive radio and precoding have been introduced to broadcast channels in order to improve system performance. Information theoretic metrics, such as outage probability and diversity multiplexing tradeoff, are developed to facilitate performance evaluation. In the absence of direct S-D links, the proposed protocols can achieve a multiplexing gain close to one, whereas the traditional two-hop scheme only achieves a diversity gain of1/2. In the presence of direct S-D links, the proposed protocol can still outperform the comparable scheme, particularly at high multiplexing gains. Regarding to the channel state information (CSI) assumptions, in the absence of direct S-D links, the source does not need to know CSI. In the presence of direct S-D links, the use of precoding requires an extra assumption that the global CSI is available at the source.

Key words:

Cooperative diversity, broadcast channel, downlink channels, diversity multiplexing tradeoff.

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1. Introduction:

Cooperative diversity has been recognize as an efficient and low cost technique to combat multi-path fading in wireless environments. The key idea of cooperative communications is for nodes to cooperate with each other and form a virtual antenna array. The design of cooperative transmission protocols for the simple scenario with only one source-destination pair has been extensively studied , and the application of cooperative diversity to multi-user scenarios has gained increased attention. For example, several efficient protocols have been developed for two-way relay channels, where network coding, a technique originally developed in wireline systems, has been combined with cooperative Diversity.

The broadcast channel is one of the fundamental building blocks of wireless communication networks. It typically consists of multiple destination nodes, each of which needs to receive different information from a common source. Examples of broadcast channels can be found in traditional cellular networks where a base station delivers messages to mobile users, or in a sensor network where a data fusion center sends command information to multiple sensors.

The design of cooperative broadcast protocols is quite challenging as the broadcast channel is severely limited by co-channel interference. For example, in a broadcast channel, a message for one destination causes strong interference at the other destinations. One approach to avoid such co-channel interference is to assume that there are no individual messages and each destination decodes all source messages. however, the impact of fading and the achievable diversity gain were not addressed.

A new form of cooperative broadcast transmission protocol has been developed, where the use of multiple antennas has been proposed to combat co-channel interference. In the concept of cooperative broadcasting has been applied to flooding and the problem of connectivity has been focused.

The contributions of this paper are two-fold:

· *In the absence of direct S-D links:* a new cooperative broadcast protocol is devised that realizes a multiplexing gain of $M/M+1$, where M denotes the number of destinations. Note that a traditional two-hop transmission scheme with relay selection can only achieve a multiplexing gain of 1/2. In addition, two sim-ple modifications are applied to the proposed broadcast protocol to enhance system performance. One, inspired by cognitive radio, pushes the achievable diversity gain close to the maximum possible diversity gain. The second approach is developed to increase the multiplexing gain close to one when there are sufficient reliable relays.

· *In the presence of direct S-D links:* a new cooperative broadcast protocol is developed where the source transmission and relay forwarding are carefully coordinated and distributed beamforming is applied to ensure interference avoidance. The diversity-multiplexing tradeoff has been used for performance evaluation. Recall that the cooperative broadcast protocols proposed in cannot achieve a better diversity-multiplexing tradeoff than non cooperative scheme for the multiplexing gain larger than 1/2. We will show that the proposed broadcast protocol can realize a diversity-multiplexing tradeoff better than the one achieved by the non-cooperative scheme and the existing cooperative scheme particularly at large multiplexing gains.

2. Materials and Methods:

the methods of cooperative transmission protocols for wireless broadcast channels are as follows.

2.1. Transmission Strategy for the scenario without direct S-D links

Consider a communication scenario with one source node, M destinations, and L relays. Each of the M destinations is to receive a different message from the source with the help of the relays. A symmetric system has been assumed, where all users have the same targeted data rate R. Note that R is the targeted data rate for each user Due to the symmetry of time division duplex systems, the incoming channe l and the return channel are assumed to be symmetric. In this section, it is assumed that there is no direct link between the source and destinations, as in, so the source will first deliver information to the relays which shall forward the source information to the destinations.

2.1.1. Description for the proposed broadcast transmission protocol

The proposed transmission strategy consists of two phases: initialization and data transmission. During initialization, relay selection is preformed, which ensures that only the relays with good channel conditions participate in the data transmission.The system overhead needed to obtain necessary channel state information (CSI)

For data transmissions, each data frame consists of $P = M + 1$ time slots During the first time slot, the source broadcasts the message $s1$ at the rate $M+1/M$ R which is intended for the first destination. During the second time slot, the source broadcasts a new message, $s2$, at the rate $M+1/M$ R intended for the second destination. the backoff period of each relay can be set inversely proportional to its channel condition,so the relay with the best channel condition shall be selected because it has the shortest backoff period. In such a way, relays do not have to talk

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to each other and the relay selection can be accomplished in a distributed way.

Regarding to the CSI assumption required by the proposed transmission protocol, the source does not need to know any CSI. information about for its incoming and outgoing channels. However, a more bandwidth efficient method is to apply advanced channel estimation approaches, where the a priori information contained in the observation can be exploited to achieve blind channel estimation.

2.1.2.Outage performance and diversity-multiplexing tradeoff

Outage probability will be used as the criterion for performance evaluation since the probability of error of the maximum likelihood (ML) detector can be tightly bounded by the outage probability at high SNR. Furthermore, the use of the outage probability gives us a better understanding between the three parameters, the data rate, the error performance and the SNR. Although all users have the same targeted data rate, different users shall have different diversity-multiplexing tradeoff.

The following theorem provides the achievable diversity-multiplexing Tradeoff conditioned on K for the proposed scheme

Theorem *1:* Assume all wireless channels are independent identically Rayleigh faded and there are no direct links between the source and destinations. Provided that there are K qualified relays, K ≥ M, the achievable outage probability is $P(OK)=\ell^{-d_{two\text{-}hop,k}^{(r)}}$, where $d_{two\text{-}hop,k}^{(r)}=(K-M+1)(1-M+1/M\ r)$,for $0<r<M/M+1$;

Theorem *2:* By using the proposed cooperative transmission protocol, the achievable diversity multiplexing tradeoff for the user with the worst performance is $d_{two\text{-}hop}=(L-M+1)(1-M+1/M\ r)$,for $0<r<M/M+1$;

2.1.3. A cognitive radio inspired approach to increase diversity gain

The main reason for the loss in diversity gain is that relays cannot be reused. At the m-th time slot,m−1 relays have been used previously and hence only K −m+1 relays are available for the (m−1)-th user. The key step to increasing diversity gain is to enable relay reuse. Take the m-th time slot as an example. According to the proposed protocol, two messages will be transmitted simultaneously, sm by the source and sm−1 by a relay, Rm−1. Without losing of generality, let Rm denote the relay with the best connection to the m-th destination, and consider that this relay has been scheduled previously, which means that the relay Rm does not have the priori information about sm−1. As a result, Rm is not able to decode sm from the received mixture, and hence is not able to help the m-th user.

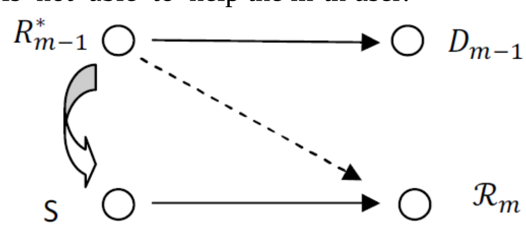


Fig. A diagram to illustrate the cognitive radio inspired approach.

An important observation is that the transmission power at the source will not be too large since a relay will be scheduled to transmit only if it has a good connection to the source. Specifically the averaged transmission power at the source can be bounded by a constant.

Hence this proposed approach can achieve the diversity gain L−1, which is the maximum diversity gain minus one, for all destinations. Compared to the scheme discussed previously, the achievable diversity gain is no longer a function of M. So inviting as many users as possible into cooperation can increase the multiplexing gain and will not cause any loss of the diversity gain.

2.1.4. A Simple Approach to increase the achievable multiplexing gain

As stated in Theorem 1, the achievable multiplexing gain for the proposed scheme is M/M+1 . To increase the achievable multiplexing gain, it is desirable to invite a large number of destinations so that M/M+1 → 1. However, increasing M not only reduces the achievable diversity gain L −M + 1, but also increases the system complexity.

The main reason for the loss in multiplexing gain is that one extra time slot is required for relay transmission compared with the schemes. An effective way to reduce the significance of this extra time slot in one frame.

2.2 Transmission Strategy for the scenario with direct S-D links

Here, we consider a more challenging scenario where the destinations can hear the source directly. Such a scenario is difficult because the message transmitted by the source for the m-th destination can cause interference for the other destinations. In this section, we will assume that the source has the access to the global CSI. Opportunistic scheduling will be carried out, where the M destinations are served according to a worst S-D connection first rule.

Specifically the destination with the poorest connection to the source will be scheduled first, and the one with the best connection will be served at last. The reason to schedule a destination with a poorer S-D connection earlier is due to the half-duplexing constraint, where the number of helpful relays becomes less for the destination served later. Since the system performance is bottlenecked by those destinations with poorer S-D connections, it is reasonable to serve destinations with poor S-D connections first. the amplify-forward strategy will beused for relaying in the following.

2.2.1Protocol Description and Signal Model

During the first time slot, the source broadcasts the message s(1) which is a mixture of the two symbols, s(1) = α11s1 + α12˜s2, where s1 is the message for the first destination and the structure of ˜s2 will be discussed later as well as the design for the coefficients, α11 and α12. Each of the L relays receives
yRi(1) = hSRis(1) + nRi(1),
where nRi(1) is the additive white complex Gaussian noise at the i-th relay with power Pn. During the second time slot, two nodes transmit simultaneously.

Regarding to the CSI assumption required by the proposed protocol, the source needs to know the global CSI, so the precoding coefficients can be constructed accordingly. To facilitate the distributed strategy of relay selection, each relay needs to know its local CSI. As can be observed from, each destination only needs to know the CSI of its connections to the source and the relay if simple detection algorithms, such as zero forcing approaches, are used. however, each destination has to know hSRm as well.

2.2.2.Outage performance and achievable diversity-multiplexing tradeoff

the overall outage probability can be expressed as P(O) = max{P(O1), . .,P(OM)} since the user with the oorest performance dominates the system. The following theorem provides the outage performance achieved by the proposed protocol.

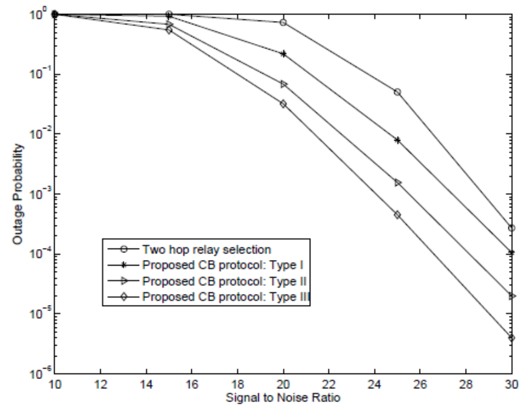
Theorem *3:* Assume all addressed wireless channels are i.i.d. Rayleigh faded and the destinations can hear the source directly. The outage probability achieved by the proposed cooperative broadcast protocol can be approximated at high SNR as

$$P(0)=\ell^{-d(r)},$$

where d(r)=(L-M+1)(1-M+1/M r) for 0<r<M/M+1, which means that diversity gain no larger than one can be achieved for the multiplexing gain 1/2 ≤ r ≤ 1.

3. Results:

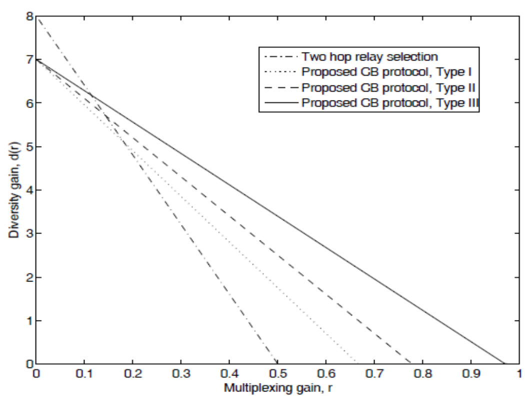
1.Outage probability versus signal to noise ratio is



(a) Setup One: $R = 4$, $L = 6$ and $M = 3$

The outage probability achieved by the proposed broadcast transmission protocols and the comparable schemes vs SNR. It is assumed that there is no direct link between the source and destination nodes.

2.Divercity gain versus multiplexing gain is



The diversity multiplexing tradeoff achieved by the proposed broadcast transmission protocols and the comparable schemes. t is assumed that there is no direct link between the source and destination nodes. The number of the qualified relays and destination nodes is K = 8 and M = 2.

4. Conclusion:

In this paper, several new cooperative transmission protocols for wireless broadcast channels have been described. Provided that there is no direct S-D link, the proposed broadcast protocols can achieve a multiplexing gain close to one provided that there are sufficient relays, whereas the traditional two-hop scheme can only achieve a diversity gain of 1/2. Provided that there are direct S-D links, the proposed protocol can still outperform competing schemes particularly at high multiplexing gains. In addition to simulation results, analytical results have been developed to facilitate performance evaluation.

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