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A PATH FOR HORIZING YOUR INNOVATIVE WORK

VARIOUS COOPERATIVE DIVERSITY PROTOCOLS

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Abstract: Cooperative diversity or cooperative communication as it is also called is a method to combat fading in wireless networks, whether it be a wireless sensor network or ad-hoc network or a cellular network. In the context of ad hoc network, cooperative diversity is a novel technique proposed for conveying information, where closely located single-antenna network nodes cooperatively transmit and/or receive by forming virtual antenna arrays. It is an energy-efficient class of cross-layer network algorithms that exploit the broadcast nature and inherent spatial diversity of the channel. With the application of cooperative diversity, sets of wireless terminals get benefitted by relaying messages for each other to propagate redundant signals over multiple paths in the network. This way of redundancy allows the ultimate receivers to essentially average channel variations resulting from shadowing, fading and other forms of interference.

Keywords: Cooperative diversity, MIMO, Relay, Protocols.

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INTRODUCTION

The increasing demand for wireless multimedia and interactive Internet services, along with rapid proliferation of a multitude of communications and computational gadgets, are giving fuel to intensive research efforts on the design of novel wireless communication systems architecture for very high speed, reliable and economic transmission solutions. The introduction and rapid development of MIMO (multiple-input and multiple-output) systems has promised significant improvements in reliability and throughput for Ad hoc networks; by utilizing multiple antennas at both the transmitter and the receive side.

However, this technique is clearly advantageous for cellular base stations, but not feasible for mobile devices, due to their sizes and power constraints. An alternate to this is a newly developed technique known as multi-user cooperative diversity that allows a single antenna user to achieve transmit diversity benefits by sharing their physical resources through a virtual transmit and receive antenna array. The major benefit of this technique includes the diversity – because different paths are likely to fade independently, having different beam forming gains and different mitigations of the interference.

Wireless communication systems suffer from fading in their channels which causes errors in data transmission. Multiple-input multiple-output (MIMO) is an effective technique to combat channel fading to obtain diversity gain and/or capacity increase of a wireless communication system.

However, multiple antennas in a MIMO technique are prohibitive sometimes for mobile devices due to their limitation on size, cost, and hardware complexity. Avoiding these limitations in MIMO techniques, a new technique named cooperative diversity has been introduced for wireless communications.

In cooperative diversity, multiple terminals each with a single antenna could assist each other in data transmission, sharing their resources in order to obtain diversity gain. The basic motive behind it is that single-antenna mobiles in a multi-user scenario can “share” their antennas in a manner that creates a virtual MIMO system. Several important milestones in this area have been achieved, leading to a flurry of further research activity. It is our hope that this article will serve to illuminate the subject for a wider audience, and thus accelerate the pace of developments in this exciting technology. Cooperative diversity has been considered for the standards of next generation wireless communication systems such as 3GPP LTE (Long Term Evolution)-Advanced and IEEE 802.16j.

MATERIALS AND METHODS

To illustrate the main concepts, the example wireless network considered is shown in the following Fig. 1, in which terminalsT1 andT2 transmit to terminals T3 and T4 , respectively. This example might correspond to a snapshot of a wireless network in which a higher level network protocol has allocated bandwidth to two terminals for transmission to their intended destinations or next hops. For example, in the context of a cellular network, T1 and T2 might correspond to handsets and T3=T4 might correspond to the base station . As another example, in the context of a wireless

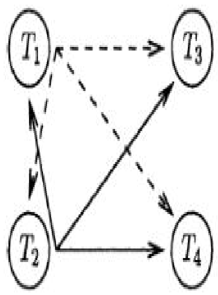

Fig-1 Illustration of radio signal paths in an example wireless network where terminals T1 & T2 are transmitting information to terminals T3 and T4

local-area network (LAN), the case T3≠T4 might correspond to an ad hoc configuration among the terminals, whereas the case T3=T4 might correspond to an infrastructure configuration, where T3 serves as an access point. The broadcast nature of the wireless medium is the key property that allows for cooperative diversity among the transmitting terminals: transmitted signals can, in principle, be received and processed by any of a number of terminals. Thus, instead of transmitting independently to their intended destinations, T1 and T2 can hear each other's transmissions first and then jointly communicate their messages. Inspite of the fact that these extra observations of the transmitted signals are available for free (except, possibly, for the cost of additional receive hardware) wireless network protocols often ignore or discard them.

In the most general case, T1 and T2 can pool their resources, such as power and bandwidth, to cooperatively transmit their information to their respective destinations which corresponds to a wireless multiple-access channel with relaying for T3=T4 , and to a wireless interference channel with relaying for T3≠T4. At one extreme, corresponding to a wireless relay channel, the transmitting terminals can focus all their resources on transmitting the information of T1 ; in this case T1, acts as the "source" of the information, and T2 serves as a "relay." Such an approach might provide diversity in a wireless setting because, even if the fading is severe betweenT1 and T3 , the information might be successfully transmitted through T2 . Similarly, T1 and T2 can focus their resources on transmitting the information of T2 , corresponding to another wireless relay channel.

As in many current wireless networks, such as wireless LANs and cellular system, we divide the available bandwidth into orthogonal channels and allocate these channels to the transmitting terminals, allowing our protocols to be readily integrated into existing networks. As an easy by-product of this choice, we are able to treat the multiple-access (single receiver) and interference (multiple receivers) cases shown in above figure simultaneously, as a pair of relay channels having signaling between the transmitters. Furthermore, removing the interference between the terminals at the destination radio(s) substantially simplifies the receiver algorithms and the outage analysis for purposes of exposition.

For all of our cooperative protocols, transmitting terminals should also process their received signals; however, current limitations in radio implementation preclude the terminals from full duplex operation, i.e., simultaneous transmision and receival in the same frequency band. So, half duplex operation will be considered.

Fig.2 illustrates our channel allocation for an example time-division approach with two terminals.

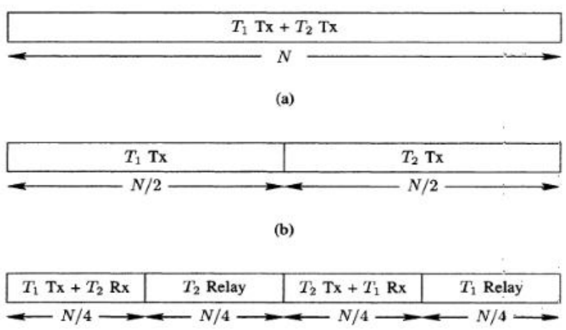

Fig-2: Example time division channel allocation for (a)direct transmission with interference,(b)orthogonal direct transmission and (c)orthogonal cooperative diversity.

Due to the symmetry of the channel allocations, we focus on the message of the "source" terminal taken as Ts, which employs terminal Tr as a "relay," in transmitting to the “destination” terminal Td , where s,r belongs to{1,2} and d belongs to{3,4}. We utilize a baseband-equivalent, discrete-time channel model for the continuous-time channel, and we assume N consecutive uses of the channel, where N is large.

For direct transmission, our baseline for comparison, the channel is modeled as

$$Y_d[n] = a_{s,d}Xs,[n] + Z_d[n]$$

For, say, n=1,….,N/2,where Xs[n] is the source transmitted signal, and yd[n] is the received signal at the destination. The other terminal transmits for n=N/2+1,…..,N.

For cooperative diversity, we model the channel during the first half of the block as

$$y_r[n] = a_{s,r}\, x_s[n] + z_r[n]$$
$$y_d[n] = a_{s,d}\, x_s[n] + z_d[n]$$

for n=1,….,N/4

For the second half of the block, we model the received signal as

$$Yd[n] = a_{r,d} \times_r [n] + Z_d[n]$$

for n=N/4+1,….,N/2.

Two important parameters of the system selected for evaluating the performance are SNR without fading and the spectral efficiency given by:-

$$\text{SNR}:=\frac{2P_c}{N_0W}=\frac{P}{N_0}$$

and $R:=2r/W$ b/s/Hz respectively.

RESULT AND DISCUSSION

The process of cooperative diversity can be viewed from two different angles:-

One, from the transmitter’s end and another from the receiver’s end. At the transmitter’s end various protocols are used and at the receiver’s end various combining techniques are employed. Both the prospects are discussed below:-

Cooperative Diversity Protocols:

we describe a variety of low-complexity cooperative diversity protocols that can be utilized in the network, including fixed, selection, and incremental relaying.

These protocols employ different types of processing at the relay terminals, and different types of combining at the destination terminals. In case of fixed relaying, we allow the relays to either amplify their received signals subject to their power constraint, or to decode, re-encode, and retransmit the messages. Among several adaptive strategies possible, selection relaying builds upon fixed relaying by allowing transmitting terminals to select a suitable cooperative (or non-cooperative) action based upon the measured SNR between them. Incremental relaying tries to improve upon the spectral efficiency of both fixed and selection relaying by exploiting limited feedback from the destination and relaying only when necessary. They are being discussed below one by one:-

A. Fixed Relaying:-

1) **Amplify and forward:** The source terminal transmits it's information as Xs[n],say,for n=1,....,N/4. During this interval,the relay processes yr[n],and relays the information by transmitting $x_r[n] = \beta y_r[n - N/4]$

for n=N/4+1,.......,N/2. To remain within its power constraint (with high probability), an amplifying relay must use gain

$$\beta \le \sqrt{\frac{P}{|a_{s,r}|^2 P + N_0}}$$

where we allow the gain of the amplifier to depend upon the fading coefficient $a_{s,r}$ between the source and relay, which the relay estimates to high accuracy.

2) **Decode and Forward:** Here the relay processes $y_r[n]$ by decoding an estimate $\hat{x}_s[n]$ of the transmitted signal from the source. Also, under a repetition-coded scheme, the relay transmits the signal $x_r[n] = \hat{x}_s[n - N/4]$ for n= N/4+1,.....,N/2.

B. Selection relaying:-

If the measured $|a_{s,r}|^2$ falls below a certain threshold, the source simply continues its transmission to the destination, in the form of repetition or more powerful codes. If the measured $|a_{s,r}|^2$ lies above the threshold, the relay forwards what it received from the source, using either amplify-and-forward or decode-and-forward, in an attempt to achieve diversity gain.

C. Incremental Relaying:-

We describe incremental relaying protocols as that which exploit limited feedback from the destination terminal, e.g., a single bit indicating the success or failure of the direct transmission, that we will see can dramatically improve spectral efficiency over fixed and selection relaying. These incremental relaying protocols can be viewed as extensions of incremental redundancy, or hybrid automatic-repeat-request (ARQ), to the relay context. In ARQ, the source retransmits if the destination provides a negative acknowledgment via feedback; in incremental relaying, the relay retransmits in an attempt to exploit spatial diversity.

CONCLUSION

This report describes wireless cooperative communication as a technique that allows single antenna mobiles to share their antennas and thus enjoy some of the benefits of multiple antenna systems. Several signaling schemes for cooperative communication are presented. Practical implications and requirements on system designs are discussed, as well as extensions to the basic idea. Results to date are indicative of a promising future for cooperative communication.

RECOMMENDATION

1) It is assumed that the various spreading codes being used were orthogonal. This need not be the case. Any codes may be used, along with multiuser detection, in order to have optimum performance.

2) The cooperative strategy involves resending, in some sense, information using a cooperative signal. Another possibility is for the two users to always transmit new information, even during the cooperative periods, thus necessitating the use of sequence detection due to the inter symbol interference that would result from such a strategy. It is not clear at present if this strategy would result in increased performance or not.

3) Even though we have analyzed only the case of each user having one partner, it is clear that a generalization of this concept would involve multiple partners, thus leading to even better performance, especially more robust data rates. However, the incremental gains from additional partners will diminish as the number of partners grows.

4) Finally, only physical layer issues have been presented. However, there are several higher layer issues which have not been addressed but which, nevertheless, are interesting, challenging and difficult to resolve. These involve questions such as who will partner with whom, under what conditions will they partner, at which point on the achievable rate region will they operate and why, and who decides which mobiles partner: the mobiles themselves or the BS?

5) An interesting open problem is the development of design criteria specifically for codes that optimize the performance of coded cooperation. Some work in this field has already taken place as in [15] but more scope is still there.

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