Dual-Hop Network with Cooperative Communication

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***Abstract*-The paper deals to proposed a cooperative communications to exploit spatial diversity gains inherent in multi-user wireless systems without the need of multiple antennas at each node. Transmit diversity generally requires more than one antenna at the transmitter. However, many wireless devices are limited by size or hardware complexity to one antenna. Which communication channels are in use and which are not, and instantly move into vacant channels while avoiding occupied ones. The proposed work optimizes the use of available radio-frequency (RF) spectrum while minimizing interference to other users. In its most basic form, CR is a hybrid technology involving software defined radio (SDR) as applied to spread spectrum communications.**

I. INTRODUCTION

The mobile wireless channel suffers from fading, meaning that the signal attenuation can vary significantly over the course of a given transmission. Transmitting independent copies of the signal generates diversity and helps in combating signal fading due to multi-path propagation in wireless medium. For transmitting independent copies of a signal, that is to achieve transmit diversity, multiple antennas will be required at the source terminal which may not be practical for certain scenarios due to size, cost, hardware limitations. Examples include most handsets (size), wireless sensor networks (size, power).Spatial diversity is generated by transmitting signals from different locations, thus allowing independently faded versions of the signal at the receiver [1]. Cooperative communication generates this diversity in a new and interesting way. Cooperative communication involves two main ideas: Use relays to provide spatial diversity in a fading environment [1, 2]. Envision a collaborative scheme where the relay also has its own information to send, so both terminals help each other to communicate by acting as relays for each other. One can think of a cooperative system as a virtual antenna array, where each antenna in the array corresponds to one of the partners. The partners can overhear each other's transmissions through the wireless medium, process this information and retransmit to collaborate. This provides extra observations of the source signals at the destinations, the observations which are dispersed in space and usually discarded by current implementations of cellular or ad-hoc systems. With cooperation, users that experience a deep fade in their link towards destination can utilize quality channels provided by their partners to achieve the desired Quality of Service.

II.COOPERATIVE COMMUNICATION

The term cooperative communications typically refers to a system where users share and coordinate their resources to enhance the transmission quality. This idea is particularly attractive in wireless environments due to the diverse channel quality and the limited energy and bandwidth resources. With cooperation, users that experience a deep fade in their link towards the destination can utilize quality channels provided by their partners to achieve the desired quality of service (QoS). This is also known as the spatial diversity gain. In a cooperative communication system, each wireless user is assumed to transmit data as well as act as a cooperative agent for another user. Two features differentiate cooperative transmission schemes from conventional non-cooperative systems:

1) the use of multiple users' resources to transmit the data of a single source,
2) a proper combination of signals from multiple cooperating users at the destination.

A canonical example is shown in Fig. 1, where we have two users transmitting their local messages to the destination over independent fading channels. Suppose that the transmission fails when the channel enters a deep fade, i.e., when the signal-to-noise ratio (SNR) of the received signal falls below a certain threshold, as indicated with the grey region in Fig. 1. If the two users cooperate by relaying each others' messages and the inter-user channel is sufficiently reliable, the communication outage occurs only when both users experience poor channels simultaneously.

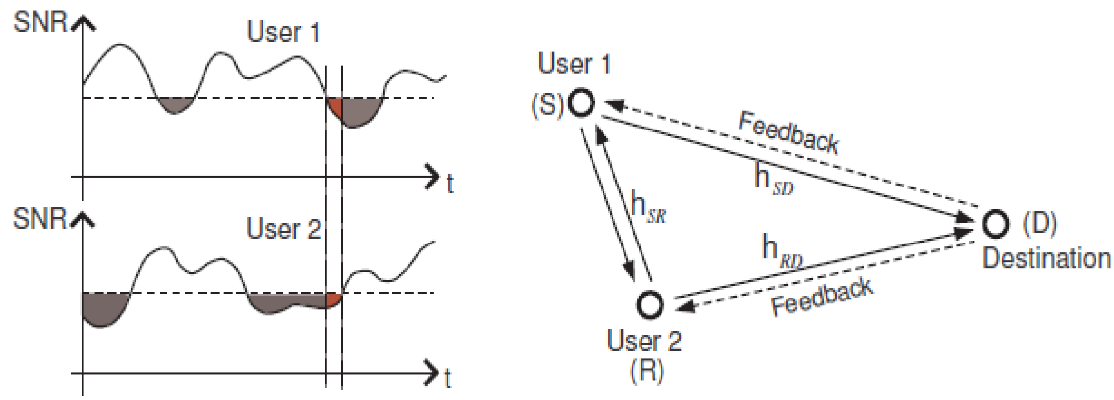

Fig.1. A three node cooperative network model

Cooperative techniques utilize the broadcast nature of wireless signals by observing that a source signal intended for a particular destination can be "overheard" at neighboring nodes. These nodes, called relays, partners, or helpers, process the signals they overhear and transmit towards the destination. The relay operations can consist of repetition of the overheard signal (obtained, for example, by decoding and then re-encoding the information or by simply amplifying the received signal and then forwarding), or can involve more sophisticated strategies such as forwarding only part of the information, compressing the overheard signal, and then forwarding. The destination combines the signals coming from the source and the relays, enabling higher transmission rates and robustness against channel variations due to fading.

III.COOPERATIVE COMMUNICATION SIGNALLING TECHNIQUES

At each time instance, one user acts as the source node while the other user serves as the relay node as shown in Fig. 1. Each user has the right to serve as the source node in a typical cooperative system [1, 2]. At first, the source, e.g. user 1, broadcasts its message to both the relay node and the destination. The relay node can then employ any one of the following cooperative communication signalling techniques to forward the message to the destination. The main and most popular cooperative signaling techniques based on the concept of relaying are:

A) Decode and Forward Method
B) Amplify and Forward Method

A. Decode and Forward Method:

If the relay node employs the Decode and Forward (DF) scheme, it will decode the message received from the source, re-encodes it and then forwards the message to the destination subsequently as shown in Fig.2. When the regenerated message is encoded to provide additional error protection to the original message, it is also referred to as coded cooperation. At the destination, signals from both the source and the relay paths are then combined for detection. This signalling has the advantage simplicity and adaptability to channel conditions.

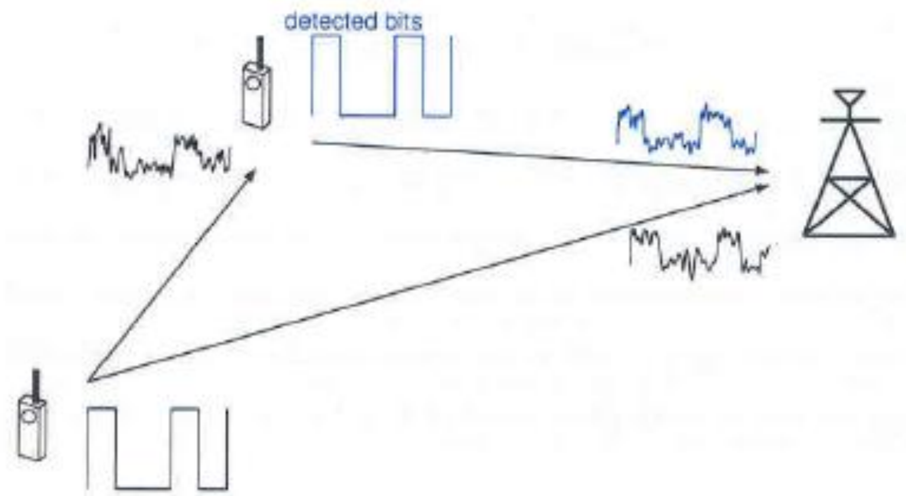

Fig.2 Decode and Forward Method

It is possible that the detection by the partner is unsuccessful, in which case cooperation can be detrimental to the eventual detection of the bits at the destination. To avoid the problem of error propagation, hybrid decode and forward method can be used where, at times when the fading channel has high instantaneous signal to noise ratio, users detect and forward their partners data, but when the channel has low SNR, users revert to a non-cooperative mode.

***B. Amplify and Forward Method*:**

If the Amplify and forward (AF) scheme is employed, the relay node simply amplifies the received signal and forwards it directly to the destination without decoding the message.

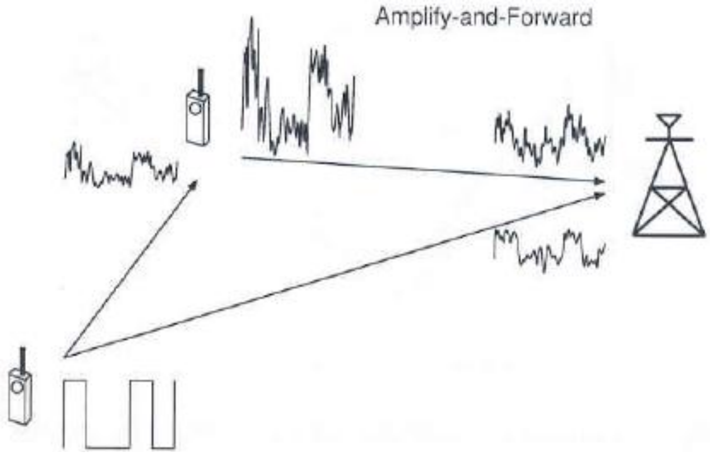

Fig.3. Amplify and Forward Method

Each user in this method receives a noisy version of the signal transmitted by its partner. As the name implies, the user then amplifies and retransmits this noisy version. The base station combines the information sent by the user and partner, and makes a final decision on the transmitted bit (Fig.3). Although noise is amplified by co-operation, the base station receives two independently faded versions of the signal and can make better decisions on the detection of information. In amplify and forward it is assumed that the base station knows the interuser channel coefficients to do optimal decoding, so some mechanism of exchanging or estimating this information must be incorporated into any implementation. The advantages of relay cooperation often rely on sufficiently reliable interuser channels [3]. For example, in the DF scheme, a node is able to relay the message only if it is able to receive from the source reliably while, in the AF scheme, the quality of the relayed signal is limited by the quality of the source-relay link since both the signal and noise are amplified at relays. Therefore, relays should be adopted only if the source-relay channel is sufficiently reliable. This observation leads to the selective relaying (SR) cooperation scheme where relays are selected to retransmit the source message only if the quality of the transmission over the inter-user channel meets a certain criterion.

IV. ADVANTAGES OF COOPERATIVE COMMUNICATION

The main advantages of cooperative communications are:

A. Higher Spatial Diversity:

As a simple example, Fig. 4a shows a small net-work of four mobile nodes. If the channel quality between mobile nodes S and D degrades severely (e.g., due to shadow or small-scale fading), a direct transmission between these two nodes may experience an intolerable error rate, which in turn leads to retransmissions. Alternatively, S can exploit spatial diversity by having a relay R1 overhear the transmissions and then forward the packet to D as discussed above. The source S may resort to yet another terminal R2 for help in forwarding the information, or use R1 and R2 simultaneously. Similar ideas apply to larger networks as well. Therefore, compared with direct transmission, the cooperative approach enjoys a higher successful transmission probability [4, 5]. We note here that cooperative communications has the ability to adapt and to mitigate the effects of shadow fading.

B. Higher Throughput-Lower Delay:

In Fig.4a, if Rate2 and Rate3 are higher than Rate1 such that the total transmission time for the two-hop case through R2 is smaller than that of the direct transmission, cooperation readily outperforms the legacy direct transmission, in terms of both throughput and delay perceived by the source S. Furthermore, for relays such as R1 and R2, it turns out that their own individual self-interest can be best served by helping others [4,6].

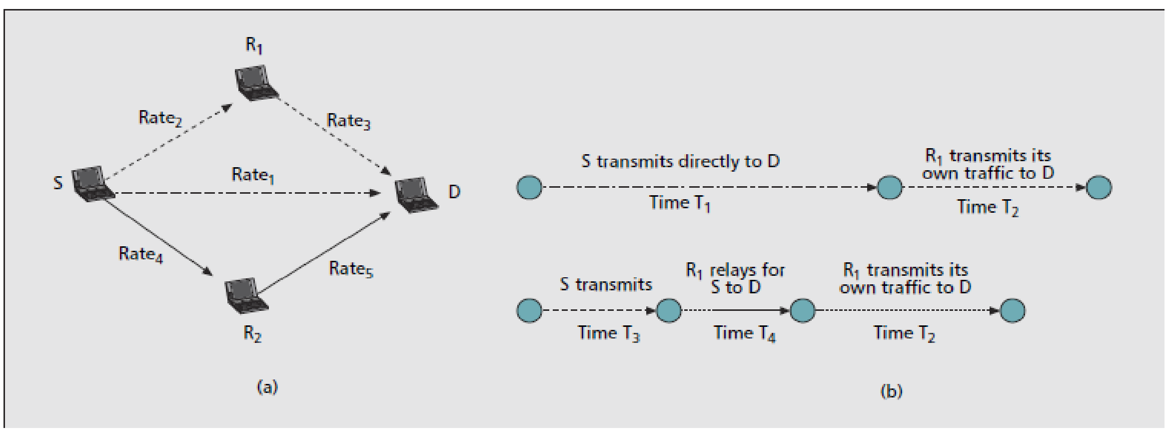

Fig.4. a) Cooperation in a network; b) illustration of the delay and throughput improvement achieved by cooperation in the time domain

As further illustrated in Fig.4b, the intermediate node R1 that cooperates enjoys the benefit of lower channel-access delay, which in turn can be translated into higher throughput.

V.COOPERATIVE COMMUNICATION IN DUAL HOP NETWORK

A. The Model:

The model for the received signal and the channel for a link between any pair of nodes i and j is given by

$$y_j = h_{ij}x_i + n_j$$

Where xi is the signal transmitted by node i, $h_{ij} \rightarrow C\mathcal{N}(0,\Omega_{ij})$ is the complex channel gain over the link i → j, $n_j \rightarrow C\mathcal{N}(0,N0)$ is additive white Gaussian noise at node j. The channel gains, noise, and transmitted signals are independent. The channel gain h_{ij} captures the effects of fading as well as path loss by setting $\Omega_{ij} = d^{-\alpha}{}_{ij}$, where d_{ij} denotes the distance between node i and node j, and α is the path loss exponent.

B.Dual Hop Relay Network:

Consider N relay nodes as shown in Fig.5, denoted by R_k, k = 1, ・ ・ ・ , N, and let h_{Sk} and h_{kD} denote the complex channel coefficients from the source S to the relay R_k and from R_k to destination node D, respectively. The source node can transmit information to the destination node directly, or transmit information to the destination node via a relay. The relays operate in DF mode, whereby relays are selected proactively to forward the information. The use of relays results in a division of the transmission time into two slots:

i) the first slot for the transmission from the source i.e., S broadcasts its message X_S in the first stage to the destination and to the relays. The received signals at the relay and the destination can be expressed as $X_k = h_{Sk} \cdot X_S + W_R$ and $X_{D1} = h_{SD} \cdot X_S + W_{D1}$, where h_{Sk} and h_{SD} are the channel coefficients for the S-R_k and the S-D link and W_R and W_{D1} denote the additive channel noise.

ii)The second slot for the transmission from the relay ie, the set of relays $\{R_k$, k = 1, ・, N$\}$transmits symbol $U_k = f(X_k)$ as a function of the received signal X_k simultaneously to the destination in the second stage. Consequently, the signal received at D

$$Z = \sum_{k=1}^{N} h_{kD}U_k + W_D$$

Where W_D is the AWGN with unit variance and N is the total number of relay nodes in the network.

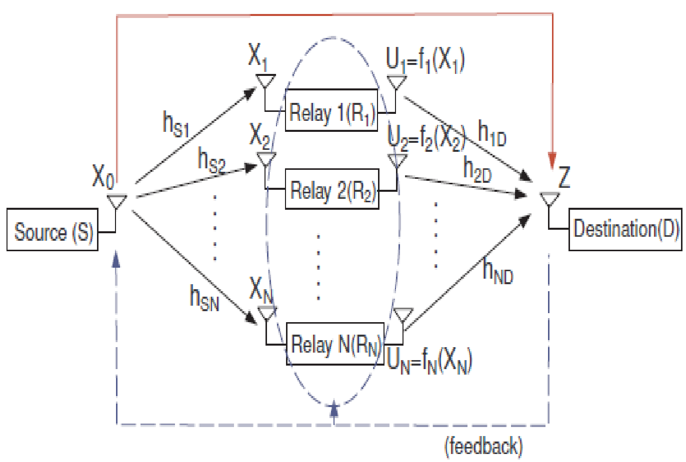

Fig.5. Dual Hop Relay Network

VII .CONCLUSION

In cooperative communication, a user can share the resources of other users to convey their message to the destination. In this system two or more active users in a network can share their information and jointly transmit their messages, either at different times or simultaneously. This results in advantages like spatial diversity, greater reliability and reduction in cost. We have studied the different cooperative signalling techniques for maintaining the data integrity at the destination. We identified the similarities between a dual hop network and a wireless sensor network application and showed how cooperative communication technique can be used by the sensors for reliable communication.

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