Cooperative Diversity in Wireless Networks: A Survey

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Abstract— This paper, emphasize that to procure theoretical achievement of cooperative diversity is not forthright and also address concerns related to networking and protocol facet of cooperation. Cooperative diversity is a technique in which numbers of radio terminals relay signals for one another. Cooperative diversity outcomes when cooperative communications is used mainly to clout the spatial diversity convenient among scattered radios. In this paper various cooperative diversity proposals and their utilization in different wireless networks are considered. Also, the brunt of cooperative diversity on the energy consumption and career of sensor network and the brunt of cooperation in cognitive radio are considered. Here, user scheduling and radio resource allocation techniques are also considered which are advanced in order to conveniently integrate various cooperative diversity approaches.

Key words: Cooperative Diversity, Cognitive Radio, Relay, Scheduling, life time of networks

I. Introduction

This survey presents an analysis of existing work about cooperative diversity. To this end, focus first on the physical layer aspects of cooperative diversity with fixed source, destination and relay nodes [1]. In this context the characteristics of nodes in a cooperative scheme and find research contributions proving that cooperative diversity offers gains compared to non-cooperative schemes. This paper summarize contributions about coding in cooperative diversity schemes, optimum position of a relay node in respect to source and destination, and using multiple relaying nodes. Secondly, provides the related work regarding the networking aspects of cooperative diversity. More specifically, works on relay selection, MAC, and routing issues in cooperative diversity [2]. Also, research contributions regarding the enforcement of cooperation among selfish nodes in a commercial network. Finally, present existing or upcoming standards which incorporate ideas of cooperative diversity and conclude this paper by discussing terms which are used as synonyms for cooperative diversity for clarification [3].

II. Cooperative diversity: a critique

Here we discussed about the existing work about cooperative diversity. To this end, we focus first on the physical layer aspects of cooperative diversity with fixed source, destination and relay nodes. In this context we address the characteristics of nodes in a cooperative scheme and find research contributions proving that cooperative diversity offers gains compared to non-cooperative schemes. We also encapsulate optimum situation of a relay node in respect to source and destination, and using multiple relaying nodes. Secondly, we provide the related work regarding the networking aspects of cooperative diversity [4].

A. *Physical Layer Facet*

In this section we elaborate on physical layer aspects of cooperative diversity. To this end, we consider scenarios where nodes have predefined roles (source, destination, and relay) and where source and destination know their relaying nodes a priori. We start with the characteristics of nodes in a cooperative diversity scheme. Then we present related work that proves that cooperative diversity has the means to effectively mitigate small-scale fading [5]. We summarize work that elaborates on the coding schemes in context of cooperative diversity, find contributions regarding the optimum position of a relay node in respect to its source and destination node, and finally, discuss the benefit of using multiple relaying nodes for a source/destination pair.

B. *Essence of Nodes*

Primarily consider the essence of nodes in cooperative diversity and their modified behaviour with respect to non-cooperative schemes [6]. To this side, we target in the following on the characteristics of source, relay and destination:

1) *Source*

The source node needs to be aware that its transmission is forwarded by a relaying node. Since the relaying happens only after the transmission from the source, the destination may not acknowledge the packet transmission from the source until the reception from the relay.

2) *Relay*

Relays can basically operate in one of three modes which are called Amplify and Forward (A&F), Decode and Forward (D&F), and Compress and Forward (C&F).

3) *Destination*

Basically, the destination can try to decode the packet after the reception from the source or also wait until it has received the data from source and relay. In the former case, the destination could advice the source and the relay whether a cooperative transmission is mandatory after the receiving from the source. In case of a fortunate direct transmission, the time and energy needed for the cooperative transmission is grant.

C. *Power Allocation*

Commonly, researchers conclude a total energy constraint which is equal for cooperative and non-cooperative schemes. Thus, the transmission energy of the source in a non-cooperative scheme needs to be shared among the source and the relays. Allocating the same energy amount to the source and all relays is a straight-forward solution which is preferable in case of unknown CSI [7]. By knowing all actual CSI or at least their statistics, we can achieve higher cooperation gains by allocating the transmission energy depending on the CSI of the nodes.

D. *Modulation*

Hierarchical modulation served as an encouraging research direction for cooperative diversity. This modulation technique uses two modulation schemes together in the same transmission. Thus, a single transmission consists of two data streams with different reliability. Implementing hierarchical modulation to cooperative diversity means that the source uses the less robust but quick modulation scheme to transmit the data and the more robust one for signalling and controlling information [8]. Thus, the relay is expected to decode the complete information where else the destination decodes only the signalling information. In the cooperative transmission stage, the relay complements the disappeared information at the destination.

III. EMERGING STANDARDS

The current investigation contributions regarding cooperative diversity display its value for wireless communication systems. In the following we ornamented about the current standard which already supports cooperative diversity. Moreover, we take a look into the growing standardization efforts regarding International Mobile Telecommunications-Advanced (IMT-Advanced) (cf. fourth generation of cellular wireless standards).

A. *WiMAX - IEEE 802.16j*

The Worldwide Interoperability for Microwave Access (WiMAX) IEEE 802.16j standard [IEEE09] introduces dedicated relay stations which support their associated base stations and should reduce the cost of WiMAX infrastructure roll outs [9]. Two different types of relay stations exist:

- Transparent relay stations do not transmit their own control frames and thus, do not extend the range of their base station but increase its capacity. This kind of relay stations has to use the same frequency channels as the base station.
- Non-transparent relay stations increase the coverage range of a base station by transmitting control frames. These relay stations are not limited to the frequency channels of the base station.

1) *Cooperative Source Diversity:*

all stations engage in the cooperation process transmit the same signal using the same time-frequency resource together.

2) *Cooperative Transmit Diversity:*

engage stations use D-STC to transmit the signals using the same time frequency resource together.

Cooperative Hybrid Diversity: is a sequence of both other modes using D-STC at engage nodes. Some of the stations transmit the same signal, i.e., use the same code for their transmission.

b) WiMAX IEEE 802.16m

One of the candidates is WiMAX IEEE 802.16m. The relaying options of this ongoing standard are reduced compared to IEEE 802.16j. Relay stations are fixed, have to be non-transparent, and have to use the same frequency resources as the base station. The relay station is responsible for scheduling the access of the mobile stations assigned to it (decentralized scheduling). The standard supports at most two hop connections, i.e., it allows only one relay station between mobile and base station. Also other optional features specified in IEEE 802.16j are omitted in IEEE 802.16m, one of them being the support of cooperative diversity [10].

IV. COOPERATIVE DIVERSITY PROTOCOLS

The processing of the signal at the relay node which is received from the source is described with the help of cooperative transmission protocols. Different transmission protocols are discussed here [11].

A. *Decode and forward*

The most popular method for processing the signal at the relay node is decode and forward, in this technique, the relay detects the source data, decodes and then transmits it to the desired destination. The concept of the Decode and Forward technique is shown in Figure 1.

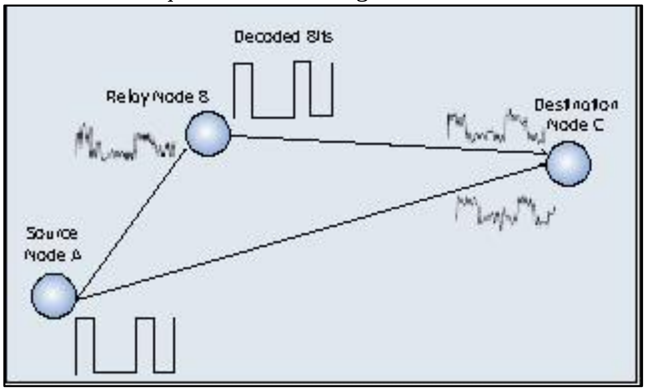

Fig. 1: Decode and Forward technique

An error amending code can also be enforced at the relay station. This can help the received bit errors to be amended at the relay station. Nonetheless, this is only feasible, if the relay station has abundant computing power [12].

B. *Amplify and forward*

Amplify and Forward approach directly amplifies the signal received by the relay before forwarding it to the destination. This approach was recommended by J. N. Laneman and G. W. Wornell [13], and is optimal when the relay station has minimum computing power. Yet, one considerable impediment of this approach is that the noise in the signal is also amplified at the relay station, and the destination receives two separately faded versions of the signal. Figure 2 shows amplify and forward technique.

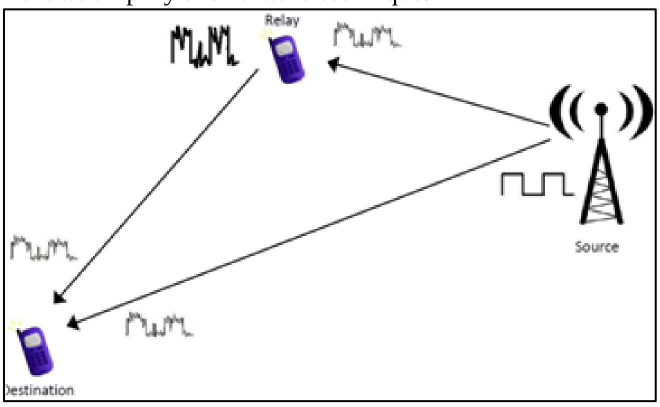

Fig. 2: Amplify and forward technique

V. APPLICATIONS OF COOPERATIVE DIVERSITY

Cooperative diversity can be used in number of fields like cooperative sensing in cognitive radio, wireless ad hoc networks, wireless sensor networks and number of other fields. Multiple applications of cooperative diversity are illustrate in the following sections.

A. Cooperative diversity in wireless sensor networks

Wireless sensor networks (WSNs) are a broad class of wireless networks consisting of small, inexpensive and energy limited devices [20]. Due to the fact that nodes are battery powered, energy efficiency is one of the main challenges in designing Wireless sensor networks. Schemes have been developed recently for energy saving of the protocol stack in specific layers. For example, multi-hop routing and clustering improve the energy efficiency of large scale WSNs. As nodes can communicate directly over small distances and have limited transmission range multi hop routing is necessary. However, it is restricted to networks of extremely high densities [14]. Clustering is a method of partitioning the network into local clusters, and each cluster has a node called cluster-head (CH).

Energy saving protocols has also been developed in the physical layer. Like all other wireless networks, wireless sensor networks suffer from the effects of fading. Cooperative diversity is a technique used to mitigate the impact of fading. This model of diversity is specifically appropriate towards WSNs since size and power restrict nodes from possessing more than one antenna. Cooperation is accomplished using the simple amplify-and-forward method. These results can be used to anticipate the impact of cooperative diversity on the lifetime of sensor networks. Here various design aspects of cooperative diversity used in wireless sensor network are discussed.

B. Clustering Protocol

The network is clustered using a distributed algorithm where CHs are selected randomly. These classes of algorithms are practical to implement in WSNs since WSNs are organized in a distributed fashion. The role of CH is evenly distributed over the network and each CH performs ideal aggregation, i.e., all cluster data is aggregated into a single packet [15].

C. Routing Protocol

Multi-hop path from each Cluster head to the data sink is established with the help of multi hop routing (MHR). MHR gives a good performance in stationary networks comprising of nodes having fixed transmission power levels. A simple iterative algorithm is used in MHR that begins with broadcasting the nodal hop number for the nodes neighbouring the data sink. The neighbouring nodes in turn update and broadcast their hop number and the process continues until each node in the network determines its min-hop path to the data sink [16].

VI. Conclusion

In this survey, we have presented a theoretical analysis of cooperative diversity in various fields like wireless networks, cognitive radio and resource allocation for IEEE 802.16j and IEEE 802.16m. For wireless network analysis the knowledge of the spatial distribution of nodes is used to determine the number of packets to be transmitted as a function of distance from a sink. The overview of cooperative diversity with networking expects which includes the physical layer aspects, characteristics of nodes in cooperative diversity and their modified behaviour with non-cooperative schemes. The survey also includes the power allocation and modulation techniques with various cooperative diversity protocols like decode and forward and amplified and forward. This also focused on the various applications of cooperative diversity like the application of cooperative diversity in wireless sensor networks, clustering protocols and routing protocols. Cooperative election diversity method is shown to be a auspicious cooperative diversity method related to the other more complicated cooperative diversity schemes which desire coherent signal combining at the mobile station.

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