Cooperative Diversity in Wireless Networks

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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 paper 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. Proposed Methodology

A. *Efficient cooperative diversity schemes for IEEE 802.16j*

The IEEE 801.16e standard which is based on Orthogonal Frequency Division Multiple Access (OFDMA) provides high data rate to the mobile users in a cell with an approximate coverage radius of 8 km [9]. Developments are made in the form of IEEE 802.16j for increasing the coverage area of IEEE 802.16e standard. The wireless terminals have a drawback of not being able to transmit and receive simultaneously at the same time, relaying requires two phases. First phase involves source to relay communication and in the second phase information is transmitted from relay to destination. Multiplexing loss occurs because of the two phase communication since each data block is transmitted twice. Thus scheduling and radio resource allocation needs modifications in the case of multi hop cellular networks over conventional scheduling algorithms designed for the single-hop networks. This is due to the fact that apart from signal to noise ratio the end-to-end performance which also includes the effect of multiplexing loss should be considered. Multi-hop cooperation schemes should only be used only when it has the ability to provide end-to-end throughput greater than that of direct transmission (without relay). In a practical multi-user scenario the work on performances of cooperative diversity schemes is limited. In [10], it can be seen that when relay node can correctly decode the packets from source, the cooperative relay transmissions are used, which in turn causes throughput loss. In [11], end-to-end link adaptation and link selection methods have been developed for a single user in an Orthogonal Frequency Division Multiplexing (OFDM) Time Division Duplex (TDD) based wireless relay network.

The emerging IEEE 802.16j standard may allow without relay transmissions in the second phase. However the amount of radio resource allocation which will be done is not specified by the current standard. It is too complex to do the radio resource allocation along with path selection for each sub-channel. The different design aspects for IEEE 802.16j using Cooperative diversity are discussed below.

B. *System Model*

IEEE 802.16j based on two-hop cellular network is considered here. The without relay system corresponds to the single hop IEEE 802.16e based cellular network. Multiple users and multiple (fixed) relays are considered within a single cell. Low mobility users are considered. Thus during one frame the channel gain of each sub-channel remain unchanged. A sub-channel compose of multiple sub-carriers with almost equal SNR levels, for this reason every sub-channel can be modeled as a flat fading channel with a given SNR.

Decode-and-Forward (DF) scheme is used at the relay nodes where the signal is demodulated, decoded, re encoded and finally the signal is forwarded which was received from the source terminal during the first phase. Repetition based relaying, where the relay repeats the information received from the BS is considered. Hybrid-Automatic Repeat Request (ARQ) is provided by using transmit and receive diversity scheme. Also in the model the MAC-Protocol Data Unit (PDU) packets are transmitted in Forward Error Correction (FEC) blocks [36].The receivers use cyclic redundancy check to check whether a block is received correctly or not. The probability of not detecting a block is assumed to be negligible. Even if one bit is received in error the block is discarded. ARQ is not implemented. AMC is then used for each sub-channel and frame based on the selection method and low complexity end-to-end link adaptation. The considered modulation modes are BPSK, QPSK, 16-QAM and 64-QAM. The considered FEC includes convolution coding with the following code rates: 1/2, 2/3, 3/4, 5/6, 7/8 and 1 [12]. Combining each modulation and coding modes gives one AMC mode. Since AMC is used, keep the transmit power from the relays and the BS constant. The terminals in the network consist of single antenna.

Throughput can be defined as the number of payload bits per second per hertz and per channel used and which are received correctly at the receiver.

C. *Cooperative diversity strategy*

Each cooperative diversity strategy treated, the transmission for every user in each phase appear at a given sub-channel j. The Multiple cooperative diversity strategies are:

1) *Cooperative Transmit Diversity–1.*

The MS (main station) and RS (relay station) listen to the transmission of the BS during the first phase. In the second phase, both BS (base station) and RS transmit simultaneously to the MS. When the same AMC mode is used for the two phases such transmission scheme can be realized, provided that the two phases have equal duration. Base station and Relay station uses cooperative space time coding in the form of Alamouti scheme [13].

2) *Cooperative Transmit Diversity–2*

Cooperative diversity schemes 1 and 2 are almost same; the difference is that, in cooperative transmit diversity-2 the main station does not modifies the signal received during the first phase in any form. Therefore, the AMC mode in each phase can be chosen independently and the two phases do not have to have equal duration.

3) *Cooperative Receive Diversity*

It also consists two phases, out of which in the first phase the source transmits at a particular AMC mode while the relay and the destination nodes receive the signal. In the second phase, the relay repeats with the same AMC mode and the BS remains silent. After Maximum Ratio Combining (MRC), the MS achieves cooperative receive diversity. Even if this strategy can accomplish the same post processing SNR as that of cooperative transmit diversity–2, it endure from a potentially higher multiplexing loss due to the need for identical AMC modes and hence equal–duration phases. Hence, cooperative receive diversity cannot outperform cooperative transmit diversity–2.

4) *Cooperative Selection Diversity*

With conventional relaying, the S→R transmissions occur in the first phase. The destination chooses not to receive during the first phase. In the second phase, only the relay transmits. The destination relies solely on the signals received via the R→D link. Base station chooses between conventional relaying and direct transmission in this scheme.

IV. RELATIVE PERFORMANCE EVALUATION OF THE COOPERATIVE DIVERSITY SCHEMES

Performance evaluations are done using the scheduling and radio resource allocation. The average end-to-end throughput is calculated per channel use, i.e., the average is taken over the radio resources allocated to the users in order to provide conclusions that are not sensitive to the system parameters. An FEC block is comprised of 96 coded bits. One sub-channel is comprised of 8 data sub-carriers and one pilot subcarrier over t consecutive OFDM symbols. The term t, $t \in \{2, 3, 6, 12\}$ represents the number of OFDM symbols required to transmit one FEC block. It depends on the selected modulation mode with AMC. The duration of the second-phase is fixed to 12 OFDM symbols. The first phase can use up to 12 OFDM symbols. The scalable OFDMA mode with 1024 subcarriers with a system bandwidth of 10 MHz is considered. Consider users with speeds up to 7.7 km/h such that the 50% coherence time is greater than or equal to 10ms. The frames have 5 ms of duration. Time constant T is set to 100 in order to provide fairness to users. For the S→R links the wireless channel model is used with a path-loss exponent of 3 and a Rician factor K of 10. The selected model has a 90% coherence bandwidth of 17 subcarriers. For the R→D and S→D links the Non-LOS (NLOS) channel is used with a path-loss exponent of 3.5. The total Effective Isotropic Radiated Power (EIRP) from the BS is fixed as 57.3 dBm. Since the relay terminals are simpler than a BS and transmit at lower power, we assume that the total EIRP from each relay station is fixed as 47.3 dBm. The heights of the MSs, BS and RS are 1.5 m, 32 m and 10 m, respectively. Carrier frequency is 2.5 GHz. Based on these assumptions; path–loss at each link is calculated accordingly. The effect of shadowing is not considered.

V. RESULT AND DISCUSSION

Our performance measures are the overall average throughput per channel use and the throughput gain for a single user at different positions in the cell. Average throughput gain of scheme A with respect to scheme B is defined as

$$\text{throughput}_{\text{gain}(A,B)} = \frac{(P^A - P^B)}{P^B} \times 100 \qquad (1)$$

Where P^A and P^B are the average throughput values of a single user at a given position in the absence of other users. Figure.1 shows throughput gain (cooperative transmit diversity-2, without relay). Also observe that around the BS, i.e., up to 6 km, the gain is zero. In this region direct transmission provides the highest end-to-end throughput.

In the presence of multiple users in the cell, Figure.2 presents the overall average throughput per channel use as a function of the total number of relays in the cell. The average throughput is calculated within a range greater than 6 km and smaller than 14.85 km to the BS, which is the coverage area where relaying improves the performance compared to w/o relay system.

In Figure.3 is plotted the throughput gain (cooperative transmit diversity-2, cooperative selection diversity). The cooperative transmit diversity–2 brings a throughput gain of around 25% in most of the region where throughput gain is significant.

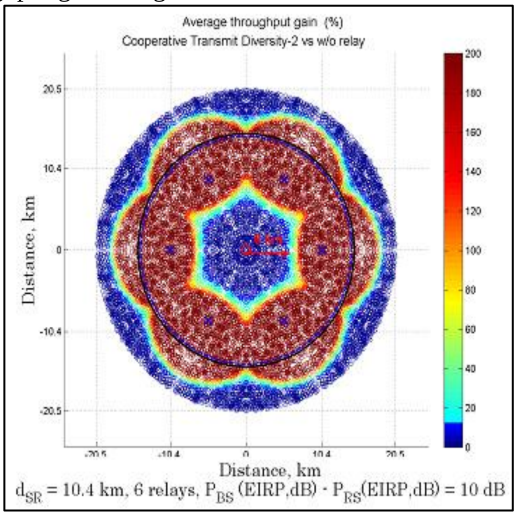

Fig. 1: Average throughput gain throughput gain (cooperative transmit diversity-2, w/o relay) at different position in the cell

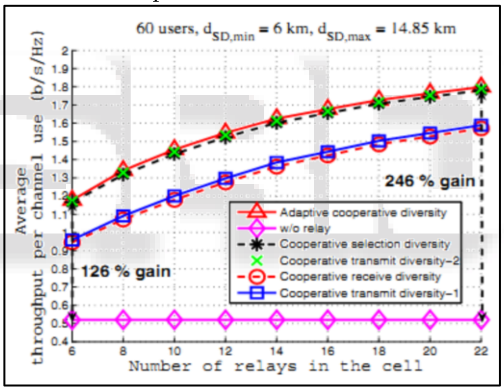

Fig. 2: Average throughput per channel use versus the number of relay stations in the cell. Minimum and maximum distances of the users to the base station are 6km and 14.85krespectively

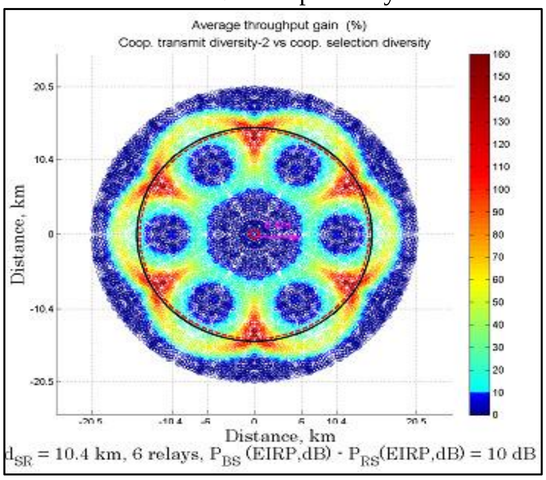

Fig. 3: Average throughput gain throughput gain (cooperative transmit diversity-2, cooperative selection diversity) at different position in the cell.

Figure.4 shows throughput gain (cooperative transmit diversity-2, cooperative transmit diversity-1). The cooperative transmit diversity–1 can outperform the cooperative transmit diversity– 2 only at distances far from both the BS and the closest RS.

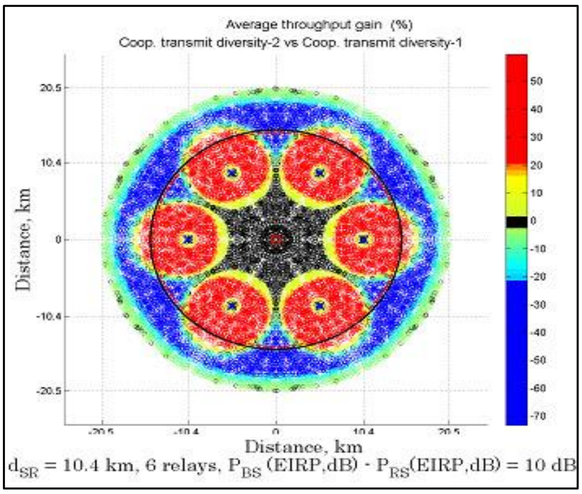

Fig. 4: Average throughput gain throughput gain (cooperative transmit diversity-2, cooperative transmit diversity-1) at different position in the cell.

VI. Conclusion

In this paper, 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.

References

[1] Vivek K. Dethe, Dr. C.V. Ghule, Dr. Om Prakash, “Co-operative Amplify and Forward Relaying Strategy for Mobile Adhoc Network for Efficient Communication”, International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering ISO 3297:2007 Certified Vol. 5, Issue 2, February 2017.

[2] Amrita Dubey, Anandvardhan Bhalla, “A Review of Relay selection based Cooperative Wireless Network for Capacity Enhancement”, International Research Journal of Engineering and Technology (IRJET), Volume: 04 Issue: 1 | Jan -2017.

[3] Devashish Biswas, ChandraSakhar Prasad Vind, “Review on Cooperative Diversity inWireless Sensor Networks”, IJARIIE-ISSN(O)-2395-4396, Vol-2 Issue-5 2016.

[4] Odilson T. Valle, Carlos Montez, Gustavo Medeiros de Araujo, Francisco Vasques and Ricardo Moraes, “NetCoDer: A Retransmission Mechanism for WSNs Based on Cooperative Relays and Network Coding”, Alessandro Bogliolo Received: 4 March 2016; Accepted: 20 May 2016; Published: 31 May 2016.

[5] Sheraz Ali Khan, Muhammad Moosa, Farhan Naeem, Muhammad Hamad Alizai, And Jong-Myon Kim, “Protocols and Mechanisms to Recover Failed Packets in Wireless Networks: History and Evolution”, IEEE Access, Received July 7, 2016, accepted July 16, 2016, date of publication July 20, 2016, date of current version August 26, 2016.

[6] Saurabh Patodi, Richa Sharma, Aniruddha Solanki, “UMTS Networks Architecture Mobility”, International Journal of Advanced Research in Computer Science and Software Engineering, Volume 5, Issue 7, July 2015.

[7] Ernesto Zimmermann, Patrick Herhold, Gerhard Fettweis, “A Novel Protocol for Cooperative Diversity in Wireless Networks”, In 2012 International Zurich Seminar on Communications, accepted, February 2014.

[8] Intzar Ansari, Prof. Hemant Soni, “An Extensive Review on Cooperative Wireless Mobile Networks”, International Journal of Recent Development in Engineering and Technology Website: www.ijrdet.com (ISSN 2347-6435(Online) Volume 3, Issue 4, October 2014).

[9] Aniruddha Singh, Abhishek Vaish, Pankaj Kumar Keserwani, “Research Issues and Challenges of Wireless Networks”, International Journal of Advanced Research in Computer Science and Software Engineering, Volume 4, Issue 2, February 2014.

[10] Rinu Titus, Unnikrishnan M, Premkumar C.V, “A Survey on Incremental Relaying Protocols In Cooperative Communication”, Volume: 03 Special Issue: 15 | Dec-2014 | IWCPS-2014.

[11] Ms. Pallavi H. Chitte, Mr. D.K. Chitre, “ Energy Efficient Protocol for Clustered Cooperative Sensor Network”, International Journal of Advanced Research in Computer Engineering & Technology (IJARCET) Volume 2, Issue 7, July 2013.

[12] P.K.Poonguzhali, V.S.Jayanthi, “A Research on Cluster Based Routing Methodologies for Wireless Sensor Networks”, International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering ISO 3297:2007 Certified Vol. 1, Issue 9, December 2013.

[13] Juhi Garg, Priyanka Mehta and Kapil Gupta, “A Review on Cooperative Communication Protocols in Wireless World”, International Journal of Wireless & Mobile Networks (IJWMN) Vol. 5, No. 2, April 2013.

[14] Umesh Kumar Singh, Kailash Chandra Phuleriya ,Lokesh Laddhani, “Study and Analysis of MAC Protocols Design Approach for Wireless Sensor Networks”, International Journal of Advanced Research in Computer Science and Software Engineering, Volume 2, Issue 4, April 2012.

[15] Tauseef Jamal1, Paulo Mendes, Andre Zuquete, "Wireless Cooperative Relaying Based on Opportunistic Relay Selection", International Journal on Advances in Networks and Services, vol 5 no 1 & 2, year 2012.
[16] Gurpreet Kaur and Partha Pratim Bhattacharya, "A Survey on Cooperative Diversity and Its Applications in Various Wireless Networks", International Journal of Computer Science & Engineering Survey (IJCSES) Vol.2, No.4, November 2011.
[17] Helmut Leopold Adam, "Cooperative Diversity in Wireless Networks: Relay Selection and Medium Access", 8, 2011.