A new review on Cooperative diversity in wireless networks

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Abstract: Today, wireless communication systems will be built for cooperation rather than for more coexistence. Cooperative communication is a hot topic of current research and many researchers believe it to be the next big step after multiple-input multiple output systems. The important idea is that multiple nodes cooperate in order to increase the link quality, reliability and data rate of the system. In the future, the density of active nodes competing for a common wireless channel in cellular as well as access or ad hoc networks will increase significantly. Therefore, node cooperation is an efficient means of achieving these gains.
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1. Introduction

Cooperative diversity is a wireless transmission technique so as to overcome fading. It is a diversity technique which is obtained using signal relaying nodes. The relay nodes transmit its received signal from the source node to the destination node, which receives two non independent signals from the relay and the source node. Cooperative diversity is a virtual multiple antenna technique which exploits multiple antenna signal processing. It has recently been proposed as a promising technology to achieve spatial diversity in wireless networks. Single antenna nodes in wireless networks share their antennas and transmit cooperatively as virtual MIMO systems. Thus spatial diversity can be achieved and multipath fading can be effectively mitigated.

Cooperative diversity networks technology is a promising solution for the high data rate coverage required in future cellular and ad-hoc wireless communication systems. There are two main advantages of this relaying technology. The low transmit power requirements and the spatial diversity that can mitigate fading. Cooperative diversity networks combine the usual power saving with the spatial diversity provided by the antennas of separate nodes. The basic idea is that between the transmitter and receiver nodes, there can be another node, which can be used to provide diversity by forming a virtual multi antenna system. In regular cooperative-diversity networks, in addition to the direct link all relays participate in sending the source signal to the destination.

By enhancing diversity, cooperation in wireless networks allows increasing the transmission reliability and extending the radio coverage without the need of implementing multiple antennas at the terminals. In wireless networks, antenna diversity technique has been commonly used to combat the deleterious effect of the fading. These techniques require the terminals to be of reasonable size so as to support multiple antennas, a requirement that proves to be unfeasible for future wireless terminals which are expected to be small and light. Recently cooperative diversity in wireless networks have gained much interest in the wireless research community due to its ability to mitigate fading through achieving spatial diversity, while resolving the difficulties of installing multiple antennas on small communication terminals. Basic idea is in addition to the direct signal from source to the destination, multiple cooperative nodes (relays) collaborate together to relay the signal from the source node to the destination node. As a result the destination can receive multiple independent copies of the same signal and can achieve diversity through the establishment of a virtual antenna array. Other benefits are expansion of the radio coverage without using high power levels at the source, increase of connectivity and higher capacity.

2. Important issues in the area

2. 1 System modeling taking interference into consideration: In network scenario, cooperative relay system can suffer from co channel and adjacent channel interference. Hence, the effect of this interference needs to be addressed.

2. 2 Power optimization based on link condition: Wireless nodes generally have limited battery power. If relay based systems have some feedback mechanism, then power can be allocated based on link condition. Such dynamic allocation of power may save battery power or boost the data transfer rate and hence an important area to be investigated.

2. 3 Full duplex operation of relays: Relay operation in half- duplex mode creates system bandwidth expansion. Full-duplex relay operating in single frequency can solve this problem. Hence, further investigation is necessary for full duplex relay operation.

2. 4 Spectral efficiencies: Orthogonal transmission from relays to receiver in different time slots effect the spectrum efficiency. Relays can interact with the receiver using orthogonal codes to avoid bandwidth expansion. Therefore, issues of orthogonal code design for distributed relay nodes may be addressed in future.

2. 5 Complexity performance trade off: Relays can process the signal in non-regenerative (Amplify and forward-AF) or regenerative mode (Decode and forward-DF) depending on their functionality. Non-regenerative mode of operation puts less processing burden as compared to regenerative mode; hence often preferred when complexity and latency are important issues. Scope exists in future for non-regenerative mode of relay operation. Noise amplification is a major issue in non regenerative mode of operation.

2. 6 Multi-hop communication: The research community has increased its attention towards wireless multi-hop communication due to its envisioned application of Ad-Hoc networks, sensor network, and range extension of cellular networks.

2. 7 Modeling of relay links in various environments: Radio propagation suffers with path loss, shadowing and multi-path fading which depends on regional geography. Statistical behaviors' of various propagation environments are available in literatures. Relay links can be modeled in such propagation environment.

2. 8 Diversity combining techniques for relay systems: Most of the system models were considered selection combining and maximum ratio combining at the receiver. In future, other type of diversity combining techniques such as equal gain combining, switch combining etc, can be incorporated in relay based system.

2. 9 Node cooperation with cross-layer design: Node cooperation is a powerful technique to improve the performance of wireless sensor network. Sensor nodes are powered by small battery that may not be recharged easily. So reducing energy consumption is an important issue for such type of network. Protocol layering in network design provides modularity for network protocols that facilitates standardization and implementation. Investigation of cross-layer optimization is another issue.

2. 10 Bidirectional user cooperation: In user cooperation, users terminal not only have to transmit its own data, but also other users data by sharing some of the resources. Extension of work for bidirectional user cooperation may be addressed.

2. 11 Base station cooperation: in traditional cellular system, user terminals communicate with a parent base station. User near the outskirts of cell can see other neighboring base stations and become an active source for generating interfering signals. To overcome this problem, neighboring base stations can also cooperate with parent base station and form joint decoding of received signals. Relay cooperation can be extended for base station cooperation.

3. Focus of research

Cooperative diversity combining techniques, fading channel modeling, performance of amplify and forward protocol, performance analysis of MRC and generalized selection combining techniques with an input threshold.

4. Research for selection of research issue

The next generation wireless systems are supposed to handle high data rate as well as large coverage area. It should consume less power and utilize bandwidth efficiently. At the same time, the mobile terminals must be simple, cheap and smaller in size. In wireless environment, the quality of received signal level degraded due to path loss and shadowing from various obstacles in propagation path. In addition to this, signal quality suffers from fading due to constructive and destructive interference of multipath components which makes it difficult for the receiver to extract the message correctly. Effect of fading can be suppressed by diversity technique in which replicas of signal is provided to the receiver. Receiver can make a decision on behalf of these replicas; hence, reliability of reception can be improved. Diversity can be achieved with the help of multi-antenna systems where multiple antennas are installed at transmitter/receiver. However, implementing multiple antennas at wireless terminal is not practical due to size; cost and weight constraints .Cooperation among nodes creates spatial diversity in wireless network, even if individual nodes do not use antenna arrays for transmission and reception. Here, diversity gain can be translated into robustness against fading for same transmit power or substantially reduced transmitted power for same level of performance.

5. Literature review

Cooperative diversity networks technology is a promising solution for high data rate coverage required in future wireless communication systems. There are two main advantages of this technology; the low transmit RF power requirements, and the spatial diversity gain [1]. In this paper, comprehensive analyses of the incremental-best relay cooperative diversity, in which limited feedback from the destination terminal, e.g., a single bit indicating the success or failure of the direct transmission. If the destination provides a negative acknowledgment via feedback; in this case only, the best relay among _ available relays retransmits the source signal in an attempt to exploit spatial diversity by combining the signals received at the destination from the source and the best relay. The best relay is selected as the relay node that can achieve the highest signal to noise ratio at the destination node. Here the receiver has to wait for the retransmission of signals from the best relay. It will take additional time. So for delay sensitive applications, this would not be a good solution. While the relay is responding for the signal from the receiver, it can't respond for any signals coming from some other nodes. In this paper, the channel is Rayleigh faded and combining scheme used was MRC. So the receiver should add up all branches coherently. It consumes lot of power because each branch requires sufficient power for processing the signal passing through it. Moreover for no coherent modulation schemes, it won't give better performance. End to end performance of two-hop transmission systems with relays over Rayleigh fading channel is mentioned in [2].Here only one relay is considered. If the relay misbehaves, performance of the system becomes very poor. Authors won't mention about the combining techniques. Modulation scheme used is BDPSK. It is possible to use MRC in this system for better performance. In [3], low complexity cooperative diversity protocols that combat fading induced by multipath propagation in wireless networks are mentioned. This paper deals with single relay system and combining technique used at the receiver end is not given. It is possible to use MRC in this for better performance. In [4], selection combining in cooperative relaying networks over

Rayleigh fading channel is given. This combining technique is useful when the transmitter uses no coherent modulation schemes. For coherent modulation schemes it won't give better performance. Because co phasing is not done in selection combining scheme, so any phase variations occurred during channel transmission are not cancelled at the receiver end and it may lead to degradation in the performance. Also selection combining scheme considers only one branch signal for processing. In [5], generalized selection combining for amplifies and forward cooperative diversity networks are given. Here the performance of the combiner under Rayleigh fading channel with amplifies and forward protocol using BPSK modulation scheme is mentioned. This system is applicable for no coherent communication systems only. It is possible to use MRC in this system for better performance.

In [6], comparison of diversity combining techniques for Rayleigh fading channels is mentioned. Here basic combining techniques like Selection combining (SC), equal gain combining (EGC) and maximum ratio combining techniques (MRC) are given. Each has its own advantages and disadvantages. For no coherent communication systems SC is preferred where as for coherent modulation schemes, MRC is used. Moreover MRC requires channel state information such as channel attenuation and phase variations. Both EGC and MRC require co phasing, but performance of EGC is poor compared to MRC. In [7], analysis of generalized selection diversity systems in wireless channels under rician fading channels is given. It is applicable only for microcellular and picocellular environments. In [8], performance analysis of linear diversity combining schemes on Rayleigh fading channels with binary signalling and guassian weighting errors are given. Here the error probability performance of MRC,EGC SC and GSC diversity schemes for i.i.d Rayleigh fading channels with guassian channel estimation errors are explained. In this case the power consumption at the receiver side will be more. In [9], Sensitivity to timing errors in EGC and MRC techniques over Rayleigh and Nakagami-m fading channels are given. Here the use of these two techniques causes high power consumption at the receiver end. In [10], MRC and GSC diversity combining with an output threshold is mentioned. This system checks the combined output SNR and if it is less than a predetermined threshold, it tries to increase the SNR by combining branch signals. This system has a limitation that each time after processing all branch signals, combiner should verify the output SNR.

In [11], performance analysis of adaptive decodes and forward cooperative diversity networks with best relay selection are given. Here, from the receiver end, a feedback signal is given to the relay side, if the information has not been properly received. The relay which has highest SNR will retransmit the information to the receiver. Since this system uses decode and forward (DF) technique, it consumes time for decoding the signal received from the source. So for delay sensitive applications this system will not give better performance. The authors in [12]-[18], authors mentioned the performance of cooperative diversity with amplify forward and decode and forward protocols in Rayleigh and Nakagami fading channels using various combining schemes. In [19], [20] performance of decode and forward and hybrid decode amplify and forward protocols are given.

In [21], [22] the performance of generalized selection combining (GSC) scheme with input threshold have been mentioned. Here the receiver tries to use acceptable diversity paths by comparing the SNR of each path against a certain threshold. In my work a new method is suggested at the receiver end. Signals from various relays, which are above certain threshold SNR are combined using MRC technique. Performance the analysis of input thresholded MRC (IT MRC) under Rayleigh fading channel in cooperative communication networks. That is the relay signals greater than the threshold are combined effectively using MRC with an input threshold, So that the power at the receiver side may be saved effectively.

6. Conclusion

Need for high performance wireless communication systems are one of major goals of today's research. MIMO techniques are a solution for high performance. From the implementation point of view, there are still difficulties in accommodating multiple antennas in many types of wireless terminals and therefore the benefits promised by MIMO are yet to be fully exploited.

Cost of antennas and complexity makes MIMO difficult to get accepted. Instead of using separate antennas we can use nodes in the network as antennas which in turn use the cooperation of sender and nodes to avail multi antenna structure and so is known as cooperative communication.

We can achieve same performance output from optimized cooperative schemes as that of MIMO systems. Hardware complexity and cost are less in cooperative communication. This concept has applications in various wireless standards.

6.1. Need for high performance wireless communication systems with fewer electronics and lower power consumption.

6.2. Disadvantages of common MIMO systems and achieve the same performance output from optimized cooperative schemes.

6.3. Applicability to various wireless standards.

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References

1. S. Ikki and M. H. Ahmed, "Performance analysis of Cooperative Diversity with Incremental-Best-Relay Technique over Rayleigh Fading Channels," IEEE Trans. Commun., vol. 59, no. 8, pp. 2152-2161, August 2011.
2. M. O. Hasna and M.-S. Alouini, "End-to-End performance of transmission systems with relays over Rayleigh-fading channels," IEEE Trans.Wireless Commun., vol. 2, no. 6, pp. 1126-1131, Nov. 2003.
3. J.N.Laneman, D.N.C.Tse, and G.W. Wornell, "Cooperative diversity in wireless networks: efficient protocols and outage behavior," IEEE trans. Inf. Theory,vol.50, Dec. 2004.
4. S. Ikki and M. H. Ahmed, "Performance of Selection Combining In Cooperative Relaying Networks over Rayleigh Fading Channel," in Proc. IEEE ICC 2008.
5. S. Ikki and M. H. Ahmed, "Performance Analysis of Generalized Selection Combining For Amplify and Forward Cooperative diversity Networks" in Proc. IEEE ICC 2009.
6. Thomas Eng,Ning Kong, "Comparison of diversity combining techniques for Rayleigh fading channels," IEEE trans. on Commns.,vol.44, no.9, Sept.1996.
7. A.Annamalai and C.Tellambura, "Analysis of Generalized selection diversity systems in wireless channels," IEEE trans. On Vehicular technology, vol.55, no.6, November 2006.
8. Ramesh Annavajjala and Laurence B. Milstein, "Performance analysis of diversity combining schemes on Rayleigh fading channels with binary signaling and guassian weighting errors," IEEE trans.on Wireless Commns., vol.4, no.5, Sept. 2005.
9. Yunjing Yin,John P.Foneska and Israel Korn, "Sensitivity to Timing errors in EGC and MRC Technique," IEEE trans. On Commns.,vol.51,no.4, April 2003.
10. Hong-Chuan Yang and Mohamed Slim Alouini,"MRC and GSC Diversity combining with an output threshold," IEEE Trans. Vehicular Technology, vol. 54, no. 3, pp. 10811090, May 2005.
11. S. S. Ikki and M. H. Ahmed, "Performance analysis of adaptive decode and-forward cooperative diversity networks with the best relay selection scheme," IEEE Trans. Commun., vol. 58, no. 1, pp. 68-72, Jan. 2010.
12. S. Ikki and M. H. Ahmed," On the performance of amplify and forward cooperative diversity with

the Nth best relay selection scheme," in Proc. IEEE ICC 2009.
13. S. Ikki and M. H. Ahmed, "Performance Analysis of Incremental Relaying Cooperative Diversity Networks over Rayleigh Fading Channels," in Proc. IEEE WCNC 2008.
14. S. Ikki and M. H. Ahmed, "Performance Analysis of Incremental Best Relay Amplify and Forward Technique," in Proc. IEEE "GLOBECOM" 2009.
15. S. Ikki and M. H. Ahmed, "Performance Analysis of Cooperative Diversity Using Equal Gain Combining (EGC) Technique over Rayleigh Fading Channels," in Proc. IEEE ICC pp.5336-41, June 2007.
16. S. Ikki and M. H. Ahmed, "Performance Analysis of Incremental Relay Selection Decode and Forward Technique," in Proc. IEEE "GLOBECOM" 2009.
17. S. Ikki and M. H. Ahmed, "Performance Analysis of Decode and Forward Cooperative Diversity Using Differential EGC over Nakagami-m Fading Channels," in Proc. IEEE ICC 2009.
18. S. Ikki and M. H. Ahmed," Multi branch decode and forward cooperative diversity networks performance analysis over Nakagami-m Fading Channels," IET Commn., Vol.5, Iss.6, pp. 872-878, 2011.
19. K.Raj Kumar and Giuseppe Caire,"Coding and Decoding for the Dynamic Decode and Forward Relay Protocol," IEEE ISIT 2008.
20. He Chen and Ju Liu, "Performance Analysis of SNR based Hybrid Decode Amplify Forward Cooperative Diversity Networks over Rayleigh Fading Channel,"in Proc. IEEE WCNC 2010.
21. M.K. Simon and M.S. Alouini,"Performance analysis of generalized selection combining with threshold test per branch(T-GSC)," IEEE Trans. Veh. Technology, vol. 51, no. 11,pp. 1018–1029, 2002.
22. H.C.Yang and M.S.Alouini,"Generalized switch and examine combining(GSEC): A low complexity combining scheme for diversity rich environments," IEEE Trans. Commun.,vol. 52,pp. 1711-1721,Oct. 2004.

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