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Cooperative Wireless MAC Layer Scheme for Ad Hoc Network

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ABSTRACT

This article proposes a new Mac layer scheme for wireless adhoc network (WANET) improving the overall the network reliability and lifetime by using cooperative communication. We focus our work on a way to define an adhoc node among the neighbourhood of another node, efficiently and with sending messages using directional antennas. We propose a solution based on an automatic forwarder selection and a link state evaluation in order to define the adhoc node. This automatic selection uses a cluster group identifier uniformly spread in the network and ensures that only few nodes at the time will be chosen as transmitting node. Our analytical results show that proposed model increases the overall reliability of the ad hoc network increasing the cooperativeness and the network capacity also increases.

Keywords: WANET, directional antennas, Cooperative communications, MAC Protocol , Reliability

1. Introduction

The major aim of this paper is to fill the gap between the co-operative communication for the nodes at the physical layer and the MAC layer scheme for WANET. The cooperative radio communication techniques use multiple antennas, rather than using multiple antennas the cooperative ad hoc communication uses multiple nodes equipped with a single directional antenna using distributed coding scheme to achieve similar results.

The cooperative communication scheme is itself an inherently a solution for ad hoc network, and there are issues at multiple levels of the network stack to solve in order to reach the capacity and reliability offered by the diversity. This paper mainly focuses on finding the good trade-off between the issues at the Mac layer and the physical layer performances. We propose a Mac layer scheme (CooAd-MAC) that used a distributed approach to select an ad hoc node in an efficient way without extra overhead in sending and processing. The reliability of the communications that use cooperation helps us to design an acknowledgment aware solution.

The paper is organized as follows. In section 2, we present the related work. In section 3, we introduce the design of our solution. In section 4, we present performance results and ananalysis. Finally we conclude the paper and present some future works.

2. Literature Survey

The cooperative communication derived from diversity techniques using co-located antennas has received lot of interests. Laneman et al. [1] and others [2,3] have developed a set of cooperative communication scheme for distributed wireless network like: ad hoc networks or sensors networks. Their respective works has paved the way for a lot of studies using cooperative transmission on a real MAC layer framework. Ji et al. [4] and Lin et al. [5] proposed different framework for Cooperative MAC protocol. These solutions are based on network-assisted diversity multiple access (NDMA). These Authors present a novel throughput-efficient medium access scheme for WSN. This scheme enables a node to retrieve a packet from many previously received packets(MPR [6]). In [7] Liu et al. proposed the first cooperative MAC protocol called "CoopMac" based on the well knows

IEEE 802.11 protocol. They defined two alternative solutions CoopMAC I and CoopMAC II. In CoopMAC I, a new frame HTS (Helper ready To Send) is added to the IEEE 802.11, to inform others that an alternative node (a ADHOC relay node) will help the sender to transmit more efficiently. Then, in CoopMAC II, HTS frame is not used; instead they used the RTS header to advise which node should act as a adhoc relay node. Chou et al. [8] present a solution to perform cooperative communication in distributed wireless networks. Authors claim that only one adhoc relay must participate in the cooperative transmission. In order to select the ADHOC relay node among its neighbors, they developed mechanisms

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such as a busy tone and a special RTS (Relay-RTS). This RRTS is used with the classic RTS/CTS mechanism to inform the source and the adhoc relay node chosen. Most of these solutions used extra messages in order to setup the cooperative process and select the adhoc relay node. In a WANET context, where the resources are limited, the use of these sent packets should be avoided to reduce the power consumption.

3. COOPERATIVE COMMUNICATION DESIGN

In cooperative wireless communication, we are concerned with a wireless network, of the cellular or ad hoc variety, where the wireless agents, which we call users, may increase their effective quality of service (measured at the physical layer by bit error rates, block error rates, or outage probability) via cooperation. In a cooperative communication system, each wireless user is assumed to transmit data as well as act as a cooperative agent for another user.

Cooperation leads to interesting trade-offs in code rates and transmit power. In the case of power, one may argue on one hand that more power is needed because each user, when in cooperative mode, is transmitting for both users. On the other hand, the baselines transmit power for both users will be reduced because of diversity. In the face of this trade-off, one hopes for a net reduction of transmit power, given everything else being constant. Similar questions arise for the rate of the system. In cooperative communication each user transmits both his/her own bits as well as some information for his/her partner; one might think this causes loss of rate in the system. However, the spectral efficiency of each user improves because; due to cooperation diversity the channel code rates can be increased. Again a trade-off is observed. The key question, whether cooperation is worth the incurred cost, has been answered positively by several studies. One may also describe cooperation as a zero-sum game in terms of power and bandwidth of the mobiles in the network. The premise of cooperation is that certain (admittedly unconventional) allocation strategies for the power and bandwidth of mobiles lead to significant gains in system performance. In the cooperative allocation of resources, each mobile transmits for multiple mobiles. Cooperative communications is a promising technique that would enhance the design of the WANETs. In this context, we have to face also new challenges that need to be solved in order to design a full functional system. One of these challenges is to find a way to select a adhoc relay node that will efficiently forward packets in a cooperative way, in order to reach an improvement on channel capacity. In the following section of this document, we present our solution based on an automatic forwarder selection and a Link-state evaluation that enable our MAC layer to define some neighbours as adhoc relay node.

A. Automatic forwarder selection Nodes: in cooperative network are efficiently using broadcast property of the wireless medium to improve the communication between two nodes in the networks by sending on the same channel a copy of the main communication. To reach the trade-off between gain brought by the cooperation and the overhead introduced, Fan et al. [9] and Moh et al.[10] show that the best cooperation happens in the case of a few nodes cooperation instead of a multiple-nodes cooperation pattern. Based on this observation we have developed an approach that enables the node that want to send a packet to pre-define a small set of adhoc relay nodes that will help to forward packets to the destination. To select some possible adhoc relay nodes our approach introduces a new ID: a adhoc_group Identifier, which is an ID embedded in the adhoc node (different from the node address; and not unique in the network). The adhoc_group Identifier is enabling during the auto-configuration process by each WANET. Each time a node want to send a packet, it should first draw a random number among the possible value of adhoc_group identifier, put the result inside the packet header and sends it to the destination. After, all the nodes hearing the packet be broadcasted on the channel have to check the adhoc_group identifier included into the packet header. If the identifier into the packet header matches with their own predetermined adhoc_group id, they could become an adhoc relay node for this communication. Otherwise, the packet will be dropped. As example in figure 2, the adhoc_group identifier draw by the node S is 1 and the node R and T which are in that adhoc_group should now be considered to forwarding the packet. To set up its own adhoc_group Identifier each WANET node picks a random number uniformly distributed between 0 and A, the average number of neighbours in the network calculated as a function of the network size R and the number of nodes present in the networks. We are using adhoc_group identifier to limit the number of adhoc relay nodes of each communication. We assume that the number of adhoc relay nodes will be on average close to one, the optimum number of adhoc relay node. This identifier will be set up during the network deployment and will be tie to the network topology. In order to avoid any collision, two nodes in the same neighbourhood should not have the same adhoc_group ID (a node may have two neighbours with the same adhoc_group ID), the auto configuration process should take into consideration the adhoc_group ID of its neighbours when it determines its own adhoc_group ID. The approach presents the process in order to draw the adhoc_group identifier of each node. In our approach, A list is a list of A available values for adhoc_group identifier.

B. Link-State Evaluation

In the previous section, we established a distributed strategy to pick a possible adhoc relay node among the neighbourhood of another node willing to send a packet. But in order to be efficient, the cooperation should occur if and only if the cooperative communication enhances performance of the transmission as well for the overall performance. So to know if the cooperative communication, with the help of an adhoc relay node, would improve the communication, we design a link state approach. The link state approach is running on each node that has been elected to act as an adhoc relay node during automatic forwarding selection process. This process will help the elected adhoc relay node to determine if it should be involved into the adhoc relaying process. The adhoc relay node will estimate the channel quality of its link towards the destination and will compare it to the link quality from the source to the destination. For that, each node stores a link state table, this table contains the quality of each link it has with every neighbour. If the link quality is better than the link quality to the source, we use the cooperation. To estimate and process the channel quality the elected nodes will retrieve the RSSI (Receive Signal Strength Indicator) from the physical layer. The RSSI measured by the 802.15.4 devices enable the approach to get the link quality indication (LQI) of the channel. We based our solution on a CSMA-like MAC Layer adapted to the WSN [14], where the duty cycle has been reduced as much as possible to lower the overall energy consumption. To reduce consumption from idle-listening a well-known technique consists of using a preamble in order to inform the other nodes that a packet will be sent [13, 14]. For our purpose to initiate the cooperative communication the sleep phase could be a problem, because some of neighbours' could be involved in the relaying process. Nodes who hear a preamble should process the approaches previously described with the intention of participating to the cooperative process.

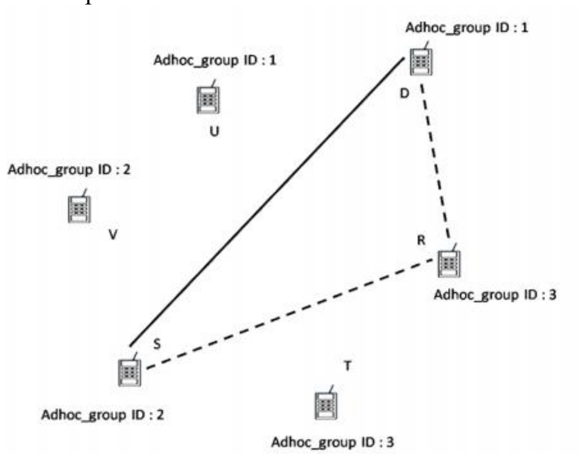

Figure 1 - Cooperative communication scenario

As example in Figure 1, the node R and T, after their election by S (by checking the adhoc_group Identifier embedded in the packet) should consider forwarding the packet from S. Node R checks the LQI of its link to D in its Link table and computes the capacity of this link based on average SNR (Signal Noise Interferences Ratio), and decides if it will forward the packet from S. Our solution does not provide any guaranties on the fact that only one node at the time would act as adhoc relay per communication, but the number of adhoc relay per communication is close to one if the automatic forwarder process is well configured. To design our link state evaluation approach and the LQI, we essentially based our work on both the characteristics of the WANET physical layer used in the IEEE 802.15.4 standard [12] to retrieve the bit error rate and Space-Time-Coded Cooperative Diversity scheme defined by Laneman et al. [9] Assuming these two bases, the adhoc relay node is able to characterize the transmission quality between two-neighbour nodes with and without its cooperation. Considering the Maximum Ratio Combining Diversity [11] the SNR of the diversity combiner is the sum of the SNR of each transmission. Then, we can determine the bit error rate of a cooperative transmission. For the capacity of the channel in cooperative transmission, we sum the mutual information and obtain equation 1 where W is the bandwidth as defined in IEEE 802.15.4 [12] SNR rd is the SNR between the adhoc relay and the destination and SNR sd is the SNR between the source and the destination. Derived from the formula 1 and the information stored by the adhoc relay node (LQI), the adhoc relay is now able to take the decision of forwarding the packet. The forwarding process could be triggered by a couple of criteria like the capacity of the channel or the transmission error rate. The discussed Approach summarizes the processes that occur during the reception of a packet by a random node into the network.

C. MAC layer protocol details for WANET using cooperative communication

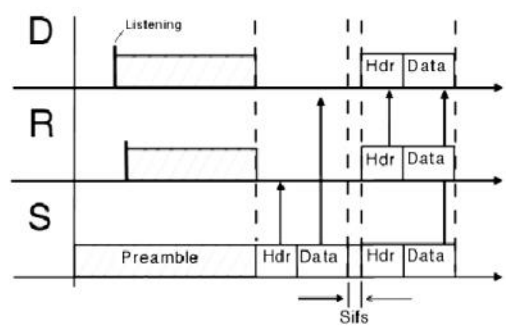

Figure 2 - Frame sending sequence between a source S, a relay R and a destination D

In Figure 2, we present a frame sending sequence of our protocol. Node S used a preamble for the synchronization with its neighbours then, the cooperative communications occurs in two steps. :

First is the transmission of the packet from the source to the destination, then all nodes hearing the message should check if they have to consider forwarding it. In the second step, using the Space-Time-Coded Cooperative Diversity, the packet must be sent by the source and the adhoc relay at the same time. 4. License transfer All authors are required to complete the JSPMO license transfer agreement before the article can be published, which they can do online.

4. PERFORMANCE RESULTS AND ANALYSIS

This subsection presents analytical results showing the behaviour of a WANET taking advantage of cooperative communications. Our simulator implements cooperative communication model previously defined in [cf. Lanman et al [1]] in addition to our proposed approach. For each plot point presented here is an average calculated with all data coming from all the possible communication into a total number of 100 nodes equipped with directional antennas with a network density 0f 0.01 to 0.30 with 5 topologies having an iteration of 50 times. we considered the transmission range of 50 meters with an attenuation factor of 3 in a path loss free space model of IEEE 802.15. the receiver sensitivity is taken as -90 dbm. the packet size considered as 250 bits and the acknowledgement size of 40 bits including ACK and NACK. Reliability: In figure 3, we are showing a comparison between two different retransmissions schemes using the cooperative communication: ACK and NACK. As result, we could see that the NACK scheme in the case we are using cooperative communication outperform the others by an order of magnitude of 64% and 56% in the two different case of figure.

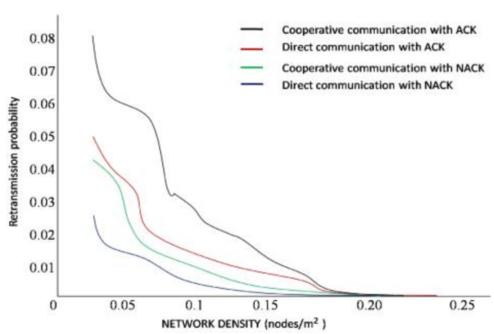

Figure 3 - Retransmissions probability as function of the nodes density

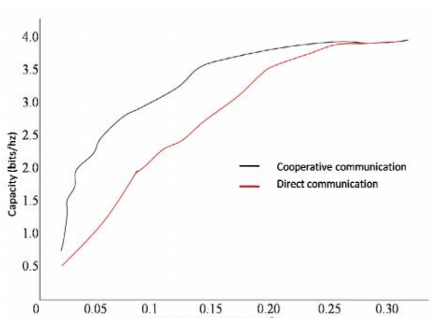

Figure 4 -Capacity as function of the nodes density

Network capacity: Figure 4 shows us the average channel capacity as function of the density. We can see that the capacity reaches its maximum when the network density is close to 0.075 node/m^2. Note that the cooperative capacity is far beyond the real adhoc nodes capacity but this gives information about the possible performances of our solution [3].

Our simulations show that CooAd-MAC enhances the packet delivery ratio and the reliability of the network in the case of a low dense network (lower than 0.10nodes/m2). The acknowledgment traffic is also reduced by our solution. The capacity using cooperative communication is far beyond the real adhoc nodes capacities pointing out that some research need to be done in adaptive modulation dedicated to ADHOCs networks.

5. CONCLUSION AND FUTURE WORK

In this paper, a new cooperative MAC protocol tailored for WANET is proposed. In order to fulfill the set of constraints imposed by the cooperative communication scheme and the wireless adhoc networks scheme we have developed an approach allowing the automatic selection of the forwarder node (adhoc relay node) using only few message exchanges during the network setup phase. To optimize the selection of the adhoc relay node approach we are using a cross-layer design to fetch information from the physical layer. Our simulations show that the proposed solutions brought enhancements like capacity and reliability to the network in the case of a low dense network. Nevertheless in case of a massively dense network, the use of cooperation techniques do not bring any enhancements and even will have a negative impact on the performances. This is due to the fact that most of wireless links in the network are good enough to carry traffic with very few loss provoked by interferences coming from others transmitting node. This issue is not balancing the overload of a cooperative communication. This concern lead us toward fact that any MAC layer scheme that are exploiting cooperative communication should be used in adaptive way, in order to be efficient in any case. In our future works we will focus on packet delivery ratio as function of the nodes density among the relay nodes and comparison of the number of packets sent and the theoretical value as function of the nodes density also well suited for adhoc networks.

REFERENCES

[1] J. N. Laneman and G. W. Wornell. Distributed Space-Time-Coded Protocols For Exploiting Cooperative Diversity In Wireless Networks. Ieee Trans. On Inf. Theory, 49(10):2415–2425, 2003.

[2] S.M. Alamouti. A Simple Transmit Diversity Technique For Wireless Communications. Ieee J. Sel. Areas In Comm., 16(8):1451–1458, Oct 1998.

[3] M. Dohler, A. Gkelias, and A.H. Aghvami. Capacity Of Distributed Phy Layer Sensor Networks. Ieeetrans. On vehicular technology, 55(2):622–639, March 2006.

[4] W. Ji and B. Y. Zheng. A Novel Cooperative Mac Protocol For Wsn Based On Ndma. In Proc. Of The 8th International Conference On Signal Processing (Icsp'06), Pages 16–20, 2006.

[5] R. Lin and A.P. Petropulu. A New Wireless Network Medium Access Protocol Based On Cooperation. Ieee Trans. On Signal Processing, 53(12):4675–4684, Dec. 2005.

[6] L. Tong, Q. Zhao, and G. Mergen. Multipacket Reception In Random Access Wireless Networks: From Signal Processing To Optimal Medium Access Control. Ieee Communication Magazine, 39(11):108–112, Nov 2001.

[7] P. Liu, Z. Tao, and S. Panwar. A Cooperative Mac Protocol For Wireless Local Area Networks. In Proc. Of The International Conference On Communications (Icc 2005), Volume 5, Pages 2962–2968, 2005.

[8] C.T. Chou, J. Yang, and D. Wang. Cooperative Mac Protocol With Automatic Relay Selection In Distributed Wireless Networks. In Proc. Of The Fifth Ieee International Conference On Pervasive Computing and Communications Workshops (Percomw '07), Pages 526–531, 2007.

[9] Y. Fan and J. Thompson. Mimo Configurations For Relay Channels: Theory and Practice. Ieee Trans. On Wireless Comm., 6(5):1774–1786, May 2007.

[10] S.Moh, C.Yu, S.-M. Park, H.- N. Kim, and J.Park. Cd-Mac: Cooperative Diversity Mac For Robust Communication In Wireless Ad Hoc Networks. In Proc. Of The International Conference On Communications (Icc '07), Pages 3636–3641, June 2007.