An Innovative Network Allocation Vector Setting in MANET using MAC

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Abstract: **A Mobile Ad-hoc Network (MANET) is a self configured network of mobile terminals connected by wireless links. Mobile terminals such as cell phones, portable gaming devices, PDAs (Personal Digital Assistants) and tablets all have wireless networking capabilities. By participating in MANETs, these terminals may reach the Internet when they are not in the range of Wi-Fi access points or cellular base stations, or communicate with each other when no networking infrastructure is available With the dramatic development of the wireless local area networks (WLANs), there is great interest in increasing the data rate between the stations and the access point (AP). Multiple input multiple outputs (MIMO), an important technology to enhance the physical layer capability, can achieve this target via simultaneous packet transmissions. Cooperative communication, which utilizes nearby terminals to relay the overhearing information to achieve the diversity gains, has a great potential to improve the transmitting efficiency in wireless networks. To deal with the complicated medium access interactions induced by relaying and leverage the benefits of such cooperation, an efficient Cooperative Medium Access Control (CMAC) protocol is needed. In this paper, we propose an innovative network allocation vector setting is provided to deal with the varying transmitting power of the source and relay terminals. The proposed CMAC significantly prolong the network life time under various circumstances.**

Keywords: Network lifetime, NAV Setting cooperative communications, medium access control protocol, relay selection, distributed coordination function (DCF).

I. INTRODUCTION

Mobile Ad-hoc Network (MANET) is a self configured network of mobile terminals connected by wireless links. Mobile terminals such as cell phones, portable gaming devices, PDAs (Personal Digital Assistants) and tablets all have wireless networking capabilities. By participating in MANETs, these terminals may reach the Internet when they are not in the range of Wi-Fi access points or cellular base stations, or communicate with each other when no networking infrastructure is available. MANETs can also be utilized in the disaster rescue and recovery. One primary issue with continuous participation in MANETs is the network lifetime, because the aforementioned wireless terminals are battery powered, and energy is a scarce resource. Cooperative Communication (CC) is a promising Technique for conserving the energy consumption in MANETs. The wireless transmission between a pair of terminals can be received and processed at other terminals for performance gain, rather than be considered as an interference traditionally. CC has been researched extensively from the information theoretic perspective and on the issues of relay selection. Recently, the work on CC with regard to cross-layer design by considering cooperation in both physical layer and MAC layer attracts more and more attention. Without considering the MAC layer interactions and signaling overhead due to cooperation, the performance gain through physical layer cooperation may not improve end-to-end performance. Cooperative MAC (CMAC) protocol considering the practical aspect of CC is vital. Liu et al. have proposed a CMAC protocols named Coop MAC to exploit the multi-rate capability and aimed at mitigating the throughput bottleneck caused by the low data rate nodes, so that the throughput can be increased with the similar goal have proposed a CMAC protocol for wireless ad hoc network. However, beneficial cooperation considering signaling overhead is not addressed in previous papers. A busy-tone-based cross-layer CMAC protocol has been designed to use busy tones to help avoiding collisions in the cooperative scenario at the cost on transmitting power, spectrum, and implementation complexity. A reactive network coding
aware CMAC protocol has been proposed by Wang et al.In which the relay node can forward the data for the source node, while delivering its own data simultaneously.

A distributed CMAC protocol has been proposed to improve the lifetime of wireless sensor networks, but it is based on the assumption that every node can connect to the base station within one hop, which is impractical for most applications. The existing CMAC protocols mainly focus on the throughput enhancement while failing to investigate the energy efficiency or network lifetime. While the works on energy efficiency and network lifetime generally fixe on physical layer or network layer. Our work focuses on the MAC layer, and is distinguished from previous protocols by considering a extend network lifetime. The tradeoff between the gains promised by cooperation and extra overhead is taken into consideration in the proposed protocol. In addition, in the previous works, very little attention has been paid to the impact brought by varying transmitting power in CC on the interference ranges, since constant transmitting power is generally used. The interference ranges alteration in both space and time will significantly affect the overall network performance.

In this paper, we propose an innovative Network Allocation Vector (NAV) setting. From the perspective of information theory, higher diversity gain can be obtained by increasing the number of relay terminals. From a MAC layer point of view, however, more relays lead to the enlarged interference ranges and additional control frame overheads. We employ single relay terminal in this paper to reduce the additional communication overhead. CMAC initiates the cooperation proactively, and utilizes the decode and forward protocol [1] in the physical layer. We summarize our contributions as follows.

- To deal with the presence of relay terminals and dynamic transmitting power, we provide an innovative NAV setting to avoid the collisions and enhance the spatial reuse.
- We propose CMAC that focuses on the network lifetime extension, which is a less explored aspect in the related work. By considering the overheads and interference due to cooperation

The rest of the paper is organized as follows. We present preliminaries and model in Section 2. In Section 3, we describe the proposed CMAC protocol. In Section 4, we further elaborate the detail of the CMAC, including the best relay selection strategy, the cross-layer power allocation scheme and the NAV setting Simulation results and discussions are addressed in Section 5. Conclusions are drawn in Section 6.

II. PRELIMINIARIE & MODELS

In this section, we present the employed system and NAV Setting model and the background knowledge about DCF and decode and forward protocol. As the involvement of relaying and varying transmitting power, the interference ranges in CMAC is changing during one transmit session.

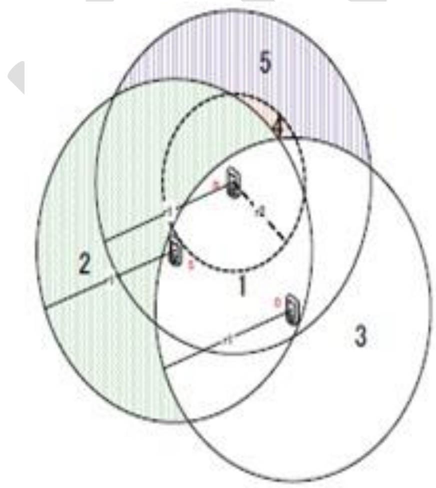


Fig. 1 An illustration for the NAV setting ranges

In order to avoid the interference and conserve the energy, delicate NAV setting is required. NAV limits the use of physical carrier sensing, thus conserves the energy consumption. The terminals listening on the wireless medium read the duration field in the MAC frame header, and set their NAV on how long they must defer from accessing the medium. Taking IEEE 802.11 DCF for instance, the NAV is set using RTS/CTS frames (Fig. 2). No medium access is permitted during the blocked NAV durations. Comparing with the simple NAV setting in DCF, the setting in CMAC needs to be considerably modified.

2.1 DCF (Distributed Coordination Function)

The basic operations of the proposed CMAC are based on the IEEE 802.11 DCF (Distributed Coordination Function). In DCF, after a transmitting terminal senses an idle channel for a duration of Distributed InterFrame Space (DIFS), it backs off for a time period that chosen from 0 to its Contention Window (CW). After the back off timer expires, the well-known RTS-CTS-DATA-ACK procedure is carried out in (Fig. 2).

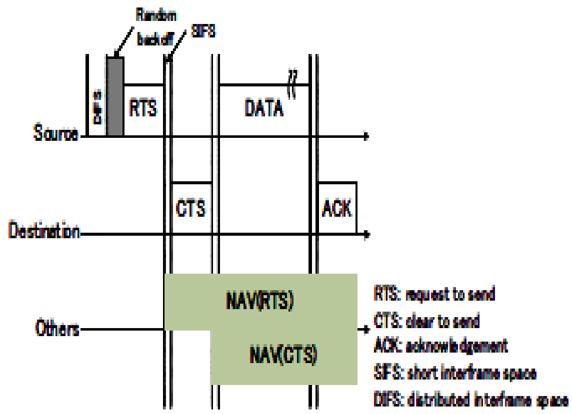


Fig. 2 IEEE 802.11 DCF

Any terminal overhearing either the RTS or the CTS extracts the information contained in the MAC frame header, and sets its NAV to imply the time period during which the channel is busy.

2.2 Decode & Forward

CMAC utilizes the Decode and Forward (DF) protocol [1] with Maximum-Ratio-Combiner (MRC) in the physical layer. Due to the limited space, the details of DF are presented at Appendix A.

III. THE PROPOSED CMAC PROTOCOL

In this section, with the objective of prolonging the network lifetime and increasing the energy efficiency, we present a novel CMAC protocol, namely CM. When cooperative relaying is involved, the channel reservation needs to be extended in both space and time in order to coordinate transmissions at the relay. To deal with the relaying and dynamic transmitting power, besides the conventional control frames RTS, CTS and ACK, additional control frames are required. CMAC introduces two new control frames to facilitate the cooperation, i.e., *Eager-To-Help* (ETH) and Interference-Indicator (II).

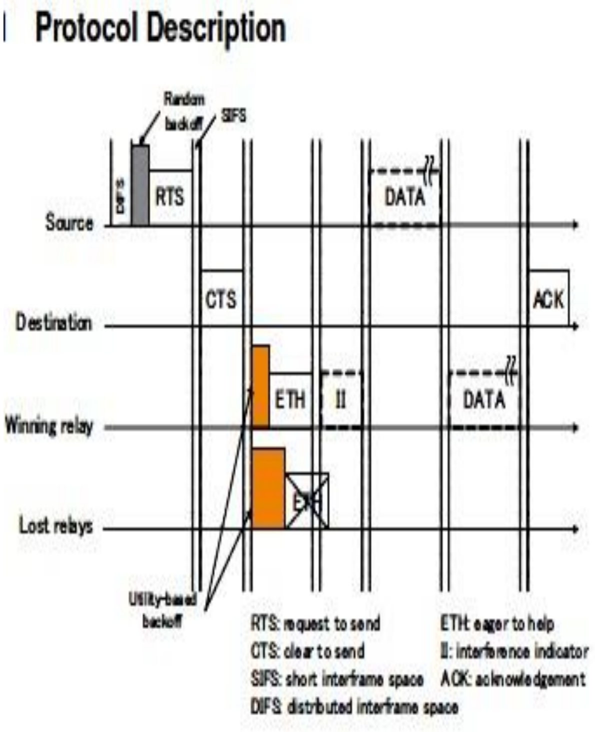
- *Eager-To-Help (ETH)*

The ETH frame is used for selecting the best relay in a distributed and lightweight manner, which is sent by the winning relay to inform the source, destination and lost relays. In this paper, the best relay is defined as the relay that has the maximum residual energy and requires the minimum transmitting power among the capable relay Candidates.

- *Interference-Indicator (II)*

The II frame is utilized to reconfirm the interference range of allocated transmitting power at the winning relay, in order to enhance the spatial reuse. Among all the frames, RTS, CTS, ETH and ACK are transmitted by fixed power. And the transmitting power for the II frame and data packet is dynamically allocated. We denote the time durations for the transmission of RTS, CTS, ETH, ACK and II frames by *TRTS*, *TCTS*, *TETH*, *TACK* and *TII*, respectively.

The frame exchanging process of CMAC is shown in Fig. 3 Similar to the IEEE 802.11 DCF protocol, the RTS/ CTS handshake is used to reserve the channel at first. As we know, the cooperative transmission is not necessary in the case that the transmitting power is small



because the additional overhead for coordinating the relaying overtakes the energy saving from diversity gain.

IV. DETAIL & SUPPLIMENT OF CMAC

In this section, we elaborate the detail and the supplement of the proposed CMAC. Specifically, we address the utility-based best relay selection strategy, and the NAV (network allocation vector) setting in the following subsections.

4.1 Utility-based Best Relay Selection

Selecting the best relay distributed and efficiently affects the performance of the CMAC protocol significantly. The existing relay selection schemes that incorporated into the CMAC protocols, largely depend on the instantaneous channel condition, which based on the assumption that the channel condition is invariant during one transmit session. For MANETS that deployed in heavily built-up urban environments or heavy traffic environments, this assumption is hard to guarantee. This implies that the "best" selected relay terminal according to channel condition during the route construction or handshaking period may not be the best one in the actual data transmission period. Selecting the best relay terminal based on the instantaneous location instead of instantaneous channel condition may be more reasonable for MANETs. In this paper, we propose a distributed energy-aware location-based best relay selection strategy which is incorporated into the control frame exchanging period in CMAC. The location information of individual wireless devices can be obtained through GPS or other localization algorithms. The required location information of source and destination is carried by RTS and CTS frames. Thus no additional communication overheads are involved. CMAC chooses the best relay based on a utility-based back off, which depends on the required transmitting power to meet certain outage probability (related to individual location) and the residual energy of individual terminals. It is carried out in a distributed, lightweight and energy-efficient fashion, in which the back off of the relay that has the minimum utility value expires first. We define the Back off Utility function for relay *r* as

$$BUr = \tau \min (E/Er, \delta) \times P^{C}_{r}/P^{D}_{s}/2$$

where Er is the current residual energy of relay r, P^{C}_{r} is the transmitting power at relay r in cooperative mode, and P^{D}_{s} is the transmitting power at source s in direct mode (both obtained through the equations in Section 2). The parameters in Eqn. (2) include the energy consumption threshold δ,the constant unit time τ, and the initial energy E. Intuitively, the terminal with high residual energy and low transmitting power has a comparatively short back off time.

Different from the existing best relay selection schemes, the proposed strategy utilizes the location information and takes the residual energy into considerations. Besides, it is completely distributed and every terminal makes the decision independently. Using the proposed relay selection strategy, the energy consumption rate among the terminals can be balanced, and the total energy consumption can be reduced.

4.2 Special Reuse Enhancement

Comparing with the simple NAV setting in DCF, the setting in CMAC needs to be considerably modified.

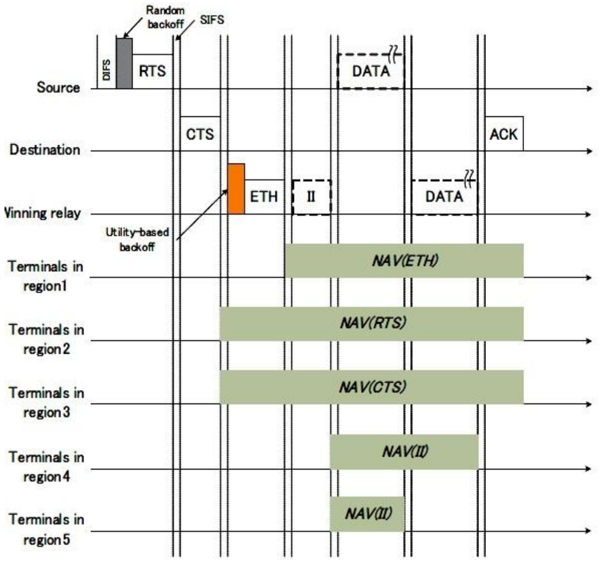


Fig. 5 NAV setting for CMAC

The presence of relays will enlarge the interference ranges and the dynamic transmitting power makes the interference ranges vary during one transmit session. Impropriate NAV setting induces energy waste and collisions. Specifically, setting the NAV duration too short will wake up the terminal too soon, which results in energy waste due to medium sensing. On the other hand, setting it too long will reduce

The spatial efficiency which results to the performance degradation in terms of throughput and delay. Thus, effective NAV setting is necessary and critical. Unfortunately, most of the previous works does not address the NAV setting issue in CC [9], not to mention the one with varying transmitting power. In this paper, we divide the transmission ranges for the source, destination and relay to five different regions (Fig. 4). Since different transmitting power lead to different transmission ranges, there exist two ranges for the relay. As shown in Fig. 1, the solid circle denotes the transmission range for fixed transmitting power (with radius $r1$), and the dashed circle denotes the transmission range for the allocated transmitting power (with radius $r2$). Notice that it is not necessary to consider the transmission range with allocated transmitting power at the source, since all the terminals lie inside the solid circle of the source will interfere with the ACK. Thus, they must defer accessing the medium until the very end of the whole session. In the following, we address the specific NAV setting for our CMAC from the perspective of different regions by Fig.5.

Region 1: (The terminals that can receive both the RTS and CTS) the terminals in this region are the relay candidates. According to our CMAC, they contend for the winning relay after the RTS/CTS exchange. Upon receiving the ETH, all the lost relays should keep silence until the whole transmit session is finished. Notice that for the sake of the relay selection, the terminals cannot set their NAVs as soon as they receive the RTS as in the IEEE 802.11 DCF. All the neighboring terminals have to wait until the end of the CTS and then make their decisions. Thus, the NAV duration in region 1 is $TII + TACK + 16(L + Lh)/2R + 4S\,IFS$.

Region 2: (The terminals that can receive the RTS but not the CTS) those terminals set their NAV durations until the end of the ACK, which is $Tmax\,Backo\,f\,f + TETH + TII + TACK + 16(L + Lh)/2R + 5S\,IFS$.

Region 3: (The terminals that can receive the CTS but not the RTS) the same as the terminals in region 2, they set their NAV until the end of the ACK.

Region 4: (The terminals that can receive the II) as we mentioned before, according to different transmitting power, there exist two transmission ranges at the relay. One is the transmission range for the ETH message with fixed transmitting power (large solid circle with radius $r1$ in Fig. 4), the other is the transmission range for the II message and data with allocated transmitting power (small dashed circle with radius $r2$ in Fig. 4). The terminals in region 4 fall inside the small transmission range at the relay, they should defer the medium access until the end of the data transmissions (two phases). Recall that in 802.11 DCF, the nodes outside the transmission ranges of source and destination do not set NAV, they use physical carrier sensing to avoid the possible collision. Thus, same as the setting in 802.11 DCF, the NAV duration for nodes in region 4 ends before the ACK frame. The NAV duration for them is $16(L + Lh)/2R + 2S\,IFS$.

*Region 5***:** (The terminals that can receive the ETH but not the II) the terminals in this region fall inside the large transmission range at the relay but outside the small one. Those terminals have a relatively short NAV duration comparing to the terminals in region 4, which is only $8(L + Lh)/2R$.Since when the source finishes its data transmission, the terminals in region 5 and the relay may not interfere with each other. By utilizing II frame, the nodes in this region may initiate their transmission in advance given they are outside the interference range of the destination

V. PERFORMANCE EVALUATIONS

In this section, we evaluate CMAC via extensive simulations comparing with IEEE 802.11 DCF and Coop-MAC [7]. Since the purpose of our scheme is to prolong the network lifetime and increasing the energy efficiency, the evaluation metrics in this paper are the transmitting power, total energy consumption, network lifetime, aggregated throughput and average delay. The transmitting power denotes the power consumed at transmit amplifier (without the power consumed at transmit circuitry). The total energy consumption is the summation of the transmitting (including both transmit amplifier and circuitry) and receiving energy cost at the source, destination and relay. The lifetime is defined as the duration from the network initialization to the time that the first terminal runs out of power. To validate the performance improvements in CMAC, we utilize both the single-hop scenario and the multi-hop multi-connection scenario. The simulation is carried out in QualNet network simulator [07]. The initial energy of all

TABLE 1
Simulation parameters

RTS	**160 bits**	**Noise power**	**−60 dBm**
CTS	**144 bits**	**Fixed transmit power**	**10 dBm**
ACK	**112 bits**	**Data rate**	**1 Mbps**
ETH	**192 bits**	**Path loss exponent α**	**3**
II	**80 bits**	**Initial energy *E***	**1 J**
PHY header	**192 bits**	**Energy threshold δ**	**10**
MAC header	**272 bits**	**Power threshold Ap**	**0 dBm**

the terminals are set to 1 J. The propagation channel of two ray path loss model is adopted. Constant data rate with 1 Mbps is used in CMAC and DCF, while adapted data rates with 1, 2, 5.5 Mbps are used in CoopMAC. The fixed transmitting power used for control frames is set to 10 dBm and, the fixed transmitting power used for data frame in Coop MAC is set to 15 dBm due to the high data rate (the transmitting power for the data frames in CMAC and DCF is dynamically allocated). The simulation settings and parameters are listed in Table I.

5.1 Single-Hop Scenarios

An illustration of the single-hop scenario. We first compare our CMAC with the IEEE 802.11 DCF in a single-hop scenario that only consists of three terminals (one source, one destination and one relay), to show the differences between cooperative and non-cooperative communication on energy consumption. As shown in Fig 6, the distance between source and destination changes from 5 m to 30 m, and angles ∠*SDR* and ∠*DS R* keep at arcos (2/3).

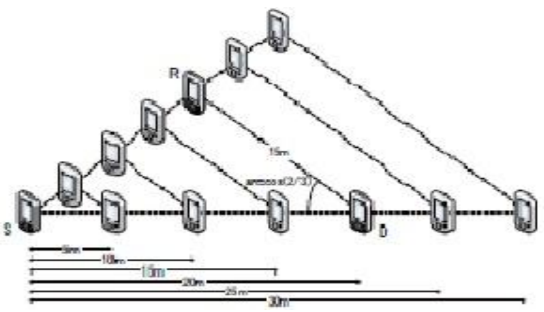


Fig.6 An illustration of the single-hop scenario.

5.2 Multi-Hop Multi Connection Scenerios

Next, we illustrate the performance of CMAC in a realistic multi-hop multi-connection scenario along with IEEE 802.11 DCF and Coop MAC. This complex scenario takes the interference and collision caused by different connections into account. As shown in Fig. 7, terminals are randomly placed in a square area of 200 × 200*m*2.

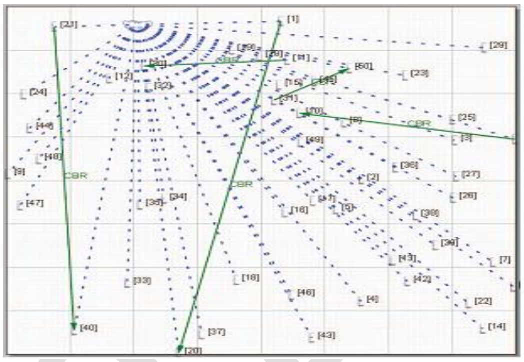


Fig. 7 A snapshot of the multi-hop network.

The dashed lines indicate that all the terminals belong to the same subnet. The 5 solid lines indicate that 5 Constant Bit Rate (CBR) connections, in which sources (nodes 1, 11, 21, 31, 41) transmit UDP-based traffic at 1 packet per 100 milliseconds to the destinations (nodes 20, 30, 40, 50, 10) through multi-hop. The data payload length is set to 1024 bytes (unless stated otherwise). AODV routing protocol is used to establish the routing paths, which is widely used in MANETs. Other routing protocols as DSR or energy aware routing protocol can also be used, the performance of the proposed MAC layer scheme is independent of network layer schemes.

We vary the number of terminals in the area from 20 to 60 while keeping the number of CBR to 5. In Fig.8, we compare the network lifetime of CMAC with IEEE 802.11 DCF and Coop MAC in a static network. It is clear that our CMAC always outperforms DCF and Coop MAC in all cases. Coop MAC [7] is designed to increasing the throughput, in which fixed transmitting power and adapted data rates are utilized. It is reasonable that the network lifetime of Coop MAC is the shortest, due to the lacking of power control and the additional control overhead for cooperative communication.

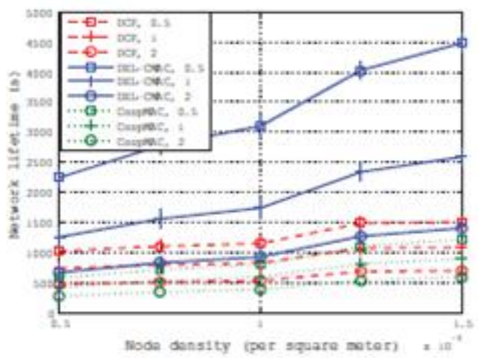


Fig.8 Network lifetime versus the node density in a static environment (with 95% confidence interval).

The performance gain of CMAC over DCF and Coop MAC raises as the number of terminals increases. The reason can be explained from the following two aspects. First, if the node density is low, some terminals have to play the role as the source and cooperative relay alternately. This additional relay energy cost is expected to impact the performance negatively. The growing availability of relay candidates results in balanced energy consumption. To be more specific, if the node density is high enough, the terminals having their own data to send or serving as routing relay are rarely selected as the cooperative relay for other connections. Because their residual energy is lower than the others. Second, the higher the node density is, the higher the probability that relay candidates are located in the ideal positions for the existing source-destination pairs. Thus, high node density leads to a transmitting power reduction for both source and relay by our optimal power allocation scheme. To be specific, at least 2.2 and 3.9 times lifetime improvements for case $P\_/P$ = 0.5, and 1.4 and 2.4 times lifetime Improvements for cases $P\_/P$ = 2, can be obtained by CMAC over DCF and Coop MAC, respectively.

VI. CONCULSION

In this paper, we have proposed a novel distributed energy adaptive location-based cooperative MAC protocol for MANETs. By introducing CMAC, both energy advantage and location advantage can be exploited thus the network lifetime is extended significantly. We have also proposed an effective relay selection strategy to choose the best relay terminal and a cross-layer optimal power allocation scheme to set the transmitting power. Moreover, we have enhanced the spatial reuse to minimize the interference among different connections by using novel NAV settings.

We have demonstrated that CMAC can significantly prolong the network lifetime comparing with the IEEE 802.11 DCF and Coop MAC, at relatively low throughput and delay degradation cost. As a future work, we will investigate our CMAC for larger scale network size and with high mobility. We will also consider to develop an effective cross-layer cooperative diversity-aware routing algorithm together with our CMAC to conserve energy while minimizing the throughput and delay degradation cost.

REFERENCES

[1]. Li Shi-Chang, Yang Hao-Lan and Zhu Qing-Sheng, "Research on MANET Security Architecture Design", In IEEE Conference on Signal Acquisition and processing, pp. 90-93, June 2010.

[2]. Ke B W, Zhang Y J, Liew S C. Media access control with spatial correlation for MIMO ad hoc networks. In: Proceedings of IEEE ICC'07. Glasgow, Scotland:3660-3665, 2007

[3]. Dimic C, Nicholas D S, Zhang R. Medium access control- physical cross-layer design. **21**(5): 40-50, *IEEE Signal Processing Magazine*, 2004.

[4]. Vinay Kumar Pandey & Harvir Singh. "Enhanced Secure Routing Model for MANE", CS & IT-CSCP 2012 DOI: 10.5121/csit.2012.2405, pp. 37–44, 2012.

[5]. Wang N-C, Huang Y-F, Chen J-C A stable weight-based on demand routing protocol for mobile ad hoc networks. Information Sciences: an International Journal, Volume 177, Issue 24:5522–5537, 2007.

[6]. H. Shan, H. Cheng, and W. Zhuang, "Cross-Layer Cooperative MAC Protocol in Distributed Wireless Networks," *IEEE Trans. Wireless Communication*, vol.10, no.8, pp.2603-2615, Aug. 2011.

[7]. http://www.scalablenetworks.com/Dit/products/qualnet/

[8]. Chen S B, Chen W, Huang W L, et al. A cross-layer approach to enable multipacket transmission in MIMOSDMA based WLAN. *Journal of Zhejiang University*, 10(2): 271-278.Dimic C, *A*, 2008. Nicholas D S, Zhang R. Medium access control

[9]. Physical cross-layer design. *IEEE Signal Processing Magazine*, 2004, **21**(5): 40-50.

[10]. D. B. Johnson, D. A. Maltz, and J. Broch, DSR: The Dynamic Source Routing Protocol for Multi-Hop Wireless Ad Hoc Networks. in Ad Hoc Networking, ch. 5, pp. 139-172. Addison-Wesley, 2001.

[11]. C. E. Perkins and E. M. Royer, Ad hoc Networking, ch. Ad hoc On-Demand Distance Vector Routing. Addison-Wesley, 2000.

[12]. Bianchi G. Performance analysis of the IEEE 802.11 distributed coordination function. *IEEE J. Select. Areas Communication*, **18**(3): 535-547, 2000

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