Adaptive Technic for the Network Lifetime of Mantes through Cooperative MAC Protocol Design

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ABSTRACT:

Wireless sensor networks (WSNs)consist of sensor node with sensing and communication capabilities. The important problem of applications of WSNs are Energy conservation and increasing throughput. Cooperative Communication(CC), which utilizes nearby terminals to relay the overhearing information to achieve the diversitygains, has a great potential to improve the transmitting efficiency in wireless networks. In this paper, a novel cross-layer Distributed Energy-adaptive Location-based CMAC protocol has been proposed,namely DEL-CMAC, for Mobile Ad-hoc NETworks (MANETs). The design objective of DEL-CMAC is to improve the performance of theMANETs in terms of network lifetime and energy efficiency. A practical energy consumption model is represented in this paper, which takes the energy consumption on both transceiver circuitry and transmit amplifier into account. A distributed utility-based best relay selectionstrategy is incorporated, which selects the best relay based on location information and residual energy. Furthermore, an innovative network allocation vector setting is provided to deal with the varying transmitting power ofthe source and relay terminals. We show that the proposed DEL-CMAC significantly prolongs the network lifetime under variouscircumstances even for high circuitry energy consumption cases by comprehensive simulation study.

KEYWORDS: Energy Conservation , WSNs , Network lifetime, cooperative communication, medium access control protocol, relay selection.

I.INTRODUCTION

Mobile Ad-hoc Network(MANET) is a self configured network of mobile terminals connected by wireless links. Mobile terminals such as cellphones, portable gaming devices, personal digital assistants,(PDAs)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. MANET scan also beutilized in the disaster rescue and recovery described in [13].One primary issue with continuous participation in MANETs is the network lifetime, because the aforementioned wireless terminals are battery powered, and energy is as carcere source.energy consumptionin MANETs. The broadcast nature of the wireless medium (theso-called wirelessbroadcastadvantage)isexploited in cooperative fashion. The wireless transmission between a pair of terminal scan be received and processed at other terminals for performance again, rather than be considered as an interference traditionally. can provide gains in terms of there quired transmiting power due to the spatial diversity achieved via user cooperation. However, if we take into account the extra processing and receiving energy consumption required for cooperation, CC is not always energy efficient compared to direct transmission.There is a tradeoff between the gains in transmitting power and the losses in extra energy consumption overhead. CC has been researched extensively from the information theoretic perspective [1], [2], [4], [5] and on the issues of relay selection [8], [11], [12]. Recently, the work on CC with regard to cross-layer design by consideringcooperation 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 CMAC [7] 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, Zhu and Cao [8] have proposed a CMAC protocolorwirelessad hoc network. However, beneficial cooperation considering signaling overhead is not addressed in [7] and[8].

A busy-tone-based cross-layer CMAC protocol [9] hasbeen designed to use busy tones to help avoiding collisionsin the cooperative scenario at the cost on transmittingpower, spectrum, and implementation complexity. Areactive network coding aware CMAC protocol has beenproposed by Wang et al. [10], in which the relay node canforward the data for the source node, while delivering itsown data simultaneously. But the network lifetime is notaddressed in [10].

A distributed CMAC protocol [11] hasbeen proposed to improve the lifetime of wireless sensornetworks, 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. A CMAC protocolfor vehicular networks, particularly for gatewaydownloading scenarios, has been designed by Zhang et al.[12]. A drawback is that it can only be utilized inthe scenario that all the vehicles are interested in the sameinformation. Moreover, Moh and Yu [13] have designed aCMAC protocol named CD-MAC which lets the relaytransmit simultaneously with the source using space-timecoding technique. Shan et al.have explored a conceptof cooperation region, whereby beneficial cooperativetransmissions can be identified[11]. However, energy consumptionis not evaluated for both of them.

The existing CMAC protocols mainly focus on thethroughput enhancement while failing to investigate theenergy efficiency or network lifetime. While the works onenergy efficiency and network lifetime generally fixate onphysical layer [6] or network layer [5]. Our work focuseson the MAC layer, and is distinguished from previous protocolsby considering a practical energy model (i.e., energyconsumption on both transceiver circuitry and transmitamplifier), with the goal to enhance energy efficiency andextend network lifetime. The tradeoff between the gainspromised by cooperation and extra overhead is taken intoconsideration in the proposed protocol. In addition, in theprevious works, very little attention has been paid to theimpact brought by varying transmitting power in CC onthe interference ranges, since constant transmitting power isgenerally used. The interference ranges alteration in bothspace and time will significantly affect the overall networkperformance. We also address the issue of effective coordinationovermultiple concurrent cooperative connectionswith dynamical transmitting power in this paper.

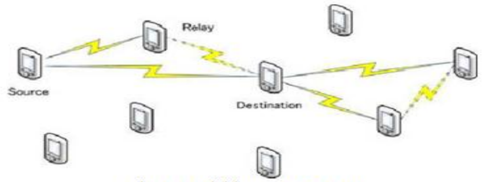


Fig.1 Multi hop MANET

In this paper, we propose a novel distributed energyadaptivelocation-based CMAC protocol, namely DELCMAC,for MANETs. DEL-CMAC is designed based on theIEEE 802.11 distributed coordination function (DCF), whichis a widely used standard protocol for most of wireless networks.DEL-CMAC comprises a relay-involved handshakingprocess, a cross-layer power allocation scheme, adistributed utility-based best relay selection strategy, andan innovative Network Allocation Vector (NAV) setting.From the perspective of information theory, higher diversitygain can be obtained by increasing the number of relay terminals.From a MAC layer point of view, however, morerelays lead to the enlarged interference ranges and additionalcontrol frame overheads. We employ single relay terminalin this paper to reduce the additional communicationoverhead. DEL-CMAC initiates the cooperation proactively,and utilizes the decode and forward (DF) protocol [1] in thephysical layer. We summarize our contributions as follows.

II.SYSTEM MODEL

As shown in Fig. 1, a multi-hop MANET with randomlydeployed mobile terminals is considered, where all terminalshave the capability to relay. To come up with a reasonablesystem model, we assume that data connectionsamong terminals are randomly generated and the routesare established by running Ad hoc On-demand

DistanceVector (AODV) [9], which is a widely used conventionalrouting protocol for MANETs. There are two types of relayterminals in our network, i.e., routing relay terminals andcooperative relay terminals.

In the system model, AODVbuilds the route in a proactive manner by selecting therouting relay terminals firstly. When a route is established,DEL-CMAC initiates the cooperation in a hop-by-hopmanner by selecting the cooperative relay terminals. Inthis paper, the source and destination terminals are referred to the terminals at MAC layer, and the relay terminals indicate the cooperative relay terminals. For convenience, we use term source, relay and destination in the remainder of the paper to denote the source terminal, relay terminal anddestination terminal respectively.

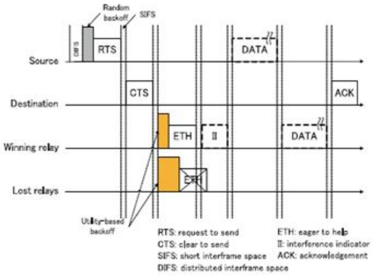


Fig.2:The frame exchanging process of DEL-CMAC.

introduces two new control frames to facilitate the cooperation,i.e., Eager-To-Help (ETH) and Interference-Indicator (II).The ETH frame is used for selecting the best relay in a distributedand lightweight manner, which is sent by the winningrelay to inform the source, destination and lost relays.In this paper, the best relay is defined as the relay that hasthe maximum residual energy and requires the minimumtransmitting power among the capable relay candidates.The II frame is utilized to reconfirm the interference rangeof allocated transmitting power at the winning relay, inorder 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 datapacket are dynamically allocated.We denote the time durationsfor the transmission of RTS, CTS, ETH, ACK and IIframes by TRTS, TCTS, TETH, TACK and TII , Respectively.PROTOCOL

DESCRIPTION

3.1 Operations at the Source

i.When a source wants to initiate the data transmissionwith payload length L bytes, it first senses thechannel to check if it is idle. If the channel is idle forDIFS, the source chooses a random backoff timerbetween 0 and CW. When the backoff counterreaches zero, the source sends out a RTS to reservethe channel. Notice that different from DCF, the locationinformation of the source is carried in the RTS,which is used in the optimal power allocation.

ii. If the source does not receive a CTS withinTRTS þ TCTS þ SIFS, a retransmission process will beperformed. Otherwise, in the case that FLAG_P ofCTS is 0, the DEL-CMAC is reduced to DCF protocol,and we omit its operations in the following. In thecase that FLAG_P is 1, the source waits for anotherTmaxBackoffTETH SIFS, where TmaxBackoff is the maximumbackoff time for the relay.If ETH is not received, which means that no capablerelay exist, the source sends the data by direct transmissionwith data rate R.

iii. If both CTS and ETH are received, after waiting forTII þ SIFS, the source initiates a cooperative transmissionwith data rate 2R using the optimal transmittingpower PC which is piggybacked in the ETH.Notice that in order to maintain the end-to-endthroughput, doubled data rate is employed in thecooperative transmission mode. We assume that theterminal can support two transmission rates by differentcoding and modulation schemes.

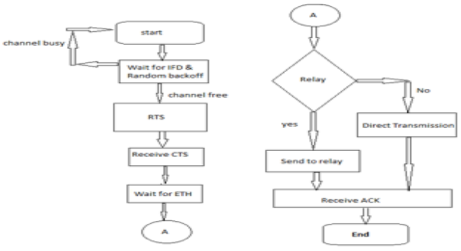


Fig.3: Flow chart of source node operation

Operations at the Destination

i. Upon receiving the RTS, the destination sends aCTS back after SIFS. The CTS contains the locationinformation of the destination, the FLAG_P, andthe transmitting power for the direct transmissionPD(in the form of dB m, occupying 4 bytes),which is used for the possible relay contention.

ii. In the case that FLAG_P is 1, if the destination

has not heard any ETH within TmaxBackoff TCTS TETH SIFS, it assumes that the direct transmissionwill be performed and waits for the datapacket from the source.

iii. Otherwise, the destination waits for the data packetsfrom the source and winning relay. If the destinationcan decode the combined signals correctly,it sends back an ACK. Otherwise, it just lets thesource timeout and retransmit.

3.2 Operations at the Relay

i. Any nodes other than source and destination will act as relay node. In this mode of operation relay nodes calculates source and destination vector distance from that node from RTS and CTS frame received powers.

ii. After calculating vector distance to both source and destination from relay nodes are summed up to get hopping distance. (source to relay+relay to destination).

Residual battery power of relay nodes are calculated by own. Finally the relay which has both least hopping distance and more residual battery energy will send eager to help ETH frame very early. Other relays stops sending ETH after receiving one ETH. Thus best relay node selected

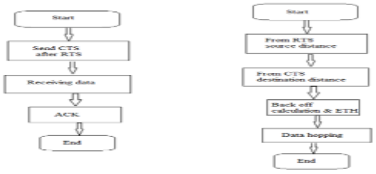
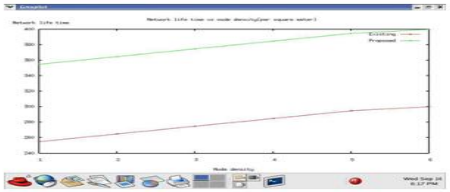
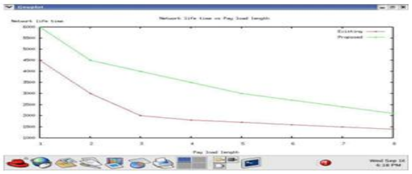


Fig.4:Flow chart for operation of destination and relay node.

PERFORMANCE AND SIMULATION STUDY



Graph.1 Comparison between node density vs network lifetime



Graph.2 Comparison between payload length vs network lifetime

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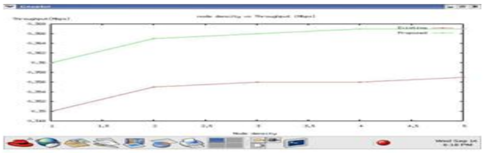
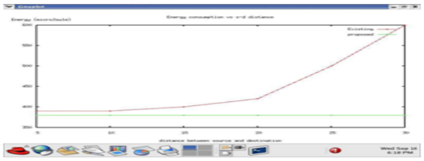


Graph.3 Comparison between Node density vs Throughput



Graph.4 Comparison between energy consumption vs s-d distance

V.CONCLUSION

By introducing DEL-CMAC, both energy advantageand 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 DEL-CMAC can significantly prolong the network lifetime comparing with the IEEE 802.11 DCF and CMAC, at relatively low throughput and delay degradation cost.As a future work, we will investigate our DEL-CMACfor larger scale network size and with high mobility.

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