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A Mobility Based Cooperative MAC Protocol for Wireless Networks

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Abstract— **In this paper, we propose a cooperative MAC protocol based on IEEE 802.11 standard for wireless ad hoc networks. In this protocol, a low data rate direct transmission link is replaced by two faster transmission links using an appropriate relay node. We investigate the challenges and issues of this problem by designing an efficient MAC scheme to improve the network throughput by finding the best relay node. Assuming that the relay node is fixed for a given interval time, the effect of nodes' mobility in finding the best relay node is investigated. The proposed scheme introduces a solution to improve the throughput and preserve the cooperation stability in the mobile ad hoc networks. To validate the protocol, we compare the results with CoopMAC protocol. Simulation results show that the proposed protocol outperforms the CoopMAC protocol in terms of throughput.**

Keywords-*Cooperative, Diversity, Relay, Helper selection, Throughput, MAC.*

I. Introduction

The next generation wireless communication systems are expected to provide and support a variety of services including voice, data, and video. The explosive demand for these services and applications needs communication systems with higher data rate and enhanced reliability.

On the other hand, in wireless environments fading is an important challenge, which has a destructive effect on the network performance, i.e., throughput and delay. Effective transmission of multiple copies of the same signal over essentially independent channels, which is known as diversity, is an efficient technique that can be used to reduce the negative effects of fading. Some well-known forms of diversity to combat fading are spatial diversity, temporal diversity, and frequency diversity [1]. Due to the small size of the mobile nodes, deployment of antenna array as the Multiple Input Multiple Output (MIMO) systems is infeasible. In order to overcome this limitation, a new concept of diversity is emerged by the utilization of cooperative communications, which is called cooperative diversity [2], [3]. Cooperative diversity is proposed to take advantage of the spatial diversity gains by allowing different nodes in a wireless network to share their resources and cooperate through distributed transmission. This cooperation is achieved by relaying overheard information at stations surrounding a source and there for it causes multiple transmission paths to the destination. In the cooperative communications, single-antenna mobile terminals share antennas from other mobiles to generate a virtual multiple-antenna system that achieves more reliable communication and higher diversity gain. The main advantages of such cooperative communications include [4]:

- Improve the communication reliability over a time-varying channel.
- Increasing the transmission rate and decreasing communication delay across the network.
- Decreasing the transmitter power and interference, and improving spatial frequency reuse [5].
- Enlarge the transmission range of each node in the network by exploiting helper nodes and subsequently extending network coverage.

Some related works on cooperative communications focus on various issues in the physical layer, and the advantages are often demonstrated by analyzing signaling strategies based on information theory and usually ignore the overhead that is needed to set up and maintain the coordinated transmissions [6], [7]. In practice, due to the required error control scheme, the payload field is limited and the overhead of the protocols is not negligible especially when the payload length is short. Therefore, the cooperation gain may disappear if higher-layer protocols are not appropriately designed. In fact, the higher-layer protocols should operate according to the time-varying channel status. Furthermore, due to user mobility, the cooperation may be inefficient under certain network conditions [2]. Therefore, a higher-layer protocol for cooperative wireless communications should be not only payload-oriented, but also channel-adaptive.

In this paper, we focus on how physical-layer cooperation can influence and integrate with the MAC layer for higher gains and more reliable communication. Particularly, we investigate the impact of the nodes mobility on the selected helper and network throughput assuming that the selected helper is fixed for some time interval.

The rest of this paper is organized as follows. In section II, we present some background materials about the legacy IEEE 802.11 protocol and review some of the related works to this paper. The problem statement and system model is stated in section III. In section IV, the Cooperative MAC protocol (CoopMAC) from reference [8] is discussed and some of its limitations are investigated. In section V, the proposed cooperative MAC protocol is presented. In this section, we investigate about optimal helper selection algorithm by considering the mobility effect. The performance of the proposed protocol in terms of the throughput is presented in section VI via simulations. The paper is concluded in section VII, and some remarks on further research on the cooperative MAC design is discussed.

BACKGROUNDS AND RELATED WORKS

A. IEEE802.11 MAC Protocol

IEEE 802.11b which is introduced in 1999 provides detailed specifications for both Medium Access Control (MAC) and Physical (PHY) layers. This standard provides four physical layer rates including 1, 2, 5.5, and 11 Mbps at the 2.4 GHz frequency band. The basis of the IEEE 802.11b WLAN MAC protocol is Distributed Coordination Function (DCF), which has based on Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) with binary exponential back-off scheme. The DCF scheme can use in two modes. The default one, known as the basic access mode, is a two-way handshaking technique. Each station needs to sense the channel before data transmission and can send data packet if the channel is idle. A positive MAC acknowledgment (ACK) has transmitted by the destination station to confirm the successful packet transmission. The other one is a four-way handshaking technique, which uses a virtual carrier sensing to avoid collision, by the use of the Request-To-Send (RTS) and Clear- To-Send (CTS) control frames. These two control frames are used to set the Network Allocation Vector (NAV), where the reservation information of the channel is stored. This technique has introduced to avoid the hidden terminal problem. After successfully exchanging the control packets, a data packet is sent and the destination sends back positive acknowledgment (ACK) if the packet has received correctly. However, one of the problems in IEEE 802.11b is "Performance Anomaly" which means the low data rate stations significantly degrade the performance of WLANs [9]. In IEEE 802.11b, each station has an equal probability to access the channel. Therefore, the low data rate stations hold the channels more than the high data rate stations. It leads to more delay and reducing the bandwidth utilization of high data rate stations. As a result, the overall throughput of the network decreased. Therefore, a Cooperative MAC (CoopMAC) protocol should implement to share high data rate links among all the stations and provide high throughput for the network.

B. Related Works

There are different studies on various types of cooperation between nodes in a network and their performance under various network scenarios. In [8] a cooperative protocol, which is called CoopMAC, is proposed, that uses a packet relay concept to enhance the system throughput. Some details about this scheme are provided in section IV. Another similar concept is Relay-Enabled Medium Access Control Protocol for Wireless Ad hoc Networks (rDCF) which is proposed in [10]. In these protocols, each node has to keep a table containing the list of neighbors and their characteristics. The major differences between [8] and [10] are in the procedure of updating the helper list. In rDCF, the list has updated by decoding the CTS frame, which includes an additional field that indicates the data rate between the sender node and the receiver node. In CoopMAC, nodes in the network decode the control frames and the helper list is maintained by measuring the received signal strength of the control frames. In [11], the CoopMAC is extended by incorporating Quality of Service (QoS) requirements of multimedia nodes, which improves the system throughput by using a persistence factor during the channel access. In [12], the CoopMAC protocol is developed by including the concept of packet aggregation and three contention phases in order to choose the helper node. With joint routing and cooperation, a cross-layer approach is introduced in [13]. Clusters of nodes near each transmitter configure Virtual Multiple-Input Single-Output (VMISO) links to a receiver and transmitter on the routing table. In addition, space-time codes are utilized to support transmission over a long distance, which reduce the number of transmission hops and improve communication reliability. In [14] a Busy-Tone-Based Cross-Layer Cooperative MAC (CTBTMA) protocol is proposed. In [15], [16] spatial diversity concept in packet transmission is reported to improve the system throughput. These protocols have two phases: In the first phase, far away node transmits its packets at high data rate if it cannot send packets to the destination by a direct link. In the second phase, all the nearby nodes that are successfully decoded the packet transmission relay the decoded packets simultaneously. In [17] a type of network coding is deployed to increase the system throughput.

Despite the fact that rDCF and CoopMAC protocols yield high throughput, some drawbacks should be addressed. The motivation of this work is to enhance these protocols by increasing the level of cooperation among the neighboring nodes, specifically when the nodes are mobile. In this paper, we introduce a new cooperative protocol MAC in order to resolve drawbacks of the CoopMAC protocol that can increase the system throughput.

II. PROBLEM STATEMENT

The main idea for cooperating is to replace a low rate direct transmission link by two faster links and the main challenge is on selecting the helper node. In order to improve the system throughput, different nodes between sender and receiver are considered as helper candidates and their corresponding transmission times are computed. The best helper is a node which has the minimum transmission time for a given time period. The CoopMAC protocol, which is introduced in [8], deploys this idea to increase the WLAN throughput for static nodes. However, the simulation results indicate that this scheme is not efficient for mobile nodes scenarios. Therefore, the obvious question is extending the helper selection mechanism taking into account the nodes' mobility. We consider the mobility pattern of helper such as speed and direction to choose the best helper in a WLAN, which is deploying the IEEE 802.11 DCF mode at the MAC layer.

A. System Model

The network is assumed to include several mobile nodes, which are placed uniformly and randomly within the carrier sense range of each other. That is all nodes can hear other's transmissions. Consider a subset of nodes as the source nodes that communicate with a specific destination placed in a random location in the same area. In addition, the transmission power of all nodes is the same and fixed.

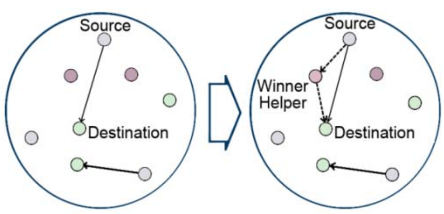

Figure 1. System Model (a) non-cooperative scenario (b) cooperative scenario

The nodes mobility model is random waypoint model [18]. In this model, each station is static for a pause time. Then it chooses a random destination in the covered area and moves to there by a random speed. After arriving to that destination, it would be stay there for a pause time, then chooses another destination in the covered area, and moves to it. This behavior repeats all the time.

The aim is to find a helper if it is possible and replace a direct low data rate link by two faster ones as it is shown in Fig. 1.

The data rates between the source, destination, and possible helper are denoted by R_{sd} , R_{sh} and R_{hd} , which are transmission rate between the source (S) and the destination (D), transmission rate between the source and the helper (H), and transmission rate between the helper and the destination, respectively.

B. Cooperation or not Cooperation

Information theory analysis provides some criteria to find in which scenarios the cooperation leads to capacity gain. Protocol overhead and limited payload length can reduce the cooperation gain. Due to the incurred cooperation complexity in the system, a MAC protocol must design carefully to avoid unnecessary cooperative transmissions. That is enquiries are sent out to the selected potential helper to check whether it can improve the source-destination single hop by a higher rate two-hop transmission. However, the helper selection would not be optimal if it is based on the chronicle transmissions because information about the location of nodes is out-of-date frequently in mobile networks. Furthermore, the required information exchanges for a helping request may have inefficient results. Therefore, the cooperative protocol should avoid unnecessary cooperative transmissions and unnecessary change of the helper to decrease the transmission overhead.

C. Evaluation Criteria

Cooperation between nodes can improve throughput of the network by increasing transmission rate and decreasing time of a successful packet transmission. However, by constant transmission power of all the senders, cooperative communication increases the interference range, which is hostile to spatial frequency reuse. Therefore, we need to balance these two aspects. Most existing cooperative MAC protocols use the strategy of rate maximization. We can use control frames (RTS/CTS) and NAV settings to relief interference problem and reduce the hidden and exposed terminal problems. We consider rate maximization and throughput enhancement mainly in this paper.

(a) (b)

III. COOPMAC PROTOCOL

A. A review of CoopMAC

In CoopMAC protocol [8], each node should listen to all other packet transmissions and maintain a table of helper nodes that may help its packet transmission. The entries of this table are the data rate from S to H (R_{sh}), data rate from H to D (R_{hd}), time of updating and the number of failures. When a node has a packet to send, it accesses the channel by using a contention mechanism specified in DCF. After winning in the channel-access contention, the sender searches through its table and finds the best helper node. The sender node calculates the time of packet transmission to the destination through the best helper node. If the time to reach the destination through the helper node is less than the direct transmission time (at a data rate R_{dir}), sender node sends RTS frame which contains the address of the helper node. If the helper node can support the packet transmission, it sends a frame called HTS (Helper ready To Send). This frame contains the currently supported data rate by the helper node. After receiving this frame, the destination node sends a CTS frame that contains the modified packet transmission time. After the time out of the HTS frame, the destination node sends the CTS frame, which allows packet transmission at direct data rate R_{dir} . When a node overhears a packet transmission, it updates its table by decoding Physical Layer Convergence Procedure (PLCP) header. A helper node has deleted from the list if the number of transmission failure through that helper node exceeds certain threshold.

B. *Some Points on CoopMAC*

In CoopMAC protocol, a sender chooses a helper from its neighboring nodes, which are stored in the list of potential helpers (Cooptable), based on the throughput improvement. Whenever there are two or more helper nodes that have the same throughput, the sender node randomly selects one of them as helper. Simulation results in [8] show that in static environments, the system throughput of CoopMAC protocol is much higher in comparison with that of IEEE 802.11. However, in mobile environments the improvement in the system throughput using CoopMAC is not so satisfactory. The reason is that in the mobile environment the sender node needs frequently to update the list of the helper nodes and chooses the best helper for each packet. This increases the packet transmission time. Furthermore, in CoopMAC protocol, updating of the helper table is based on received packets from the helper nodes. Therefore, when the network traffic is low or there is no traffic at all for a while, the information in Cooptable might be out-of-date. In addition, due to the nodes mobility the selected helper may not be the best helper in near future.

In order to relief this drawback, we consider the direction and speed of the mobile node for choosing the proper helper. In fact, the most proper helper is the node, which its direction is close to the source and destination and remains in this direction for more time. In the rest of the paper, we explain the details of proposed MAC protocol.

IV. The Proposed MAC Protocol

The proposed protocol is an extension of the CoopMAC [8]. A major modification in this protocol is in selecting the helper node. Consider an interval time with duration of Δt. In order to select the most proper helper, we consider the node, which is the best relay node at the beginning of this period as well as at the end of Δt using prediction. This prediction is based on mobility features like direction and speed. Therefore, we maintain the stability of mobile nodes for helper selection and could achieve a higher throughput than CoopMAC protocol.

In this helper selection method, the helper nodes monitor instantaneous channel conditions toward the source and destination via the RTS and CTS packets, same as CoopMAC protocol. The selected path is one that is more stable and faster to transmit the information for a Δt period and the time of packet transmission would be reduced. The proposed protocol uses the same RTS, CTS, and HTS (Helper ready To Send) packet format specified in CoopMAC. HTS is a new packet introduced in CoopMAC to facilitate the cooperation and it is for helper to acknowledge its participation. It has the same format as CTS in the 802.11 standard. The RTS packet in CoopMAC has a bit difference with RTS in the 802.11 standard. It has an extra field for helper MAC address and two extra fields for R_{sh} and R_{hd} .

A. *Proposed Scheme*

When a source station has data to send, it should first sense the channel. If the channel is free for a DISF time, and source completed the required back-off mechanism, the source node initiates its transmission. It makes it by sending an RTS packet to its destination. Then it reserves the channel for transmitting data for a required time. The destination node transmits CTS packet that includes a field contains direct transmission rate between itself and the source. The common neighboring source and destination nodes, which receive both RTS and CTS packets then investigate maximum cooperative source-destination transmission rate. A common neighboring node, introduce itself as potential helper if it can satisfy (1) [19], i.e., a node that can create a two-hop path faster than direct transmission to transmit the source data.

$$\frac{1}{R_{sh}} + \frac{1}{R_{hd}} < \frac{1}{R_{sd}} \qquad (1)$$

We should note that assuming constant transmit power, R_{sh} and R_{hd} can be estimated by measuring power strength of RTS and CTS packets at all nodes which receipt these packets. Furthermore, R_{sd} is inserted within the CTS packet. If a node has ability to reduce the duration of transmission, advertises itself as helper and sends an HTS packet back to source. If source does not receive a HTS packet but does hear CTS from destination, then the source node initiates data transmission toward destination directly. Therefore, the proposed protocol can switch between cooperative and non-cooperative states.

B. *Optimum Helper Selection*

In order to find the best helper, we should consider different features between nodes. In CoopMAC protocol, only the rates between source and helper, between source and destination and, between destination and helper are considered by using (1). However, if we consider the mobility feature of nodes, choosing the best helper will be a bit different. Due to mobility, distance between nodes is changed and it has important effect on the power of signals and the rates between nodes. Therefore, if we want to find the best helper we should use (1) for every packet which has high overhead in the network.

On the other hand, if we consider the best helper to be fixed for a period, using (1) for finding the best helper cannot represent the mobility feature of nodes in this period. This measure is suitable at the beginning of this period but during the period the rates will be changed due to the mobility. It causes the selected helper will not be a proper helper in the future. Therefore, when a helper is chosen we need to predict the future position of this node in this period based on its mobility direction and speed. In the next section, we use mobility features to obtain mobility prediction.

C. Mobility Prediction

As it is discussed, the node that leads to faster two-hop path for data relaying is the best helper between different candidates. It means that the best helper should have the least $\frac{1}{R_{sh}}+\frac{1}{R_{hd}}$. In addition, we consider the source and destination should choose the best helper for Δt second. Therefore, we need to predict which helper is best in this duration. We should consider the direction and speed of helper nodes in this duration. If a node is coming closer to the source and destination, and it remains in this direction more than other nodes it will be the best helper in Δt duration.

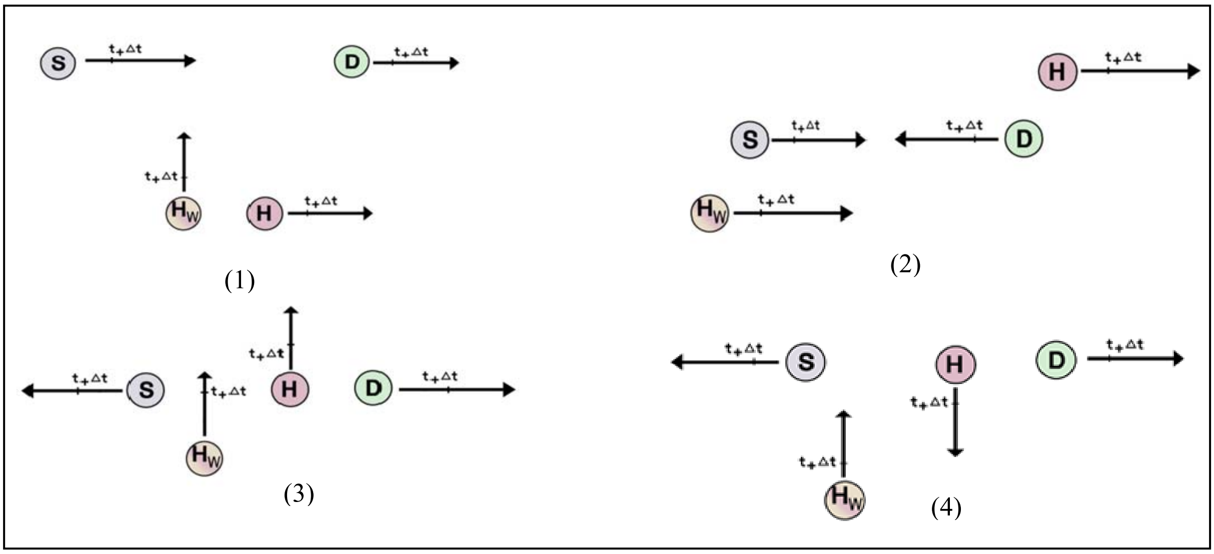

Figure 2. Various situations between source, destination, and helper nodes.

Figure 2 shows the various situations between helpers, source and destination. In this figure, the source and destination nodes are represented by *S* and *D* respectively and the nodes motion vector are shown. For simplicity, the figure shows just two nodes among the candidate nodes surrounding the source and destination. Furthermore, *H* and H_W are the candidate helper for cooperation.

In Fig. 2.1, *S* , *D* and *H* move parallely to a same direction. H_W moves toward up and it is approching to *S*. We can see that *H* and H_W almost have the same situation toward *S* and *D*. Howevere, due to the mobility, the distance between H_W and *S*, will be decreased. In the t+ Δt moment, the distance between H_W from *S* and *D*, is shorter than the distance *H* from *S* and *D*. Therefore, H_W is a better helper than *H*. Fig. 2.2 shows situation that H_W is better than *H*, obviously.

In Fig. 2.3, we can see the distances between *S* and *H*, and between *D* and *H*, are shorter than

distances between them and H_W at the beginning of Δt duration. Therefore, it seems *H* would be better helper. However, mobility makes the *H* far from *S* and *D*, after Δt second and *H* will be inappropriate distances from *S* and *D* at the begining, is coming closer to *S* and *D* during the Δt second. So it will be better helper.

In Fig. 2.4, *S* and *D* are going far from each other. H_W is coming toward them but *H* is going far from them. At the first look, it seems that *H* is an appropriate candidate to be the helper. However, H_W is coming to *S* and *D* and hence it is a better helper than *H* during Δt time elapsing.

In order to predict the mobility and its effect in choosing the best helper, we should follow the node direction in Δt duration. We use random waypoint model for mobility of nodes. In this model, a random destination, a random speed and the start time of motion are considered for each node. Therefore, by using velocity vector and start time of motion, we can predict the situation of nodes in each moment of time using (2) and (3).

$$X_{new(t+\Delta t')} = X_0 + |V|\Delta t' \cos\theta \qquad (2)$$

$$Y_{new(t+\Delta t')} = Y_0 + |V|\Delta t' \sin\theta \qquad (3)$$

In these formulas, variable t is the start time and $\Delta t'$ is the time duration that past from the beginning of the motion. Figure 3 shows the velocity vector and different situations of node in its direction. In the process of the heper selection, the new position of the candidate nodes are computed at first. These are the exact positions of mobile nodes in the beginig of the process of helper selection. Then, by using new destances between nodes, new rates between them are computed too. We consider $A^{(new)}$ as the rate condition at the beginning of the process of helper selection using (4).

$$A^{(new)} = \frac{1}{R_{sh(new)}} + \frac{1}{R_{hd(new)}} \quad (4)$$

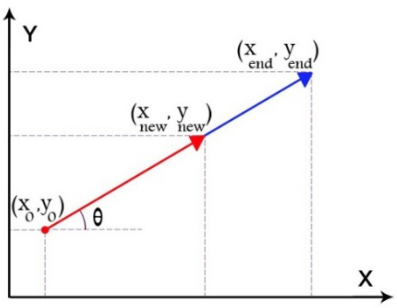

Figure 3. Velocity vector.

In random waypoint model, the destination of nodes that is shown by (x_{end}, y_{end}) in Figure 3 is known. If we consider the mobility effect, it is important to know the rates between selected helper and source, and between helper and destination at the end of the motion of the helper. If the helper node is coming closer to the source and destination, these rates will be higher than the rates at the beginning of the process of helper selection. Therefore, we consider $A^{(end)}$ as the rate condition at the end of the motion of the helper node using (5).

$$A^{(end)} = \frac{1}{R_{sh(end)}} + \frac{1}{R_{hd(end)}} \quad (5)$$

By using (x_{end}, y_{end}) and (x_{new}, y_{new}) we can compute the time duration, which the helper remains in this direction. This time is called *Stable Time (ST)* that is computed by (6).

$$ST = \frac{\sqrt{(x_{end} - x_{new})^2 + (y_{end} - y_{new})^2}}{|V|} \quad (6)$$

If the *ST* is short, it means that the helper node does not remain in this direction more ever. We consider Δt as the time duration, which the same source and destination does not change the selected helper. Therefore, a helper that its *ST* is near to Δt duration does not change its direction in this duration. We introduce *Remaining Time* (RT) as a measure to compare *ST* and Δt duration.

$$RT = \Delta t - ST \quad (7)$$

In order to find the best helper, a new condition based on $A^{(new)}$, $A^{(end)}$ and RT is introduced as a *Selection Condition (SC)* that is represented in (8). Without loss of problem generality if $RT < 1$, we consider $RT = 1$.

$$SC = \left(1 - \frac{1}{RT}\right) A^{(new)} + \frac{1}{RT} A^{(end)} \quad (8)$$

The best helper is the candidate node that minimizes SC condition. Based on (8), if RT is short, we prefer to select the helper based on the end of its motion. It means that in this situation, we can predict the future of helper nodes and therefore we prefer the nodes that are coming closer to the source and destination. If RT is long, we cannot predict the future of the helper nodes and we prefer to decide based on the observation at the beginning of the process of helper selection. After finding the best helper, we investigate condition (1). If the helper satisfies this condition, the two-hop path replaces the direct path.

After finding the best helper, the transmission algorithm is same as [8]. When source station *S* has data of length L to send, it senses the channel. If the channel is free for a DISF time, it should search through the helper table. If it finds the best helper, then it sends a CoopRTS with helper address, R_{sh} and R_{hd}. If it does not receive any CTS from destination and neither any HTS from helper in duration of *2SIFS + CTS*, probably there is a collision and the source should perform regular random back- off. If source receives a CTS message but not any RTS message, it should transmit through the direct link. If both of HTS and CTS are received by source, it can perform two-hop transmission if condition (1) is satisfied. The best helper receives the data packet completely and then forwards the data frame to ultimate destination after a SIFS time interval. The destination node transmits an ACK packet to the source node if it receives data packet completely, after a SIFS time interval. Figure 4 shows the transmission data flow.

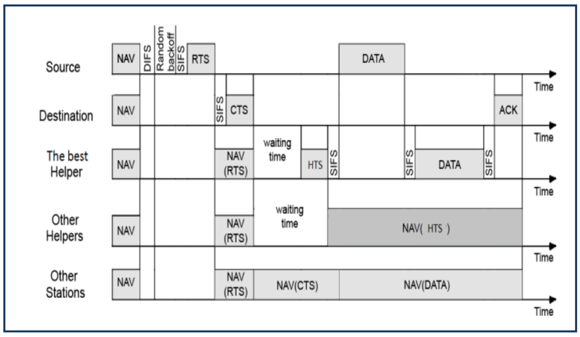

Figure 4. Transmission data flow

SIMULATION RESULTS

To validate the performance improvement of the proposed protocol compared to the CoopMAC protocol, we have used the simulator of CoopMAC, which is developed by using the C programing language in [8]. In order to get exact comparison between proposed protocol and the CoopMAC, we use the same parameters set up in [8] in Ad Hoc mode and modify the helper selection procedure. We show in Table I, the set of main parameters used in the simulation [8].

In order to ensure that all nodes in the transmission range can receive data successfully, control frames and data overheads frames have transmitted in the same basic rate (1 Mbps for 802.11). In the simulations, mobile stations have placed randomly in a circle with a radius of 100 meters. Packets have transmitted at different rates, depending on the distance between the stations. The relation between the rates and the ranges is shown in Table II. For example, there is 11 Mbps packet transmission link between two nodes with 48.2 meters distance. It is assumed that the network operates under a heavy load condition. The traffic has evenly distributed for all the stations in the network. Packets with fixed length (1024 bytes MSDU) arrive in to a node according to a Poisson distribution with the average rate 500 packet/sec. Both the CoopMAC and the proposed protocol share the same minimum and maximum window sizes. We consider Δt duration for both algorithms about 10 seconds and max speed is 1 m/s.

TABLE I. PARAMETERS USED IN SIMULATION

PARAMETERS USED IN SIMULATION	
MAC header	272 bits
PHY header	192 bits
RTS	352 bits
CTS	304 bits
ACK	304 bits
Data rate for MAC & PHY header	1 Mbps
Slot time	20 μs
SIFS	10 μs
DIFS	50 μs
aCWmin	31 slots
aCWmax	1023 slots
retry Limit	6

TABLE II. PHYSICAL MODEL PARAMETRS

Data Rate (Mbps)	11	5.5	2	1
Range (M)	48.2	67.1	74.1	100

The simulations are done by considering mobile nodes and the results of the proposed helper selection mechanism and CoopMAC protocol are compared. The results show the improvement of throughput in proposed protocol. Figure 5 compares the achieved throughput versus number of nodes. The reason of this improvement is that in the CoopMAC protocol the process of helper selection has only based on the observations at beginning of the helper selection. Therefore, it is not optimal and it may lose the cooperation gain. However, in the proposed protocol, the process of the helper selection is based on some mobility features like direction and speed. In this selection, the future of selected helper is considered and if it is an efficient node in Δt duration, we will prefer it.

However, in the cooperative protocols, increasing the number of nodes increases the probability of finding a two-hop path by using a helper node and therefore, the throughput will increase. In fact, when there are many nodes in a network, the probability of finding helpers that have the similar situation (similar position and similar velocity vector) is increased. Therefore, there is not any important difference between CoopMAC and proposed protocol, and the results of both of these helper selection algorithms are close.

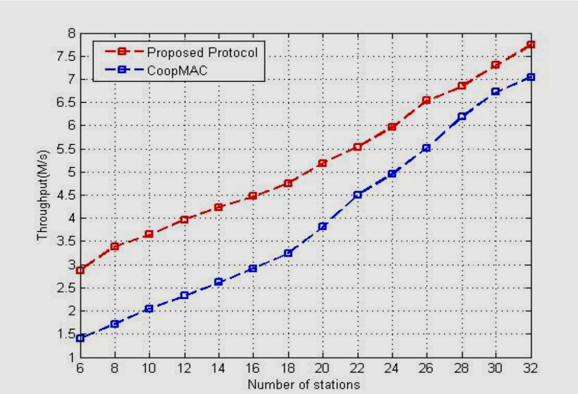

Figure 5. Throughput vs. number of Stations. MSDU=1024Byte

Another important feature that has significant effect on each MAC protocol is the size of the MSDU. Increasing the packet size increases the throughput. The reason is that the channel is less occupied by PHY and MAC overhead transmission.

On the other hand, when the payload length is less than a predefined threshold, the cooperation decreases the throughput due to overheads added to the network. The proposed protocol considers this situation and develops the cooperation scheme when the payload length is more than a predefined threshold. Figure 6 shows that increasing the payload length increases the throughput. Therefore, due to the less overhead in the proposed protocol, it has better performance in terms of throughput compared to the CoopMAC scheme.

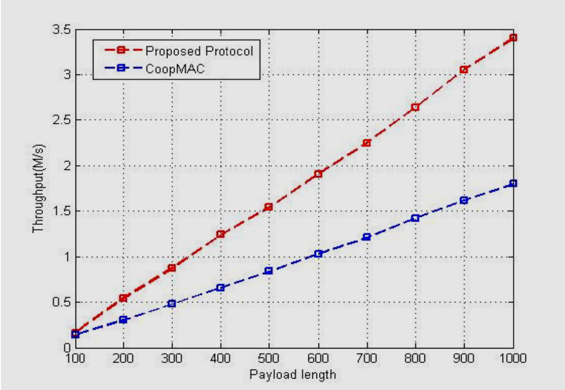

Figure 6. Relation between the payload size and throughput gain. Number of stations is 8.

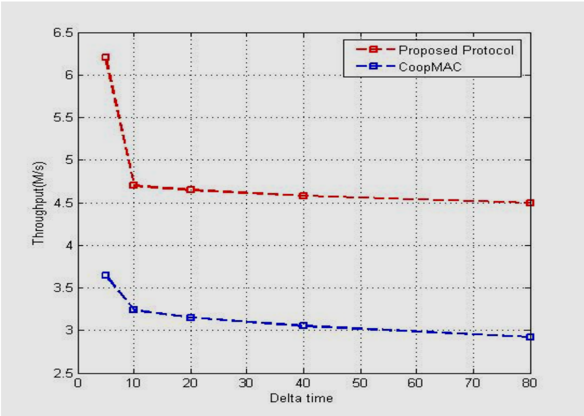

Figure 7. Impact of mobility: max speed = 1 m/s, 18 stations, heavy load with MSDU size of 1024 bytes.

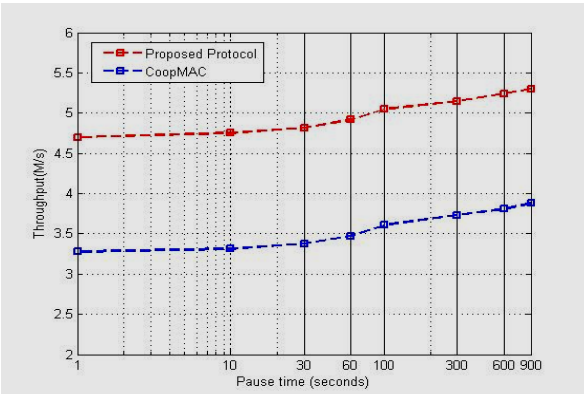

Figure 8. Impact of time duration.

In Fig. 7, we investigate another mobility feature in proposed protocol compare with CoopMAC in Ad Hoc mode. In random waypoint model, which is adopted in this paper, one of the features is *pause time*. Before nodes start to move through the selected direction, with the specified speed, each node should remain stationary during the pause time. As shown in Fig. 7, when the pause time increases, the throughput achieved by proposed protocol is increased much better than CoopMAC.

In last simulation result, we investigate the effect of Δt time interval. As shown in Fig. 8, when Δt is short, the proposed protocol has higher performance in throughput than CoopMAC since it can predict the future of mobile helper better than CoopMAC.

V. CONCLUSION AND FUTURE RESEARCH

In this paper, we investigate cooperative MAC protocols for mobile nodes. We proposed a new cooperative MAC protocol for mobile nodes in Ad-Hoc networks based on mobility features like direction and speed. In this protocol, we assume that the source and destination do not change the helper for a period because choosing a helper per each packet is not practical. The proposed protocol investigates the future of candidate nodes to find a helper, which is the best helper in Δt duration. Simulation results show that this protocol outperforms the CoopMAC protocol in terms of the network throughput. The most important future work is to predict the mobility effects and energy consumption by the helpers in cooperation environment.

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