Innovative Channel Release Schemes for Mobile ad hoc Networks

N. Nakamura†, D. Chakraborty‡, A. Chayabejara†,
G. Kitagata†, T. Suganuma†, G. Chakraborty* and N. Shiratori†

†Research Institute of Electrical Communication, Tohoku University
2-1-1 Katahira, Aoba-ku, Sendai 980-8577, Japan
{nakamura, apichet, minatsu, suganuma, norio}@shiratori.riec.tohoku.ac.jp
‡National Institute of Information and Communications Technology Tohoku Research Center
2-1-1 Katahira, Aoba-ku, Sendai 980-8577, Japan
deba@tohoku.jgn2.jp
* Dept. of Software & Information Science Iwate Prefectural University
152-52 Sugo, Takizawamura Takizawa, Iwate 020-0193, Japan
goutam@soft.iwate-pu.ac.jp

ABSTRACT

In wireless network RTS/CTS frame exchange protocol is widely used to avoid packet collisions. However, the protocol lacks the ability to release the reserved but unused channel. For Mobile Ad hoc NETworks (MANET), this often keeps the channel unnecessarily inaccessible, resulting in inefficient channel utilization. In this paper, we propose innovative schemes which can optimize the Medium Access control mechanism by using wasted channel for MANET deployed over IEEE 802.11. The proposed schemes are based on different variations of *extra frame transmission* method. NAV (Network Allocation Vector) updating scheme is also introduced to provide higher channel efficiency. For further improvement, we combine those schemes with specific parameters. The combination of schemes can achieve throughput more than 40% compared to standard IEEE 802.11 and at the same time compatible with IEEE 802.11.

Keywords: MANET, RTS/CTS, channel release, NAV

1 Introduction

In wireless network, performance is dependent upon medium access control protocol. Carrier Sense Multiple Access (CSMA) is commonly used for its simplicity. But CSMA is unable to handle the hidden terminal problem, especially in ad hoc networks, where multihop communication among nodes is common. To overcome this problem, a frame exchange protocol is used, called RTS/CTS handshaking. It was first proposed by [2].

There have been a lot of researches on developing the wireless medium access control (MAC) that efficiently shares limited resources between all stations [1],[2]. At present, IEEE 802.11 MAC is clearly the most accepted and widely used wireless technology. The IEEE 802.11 works based on CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance) and adopts a random access scheme where packets are sent randomly to reduce the number of collisions as much as possible. In addition, IEEE 802.11 introduces a mechanism called Request-To-Send/Clear-To-Send (RTS/CTS) handshaking and Virtual Carrier Sensing to further reduce the chance of collisions that can occur due to hidden terminal problems.

However, it is observed [3] that hidden and exposed terminal problems are exacerbated in MANET while using IEEE 802.11. The ultimate result is heavy degradation in throughput and instability of networks. In [4], it is shown that this problem is more severe in large and dense ad hoc networks. So improvement of performance degradation for IEEE 802.11 over the MANET is an important issue.

"False blocking" problem unnecessarily prohibits nodes from transmitting at a given instant[12]. In worst case, all the neighboring nodes are blocked and can not transmit frames and they are put into the deadlock state. This happens when RTS frame reserves the channel but the channel remains unused. Ray et al. [12] proposed "RTS Validation", where a channel is released when each node assumes that CTS is missing, after it receives RTS frame, based on the physical carrier sensing.

In [13], with the same motivation we proposed a scheme called "Extra Frame Transmission" to manipulate frame transmission during RTS/CTS handshaking. When no CTS is received for some specific duration after node sends an RTS frame , it will send immediately another small frame to other destination. Both these schemes [12],[13] reuse the channel unnecessarily reserved. The main difference between RTS Validation scheme and Extra Frame Transmission scheme is, which node to detect the interruption of RTS/CTS handshaking. In [13]it is done by Sender, whereas in [12] neighboring nodes are responsible for interruption detection.

In this paper, we propose another type of extra frame, called "Reverse Extra Frame". We also note that there is scope for improvement when channel release schemes are not applicable. To reuse the channel as much as possible, we modify NAV operations to increase the chance of channel reuse. In addition, focusing on the fact that these schemes can work independently, we combine modified schemes together. Moreover, our proposed mechanisms are free from compatibility problems with standard IEEE 802.11. Results from simulations verify the effectiveness of our schemes. It is observed that our combination of schemes leads to a 42% gain in throughput compared to IEEE 802.11.

The rest of this paper is organized as follows. In Section 2, we discussed the Related Works. Basic operations of the IEEE 802.11 is explained and its operation in MANET during RTS/CTS failure is described in Section 3. Our proposed scheme of our enhancement of IEEE 802.11 is explained in Section 4. The effectiveness of our scheme and evaluation of our proposal is discussed in Section 5. Finally we conclude our work in Section 6.

2 Related Works

In RTS Validation scheme[12], upon overhearing an RTS packet, nodes listen whether the corresponding DATA packet transmission has taken place or not. If each node finds the channel as idle during the expected DATA packet transmission period following an RTS, then the node will release the NAV registered by that RTS frame and stop deferring.

Based on the observation of physical carrier sensing, if the medium remains idle for a certain duration since node receives RTS frames, the neighboring nodes will conclude that an interruption of RTS/CTS handshaking has occurred, then the nodes release the channel independently.

In [11], a scheme named CRTS (Cancel RTS) is proposed, which let the reserved channel free in order to improve degradation of channel utilization caused by the failure of getting the channel during RTS/CTS handshaking. In this scheme, when sender node does not receive CTS correctly for its RTS, it sends CRTS frame, and then neighboring nodes who overhear CRTS will cancel the NAV set by the RTS. However CRTS suffers from not only compatibility problem by introducing a new CRTS frame but also the overhead increases, because the sender node sends CRTS frame to just notify the interruption of handshaking every time it fails to get CTS frame during RTS/CTS handshaking.

3 Background

The IEEE 802.11 describes two medium access functions called Point Coordination Function (PCF) and Distributed Coordination Function (DCF). In this paper, we focus on IEEE 802.11 DCF that provides a distributed access mechanism scheme over ad hoc networks.

IEEE 802.11 DCF is based on CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance). It provides basic access mechanism using two-way handshaking and four-way handshaking. We present only the basic functional overview of the IEEE 802.11 standard here. More details can be found in [7].

3.1 Basic access mechanism

IEEE 802.11 DCF is based on carrier sense multiple access (CSMA) technique. A station desiring to transmit, senses the medium whether another station is transmitting before initiating a transmission. If the medium is sensed to be free for a DCF Interframe Space (DIFS) [1] interval, the transmission may proceed. On the other hand, if the medium is busy, the station must defer its transmission until the end of the current transmission. Then, it will wait for an additional DIFS interval and generate a random backoff timer before transmission. The counter is decreased as long as the medium is sensed as idle and frozen when the medium is busy and resumed when the medium is sensed as idle again for a time longer than a DIFS interval. Only when the backoff counter reaches zero, the station can transmits its packets.

The backoff counter is uniformly chosen between $(0, \omega - 1)$. The value ω, known as Contention Window (CW), represents the contention level in the channel. At the first transmission attempt, ω is set to CW_{min}. After each transmission failure, ω is doubled up to a maximum value of CW_{max}.

Since stations can not listen to the channel while transmitting, collision detection is not possible in wireless medium. An ACK is transmitted by the receiving station to confirm the successful reception. Receiving station waits for a SIFS interval after receiving data frame correctly. After that it sends back an ACK to the sending station. In case of missing an ACK, sender assumes a transmission loss and schedules retransmission after doubling the CW.

3.2 RTS/CTS handshaking mechanism and virtual carrier sensing

The RTS/CTS access method is provided as an option in IEEE 802.11 to reduce the collisions caused by hidden terminal problem. A station that needs to transmit large data frame (longer than predefined RTS-Threshold value), follows the backoff procedure as the basic mechanism described before. After that, instead of sending data frame, it sends a special short control frame called request-to-send (RTS). This frame includes information about the source, destination, and duration required by the following transaction (CTS, DATA and ACK transmission). Upon receiving the RTS, the destination responds with another control frame called Clear-To-Send (CTS), which also contains the same information. The transmitting station is allowed to transmit data only if the CTS frame is received correctly.

All other nodes overhearing either RTS and/or CTS frame adjusts their Network Allocation Vector (NAV) to

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[1] Four types of interframe space have been specified in IEEE 802.11 to prioritize different accesses, Short IFS (SIFS) for highest priority, followed by DCF IFS (DIFS), PCF IFS (PIFS), and Extended IFS (EIFS) respectively.

the duration specified in RTS/CTS frames. The NAV contains period of time in which the channel will be unavailable and is used as virtual carrier sensing. Stations defer transmissions if either physical or virtual sensing finds the channel being busy. Nevertheless, if receiver's NAV is set while data frame is received, DCF allows the receiver to send the ACK frame.

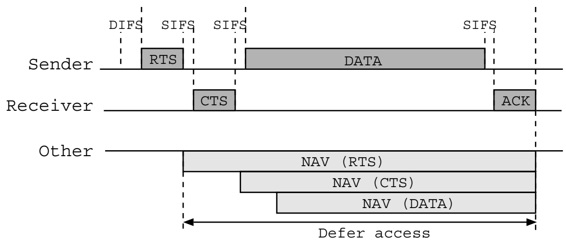

Figure 1: The RTS/CTS access mechanism

The effectiveness of RTS/CTS mechanism is shown in [8] as it can early detect the collisions by the lack of CTS. Here it considered that an absence of CTS implies a collision has occurred and thus can effect an early detection. However, the protocol cannot free or reallocate the channel that was already reserved by the previous RTS frame. Stations receiving only the RTS frame but not CTS, cannot assume that transmission does not take place. Therefore, they defer for an interval declared in last RTS. This results in wasting of channel capacity around the sender node.

3.3 RTS/CTS induced false blocking

In this Section, we analyze the situations when CTS is not received at the sender and how to improve the channel utilization in each occasion.

Situation 1: Backoff timers at two or more stations reach zero at the same time and they send RTS frame simultaneously, so the sender fails to get the CTS frame. This happens more frequently as network traffic increases.

Situation 2: It is illustrated in Figure 2. Station S starts the RTS/CTS sequence while another transmission between M and N, which interferes the reception but is out of S's sensing range, is carrying on. Even if the RTS correctly reaches the receiver, the virtual carrier sensing at station R will forbid the CTS response.

Situation 3: It occurs when intended receiver, R, moves to a new position, which is out of communication range of S as shown in Figure 3. Hence, it cannot receive RTS from S.

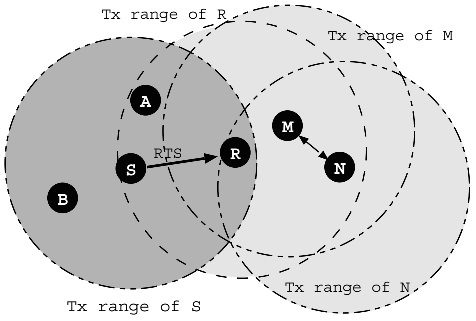

Figure 2: Illustration of situation 2

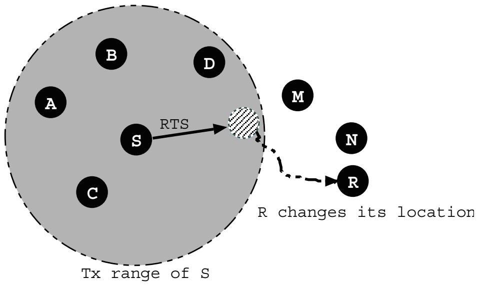

Figure 3: Illustration of situation 3

The above situations are regularly found in MANET where stations route packets through each other in multihop fashion, as stations are free to move arbitrarily. In wireless network only node is allowed to transmit at a particular time and many nodes around the receiver may be blocked. The neighbors of the blocked node are unaware of this blocking. So a node may initiate a communication with a node that is presently blocked and consequently the destination does not respond to the RTS packet. However, the sender interprets it as channel contention and enters backoff. The neighboring nodes are prevented from decrementing backoff counter and sending packets because of the NAV set by RTS.

This false blocking is a consequence when all the nodes that receives RTS inhibits themselves from transmitting. This problem can get severe when it is occurred in circular way, which can create pseudo deadlock[12]. This leads to lower channel utilization and route failure. Therefore releasing unused channel is important for channel stability. RTS Validation reduced above problem but there is still wasted channel capacity.

By our proposed schemes, we try to reuse the wasted channel capacity as much as possible.

4 Enhancements for Efficient Channel Utilization

In this section, we present three different approaches and their modification for optimal use of otherwise wasted channel capacity in MANET. In our proposed schemes we tried to unlock the unnecessarily blocked channel by using NAV update and also tried some aggressive methods to recover as much as possible and minimize the channel lose due to false blocking.

We have described each of our proposed schemes, (i) Extra Frame Transmission (EFT),(ii) Reverse Extra Frame Transmission (R-EFT), with its extension, and (iii) Combination of schemes in different subsequent subsections.

4.1 Modification of NAV operation

In case of RTS Validation mechanism [12], when the node has already been deferred, it can not set NAV back to the previous value that has already been set by other RTS frames. Besides that, RTS Validation may not be always available. Higher the amount of network traffic, unavailability of RTS Validation will be more frequent. As a result, RTS Validation can not fully utilize the unused channel. Thus the efficiency of channel reuse will be reduced. Improvement is possible, if RTS Validation works irrespective of NAV set.

With the above considerations, we modify the NAV operation with three new variables as follows:

(i) We divided the original NAV in two parts: one is sets of NAV_k indexed with the corresponding node's ID, and the other is NAV_{other}.

(ii) NAV used for the operation is calculated by the maximum value in the sets of NAV_k and NAV_{other}.

(iii) NAV_k is adjusted when overhearing RTS/DATA frame from node $node_k$, and NAV_{other} is adjusted by cases, other than RTS/DATA frame, like receiving CTS frame or suffering from collision.

(iv) Allowing NAV_k to override by newer value in the duration field. It means, when node overhears RTS/ DATA frame of node k then NAV_k will be updated by the duration the frame has.

(v) If needed, RTS Validation will reset NAV_k.

NAV updating scheme can handle NAV for multiple nodes with record of corresponding senders' ID, related to failure of RTS/CTS handshaking, and gives the flexibility and convenience to cancel the NAV even if NAV has already set. This modification is helpful for RTS Validation to cancel the NAV and improve the channel capacity.

In addition, there is benefit of NAV updating in Extra Frame Transmission scheme, discussed in the following section.

4.2 Extra Frame transmission (EFT)

Extra Frame Transmission works as shown in Figure 4. After sender transmitted RTS for *receiver 1* and has waited until it conceives that CTS will not come back, it picks a frame from the sending queue and immediately transmits it to the alternate receiver, if an appropriate one exists. We explain the term *'appropriate frame'* in the following paragraphs. The extra frame will be removed from the queue if the transmission is completed (confirmed by ACK from receiver) [7] or the transmitted extra frame is broadcasted. Regardless the success of extra frame transmission, the sender goes back to normal operation by scheduling the retransmission of the original frame with doubled CW.

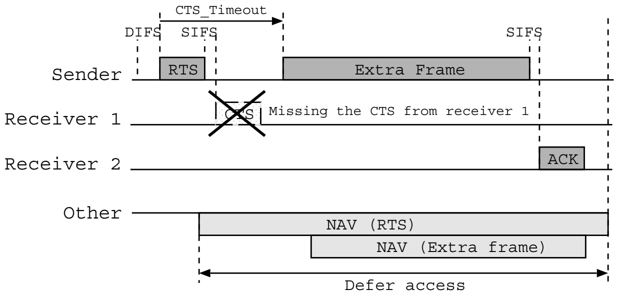

Figure 4: Extra frame transmission

Since the standard protocol does not specify the timeout value for CTS response, sender normally stays idle till the end of the allocated duration. However, the RTS/CTS sequence uses strict timing. So we introduce a new parameter, Handshake_Timeout_S, which accounts for the maximum time that may require to receive a CTS. Having waited for this Handshake_Timeout_S, sender is assured that the CTS response from receiver will not come at all.

The transmitted extra frame, should maintain the following properties:

1. Extra frame should be destined to a station different from the currently attempted one. Since no reply received from the current destination, any further attempt to the same station will be futile.

2. The selected Extra frame should be a broadcast frame (which is irrelevant to RTS-threshold), or unicast frame smaller than RTS-threshold. So that, this frame can be immediately transmitted without following RTS/CTS frame exchange protocol.

3. The chosen extra frame should be the first in the queue destined for a particular receiver. For example, if there are two frames for the same destination at the sender, and the first frame is larger than RTS-Threshold but the second frame is not, then none of the frame will be sent. Even though second frame may satisfy the first two conditions. This constraint is considered to avoid any out-of-order transmission.

It has been observed that with the increase in traffic load and node density, the chance of false blocking increases. In that case, there is a fair chance of a successful transmission of this *extra frame* because channel around sender has been already reserved by previous RTS frame.

In this process we can deliver a frame that can not be sent in normal operation.

With NAV updating schemes, introduced earlier, the benefits of this scheme can be **double** folded. The nodes who received the RTS and blocked their channel will be allowed to cancel the original NAV duration.

Actually nodes will readjust the previously set NAV with the duration of extra frame. NAV of extra frame should have shorter value in duration field than current NAV for the RTS sender; node can indirectly cancel its NAV. So if the selected extra frame is a broadcast frame, whose NAV duration is zero, the overhearing nodes can re-set the NAV value for RTS and completely cancel the NAV. Even if RTS-threshold is set to zero, Extra Frame can release the channel effectively.

4.3 Combination of RTS Validation and Extra Frame transmission

Extra Frame Transmission and RTS Validation [12] independently on sender node and neighboring nodes respectively. For further performance improvement, we propose an approach to combine RTS Validation and Extra Frame.

Since an appropriate Extra Frame can not be always available in the waiting queue of sender node, the channel reuse is not available as frequently as RTS Validation. Though if it is available, it has the ability to deliver data as an extra frame. To utilize this ability, we entrust mainly Extra Frame Transmission with delivering the Extra Frame Transmission and entrust RTS Validation with releasing channel. To work together in parallel, we set two parameters, Handshake_Timeout_N, Handshake_Timeout_S as follows:

Handshake_Timeout_S :

$$RTS\_Tx\_time + propagation\_delay + SIFS + CTS\_Tx\_time + propagation\_delay$$

Handshake_Timeout_N :

$$propagation\_delay + SIFS + CTS\_Tx\_time + propagation\_delay + SIFS + propagation\_delay + SIFS$$

Where T_x represents the transmission time.

With these parameters, when a node detects the interruption of RTS/CTS handshaking, and if an extra frame is available, the extra frame will deliver a small data as well as release the channel by virtue of NAV updating. Even if there are no extra frames, RTS Validation just releases the NAV. Therefore complementing both mechanisms together lead to improvement of channel efficiency.

4.4 Reverse Extra Frame Transmission (R-EFT)

To allow the neighboring nodes, who overhear the RTS, we propose an aggressive way of channel reuse, by introducing a new type of extra frame called "Reverse Extra Frame". The timing to transmit it is same as that of releasing channel of RTS Validation. So it can be said as a subset of RTS Validation.

The idea stem from the fact that, generally speaking, once RTS frame has been sent, it is relatively free from collision for the duration specified in the RTS frame. If one of the neighboring nodes can send a frame to the sender, its frame is expected to reach successfully. To exploit this relatively safe period of time to reuse the channel, we allow the neighboring nodes to send an *extra frame* to the node who originates the RTS. Reverse Extra Frame Transmission works as shown in Figure 4.

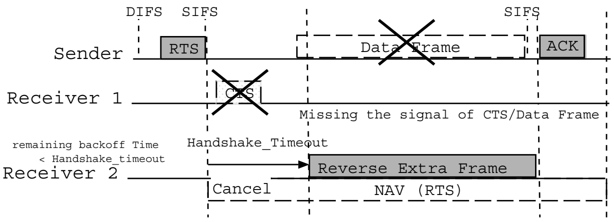

Figure 5: Reverse Extra Frame transmission

It is not possible to completely prevent the reverse extra frames from collision because there can be several eligible candidates for sending an extra frame. To reduce the probability of collision, the following constraints are introduced:

- Reverse Extra Frame should be the first frame in the queue, and be destined to the node which RTS frame had sent.
- The length of the duration in reverse extra frame should be smaller than that of the duration specified in RTS.
- The node should have a short backoff timer that would have expired if node does not receive RTS frame.

If an appropriate reverse extra frame is found, it will be sent immediately, and will be removed from the queue if the transmission is completed (confirmed by ACK from sender). Then the node goes back to the normal operation, regardless the successful transmission of Reverse Extra Frame.

We have earlier seen that even when RTS/CTS handshaking is interrupted, the neighboring nodes will be inhibited from transmitting. RTS Validation can release the channel, but the nodes can not recover from the loss incurred by the interruption. Because, when the nodes sensed the channel as busy, their backoff timers were halted and stopped decrementing during RTS/CTS handshaking.

When Reverse Extra Frame is available, nodes can make up the above loss of time. Because without performing RTS/CTS handshaking, node transmits the data frame which is supposed to send in the near future. But due to the restriction imposed to prevent collision, Reverse Extra Frame may not always available. When there is not Reverse Extra Frame, to compensate the loss of time, we allow the nodes to decrement their respective backoff timer.

We allow those nodes to decrement the time equal to the "Handshake_Timeout" from their respective remaining backoff timer. But for those nodes who's remaining time of the backoff timer is less than or equal to the "Handshake_Timeout", to differ their access to avoid collision, it will choose a uniform random backoff time from $(0, current\ backoff\ time)$.

So when Reverse Extra Frame are not available, the nodes will decrease backoff timer for the deferred time as if it had not been interrupted. We can thus reduce the waiting time for the node before transmitting and increase throughput.

4.5 Compatibility with IEEE 802.11

CRTS [11] is releasing the NAV by introducing an extra frame. Whereas, our schemes keep the format unchanged. Thus our proposed schemes is compatible with the existing IEEE 802.11 standard. Even if there are stations that does not support our enhancement, they will also work as well.

5 Performance evaluation and discussions

5.1 Simulation scenario

Most widely recognized network simulator, *ns-2*, [9] is used to evaluate the effectiveness of our mechanism. Performance comparisons between IEEE 802.11 standard [7], RTS Validation [12] and our proposed enhancements have been done.

The network model is a multi-hop wireless topology using AODV (Ad hoc On demand Distance Vector) as routing protocol [10]. The link layer is a shared media radio with nominal channel bit rate of 1 Mbps. The antenna is omni-directional with radio range of 250 meters.

Some parameters are listed here; slot time = 20 μs, SIFS = 10 μsec, DIFS = 50 μsec, propagation delay = 2 μsec, RTS-Threshold = 0 bytes.

Traffic source and destination pairs are randomly spread over the network. Type of traffic is constant bit rate (CBR) with packet size randomly chosen between 512-2048 bytes, to prove that our evaluation process is not affected by frame size. We have created 30 CBR traffic. Sum of each sender's transmission rate is represented as *offered load*.

In each experiment, we run the simulation on the 1500 x 500 m^2 field for 700 seconds. We start measuring from 100 seconds and up to 700 seconds. Every plots in these graphs is the average of at least 50 simulations. As a default parameters of each simulation, we define the number of stations as 50. And each node moves according to Random Waypoint with parameters $max\_speed = 10\,(m/sec)$, $min\_speed = 0\,(m/sec)$, $pause\_time = 50\,(sec)$.

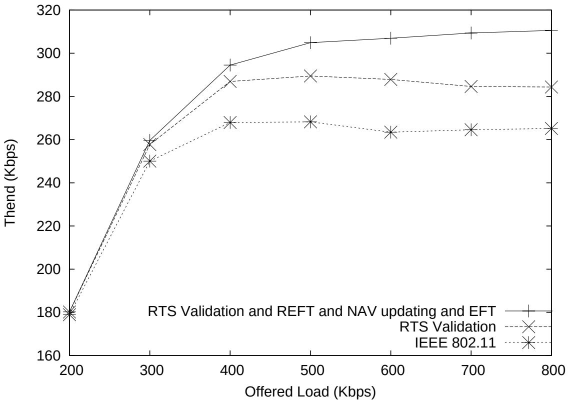

Figure 6: End to End Throughput (T_e) as a function of offered load

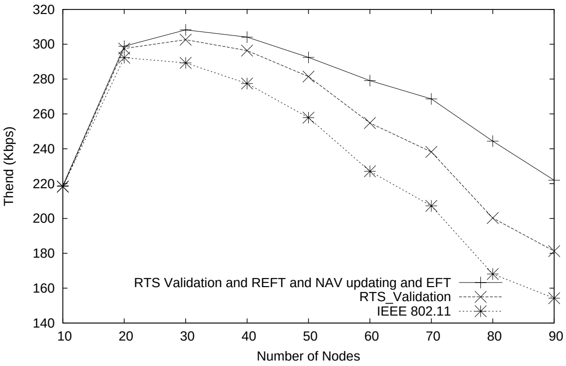

Figure 7: End to End Throughput (T_e) as a function of number of Nodes

5.2 Results and Analysis

In this section we compare the performance between our proposed schemes with RTS Validation. We ran our simulation in two different scenarios. In one, the offered load is varying in between 200 kbps to 800 kbps and in another, the number of nodes is varying from 10 to 90.

We evaluate the effects of our schemes mainly in terms of end-to-end throughput (T_e) and MAC layer throughput (T_M) with above two scenarios. T_e is computed as the total amount of CBR data successfully sent by source node and received by destination node per unit time. T_M is computed as summation of data frame size successfully sent by each node per unit time. Suppose, u_i is the data frame size in bit successfully transmitted by node i. If the total transmission time is t, then T_M in bits per second (bps) is defined as:

$$T_M = \frac{\sum_{i=1}^{i=N} u_i}{t} \tag{1}$$

Figure 6 and Figure 7 show the improvement compared with IEEE 802.11 standard and RTS Validation with two scenarios.

Figure 6 shows end-to-end throughput (T_e) of various schemes with respect to network traffic load. When offered load is low where the interruption of RTS/CTS is not so much frequent, all the schemes shows similar T_e. As traffic increases, throughput of our proposed schemes achieve highest T_e due to the channel reuse effect.

When the number of nodes is varying, with the increase in number of nodes, interference also increases. As a result, the interruption of RTS/CTS handshaking occurs more frequently. In this case, the false blocking becomes severe, and it leads to performance degradation. Even in this condition, our combined scheme realizes the performance improvement up to 42 % compared to IEEE 802.11 standard (Figure 7).

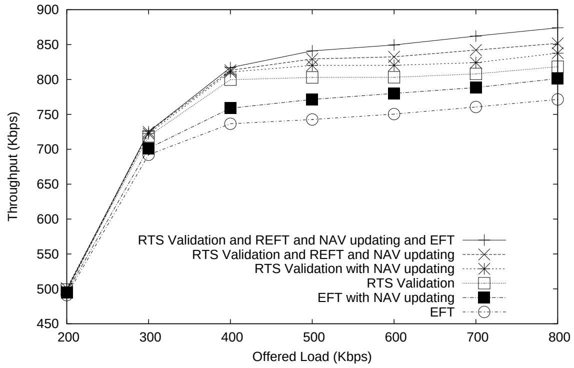

Figure 8: MAC layer throughput (T_M) comparison as a function offered load

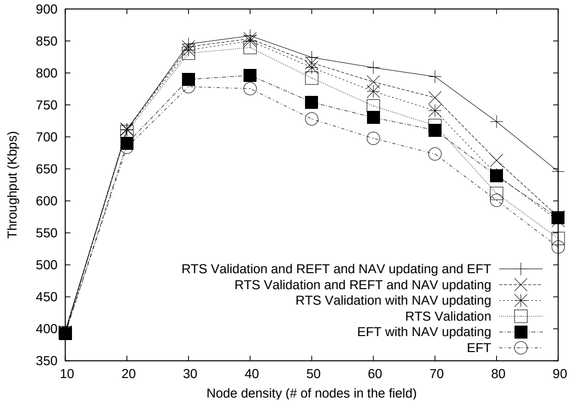

Figure 9: MAC layer throughput (T_M) as a function of node density

To analyze the effectiveness of our combination of schemes and give a clearer view, we show the comparison of throughput (T_M) as a function of offered load in Mac layer for six different combinations of schemes in Figure 8.

In case of offered load varying scenario, Figure 8 shows, NAV update scheme improves the T_M of Extra Frame and RTS Validation respectively. RTS Validation with NAV updating is more effective than Extra Frame with NAV updating due to the increase of occurrence of channel release. RTS Validation including its variants (RTS Validation with NAV updating and Reverse Extra Frame) yield high performance on proposed combination schemes.

On the other hand, when the number of nodes is varying, Figure 9 shows, T_M of RTS Validation including its variants is rapidly decreasing with the increase in number of nodes. In worst case, the performance of RTS Validation is less than that of Extra Frame with NAV updating. This is because RTS Validation and its variants are based on physical carrier sensing, they are very much sensitive to the number of transmission in the networks.

Even above severe condition, Extra Frame can keep improvement level higher due to its two fold advantage of sending extra frame as well as releasing the channel. The combination of EFT and R-EFT shows a much steadier nature even with increase in number of nodes. The improvement is more visible when the number of nodes are 60 or more.

Therefore combination of RTS Validation and its variants and Extra Frame works in a complementary style. This leads to high performance on both scenarios.

In our proposed combination of schemes, we reused the channel as aggressively as possible. So in order to verify whether there is any degradation in reliability by this enhancement, we measured the delivery rate of each unicast frame.

Packet Delivery Rate (R_p) is computed as:

$$R_p = \frac{\sum_{i=1}^{i=N} R_i}{\sum_{i=1}^{i=N} S_i} \qquad (2)$$

S_i means total data size of unicast data frame node i sent, R_i means total data size of ACK frame node i received.

Figure 10 and Figure 11 show CBR Packet Delivery Rate as a function of offered traffic load and node density for RTS Validation and IEEE 802.11.

In both scenarios, when the interruption of RTS/CTS is not so much frequent, all of the schemes shows similar R_p. But as the interruption of RTS/CTS handshaking becomes frequent, our combination of schemes yields higher R_p than others. This is because our schemes deliver more frames to the destinations due to releasing/reusing channel aggressively. Therefore with this results, we can verify that there is not degradation in reliability.

6 Conclusion

In this paper, we have shown the inherent inefficiency of the RTS/CTS handshaking mechanism in mobile ad

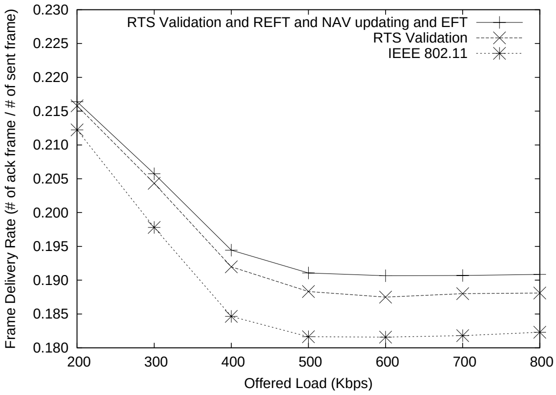

Figure 10: Frame Delivery Rate as function of offered load

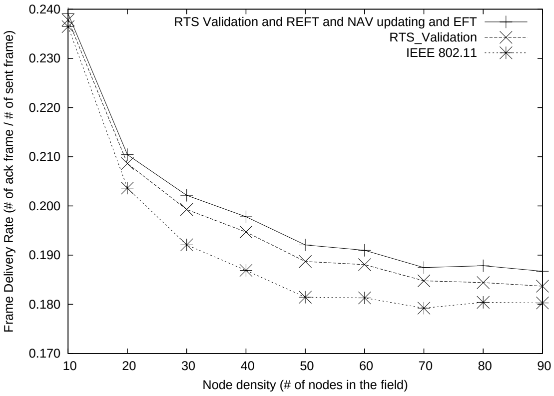

Figure 11: Frame Delivery Rate as a function of node density

hoc networks, when allocated channel is not utilized. We proposed an enhancement to the IEEE 802.11 that can aggressively reuse and release channel to overcome the inefficiency due to this otherwise wasted channel. Our enhancement does not suffer from any compatibility problems and generate no additional overhead, which is a vital criteria when network traffic is high.

Extensive simulations considering various scenarios have been done to evaluate our proposed schemes. It shows that our method considerably improves the throughput compared to standard IEEE 802.11 and other existing scheme and achieve more than 40% gain in throughput compared to IEEE 802.11.

Our aim is to further investigate various other situations, for example, using TCP traffic instead of CBR, different routing protocols, and influence of packet size on the performance, along with other simulation conditions. We also like to validate the effectiveness of our schemes through mathematical analysis.

Acknowledgement

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