Ensuring Effective Channel Release and Reuse Schemes on MANET

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abstract In wireless networks in order to avoid packet collisions due to hidden terminal problem, RTS/CTS handshaking mechanism is commonly used. However, in multihop topology, RTS/CTS handshaking may induce unnecessary blocking of channel and reduce the throughput. In this paper, we proposed schemes to overcome the performance degradation by using aggressive channel release and reuse. Our schemes are evaluated by using ns-2 simulator and it confirms that our solutions can achieves considerable improvement in throughput compare to standard and other competitive methods.

1 Introduction

In recent years, mobile and wireless communication has become more popular because of its convenience and low price. However, the communication over wireless medium can support very low bandwidth, together with high delay and error. Besides, collision detection is difficult to implement. All these issues need to be considered when designing access control for wireless medium. Many research [1, 2] have focused on developing the wireless medium access control (MAC) that efficiently share limited resources between all stations. Among these, the IEEE 802.11 MAC is clearly the most accepted and widely used one at present.

IEEE 802.11 introduces Request-To-Send/Clear-To-Send (RTS/CTS) handshaking protocol and Virtual Carrier Sensing to further reduce the probability of collisions that can occur due to hidden terminal problems.

However, hidden and exposed terminal problems exacerbate in MANET while using IEEE 802.11 [3]. The ultimate result is heavy degradation in throughput and instability of networks. It is shown that this problem is more severe in large and dense ad hoc networks [4]. 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 [10]. In worst case, it can lead to a pseudo deadlock situation when all the neighboring nodes may get blocked and can not transmit frames for long periods of time. This happens when RTS frame reserved the channel but the channel remains unused. Ray et al. [10] 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.

On the other hand, in [11], we proposed further aggressive schemes to release and reuse the unused channel with minimizing wasted channel as much as possible. To ensure that, we introduce "NAV updating" scheme to increase the probability of RTS Validation and our proposed channel schemes. In addition, to reuse the channel aggressively, we introduced two kinds of extra frame. For further performance improvement, we combined them together so that it works in a complementary way.

In this paper, we explain the proposed schemes in detail. Through simulations, we have shown that our scheme achieves considerable improvement in throughput compare to standard and other related methods. Moreover, our proposed solutions are compatible with standard IEEE 802.11, and therefore could be easily deployed.

The rest of this paper is organized as follows. In Section 2, we discuss the RTS/CTS mechanism and its effects on false blocking. Our proposed schemes to enhance IEEE 802.11 performance is explained in Section 3. Simulation results and evaluation of the proposed schemes are discussed in Section 4. Finally we conclude our work in Section 5.

2 Background

2.1 RTS/CTS Handshaking mechanism for carrier sensing

To determine whether the medium is available for transmission, carries sensing is used. MAC protocol used in DCF is CSMA. It is consists of two types of carrier sensing functions: (i) physical carrier sensing and (ii) virtual carrier sensing. For physical carrier sensing traditional CSMA is used, whereas, RTS/CTS (Request-To-send/Clear-To-Send) mechanism and NAV (Network Allocation Vector) is used for virtual carrier sensing as illustrated in Figure 1.

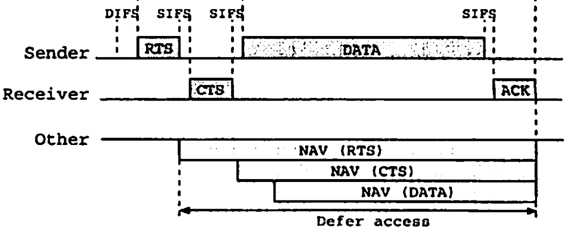

Figure 1: RTS/CTS access mechanism

RTS/CTS was first proposed in [2]. This protocol is called Multiple Access with Collision Avoidance (MACA) and in [1] a modified version of MACA for wireless (MACAW) is proposed, which includes a MAC level acknowledgment. IEEE 802.11 standard uses a variation of MACAW along with CSMA.

The effectiveness of RTS/CTS mechanism, due to its ability for early detection of collision from the absence of CTS, is examined in [8]. An absence of CTS implies a collision has occurred and with this idea, collision can be detected early. However, the protocol cannot free or reallocate the channel that was already reserved by the RTS frame. Stations receiving only the RTS frame but not CTS, cannot assume that the transmission is not taking place. Therefore, they defer the use of the channel for an interval declared in the last RTS. This results in wasting of channel capacity around the sender node.

2.2 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 different possible situations.

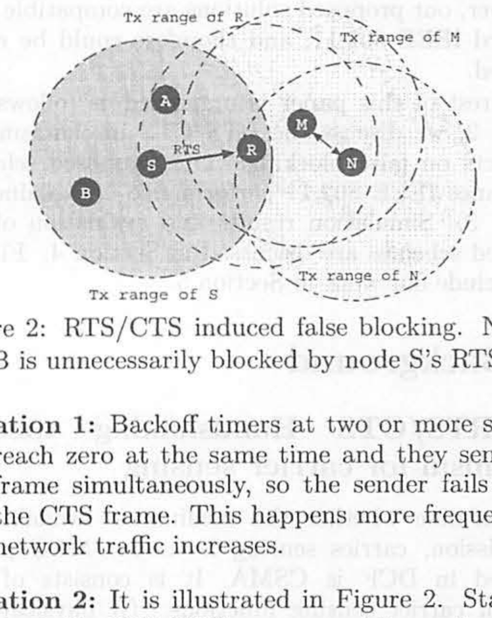

Figure 2: RTS/CTS induced false blocking. Node A and B is unnecessarily blocked by node S's RTS

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, which interferes the reception but is out of S's sensing range, is been carrying on say, between N and M. 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 the intended receiver moves to a new position, which is out of communication range of sender and cannot receive RTS.

The above situations regularly happen in MANET where stations route packets through each other in multi-hop fashion, as stations are free to move arbitrarily. In wireless network only a single node is allowed to transmit at a particular time and many nodes around the sender are 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 can not respond to the RTS frame. However, the *sender* interprets it as channel contention and enters backoff. Its neighboring nodes are prevented from decrementing backoff counter and from sending frames because of the NAV set by RTS.

These false blocking takes place because all the nodes that receives RTS inhibits themselves from transmitting. This problem can get severe when it occurs in circular fashion creating pseudo deadlock [10]. This unnecessary blocking leads to lower channel utilization and route failure. Therefore, releasing unused channel is an important issue. RTS Validation partially reduces the above problem but channel capacity is still wasted.

The proposed schemes in next section are to reuse the wasted channel capacity as much as possible, keeping compatibility with IEEE 802.11.

3 Enhancements for Efficient Channel Utilization

In this section, we present two approaches to reduce the wasted channel due to false blocking over MANET. In one, unnecessarily blocked channel are released. In the other, we considered two aggressive approaches to reuse the channel by using extra frames.

We have described channel release & reuse schemes, (i) modification of NAV operation, (ii) Extra Frame Transmission (EFT), (iii) Reverse Extra Frame Transmission (R-EFT) in different subsequent subsections. Finally we combine these schemes.

3.1 NAV updating scheme

In case of RTS Validation mechanism [10], 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. As a result, RTS Validation can not always 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:

1. We divided the original NAV in two parts: one is the sets of NAV_k indexed with the corresponding node's ID, and the other is NAV_{other}.
2. NAV used for the operation is calculated by the maximum value in the sets of NAV_k and NAV_{other}.
3. NAV_k is adjusted when overhearing RTS/DATA frame from node $node_k$. NAV_{other} is adjusted by cases, other than RTS/DATA frame, like receiving CTS frame or suffering from collision.

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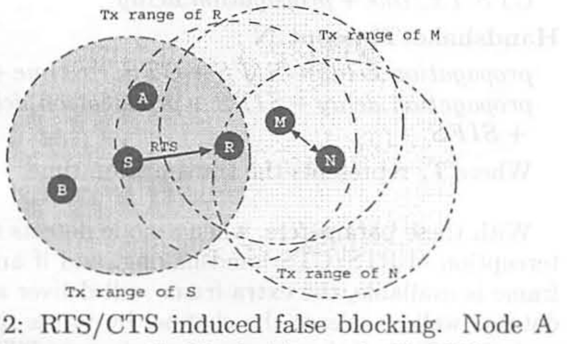

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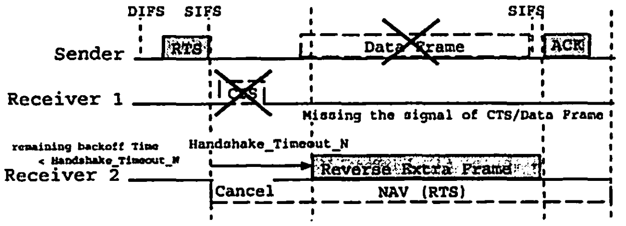

Figure 4: Reverse Extra Frame transmission

2. The length of the duration in reverse extra frame should be smaller than that of the duration specified in RTS.

3. 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 be sent in the near future. But due to the restriction imposed to prevent collision, Reverse Extra Frame may not be always available. When there is no 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.

3.4 Combination of RTS Validation and Extra Frame transmission

To minimize wasted channel as much as possible, in this section, we describe the way to allow nodes to perform channel release & reuse scheme concurrently.

EFT and RTS Validation [10] including R-EFT independently on sender node and neighboring nodes respectively. For further performance improvement, we propose an approach to combine RTS Validation and EFT schemes.

Since an appropriate Extra Frame can not be always available in the waiting queue of sender node, the channel reuse scheme is not available as frequently as RTS Validation scheme. Though if it is available, it has the ability to deliver data as an extra frame. To utilize this ability, we entrust mainly EFT with delivering the Extra Frame 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 the improvement of channel efficiency.

4 Simulation Result and Evaluation

Most widely recognized network simulator, *ns-2*, is used to evaluate the effectiveness of our mechanism. Performance comparisons between IEEE 802.11 standard [7], RTS Validation [10] 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 [9]. 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.

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. End-to-end throughput (Th_{end}) is computed as the total amount of CBR data successfully sent by source node and received by destination node per unit time. Every plots in these graphs is the average of at least 50 simulations.

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

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. Sum of each sender's transmission rate is represented as *offered load*.

As a performance metric end-to-end throughput (Th_{end}) of our proposed schemes is compared with RTS Validation and standard IEEE 802.11 varying the offered load with number of nodes set at 30, 40 and 50 respectively.

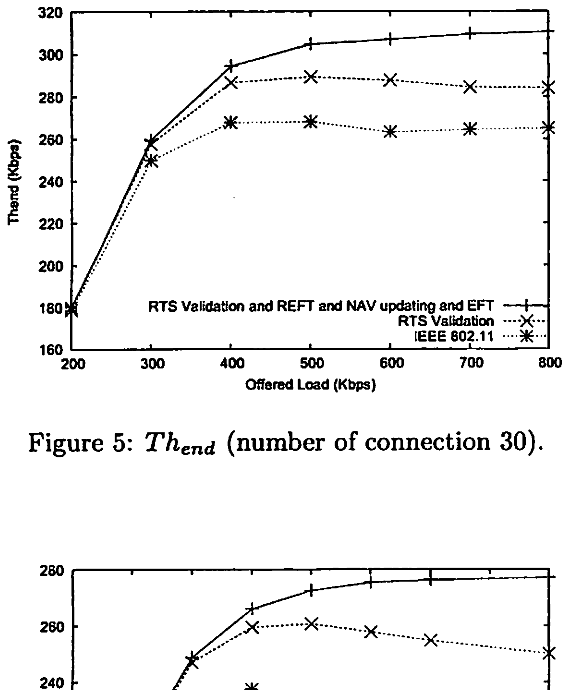

Figure 5: Th_{end} (number of connection 30).

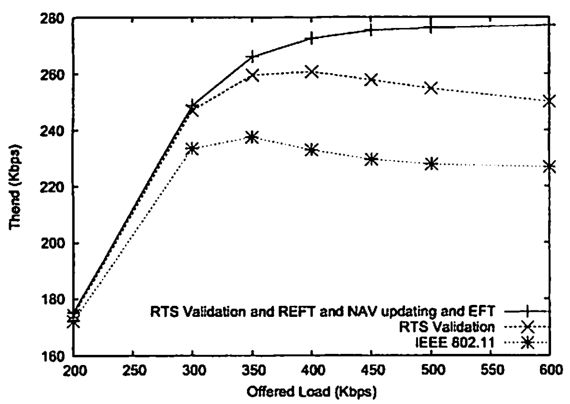

Figure 6: Th_{end} (number of connection 40).

Figure 5 shows Th_{end} of various schemes with respect to network traffic. When offered load is low, all the schemes shows almost similar throughput. In this case, the effect of channel reuse schemes can not be

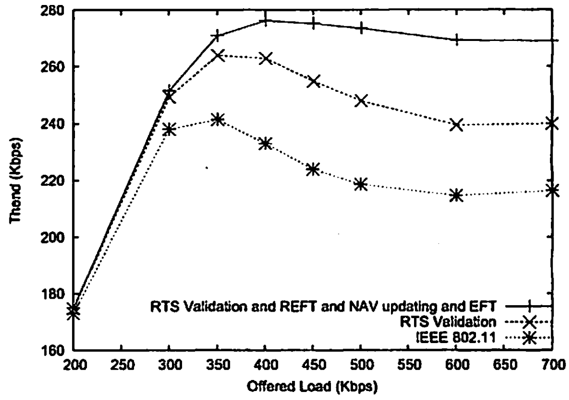

Figure 7: Th_{end} (number of connection 50).

expected because interruption of RTS/CTS handshaking does not occur so frequently. As traffic increases, due to the channel reuse effect, our proposed scheme achieves the highest throughput.

As the number of connection increases, with high traffic rate, both RTS Validation [10] and IEEE 802.11 shows performance degradation, because with the increase in number of connection, number of transmission also increases. This will cause more frequent false blocking. Even in such severe condition, our scheme shows much steady throughput as shown in Figure 6 and 7.

In another scenario, throughput is measured, where number of nodes in the network is a function of offered load, fixed at 450 kbps,

Th_{end}. Figure 8 shows IEEE 802.11 suffers from heavier performance degradation than in case of varying number of connection scenario. Even in severe condition, our scheme can realize higher Th_{end} than other schemes.

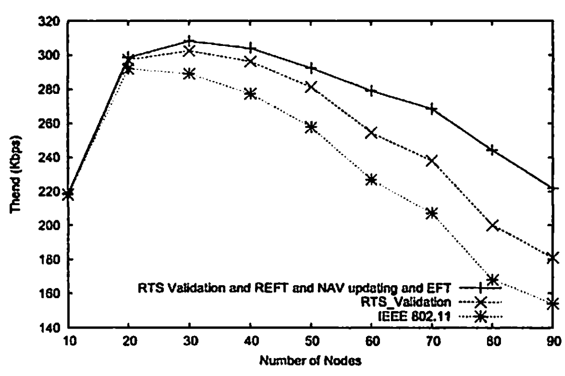

Figure 8: Th_{end} (number of connection 30 and offered load is fixed at 450 kbps).

This is because RTS Validation and its variants detect the interruption of RTS/CTS handshaking if any signal has not been sensed by physical carrier sensing. As the number of connections/nodes increases, more often frames will be reached. Thus interruption detection would be interfered more often resulting in performance degradation. While EFT scheme is invoked when CTS frame is missing, it is unrelated to physical carrier sensing used by RTS validation. Therefore, schemes combined with EFT can keep improvement level high due to its two fold advantage of sending extra frame as well as releasing the channel even when the number of connections/nodes is large. Complementing proposed schemes together leads to steady performance even with increase in number of connections/nodes.

5 Conclusion

In this paper, we have shown that our proposed approach of aggressive schemes can reuse and release wasted channel as much as possible. Simulations show that our method considerably improves the throughput compared to standard IEEE 802.11 and RTS Validation when false blocking occurs frequently. In our future work, we would like to further investigate the scope of improvement.

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