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Enhancing the QoS of wireless Ad hoc networks by improving the Throughput

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Abstract. The hottest research direction in wireless ad hoc network is in the field of throughput enhancement. The purpose of such analysis is to improve the throughput by allowing as much as possible concurrent transmissions among neighbouring nodes using single channel and by reducing the number of retransmissions which reduces the load on the channel. Using a high-throughput MAC protocol, called Concurrent Transmission MAC (CTMAC) protocol, which supports concurrent transmission while allowing the network to have a simple design with a single channel, single transceiver, and single transmission power architecture. By implementing the fragmentation algorithm in CTMAC a significant gain in throughput can be obtained compared with CTMAC. To avoid collision while accessing, a mechanism called Proportional Fair Contention algorithm is proposed. It is proposed that by adjusting the Length of access slot in the Additional control Gap (ACG), more number of concurrent data transmissions with more than two nodes is possible and the size of ACG is adjusted depending on the maximum tolerable interference power, also the number of entries in the Active neighbour list information. Simulation results designate that compared to CTMAC protocol, the proposed algorithm achieves a significant increase in network throughput thereby improving the Quality of service.

Keywords: Fragmentation, CTMAC protocol, Throughput, PFCR

1. Introduction

A wireless ad hoc network is a decentralized wireless network, where each node is willing to forward data for other nodes, and the determination of that master node is made dynamically based on the network connectivity. Since Ad hoc wireless networks promise convenient infrastructure-free communication, the routing requires that nodes cooperate to forward each others packets through the network. This means that the throughput should be maintained in such a way that, it ought to support concurrent transmission. Least configuration and quick deployment make ad hoc networks suitable for emergency situations like natural disasters or military conflicts. The presence of a dynamic and adaptive routing protocol will enable ad hoc networks to be formed quickly.

IEEE 802.11 DCF [4] has been regarded as the basic Media Access Control (MAC) protocol for MANETs. It is based on CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance), with extensions to allow for the exchange of RTS/CTS (Request-To-Send/Clear-To-Send) packets between the transmitter and the receiver before the actual transmission of DATA packets. It prohibits any concurrent transmission among neighboring nodes even when the transmission is possible. When the node A sends packets to node B, after exchanging control packets RTS/CTS between node A and B, the transmissions between other nodes are prohibited until the end of transmission A→ B as in Fig 1. In MANETs, a packet can be received successfully even if there exist other overlapping or interfering packets, only if its instantaneous power is larger than the instantaneous joint interference power by a minimum certain threshold

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factor. This effect is the capture effect, and the threshold factor can be called Signal-to-Interference-and-Noise Ratio (SINR).The above concept make concurrent transmissions possible between neighboring nodes in a MANET by using CTMAC protocol which is distributed and adaptive MAC protocol.

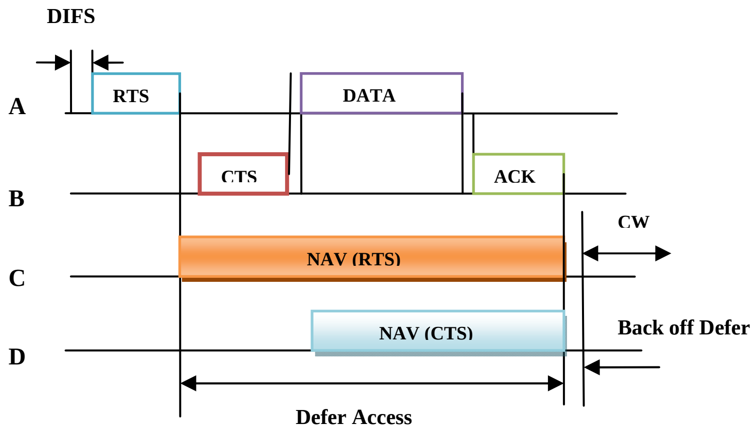

Fig. 1: An illustration of IEEE 802.11

The rest of the paper is organized as follows: Section II describes the related work pertaining to the paper. Section III depicts the basic design of CTMAC protocol using Fragmentation and then the algorithm is meticulously discussed and the results are summarized in later sections.

2. Literature Survey

The authors of [3] proposed a new protocol called POWMAC uses an access window (AW) to allow for a series of RTS/CTS exchanges to take place before several concurrent data packet transmissions can commence. The length of the AW is dynamically adjusted based on localized information to allow for multiple interference limited concurrent transmissions to take place in the same vicinity of a receiving terminal. Compared to CTMAC protocol it uses an extra packet Decide to send (DTS) to inform the neighbors about the power level that is used for data transmission. Jae Hyun Kim et al. (2000) [2] suggests the performance of wireless media access control (MAC) protocols with Rayleigh fading, shadowing, and capture effect are analyzed. CSMA/CA protocols are based on the standard for wireless LAN's IEEE 802.11. The throughput and packet delay of CSMA/CA in a radio channel model show better performance than in an error-free channel model in high-traffic load.

The Disadvantage of CTMAC protocol is that the throughput may be degraded due to lack of acknowledgement which leads to retransmission of Data packets. This can be overcome by using a Fragmentation algorithm, which adjusts the fragment size dynamically depending on the channel quality.

When the channel quality is bad shorter Frame size is used, and when the channel quality is good longer Frame size is used. Also the throughput can be further enhanced by adjusting the number of access slot in the additional control gap, which depends on the Maximum tolerable interference, and also the number of entries in the Active neighbour list.

3. Proposed Architecture

CTMAC protocol is a distributed, asynchronous and adaptive MAC protocol. It requires a very simple standard IEEE 802.11 circuitry, and works on the single channel and single transmission power architecture.

3.1. Operations of CTMAC Using Fragmentation

The operation of CTMAC using fragmentation is illustrated in Fig. 2. Consider the transmissions A → B , C → D and E → F. Node A first transmits an RTS packet to node B, including information such as the scheduled start times of A's DATA packet and B's ACK packets. Node B replies with a CTS packet to node A, including similar information.

This information is needed so that a node in the neighborhood of A or B can determine whether or not it can receive a data packet from some other node concurrently while A is transmitting data packet to B. Once

RTS/CTS packets are exchanged, node A (Master Node) ceases from sending its data packet for the duration specified by ACG. During the ACG period the slave transmitter, or the receiver exchange control packets and schedule their transmission if possible. If the transmission between node C → D and E → F is successfully scheduled, then the three transmissions can be done parallel if it satisfies the two essential requirements: First the starting time of node A's DATA packet will be the same as node C's DATA packet. Second the data packet size of master node should be greater than or equal to slave node to avoid the collisions.

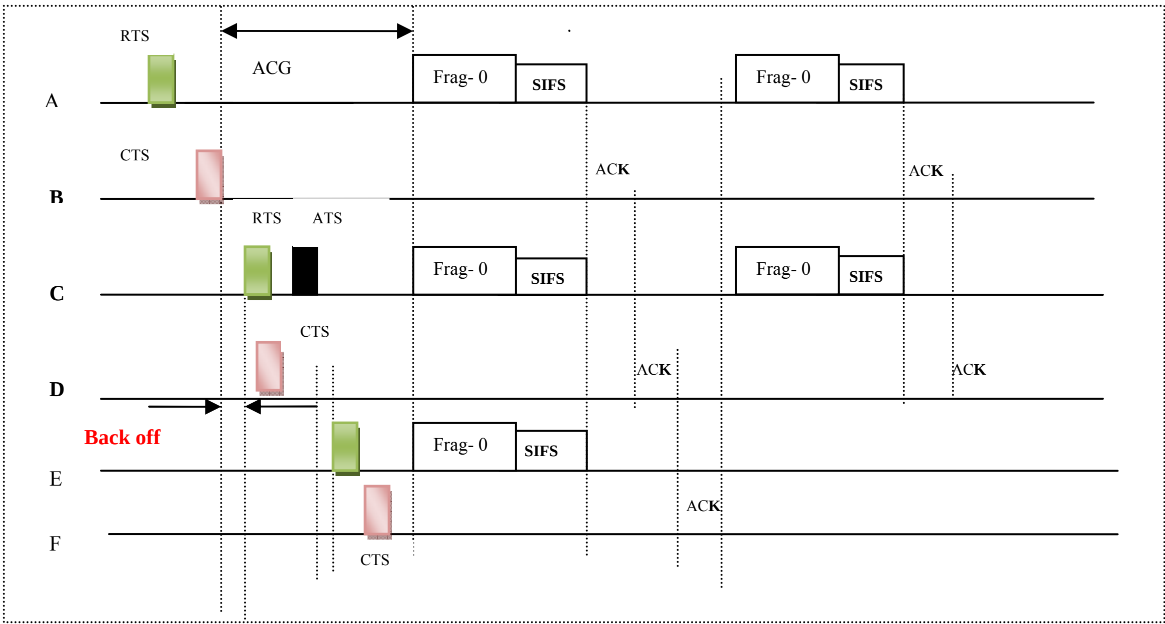

Fig. 2: Operation of CTMAC using Fragmentation

After maintaining the ANL information (discussed later) the Data packets are fragmented and send concurrently in order to avoid the retransmission of data packets, thereby improving the throughput. Also to avoid collision the ACK packets are sequenced.

3.2. Maintaining Active Neighbor list

For concurrent transmission control the information has to be recorded in the Active Neighbor list (ANL). For concurrent transmissions the nodes has to exchange more control packets. To utilize potential concurrency in CTMAC, an additional control gap (ACG) is inserted between the RTS/CTS/ATS (Abort-To-Send) packets and the DATA packet. When a node receives control packets destined for other nodes, it does not need to immediately postpone its transmission. Rather, it records necessary information in its ANL. For the concurrent transmissions to proceed successfully, the interferences between them should be tolerable. A node updates its ANL only when it receives control packets that are destined for other nodes. Based on the packet received, a node takes one of the following four actions:

ADD: Adds an entry in its ANL to record the information obtained from the packet, when the node receives a RTS or a normal CTS packet, it. However, if the received packet is a negative CTS packet, the node will do nothing.
MODIFY: The node will update the corresponding entry with the new value, if the received packet is an ATS packet carrying a T_{data} or T_{ack} value different from the previous RTS from the same node,
DELETE: When an aborting ATS is received, the node deletes the corresponding entry from its ANL.
EMPTY: If the transmission has finished successfully, it will empty its ANL.

3.3. Updating ACG

The need for updating the additional control gap is to allow more number of nodes to transfer data packets, thereby increasing the throughput of the network. The Size of ACG depends mainly on the number of entries in the Active neighbor list as in Table 1.

Table. 1: ANL Information

	Node A	Node B
ANL	$A_{address}$, G_{ab}, $T^{(ab)}_{data}$,	$B_{address}$, G_{ab}, $T^{(ab)}_{data}$, $T^{(ab)}_{ack}$, D, $P^{(a)}_{MTI}$
RTS(A→B)		
CTS(B→A)		

The Abbreviations are expanded as below.

- $A_{address}$ is the address of the active node *A*.
- G_{ab} is the estimated channel gain between nodes a and *b*, computed as follows: $G_{ab} = \frac{P}{P}$ where $P^{(b)}_{rx}$ is the signal power of the received control packet of node A, and P_{tx} is the single transmission power, which is common to all nodes.
- $T^{(ab)}_{data}$ and $T^{(ab)}_{Ack}$ are the starting times of the DATA and ACK packets of the transmission between nodes A and B . $P^{(a)}_{CNT\_D}$
- MT*I* is the maximum tolerable interference of a receiver node A, denoted by .

The aim is to choose an ACG size that maximizes the chances of concurrent data transmissions. To achieve that, terminal B examines two history values: the actual interference perceived by terminal B during its reception, and the number of concurrent data transmissions and receptions in B's vicinity. To prevent fluctuations in the ACG Values, the ACG size is incremented or decremented in steps of 1. To ensure the correct completion of the concurrent transmissions, and to avoid collision between Data packet and Acknowledgement (ACK) packet, ACK packet sequence mechanism is used.

4. Implementation and Results

```
Algorithm 1 Modified CTMAC Protocol
Algorithm
CASE: RTS HEARD FROM Node
If "ANL is Empty"
        Packet belongs to MASTER node
        Exchange control Packets
then
                Insert ACG
                Use PFCR algorithm to avoid
                collision
                Other nodes exchange control
                packets and Update ANL.
else
        SLAVE node exchange control packets.
        Update information in ANL
end if
CASE: TIMER EXPIRED
If  Data packets areTransmitted
        then
        ACK packets send by sequence
        First Master node sends ACK
        Second Slave node
end if
```

```
if ACK TIMEOUT AND Node status is "Waiting
for Secondary ACK" then
        Fragment the data packet size to shorter
        Frames
        else
        Fragment the Data packet size to Longer
        Frame size
end if

CASE:  Increasing ACG for more
Simultaneous transmission

            Number of Access slot (N_ACG)
            set to 1(one master and one slave).
            Values has o be increased until
            reaches threshold value.

            If
                No. of Concurrent slave
            Transmission ≥ N_ACG
             then
                N_ACG = N_ACG      1
```

In CTMAC protocol, when a packet is not acknowledged successfully or is discarded, a retransmission will be scheduled. Retransmissions are the main causes of poor throughput performance and channel utilization. Even though the MAC ACK can shorten the delay overhead of retransmissions, it is still a main factor of performance degradation, especially in the wireless environment, where retransmissions are mainly caused by frame errors rather than collisions.

Normally collisions may appear as frame errors at the receiver end. The maximum throughput can be obtained by dynamically changing the frame size according to variations in wireless channel quality. When the channel quality is good, a longer frame size could be used; similarly, when the channel quality is bad, a shorter frame size is used to lower the number of retransmissions.

5. PERFORMANCE ANALYSIS

Fig. 3 shows the comparison of performance of CTMAC and CTMAC-F with number of nodes. As the number of nodes increases the throughput will increases. Let us assume there are m transmission pairs where the transmitter is saturated. The destination nodes of all transmissions are chosen randomly from nodes in the neighboring grids of the corresponding transmitters. The density of nodes greatly affects the network throughput under CTMAC scheme. With the increase of node density, the average distance between the transmitter and the receiver is decreasing, because the receiver is in the neighboring grids of its transmitter. Thus, the number of schedulable simultaneous transmissions increases, resulting in the enhancement of throughput. There will be more potential concurrent transmissions if there are more contending transmissions. By using the fragmentation steps in CTMAC the throughput can be further increased about (80%) compared to CTMAC protocol.

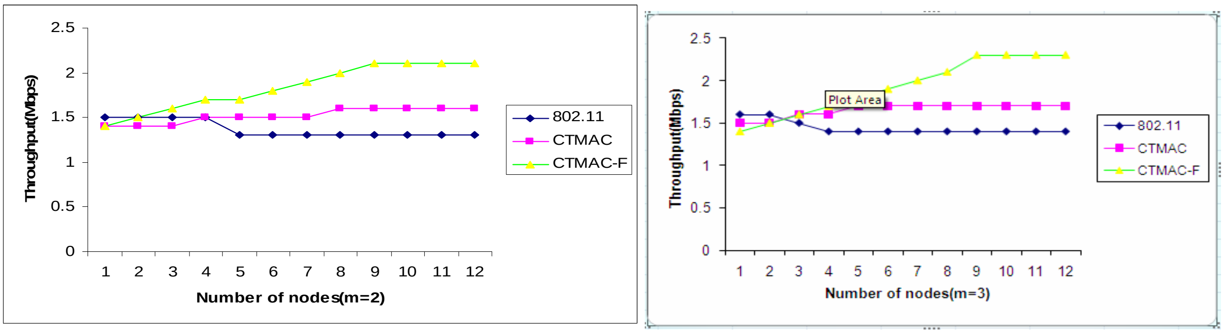

Fig. 3: Performance of CTMAC-F and other protocols.

6. CONCLUSION AND FUTURE WORK

In today's world wireless Ad hoc network is used all over and the need for High throughput MAC protocol can be achieved by using concurrent transmission among neighboring nodes called CTMAC protocol with fragmentation. Besides tuning the parameters of CTMAC and investigating its performance under various scenarios, our future work will also address other techniques for capacity enhancement.

7. Acknowledgements

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