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Analysis and the Performance Effectiveness of RTS /CTS mechanism in IEEE 802.11

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Abstract:
IEEE 802.11 is one of the most organized technologies in wireless LANs.There are two access mechanism of IEEE 802.11 DCF; Basic access mechanism and RTS/CTS mechanism. There are several parameters that have significant impact on network performance when RTS/CTS mechanism is taken into account. The Parameters include packet payload, network traffic, and interference range, mobility of node and fairness issue. In this survey paper,we find the performance efficiency on several parameters.
Keywords: Wireless LAN, RTS/CTS,IEEE802.11,DCF etc

1. INTRODUCTION

Wireless communication is one of the fastest-growing technologies. The demand for connecting devices without the use of cables is increasing everywhere. Wireless local area networks (WLAN) are being developed to provide high bandwidth to users in a limited geographical area. Data rates for WLANscan be expected to range from 1Mbps to 20Mbps (now to 54Mbps). Wireless LANs can be found on college campuses, in office building, and in many public areas. Wireless technology has helped to simplify networking by enabling multiple computer users to simultaneously share resources in a home or business without additional or intrusive wiring. These resources might include a broadband Internet connection, network printers, data files, and evenstreaming audio and video. This kind of resource sharing has become more prevalent as computer users have changed their habits from using single, stand-alone computers to working on networks with multiple computers, each withpotentially different operating systems and varying peripheral hardware.

In an ad hoc wireless network where mobile units employ Omni-directional antennas, each communication channel is shared by closely located mobiles. The sharing of this channel is controlled by the employed Medium Access Control (MAC) protocol. The network’s throughput efficiency is determined by the working of this MAC protocol. To further increase the efficiency of the operation, carrier sense based MAC algorithms are used, requiring the mobile terminal to first sense the channel to determine that it is idle and only then attempt its packettransmission.IEEE has defined the specifications for a wireless LAN, called IEEE 802.11, which covers the physical and data link layers. The IEEE 802.11 wireless LANs, also known as Wi-Fi [1], has been classified into several standards including 802.11b, 802.11a, and 802.11g. The 802.11b and 802.11g are working in the 2.4 GHz Industrial-Scientific-Medical (ISM) band. The 802.11a operates at 5 GHz Unlicensed National Information Infrastructure U-NII/ISM bands in the US, and license-free 5 GHz bands elsewhere. Unlicensed frequency band of 2.4 - 2.485 GHz is an increasingly cluttered zone with interferences from microwave ovens, cordless phones, wireless cameras, Bluetooth and other RF solutions. The 802.11g WLAN has a data rate up to 54 Mbps like 802.11a but in lower frequency. Although 802.11a version enjoys more available channel for frequency, it suffers from multi-path propagation. In other words, with a certain power level, 802.11a has a shorter transmission distance, in comparison to 802.11g.

IEEE 802.11 is a set of medium access control(MAC) andphysical layer (PHY) specifications for implementing wireless local networks (WLAN)[3] computer communication in the 2.4,3.6,5 and 60 GHz frequency bands. They are created and maintained by the IEEE LAN/MAN Standards Committee (IEEE802). The base version of the standard was released in 1997 and has had subsequent amendments. The standard and amendments provide the basis for wireless network products using the Wi-Fi brand. While each amendment is officially revoked when it is incorporated in the latest version of the standard, the corporate world tends to market to the revisions because they conciselydenote capabilities of their products.Basic Service Set:IEEE 802.11 defines the basic service set (BSS) as thebuilding block of a wireless LAN. A basic service set is made of stationary ormobile wireless stations and an optional central base station, known as the access point (AP). Figure 1(a) shows two sets in this standard. The BSS without an APis a stand-alone network and cannot send data to other BSSs. It is called an ad hocarchitecture. In this architecture, stations can form a network without the need ofan AP; they can locate one another and agree to be part of a BSS. A BSS with anAP is sometimes referred to as an infrastructure network.

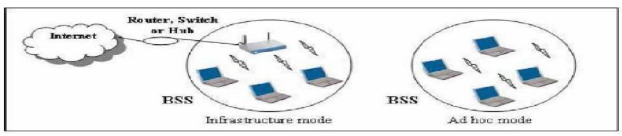

Fig 1(a): Basic Service Set

Extended Service Set: An extended service set (ESS) is made up of two or more BSSs with APs. In this case, the BSSs are connected through a **distribution system**, which is usually a wired LAN. The distribution system connects the APs in the BSSs. IEEE 802.11 does not restrict the distribution system; it can be any IEEE LAN such as an Ethernet. Note that the extended service set uses two types of stations: mobile and stationary. The mobile stations are normal stations inside a BSS.
The stationary stations are AP stations that are part of a wired LAN. Figure 1(b) shows an ESS.

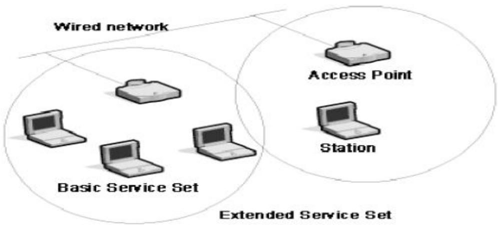

Fig 1(b): Extended service set

2. RTS/CTS mechanism:

This mechanism extends the basic method with the exchange of Request-to-Send (RTS) control packet and Clear-to-Send (CTS) control packet prior to the exchange of DATA and ACK packet. This is also known as request-to-send/clear-to-send (RTS/CTS) access method. Before transmitting a packet, a station operating in RTS/CTS mode "reserves" the channel by sending a special Request-to-Send (RTS) short frame. The destination stationacknowledges the receipt of an RTS frame by sending back a Clear-to-Send (CTS) frame, after which normal DATA packet transmission and ACK response occurs. Since collision may occur only on the RTS frame, and it is detected by the lack of CTS response, the RTS/CTS mechanism allows increasing the system performance by reducing the duration of a collision, especially when the DATA packets are large. It also solves the hidden terminal problem experienced in wireless networks. Here we present the main feature of IEEE 802.11 DCF, with respect to RTS/CTS access method. When a transmission is detected on the channel and reactivated when the channel is sensed idle again for more than a DIFS. The node transmits a Request-to-Send (RTS) packet. If a node receives an RTS packet, it responds, after a SIFS, with a Clear-to-Send (CTS) packet. The transmitting node is allowed to transmit its DATA packet only if the received CTS packet is correct, which is then replied with an ACK packet. The RTS and CTS packet contains the total duration of packet transmission. All the neighbor nodes that overhear either the RTS or CTS, update their Network Allocation Vector (NAV) for that duration of time in which the channel will remain busy and these nodes defer their transmission for that duration when the NAV is set (Figure 2). This allows a collision-free transmission for the DATA and ACK packet. This mechanism of deferring transmission based on the NAV is known as virtual carrier sensing and it effectively reserves the channel for the current dialog. The RTS/CTS mechanism is very effective in terms of system performance, especially when large packets are considered [4], as it reduces the length of the control packets involved in the contention process.

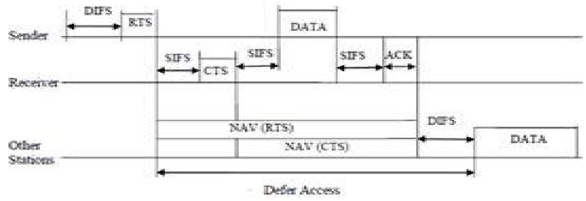

Fig 2 : RTS/CTS method

3. Effect of following parameters on RTS/CTS mechanism

Several parameters including packet payload, network size, large interference range, mobility of node and fairness affects thenetwork performance with and without RTS/CTS mechanism. A survey is done based on these parameters to find the effectiveness of RTS/CTS mechanism. Throughput and access delay as performance metrics.

3.1- Effect of packet payload

Packet payload is the payload size of the data packet. Throughput performance is strongly dependent on load offered to the system.RTS/CTS mechanism has positive and negative effects in different situations. When packet size is 68 Bytes throughput is more when RTS/CTS is off .Access delay is more when RTS/CTS is on for 68 Bytes in presence of hidden terminals [2].Hidden terminal is not assumed in [5,6,7].The throughput performance is more effective when payload size is more than 6000 bits with RTS/CTS on in presence and absence of hidden terminal. This is due to the fact that collisions take place with small RTS packets only. Overall performance is not affected under low load as compared to high load when collisions take place due to hidden terminal problem. Authors in [2] also simulated on per station basis i.e. one station uses RTS/CTS mechanism, others do not. It has been shown that there is no individual gain for each station but there issmall degradation in overall performance. The trade-off between pros and cons of RTS/CTS show that it is profitably applied in conjunction with the adaptive contention window only for long packets (6000 bits), while in the basic standard; it provides benefits for packets longer than 2000 bits [8].Authors in [8] proposed an Adaptive Contention Window mechanism, which dynamically selects the optimal back off window. They showed that adaptive technique shows better performance only when the packet size is short. They found in adaptive mechanisms that performance degrades even though the RTS/CTS mechanism is applied in presence of hidden terminals. Thus RTS/CTS mechanism proves better for large packet sizes. Small packet sizes induce overhead in network performance.

3.2 Effect of Network traffic

There is a great influence on network performance when network traffic is considered i.e. number of nodes or stations. It is more desirable to apply RTS/CTS mechanism when network size increases considerably. The authors in [5] illustrates that the basic access performs better than RTS/CTS when the number of contending stations is relatively small (n=5) for all packet size values.RTS threshold decreases as number of contending stations increases.

Authors in [10] used Bianchi model [9] and analyzed throughput for 1Mbps and 6Mbps with different maximum back off stages with varying network size. It has been observed that saturation throughput increases with maximum back off stages.RTS/CTS mechanism shows better performance as number of station increases for 1000 octet packet size. Basic access mechanism outperforms RTS/CTS mechanism only when number of nodes is less than 20[10].Thus RTS/CTS mechanism outperforms basic access scheme when network traffic is heavy under ideal conditions.

3.3 Effect of large interference range

Interference range is the range in which nodes in receiving mode is interfered by unrelated senders. Figure 3 shows that d is distance between sender and receiver, Riis the interference range and Rtx is transmission range in which nodes can successfully receive nodes at receiver.RTS/CTS mechanism is ideally used to reduce collisions due to hidden terminal problem only when hidden nodes are within the interference range of receiver. But practically it is not possible due to large interference range.

Authors in [11] has proved mathematically that network performance degrades with RTS/CTS mechanism when distance between sender and receiver i.e. d exceeds transmitter range. Authors have assumed 10db as capture threshold. Interference range is receiver centered. Large physical carrier sensing range helps in reducing interference. There is hardware limitation when large carrier sensing is considered. Single chain topology with 190 meters of inter nodal distance is shown in figure 4. Transmission range is 250 meters and interference range is 550 meters.Channel utilization is 1/3 of capacity of chain without large interference range. This is because when node 1 transmits, node 2 and node 3 cannot transmit simultaneously. Channel utilization is ¼ of capacity of chain with large interference range. The reason lies behind the fact that now node 4 also cannot simultaneously transmit along with node 2 and node 3.Large interference range results in more collisions on control frames and data frames which results in TCP instability and unfairness [12].Authors in [10] proposed CCR (Conservative CTS reply) scheme to combat large interference range. In this scheme a node only replies a CTS packet for a RTS when the receiving power of that RTS packet is larger than a certain threshold (CTS-REPLY-THRESHOLD), even if the RTS packet is received successfully and this node is idle. This CTS-REPLY-THRESHOLD should be larger than the threshold required for a node to successfully receive a packet. Many simulation experiments were performed which reduced most number of collisions.

Authors in [13] proposed Adaptive MAC layer scheme (AMAC) by analyzing [10] .They simulated various experiments on chain topology and random topology to find the throughput and data packet corruption ratio. We observe that AMAC scheme is more effective in terms of throughput as compared to CCR scheme as it needs more hops to reach destination.

Thus collisions caused by large interference range are mostly reduced when RTS/CTS mechanism is applied with AMAC or CCR scheme.

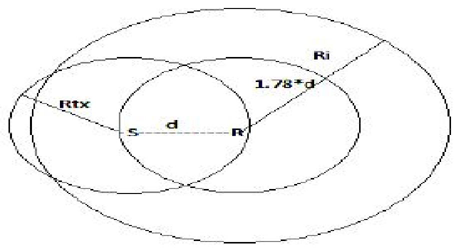

Fig 3: Effecetiveness of RTS/CTS when d is larger than Transmitting Range

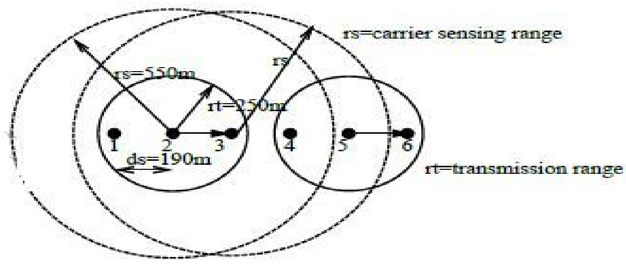

Fig 4: Effect of interference to capacity of chain

123456rs=550mrsrt=250mds=190mrs=carrier sensing rangert=transmission range.

3.4 Effect of mobility of node

Authors in [14] performed simulations considering mobility of node with and without RTS/CTS mechanism. Hidden nodes are considered with simulation time of 800 seconds in chain topology. It is inferred from [13] that as node moves during 350 seconds to 650 seconds collisions occurred and hence retransmission of packets takes place. The author also concludes that retransmission attempts are 8 times lesser when RTS/CTS scheme is disabled. This happens because when RTS/CTS scheme is enabled, control packets transmission takes place which reduces number of collisions and therefore retransmissions of data packets reduces. Thus there is significant drop in collisions when RTS/CTS scheme is enabled. Hence RTS/CTS mechanism plays a vital role in hidden node problem when mobile nodes are considered.

3.5 Effect of fairness

Fairness is one of the major issues in adhoc networks. Fairness means sharing of channel utilization. In paper [15], authors have proposed new back off scheme in 802.11 MAC standards. Fair share estimation is calculated at all nodes present in network. In new back off scheme, if a node estimates that it has got more share, it will double its contention window size until it reaches a maximum value (CWmax) so that its neighbors can have more chances to recover earlier from back off procedure and win access to the channel and vice versa. If a node estimates that it has got only its fair share, it will hold onto its current contention window size. Simulations results show that the new back off scheme has achieved far better fairness than original back off scheme. But this fairness is achieved at some cost of lower throughput.

In paper [16], authors have introduced fairness index that is useful in all resource allocation schemes. Jain's fairness index is unit for fairness as considered in [15].Particularly in distributed systems, where a set of resources is to be shared by a number of users, fair allocation is important. If goal is to provide the same throughput to all nodes, the fairness index is calculated as follows:

$fairnessindex = (Ti)\ 2\ nTi2$

where T is the throughput of a particular flow and n is the no of flows in the system. Authors in [5] have evaluated the fairness in grid and cross topologies. Fairness increased about 20% when RTS/CTS scheme is enabled.

Jain's fairness index decreases as number of hosts increases. This happens mainly due to the fact that after a collision, the first host that successfully transmits a frame is favored compared to the others but fairness index remains acceptable [17].Thus RTS/CTS scheme is beneficial in achieving fairness in grid and random topologies but it is not beneficial in chain topologies.

4. CONCLUSION

When RTS/CTS mechanism is taken into consideration several parameters have significant impact on networkperformance**.** We have analyzed that RTS/CTS mechanism is very effective for large packet sizes whereas for small packet size it incurs a delay by the additional load of the RTS and CTS packets before the actual transmission of the data packets**.**

As we conclude that forimproving the default RTS/CTS mechanism is to decrease the induced overhead innetwork performance due to control packe***ts.***Use of RTS/CTS is advantageous in different situations

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