ECE 578
FUNDAMENTALS OF COMPUTER NETWORKS

Project – 1
Simulating the Distributed Coordination Function (DCF) of 802.11

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CONTENTS

INTRODUCTION

This project deals with the software implementation and performance analysis of different variants of carrier-sense multiple access with collision avoidance (CSMA/CA), in compliance with the 802.11 Distributed Coordination (DCF) protocol. DCF is the fundamental medium access control (MAC) technique of the IEEE 802.11-based WLAN standard. DCF uses a binary exponential backoff algorithm with CSMA/CA. CSMA/CA is a network multiple access method in which virtual carrier sensing may or may not be enabled. The use of virtual carrier sensing reduces the amount of time wasted on detecting packet collisions. In general, the nodes attempt to avoid collisions by beginning transmission only after the channel is sensed to be idle. When it does transmit, a node transmits its packet data in its entirety. If the channel is idle, the node waits for a randomly chosen period of time known as the backoff period.

In this report, we analyze the performance of two different network topologies after simulating their behavior. The first scenario involves a Single Collision Domain with Nodes A and C transmitting data to nodes B and D respectively. This involves parallel transmission within the same collision domain. The second scenario deals with the hidden terminal problem where Nodes A and C act as hidden nodes while transmitting data to node B. For both scenarios, we simulate the standard CSMA/CA as well as CSMA/CA with virtual carrier sensing (VCS) enabled. As part of this project, we also evaluate parameters such as throughput, number of collisions and fairness index and plot their graphs as a function of the packet arrival rate (λ). This rate of arrival determines the arrival times of the random Poisson-distributed traffic.

The project was divided into two scenarios between the group members. While Jeffin focused on the Single Collision Domain, Safkat concentrated on Hidden Terminals. Relevant simulation data were collected, corresponding graphs were plotted as per the requirement of the project report and finally, detailed interpretations were provided on the outcomes.

DEVELOPMENT OF SIMULATIONS

The different scenarios were developed and simulated via MATLAB. For devising the algorithmic part of the project, the group members arranged regular discussion sessions and utilized online resources. All the parameters defined in the project specification were used for the simulations. We initially worked with very low simulation times in order to focus on the transmission of only a few packets. The timing diagrams obtained on a small scale were compared to expected timelines drawn by hand. We attempted to explore all possible test cases such as ACK-DATA collisions, RTS_A-RTS_C collisions and RTS-CTS collisions in order to model the scenarios as accurately as possible. Finally, the simulation time was increased as per the requirement of the project and the operation of the network was verified using the MATLAB workspace and timing diagrams.

The Poisson distributed traffic was generated by first drawing random samples from a uniform distribution and then converting them to exponentially distributed samples with the parameter (λ). These sample values were then converted to arrival times and eventually to slot numbers. The various parameters such as DIFS, SIFS, Contention Window (CW), Backoff Period, ACK, and Packet length were initialized, and the simulation ran in a loop for a period of 10 seconds.

a) **Single Collision Domain CSMA/CA:**
   The simulation consists of a set of conditional statements that monitor the current status of Nodes A and C. Collisions take place only when both nodes choose the same backoff value. In this case, both nodes will choose a new backoff period after doubling their contention window so that the probability of a collision now gets reduced.

b) **Single Collision Domain CSMA/CA with VCS:**
   For modeling and simulating this scenario, additional lines were inserted to the code for the single collision domain CSMA/CA without VCS in order to handle RTS, CTS and to freeze the relevant node (for a period of NAV_RTS). Only collisions caused due to the same backoff value i.e., RTS_A-RTS_C collisions, were required to be considered for this scenario.

c) **Hidden Terminals CSMA/CA:**
   In this case, nodes A and C reside in different collision domains and cannot hear each other. These nodes send data packets to a common access point, B. The successes and collisions at this receiver were monitored by taking data

packet collisions, ACK_A-DATA_C collisions and ACK_C-DATA_A collisions into account during simulation.

d) Hidden Terminals CSMA/CA with VCS:

Implementing VCS within the standard Hidden Terminals CSMA/CA involved freezing the relevant node (for a period of NAV_CTS) after successful receipts of CTS at both nodes. For accurate modeling of this scenario, RTS_A-RTS_C and RTS-CTS collisions at the receiver were monitored.

RESULTS

1. Throughputs at Node A and C:

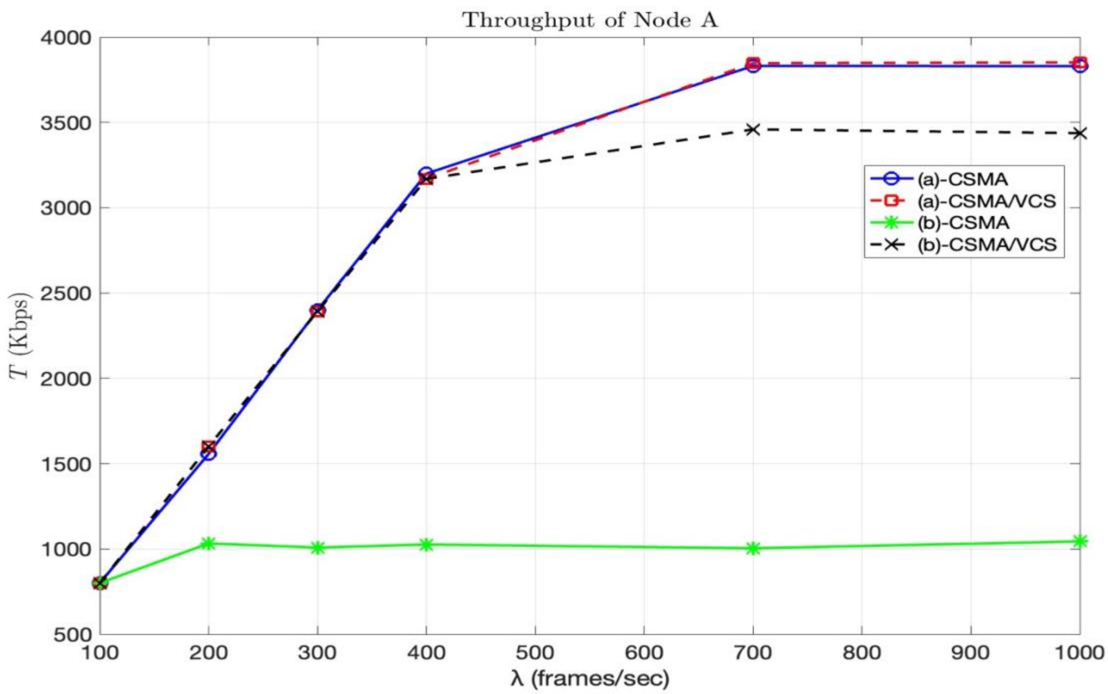

Figure 1 - Throughput of Node A

In general, we can see that the throughput rises with the increasing number of packet arrivals at both nodes A and C except in the case of the standard hidden terminals. This could happen due to increased collisions taking place in such a scenario (refer to Figures 3 and 4 below) when the nodes cannot hear each other and hence, transmit independently.

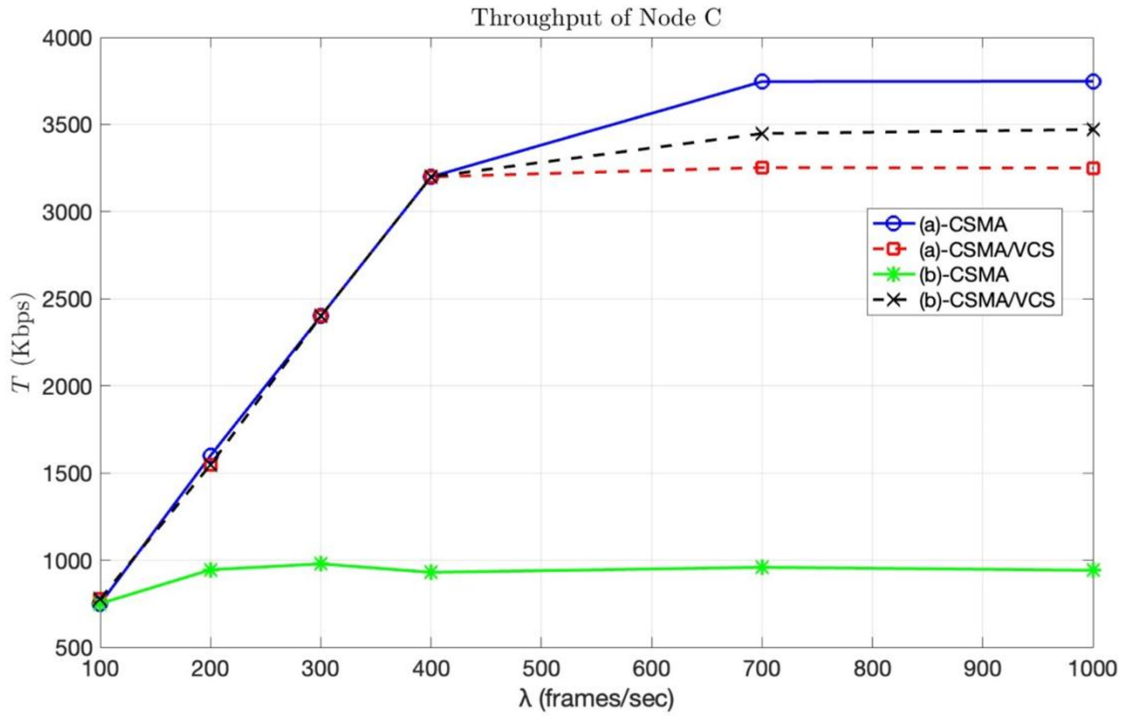

Figure 2 - Throughput of Node C

Since the blue and red lines in Figure 1 lie on each other, there is no effect of virtual carrier sensing on the throughput of Node A when it resides in the same collision domain as node C. However, virtual carrier sensing worsens the throughput of node C (when it resides in the same collision domain as node A) for λ greater than 400 frames/sec. For scenario A in general, network utilization is low initially but rises as λ is increased. At high values of λ, almost the entire bandwidth gets utilized.

As compared to Scenario A, the effect of virtual carrier sensing on throughputs is much more profound in Scenario B. For both nodes A and C, it can be observed that the introduction of virtual carrier sensing improves their respective throughputs significantly. This is because collisions are detected earlier when VCS is enabled in scenario B and hence, less time is lost in collisions and more time is spent transmitting data. From a holistic observation of the above figures, it is not hard to infer that the combined throughputs of nodes A and C is maximized when both the nodes reside in the same collision domain and virtual carrier sensing is disabled.

2. Number of Collisions

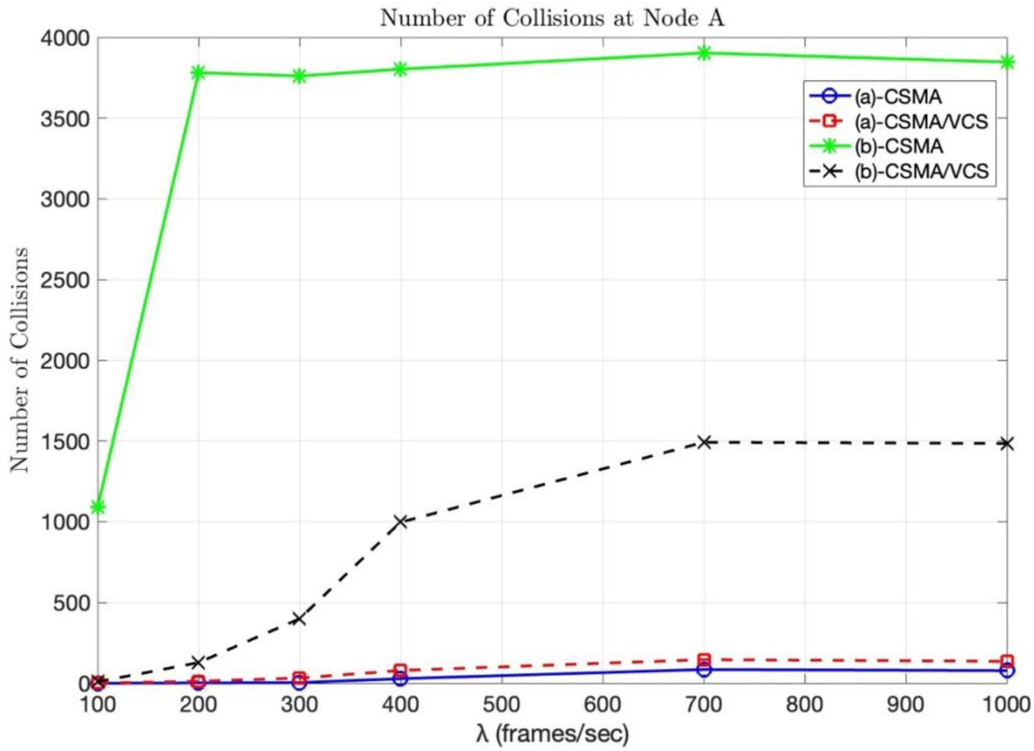

Figure 3 - Number of collisions at node A

The number of collisions at nodes A and C is either equal (i.e., in the single collision domain) or almost equal (i.e., for hidden terminals). This fact can be verified by observing how closely Figures 3 resembles Figure 4. The number of collisions at both nodes is exactly equal in scenario A since a collision occurs only when both nodes choose the same backoff period and transmit simultaneously. For scenario B, the number of collisions at nodes A and C are unequal because besides data packet collisions, collisions also occur when ACK_A collides with DATA_C (in which case collision at node C is increased by 1 but node A gets a success) or ACK_C collides with DATA_A (in which case collision at node A is increased by 1 but node C gets a success). These ACK-DATA collisions occur randomly and are governed by the Poisson-distributed traffic.

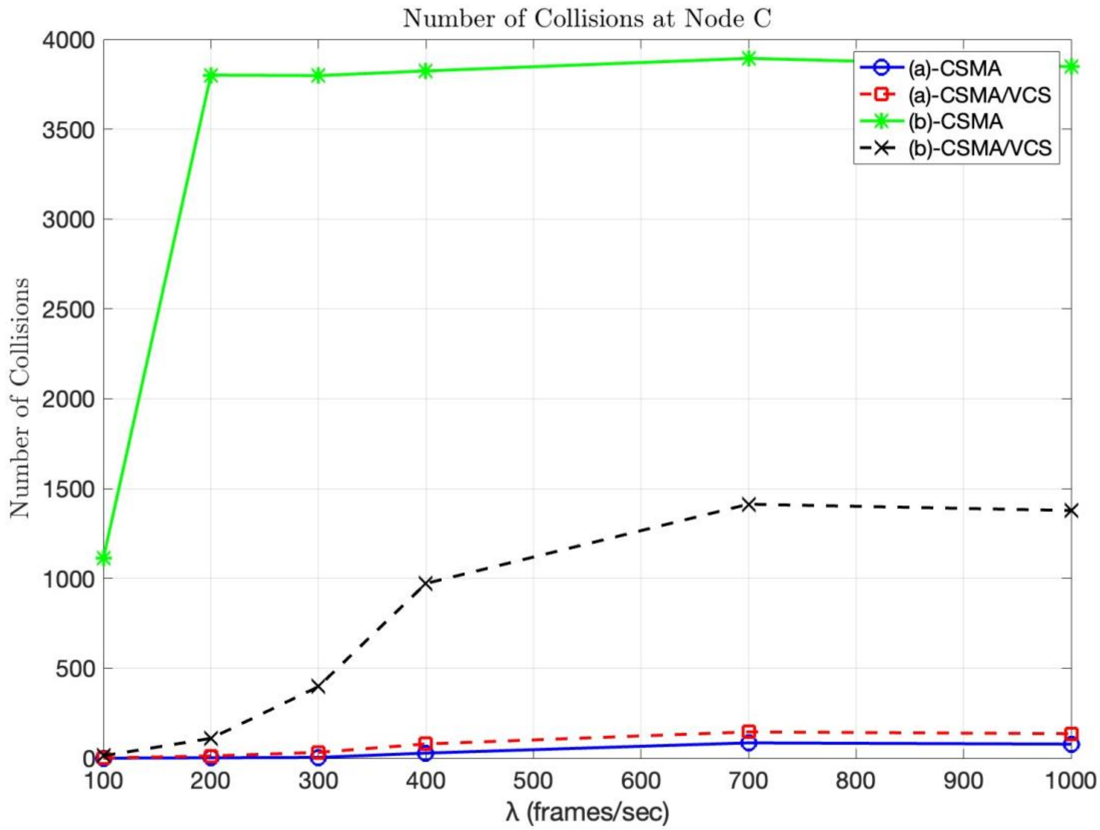

Figure 4 - Number of collisions at node C

In scenario A, the introduction of virtual carrier sensing causes only a very slim increase in the number of collisions. This probably happens because collisions are resolved more quickly when VCS is enabled and hence, retransmissions occur more frequently increasing the likelihood of data or RTS-RTS collisions.

From the graphs of Figures 3 and 4, it is also easy to observe that packets collide much more frequently in scenario B than in scenario A. This is because the nodes in scenario B cannot hear each other and transmit independently. Like throughputs, the effect of virtual carrier sensing on the number of collisions is more profound in scenario B as compared to scenario A. Enabling VCS causes the number of collisions in the channel to decrease drastically.

3. Fairness Index:

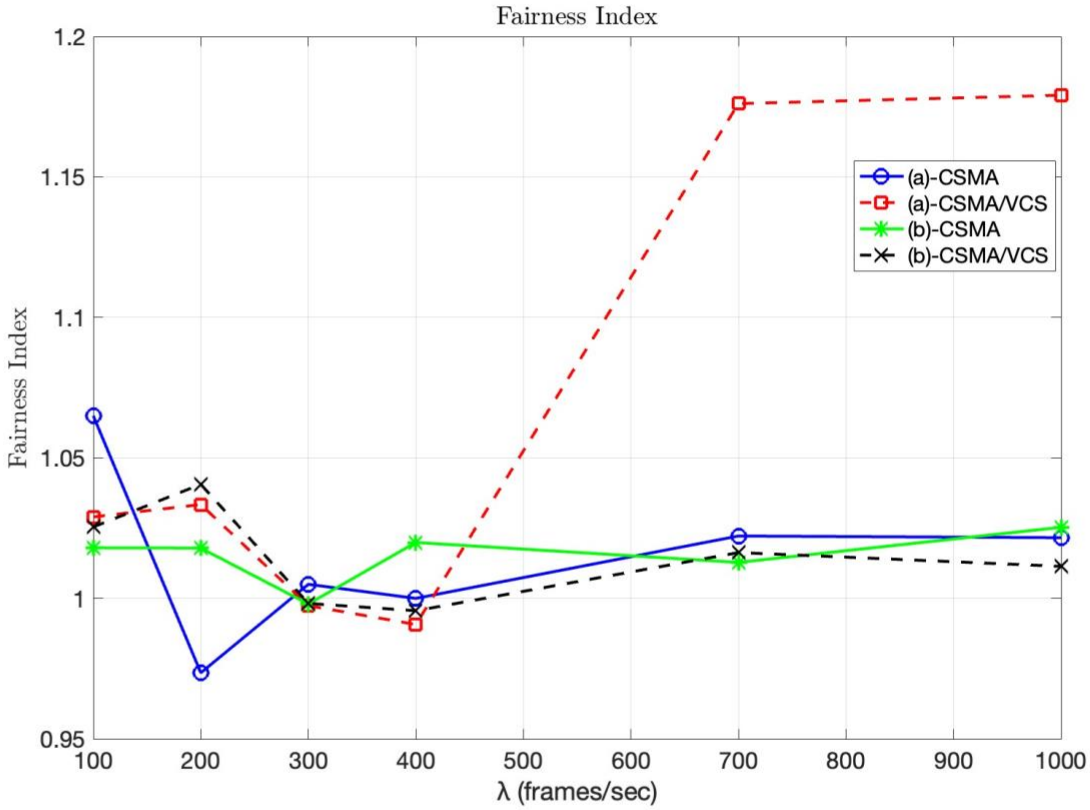

Figure 5 – Fairness Index

Since the number of collisions at node A equals the number of collisions at node C for scenario A (refer to Figures 3 and 4), the fairness indices for scenario A depend solely on the successes of nodes A and C. For each of the four cases, there is some degree of randomness in the fairness indices (indicating unequal number of transmissions made by nodes A and C) for low values of λ. However, the fairness indices go close to unity (indicating equal number of transmissions made by nodes A and C) for higher λ in every scenario except the single collision domain CSMA/CA with VCS enabled. This phenomenon can be very well explained by comparing Figures 1 and 2. By observing these figures, it can be deduced that at high λ the throughputs at nodes A and C are very similar in magnitudes for every case except the single collision domain with VCS enabled. Node A has a significantly higher throughput than node C in the case of the single collision domain with VCS. Hence, for this scenario, node A spends more time transmitting than node C resulting in a fairness index biased towards A (as indicated by a value greater than unity).