24.765 CSMA/CA Model and Simulation Results

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Abstract:

This paper explorer performance issues with regards to CSMA-CA, the shared resolution algorithm for a collision domain, in particular 802.11. To evaluate performance a robust simulator architecture is designed and implemented. Testing is done to contrast performance of a network with and without an access point routing, which relates to wireless home networks.

Keywords:

CSMA/CA, network simulations, wireless home networking

Introduction

There are many differences between the protocols for wireless and wired internet. Wireless transmission is less of a controlled environment the wired transmission. 802.11 which, defines the wireless transmission standard contains provisions for the physical transmission, authentication, encryption, power mode, roaming and others. This assignment will only focus on the transmission of data in a steady state environment where the number of stations is fixed and an access point exists.

In a wired LAN CDMA-CD is used as the physical layer protocol. It is a good choice giving good efficiency especially for large data and being fair in terms of letting multiple devices have access to the protocol. However, for a wireless environment is it not suitable for the following reasons.

1) Hidden station problem. This is illustrated by figure 1. If station A transmits, station B is able to listen to the transmission but station C cannot because it is out of range. Because of this, station C can transmit if it has data to send and thus interfere with stations A transmission.

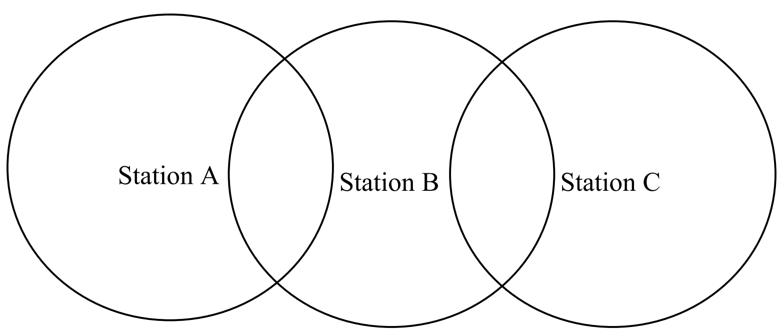


Figure 1.

2) It is difficult to detect collisions in a radio environment. Also it is more expensive to build a device that can both transmit and receive (to check the integrity of the transmission). It may not be possible to the transmitter device to notice an error and stop transmitting.
3) For a given LAN setup, it may not have complete control of the channel. There may other devices on the same channel forming another LAN.

Because of these problems wireless Ethernet uses CDMA-CA, which is Carrier-Sense Multiple Access with Collision Avoidance.

CDMA-CA defines four kinds of Interface Space used in this assignment. An inter frame space is a time between a transmission and the time the another transmission occurs. It is required to prioritize transmissions.

1) SIFS, Short interface space. This is the smallest interface space. It is necessary after a transmission for the wireless device to process the data and switch modes between receiving and transmitting if necessary. This actual time is around 28 uS.
2) PIFS, Point Coordinate IFS. This is the time at which the access point is able to get access to the channel without having to compete with all of the other devices. This can be used to do access point functionality which is defined in 802.11 such as sending out beacons. Defined as SIFS + 1 Slot time which is around 28+50 = 78 uS.
3) DIFS, Distributed IFS is the time the transmission of a message which the stations can again start transmitting messages. Defined as PIFS + 1 slot time = 132 uS.
4) EIFS, Extended IFS, not used in the assignment.

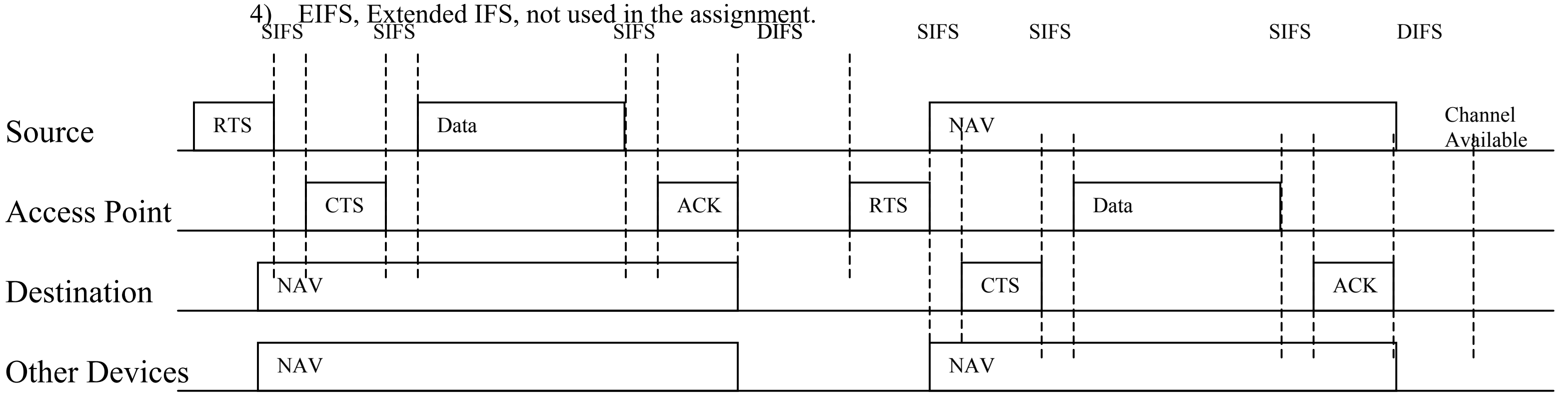


Figure 2.

The operation of CDMA-CA is illustrated in Figure 2. It demonstrates the procedure to transmit a packet from a source to a destination going through the access point. A transmission begins by the source sensing that the channel is idle and having its back off timer run to zero. It begins by sending a RTS (Request to Send) frame. If no other station is also transmitting the frame may successfully be received by the access point. At this point the access point sends out a CTS (Clear to Send). Once received the source sends out the data frame. The access point acknowledges it with a ACK (acknowledgment) frame, and the transmission of the data frame is confirmed successful. Next the access point wait for the next available time to send and then using the same procedure sends the data frame to the destination.

CDMA-CA uses virtual carrier sensing. In the RTS and CTS frames the time that is required to complete the transmission (to the ACK frame) is included. This solves the hidden station problem. That station might not be able to detect the RTS or any subsequent transmission from the source however it will detect the CTS frame. At this point it reads the NAV (network allocation vector) and will not try to send until this time runs out.

The example illustrates a transmission between two stations and the access point. This style of transmission requires station to station traffic to be sent twice which is inefficient. It is possible for Ad-hoc network to be creating without an access point, and transmissions to be sent peer to peer without having to be sent twice. Despite station to station traffic having to be sent twice the access point scenario is the most common. The access point is also likely to be connected to the wired network with internet and server connections. In many environments most of the traffic of the network is likely to go from access point to a station or vise vera rather then station to station.

Like CDMA-CD, CDMA-CA contains a back off algorithm. It is very similar and the formula to determine the time is given by 2^{k+2}. As CDMA-CD there is a maximum of 16 resend attempts before a packet is dropped.

It is possible for a wireless network to be configured with a RTS threshold. The RTS threshold is a size at which if the data packet is smaller then, the data packet can be sent without the RTS, CTS overhead. The reason behind the RTS and CTS is because during a transmission it is not possible to detect and collisions and bit errors. When the RTS and CTS is a lot smaller then the data frame it makes sense to use them because if there is a collision only the smaller frame gets wasted rather then have the data frame take up a lot of time on the channel and not be sent successfully. When the data packet is small it may not make sense to bother with the overhead of the CTS and RTS packet.

Wireless network contain a higher bit error rate then wired transmission. This is why there is an ACK frame sent when the data frame has been successfully received. When the ACK frame is not received by the source station it can assume that the data frame was lost and that is should retransmit the data.

Simulation Design

For this assignment a simulator was programmed from the ground up using visual c+. The simulator reuses many components from the previous CDMA-CD simulator used in assignment #1. The simulator is designed modularly as shown by figure 3. The Network, process and OS code are identical to the previous simulator. The NIC and physical layer contain all of the changes but still reuse code fragments from the previous simulator. An addition advantage to using the modular design is the fact that the process code works on both the CDMA-CA simulator and on the CDMA-CD one. The overall design is data driven not probabilistically driven. The simulator accepts data from a process and routes it to the destination. This feature should be very useful when expanding the simulator to simulate applications on the network.

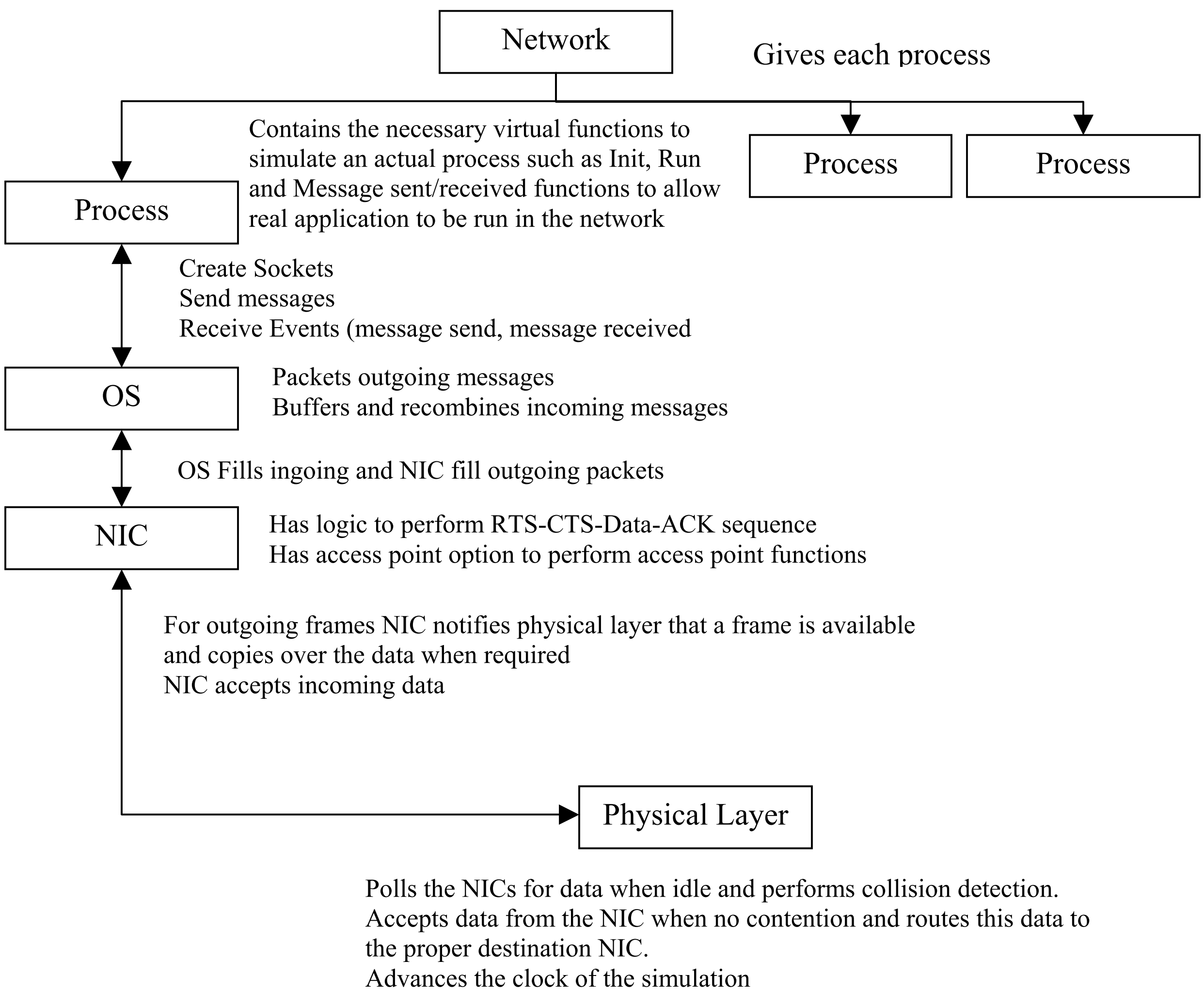


Figure 3.

Simulation setup and verification.

The simulation was setup as follows

Variable	Value
Max bit rate	11 Mbit/s
Max Packet size	1478 Bytes
SIFS	28uS
DIFS	128uS
BER	10^{-6}

From an Atheros Whitepaper the following theoretical values are obtained

Bit Rate	UDP Bit rate	TCP Bit rate
11 Mbps	7.1 Mbps	5.9 Mbps

The simulation is setup with a single server and access point. The server is sending data directly to the access point. At the point where the network has 100% loading the server is sending around 7.6 Mbps. This is higher then the 802.11b bit rate ,which can be entirely attributed to the different in packet header length. The rates are around 7% different, which would account for the difference of around 500 bits per transmission sequence. Since each physical layer preamble is around 128 bits times this is around correct. The simulation is sending UDP style traffic however the all of the UDP functionality isn't implemented yet so the result is only an estimate of the actual bit rate.

Experimentation

One of the emergent uses wireless networks is wireless streaming of data in a home networking environment. An experimental setup of wireless streaming of video data showed the following observations. When the network was setup with one wireless station and one wired station connected to the access point the streaming was seamless. When the simulation was setup with both stations connected wirelessly the video exhibited choppiness. This can be attributed to the fact that routing data through the access point takes twice at least twice the bandwidth. The question is, is routing data through the access point more then twice as inefficient due to collisions and other overheads. These experiments will try and obtain some preliminary results on this topic.

The network will be tested under various load conditions under two test setup. One is with video data being routed through the access point double the required frames, the other is sending the data through the access point simulating the fact that the data is originating on a wired station connected to the wireless network through the access point.

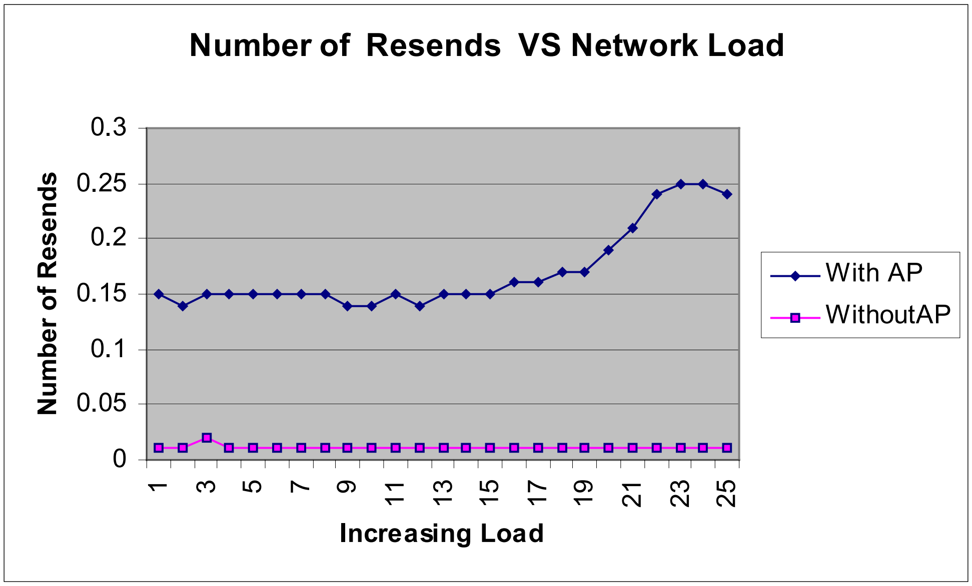
Result /Discussion

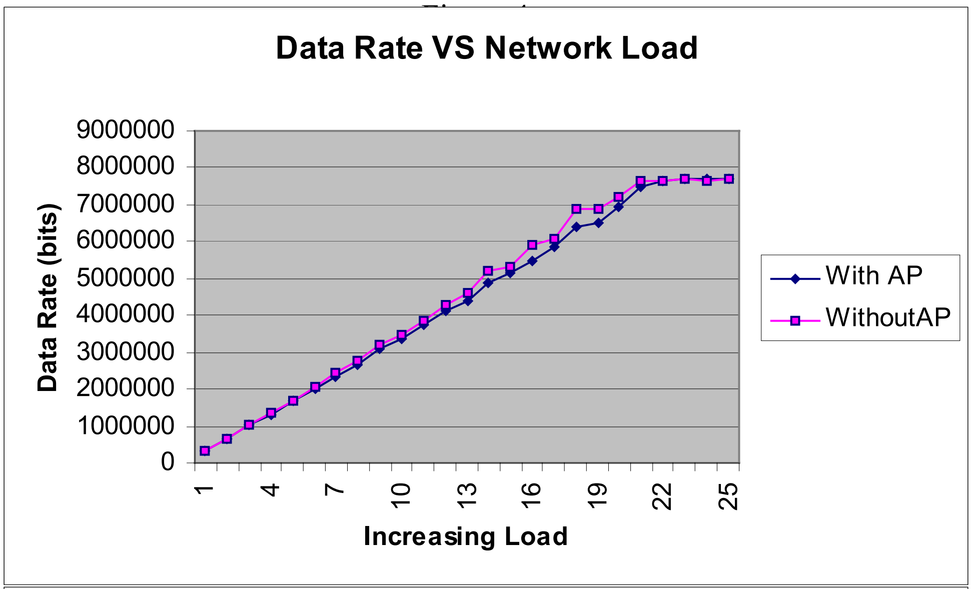
Figure 4-7 shows the results. One of the setups had data routed through the access point and the other can be said to be peer-peer. There is only one server sending data. The data rate is increased to the point of network saturation. The x-axis is in all cases test runs. Each run increased the quantity of data linearly. Note that the access point routing had only half the data sent to it to account for the access point resending all the data.

In terms of total data sent over the without AP is actually the same before saturation but because of a floating point error the withoutAP sends out more data frames then withAP as you can see with the drift. No packets are dropped or missed until saturations so everything is getting through. After saturation withAP sends out slightly more data 7.7 Mbps compared to 7.67Mbps. The reason for this is that the back off time for 802.11 is 2^{k+2}. That means for the first interval there is an equal probability of sending at any 0-7 slots. However when two devices want to send it is more likely that less time will get wasted. This is shown in figure 7, which shows less slots are wastes waiting for something to send. This small amount though is insignificant though.

The real difference is in wait time and number of resends. Both are higher in withAP then withoutAP. This is before total arrival wait time is calculated (when UDP will be properly implemented) after a packet is fully reconstructed, so in reality it is likely the wait time is even higher then the results show.

In conclusion having an access point halves the available band width but does not contribute to any additional significant efficiency loss. However having an access point raises the wait time considerably.


Number of Resends VS Network Load
Number of Resends
0.3
0.25
0.2
0.15
0.1
0.05
0
1 3 5 7 9 11 13 15 17 19 21 23 25
Increasing Load
With AP
WithoutAP


Data Rate VS Network Load
Data Rate (bits)
9000000
8000000
7000000
6000000
5000000
4000000
3000000
2000000
1000000
0
1 4 7 10 13 16 19 22 25
Increasing Load
With AP
WithoutAP

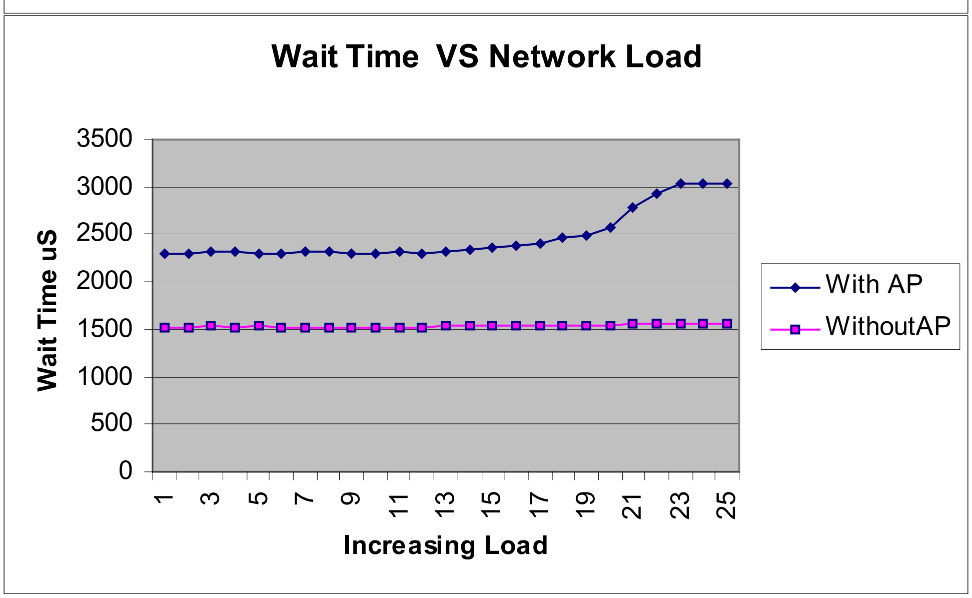

Wait Time VS Network Load
Wait Time uS
3500
3000
2500
2000
1500
1000
500
0
1 3 5 7 9 11 13 15 17 19 21 23 25
Increasing Load
With AP
WithoutAP

Figure 6

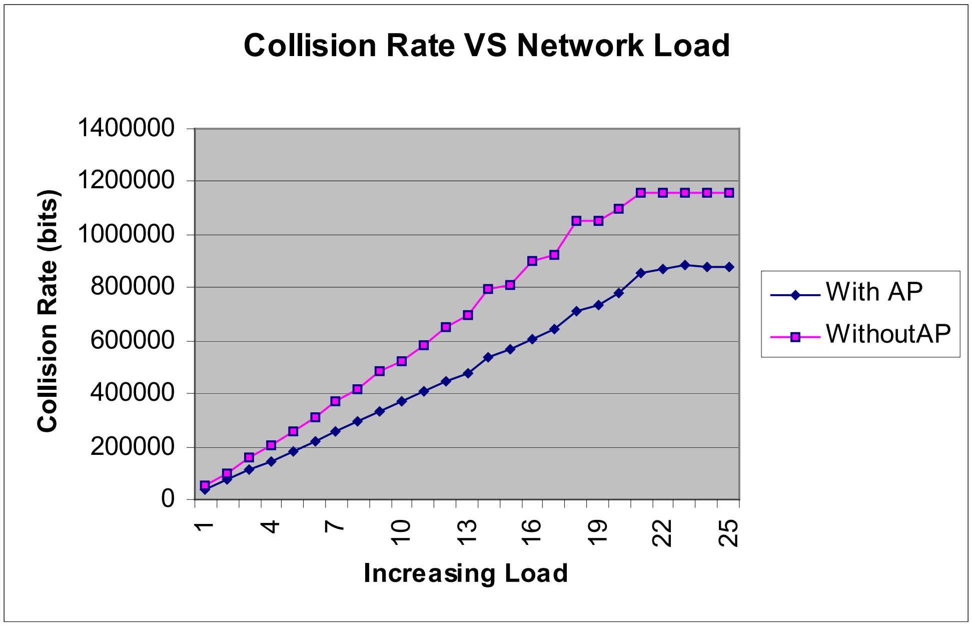

Collision Rate VS Network Load
Collision Rate (bits)
1400000
1200000
1000000
800000
600000
400000
200000
0
1
4
7
10
13
16
19
22
25
Increasing Load
With AP
WithoutAP

Figure 7