Design Specification for MAC Sub-Layer Transmitter
Part 2: DCF Control
CSCE 611 – Fall 2002

1. Introduction

The IEEE 802.11 MAC layer defines two different access methods, the Distributed Coordinated Function (DCF) and a centralized Point Coordinated Function (PCF). The basic medium access mechanism is a DCF, and it uses Carrier Sense Multiple Access with Collision Avoidance protocol (CSMA/CA), which has a built-in mechanism to avoid collisions and provide a fair mechanism to the medium access. The design specification for DCF is presented in this document. DCF is implemented in all stations, and is the basis for ad-hoc wireless networking.

1.1. Statement of Problem

In the CSMA/CD protocol, used in the 802.3 wired LAN, it is assumed that all stations can hear each other. This is not true with wireless medium where a STA may sense the medium as idle, but the fact may be otherwise. In order to solve this problem, 802.11 uses CAMA/CA mechanism together with positive acknowledgment scheme, as follows,

1. A station wanting to transmit senses the medium. If the medium is busy then it defers. If the medium is idle for a specified period then the station is allowed to transmit.
2. The receiving station checks the CRC of the packet and sends an acknowledgment packet (ACK). Receipt of the ACK indicates to the transmitter that no collision occurred. If the sender does not receive the ACK then it retransmits the frame until it receives ACK or is thrown away after a given number of retransmissions.

1.2. Design Objectives

Design a specification for 802.11 MAC Distributed Coordination Function (DCF) at the RTL (Register Transfer Level), and logic level description for the Random Backoff Algorithm, which could be used for moving lower down the levels of abstraction.

1.3. Project Assumptions and Constraints

The following assumptions are made

1. The signal is propagated through the medium with zero attenuation.
2. The network traffic is limited.
3. The receiver is NOT busy when a RTS is destined to it.
4. All Stationss understand RTS/CTS mechanism.
5. Station priority is ignored.
6. Stations receiving data type shall only consider the frame body as the basis of a possible indication to LLC.

This mechanism may fail for a very heavy traffic network.

2. Functional Description

This section gives the functional description of DCF. This DCF operation is activated when it receives a TxRDY signal from the Transmitter. DCF sets up a mechanism for automatic medium sharing between different STAs. It sends TxCLEAR signal to the Transmitter so that it can go ahead and transmit the ready frame. First, we give the overall block representation of the DCF operation. Then we go into details of each block at the RTL level, also, present a control flow for each block.

2.1.Block description of DCF

Fig. 1 shows the RTL level block description of whole operation of DCF. It contains three mains blocks namely Control Logic, Backoff Algorithm, Carrier Sense Mechanism and Network Allocation Vector (NAV).

Input: TxRDY, PHY carrier sense, RTS/CTS/Data frame
Output: TxCLEAR, PHY-CCRESET

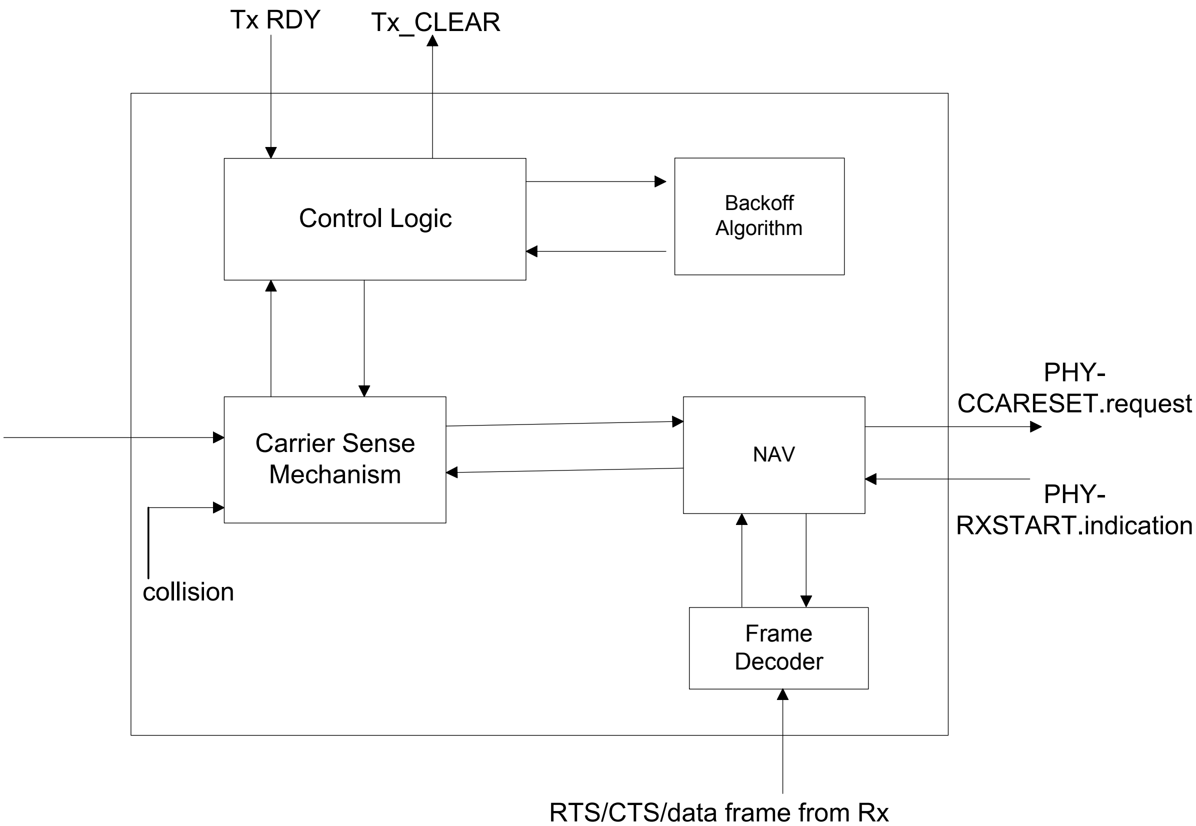

Fig. 2 Functional Description of DCF

Process: When this block receives TxRDY signal from the Transmitter it calls on the carrier sense mechanism to know the state of the medium. Carrier Sense Mechanism combines the NAV state and the STA's transmitter status with physical carrier sense to determine the busy/idle state of the medium. NAV predicts the future traffic on the medium based on the information provided by the output of Frame Decoder. Frame Decoder checks if the frame is destined to the current STA, and also decodes the duration information from it. The duration information is used to update the NAV value. The value of NAV indicates idle/busy state of the medium. Depending on the output of the Carrier Sense Mechanism the Control Logic may call Back Algorithm. The Control Logic sends TxCLEAR to the Transmitter clearing it to send the ready frame.

2.2. Backoff Algorithm

Fig. 2 shows the functional representation of the Backoff Algorithm block. It contains CW Calculator, Random Number Generator and Backoff Time Calculator. The function of this block is to calculate a random backoff time, which is decremented while the medium is idle. This block is called on by the control logic when it senses the medium as busy.

Input: Signal from Control Logic, SSRC, SLRC,
Output: Signal to the Control Logic
Process: A signal from Control Logic activates this block. The operation of this block starts with the calculation of CW. Its output is given to Random Generator, which generates a number in the interval [0,CW]. Finally, the backoff time is calculated.

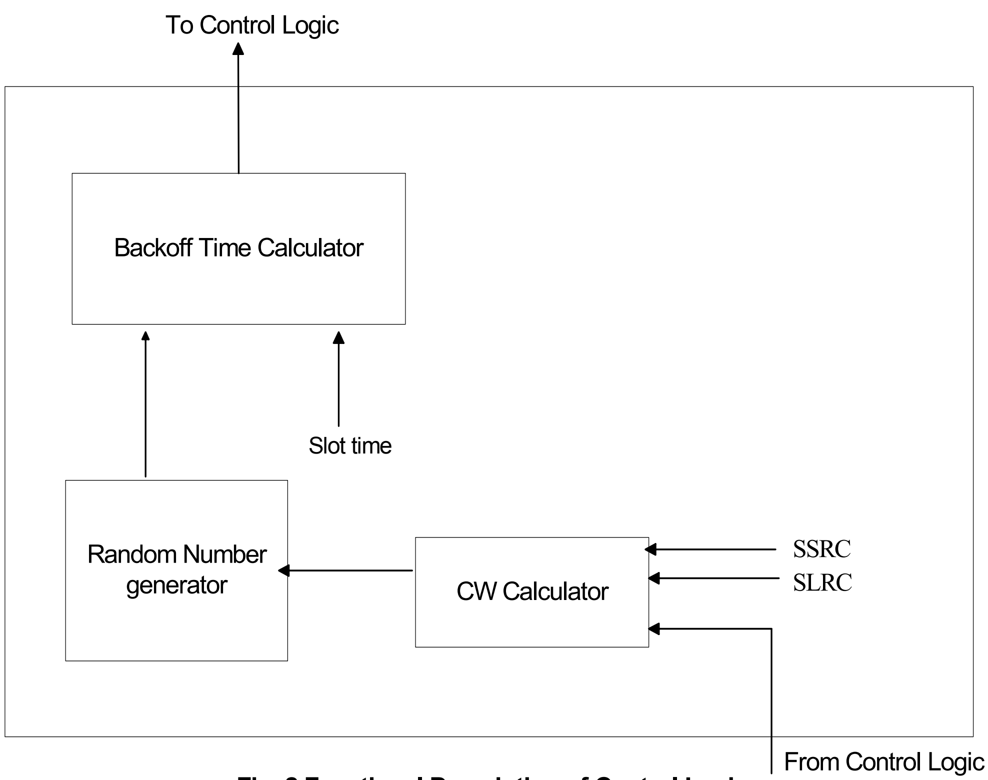

Fig. 2 Functional Description of Control Logic

3. Behavioral and RTL Description

In this section we, give the behavioral representation of each of the blocks given in the functional description.

3.1. State machine for DCF operation

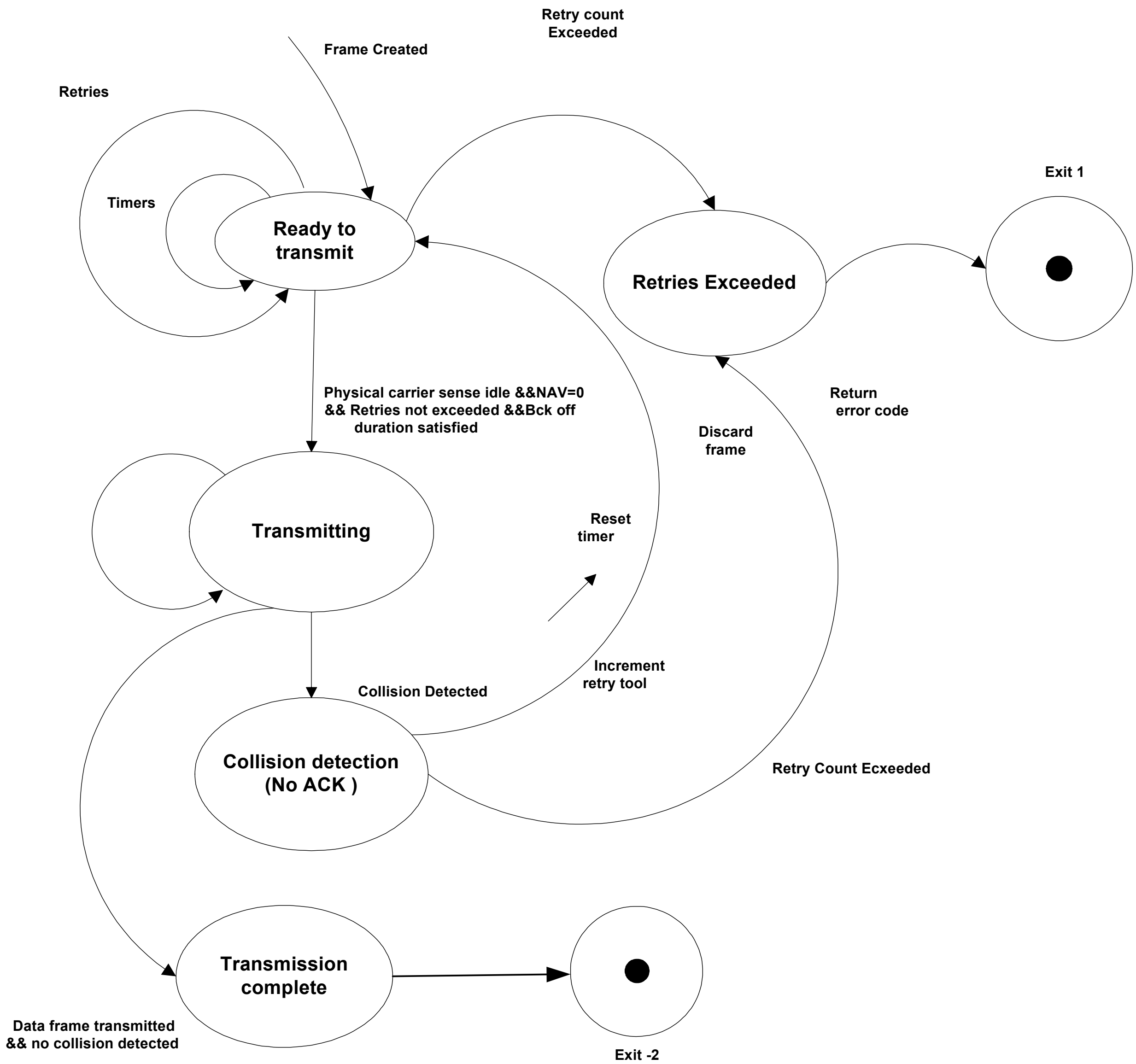

Fig. 3 State Machine for DCF

Fig. 3 gives the state diagram of the DCF. The DCF operation starts when a frame is ready to be sent.

States of the DCF operation:

Ready to transmit: This is the first state in the cycle. This state occurs when a frame is ready to be sent. This state is also reached when a collision is detected i.e. Ack is not received by the sending STA.

Transmitting: When in Ready to transmit state, if the PHY carrier sense is idle and NAV = 0 and retries not exceeded and backoff duration satisfied, this state occurs.
Collision Detection (no ACK): This state exists when a sending STA does not receive an ACK from the receiving STA.

Transmission Complete: This state occurs when the transmission of the data frame is successful and no collision is detected.

Retries exceeded: This state occurs when the number retries exceed dot11 ShortRetryThreshold for frames shorter than RTS threshold, and number of retries exceed aLongRetryLimit for frames longer than RTSThreshold. After this state the fame is discarded.

3.2. Control Flow for DCF

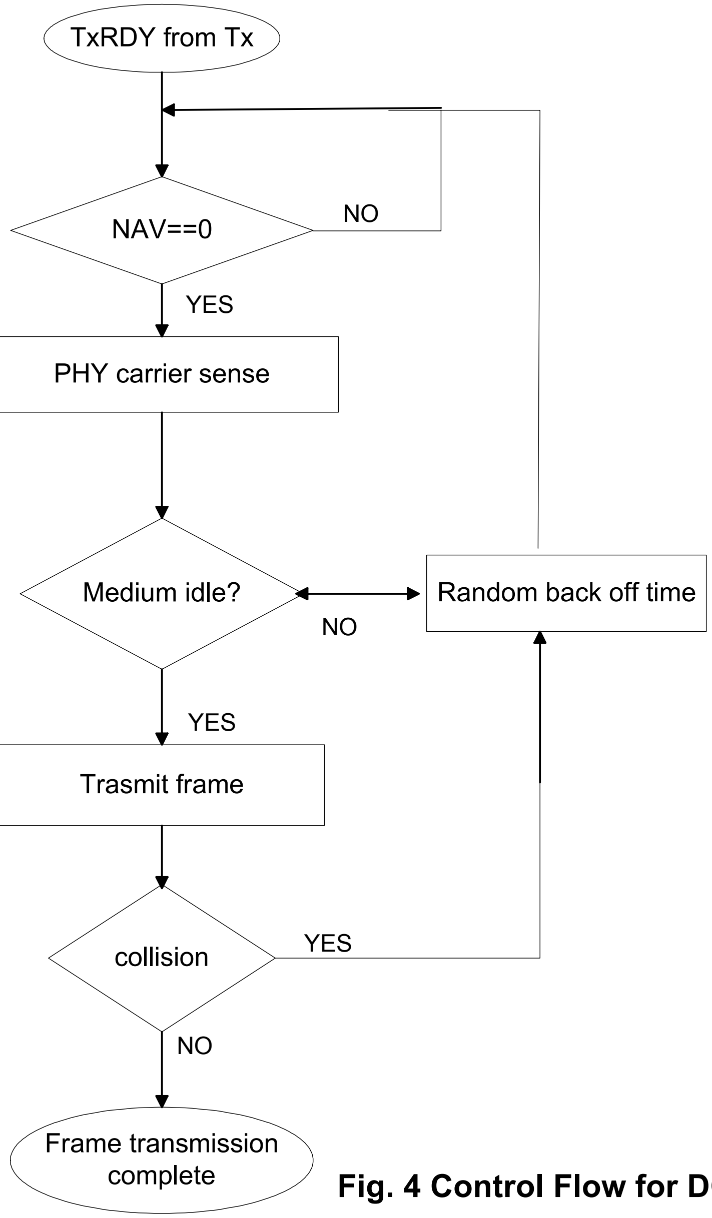

Fig. 4 Control Flow for DCF

The figure gives the behavioral description of the DCF. As said this block is activated when it receives TxRD signal from the Transmitter. Then it checks the NAV value. If it is zero, it checks the PHY carrier sense. If the medium is idle, frame is sent and ACK is expected. If there is no ACK received collision is assumed to have occurred. In that case random backoff time is calculated, and set to decrement, when the medium is idle. When this value reaches zero frame is retransmitted and the process goes over.

3.3 Control Flow for NAV

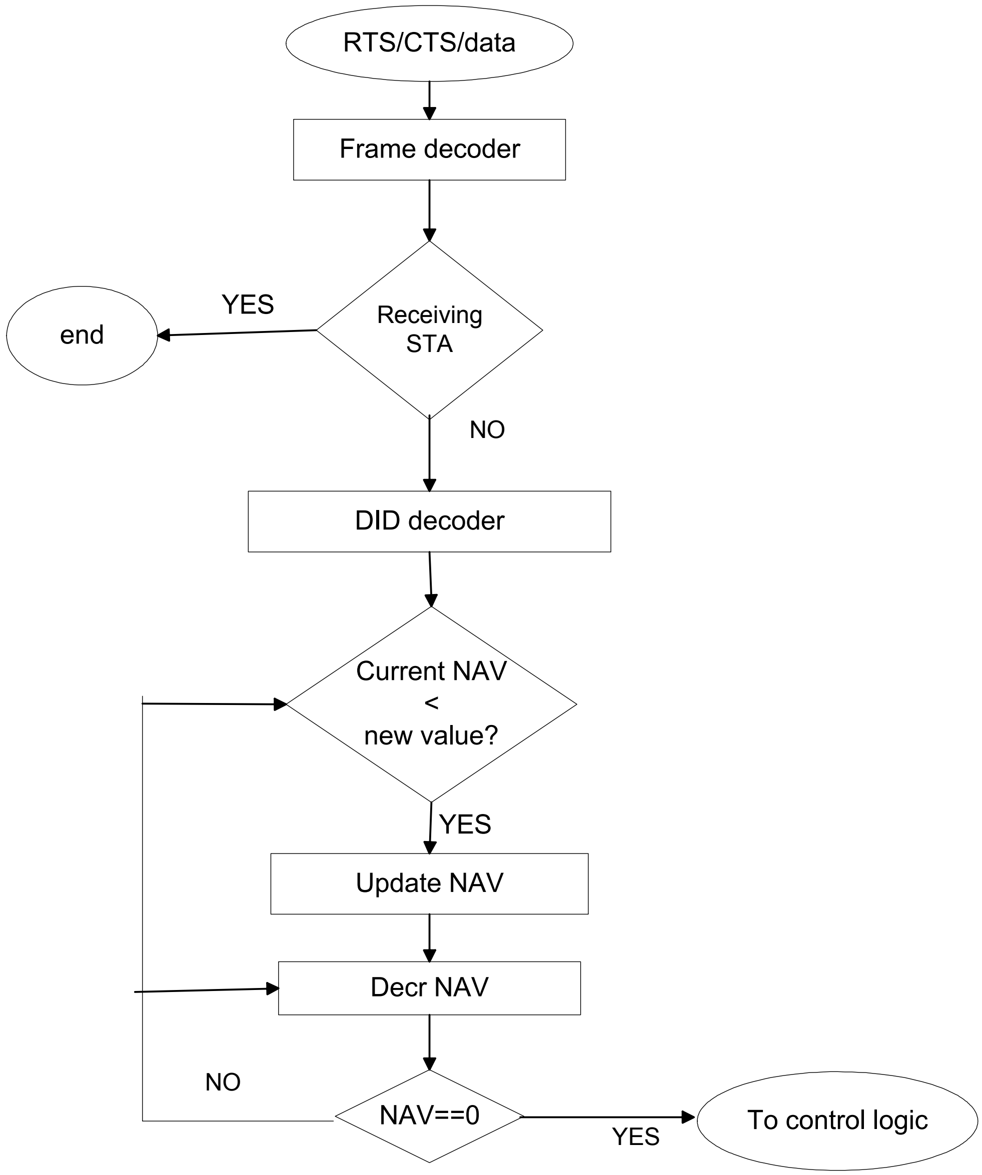

Fig. 5 Control flow for NAV

NAV sets up a virtual carrier sense mechanism as follows. RTS/CTS/Data frame is decoded and the RA field of the frame is checked with the STA address. If the frame is destined for this STA, NAV won't be updated. If not, duration ID is decoded from the field. This duration is checked with current value of NAV. If greater, NAV value is update to the new value. NAV value is then decremented till zero. During this duration data exchange between the sending and receiving STAs is assumed too have been completed. So, when NAV reaches zero, medium is assumed o be idle and transmission is carried out.

3.3. Time Scale description of DCF Diagram

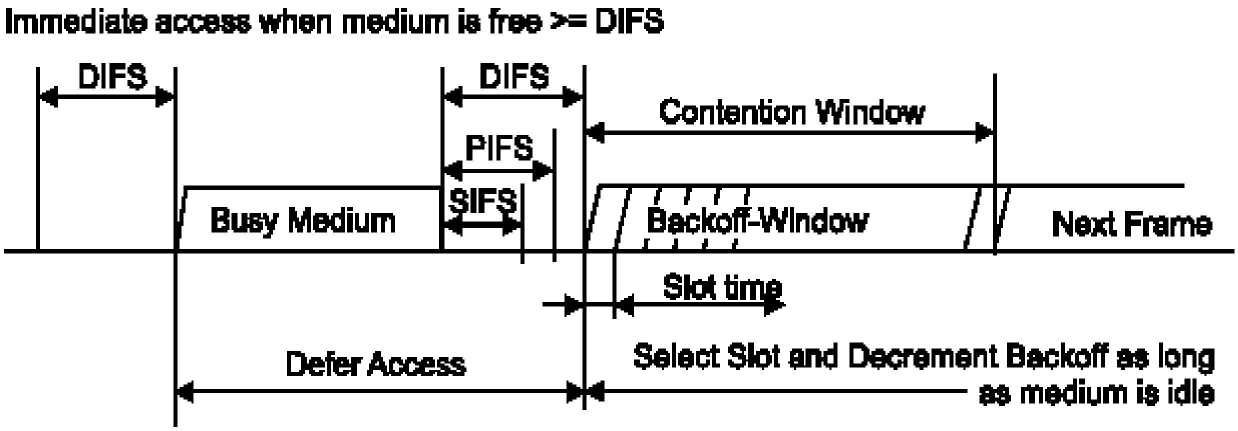

Fig. 6 DCF Relationships

This figure gives description of DCF on a time scale as shown below. As we see when a STA becomes ready to transmit it senses the medium for a period of DIFS. If it senses that the medium was busy during this interval, the STA defers transmission to later time that depends on the backoff time. The backoff time is calculated using the following relationship

Backoff Time = Random() * aSlotTime

Random() is a value in the interval [0,CW], where CW take a value between aCWmin and aCWmax i.e. aCWmin < CW <aCWmax. The values of aCWmin and aCWmax are defined for PHY. Value of CW is incremented exponentially as shown below.

For example if we take Frequency-Hopping Spread Spectrum as PHY values are 63 and 1023 for aCWmin and aCWmax, respectively.

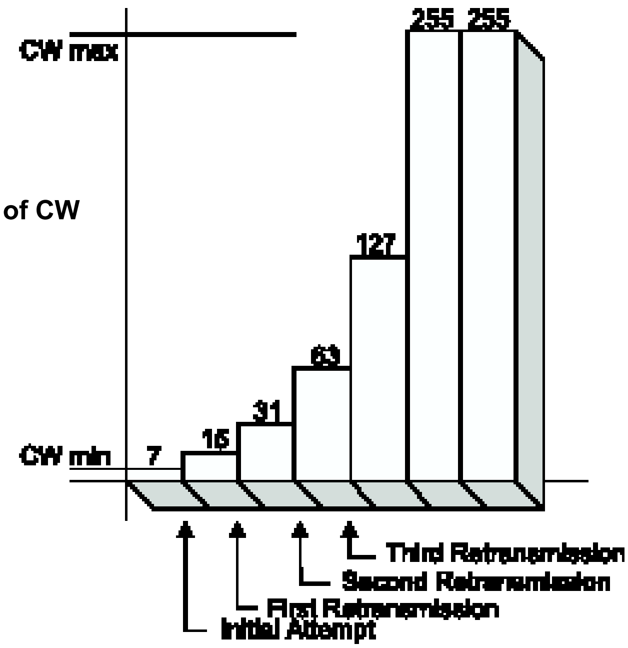

Fig. 7 Exponential rise of CW

4. Performance Estimation

The performance of our design is estimated based on the backoff time calculations. The performance is bettered if the backoff time of each STA is evaluated to a unique value. In such a scenario the probability of occurrence of a collision is far reduced.

4.1 Performance Estimation and Measurements

The random backoff time is calculated by multiplying slot time with a random number, which is generated using random number generator using the contention window width. The total delay in the generation of a frame can be estimated by

$$\boxed{\text{Tdelay=DIFS+busy period+DIFS+backofftime+ time to send frame}}$$

The frequency of operation is 2.5 MHz.
Therefore, the clock cycle time period =1/frequency

5. Summary and Conclusions

We presented in this project, the design specification of the 802.11 MAC layer's Distributed Coordinated Function. We first gave an overall block representation of the DCF. Then, we dealt in detail, the functionality of Backoff Algorithm block. We designed a logic level model for the backoff algorithm. This block is very important in the successful operation of the DCF. The DCF has to make sure that random backoff time of each STA is different.

We as a team worked on the DCF, a basic access method in 802.11 MAC. We tried to move through different levels of abstraction. We first presented RTL level description of the DCF. Then we moved down a level to the logic level for the Backoff Time Algorithm. By doing so, we put into practice what we learnt throughout this semester. Hence, we think that we deserve an “A” for the effort we have put into this project.

Now that we have designed a specification for DCF, we would like to use the specification of other sections of the 802.11MAC and assemble them into a single specification for complete 802.11 MAC. Further, we would simulate an ad hoc wireless network and test the performance of the design. If this test gives good results we would go ahead and do the place and route for our design. Then we would move to design of PHY layer and come up with a complete product for the 802.11.

6. References

1. Part 11: Wireless LAN Medium Access Control (MAC) and Physical layer Specifications, ANSI / IEEE Std 802.11, 1999 Edition.

2. IEEE 802.11 Handbook, A Designer’s Companion.

3. Ethernet / IEEE 802.3 Family, 1992 World Network Data Book/Handbook.

4. http://www.inrialpes.fr/planete/people/aad/infocom2001.pdf

Appendix A

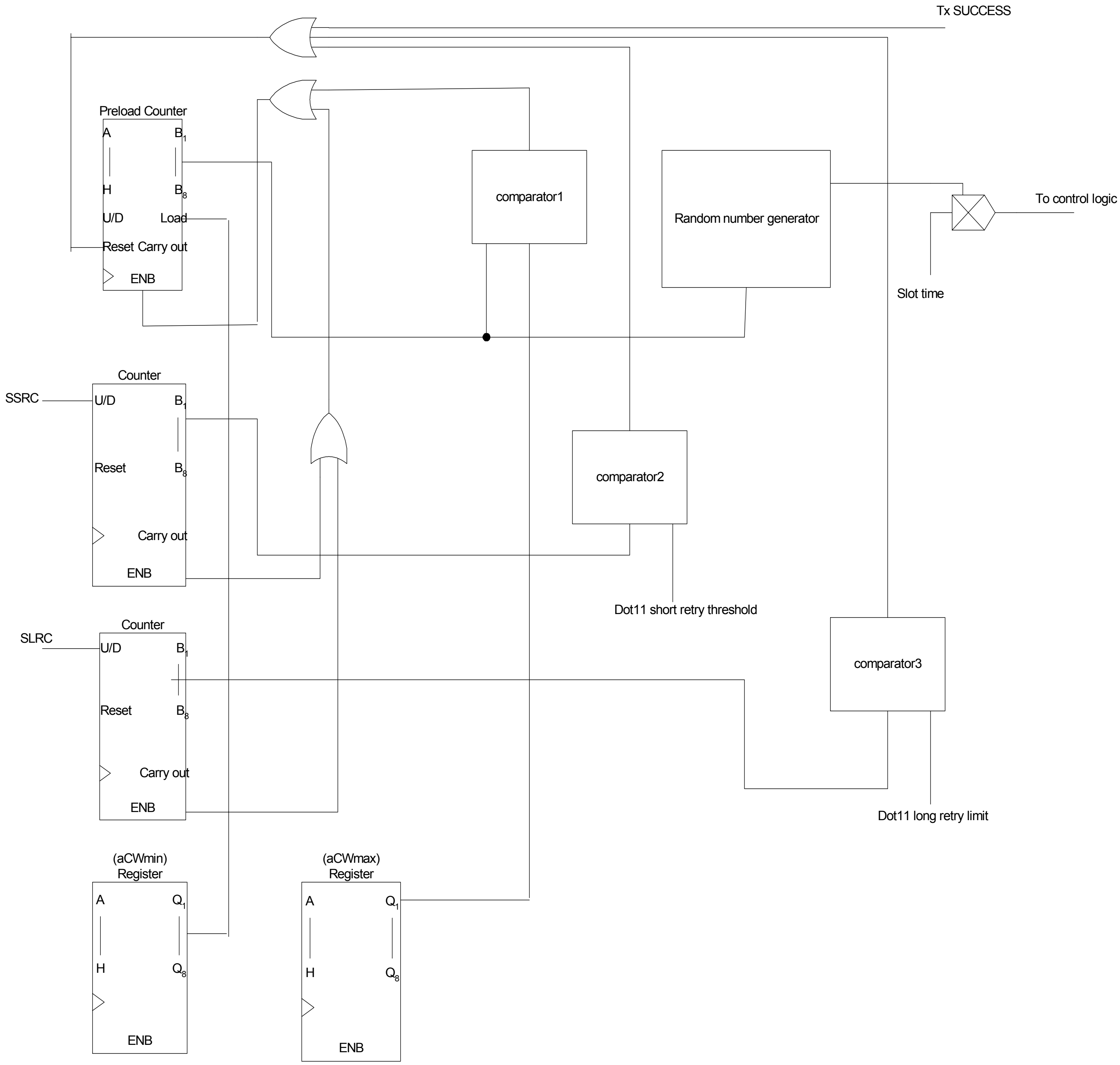

Fig. 8 Logic Level Diagram for Backoff Algorithm

Appendix B

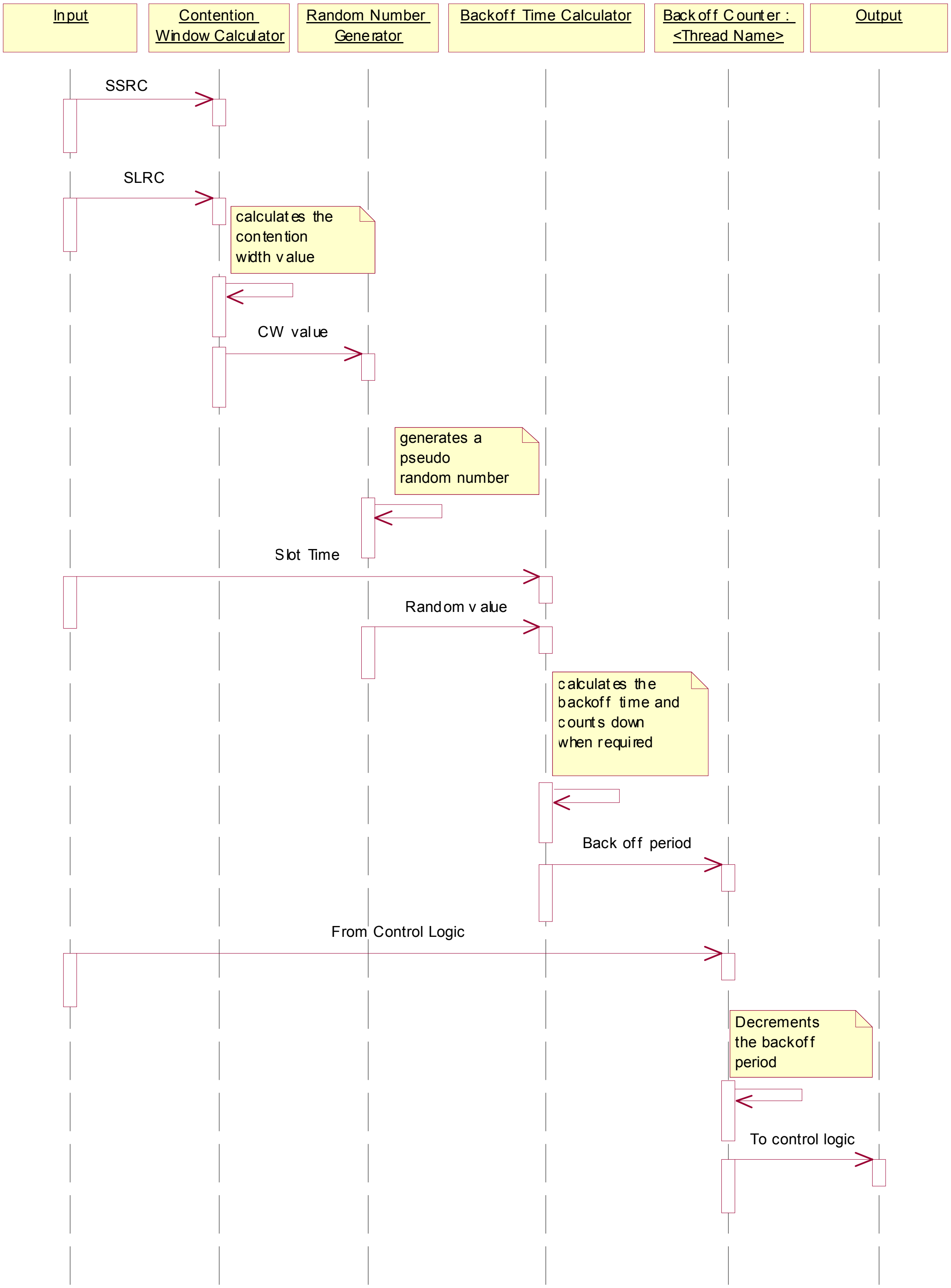

Fig. 9 Sequence Diagram for Random Backofff Algorithm