International Journal of Ethics in Engineering & Management Education
Website: www.ijeee.in (ISSN: 2348-4748, Volume 1, Issue 3, March 2014)

Implementation of Anticollision Algorithm (Slotted ALOHA) using VHDL

T. NAGA RAJU
Asst. Professor
RVR Institute of Engineering & Technology
Hyderabad, India
nagraj2468@gmail.com

Harikrishna Musinada
Professor & HOD, ECE
RVR Institute of Engineering & Technology
Hyderabad, India
yemhechkay@gmail.com

Abstract: **The ALOHA net used a new method of medium access (ALOHA random access) and experimental UHF frequencies for its operation, since frequency assignments for communications to and from a computer were not available for commercial applications in the 1970s. But even before such frequencies were assigned there were two other media available for the application of an ALOHA channel – cables and satellites. In the 1970s ALOHA random access was employed in the widely used Ethernet cable based network and then in the Marisat (now Inmarsat) satellite network. In the early 1980s frequencies for mobile networks became available, and in 1985 frequencies suitable for what became known as Wi-Fi were allocated in the US. These regulatory developments made it possible to use the ALOHA random access techniques in both Wi-Fi and in mobile telephone networks. ALOHA channels were used in a limited way in the 1980s in 1G mobile phones for signaling and control purposes. In the 1990s Telecom Finland greatly expanded the use of ALOHA channels in order to implement SMS message texting in 2G mobile phones. In the early 2000s additional ALOHA channels were added to 2.5G and 3G mobile phones with the widespread introduction of GPRS, using a slotted ALOHA random access channel combined with a version of the Reservation**

Key words: **MAC, FPGA, ALOHA, VHDL, GPRS, BBN, ALOHAnet, CDPD, GSM**

1. INTRODUCTION

A network of computers based on multi-access medium requires a protocol for effective sharing of the media. As only one node can send or transmit signal at a time using the broadcast mode, the main problem here is how different nodes get control of the medium to send data, that is "who goes next?". The protocols used for this purpose are known as Medium Access Control (MAC) techniques. The key issues involved here are - Where and how the control is exercised.

An improvement to the original ALOHA protocol was "Slotted ALOHA", which introduced discrete timeslots and increased the maximum throughput. 'Where' refers to whether the control is exercised in a centralized or distributed manner. In a centralized system a master node grants access of the medium to other nodes. A centralized scheme has a number of advantages as mentioned below:

1. Greater control to provide features like priority, overrides, and guaranteed bandwidth.
2. Simpler logic at each node.
3. Easy coordination.

Although this approach is easier to implement, it is vulnerable to the failure of the master node and reduces efficiency. On the other hand, in a distributed approach all the nodes collectively perform a medium access control function and dynamically decide which node to be granted access. This approach is more reliable than the former one. 'How' refers to in what manner the control is exercised. It is constrained by the topology and trade off between cost-performance and complexity. The MAC techniques can be broadly divided into four categories; Contention-based, Round-Robin, Reservation-based and. Channelization-based. Under these four broad categories there are specific techniques.

In this paper we are designing the slotted aloha algorithm by using VHDL and verifying the functionality. Xilinx ISE development tool is used for simulation and synthesis of the design. Finally, the synthesized designs are ported onto Xilinx FPGA.

1.1 ALOHA : The ALOHA scheme was invented by Abramson in 1970 for a packet radio network connecting remote stations to a central computer and various data terminals at the campus of the university of Hawaii. A simplified situation is shown in Fig. Users are allowed random access of the central computer through a common radio frequency band f1 and the computer centre broadcasts all received signals on a different frequency band f2. This enables the users to monitor packet collisions, if any. The protocol followed by the users is simplest; whenever a node has a packet to sent, it simply does so. The scheme, known as Pure ALOHA, is truly a free-for-all scheme. Of course, frames will suffer collision and colliding frames will be destroyed. By monitoring the signal sent by the central computer, after the maximum round-trip propagation time, and user comes to know whether the packet sent by him has suffered a collision or not.

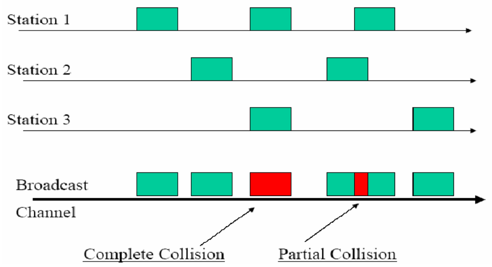


Fig. 1: Collision in Pure ALOHA

It may be noted that if all packets have a fixed duration of τ (shown as F in Figure), then a given packet A will suffer collision if another user starts to transmit at any time from τ before to until τ after the start of the packet A as shown in Fig. This gives a vulnerable period of 2τ. Based on this assumption, the channel utilization can be computed. The channel utilization, expressed as throughput S, in terms of the offered load G is given by S=Ge-2G.

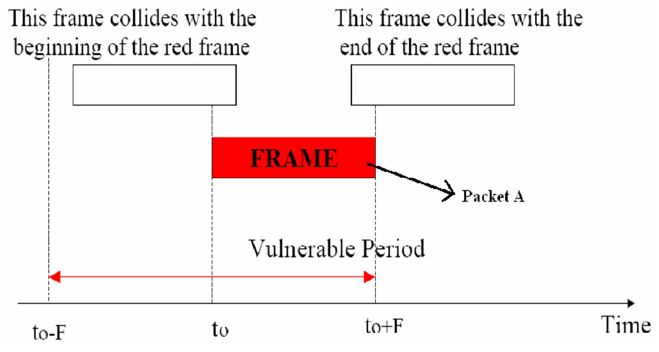


Fig. 2. Vulnerable period in Pure ALOHA

Based on this, the best channel utilization of 18% can be obtained at 50 percent of the offered load. At smaller offered load, channel capacity is underused and at higher offered load too many collisions occur reducing the throughput. The result is not encouraging, but for such a simple scheme high throughput was also not expected.

2. LITERATURE SURVEY

The purpose of slotted aloha algorithm is to avoid collision. The algorithm used here is slotted aloha protocol, which reduces the number of collisions by reducing the number of responses. In this protocol the reply has to be within a slotted time period, which would avoid collision with other responses, since other replies will be in other time. This algorithm has proven to reduce energy consumption by simply reducing the number of responses. In this project we are designing the slotted aloha algorithm by using HDL and verifying the functionality. The source code is written in VHDL and simulated using Xilinx ise8.2 and check the functionality of the algorithm and dumping is done in FPGA.

3. ALOHANET

ALOHAnet, also known as the ALOHA System or simply ALOHA, was a pioneering computer networking system developed at the University of Hawaii. ALOHAnet became operational in June, 1971, providing the first public demonstration of a wireless packet data network. The ALOHAnet used a new method of medium access (ALOHA random access) and experimental UHF frequencies for its operation, since frequency assignments for communications to and from a computer were not available for commercial applications in the 1970s. But even before such frequencies were assigned there were two other media available for the application of an ALOHA channel – cables and satellites. In the 1970s ALOHA random access was employed in the widely used Ethernet cable based network and then in the Marisat (now Inmarsat) satellite network. ALOHA channels were used in a limited way in the 1980s in 1G mobile phones for signaling and control purposes. In the 1990s, Matti Makkonen and others at Telecom Finland greatly expanded the use of ALOHA channels in order to implement SMS message texting in 2G mobile phones. In the early 2000s additional ALOHA channels were added to 2.5G and 3G mobile phones with the widespread introduction of GPRS, using a slotted ALOHA random access channel combined with a version of the Reservation ALOHA scheme first analyzed by a group at BBN.

One of the early computer networking designs, development of the ALOHA network was begun in 1968 at the University of Hawaii under the leadership of Norman Abramson and others. The goal was to use low-cost commercial radio equipment to connect users on Oahu and the other Hawaiian islands with a central time-sharing computer on the main Oahu campus. The original version of ALOHA used two distinct frequencies in a hub/star configuration, with the hub machine broadcasting packets to everyone on the "outbound" channel, and the various client machines sending data packets to the hub on the "inbound" channel. If data was received correctly at the hub, a short acknowledgment packet was sent to the client; if an acknowledgment was not received by a client machine after a short wait time, it would automatically retransmit the data packet after waiting a randomly selected time interval. This acknowledgment mechanism was used to detect and correct for "collisions" created when two client machines both attempted to send a packet at the same time.

ALOHAnet's primary importance was its use of a shared medium for client transmissions. Unlike the ARPANET where each node could only talk directly to a node at the other end of a wire or satellite circuit, in ALOHAnet all client nodes communicated with the hub on the same frequency. This meant that some sort of mechanism was needed to control who could talk at what time. The ALOHAnet solution was to allow each client to send its data without controlling when it was sent, with an acknowledgment/retransmission scheme used to deal with collisions. This became known as a pure ALOHA or random-accessed channel, and was the basis for subsequent Ethernet development and later Wi-Fi networks. Various versions of the ALOHA protocol (such as Slotted ALOHA) also appeared later in satellite communications, and were used in wireless data networks such as ARDIS, Mobitex, CDPD, and GSM. Also important was ALOHAnet's use of the outgoing hub channel to broadcast packets directly to all clients on a second shared frequency, using an address in each packet to allow selective receipt at each client node.

4. THE ALOHA PROTOCOL:

4.1. Pure ALOHA: The first version of the protocol (now called "Pure ALOHA", and the one implemented in ALOHAnet) was quite simple:

1. If you have data to send, send the data.
2. If the message collides with another transmission, try resending "later".

The first step implies that Pure ALOHA does not check whether the channel is busy before transmitting.

The critical aspect is the "later" concept: the quality of the back off scheme chosen significantly influences the efficiency of the protocol, the ultimate channel capacity, and the predictability of its behavior.

To assess Pure ALOHA, we need to predict its throughput, the rate of (successful) transmission of frames. First, let's make a few simplifying assumptions:

1. All frames have the same length.
2. Stations cannot generate a frame while transmitting or trying to transmit. That is, if a station keeps trying to send a frame, it cannot be allowed to generate more frames to send.
3. The population of stations attempts to transmit (both new frames and old frames that collided) according to a Poisson distribution.

Let "T" refer to the time needed to transmit one frame on the channel, and let's define "frame-time" as a unit of time equal to T. Let "G" refer to the mean used in the Poisson distribution over transmission-attempt amounts: that is, on average, there are G transmission-attempts per frame-time.

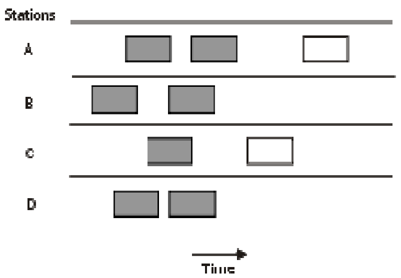


Fig.3. Pure Aloha

Consider what needs to happen for a frame to be transmitted successfully. Let "t" refer to the time at which we want to send a frame. We want to use the channel for one frame-time beginning at t, and so we need all other stations to refrain from transmitting during this time.

Moreover, we need the other stations to refrain from transmitting between $t-T$ and t as well, because a frame sent during this interval would overlap with our frame.

For any frame-time, the probability of there being k transmission-attempts during that frame-time is:

The average amount of transmission-attempts for 2 consecutive frame- times is 2G.Hence, for any pair of consecutive frame-times, the probability of there being k transmission-attempts during those two frame-times is:

$T= (2G)^k e^{-2G}/k!$ ……………….. (1.1)

Therefore, the probability ($Prob_{pure}$) of there being zero transmission- attempts between $t-T$ and $t+T$ (and thus of a successful transmission for us) is:

$Prob_{pure} = e^{-2G}$………………… (1.2)

The throughput can be calculated as the rate of transmission-attempts multiplied by the probability of success, and so we can conclude that the throughput

(S_{pure}) is:

$S_{pure} = Ge^{-2G}$………………… (1.3)

The maximum throughput is $0.5/e$ frames per frame-time (reached when $G = 0.5$), which is approximately 0.184 frames per frame-time. This means that, in Pure ALOHA, only about 18.4% of the time is used for successful transmissions.

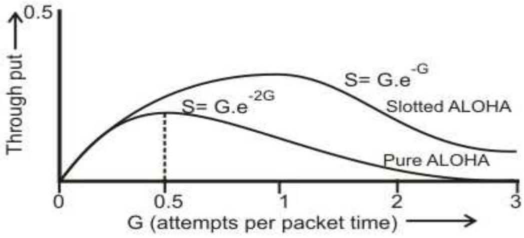


Fig. 4. Comparison of Pure Aloha and Slotted Aloha on Throughput Vs Traffic Load

4.2. Slotted ALOHA: An improvement to the original ALOHA protocol was "Slotted ALOHA", which introduced discrete timeslots and increased the maximum throughput. A station can send only at the beginning of a timeslot, and thus collisions are reduced. In this case, we only need to worry about the transmission-attempts within 1 frame-time and not 2 consecutive frame-times, since collisions can only occur during each timeslot. Thus, the probability of there being zero transmission-attempts in a single timeslot is:

$Prob_{slotted} = e^{-G}$………………….. (1.4)

The probability of k packets is:

$prob_{slotted}k = e^{-G}(1-e^{-G})^{k-1}$………………….(1.5)

The throughput is:

$S_{slotted} = Ge^{-G}$……………. (1.6)

The maximum throughput is 1/e frames per frame-time (reached when $G = 1$), which is approximately 0.368 frames per frame-time, or 36.8%.

Slotted ALOHA is used in low-data-rate tactical satellite communications networks by military forces, in subscriber-based satellite communications networks, mobile telephony call setup, and in the contactless RFID technologies.

5. SLOTTED ALOHA

In slotted ALOHA, the time is dividing into slots of duration equal to the transmission time of a single packet. Each user is required to synchronize the start of transmission of its packets to coincide with the slot boundary. When two packets conflict, they will overlap completely rather than partially, providing an increase in channel efficiency over pure ALOHA. The pessimistic assumption that a collision results in the loss of two packets is usually made in the analysis of an ALOHA protocol. Using this assumption, the maximum value of the throughput in a pure ALOHA is about 18% and in slotted ALOHA is about 36%.

Radio networks operate in interference-limited environments because large number of wireless terminal has allocated only a limited amount of spectrum. Packet collisions among multiple transmitters lead to delays in getting packets to their intended recipients and to inefficiencies in using the precious radio resource. The radio medium is, by its nature, a broadcast medium, since all nodes within range of the transmitter can receive the data. When more than one transmitter sends packets over the same radio coverage range, a collision occurs. In radio networks, such collisions are not always fatal to both packets. A process called capture may allow the receiver to decode the intended packet despite the collision because the signal-to-interference is high enough for decoding. This effect usually occurs when a nearby node is sending the desired transmission, and the interferer is further away and transmitting at the same power as the desired transmitter, or when the interferer is sending at lower power than the desired transmitter.

5.1. The Markov Analysis: The Markov analysis formulates a Markovian model of the system and obtains the stationary state occupation probability distribution by calculating its state transition probabilities. The Markov analysis can study the dynamic behavior of the system, i.e., the behavior taking into account the system instability.

Thus, the Markov analysis is a desirable technique for the performance evaluation of multiple access protocols. However, there is a great difficulty in applying the Markov analysis to complicated protocols, which are modeled as multidimensional Markov chains with a vast amount of entries in their state transition probability matrices. Calculation of the state transition probabilities of such Markov chains is very difficult to carry out, and solving the corresponding set of simultaneous equations is infeasible. Apply the Markov analysis to the Slotted ALOHA. Consider a case in which Slotted ALOHA is used by a group of M users each with a single buffer packet. All packets are of the same size, requiring T seconds for transmission, which is also the slot-duration.

Every user is assumed to be in one of two modes: T (Thinking) or B (Backlogged). In the thinking mode, the user generates a packet in every slot with probability σ and does not generate a packet in a slot with probability 1- σ. The packet generation is an independent process distributed geometrically with mean 1/σ. In the next time slot, if transmission was successful the user remains in the thinking mode and the packet generation starts again. If packet transmission was unsuccessful the user moves to the backlogged mode and schedules the retransmission of the packet according to an independent geometric distribution with parameter ν. In other words, in every time-slot the user will retransmit the packet with probability ν and will refrain from doing so with probability 1-ν. That is the retransmission delay is geometrically distributed with mean 1/ ν. While in the backlogged mode the user does not generate any new packets.

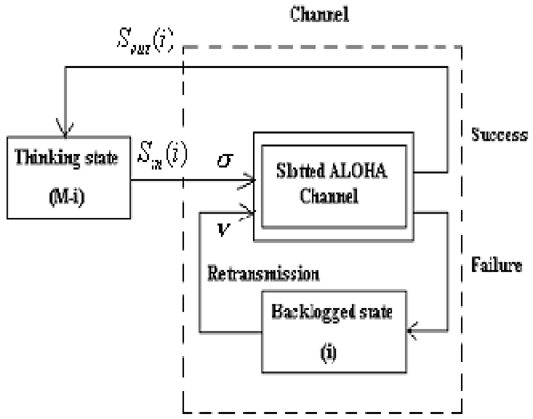


Fig.5. Feedback Model of Slotted ALOHA

Let the slots of the system be numbered sequentially, k= 0,1….and N(k) denote the number of backlogged users at the beginning of the k^{th} slot. The random variable N(k) is referred to as the state of the system. N(k) is a discrete-time Markov chain. The discrete state space will consist of the set of integers {0,1,2….M}.

The transition diagram for the system is shown in Figure 2.2.Upward transitions are possible between every state and all the higher-numbered states, since collision of any number of packets is possible. Downward transitions are possible only to the adjacent state since only one packet can be successfully transmitted in a slot, at that time the backlog is reduced by one user. The missing transition from state 0 to state 1, which is clear since if all users were thinking and a single user generated and transmitted a packet he could not cause a collision and become backlogged.

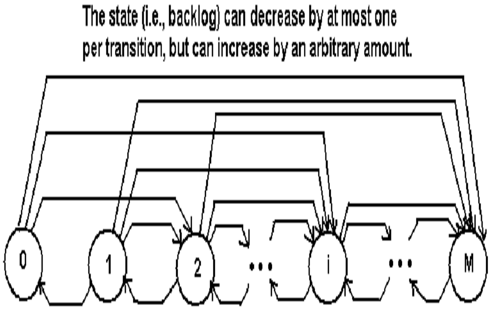


Fig.6. Markov Chain for Slotted ALOHA With M users

Because the number of backlogged users cannot exceed M the Markov chain is finite and from the Figure2.2, we can see that all states communicate. Thus, the Markov chain is also ergodic, meaning that steady-state distribution exists.

Capture can improve the overall performance of the system significantly. In a special case of this phenomenon, packets from nodes close to the access point always triumph over packets sent from nodes at the fringe of the cell coverage. This is called the near-far effect and it is undesirable in the sense that not all nodes have equal and fair access to the receiver. A useful parameter in analyzing the capture effects in packet radio protocols is the minimum received power ratio of an arriving packet, relative to the other colliding packets. This ratio is called the capture ratio γ_{cr}, also referred to as capture factor and is dependent upon the receiver and the modulation used.

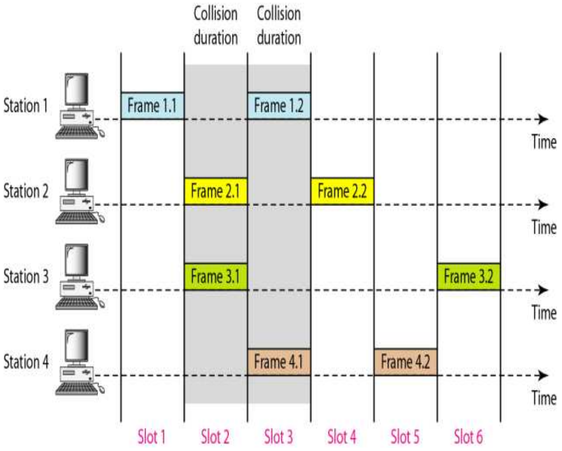


Fig.7. Frames In Slotted Aloha Network

6. DESIGN ANALYSIS

6.1 ALGORITHM:

Step1: Generate the clock pulse and request.
Step2: Here the clk pulse and request should be high i.e., 1 so that the request is answered.
Step3: Initially when clk is 1 and request is 1, then shield and answer will be 0.so the present state is idlecom and the next state is successcom,
Step4: Then probability doubles for changing the state.
Step5: When clk and request is 1 in the next interval, the shield command and answer are 1. So the present state is successcom and next state is failurecom.
Step6: Hence there will be no change in probability.
Step7: when clk and request are 1 in the next interval, the shield command and answer are 0. So the present state is failurecom and the next state is idlecom.

6.2 FLOWCHART

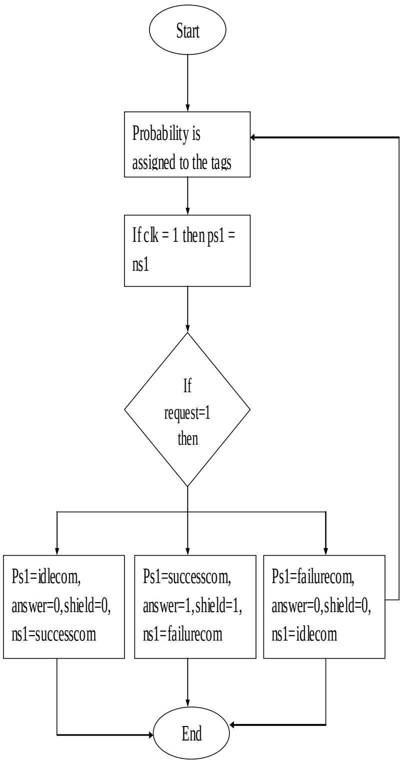
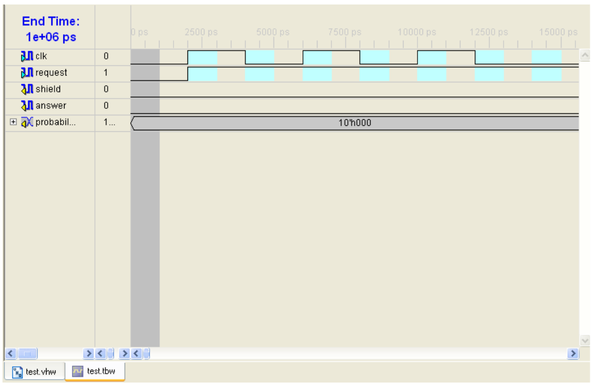


Fig.8. Flowchart of Slotted Aloha Algorithm

7. SIMULATION RESULTS

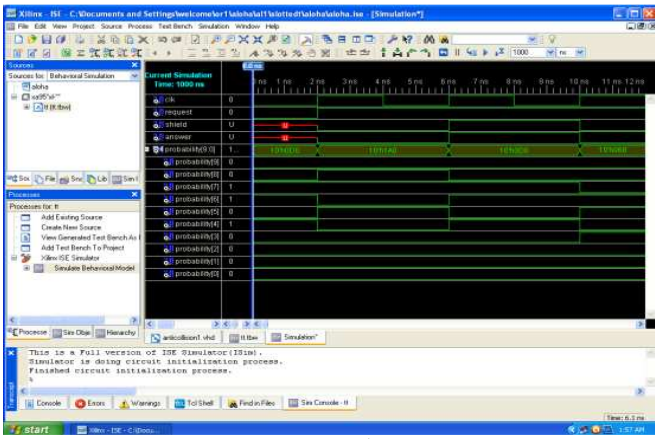
Test bench waveforms:


End Time:
1e+06 ps

clk	0	
request	1	
shield	0	
answer	0	
probabil...	1...	10'h000

Fig.9. Inputs for Clock and Request Are Given

After that create another source i.e., right click on the vhdl file and add new source and create a test bench waveforms. Give input pulses for clock and request and save the file.



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This is a Full version of ISE Simulator(ISim).
Simulator is doing circuit initialization process.
Finished circuit initialization process.
```

Fig.10. Output Test bench Waveforms

After that in processes click Xilinx ISE simulator and click simulate behavioral model and output waveforms are obtained. Here when clk and request signal are 1, and shield and answer are 0 some probability value is obtained. And then state is changed at the next interval.

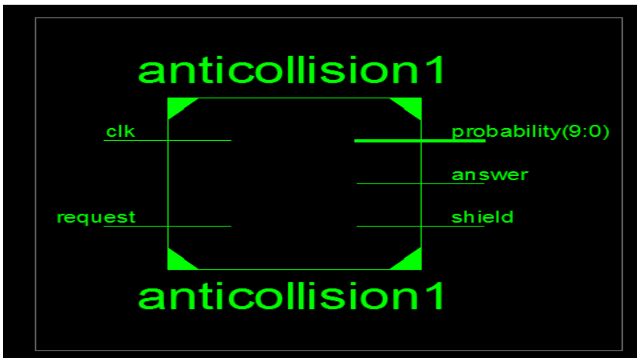


Fig. 11. RTL Schematic

This window about how slotted aloha algorithm can be implemented in hardware. This window is obtained by clicking on view RTL schematic in synthesis XST.

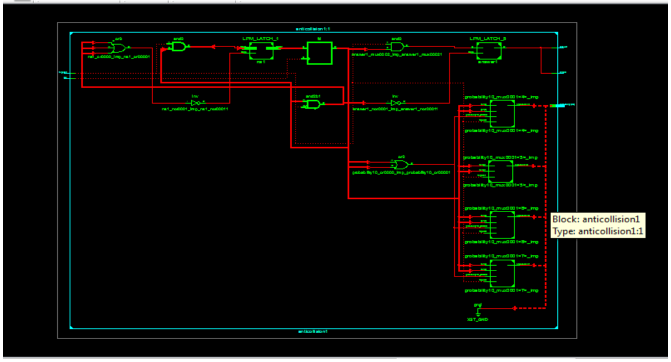
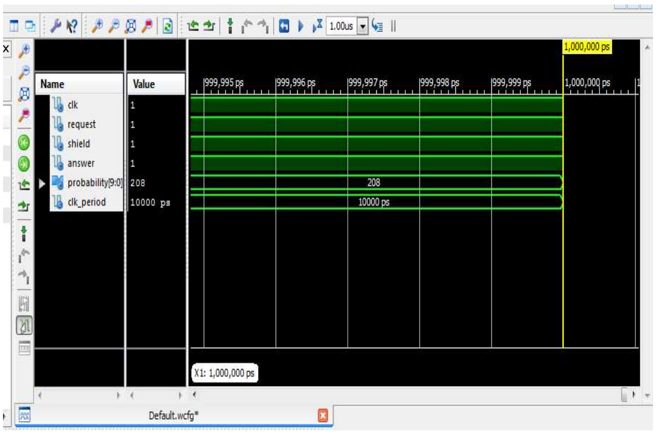


Fig.12. Circuit for Slotted Aloha Algorithm

This window gives the information about what are the components required to implement the slotted aloha algorithm in hardware and this can be obtained by clicking view technology schematic.



Name	Value
clk	1
request	1
shield	1
answer	1
probability[9:0]	208
clk_period	10000 ps

Fig.13. Output Waveforms

This window indicates the output waveforms which gives the functionality of slotted aloha algorithm i.e., at each interval the value of probability checked and change of states takes place.

8. CONCLUSION

Slotted ALOHA is a random access protocol that allows a population of relatively uncoordinated users to share a common transmissions medium. The original version of this protocol assumes that, whenever more than one packet is transmitted at the same time, the information contained in all the transmitted packets is lost. This model, reasonable in some communication environments, turns out to be too pessimistic in others, in which signals transmitted by different users arrive at the common receiver with different power levels.

Stability and throughput have been shown from a Markov chain model, which does not have to assume that packet collisions are necessarily fatal for all colliding packets. With the help of this model it is shown that a mobile radio Slotted ALOHA network has a higher throughput than the famous 1/e=0.36 and is stable under overload.

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