

# Wireless Local Area Network Frame Classification to Access Categories based on User Priority

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**ABSTRACT:** In recent years wireless interaction plays an important role in the field of communication. For proper communication standards are followed, IEEE 802 standard comprises of family of network that covers physical layer specifications of technologies from *Ethernet to wireless*.. For ease of retransmission and flexibility usually data will be coded and overhead will be added. In this paper, 802.11, a wireless standard frame classification is performed for time critical signals (voice & video) and data signals based on user priority. In this proposed work, it is designed in such a way that incoming data is prioritized and are inserted in Ethernet frames by tagging; then they are mapped to Access Categories (AC). Based on user priorities different queues are formed for every access categories and contention for the channels differential. And also to support Quality of Service (QoS) and Enhanced Distributed Channel Access (EDCA) is used which is based on 802.11e.

**KEYWORDS:** Wireless Standard, Access Categories (AC), Quality of Service (QoS), Enhanced Distributed Channel Access (EDCA), Contention.

## I. INTRODUCTION

Wireless communication is among technology's biggest contributions to mankind. Wireless communication involves transmission of information over a distance without the help of wires, cables or any other forms of electrical conductors. Transmitted distance can be anywhere between a few meters (for example, a television's remote control) and thousands of kilometres (for example, radio communication). 802.11 and 802.11x refers to a family of specifications developed by the IEEE for wireless LAN (WLAN) technology. 802.11 specify an over-the-air interface between a wireless client and a base station or between two wireless clients.

There are several specifications in the 802.11 family:

- 802.11: applies to wireless LANs and provides 1 or 2 Mbps transmission in the 2.4 GHz band using either Frequency Hopping Spread Spectrum (FHSS) or Direct Sequence Spread Spectrum (DSSS).
- 802.11a: an extension to 802.11 that applies to wireless LANs and provides up to 54-Mbps in the 5GHz band. 802.11a uses an orthogonal frequency division multiplexing encoding scheme rather than FHSS or DSSS.
- 802.11b (also referred to as 802.11 High Rate or Wi-Fi): an extension to 802.11 that applies to wireless LANs and provides 11 Mbps transmission (with a fallback to 5.5, 2 and 1-Mbps) in the 2.4 GHz band. 802.11b uses only DSSS. 802.11b was 1999 ratification to the original 802.11 standard, allowing wireless functionality comparable to Ethernet.
- 802.11e: a wireless draft standard that defines the *Quality of Service* (QoS) support for LANs, and is an enhancement to the 802.11a and 802.11b wireless LAN (WLAN) specifications. 802.11e adds QoS features and multimedia support to the existing IEEE 802.11b and IEEE 802.11a wireless standards, while maintaining full backward compatibility with these standards.

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- 802.11g: applies to wireless LANs and is used for transmission over short distances at up to 54-Mbps in the 2.4 GHz bands.
- 802.11n: 802.11n builds upon previous 802.11 standards by adding *multiple-input multiple-output* (MIMO). The real speed would be 100 Mbit/s (even 250 Mbit/s in PHY level), and so up to 4-5 times faster than 802.11g.
- 802.11ac: 802.11ac builds upon previous 802.11 standards, particularly the 802.11n standard, to deliver data rates of 433Mbps per spatial stream, or 1.3Gbps in a three-antenna (three streams) design. The 802.11ac specification operates only in the 5 GHz frequency range and features support for wider channels (80MHz and 160MHz) and beam forming capabilities by default to help achieve its higher wireless speeds.
- 802.11ad: 802.11ad is a wireless specification under development that will operate in the 60GHz frequency band and offer much higher transfer rates than previous 802.11 specs, with a theoretical maximum transfer rate of up to 7Gbps (Gigabits per second).
- 802.11ah: Also known as Wi-Fi HaLow, 802.11ah is the first Wi-Fi specification to operate in frequency bands below one gigahertz (900 MHz), and it has a range of nearly twice that of other Wi-Fi technologies.
- 802.1X: Not to be confused with 802.11x (which is the term used to describe the family of 802.11 standards) 802.1X is an IEEE standard for port-based Network Access Control that allows network administrators to restrict use of IEEE 802 LAN service access points to secure communication between authenticated and authorized devices.

The objective of all these specifications is to provide differential service to frames based on the type of data carried by them and to avoid collision during transmission over a shared channel. Wireless communication involves the transfer of both real time and non-real time data. But, the real time data is not given preference over non-real time data. This may lead to loss of real time data in case of congestion. 802.11 frames do not contain the priority field. Hence the 802.11 can be VLAN tagged with 802.1Q frame which contains the priority field. The priority is extracted and mapped to corresponding access category. Thus implementing QoS technology can be performed.

This Paper is organized as follows. Section II describes related work in this filed which explains the drawbacks of the existing technology. Section III explains EDCA specifications. Section IV presents establishment of priority queues in EDCA. Section V discusses simulation results tested for different cases for the implemented design. Finally, Section VI presents conclusion and future scope.

## II. LITERATURE SURVEY

IEEE 802.11 has gained much attention and popularity at an unprecedented rate due to its low cost, ease of deployment and mobility support. Proposal of an adaptive contention window mechanism, which dynamically selects the optimal backoff window according to the estimate of the number of contending stations, is discussed in [1]. IEEE 802.11 protocol is explained, with particular emphasis on the medium access control sub layer [2]. Proposal of a scheme named DCF+, which is compatible with DCF; to enhance the performance of reliable transport protocol over WLAN is explained in [3]. Evaluation of the contention-based channel access mechanism, called enhanced distributed coordination function (EDCF), in comparison with the 802.11 legacy MAC is discussed in [4]. The new hybrid coordination function of the IEEE 802.11e with its contention-based and contention-free (controlled) medium access control schemes is evaluated. The capability to provide QoS support is discussed in [5]. Study of backoff - based priority schemes for IEEE 802.11 and the emerging IEEE 802.11e standard by differentiating the minimum backoff window size, the backoff window-increasing factor, and the retransmission limit is discussed in [6].

However, as a simple and cost-efficient wireless technology for best effort services, lack of built-in mechanism for support of real-time services makes it unsuitable for the ever-increasing demands of multimedia services and applications, such as VoIP, IPTV that are throughput and delay sensitive. (In order to provide Quality-of-Service (QoS) support to multimedia applications, the Multiband OFDM Alliance (subsequently the WI Media Alliance) prioritized channel access (PCA) and IEEE 802.11e enhanced distributed channel access (EDCA) are proposed with attempt to provide service differentiation at the MAC layer. Both of these two schemes are based on IEEE 802.11 distributed coordination function (DCF) only with some simple but effective changes. Based on DCF procedure, there have been

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some possible solutions proposed to support differentiated service at the MAC layer to classify frame based on user priority.

### III. EDCA DESIGN SPECIFICATION

IEEE 802.11 is a set of media access control (MAC) and physical layer (PHY) specifications for implementing wireless local area network (WLAN) computer communication in the 900 MHz and 2.4, 3.6, 5, and 60 GHz frequency bands. MAC Layer and 802.11 MAC header layer is shown in figure 1 and figure 2 respectively.

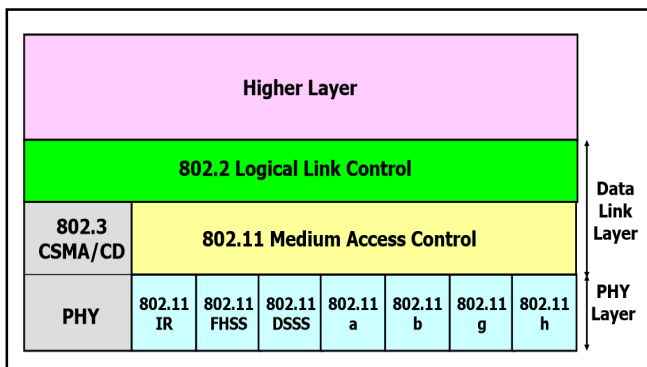


Figure 1: MAC Layer [7]

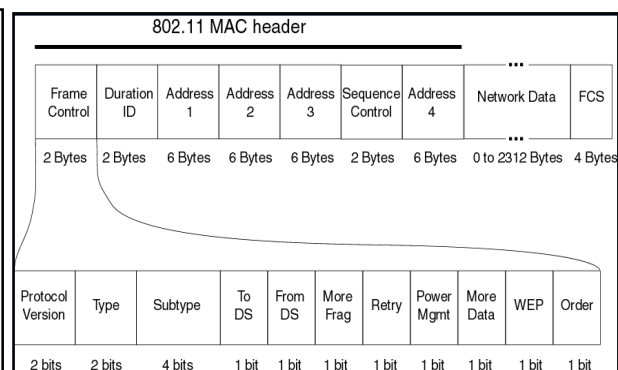


Figure 2: 802.11 MAC Layer [8]

The 802.11 standard defines two channel access mechanisms, called *coordination functions*. These coordination functions determine when a station is permitted to transmit, and when it must be prepared to receive data. The fundamental mechanism is the Distributed Coordination Function (DCF), which uses the CSMA mechanism. The basic rule of CSMA is *listen-before-talk*. The PHY provides a clear channel assessment (CCA) signal to the MAC to indicate if any other stations are transmitting. 802.11 include a virtual carrier sense mechanism to reduce problems with hidden stations. This mechanism is supplemented in 802.11e, but will not be detailed further. The second coordination function is point coordination function (PCF), to keep multiple stations from attempting to transmit simultaneously when another station stops transmitting, a random backoff is used. A station wanting to transmit will generate a random number within a range called the contention window. Once the station senses that the medium is unoccupied for a short time, it starts counting down from the random backoff. If the count reaches zero, it starts transmitting. If another station has selected a lower number and starts transmitting first, the station will hold its current backoff count and resume counting when the medium becomes clear again after the intervening transmission.

IEEE 802.3 is a working group and a collection of IEEE standards produced by the working group defining the physical layer and data link layer's media access control (MAC) of wired Ethernet. This is generally a local area network technology with some wide area network applications. Physical connections are made between nodes and/or infrastructure devices (hubs, switches, routers) by various types of copper or fiber cable.

IEEE 802.1Q is the networking standard that supports virtual LANs (VLANs) on an Ethernet network. The standard defines a system of VLAN tagging for Ethernet frames and accompanying procedures to be used by bridges and switches in handling such frames. The standard also contains provisions for a quality of service prioritization scheme commonly known as IEEE 802.1p.

Priorities are not used to transmit 802.3 and 802.11 MAC frames, and the frames themselves have no priority field. The 802.3 header has been thus modified to add a new field to classify the type of traffic. The TID (traffic ID) is used to select a UP (user priority) for prioritized QoS or a TSPEC (traffic specification) for parameterized QoS. TID values between 0 – 7 are considered user priorities and these are identical to the IEEE 802.1D priority tags. TID values between 8 –16 refer to TSPECs.

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In VLAN two mechanisms are required for the support of applications with QoS requirements i.e. to incorporate priority.

In first mechanism, the enhanced distributed channel access (EDCA) is designated; it delivers traffic based on differentiating user priorities (UPs). This differentiation is achieved by varying the following for different UP values: (a) Amount of time a STA senses the channel to be idle before backoff or transmission (i.e. AIFS), (b) the length of the contention window to be used for the backoff, or the duration a STA may transmit after it acquires the channel (TXOP).

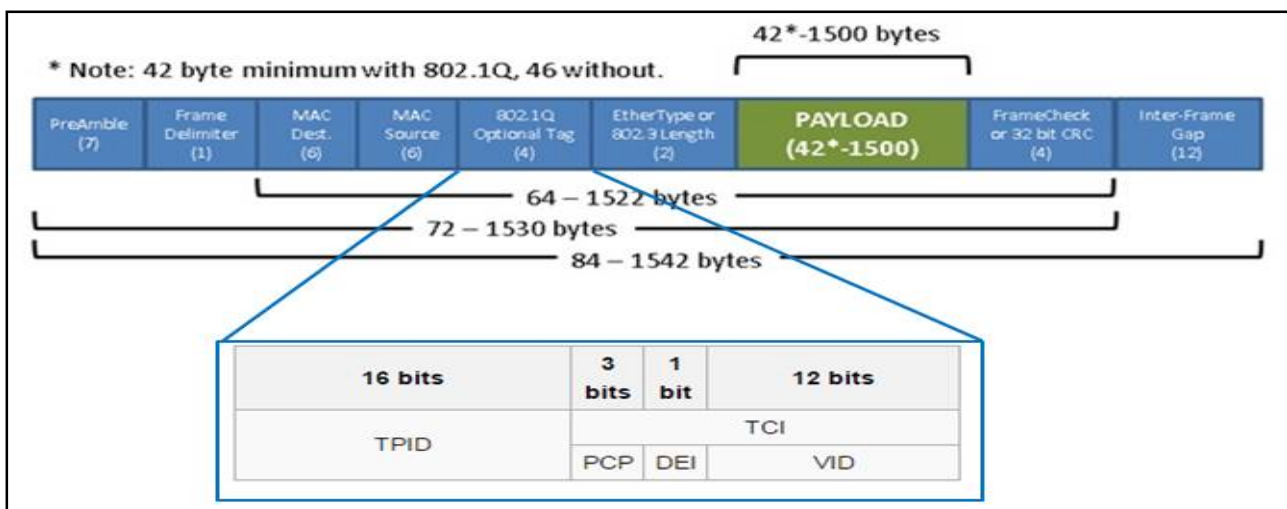


Figure 3: Ethernet Frame Format with VLAN -Tagging [9]

In second mechanism, the hybrid coordination function (HCF) controlled channel access (HCCA) is designated, it allows for the reservation of transmission opportunities (TXOPs) with the hybrid coordinator (HC). A non-access point (non-AP) QSTA based on its requirements requests the HC for TXOPs, both for its own transmissions as well as for transmissions from the QAP to itself.

Allocation of plural sub channels based on user data priority, access requests are received periodically and scheduled, and when a higher priority message is received, completion of a lower priority message is deferred and higher priority request is allocated. Thus, an improved access procedure accommodating multiple priority requests in an efficient manner is in need.

In order to implement frame classification for time critical signals (voice & video) and data signals based on user priority, changes need to be included in the standard are:

1. Establishment of 4 priority queues for traffic (Access Categories), implemented on a per-station basis.
2. Arbitrated Inter-Frame Spacing (AIFS) values for each of the 4 priority queues to replace the single Distributed Coordination Inter-Frame Spacing (DIFS) value previously used for all data and management frames.
3. Random Backoff timers defining Contention Window minimum (CWmin) and maximum (CWmax) values for each of the 4 priority queues.

## IV. ESTABLISHMENT OF PRIORITY QUEUES IN EDCA

### a. WLAN queue and schedule mechanism:

The queue and schedule mechanism is divided into four Access categories (ACs). These four AC queues provide differentiated access to the channel. The four QoS categories align to the 802.1P access categories is given in Table 1 and Figure 4 shows the queuing that is performed on a Wireless Multimedia (WMM) client or AP.

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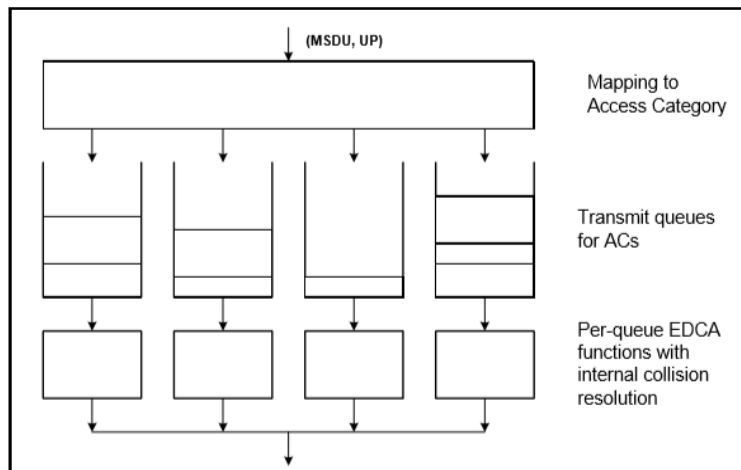
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**Table 1 : Priority Code Point (PCP) to Access Category (AC)**

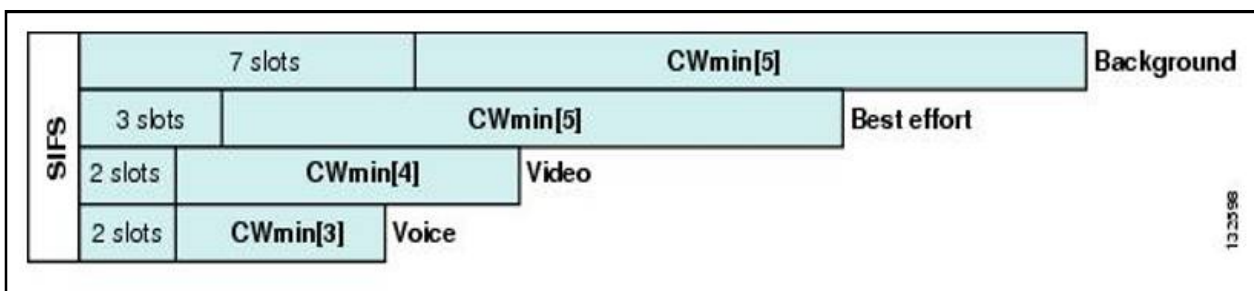
PCP	AC	Designation
111	00	Background
110	00	Background
101	01	Best effort
100	01	Best effort
011	10	Video
010	10	Video
001	11	Voice
000	11	Voice



**Figure 4: WMM queuing procedure [10]**

Each of these queues compete for the wireless channel, with each of the queues using different inter-frame space, contention window (CW) minimum (CW<sub>min</sub>) and contention window maximum (CW<sub>max</sub>) values as defined by EDCA. If more than one frame from different access categories collides internally, the frame with the higher priority is sent, and the lower priority frame adjusts its backoff parameters as though it had collided with a frame external to the queuing mechanism.

Figure 5 shows the principle behind EDCA where different inter-frame spacing and CW<sub>min</sub> and CwMax values (for clarity, CwMax is not shown) are applied per traffic classification.



**Figure 5: Example of Differential Priority [10]**

**b. Arbitration Inter-Frame Spacing (AIFS):**

It is the replacement of the Distributed Inter-Frame Spacing (DIFS) for all data and management frames, and is dependent on the access category and queue of the frame waiting transmission.

Arbitration Inter-Frame Spacing (AIFS) defines different inter-frame gaps for traffic from each of the 4 priority queues. This replaces the original DCF Inter-Frame Spacing (DIFS) which defined only a single inter-frame gap value for all data frames.

Each of the 4 priority queues has a defined inter-frame space value corresponding to the priority assigned to the queue. For example, the Voice queue is the highest priority and as such has the lowest inter-frame space timer. The AIFS timers assigned by IEEE 802.11e are all defined as Short Inter-Frame Spacing (SIFS) value plus a variable

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number of slots times (AIFSN) The AIFS Number (AIFSN) values are administrator configurable, with default values defined by the equation (1):

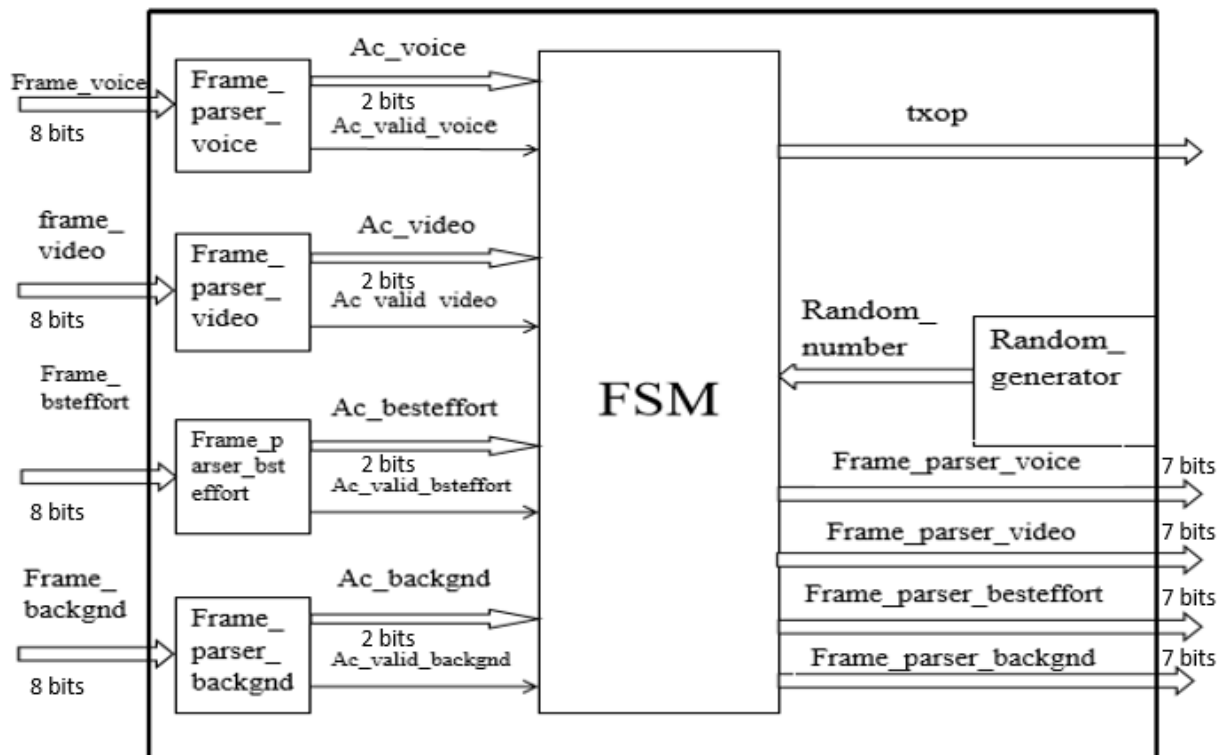
$$\text{AIFS [AC]} = \text{AIFSN [AC]} \times \text{aSlotTime} + \text{aSIFSTime} \text{ ----- (1)}$$

- Voice Queue                    1 SIFS + 2 \* slot time (AIFSN = 2)
- Video Queue                    1 SIFS + 2 \* slot time (AIFSN = 2)
- Best Effort Queue            1 SIFS + 3 \* slot time (AIFSN = 3)
- Background Queue          1 SIFS + 7 \* slot time (AIFSN = 7)

### c. Design Specification of Frame classification Module

Figure 6 shows the architecture of frame classification module. The three main sub-blocks are:

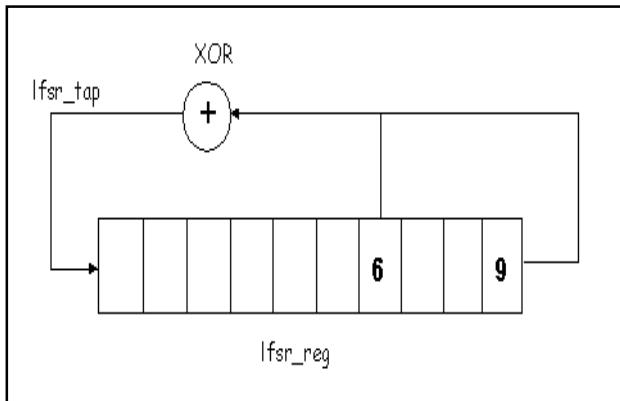
- PCP extraction (frame parser)
- Random generator
- Processing of transmission (FSM)



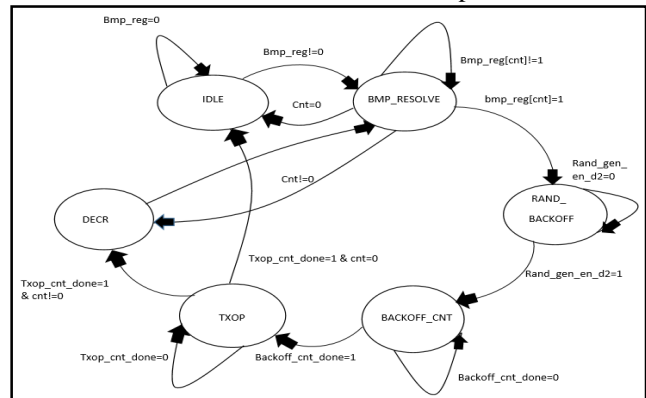
**Figure 6: Frame Classification Block diagram**

In this module, the incoming frame is checked for its validity. After a count of 23 clock pulses the PCP value is extracted from the tagged frame. The PCP values are mapped to corresponding Access Category value. Its correctness is also verified. A random Number Generator is used generate a sequence of numbers which are not truly random. In

this design maximum limit of CWmax is 1023, therefore, a 10 bit random generator satisfying the polynomial  $x^{10}+x^7+1$  is used as shown in Figure 7 and Figure 8 shows the finite state machine used for implementation.



**Figure 7: 10 bit Pseudo Random Generator**



**Figure 8: Finite State Machine**

A four bit register, Bmp\_reg is used to register the incoming frame, if the first bit is set, it implies a voice frame is waiting to be transmitted else there is no voice frame in the queue and similarly other bits imply the other categories. If this register is not zero then in the next state, BMP\_RESOLVE the categories in the decreasing order of priority is checked. Now, in the next state that is RAND\_BACKOFF a random number from the range is selected. The next state BACKOFF\_CNT runs a counter to implement wait time of the frame. The next state that is TXOP defines the transmission opportunity of the frame. The next state, DECR is used to check the next category of the frame in the queue. This process is repeated for the next category. As long as there are no frames the system will be in **IDLE state**.

## V. RESULTS AND DISCUSSIONS

The entire frame classifier is coded in Verilog. Functional verification is performed by using Xilinx ISim simulator, RTL schematic is obtained using XST synthesizer and hardware implementation verification is obtained using ChipScope Pro Analyzer. The simulation results obtained for the integrated block is as shown in figure 9.

- **Case-1:** transmission opportunity value is as per the design. The throughput values are: voice = 6, video = 9, besteffort= 5, background= 5

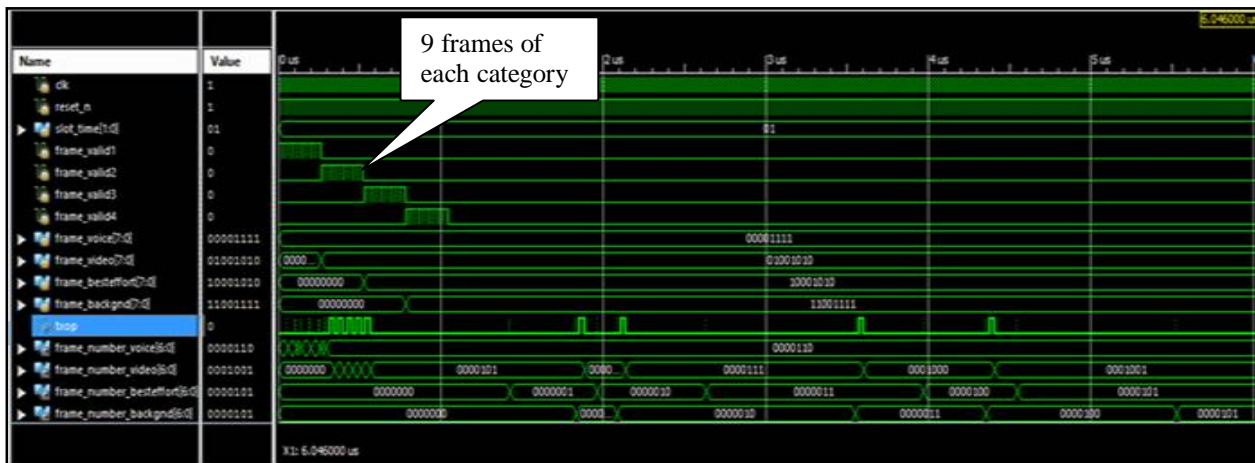


Figure 10: Simulation results of Frame classification module

- **Case-2:** Voice and video frames are given as input at the same time. But we observe in Figure 11 voice is getting served first as expected.

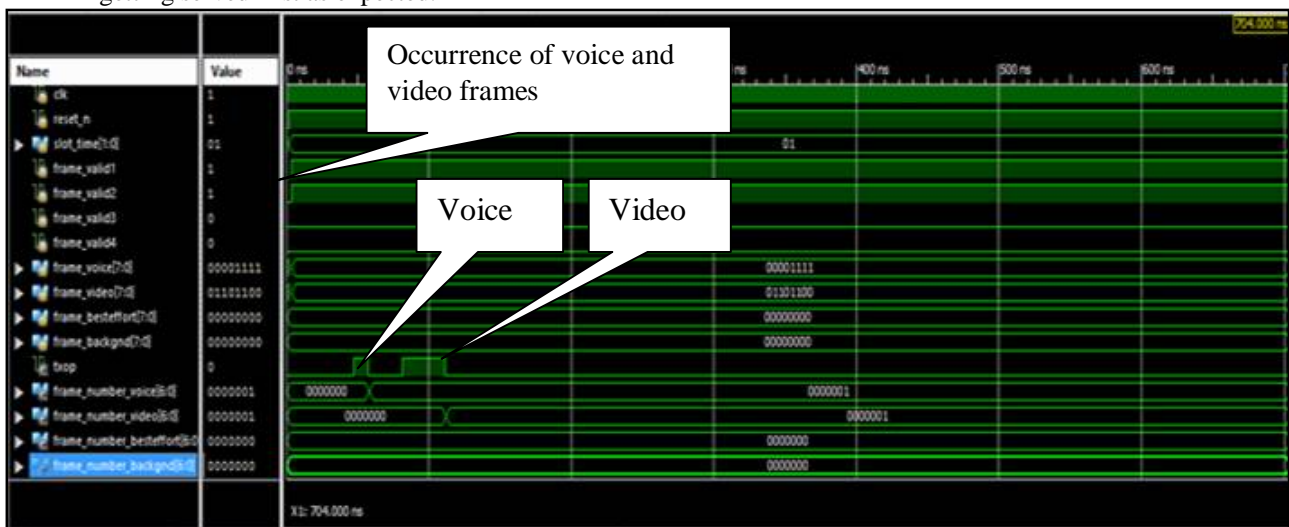


Figure 11: Simulation results of Frame classification Module with Priority

## VI. CONCLUSION & FUTURE SCOPE

Providing differential service has been achieved based on the user priority. First block in frame classifier module is concerned with extracting PCP while next block to generate random number and third block is processing of transmission is used to provide different waiting periods for different categories and thus achieving QoS.

The coding is done in Verilog. This has been simulated using Xilinx ISim simulator. The code is synthesized using XST RTL compiler. The hardware implementation is done and verified on Chipscope. Hence the code is synthesizable. In future design, random backoff counter is to be run when a frame is prevented from transmission due to presence of a higher priority frame may be considered. The technique used for frame classification which has been currently implemented in WLAN can be extended to WiFi networks also. In order to implement this 802.11e is currently working on it.



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