Implementation and Performance Evaluation of Black Burst in the Simulation Environment GloMoSim

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Abstract

IEEE 802.11 is one of the most widely installed Wireless Local Area Netowork (WLAN) technology of the world. It became popular due to its easy installation and low cast. Considering the Quality of Service (QoS) requirements, the IEEE 802.11 is unable to fulfill these requirements. The QoS presents the quality of data traffic over a network. To overcome these problems, IEEE 802.11e was introduced. IEEE 802.11e is an enhanced version of IEEE 802.11 which is designed to support QoS. The Enhanced Distributed Channel Access (EDCA) is an access mechanism of IEEE 802.11e which defines different data traffic types by assigning different priorities on the basis of their QoS requirements. The prioritized Access Categories (ACs) and their traffic types are focused. Different parameters are described which effects the performance of the network.

This thesis presents the implementation of the Black Burst technique, which focuses on QoS requirements over wireless networks. This technique is implemented in the IEEE 802.11 Medium Access Control (MAC) layer. The important parameters are discussed that effects the performance of the network. Implementation and operational chronology of Black Burst protocol is described. The protocol is implemented in the simulation environment (GloMoSim) Global Mobile Information System Simulator. The GloMoSim is a simulation software for wireless networks. Multiple scenarios are designed to present the performance evaluation and comparison of IEEE 802.11e EDCA and Black Burst.

The evaluation results shows that IEEE 802.11e is a better protocol to fulfill the QoS requirements and makes the data traffic more efficient over a network. The Black Burst also shows good performance on considering small scale network scenarios.

Acknowledgments

Thanks to Allah for His kindness in giving me the power to complete this assignment.

Then most importantly I would like to express my heartiest gratitude to my parents, Maan Jee and Abu Jee, for their blessings, support and patience.

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Contents

List of Figures

List of Tables

Chapter 1

Problem Specification

1.1 Background

IEEE 802.11 WLAN [1] standard nowadays is being used and implemented all over the world in different ways and environments. The reason of its good reputation is its low cost, simplicity and effective transmission over distributed environments. Now the IEEE 802.11 has its improved versions called 802.11b and 802.11a launched in 1999. The IEEE 802.11b supports transmission data rates upto 11 Mbit/s at the wireless medium and IEEE 802.11a version can achieve data rates of up to 54 Mbit/s over the wireless medium. In 2003, IEEE 802.11g [4] was released by enhancing PHY (Physical) layer specification. The basic mechanism of MAC of IEEE 802.11 is called DCF (Distribution Coordination Function) and the other access mechanism of IEEE 802.11 is called PCF (Point Coordination Function). PCF is seldom being used and implied over networks.

The QoS is set of qualitative and quantitative characteristics such as the bandwidth, delay, data loss and jitter.

To meet the QoS requirements over IEEE 802.11 networks, a lot of work has been done and a new version of 802.11 is developed called IEEE 802.11e [5]. IEEE 802.11e is designed to fulfill the needs of multimedia applications of modern world by prioritizing them over the network. That means, IEEE 802.11e gives more priority to multimedia applications over other applications, in order to have better throughput and delay.

IEEE 802.11e defines Hybrid Coordination Function (HCF) which is a newer version of PCF. PCF is based on centrally controlled access and rarely implemented in networks due it inefficient access mechanism. The Distribution Access Mechanism for IEEE 802.11e is called EDCA (Enhanced Distribution Channel Access) which is enhanced version of DCF. This defines the priorities for transmission by setting values and parameters for each multimedia application.

With development and research over different schemes of prioritized multimedia applications, another scheme was introduced called Black Burst [11] . This protocol is also based on distributed coordination function by making enhancement on IEEE 802.11 structure. This protocol serves prioritized mechanism for multimedia. Black Burst protocol meets the QoS requirements for high priority data stream. But in different scenarios, the performance of Black Burst is limited as compared to IEEE 802.11e.

1.2 Tasks

The task is divided into different phases. The first phase is to understand IEEE 802.11 and IEEE 802.11e, then studying the chronology and implementations of Black Burst in GloMoSim [6]. The GloMoSim is a popular simulator for mobile and wireless networks which is developed by the Parallel Computing Lab at UCLA. The next phase is the performance comparison of IEEE 802.11e with Black Burst. The results for both protocols are taken in different scenarios with different parametric values.

Chapter 2

Introduction to IEEE 802.11e

2.1 Introduction

At present, IEEE 802.11 [1] is widely used and has experienced a great success after the development of the Internet. IEEE 802.11 was released in 1997 by the IEEE (Institute of Electrical and Electronics Engineering). MAC and Physical layers are the specification for this WLAN. This standard also belongs to the well known family of IEEE 802.11x standards. Afterwards the physical specification was enhanced but not enough work has been done on the MAC layer. Then later in 1999, IEEE introduced two enhanced physical layer specifications 802.11b [3] and 802.11a [2] with data transmission rates up to 11 and 54 Mbps, respectively. The IEEE 802.11b uses the DSSS (Direct Sequence Spread Spectrum) physical layer which operates on the 2.4 GHz band with a maximum data transmission rate of 11 Mbps. IEEE 802.11a is based on the OFDM (Orthogonal Frequency Division Multiplexing) physical layer specification which operates on the 5 GHz band with a maximum data transmission rate up to 54 Mbps.

There are two system architectures defined by IEEE 802.11, BSS (Basic Service Set) and IBSS (Independent Basic Service set). In Basic Service Set, all stations (STAs) are connected with one Access Point (AP). But in IBSS, all stations are connected to each other and can communicate directly to each other, as it is illustrated in figure 2.1.

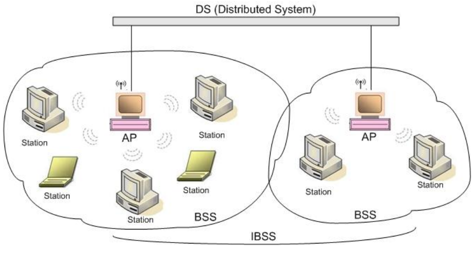


Figure 2.1: IEEE 802.11 network architecture

DCF (Distributed Coordination Function) [8] and PCF (Point Coordination Function) are access mechanisms of IEEE 802.11 MAC. Where DCF provide multiple access technique based on the CSMA/CA (Carrier Sence Multiple Acces/Collision Avoidance) protocol. PCF is a polling based technique and provides centrally controlled channel access.

DCF is the basic access mechanism of IEEE 802.11 using the CSMA/CA protocol. In this operation the sender first sense the medium and if it is idle for a short period of time called DIFS (DCF Inter Frame Space) then the sender starts the transmission otherwise it remains in waiting state for at least DIFS period of time. During the transmission from one station, all other stations remain in waiting state. When the receiver receives the data then the receiver send an ACK after the SIFS (Short Inter Frame Space). This method of transmission is called CSMA.

Backoff Procedure

In order to avoid collisions when two stations attempt to win the medium access for transmission, they have to wait for an additional time period called Backoff (BO)[9], after the DIFS period of time which presents if the medium is idle. That additional time (BO) is randomly selected by stations and they have to wait for this randomly selected time (BO value or Time) period. The stations have to wait for a BO time period after the DIFS, when medium becomes idle. After the DIFS period of time each station who have data to transmit, starts decreasing the BO value or the timer and the station whose BO value first reaches to zero first, will win the medium access.

After the transmission, this station has to wait for a DIFS period of time for the medium to be idle again and then again select a random number for backoff to decrease. At each successful transmission this BO values is reset. In the mean time the other stations will resume their backoff counters when the medium becomes idle again. The random backoff values is chosen from the range [0,CW], where CW is called the contention window and initial CW size is set to 31. On every unsuccessful transmission this contention window is doubled by using the equation 2x(cw+1)-1), and this equation increased the size of contention window until it reaches to maximum size CWmax. The CW initially starts with the value 31, which is called CWmin and is increased by its double value at every unsuccessful transmission, e.g., 31, 63, 127, 255, 511, 1023.

Example of DCF Operation

Figure 2.2 shows an example scenario of the DCF operation. Three stations, STA1, STA2 and STA3, are contending to win the medium after the DIFS time period. These all stations will choose their backoff values randomly within the fixed contention window size [0,31]. The STA1, STA2 and STA3, have chosen the backoff values 7, 16 and 18, respectively and start decrementing their backoff timers until they reach zero. In this way the STA1 wins the medium and starts its transmission, while the other stations pause their BO and wait until the STA1 will complete its transmission. In figure 2.2 the transmitting block presents the data, including SIFS and ACK time. Waiting block presents paused backoff values. After the first successful transmission, the backoff value chosen by STA1 becomes similar to the paused backoff value of STA2. The backoff values of both STA1 and STA2 are decreased and reach zero at the same time. Now both stations try to access the medium at the same time that causes a collision. In this case, both STA1 and STA2 will double their contention window size and will again choose a new BO value. In DCF operation, increment in CW size causes large probability of selection of different BO values by stations. Due to the large probability of different BO value, there is less chance of collision.

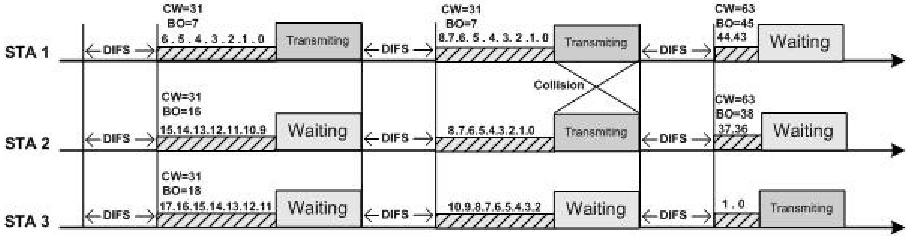


Figure 2.2: Example scenario of the operation of DCF

Limitation of IEEE 802.11

- DCF does not support QoS in the IEEE 802.11 standard.
- All types of traffic are treated in the same fashion that causes lackness in QoS.

2.2 IEEE 802.11e

IEEE 802.11e [9][5] is an enhanced version of the IEEE 802.11 standard that supports QoS. The specialty of this standard is to prioritized the data traffic according to their needs. In this standard, four different Access Categories (ACs) are defined, where ACs present the type of data in the transmission over the network, i.e. Voice, Video, Background and BestEffort. These ACs have different priority levels. In this way each high priority AC has more probability to transmit its data over the channel.

2.3 HCF (Hybrid Coordination Function)

IEEE 802.11e has defined a new function or mechanism by enhancing the PCF, called HCF (Hybrid Coordination Function)[9]. It is the centralized coordination function that merges the features of DCF and PCF to improve QoS issues. HCF provides control over the centrally and distributed channels access mechanisms similar to DCF and PCF.

2.4 EDCA (Enhanced Distributed Channel Access)

To handle the data traffic appropriately EDCA [7] defines unequal access to the medium by prioritizing the data traffic. The characteristics of EDCA is described in the following.

2.4.1 Access Categories

In EDCA, for each type of data traffic, four Access categories have been defined. For each Access category, different priorities and parameters have been defined. These parameters are called EDCA parameters. According to access categories and their priorities these data traffic types have been named AC_BK, AC_BE, AC_VI and AC_VO, for Background, Best Effort, Video and Voice, respectively. In these ACs the voice has the highest priority and background has the lowest priority. In this thesis work only voice and background traffic types have been considered for comparison and evaluation. When a frame arrives at the MAC layer it contains a priority value. This priority value is referred to as the User Priority (UP). These priority values are assigned according to data traffic and their importance. These eight priority values are from 0 to 7.

2.4.2 EDCAF (Enhanced Distributed Channel Access Function)

Every station handles four transmit queues, one for each AC and four independent EDCAFs [10].

2.4.3 EDCA Parameters

There are different parameters for different ACs and data traffic types. The time period in which medium is sensed before transmission is started, is called Arbitration Inter Frame Space (AIFS) [9]. The value of AIFS is smaller for higher priority ACs and is larger for low priority ACs. In this way the high priority ACs may have more quick and instant access to the medium as compared to low priority ACs. The AIFS is derived from following equation.

$$\text{AIFS}=\text{AIFSN x aSlotTime} + \text{aSIFSTime}$$

Where aSlotTime is the slot time, aSIFSTime is the SIFS time period and AIFSN (Arbitration Inter Frame Space Number) is used to determine the length of AIFS. Then the CW (Contention Window) size is bigger for low priority ACs and smaller for high priority ACs. So that the corresponding chosen backoff value would be smaller for high priority stations. For the low priority ACs the backoff value could expectedly be chosen bigger. The result is that the low priority ACs have to wait longer to access the medium and this causes longer delays.

2.4.4 Example of EDCA Operation

The EDCA operation is a bit similar to the DCF Operation. For example, if the medium is free or idle for a AIFS period of time, the EDCAF chooses a random backoff value from its corresponding contention window and starts decreasing the backoff value. Then EDCAF starts transmission when its backoff value reaches zero. Figure 2.3 shows an example of the EDCA operation to further explain how four ACs contend to send a frame.

The ACs of EDCAFs, AC_VO and AC_VI, have high priority and smaller AIFS time period. Because of smaller AIFS time period the high priority ACs contend to win the medium first as compared to the low priority ACs, AC_BE and AC_BK. The low priority ACs, AC_BE and AC_BK, have large value of AIFS time period and have to wait longer as compare to high priority ACs. So, high priority ACs will choose their backoff value from their contention window first and start decreasing their backoff values. In example AC_VO and AC_VI have chosen their backoff values 6, 7. And these ACs start decreasing their backoff values. The AC_VO has smallest backoff value, so its counter or BO decreases quickly and approaches zero first. The AC_VO wins the medium first

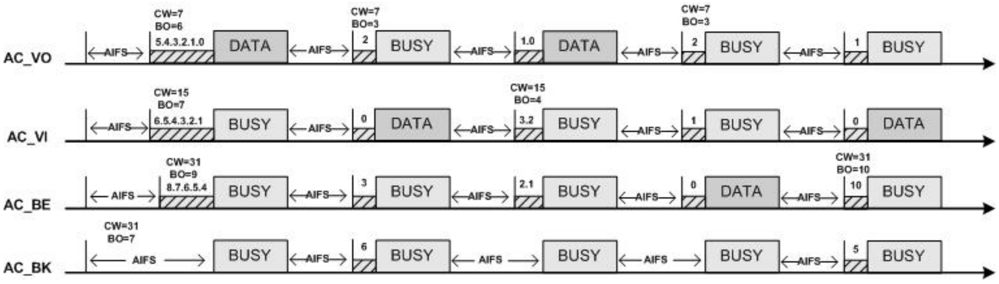


Figure 2.3: IEEE 802.11e, EDCA operation

and starts transmitting its frame. Meanwhile all other ACs pause their BO until the medium becomes idle again. The small BO values provide higher probability of wining the medium for transmission. The CW size of low priority ACs is big and there is probability that low priority ACs will choose large BO values. In this way the low priority ACs have to suffer a lot with time or have to wait a lot to win the medium in the presence of high priority ACs. Figure 2.3 shows that the AC_BK has really large number for AIFS to choose and start the backoff value and chooses a large value of BO from CW.

Internal Collision

Every AC has its own CW for which EDCAF chooses the backoff value. All CWs and BOs are independent of other EDCAFs and ACs. There is a possibility that within a station two ACs choose the same backoff value and their BOs reach zero at the same time. It causes collisions with in one station, which is called an internal collision.

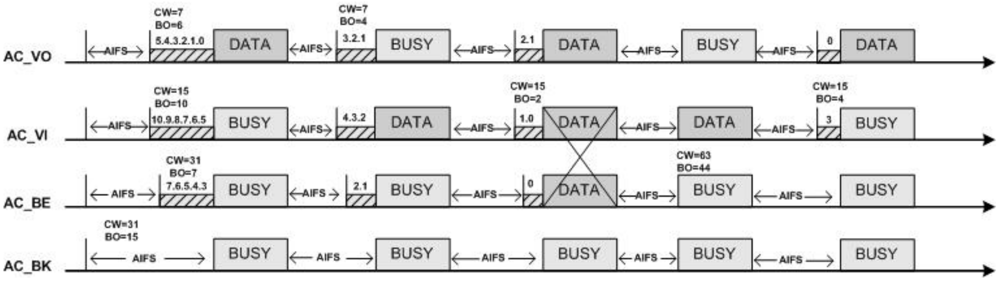


Figure 2.4: Example of internal collision in EDCA mechanism

In the case of the high priority ACs and the low priority ACs' collision, the CW of low priority AC is doubled and chooses new BO value. But the high priority AC continues its BO. In this way each time in collision of low and high priority ACs, the low priority ACs have to increase its CW and reset their BOs as shown in figure 2.4.

External Collision

There is possibility that the ACs from different stations can choose the same backoff values, that also causes a collision which is called an external collision. In the collision case of the AC_VO from station 1 and the AC_VI from station 2, both ACs increase their CWs and again choose new BOs. As it has been shown in figure 2.5.

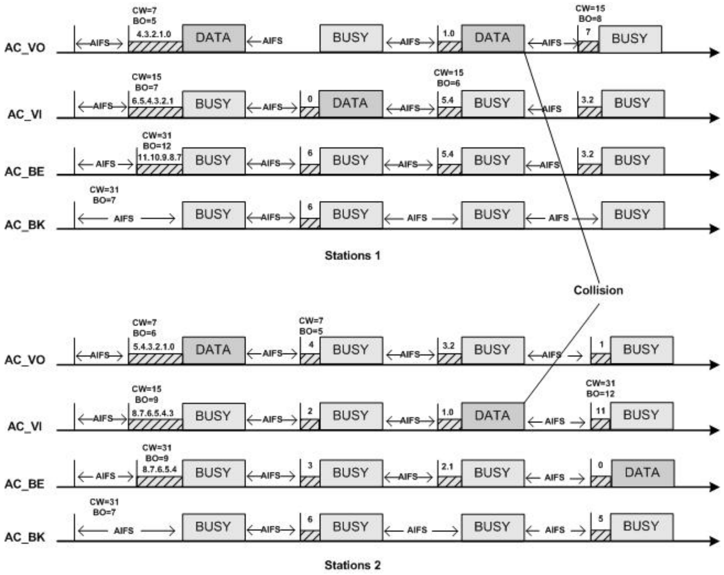


Figure 2.5: Example of external collision in EDCA mechanism

Chapter 3

Introduction to Black Burst

3.1 Introduction

Black Burst [11], is an access technique for WLAN. This technique is completely distributed and is based on the IEEE 802.11. This technique ensures the good performance using a prioritized mechanism for multimedia traffic in real time traffic scenarios. This access technique or mechanism performs in round robin behavior. In the Black Burst the QoS is measured over high and low priority data traffics such as voice and background. The operational behavior of this technique is illustrated with results over different scenarios.

3.2 Black Burst Basic Mechanism

According to the Black Burst, in the real time stations the high priority data traffic is treated under a prioritized mechanism. But low priority data traffic is treated as it is handled normally in IEEE 802.11. The high priority ACs are followed by TIFS, in order to have quick access to the medium. TIFS (Time Inter Frame Space)[11] is inter frame space and work like DIFS. The low priority ACs are handled in normal DCF fashion. The DIFS time period is longer than TIFS time period in order to give high priority ACs a quick access to the medium.

Generally in the case of high priority AC, when it contends to transmit data if the medium is idle then after a short interval of time TIFS, data will be transmitted. If the AC has access instant or contend to transmit data after a TIFS time period, and the medium is busy then the station will enter into the black burst contention period. During this contention period AC decrease its waiting timer and keeps decreasing until the medium is found idle. The moment when the medium is found idle then according to the waited time by each station sends a number of black slots called burst. These black slots can be said to be pulses of energy or noise. The number of slots are proportional to the time waited by any station. In the *tobs* (Observation Time or Medium Sensing Time) interval, the length of burst (black slots) is sensed. Only AC will win the medium who has the longest burst or medium will be won my the AC who has been waiting for longer time.

3.2.1 Black Burst Parameter

The following parameters are used in the implementation of the Black Burst protocols. The optimal values used for these parameters are given in table 3.1.

- Access Instance: The access instants is the time instance in which a station get access to the medium to transmit the data.
- TIFS (Time Inter Frame Space): Its behavior is similar to DIFS (DCF Inter Frame Space). TIFS is the time interval, the medium is sensed idle before transmission or when the burst is started. The TIFS time period is used in the high priority AC transmissions.
- DIFS (DCF Inter Frame Space): It is the time period, the medium is sensed idle before transmission or when the data is started. In the black burst technique the DIFS are used in low priority ACs as it is used in IEEE 802.11.
- tobs (Time for Observation): It is the time period, the medium is sensed idle before transmission or when the data is started. Time period of *tobs* is less than Time period of tmed (TIFS), so that the real time stations do not contend to transmit black slots or burst during observational time *tobs*.
- tunit: It is a system parameter which is used to calculate the burst length. The *tunit* value is calculated by the given equations 1 and 2 [11].

$$t_{unit} \quad \leq \quad (t_{obs} + t_{pkt} + t_{med}) \qquad (1)$$

- tbslot: It is the length of black slot (burst), where tbslot is greater than 2t and is calculated by the following equation.

$$BurstLength \quad \approx \quad t_{obs} * \{d/t_{unit}\} \qquad (2)$$

Parameters	**Values**
Slot Time	20μ sec
TIFS=SIFS+SlotTime	30μ sec
SIFS	10μ sec
tobs	4μ sec
tbslot	20μ sec
tmed	20μ sec
Number of Stations	10, 20, 30, ... ,60

Table 3.1: Parameters used in the simulation

3.2.2 Access Categories (ACs)

In the Black Burst technique only two access categories are considered, AC_VO and AC_BK, voice and background, respectively. These ACs are defined according their priorities and parameters. This thesis presents the comparison and results of only two ACs or prioritized data traffic i.e. voice and background. The ACs and their priority levels are defined in table 3.2.

Access Categories	Priority values
AC_VO	0
AC_BK	1

Table 3.2: The priorities of the ACs

3.3 Black Burst and DCF Operational Example

In Black Burst, the bursting is used for high priority ACs and the DCF approach is used for low priority ACs. The illustration of this operation is shown in figure 3.1.

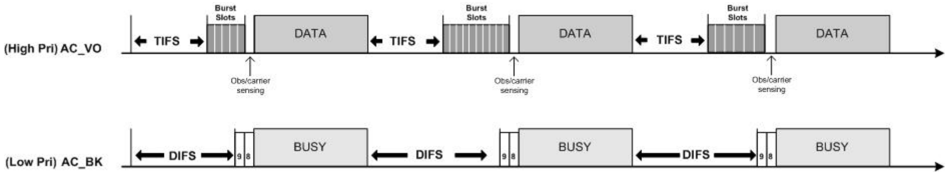


Figure 3.1: Black Burt and DCF mechanism

The high priority AC, AC_VO contends to transmit data followed by the TIFS time period and enters into black burst contention period and starts bursting. The AC_VO has higher priority due to shorter inter frame space as compare to DIFS, which is used for low priority station. After the burst of black slots, the medium is sensed in tobs time interval, to see if any other station has a longer burst to win the medium and then transmission is started by wining the medium. The low priority ACs are less able to come out from long DIFS and backoff intervals and would not be able to win the medium easily. Figure 3.1 illustrates the starvation of low priority stations or ACs. TIFS time interval does not let the low priority ACs to win the medium easily because low priority ACs have a long DIFS time interval.

3.4 Black Burst Operational Example

Black Burst handles the high priority ACs and creates round robin scheduling of data transmissions. Due to this scheduling, each time there is unique winner station and transmits the data. Possibly all the stations who try to contend the medium, will win the medium according the scheduling. The operational behavior of the Black Burst is illustrated in Figure 3.2.

Suppose there are three ACs, AC_1, AC_2 and AC_3. After TIFS time period the AC_1 contend to transmit data. When the medium is perceived to be idle, it starts the transmission. During the transmission of AC_1, the AC_2 and AC_3 contend to access the medium in different time intervals where AC_3 contended to access the medium after AC_2. Both the AC_2 and AC_3 marked their flags at time when they found the

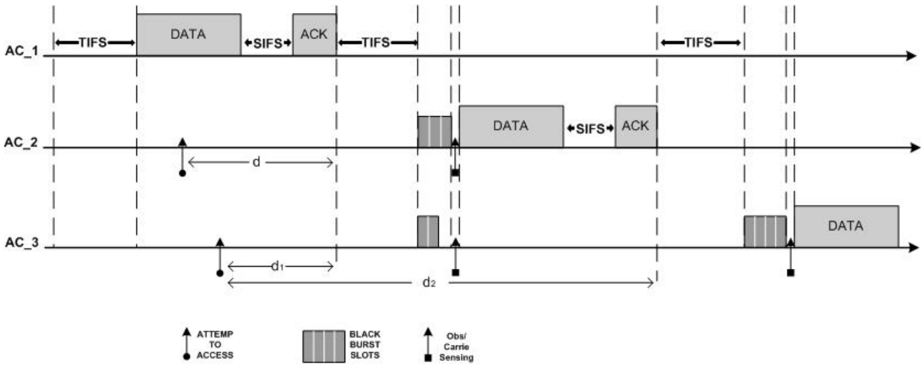


Figure 3.2: Black Burst operation

medium busy and enter into waiting state. These two ACs will wait until the medium is perceived to be idle again. The transmission of AC_1 is finished and medium is perceived to be idle again after TIFS time period, both AC_2 and AC_3 will enter into the black burst contention period and start sending the black slots or simply start bursting for as long as they have been waiting for the medium to be idle. The AC_2 has been waiting for longer time than AC_3 to access the medium. The *d* and *d1* is waiting time for AC_2 and AC_3 respectively. The burst length of AC_2 is longer than AC_3 considering the waiting times *d* and *d1*. After the transmission of the burst by ACs the medium is sensed in tobs time period. The decision is made in the tobs time period that which AC will win the medium either AC_2 or AC_3 on the behalf of burst length. According to the rules, the AC_2 has a longer burst and it will win the medium. The AC_3 again could not win the medium and has to wait again until the medium becomes idle. Then it enters into black burst contention period following TIFS time period and starts bursting. This time, the burst length of AC_3 would be longer than its previous burst length, because the previous waiting time *d1* will be included in new waiting time and it would become *d2*. This addition in waiting time causes the longer burst. Finally the AC_3 will win the medium after tobs time interval and starts its transmission.

3.5 Black Burst and EDCA Contention Period

The behavior of the contention periods of the Black Burst and EDCA is a little bit similar. By increasing the number of stations, the both techniques become different. The contention period of Black Burst prolongs by going into waiting state again and again, which causes long burst lengths. The long burst period or contention period causes load over the channel. In the Black Burst technique, the requirements of QoS regarding multimedia applications at large number of stations, is not good as compared to the EDCA access mechanism of IEEE 802.11e. In other side, in EDCA operation the contention window size is fixed for high priority Access Categories (ACs), unless there is no external collision. And on each successful or un-successful transmission the backoff values is always chosen from fixed contention window size, which is 7. The size of the network do not effect the high priority ACs and it maintains is performance.

3.5.1 Collision Resolvability

In Black Burst, the ACs are given a specific time and priority to arrive at the MAC layer in order to let them have transmission. There is almost no chance for stations or ACs to transmit data at the same time, ensuring no collision. Where EDCA in IEEE 802.11e has possibility to have collision in transmission, which is already discussed in chapter 2.

Chapter 4

Design and Implementation

This chapter presents the implementation of Black Burst over the DCF mechanism in GloMoSim [6]. GloMoSim is very popular environment for simulation that supports IEEE 802.11, DCF and some other MAC protocols. Moreover, different parameters and ACs are described with the prioritized mechanism.

4.1 Concept of Priority Mechanism

The high priority ACs use the Black Burst mechanism and the low priority ACs use the DCF mechanism. The Black Burst technique handles only two types of traffic voice and background.

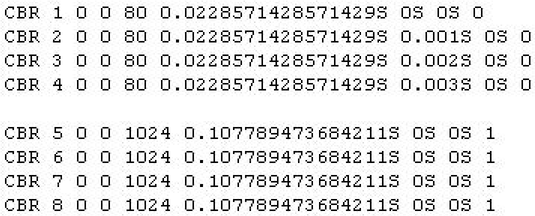
The new parameters for ACs are defined which are described in table 4.1. The '0' value presents the high priority AC and '1' presents the low priority AC i.e. AC_VO and AC_BK. In the scenarios each station is used for single a traffic type. A single station does not send voice and background data at the same time. In GloMoSim, there is no priority mechanism on the MAC layer. The priorities have been assigned on the bases of user priority. There is an appropriate way to get priorities for each traffic type from input files. Since we are using CBR application which takes input form app.conf file, therefore we are taking priorities from this file and that priorities are given by the user. The modified CBR commands are shown in figure 4.1 and general syntax of CBR command is as follow.

$$\begin{aligned}CBR < scr >< dest >< itemstosend >< itemsize >< interval >\\ < starttime >< endtime >< priority >\end{aligned}$$

The code of file has been modified in this way that CBR application can only be supported by the Black Burst technique.

AC	**Priority Level**	**Packet Size (bytes)**
AC_VO (Voice)	0	80
AC_BK (Background)	1	1024

Table 4.1: Access categories with values



```
CBR 1 0 0 80 0.0228571428571429S 0S 0S 0
CBR 2 0 0 80 0.0228571428571429S 0.001S 0S 0
CBR 3 0 0 80 0.0228571428571429S 0.002S 0S 0
CBR 4 0 0 80 0.0228571428571429S 0.003S 0S 0

CBR 5 0 0 1024 0.107789473684211S 0S 0S 1
CBR 6 0 0 1024 0.107789473684211S 0S 0S 1
CBR 7 0 0 1024 0.107789473684211S 0S 0S 1
CBR 8 0 0 1024 0.107789473684211S 0S 0S 1
```

Figure 4.1: CBR commands in app.conf file

4.2 Introduction to GloMoSim

GloMoSim stands for Global Mobile Information System Simulator which is quite popular simulation environment for mobile and wireless networks. This environment is developed at UCLA Parallel Computing Laboratory and supports parallel simulation, based on the C language. The layered architecture of the GloMoSim resembles to OSI stack and has the same idea of APIs between the layers. That brings convenience to the design of new models and protocols at different layers. GloMoSim's simulation environment is developed for the sequential execution of discrete event simulations. An event can be defined as: the occurrence that change the sequence of execution. The GloMoSim environment is available for universities as academic versions. These versions can be used for sequential execution of simulations. Table 4.2 describes the models supported by GloMoSim at each layer.

Layers	**Protocols**
Mobility	Random waypoint, Random drunken, Trace based
Radio Propagation	Two ray and Free space
Radio Model	Noise Accumulating
Packet Reception Models	SNR bounded, BER based with BPSK/QPSK modulation
Data Link (MAC)	CSMA, IEEE 802.11 and MACA
Network (Routing)	IP with AODV, Bellman-Ford, DSR, Fisheye, LAR scheme 1, ODMRP, WRP
Transport	TCP and UDP
Application	CBR, FTP, HTTP and Telnet

Table 4.2: Protocols and models supported by GloMoSim at each layer

4.3 Implementation of Black Burst

Here I am handling the ACs in different structures that have been defined according their priorities and features i.e. low and high priority.

4.3.1 BlackBurstHighPriority

The Black Burst defines a data structure *BlackBurstHighPriority.* That is used for high priority traffic and contains all high priority features in it. Some data types and the variables are used in this data structure of the Black Burst which are given in the table 4.3.

The parameter TIFS is used which is a time interval and described in section 3.2.1. The ClockType is a parameter of PARSEC that keeps the simulator time and keeps the other time parametric information i.e. t_sch_Start, t_sch_End and 'd'. The t_sch_Start is starting time when station contends to the medium or packet arrives at the MAC layer. The t_sch_End is ending time when station finds the medium idle. The parameter 'd' is distance or difference of time between t_sch_Start and t_sch_End.

Different parameters are used to keep the information and activity of the packet like, *vpktsToSend*, *pktSendUnicast*, *retxDueToCts*, *pktsDropped*, *pktsLosses*, *pktsIQueue.*

The data structure *BlackBurstAccessType* is used to handle the type of traffic considering its priority level. In this data structure two tags are used called BlackBurst_High and BlackBurst_Low. These tags are used to categorize the traffic or packet into low priority traffic type and high priority traffic type. Later on high priority traffic will be executed in the Black Burst mechanism and low priority traffic will be executed in the DCF mechanism.

Data Type	**Variable**
isAHighPriority	Bool
isRetransmission	Bool
AC	BlackBurst_AccessType
TIFS	clocktype
pktsToSend	long
pktsSendUnicast	long
retxDueToCts	long
retxDueToAck	long
pktsDropped	long
pktsLosses	long
pktsIQueue	long
t_sch_Start	clocktype
t_sch_End	long
d	long

Table 4.3: Parameters used in data structure

4.4 Sequence of Black Burst

The priorities for high ACs are defined in the input file *app.conf.* The Black Burst procedure starts from Application layer. On the same layer the priority is included. Before calling the MAC layer the Network layer calls the Black Burst function to setup the priority according to their access type and also set the parameters of *BlackBurstHightPriority* as it is described above. The Sequence of Black Burst if presented in table 4.4.

Black Burst Sequence
Mac802_11SetupPriority()
Mac802_11GetHighPriority()
GLOMO_MacNetworkLayerHasPacketToSend()
AttemptToGoIntroWaitForDifsOrEifsState()
Mac802_11_SetState(802_11_S_WF_TIFS)
Mac802_11_StartTimer(801_11_TX_TIFS)
Handle TimeOut()
Mac802_11TransmitBurst()
GLOMO_MsgPacketAlloc()
Mac802_11SetState()
StartTransmission()
TransmissionHasFinished()
Mac802_11BurstTransmitted()
SetState(M802_11_S_WFUS)
StartTimer()
HandleTimeout()
Mac802_11CarrierSense()
Mac802_11TransmitFrame()

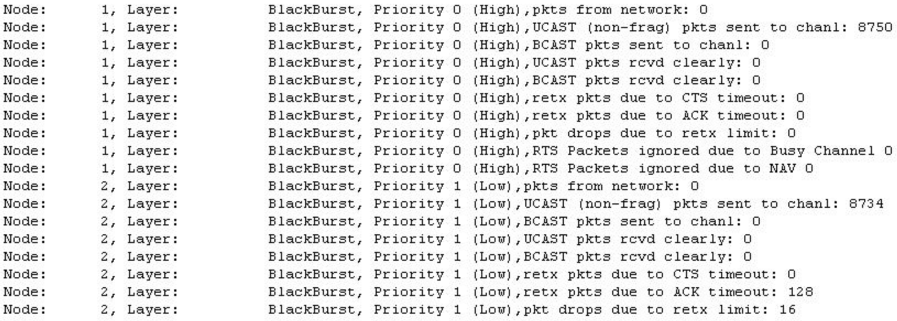
Table 4.4: Black Burst Working Sequence for Single Transmission

After setting the parameter, the network layer calls the MAC layer through the function *GLOMO_MacNewtorkLayerHasPAcketToSend()*. After performing the carrier sensing the station attempts to enter the TIFS waiting time. GloMoSim has several states to identify the individual events. The state *BLACKBURST_S_WF_TIFS* is set and TIFS timer starts by sensing the medium idle. The timer ends and an event occurs. Against this event an action *TransmissionBurst* takes place. After calculating the burst length and changing the state to *BLACKBURST_X_BURST*, it start the transmission. When the transmission is finished the station has to sense for tobs time period. In this time period, it is decided that which station will transmit the data considering the length of burst.

4.5 Updates to the System Output

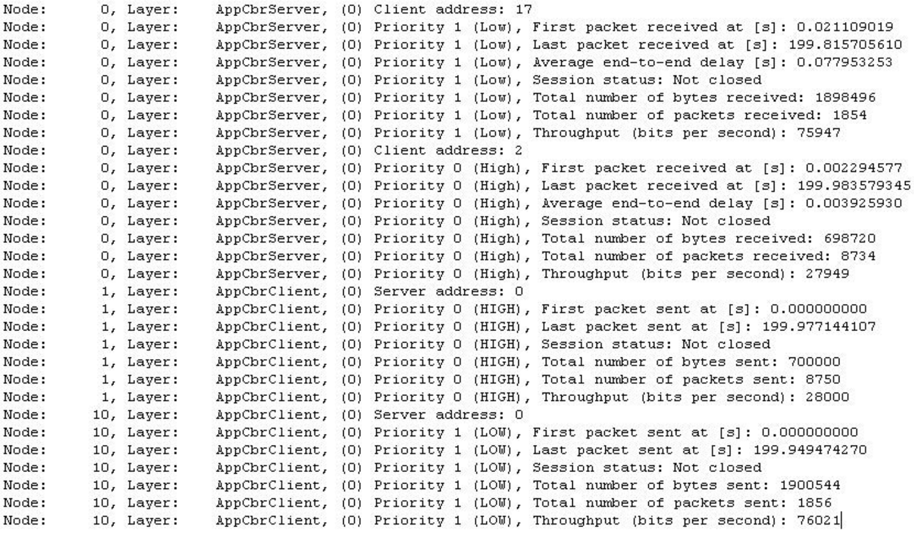
The glomo.stat file is generated to present the Black Burst statistics in an appropriate way. This file presents the total number of packets sent, received and throughput. In Black Burst statistics, the application layer was also updated in order to print and identify the flow of the transmission. For an example, the high priority station's activity was presented with *Priority 0 (High)* and for low priority station's *Priority 1 (Low)*. The example of glomo.stat file is given in figures 4.2 and 4.3.

The priority identifications are considered enough to get and print appropriate statistical information.



```
Node:      1, Layer:         BlackBurst, Priority 0 (High),pkts from network: 0
Node:      1, Layer:         BlackBurst, Priority 0 (High),UCAST (non-frag) pkts sent to chanl: 8750
Node:      1, Layer:         BlackBurst, Priority 0 (High),BCAST pkts sent to chanl: 0
Node:      1, Layer:         BlackBurst, Priority 0 (High),UCAST pkts rcvd clearly: 0
Node:      1, Layer:         BlackBurst, Priority 0 (High),BCAST pkts rcvd clearly: 0
Node:      1, Layer:         BlackBurst, Priority 0 (High),retx pkts due to CTS timeout: 0
Node:      1, Layer:         BlackBurst, Priority 0 (High),retx pkts due to ACK timeout: 0
Node:      1, Layer:         BlackBurst, Priority 0 (High),pkt drops due to retx limit: 0
Node:      1, Layer:         BlackBurst, Priority 0 (High),RTS Packets ignored due to Busy Channel 0
Node:      1, Layer:         BlackBurst, Priority 0 (High),RTS Packets ignored due to NAV 0
Node:      2, Layer:         BlackBurst, Priority 1 (Low),pkts from network: 0
Node:      2, Layer:         BlackBurst, Priority 1 (Low),UCAST (non-frag) pkts sent to chanl: 8734
Node:      2, Layer:         BlackBurst, Priority 1 (Low),BCAST pkts sent to chanl: 0
Node:      2, Layer:         BlackBurst, Priority 1 (Low),UCAST pkts rcvd clearly: 0
Node:      2, Layer:         BlackBurst, Priority 1 (Low),BCAST pkts rcvd clearly: 0
Node:      2, Layer:         BlackBurst, Priority 1 (Low),retx pkts due to CTS timeout: 0
Node:      2, Layer:         BlackBurst, Priority 1 (Low),retx pkts due to ACK timeout: 128
Node:      2, Layer:         BlackBurst, Priority 1 (Low),pkt drops due to retx limit: 16
```

Figure 4.2: Mac layer statistics in glomo.stat file



```
Node:      0, Layer:    AppCbrServer, (0) Client address: 17
Node:      0, Layer:    AppCbrServer, (0) Priority 1 (Low), First packet received at [s]: 0.021109019
Node:      0, Layer:    AppCbrServer, (0) Priority 1 (Low), Last packet received at [s]: 199.815705610
Node:      0, Layer:    AppCbrServer, (0) Priority 1 (Low), Average end-to-end delay [s]: 0.077953253
Node:      0, Layer:    AppCbrServer, (0) Priority 1 (Low), Session status: Not closed
Node:      0, Layer:    AppCbrServer, (0) Priority 1 (Low), Total number of bytes received: 1898496
Node:      0, Layer:    AppCbrServer, (0) Priority 1 (Low), Total number of packets received: 1854
Node:      0, Layer:    AppCbrServer, (0) Priority 1 (Low), Throughput (bits per second): 75947
Node:      0, Layer:    AppCbrServer, (0) Client address: 2
Node:      0, Layer:    AppCbrServer, (0) Priority 0 (High), First packet received at [s]: 0.002294577
Node:      0, Layer:    AppCbrServer, (0) Priority 0 (High), Last packet received at [s]: 199.983579345
Node:      0, Layer:    AppCbrServer, (0) Priority 0 (High), Average end-to-end delay [s]: 0.003925930
Node:      0, Layer:    AppCbrServer, (0) Priority 0 (High), Session status: Not closed
Node:      0, Layer:    AppCbrServer, (0) Priority 0 (High), Total number of bytes received: 698720
Node:      0, Layer:    AppCbrServer, (0) Priority 0 (High), Total number of packets received: 8734
Node:      0, Layer:    AppCbrServer, (0) Priority 0 (High), Throughput (bits per second): 27949
Node:      1, Layer:    AppCbrClient, (0) Server address: 0
Node:      1, Layer:    AppCbrClient, (0) Priority 0 (HIGH), First packet sent at [s]: 0.000000000
Node:      1, Layer:    AppCbrClient, (0) Priority 0 (HIGH), Last packet sent at [s]: 199.977144107
Node:      1, Layer:    AppCbrClient, (0) Priority 0 (HIGH), Session status: Not closed
Node:      1, Layer:    AppCbrClient, (0) Priority 0 (HIGH), Total number of bytes sent: 700000
Node:      1, Layer:    AppCbrClient, (0) Priority 0 (HIGH), Total number of packets sent: 8750
Node:      1, Layer:    AppCbrClient, (0) Priority 0 (HIGH), Throughput (bits per second): 28000
Node:     10, Layer:    AppCbrClient, (0) Server address: 0
Node:     10, Layer:    AppCbrClient, (0) Priority 1 (LOW), First packet sent at [s]: 0.000000000
Node:     10, Layer:    AppCbrClient, (0) Priority 1 (LOW), Last packet sent at [s]: 199.949474270
Node:     10, Layer:    AppCbrClient, (0) Priority 1 (LOW), Session status: Not closed
Node:     10, Layer:    AppCbrClient, (0) Priority 1 (LOW), Total number of bytes sent: 1900544
Node:     10, Layer:    AppCbrClient, (0) Priority 1 (LOW), Total number of packets sent: 1856
Node:     10, Layer:    AppCbrClient, (0) Priority 1 (LOW), Throughput (bits per second): 76021
```

Figure 4.3: Application layer statistics in glomo.stat file

Chapter 5

Performance Evaluation and Comparison

5.1 Introduction

In this chapter the performance evaluation of the Black Burst and the comparison with the EDCA mechanism of IEEE 802.11e is described. This chapter has been divided into two parts. The first part evaluates the performance of Black Burst technique at different parameters and scenarios. The second part describes the comparative study of Black Burst and IEEE 802.11e, EDCA mechanism.

In this chapter the throughput is used as a performance metrics, which can be defined as: The amount of data transferred from one station to another in a certain period of time. Normally the unit of the throughput is taken in bits per second (bps). The throughput is directly proportional to the available bandwidth/capacity, depending on the number of transmitting applications.

Network Topology

The network topology consists of one AP and different number of stations that will contend to transmit data to the AP. There is no inter communication between all stations and all stations are bound to transmit data to the AP. This is illustrated in figure 5.1.

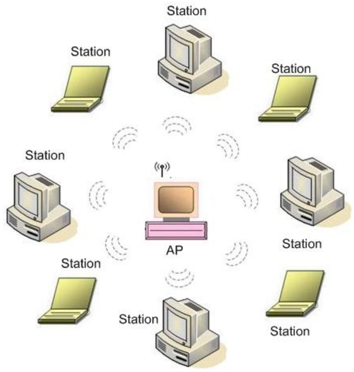


Figure 5.1: Simple network topology or methodology

5.2 Performance Evaluation

The performance of the Black Burst technique is evaluated using different scenarios including, the change in network size and changing in t-Unit value.

5.2.1 Network Size Effect of the Performance

In the Black Burst the network size really effects the performance. The reason is the large size of the burst length. The burst length is directly proportional to the time waited by any station. If there would be a large number of stations then there would be many stations who will not be able to win the medium and will go into waiting state or black burst contention period. Finally, when the stations will get their turn, then their waiting time would be really long and will generate really long bursts. Long bursts causes long delay and low throughput.

5.2.2 Number of (t-unit) Effect on the Performance

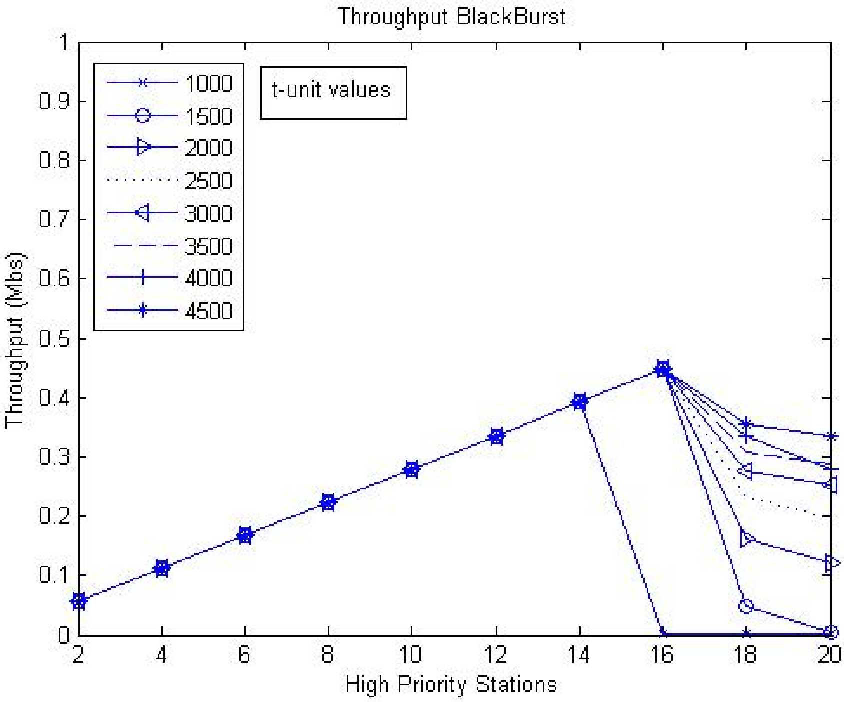


Figure 5.2: Performance evaluation of t-unit for only high priority stations

In figure 5.2, only high priority stations are considered. A constant value of t-unit is used in each simulation. In each simulation 20 stations are considered. The scenario is designed in the following way.
Simulation 1: 2 to 20 station, t-unit = 1000
Simulation 2: 2 to 20 station, t-unit = 1500
. .
Simulation 8: 2 to 20 station, t-unit = 4500

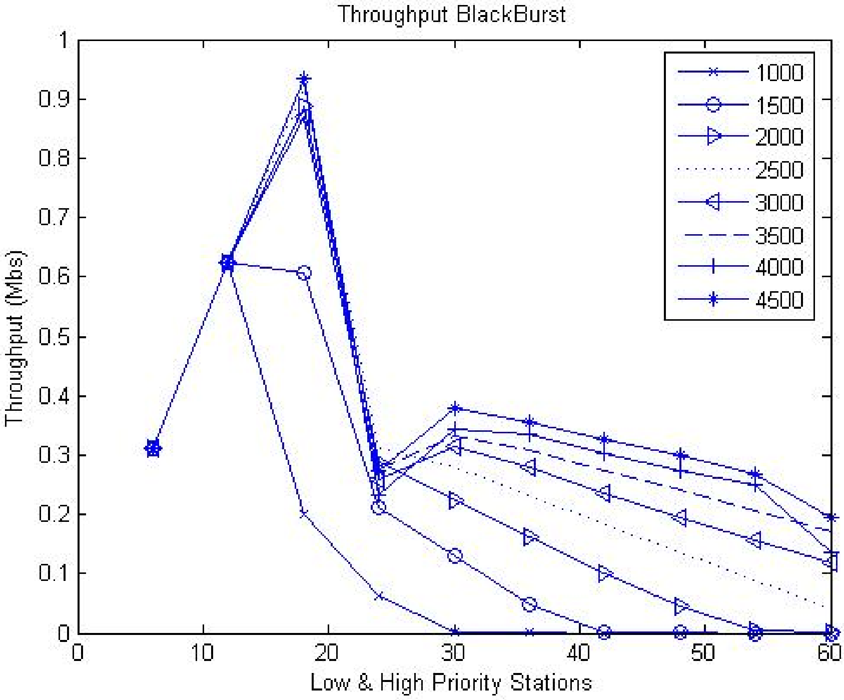


Figure 5.3: Performance evaluation of t-unit for low and high stations

In this result of figure 5.2, the throughput at t-unit value 3500 is observed optimal and has a smooth drop as compared to the throughput of other t-unit values.

In figure 5.3 equal number of high and low priority stations are considered. A constant value of t-unit is used in each simulation. In each simulation 60 stations are considered. The scenario is designed in the following way.
Simulation 1: 6 to 60 station, t-unit = 1000
Simulation 2: 6 to 60 station, t-unit = 1500
. .
Simulation 8: 6 to 60 station, t-unit = 4500

In the scenario of figure 5.3, the throughput at t-unit value 3500 is also observed optimal and has smooth drop as compared to the throughput of other t-unit values.

Considering the both figures 5.2 and 5.3, the throughput is better at t-unit value 3500. The throughput start declining by increasing the network size. At the same time the increase in the value of t-unit causes decrease in the size of burst length. The small length of burst provides more chance of winning the medium for high priority ACs. Considering network size and burst length issue, the t-unit value 3500 is observed optimal.

5.3 Performance Comparison of Black Burst and EDCA

The performance comparison is made considering the throughput and aggregated throughput. Scenarios are built by considering different network sizes. The t-unit value = 3500 is kept fixed for the Black Burst protocol.

5.3.1 Throughput at Large Network Size

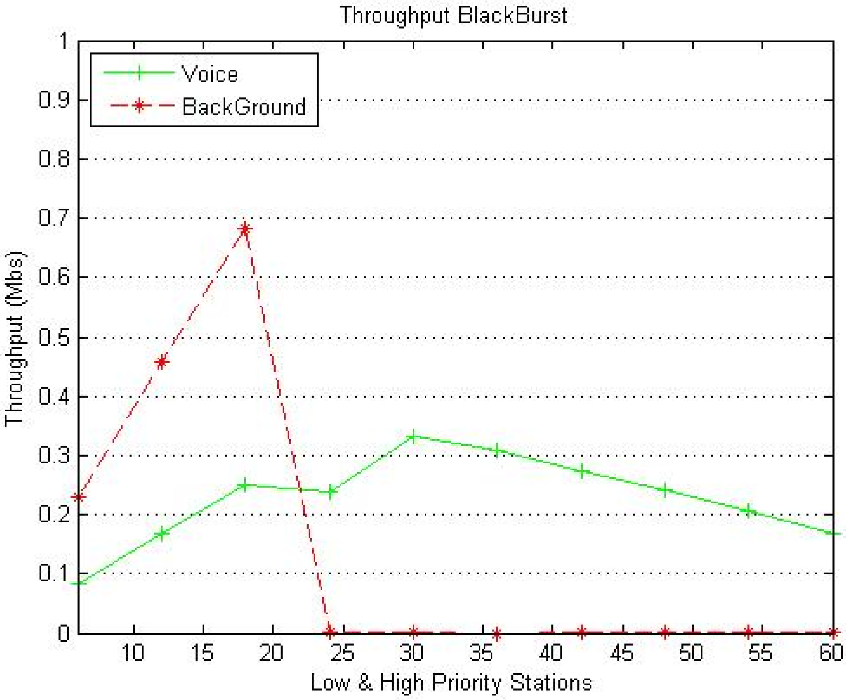


Figure 5.4: Throughput of Black Burst protocol

In the scenario of figure 5.4, equal number of low and high priority ACs are considered. The total network size is 60 stations. Voice is considered the high priority data traffic and background is considered to be low priority data traffic.

In figure 5.5, the same scenario is considered for EDCA, IEEE 802.11e as we have considered in figure 5.4. The total network size becomes with 60 stations. Only two types of data traffics are considered e.g., voice (AC_VO) and background (AC_BK).

If we compare both figures 5.4 and 5.5 then the overall throughput results of IEEE 802.11e, EDCA mechanism is better. EDCA, due to having fixed size of the CW for high priority stations causes the throughput to drop less and comparatively provide less starvation to the low priority AC.

In other hands, Black Burst having long burst lengths, not only causes the starvation for low priority stations but also with the increment of stations causes the throughput to drop for high priority ACs.

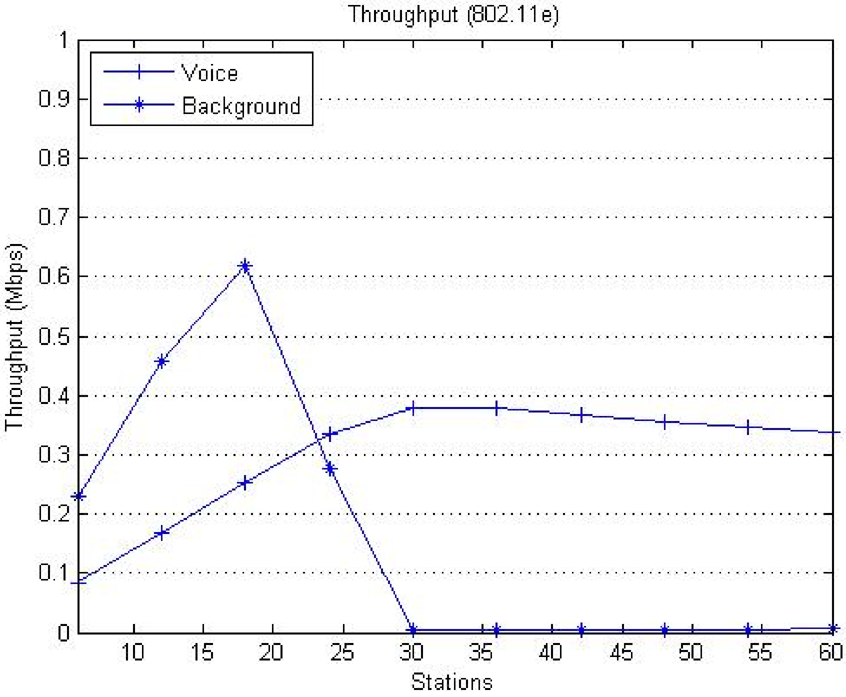


Figure 5.5: Throughput IEEE 802.11e, EDCA

5.3.2 Throughput for Small Network Size

Figure 5.6 illustrates the performance of the scenario in which the network size is 20. Equal number of high and low priority stations are considered with fixed optimal t-unit value 3500.
Figure 5.7 illustrates the performance of the scenario with same network size as it is considered for Black Burst. Comparing figures 5.6 and 5.7 shows that it is really hard to differentiate the throughput. The reason is that, the behavior of CW in EDCA and black burst contention period in Black Burst is similar in small networks. That allows high priority stations to keep winning the medium. But the difference can be seen at large networks.

5.3.3 Aggregated Throughput Comparison

These scenarios are similar, as we have considered for normal throughput comparison. In these scenarios, we are just highlighting the aggregated throughput.

In the scenario of figure 5.8, equal number of low and high priority stations are considered with fixed t-unit value of 3500. Then total network size used is 60 stations.

In figure 5.9, equal number of low and high stations are taken with the total increment of 6 stations in each simulation. Then total network size becomes 60.

If we compare both figures 5.8 and 5.9 then the aggregated throughput results of IEEE 802.11e, EDCA mechanism is better. In EDCA, the CW size is fixed that gives the high priority ACs priority and quick access to the medium independently of network size. In other hand, the black burst contention period or burst length increases with the increase of network size that effects the aggregated throughput.

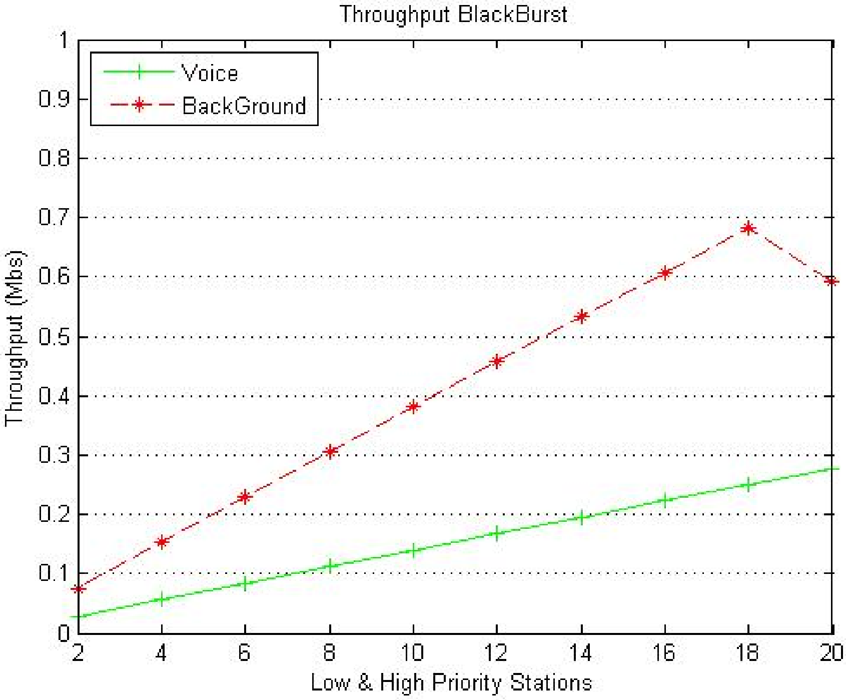


Figure 5.6: Throughput of Black Burst protocol, 20 stations

Considering all results from facts and figures, the overall performance of IEEE 802.11e, EDCA is better than Black Burst.

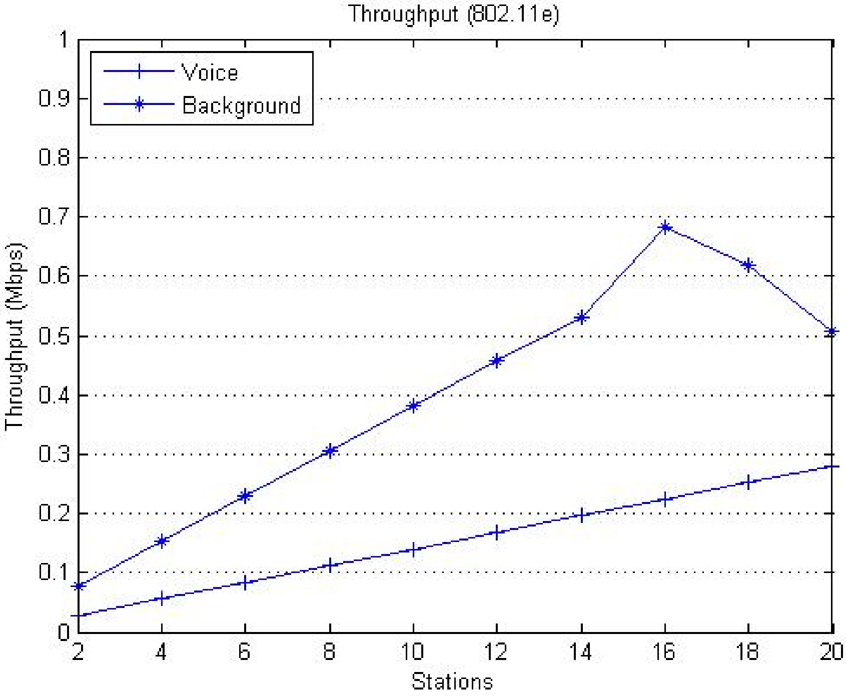


Figure 5.7: Throughput IEEE 802.11e, EDCA, 20 stations

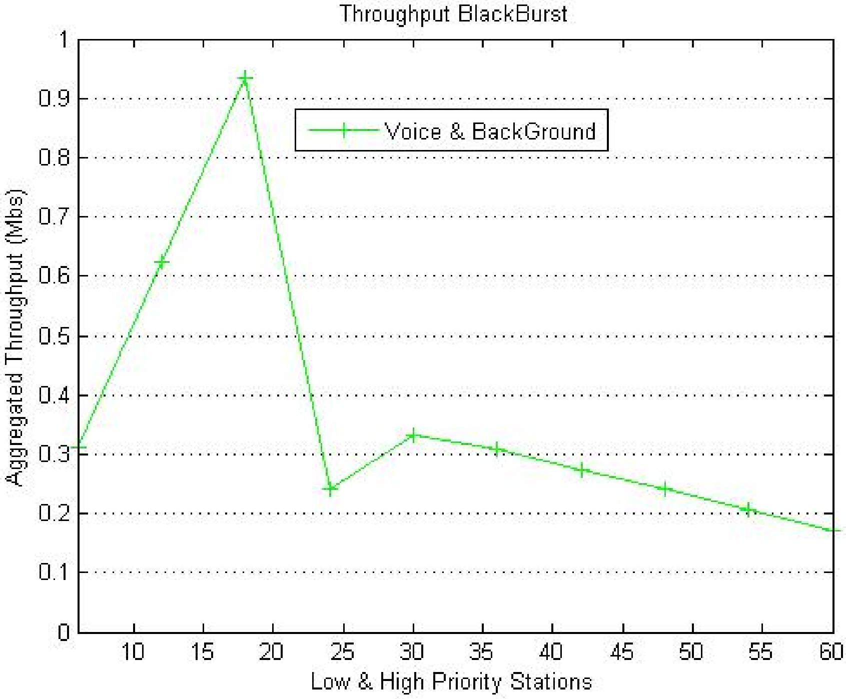


Figure 5.8: Aggregated throughput of Black Burst protocol

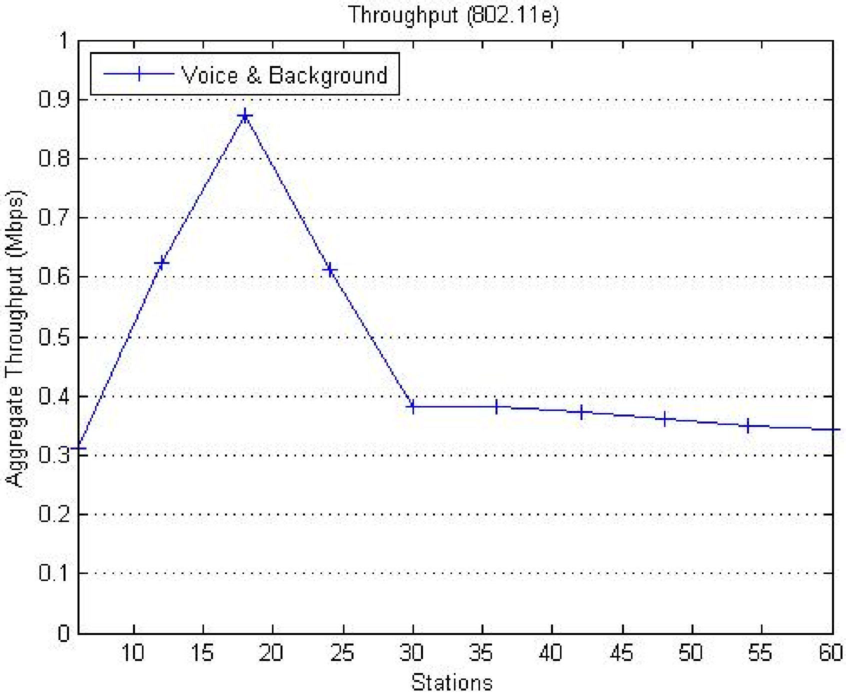


Figure 5.9: Aggregated throughput IEEE 802.11e, EDCA

Chapter 6

Conclusion And Further Research

6.1 Conclusions

Black Burst is implemented over IEEE 802.11, therefore first the DCF mechanism of IEEE 802.11 and its QoS requirements regarding to different types of data, is studied. The next step was to understand the IEEE 802.11e, EDCA mechanism. This mechanism gives the concept of prioritized data traffics over medium in real time traffic scenarios.

Black Burst is an access technique overlaid over CSMA/CA mechanism. Black Burst is a proposed technique that attempts to improve the QoS issues regarding to multimedia traffic over wireless networks. The multimedia data types having different priority, improves the quality for voice over real time traffic. In the results, throughput and aggregated throughput are considered the performance metrics in the evaluation of both techniques. There are some issues that arose in study and implementation of Black Burst.

- Considering small network, the performance is quite satisfactory but at large number of stations the performance start to degrade.
- At large networks, the performance and throughput is worse for high priority stations.
- The t-unit is system parametric value, which is calculated by the formula given in chapter 3. The purpose of this parameter is to reduce the burst length, which is used by high priority ACs to transmit high priority data traffic. From the evaluation part the 3500 is considered as the most optimal value for t-unit in order to get the suitable burst length.
- Bursts are sent by the stations who try to contend the medium when medium is busy. The burst length is proportional to the waiting time d (distance). After some transmissions the stations that had been waiting for really long time, for them, the burst length get very long and throughput starts getting bad and long delay occurs.
- EDCA operation results in better performance and throughput if we compare it with the Black Burst technique.

6.2 Further Research

The following issues are of further research.

- It is hard to find out the precise value of the t-unit in order to achieve the optimal burst length. The t-unit value is based on the inter frame space time and packet time duration.
- Burst lengths get very long if we increase the network size, that results in bad performance.
- If we increase the network size, many stations contend to access the medium. In the case of busy medium, the stations have to wait for long time. In this way the burst length starts getting long and the throughput starts declining for high priority ACs.
- The implementation of this technique became bit complicated, when low priority data traffic had to be handled in DCF fashion and high priority data traffic had to be handled in the Black Burst technique, where coordination among their inter frame spaces was difficult.
- Due to complexity of the code, it would become hard to generate different priority data traffic, e.g., Voice and Background, from the same AC or station.

Chapter 7

Summary

7.1 Summary

IEEE 802.11e is a new version of IEEE 802.11. Where IEEE 802.11 does not support QoS requirements and IEEE 802.11e tries to fulfill these QoS requirements. In this enhanced version four Access Categories (ACs) are used to handle the data traffic, but in this work only two ACs are considered to handle data traffic named AC_VO and AC_BK, for Voice and Background, respectively. These data traffics are mapped to 8 priority levels. Voice has the highest priority and Background the lowest priority. To use these ACs an ehanced version of Distributed Coordination Function (DCF) is used, called Enhanced Distributed Channel Access Function (EDCAF). This function is based on different parameters. These are: contention window (CW), which is used for the selection of backoff (BO) value. Inter frame spaces are used, which are different in according to their use and characteristics. This version has possibility of collisions, which can be in two types: 1- Internal collision, which states that, two ACs in a station, try to contend the medium at the same time because of choosing the same BO values. 2- External collision, which states that, two ACs from different stations try to contend the medium at the same time because of choosing the same BO. Black Burst is a proposed version that also focuses on QoS requirements. This technique is overlaid over IEEE 802.11 on the MAC layer. The operational behavior of Black Burst resembles the IEEE 802.11e. Bursting mechanism of Black Burst is bit similar to the BO contention period. Each time unique burst length provides the unique winner (station) to access the medium. The mechanism of Black Burst performs in round robin behavior. Two types of Access Categories (ACs) or data traffic are used named as, AC_VO and AC_BK, for Voice and Background, respectively. These traffic types are given priority numbers. The value 0 is set for high priority AC and 1 is set for low priority AC. The high priority data traffic is handled by the Black Burst technique and low priority data traffic is handled by the normal DCF operation. Different parameters are used in this technique. TIFS (Time Inter Frame Space) is used for high priority ACs, which is smaller than DIFS and provide a quick access to the medium. DIFS are used for low priority ACs. T-unit, is system parametric values that effects the burst length and the performance of the network.

Appendix A

List of Abbreviation

Abbreviation	**Designation**
AC	Access Category
AC_VO	Access Category Voice
AC_VI	Access Category Video
AC_BE	Access Category BestEffort
AC_BK	Access Category BackGround
AIFS	Arbitration Inter Frame Space
AODV	Ad-hoc On-demand Distance Vector
AP	Access Point
API	Application Programming Interface
BER	Bit Error Rate
BO	Back off
BPSK	Binary Phase Shit-Keying
BSS	Basic Service Set
CBR	Constant Bit Rate
CSMA/CA	Carrier Sense Multiple Access / Collision Avoidance
CW	Contention Window
CWmax	Contention Window Maximum
CWmin	Contention Window Minimum
DCF	Distributed Coordination Function
DIFS	DCF Inter Frame Space
DSSS	Direct Sequence Spread Spectrum
EDCA	Enhanced Distributed Channel Access
EDCAF	Enhanced Distributed Channel Access Function
FTP	File Transfer Protocol
GloMoSim	Global Mobile Information System Simulator

HCCA	HCF Controlled Channel Access
HCF	Hybrid Coordination Function
HTTP	Hypertext Transfer Protocol
IBSS	Independent Basic Service Set
IEEE	Institute of Electrical and Electronics Engineering
IP	Internet Protocol
MAC	Medium Access Control
MACA	Multiple Access with Collision Avoidance
Mbps	Mega bit per second
ODMRP	On-Demand Multicast Routing Protocol
OFDM	Orthogonal frequency-division multiplexing
PCF	Point Coordination Function
SIFS	Short Inter Frame Space
SNR	Sound to Noise Ration
STA	Station
TCP	Transmission Control Protocol
TIFS	Time Medium- Inter Frame Space
UCLA	University of California, Los Angeles
UDP	User Datagram Protocol
WLAN	Wireless Local Area Network
WRP	Wireless Routing Protocol
QoS	Quality of Service

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