Improving QoS using Adaptive TXOP Allocation in IEEE 802.11e WLAN

V. Ilayaraja
Assistant Professor(Sr.Gr)
Department of Information Technology
PSG College of Technology
Coimbatore

Vasanthakumar.K
PG Scholar
Department of Information Technology
PSG College of Technology
Coimbatore

ABSTRACT

In today's environmental world, no organization has time to wait for hours to receive data through various network channels. Everyone is looking forward to develop the Quality of Services (QoS) parameters during data transfer. IEEE 802.11e standard for Quality of Service (QoS) in Wireless Local Area Networks (WLANs) can activate with the Differentiated Services (DiffServ). IEEE 802.11e has established a new access mechanism called the Hybrid Coordination Function (HCF) that combines a contention-based Enhanced Distributed Channel Access (EDCA) and a contention free HCF Controlled Channel Access (HCCA) in a single function. In this mechanism, HCF scheduler is introduced to allocate transmission opportunities (TXOPs), to the stations. TXOP is the time under which the station can send its burst data packets to other stations that is applicable to existing scheduling algorithms. It works in accordance with channel and traffic conditions and complies with the link adaptation mechanism. Also in the existing system, TXOP has applied only to the four categories of MAC Service Data Unit (MSDU). But in proposed methodology, TXOP is applying to eight categories of MSDU with the support of DiffServ.

General Terms

IEEE 802.11e, Quality Of Service (QoS), Transmission opportunities (TXOPs).

Keywords

Enhanced Distributed Channel Access (EDCA), HCF Controlled Channel Access (HCCA), Access Categories (AC), Station (STA).

1. INTRODUCTION

All users is looking forward to develop the Quality of Services (QoS) parameters during data transfer.IEEE 802.11e defines QoS mechanisms for wireless gear that gives support to bandwidth-sensitive applications such as voice and video. Some applications over wireless networks address include video streaming, video conferencing, distance learning, etc. Because wireless bandwidth availability is restricted, quality of service (QoS) management is increasingly important in 802.11 networks.

To improve the support of QoS, IEEE 802.11e has developed a new protocol that uses differentiation mechanisms at the medium access control (MAC) layer. It uses a new medium access method called the hybrid coordination function (HCF) that combines a contention-based enhanced distributed channel access (EDCA) and a HCF controlled channel access (HCCA) mechanisms in a single function.

Recent performance evaluations of the 802.11e HCF show that HCF is more flexible than the DCF and point coordination function (PCF). HCCA is a very crucial mechanism in meeting QoS demands thus designing a scheduler for HCCA has been an active objective of research. Apart from several other drawbacks, it is shown in that the HCF scheduling algorithm is only efficient for flows with strict constant bit rate (CBR) characteristics. Although 802.11e supports QoS demands to a certain extent, there are number of challenges that must be addressed to enable comprehensive QoS support.

The key idea of this project is to exploit the channel conditions to increase system efficiency. In this paper, we follow an approach that is different from other opportunistic schedulers (e.g.,) that run on a per-packet basis. Challenges while designing a scheduler for IEEE 802.11e networks are various QoS constraints imposed on the traffic flow and transmission opportunity (TXOP) allocation by the standard draft. We develop an adaptive TXOP allocation method that is applicable to existing schedulers, such as a standard scheduler or the Grilo scheduler. The TXOP allocation algorithm adaptively adjusts the length of TXOP and assigns the residual resource to other STAs according to their channel conditions.

The proposed method allocates the minimal length of TXOP to the STA suffering from the bad channel condition and lends its TXOP to the STA with a better channel condition. The proposed method designs a TXOP allocation policy that will not only try to increase system performance but will also ensure long term fairness among STAs.

Following the conventional method to achieve fairness, maintains a lead/lag counter for each STA, which specifies the amount by which the STA is lagging behind or leading, compared with its normal service amount. Based on the lead/lag value, each STA is made to give up or receive an extra TXOP. It explore the Queue Size field of the IEEE 802.11e header to adapt the TXOP to the actual traffic condition.

The IEEE 802.11e working group has proposed a new MAC mechanism for developing QoS called HCF, which consists of EDCA and HCCA.

1.1 EDCA

Enhanced Distribution Channel Access (EDCA) supports priority differentiation among STAs and flows by using different backoff parameters.

EDCA brings traffic categories (TCs) and gives different priorities to different TCs.

EDCA has two priority schemes:

1. The InterFrame Space (IFS) priority scheme and
2. The Contention Window (CW) priority scheme.

The 802.11e introduces a new interval called arbitration IFS (AIFS), in addition to the existing two IFSs, i.e., DCF IFS (DIFS) and PCF IFS (PIFS).An STA can send a data packet or start to decrease its backoff counter after it detects the channel being idle for some IFS. The AIFS can be adjusted for each TC according to the corresponding priority. The CW priority scheme implements service differentiation by using different Contention Windows (CWs) for different TCs, which gives different backoff numbers to different priority classes.

The backoff value is set to a counter, which is a random number from the interval [1, CW+ 1], where CW is initially set to a minimum value (CWmin) and increased whenever the node is involved in a collision up to a maximum value known as CWmax. The new CW for EDCF is defined as

$newCW[AC] = ((oldCW[AC] + 1) * 2) – 1$………….........(1)

1.2 HCF

In HCF, the super frame is divided into the contention-free period that starts with every beacon and the contention period (CP). HCCA provides a centralized polling scheme for allocating guaranteed channel access to traffic flows based on their QoS requirements. During the CP, access is governed by EDCA, although the hybrid coordinator (HC) can initiate controlled access periods (CAPs) at any time. A CAP is formed by a sequence of TXOPs. A TXOP is a period of time in which an STA or the HC can transmit a burst of data frames separated by a short interframe space (SIFS) interval.

1.3 Working of HCF

The IEEE 802.11e EDCA standard provides QoS differentiation by grouping traffic into four access classes (ACs), i.e. voice, video, best effort and background. Each frame from the upper layers bears a priority value (0-7), which is passed, down to the MAC layer. Enhanced Distributed Channel Access (EDCA) introduces the concept of traffic categories. Using EDCA, stations try to send data after noticing that the medium is idle for a set time period defined by the corresponding traffic category.

A higher-priority traffic category will have a shorter wait time than a lower-priority traffic category. While no guarantees of service are provided, EDCA establishes a probabilistic priority mechanism to allocate bandwidth based on traffic categories.

Based on the priority value, the frames are mapped into the four ACs at the MAC layer. The voice AC has the highest priority; the video AC has the second highest priority; the best effort AC has the third highest priority; and the background AC has the lowest priority. Each AC has its own transmission queue and its own set of medium access parameters.

Traffic prioritization uses the medium access parameters—AIFS interval, contention window (CW), and transfer opportunity (TXOP)—to ensure that a higher priority AC has relatively more medium access opportunity than a lower priority AC. Generally, the arbitration interframe space (AIFS) is the time interval that a station must smell the medium to be idle before invoking a backoff or transmission. A higher priority AC uses a smaller AIFS interval. The Transmission Opportunity (TXOP) indicates the maximum duration that an AC can be allowed to transmit frames after acquiring access to the medium. To save contention overhead, multiple frames can be transmitted within one acquired TXOP without any additional contention, as long as the total transmission time does not exceed the TXOP duration.

If the channel is idle after the AIFS interval, the transmitting station invokes a backoff procedure using a backoff counter to count down a random number of backoff time slots.

With these medium access parameters, EDCA works in the following manner: Before a transmitting station can initiate any transmission, the transmitting station must first sense the channel idle (physically and virtually) for at least an AIFS time interval. If the transmitting station senses the channel to be busy at any time during the backoff procedure, the transmitting station suspends its current backoff procedure and freezes its backoff counter until the channel is sensed to be idle for an AIFS interval again. Then, if the channel is still idle, the transmitting station resumes decrementing its remaining backoff counter.

After each unsuccessful transmission, CW doubles till the CWmax. After each successful transmission, CW to CWmin. And the level of QoS control for each AC is determined by the combination of the medium access parameters and the number of competing stations in the network.

2. LITERATURE SURVEY

2.1 Adaptive TXOP Allocation Based on Channel

Adaptive TXOP Allocation Based on Channel Conditions and Traffic Requirements in IEEE 802.11e Networks.[1]

Methodology

The IEEE 802.11e has established a new access mechanism called the hybrid coordination function (HCF) as a step toward provisioning quality-of service (QoS) support.

This method works in accordance with channel and traffic conditions and complies with the link adaptation mechanism. Mathematical analysis and simulation results have verified that our scheme performs better when compared with reference and Grilo standard implementations.

2.1.1 Grilo Scheduler

The scheduling algorithm proposed by Grilo et al. follows a very novel approach and has been quite popular. The Grilo scheduler extends the functionality of HC by allowing it to perform the following:

1. Allocate TXOPs of variable length (instead of fixed TXOPs);
2. Poll each STA at variable and different SIs (instead of polling all STAs with period SI).

2.1.2 Reference Scheduler

This scheduler uses only the mandatory parameters in calculating two additional scheduling parameters,

1) Service Interval (SI)

2) TXOP duration.

2.2 WLAN QoS Issues and IEEE 802.11e

WLAN QoS Issues and IEEE 802.11e QOS Enhancement.[2].

Methodology

This method provides a deterministic QoS performance for applications with admission control, while EDCA only provide statistical QoS performance. To improve the QoS standard by introducing new coordination functions, the contention based medium access method, the EDCA and a extension to it a contention free HCF control channel access (HCCA), both are considered to guarantee QoS in WLAN operating in the infrastructure mode.

Through simulation it is clear that the performance of EDCA is less when the traffic load is very high. The HCCA is a centralized control mechanism it is applicable to infrastructure mode.

Prioritized Scheduling

Prioritized QoS is realized through the introduction of four access categories (ACs), which provide delivery of frames associated with user priorities as defined in IEEE 802.1D. The QoS in a WLAN using DCF is enhanced by EDCA, and it supports priority based best-effort service such as DiffServ. Each AC has its own transmit queue and its own set of AC parameters. The differentiation in priority between ACs is achieved by setting different values for the AC parameters. These priority parameters are:

1) Arbitrary inter-frame space number (AIFSn): It is the minimum time interval between the wireless medium becoming idle and the start of transmission of a frame.

2) Contention Window (CW): A random number is drawn from this interval, or window, for the backoff mechanism. The medium access function in each station maintains a backoff .

3) TXOP Limit: The maximum duration for which a QSTA can transmit after obtaining a TXOP.

2.3 Multipath Routing Protocol Using Cross-layer based QoS

Multipath Routing Protocol Using Cross-layer based QoS Metrics for IEEE 802.11e WLAN.[3]

Methodology

To achieve Quality of Service (QoS) support for multimedia traffic, IEEE 802.11e specifies Hybrid Coordination Function (HCF) Controlled Channel Access (HCCA) technique.An increased efficiency can be achieved in terms of QoS metrics, balancing the load and tolerance to faults by the use of multipath routing. The fact that routing is responsible for the successful packet delivery and QoS Support.

The simulation results demonstrate that the proposed Multi-path routing protocol helps in achieving better delivery ratio and throughput with reduced delay.

2.4 Fairness Enhancement Scheme for Multimedia Application

Fairness Enhancement Scheme for Multimedia Application in IEEE 802.11e Wireless LANs

Methodology

When stations transmit traffic generated in different multimedia applications, fairness problem occurs. In order to alleviate the fairness problem, a dynamic TXOP control scheme based on the channel utilization of network and multimedia traffic quantity in the queue of a station.

The simulation results show that the proposed scheme improves fairness and QoS of multimedia traffic. It is confirmed that the overall network performance is improved as transmission success ratio within the delay bound becomes larger.

3. SYSTEM DESIGN

3.1 Adaptive TXOP

The EDCA introduces a transmission opportunity (TXOP). A station can transmit multiple data packets consecutively until the duration of transmission exceeds the specific TXOP limit. In the EDCA, stations are allocated the same TXOP limit value. When they have identical multimedia traffic application, fair bandwidth allocation is expected.

However, if stations support multimedia traffic applications with different QoS requirements, fairness problem arise others proposed very simple schemes to allocate the TXOP limit without considering the QoS requirements of multimedia traffic.

A distributed optimal TXOP scheme uses the throughput information. In the TXOP scheme, each station measures its throughput and compares it with the target throughput. If the measured throughput is higher than the target value, the station reduces its TXOP limit; otherwise, it increases its TXOP.

A threshold- based dynamic (TBD) TXOP scheme dynamically adjusts the TXOP limit according to the queue length and the pre-setting threshold. Each station has two TXOP limit values: low (TXOPmin) and high (TXOPmax). As shown in Figure 3.1, if the queue length (Q_Len) is below the threshold, the TXOP limit is fixed at the low value; otherwise, the TXOP limit is set to the high value.

$$TXOP_{limit} = \begin{cases} TXOP_{min}, if\ Q_{Ler}, \leq TH_{queue} \\ TXOP_{max}, otherwise \end{cases} \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

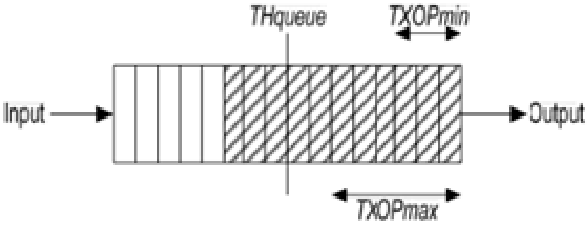


Fig 1: TXOP Allocation Mechanism

TXOP duration (TXOP)

The time needed to transmit all the packets that arrive during an SI in a TS queue at the minimum rate R. If Ni is the number of packets of mean length Li that arrive in SI with the mean rate ρ for TS i, we have

$$N_i = \left\lceil {SI * \rho}/{Li} \right\rceil, i = 1, \ldots.., n \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(3)$$

Therefore, the TXOP duration for each TSi, which is denoted by TXOPi, can be calculated as

$$TXOP_i = N_i, \left(\frac{L_i}{R} + 2.SIFS + ACK\right), \quad i = 1, \ldots.n \ \ldots\ldots\ldots \text{(4)}$$

3.2 Diffserv Mechanism

DiffServ operates on the principle of traffic classification, where each data packet is placed into a limited number of traffic classes, rather than differentiating network traffic based on the requirements of an individual flow. Each traffic class can be managed differently, ensuring preferential treatment for higher-priority traffic on the network.

The premise of Diffserv is that complicated functions such as packet classification and policing can be carried out at the edge of the network by edge routers who then mark the packet to receive a particular type of per-hop behavior. Such routers simply apply PHB treatment to packets based on the marking. PHB (Per-Hop Behaviors) treatment is achieved by core routers using a combination of scheduling policy and queue management policy.

The standard traffic classes (discussed below) serve to simplify interoperability between different networks and different vendors' equipment. Most networks use the following commonly defined Per-Hop Behaviors.

- Default PHB (Per hop behavior)—which is typically best-effort traffic
- Expedited Forwarding (EF) PHB—dedicated to low-loss, low-latency traffic
- Assured Forwarding (AF) PHB—gives assurance of delivery under prescribed conditions

3.3 SCHEDULING ALGORITHM:

3.3.1 First Come First Served (FCFS)

The processing of data is done in the order of their arrival times at the ready queue, in the case of First Come First Served (FCFS) schedulers. Here, the data from nearby neighboring nodes take less time to be processed at the intermediate nodes when compared to that of the data from the distant leaf nodes.

Also, many data packets arrive late and so they experience higher delay. The number of packet failures results from the increased delay, which affects the Qos of the system.failures results from the increased delay, which affects the Qos of the system.

3.3.2 Round Robin

Round-robin (RR) is one of the algorithms employed by process and network schedulers in Qos enhancement. As the term is generally used, time slices are assigned to each process in equal portions and in circular order, handling all processes without priority (also known as cyclic executive).

Round-robin scheduling is simple, easy to implement, and starvation-free. Round-robin scheduling can also be applied to other scheduling problems, such as data packet scheduling in computer networks. It is an Operating System concept.

In order to schedule processes fairly, a round-robin scheduler generally employs time-sharing, giving each job a time slot or quantum (its allowance of CPU time), and interrupting the job if it is not completed by then.

The job is resumed next time a time slot is assigned to that process. In the absence of time-sharing, or if the quanta were large relative to the sizes of the jobs, a process that produced large jobs would be favoured over other processes.

3.4 System Model

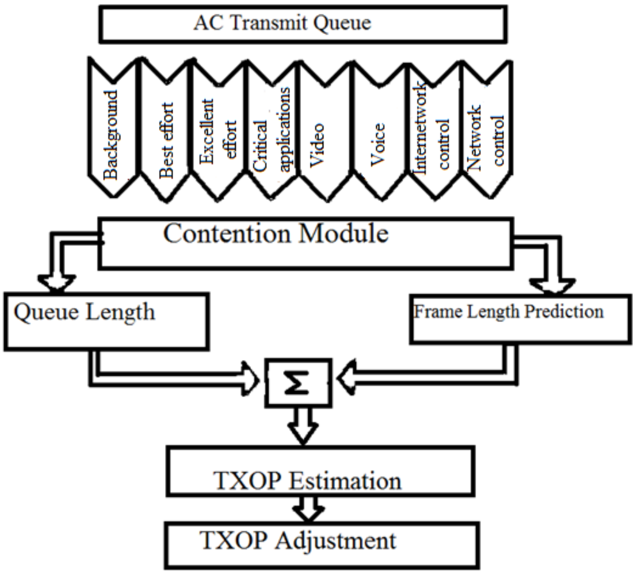
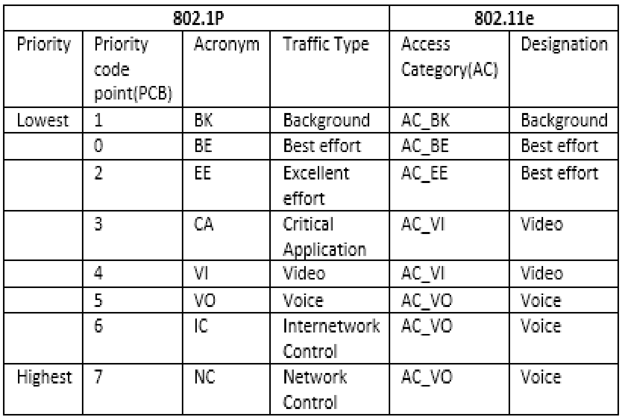


Fig 2: System Model

In the method of adaptive TXOP allocation the data are classified into different AC providing at least one frame for a particular AC. In this mechanism, HCF scheduler is introduced to allocate transmission opportunities (TXOPs), the time under which the station can send its burst data packets to other stations.

Here, TXOP is applying to eight categories of MAC Service Data Unit (MSDU) with the support of DiffServ. The eight categories of data are given in order from high priority data corresponding to low priority of data. Then TXOP is allocated to create database, the high priority is given more importance.

Table 1: Different Access Categories



802.1P				802.11e	
Priority	Priority code point(PCB)	Acronym	Traffic Type	Access Category(AC)	Designation
Lowest	1	BK	Background	AC_BK	Background
	0	BE	Best effort	AC_BE	Best effort
	2	EE	Excellent effort	AC_EE	Best effort
	3	CA	Critical Application	AC_VI	Video
	4	VI	Video	AC_VI	Video
	5	VO	Voice	AC_VO	Voice
	6	IC	Internetwork Control	AC_VO	Voice
Highest	7	NC	Network Control	AC_VO	Voice

The main algorithm is shown in Fig3.3. To provide shortterm fairness, we distinguish two types of additional service in the algorithm: excess service and compensation service. Excess service is made available when a session receives more service than required, whereas compensation service is made available due to a leading session giving up its lead.

First, lagging sessions have higher priority to receive additional services to expedite their compensation. This way, a lagging session is guaranteed to catch up, no matter what the lags of the other sessions are, and the short-term fairness property is ensured among lagging sessions during compensation.

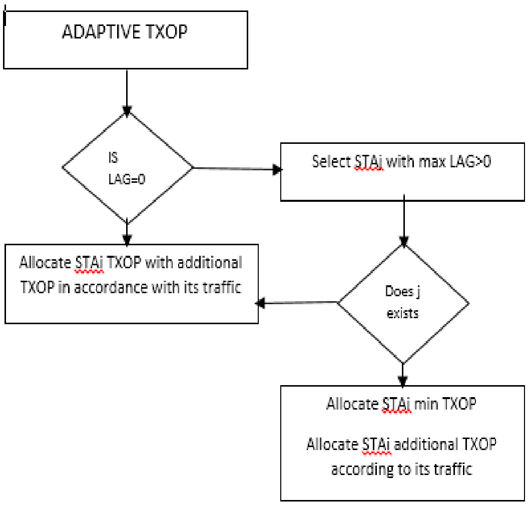


Fig 3: Flow chart

Let us take a very simple example to walk through the algorithm. Consider three STAs i, and j. Assume that STA i is in the bad channel condition for time (t1, t2) and in the good condition thereafter. Without loss of generality, assume that STAs j in good channel condition as ever and are always hungry for more bandwidth or more TXOP.

By definition of the algorithm, STA i will be given TXOPmin for the time duration (t1, t2). Therefore, quite clearly, lag i can be calculated as TXOPnormal − TXOPmin ∗ (the number of times that STA i was chosen by the scheduler), where TXOPnormal is the TXOP that STA i would have obtained in normal channel conditions.

Whenever STA j is selected by the scheduler in the time (t1, t2), they will be entitled to have that extra TXOP, which is available to the scheduler. This will clearly ensure higher throughput for this duration, in comparison with the case where STA i was allowed to have the whole TXOP that was initially allocated based on its traffic requirements.

3.5 Time Complexity

In the proposed algorithm, there are mainly four operations involved: 1) a session becoming active; 2) a session being selected to receive service; 3) an active session entering error mode; and 4) an active session becoming error free. It is easy to deduce from the main algorithm in Fig.3.3 that these operations eventually reduce to the following basic set operations: adding, deleting, and querying the element with the minimum key from the set.

All of these operations are efficiently implemented in O(logN), where N represents the number of STAs in the network, by using a binary tree data structure, which maintains the tree based on fi and ci, respectively. More precisely, one tree will maintain all nonlagging error-free STAs based on fi, and the other one will maintain all lagging error-free sessions based on ci. Since all the four operations involve only a constant number of operations, it can be implemented in O(logN).For each station the algorithmic complexity is done in 0.5 ms. The Time complexity for simulation is done in 2.5 ms.

4. IMPLEMENTATION

4.1 NS2 based Simulation

Network Simulator (Version 2), widely known as NS2, is simply an event-driven simulation tool that has proved useful in studying the dynamic nature of communication networks.

Simulation of wired as well as wireless network functions and protocols (e.g., routing algorithms, TCP, UDP) can be done using NS2. In general, NS2 provides users with a way of specifying such network protocols and simulating their corresponding behaviors.

NS2 is downloaded as .tar.gz file in Fedora OS. It is extracted in /home using the command ‘tar –zxvf nsallinone-2.35.tar.gz-C/home/root1. It can also be extracted by right click and then extract. Then proceed with following command. /install or sudo apt-get tcl8.5.10 tk8.5.10 xgraph8.5. All in one package consist of all packages of the system.

4.2 Simulation Methods

Initially an simulation window is created by adding number of nodes. The nodes represents the station for communication.

In figure 4.1 it represents the eight categories of data is applied to eight nodes in the simulation window. Creating node 15th as buffer, node 15 is considered as scheduled hcf for communicating data.

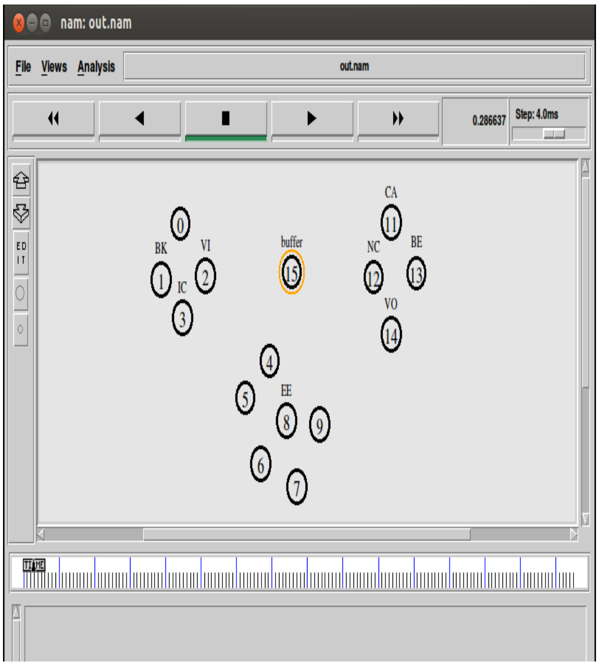
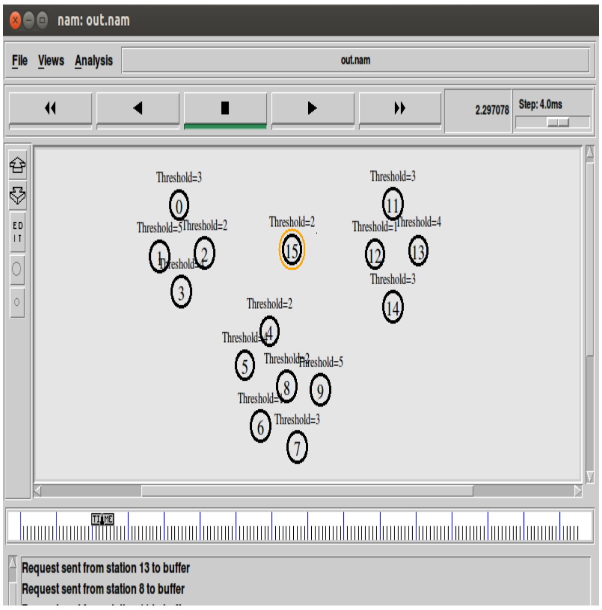


Fig 4: Node Creation

The eight access categories requests the buffer, the TXOP is allocated to higher priority to lower priority respectively.

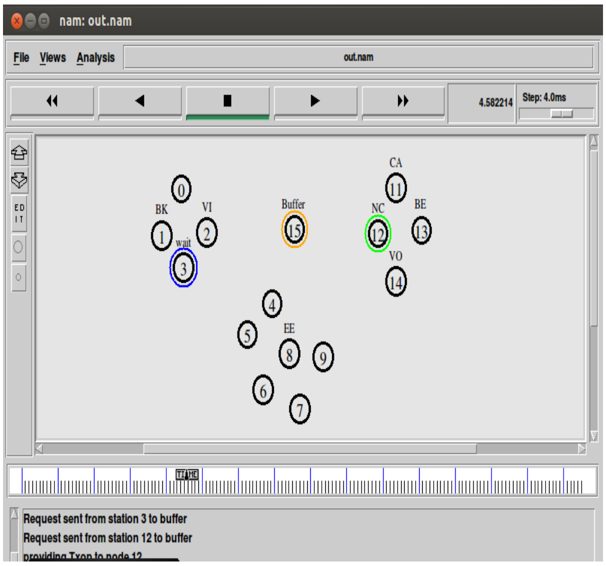
In figure 4.2 it represents the TXOP is allocation, the threshold is initially set for each of eight access categories. The eight access categories are network control, inter network control, voice, video, best-effort (BE), critical application, excellent effort and background.



Request sent from station 13 to buffer
Request sent from station 8 to buffer

Fig 5: Creating Threshold

After requests sent from eight data the buffer allocates the TXOP in Round Robin concept by higher priority to lower priority respectively.

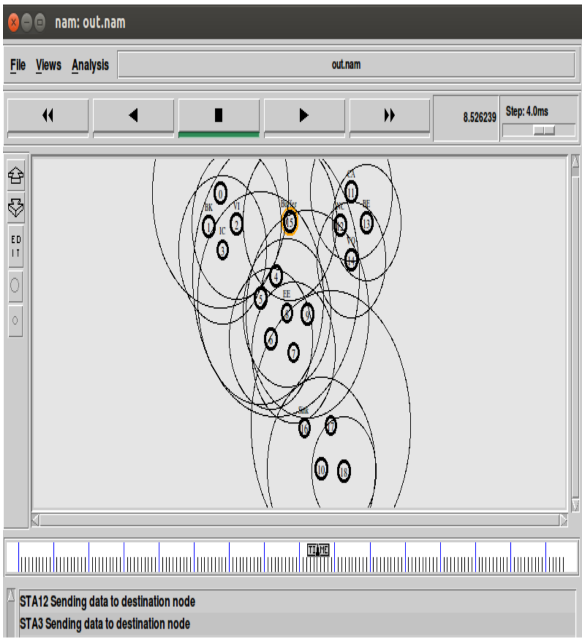


Request sent from station 3 to buffer
Request sent from station 12 to buffer
providing Txop to node 12

Fig 6: Prioritywise Allocation

In figure 4.3 it represents the prioritywise allocation for the eight categories of data in which the TXOP is allocated to higher priority to lower priority respectively. Initially network control data in given for high priority thus it waits for next station to provide TXOP.

After TXOP is allocated for eight categories of data, then the station is set for channel communication.



STA12 Sending data to destination node
STA3 Sending data to destination node

Fig 7: Data Transmission

4.3 Performance Metrices

The main QoS parameters focussed is Bandwidth and Throughput. The key idea of this work is to exploit the channel conditions to improving QoS in our system. Extensive results is to prove the efficiency of the proposed scheme over corresponding conventional implementations.

5. RESULT ANALYSIS

We evaluate the throughput and bandwidth for 8 access categories of data. The measurements were done when there are eight types of traffic: network control, inter network control, voice, video, best-effort (BE), critical application, excellent effort and background. Network control and voice traffic has the highest priority, and background data traffic has the lowest priority.

5.1 Node Speed vs Bandwidth

TitleText: Nodes speed vs Bandwidth

YUnitText: Bandwidth

XUnitText: Node Speed(m/s)

Table 2: Results of Bandwidth

FCFS	ROUND ROBIN
0 - 0.03	0 - 0.05
1 - 0.04	1 - 0.06
5 - 0.03	5 - 0.13
10 - 0.04	10 - 0.09

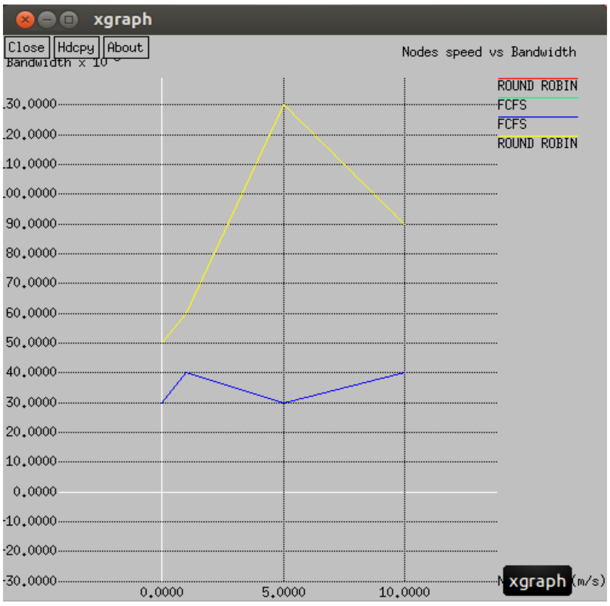


Fig 8: Graph of Bandwidth Vs Nodes Speed

In figure 5.1 graph denotes the Bandwidth vs Nodes Speed simulation results, the round robbin is more efficient than fcfs method.

5.2 Node Speed Vs Throughput

TitleText: Nodes speed vs Throughput

YUnitText: Throughput(%)

XUnitText: Node Speed(m/s)

Table 3: Results of Throughput

FCFS	ROUND ROBIN
0 -96	0-97
1-94	1-95
5-92	5-94
10-90	10-93

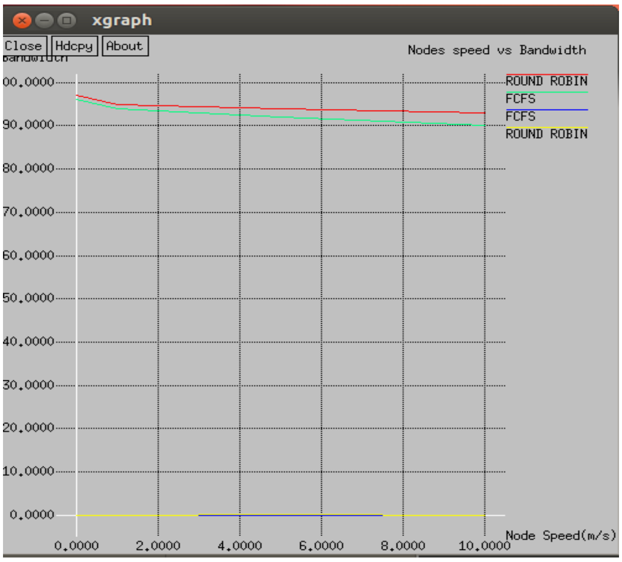


Fig 9: Graph of Throughput Vs Nodes Speed

In figure 5.2 graph denotes the Throughput Vs Nodes Speed simulation results, the round robbin is more efficient than fcfs method.

6. CONCLUSION

The paper proposed a mechanism for adaptive TXOP allocation which exploits the channel traffic condition and used it estimate and predict values to compute the TXOP. However the node of background data access class with less traffic and frames find less opportunity compared to that of other access classes.

As a future work the access classes can adapt Service Intervel according to channel condition to improve efficiency and also other QoS parameters can be accommodated for fair estimation.

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