Service Differentiation of IEEE 802.11e

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Abstract

The type of the applications for which Internet is being used has changed over the years. Multimedia applications, Real-time applications and Game playing require Quality of service. IEEE has proposed IEEE 802.11e, a quality of service extension to the wireless LAN standard IEEE 802.11. In this paper service differentiation ability of 802.11e is evaluated. Identical traffic is considered for all Access categories to quantitatively differentiate different Access categories. The results indicate, 802.11e achieves service differentiation with some limitations. NS-2.26 is used for simulation.

Keywords: *IEEE 802.11e, EDCA, quality of service, NS-2.26, metrics, evaluation.*

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1. Introduction

Internet has reached every corner of the world. Internet is not restricted to transmission of data. Because of the convergence of the networks, Internet is used for transmission of data, voice, video etc. TCP/IP set of protocols are highly robust protocols. But they are designed for wired networks and at the time when transmission of data from source to destination, itself is treated as a significant achievement. Hence IP provides only best effort service.

Best effort services of IP are suitable for applications such as file transfer, and e-mail. These applications are tolerant and they are adjusted with what the network can provide. Voice and video applications require a certain minimum bandwidth and suffer significantly with high delay and variation in jitter. These applications require service differentiation or guarantees from the network i.e., Quality of Service (QOS).

Internet is being accessed by end users primarily by using wireless interface. Mobile computing and communications makes users access the applications in spite of physical mobility. Wireless networks have several limitations and hence providing required QOS is a challenging task. IEEE 802.11 is the wireless LAN standard [1] that is widely being used. It has no intrinsic capabilities to provide QOS. IEEE provides QOS with its extension to the IEEE 802.11 standard known as IEEE 802.11e.

IEEE 802.11e provides QOS using service differentiation [2]. Service differentiation is at flow level rather than station level. Individual flows of a station can be differentiated. Transmission of voice, video and data can be differentiated and QOS can be provided to voice and video, if required. IEEE 802.11e achieves service differentiation by its various parameters. The prominent among them are:

1) *Arbitrary inter-frame space (AIFS): It is the minimum time, a station has to sense the channel idle before it can start transmitting or start random backoff.*
2) *Contention Window (CW): The time a station has to backoff after the channel remains idle for AIFS time interval. It is controlled with two other parameters, contention window minimum (CWmin) and contention window maximum (CWmax)*
3) *TXOP Limit: The maximum duration for which a station can transmit after accessing the channel without any interruption*

2. IEEE 802.11E

IEEE 802.11 deals with two layers, Physical layer and Medium access control sub layer. At the medium access control sub layer it defines two coordination functions. Distributed coordination function (DCF) is used for medium access in contention period and optional Point coordination function (PCF) for medium access in contention free period. The IEEE 802.11e standard defines a coordination function called Hybrid Coordination Function (HCF) as an extension to provide QOS. The HCF combines functions from the DCF and PCF with some enhanced, QOS-specific mechanisms. The HCF uses both a contention-based channel access method, called the Enhanced distributed channel access (EDCA) mechanism for contention-based transfer and a controlled channel access, referred to as the HCF controlled channel access (HCCA) mechanism, for contention-free transfer.

The 802.11e EDCA medium access scheme provides service differentiation by defining eight user priorities. Eight user priorities are to be mapped into four access categories (AC). The method for mapping user priorities to ACs is not defined in the standard. Each station can transmit traffic of all the ACs and ACs are provided different service. There can be any number of such stations. Each AC has a different transmission queue and each transmission queue has a different AIFS, a different set of contention window limits (CWmin and CWmax), and a different Transmission opportunity (TXOP) values.

The values are set such that the AC with higher priority gets better service relative to the AC with lower priority. AIFS value of high priority AC is low making it to access the channel quickly. Contention window values are also assigned such that, the higher priority ACs have better chance of accessing the channel after random backoff. The default AIFS, CWmin, CWmax, and TXOP values are as shown in Table 1. AC_BK, AC_BE, AC_VI, and AC_VO are ACs for background, best effort, video and voice traffic. The default values of CWmin and CWmax with frequency hopping spread spectrum (FHSS) are 15 and 1023 respectively. The default values of CWmin and CWmax with direct sequence spread spectrum (DSSS) are 31 and 1023 respectively.

Table 1: *Default values of IEEE 802.11e parameters*

AC	CWmin[AC]	CWmax[AC]	AIFS[AC]	TXOP[AC] limit (FHSS)	TXOP[AC] limit (DSSS)
AC_BK	CWmin	CWmax	7	0	0
AC_BE	CWmin	CWmax	3	0	0
AC_VI	(CWmin+1)/2-1	CWmin	2	6.016ms	3.008ms
AC_VO	(CWmin+1)/4-1	(CWmin+1)/2-1	2	3.264ms	1.504ms

3. Related Work

In [3], performance study of EDCA is done in both static and dynamic scenarios. The static scenario consists of base station and wireless nodes without any mobility. The dynamic scenario consists of base station and mobile wireless nodes. The standard metrics normalized throughput, end-to-end delay and packet loss are used. In static case, EDCA operates with its full strength comparing to the dynamic case, where the QOS scheme looses the differentiation service ability and comes down to the conventional functionality.

Performance evaluation of EDCA is done in [4] by dividing the traffic into real-time packets and non real-time packets. An analytical model is used to quantify the performance of both AIFS priority and CW priority in the EDCA. A new priority scheme, which allows the user to continuously send real-time packets, is proposed and this is compared with original IEEE 802.11e EDCA. A good balance between fairness and priority is achieved. The limitation of IEEE 802.11e in providing QOS guarantees is determined and further improvements to IEEE 802.11e are suggested. Delay is considered as the performance metric as real-time packets are considered.

Evaluation study of EDCA mechanism which supports service differentiation by assigning data traffic with different priorities based on their QOS requirements is done in [5]. The evaluation also includes the study of the role of different parameters, EDCA utilizes to realize service differentiation as well as the performance comparison of 802.11 and 802.11e along with its capability to resolve downlink/uplink fairness problem. Some important observations are made. Under heavy load, high priority ACs suffers from greater number of collisions due to their small CWmin and CWmax values. The poor performance of low priority ACs under heavy load of high priority ACs shows that high priority traffic starves the low priority traffic. 802.11e service differentiation mechanism effectively solves the downlink/uplink fairness problem well known in 802.11 networks.

Adhoc mode of operation of wireless LAN with 802.11extension to provide QOS is studied in [6]. The metrics considered are throughput, latency, jitter and packet discards. The service differentiation techniques used were: package size variation, Arbitration Interframe Space size alterations, and Binary Exponential Backoff. The results indicate that as AIFS, CWmin, and frame sizes are increased, the network presents an undesirable performance, which means that in order to establish medium access priorities and to keep a satisfactory performance, smaller values to ACs are assigned. It stresses the need for further research study of 802.11e.

An interesting observation is made in [7]. The work in this paper focuses on how to improve WLAN saturation throughput and at the same time provide differentiated service. The impact of service differentiation on saturation throughput maximization in IEEE 802.11e WLANs is studied. It theoretically proves that it is contradictory and impossible to achieve both saturation throughput maximization and service differentiation simultaneously. In other words, saturation throughput is maximized without service differentiation or service differentiation reduces the maximal achievable saturation throughput more or less.

In [8], the performance of IEEE 802.11e EDCA is studied using real world hardware in a realistic indoor working environment. TCP streams of different priorities representing traffic types, such as FTP are tested over a wireless network test-bed. QOS metrics such as throughput and delay are calculated directly from a passive capture of the channel. It is shown that EDCA is capable of providing service differentiation. However the QOS guarantee for high priority stations is achieved at the expense of service provided to stations with lower priority.

A comprehensive study of the performance of EDCA, is presented in [9]. The throughput performance of differentiated service traffic is studied and a recursive method capable of calculating the mean access delay is proposed. The difference of the countdown procedure between the EDCA and the legacy DCF, as well as the retransmission limit are studied. The effects of the CW and AIFS on the service differentiation ability of the protocol have been investigated. Number of ACs, or in other words, the traffic load, should be limited in order to provide a relatively satisfactory service level for both high priority and low priority ACs.

4. Simulation

Protocol evaluations were based on the simulation using NS-2.26. Simulation environment were consisted of 50 wireless mobile nodes forming an adhoc network, moving about over a 500m X 800m flat space for 100 seconds of simulated time. The physical radio characteristics of each mobile node’s network interface, such as the antenna gain, transmit power, and receiver sensitivity, were chosen to approximate the Lucent WaveLAN direct sequence spread spectrum radio. The parameter settings of DSSS were shown in Table 2.

Table 2: *DSSS Parameter settings*

Parameter	Value
Maximum bandwidth	2 Mbps
Frequency	914MHz
Modulation	DSSS/DQPSK
Capture Threshold	10.0 dB
Carrier Sense Threshold	1.559 e -11 dBm
Receiver Threshold	3.562 e -10 dBm

The adhoc network routing protocol used is Destination Sequenced Distance Vector (DSDV). Default values were used for all the parameters of IEEE 802.11e. Four kinds of Access categories were considered, voice, video, data, and background. Four stations act as sources of traffic and all generate traffic of all four ACs. The packet size of all the four ACs was assumed to be 1000bytes. Different rates were used, but the rate of all the ACS was same. The rates used were 500Kbps, 1Mbps, 2Mbps, 5Mbps, 10Mbps, 20Mbps. The code related to IEEE 802.11e was downloaded from the website “www.tkn.tu-berlin.de/research/802.11e_ns2” developed by Telecommunications Networks Group, Technical University, Berlin.

Movement Model

Nodes in the simulation moved according to a model called “random waypoint” mobility model. The random waypoint model is most commonly used mobility model in research community. At every instant, a node randomly chose a destination and moved towards it with a velocity chosen randomly from [0, V_max], where V_max is the maximum allowable velocity for every mobile node. After reaching the destination, the node stopped for a duration defined by the pause time parameter. After this duration, it chose a random destination and repeated the whole process again until the simulation ends.

Metrics

The following were the metrics used for evaluation

- *Number of bytes transferred per sec*
- *Average End-to-End delay*
- *Aggregate number of bytes transferred*
- *Percentage number of bytes transferred*

A. Simulation Results and Discussion

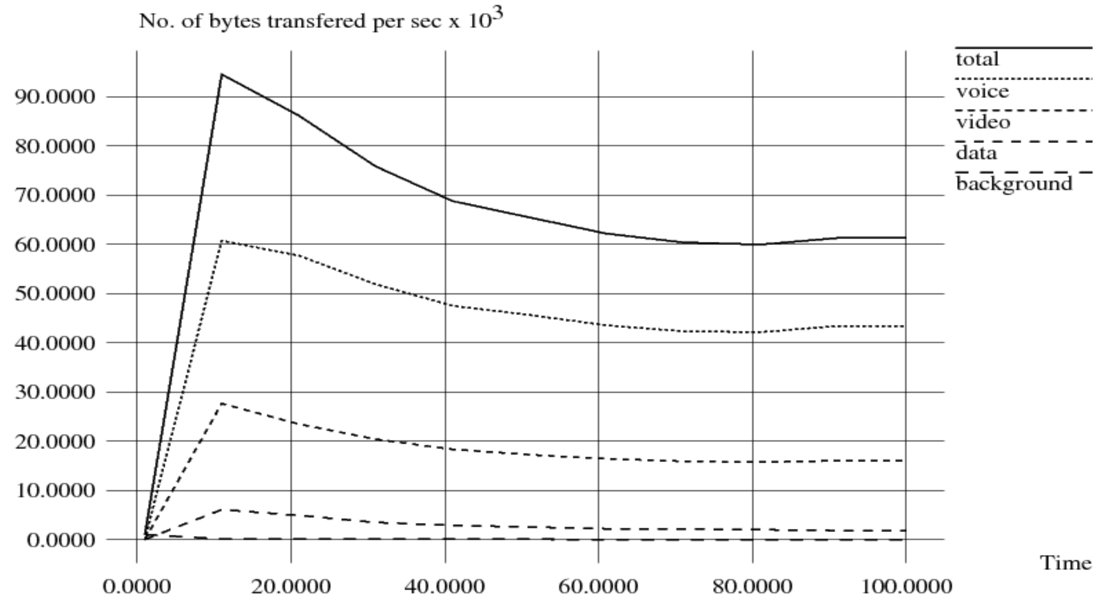

Figure 1: *Variation of number of bytes of data transferred per sec with time at rate 500 Kbps*

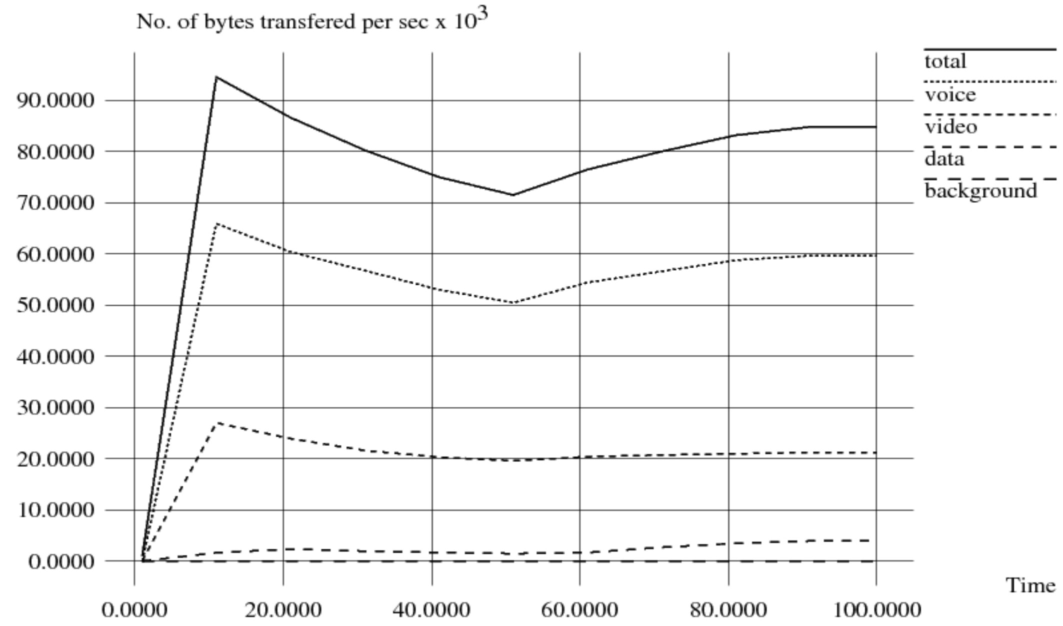

Figure 2: *Variation of number of bytes of data transferred per sec with time at rate 1 Mbps*

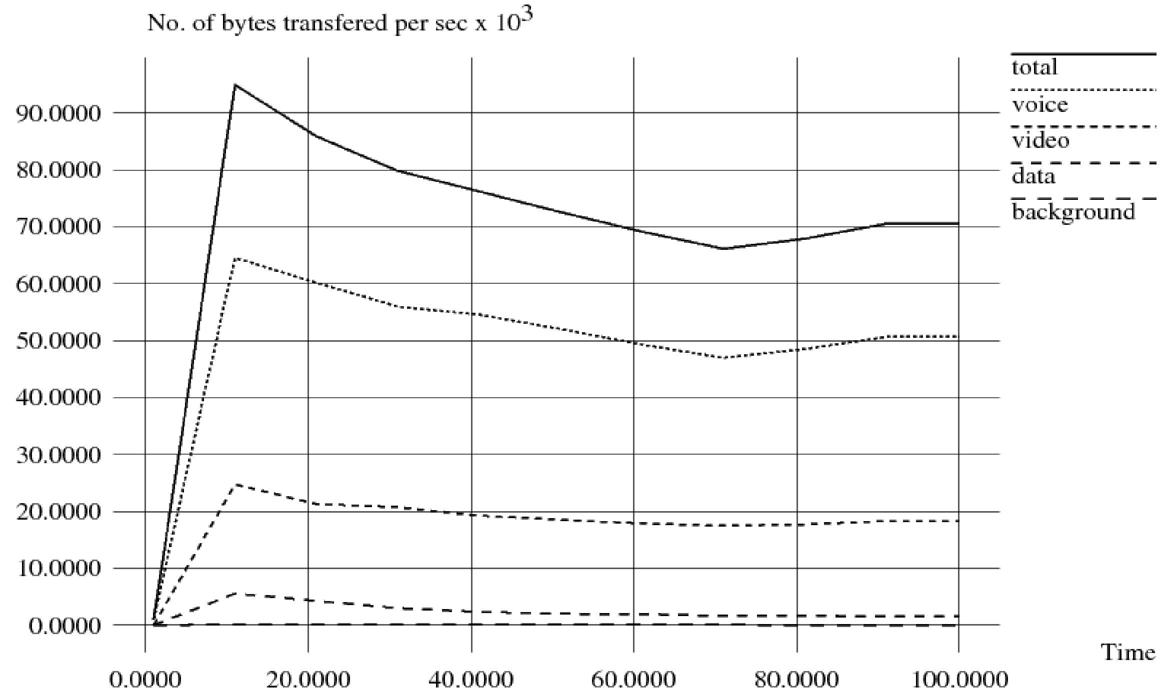

Figure 3: *Variation of number of bytes of data transferred per sec with time at rate 2 Mbps*

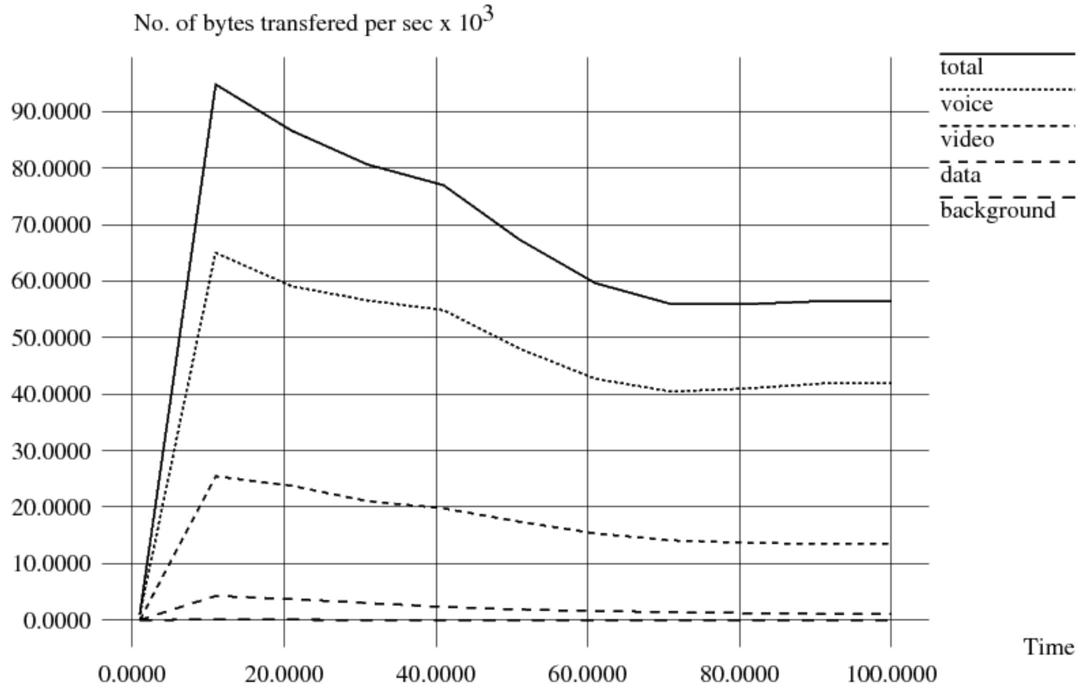

Figure 4: *Variation of number of bytes of data transferred per sec with time at rate 5 Mbps*

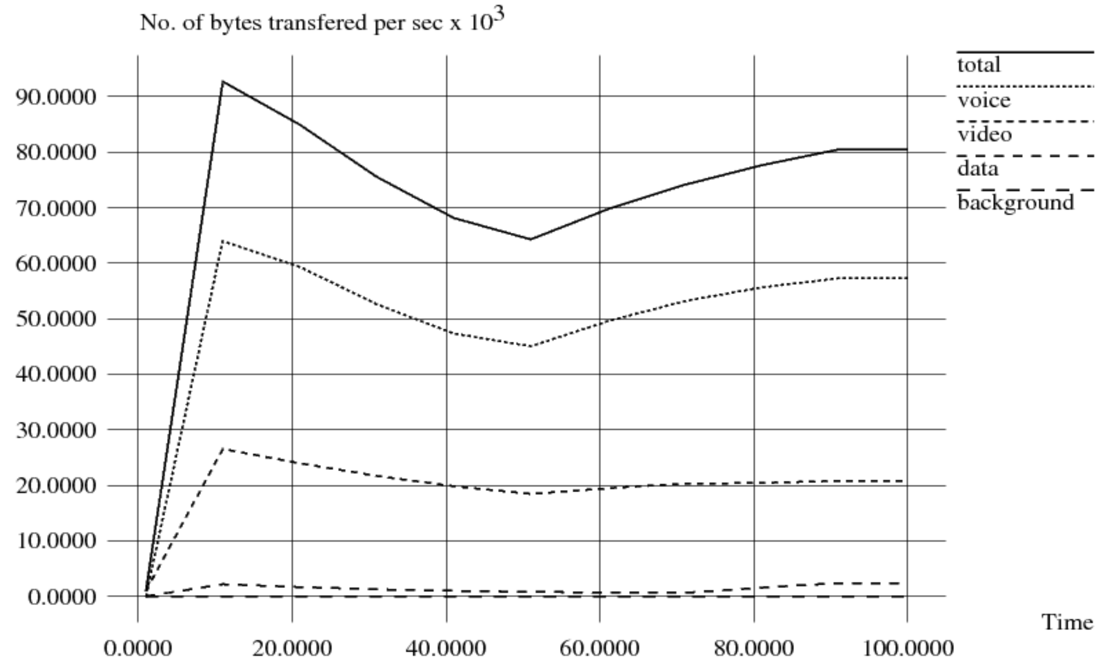

Figure 5: *Variation of number of bytes of data transferred per sec with time at rate 10 Mbps*

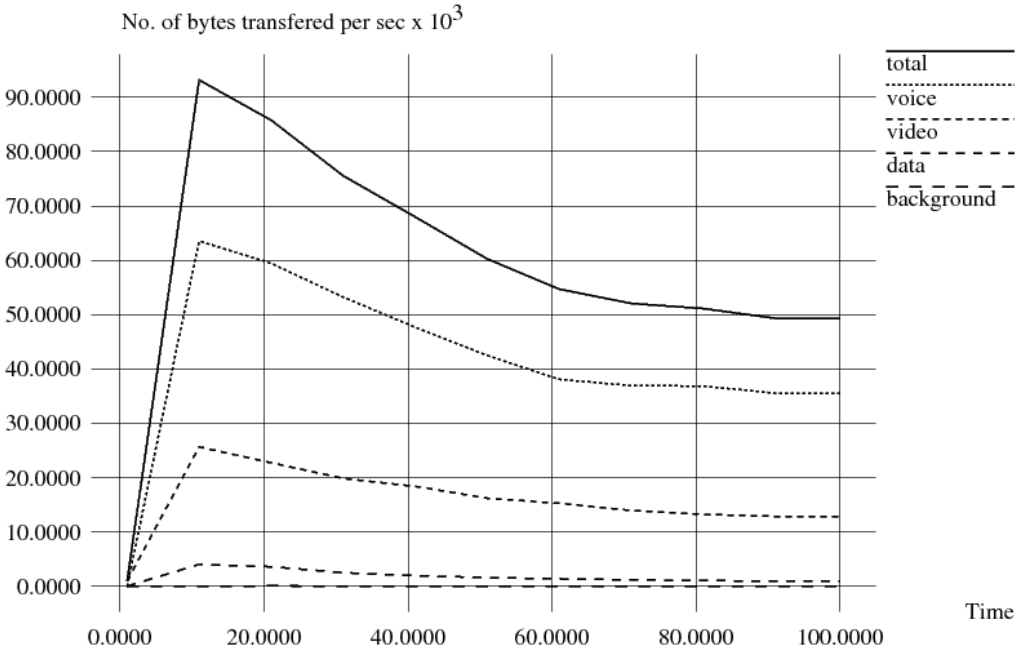

Figure 6: *Variation of number of bytes of data transferred per sec with time at rate 20 Mbps*

Table 3: *Number of bytes of data transferred by different traffic at different rates*

Rate	Total bytes	Voice	Video	Data	Background
500 Kbps	6057000	4280000	1594000	181000	2000
1 Mbps	8671000	6086000	2149000	436000	0
2 Mbps	7087000	5082000	1849000	153000	0
5 Mbps	5631000	4203000	1323000	104000	1000
10 Mbps	8279000	5860000	2095000	323000	1000
20Mbps	4876000	3524000	1263000	88000	1000

Table 4: *Average End-to-End delay by different traffic at different rates*

Rate	Voice	Video	Data	Background
500 Kbps	2.25	21.27	23.6	2.34
1 Mbps	2.34	5.56	12.01	0.0
2 Mbps	1.87	5.27	26.77	2.44
5 Mbps	2.63	5.49	16.82	1.64
10 Mbps	1.70	3.94	6.24	11.88
20Mbps	4.45	10.40	38.41	2.73

Table 5: *Percentage of number of bytes transmitted by different traffic at different rates*

Rate	Voice	Video	Data	Background
500 Kbps	70.6	26.3	2.988	0.33
1 Mbps	70.18	24.78	5.00	0.00
2 Mbps	71.7	26.09	2.15	0.04
5 Mbps	74.64	23.49	0.18	0.017
10 Mbps	70.78	25.30	0.30	0.012
20Mbps	72.27	25.90	1.80	0.012

As can be observed from Fig. 1-6, IEEE 802.11e clearly differentiated between different ACs. Voice AC because of lower values of AIFS, the assigned CWmin and CWmax assigned performs better than other ACs. Number of bytes of data transferred per second of video AC was more than that of ACs data and background. Data AC and Background AC performed poorly and a phenomenon technically called Starvation was observed. This is one of the major disadvantages of service differentiation ability of 802.11e. Service differentiation was achieved at the risk of lower throughput of some ACs. This can decrease the overall throughput significantly when higher AC traffic transmits data at lower rates.

The maximum data rate of 802.11e was assumed as 2Mbps. At lower rate of 500 Kbps, the bandwidth was not used efficiently resulting in overall low throughput. Similarly at higher rates, overall throughput was affected and was lower because of collisions. Significantly better performance was observed at 1Mbps and 2 Mbps.

At higher rates such as 20 Mbps, total number of bytes transferred per second and that of different ACs was significantly lower because of high number of possible collisions. Aggregate number of bytes transferred by different ACs is as shown in Table 3.

Average End-to-End delay of voice AC was significantly lower than that of other ACs. Average End-to-End delay of background AC could not be given much importance because of a few bytes of data transferred by it. The results related to average End-to-End delay were shown in Table 4. Voice AC transfers 71% of the total bytes, 25% by video AC, and the remaining was shared by data and background ACs. The results were shown in Table 5.

5. Conclusion

The paper evaluated the service differentiation ability of 802.11e using NS2 simulator. Identical traffic was used for all ACs and evaluation was done at different rates. 802.11e achieved service differentiation. Service differentiation was achieved at the risk of decrease in overall throughput. Of the total number of bytes transmitted, voice AC transmitted 71% of the bytes, video AC 25% of the bytes and the remaining 4% of the bytes were transmitted by data and background ACs. Very low throughput of lower priority ACs was a severe limitation of 802.11e which is called starvation. High priority ACs achieves significantly lower delays.

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