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Dynamic Load Distribution Cross-layer Algorithm for Video Transmission over IEEE 802.11n WLANs

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Abstract— The advancement of the Internet technologies has brought with it a tremendous amount of multimedia traffic. Medium access coordination function incorporated by using distributed coordination function (DCF) has the limited quality of services (QoS) in Wireless networks. So it is necessary to have a mechanism for QoS on a wireless network that video and voice over Internet protocol (IP) services can run with good quality along with other data services. This simulation analyzed the performance enhanced distributed channel access (EDCA) 802.11n for video transmission in light and heavy load using without mapping, static, adaptive and dynamic cross-layer mapping techniques. The proposed dynamic load distribution cross-layer algorithm gives better average throughput and PSNR value compared against the results derived from EDCA IEEE 802.11n, Adaptive Cross-Layer Mapping, Dynamic Adaptive Cross-layer mapping mechanism and the static mapping algorithm.

Index Terms— QoS, Cross-layer mapping, Video over WLAN, Multimedia Transmission, EDCA, 802.11n.

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1 INTRODUCTION

During recent years the IEEE 802.11 wireless local area network (WLAN) standard becomes the most popular technology all over the world, as it has unique advantages such as easy deployment, low cost, simple, flexible, mobility, higher and data transmission rates. In WLAN, a wireless user can access the Internet anywhere, anytime and enjoy the Internet while mobility with guaranteed access. It widely used in video and voices real-time applications. The IEEE 802.11 architecture supports only best-effort service (BES), and it is only better for web surfing or data transmission. In a real-time application, e.g. multimedia transmission, it does not provide any QoS. Therefore, 802.11 WLAN is not suitable for multimedia services. A mechanism is needed for enhancing the QOS for IEEE 802.11 in a multimedia traffic area. The 802.11e EDCA MAC procedure supports QoS requirements and states distributed contention-based access method for using the shared wireless platform [1]. The 802.11n backward compatible with 802.11e and supports QoS to enhanced MAC performance. The paper focused on analysis the performance of video traffic on IEEE 802.11n in heavy load environment.

2 MPEG-4 VIDEO STRUCTURE

MPEG-4 compression techniques define three types of video frames; Intra-coded, Predictive-coded, and Bidirectional predictive-coded for the producing compressed video stream. These frames are broadly known as I (Inter), P (Predictive), and B (Bidirectional). During encoding of "I" frames, the previous or successive frames are not required. It is decoded by itself. Therefore, the "I" frames coded as a still image. By using estimating video sequence of previous "I" or "P" frames, the "P" frames are encoded. By using estimating video sequence of previous and next "I" or "P" frames, the "B" frames are encoded. As per the MPEG-4 video stream coding relation, "I" frames are most important video frames then "P" frames and "P" frames more important than "B" frames. A smaller unit used for decomposing these video sequences "I", "P", and "B"; known as a group of pictures (GOP). A GOP configuration has two parameters to represent frames are G (N, M): where N parameter denotes I-to-I frame distance, and M parameter denotes I-to-P frame distance [1, 2]. The estimation encoding of MPEG-4 video shown in Fig. 1. This encoding GOP size is 9, where N=9 and M=3.

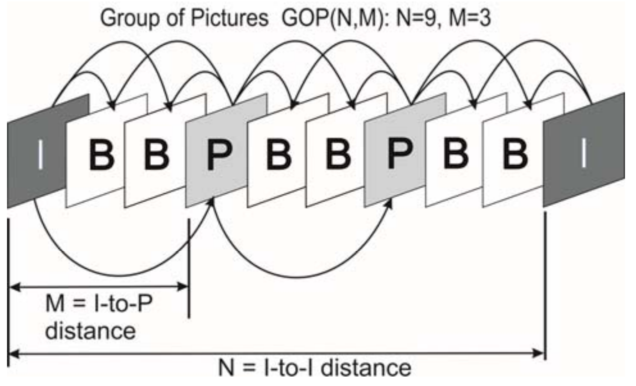

Fig. 1. Estimation Encoding of MPEG-4 of video

3 IEEE 802.11N EDCA

In IEEE 802.11e, the EDCA mechanism is modified MAC distributed coordination function (DCF). The IEEE 802.11n EDCA is backward compatible with IEEE 802.11e EDCA Legacy Devices. It categories into four different access classifications (ACs). By using four ACs (0-3) in each station (STA) it realized

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the service differentiation. The four access categories are used for voice, video, best-effort, and background traffic names as AC_VO, AC_VI, AC_BE, AC_BK respectively. These ACs are described in Fig. 1. We used short, simple names for notifications AC_BK, AC_BE, AC_VI, and AC_VO as AC0, AC1, AC2, and AC3 respectively throughout this paper. All these four access categories of IEEE 802.11n shown in Fig. 2 in which each traffic stored in separate queue by using appropriate AC instead of all traffic shared a common queue in DCF [1, 3, 4].

Table 1 show how this medium access differentiation is realized by assigning different certain values CWmin (minimum contention window) and CWmax (maximum contention window). The contention window is used to calculate the number of time slots to back off before accessing the medium. AC a higher priority can be given by assigning low values to CWmin and CWmax. A number used for time slots after a short interframe space (SIFS) period a station has deferred before either starting a transmission or invoking a backoff is known as arbitration inter-frame space number (AIFSN). The parameter transmission opportunity (TXOP) limit specifies the maximum length of the TXOP. A TXOP limits higher than zero implied that multiple frames are transmitted till transmissions does not spread outside the TXOP limit [1, 3, 4].

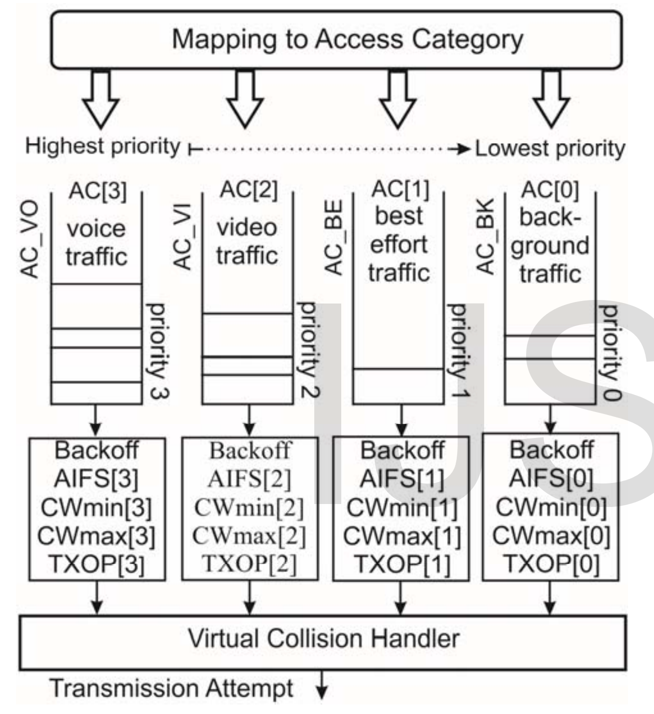

Fig. 2. Four Access Categories of IEEE 802.11n

4 CROSS-LAYER

The suggested mapping mechanism dynamically allocates the video to the most appropriated AC according to the important frame type and network traffic load at the MAC layer for reliable video transfer [1-3]. For GOP based video traffic, the loss of more significant video frames would reduce quality of received video as shown in Fig. 3. Single "I" video frame loss, causes all video frames in the same GOP to be decodable at the receiver side, and many frame error rates generated on a few packet loss rates. A 30% frame error rate caused on 3% packet loss [5].

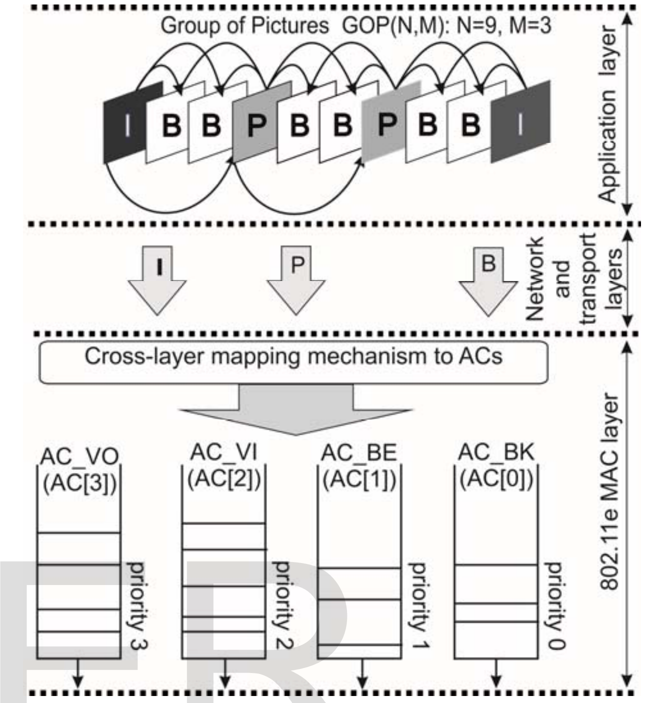

Fig. 3. Architecture of adaptive cross-layer mapping scheme

5 IEEE 802.11N

IEEE 802.11n technology officially released in late 2009. It provides enhanced wireless performance and range comparison then prior 802.11 technologies. It can work on two frequencies; 2.4 GHz or 5 GHz space for maintaining backward compatibility with prior 802.11 technologies.

For improving MAC efficiency and channel utilization, the

TABLE 1
IEEE 802.11N EDCA PARAMETER SET

Priority	Access Categories	Short Name	Designation	AIFSN	CWmin	CWmax	TXOPlimit
0 (lowest)	AC_BK	AC0	Background	7	31	1023	0
1	AC_BE	AC1	Best Effort	3	31	1023	0
2	AC_VI	AC2	Video	2	15	31	6.016ms
3 (Highest)	AC_VO	AC3	Voice	2	7	15	3.264ms

overhead can be minimized by using an aggregation mechanism in IEEE 802.11n in which the many numbers of frames transmitted over the wireless network together with aggregated packet. The aggregation method accomplishes higher system gain and useful for such applications that have shorter packets size. These applications are the voice (VoIP) [6, 7].

For meeting the requirements of higher throughput, there are two possible methods can be used in 802.11n. It first enhanced the Physical layer data rate and secondly increased the efficiency in the MAC layer. IEEE 802.11n added several new features on a level of PHY, and MAC layers for enhancing the throughput. These new enhancements in IEEE 802.11n are as follows [6, 7]:

1. MIMO-OFDM physical layer
2. Aggregation mechanism
    a. Aggregation MAC Service Data Unit (A-MSDU)
    b. Aggregation MAC Protocol Data Unit (A-MPDU)
3. Block Acknowledgement (BA)
4. Reverse Direction (RD)

5.1 MIMO-OFDM physical layer

The 802.11n adds two important technologies: 40 MHz wide channels and multiple inputs, multiple outputs (MIMO). For increasing performance and range significantly MIMO uses multiple antennas in 802.11n to transmit and receive data over multiple wireless channels. It increased the data rate within the PHY layer up to 600 Mbps; by adding MIMO technology with orthogonal frequency division multiplexing (OFDM) and increasing channel bandwidth from 20 MHz-40 MHz [6, 7].

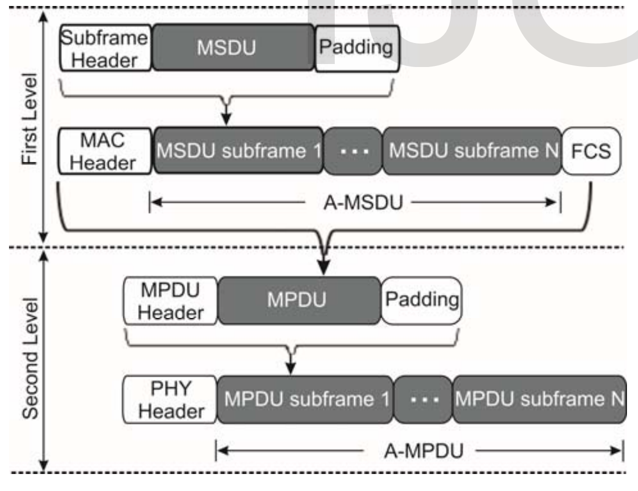

Fig. 4. Two-level Aggregation in IEEE 802.11n

5.2 Aggregation mechanism

The IEEE 802.11n MAC aggregation method designed as a two-level aggregation scheme. The first level the A-MSDU accepts multiple MSDUs to be transmitted to the same receiver combined in a one A-MPDU. MSDU subframe contains MSDU, subframe header, and padding bytes. Each A-MSDU contains many MSDU subframes; MAC header and frame check sequence (FCS). Similarly, the second-level aggregation MPDU contains an A-MSDU, MPDU header, and the padding bytes. Each A-MPDU contains many MPDU subframes, PHY header [6, 7]. The two-level aggregation mechanism was over when A-MPDU formed as shown in Fig. 4.

5.3 Block Acknowledgement (BA)

The basic mechanism of TXOP for supporting video transmission defined in IEEE 802.11e and the block ACK with TXOP mechanism of IEEE 802.11n overcomes the overhead of the traffic in transmission [6, 7].

5.4 Reverse Direction (RD)

Reverse Direction is used to improve the efficiency of TXOP. The transmission of video traffic used in forward direction in TXOP mechanism and with RD mechanism permits to the owner of TXOP to allow the unused TXOP time to its clients for reverse direction video flows to improve the channel efficiency [6, 7].

6 CROSS-LAYER MAPPING MECHANISM

IEEE 802.11n devices are backward compatible with IEEE 802.11 Legacy Devices. The EDCA features of IEEE 802.11e also used by IEEE 802.11n. As default nature of IEEE 802.11n, cross-layer architecture packets are sent to appropriate ACs according to nature of incoming traffic. Four Access Categories of IEEE 802.11n are shown AC3 for voice, AC2 for video, AC1 for the best effort, and AC0 for background shown in Fig. 2. Where AC3 has the highest priority, and AC0 has the lowest priority. Default IEEE 802.11n EDCA parameters are shown in Table 1.

Various previous studies QoS Architecture implemented for transmitting video packets by assigning the priority of the frame with their types [2, 3, 8, 9].

6.1 Static Mapping

In this mapping “I", “P”, “B” frames sends to AC3, AC2, AC1 and non-video traffic sent to AC0. In previous research work “I”, “P”, “B” frames should be sent to AC2, AC1 and AC0 respectively [3]. The AC accessed the channel as per their priority.

6.2 Adaptive Cross-Layer Mapping

The proper utilization of ACs we need some mapping mechanism for an estimate the free available space of each AC2 for video traffic and select destination AC according to the type of frame. It is possible to have some latency because some important packets sent to AC with lower priority.

Previous researchers provide adaptive mapping algorithm and video frames can go AC2 or AC1 as per the available space for the buffer [1, 2]. For performing queue management to avoid upcoming congestion in advance two parameters $Threshold_{low}$ and $Threshold_{high}$ were used. By use the use of this function and Prob_Type (Initially this value for Prob_Type for I =0, Prob_Type for P =0.6, Prob_Type for I =0.9, new probabilities calculated based upon current queue length and threshold values [1, 2].

6.3 Dynamic Cross-Layer Adaptive Mapping

Dynamic adaptive mapping mechanism sends the frames as per the dropping probability of the frame times. Initially, all frames of video are sent to AC2, and frames moved into AC1 and AC0 as per the available space in AC2. New probabilities calculated based on the current queue length, packets size and threshold values [13].

7 PROPOSED DYNAMIC LOAD DISTRIBUTION CROSS-LAYER ALGORITHM (DLDCA)

In this Load Distribution Cross-layer algorithm when a video packet reaches at EDCA, the current queue length of AC2 examined and matched against a set of $Threshold_{low}$ (20%) and $Threshold_{high}$ (80%). If the queue length is less than $Threshold_{low}$ value all frames of video data ("I" or "P" or "B") are mapped to AC2. If queue length is greater than $Threshold_{low}$ and lower than the $Threshold_{high}$, all frames of video data mapped to AC2 except "I" frame mapped to AC3 if queue length of AC3 is less than AC2. At the time of AC2 queue length higher than $Threshold_{high}$ than "P" and "B" frame of video data is mapped to AC1 and AC0 respectively. "I" frame mapped to AC1 if AC3 and AC2 are full otherwise "I" frame mapped to AC3 or AC2 whichever is less occupied. Following is the proposed dynamic load distribution cross-layer algorithm (DLDCA).

7.1 Algorithm DLDCA

```
BEGIN
    // Initialize queues Threshold values
    set $Threshold_{low}$ ← 20% of AC Queue Length
    set $Threshold_{high}$ ← 80% of AC Queue Length

    If qlen[$AC_2$] < $Threshold_{low}$ then
        Video packet → $AC_2$
    else if qlen[$AC_2$] < $Threshold_{high}$ then
        if qlen[$AC_3$] < qlen[$AC_2$] and frameType = "I"
            "I" frame → $AC_3$
        else
            Video packet → $AC_2$
    else
        if frameType = "I" then
            if $AC_3$ and $AC_2$ are full then
                "I" frame → $AC_1$
            else if qlen[$AC_3$] < qlen[$AC_2$] then
                "I" frame → $AC_3$
            else
                "I" frame → $AC_2$
        else if frameType = "P" then
            "P" frame → $AC_1$
        else
            "B" frame → $AC_0$
END;
```

8 SIMULATION MODEL

The framework for video transmission over the WLAN in NS2 on Fedora's environment integrated with Evalvid, and myEvalvid framework was used in the simulation for this study [10-14].

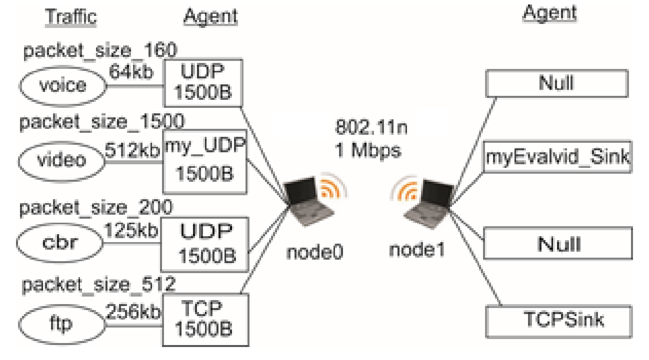

Fig. 5. Simulation Topology

For experimental setup shown in Fig. 5, the study used two senders and receiver access points with 1Mbps connectivity and simulation of unicasting MPEG-4 video transmission from the server (node0) to a client (node1) over IEEE 802.11n. For increasing the virtual collision at MAC layer of the sender node, this experimental study used FTP traffic as background traffic (256kbps) for client level. Also CBR data traffic (125kbps) at the sender, the site was used to overload the backbone of wireless networks. YUV QCIF (176*144 pixels) Foreman video traffic selected for these simulations and details of video packets and

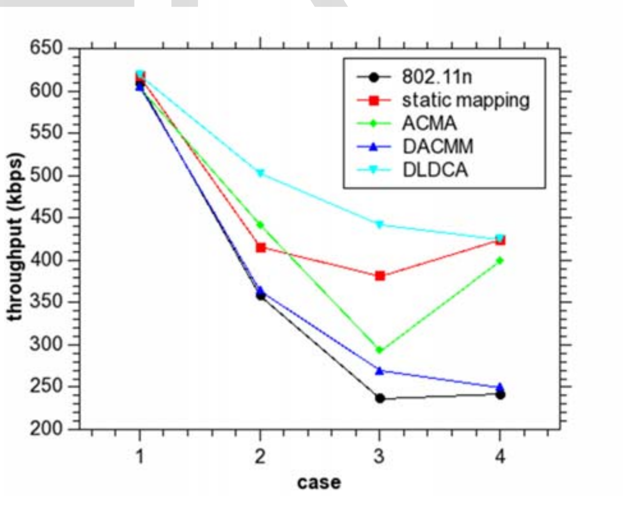

Fig. 6. Average throughput under four different loading cases

TABLE 2
VIDEO PACKETS AND FRAMES USED IN FOREMAN VIDEO SOURCE

Video Source Name	Number of Packets				Total Packets	Number of Frames			Total Frames
	Format	I	P	B		I	P	B	
Foreman	QCIF	237	149	273	659	45	89	266	400

TABLE 3
SIMULATION PARAMETER

	VoIP	Video	Best Effort	Back-Ground
Transport protocol	UDP	UDP	UDP	TCP
Access Category	AC3	AC2	AC1	AC0
Packet size	160B	1500B	200B	512B
Sending rate	64kbps	512kbps	125kbps	256kbps

frames used in this video source shown in Table 2. Each frames fragmented into 1500 Bytes size packets there after they are transmitted at the rate of 512kbos on simulated network as video frames. Packet size and sending rates shown in Table 3. In the experimental study, 50 packets of queue size were selected for all ACs. Also to the background and best-effort traffic, 64 kbps CBR voiced traffic also created at the sender site. Table 4 shows IEEE 802.11n simulation parameter for this study. Before transmission, each frame of video data was fragmented into maximum size of 1024 bytes.

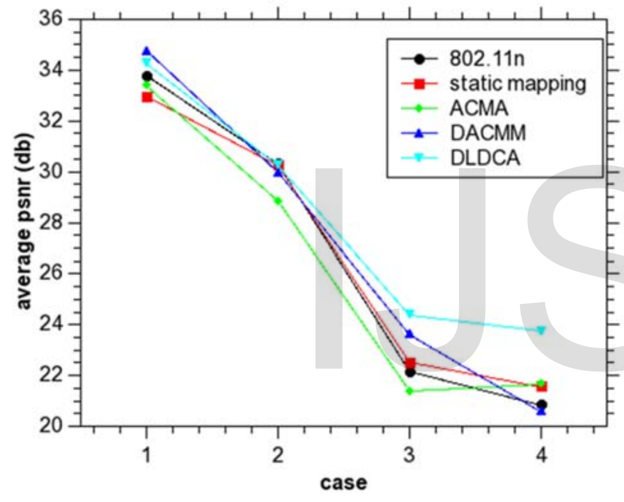

Fig. 7. Average PSNR under four different loading cases

TABLE 4
IEEE 802.11N SIMULATION PARAMETER

Parameter	Value
CBR Interval time	80µsec
Packet Size	512 bytes
Block Acknowledge type	0 (none)
RD-Reverse Direction	0
Aggregation Size	16383 bytes
Flag for Contention Free Burst (*cbr_*)	0 (CFB off)
Number of Antenna	4
MIMO System	1

TABLE 5
NUMBER OF TRAFFIC STREAM IN TRAFFIC SCENARIO

	Voice (AC[3])	Video (AC[2])	TCP (AC[1])	UDP (AC[0])
Case 1	1	3	1	1
Case 2	5	3	5	5
Case 3	10	5	10	10
Case 4	10	10	10	10

9 RESULTS AND DISCUSSIONS

The results of the proposed dynamic load distribution cross-layer algorithm compared against the results derived from IEEE 802.11n EDCA [3], Adaptive Cross-Layer Mapping (ACMA) [2], Dynamic Adaptive Cross-layer mapping mechanism (DACMM) [8] and the static mapping algorithm in [9]. This simulation study used four different loading cases that include various loads of voice traffic (in AC3), Video (in AC2), UDP (in AC1 and TCP (in AC0).

As shown in Table 5 four types of traffic flows, including video were randomly generated and transmitted over 802.11n during the entire simulation period. Investigators were analyzed the received video quality using PSNR and throughput to evaluate the effectiveness of proposed mechanism under various networks heavy load conditions.

Table 6 shows the number of video data frames lost during the transmission of the Foreman QCIF video. In heavy load, important packets (I) are saved during transmission. It improves the received video quality as a 3% important packet loss rate rates may translate into 30% frame error rates [5].

The average throughput of EDCA 802.11n network under four different loading cases shown in Fig.6. In all loading cases, the average throughput of proposed DLDCA gives better than ACMA or DACMM or the 802.11n EDCA approach.

Fig. 7 shows the PSNR variations of transmitted video for the

TABLE 6
NUMBER OF FRAME LOSS

Mapping Type	Traffic Scenario											
	Case 1			Case 2			Case 3			Case 4		
	I	P	B	I	P	B	I	P	B	I	P	B
802.11n	0	3	17	3	21	95	25	45	190	22	63	249
Static	0	7	57	1	9	177	9	82	266	11	88	264
ACMA	0	6	25	1	31	128	20	58	226	18	65	257
DACMM	0	0	5	5	16	100	18	49	205	29	55	233
DLDCA	0	0	27	0	20	35	7	60	232	7	64	261

four different loading cases as shown in Table 5. In case 1 case 2 when the simulated network is light loaded, the proposed algorithm gives the almost similar result to EDCA 802.11n. In case 3 and case 4 when network traffic is heavy loads the static mapping gave the poor performance as many packets lost because these packets moved into lower priority queues. Moreover, because of dynamic based DLDCA based on take care of significance to the video data as well as current load conditions on the network, the proposed mechanism gives better average PSNR than ACMA or DACMM or the 802.11n EDCA approach.

10 CONCLUSION

This simulation analyzed the performance EDCA 802.11n for video transmission in light and heavy load using without mapping, static, adaptive and dynamic cross-layer mapping techniques. The average throughput and average PSNR of the 802.11n network under four different loading cases including different loads were computed. Results show that the proposed dynamic load distribution cross-layer algorithm gives better average throughput and PSNR value compared against the results derived from IEEE 802.11n EDCA, Adaptive Cross-Layer Mapping, Dynamic Adaptive Cross-layer mapping mechanism and the static mapping algorithm. Therefore, the average PSNR demonstrates that the received video quality of the proposed dynamic load distribution cross-layer algorithm is better than that obtained with the other four methods.

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