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Distortion Measurement based Dynamic Packet Scheduling of Video Stream over IEEE 802.11e WLANs

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Abstract

In H.264, three different data partition types are used, which have unequal importance to the reconstructed video quality. To improve the performance of H.264 video streaming transmission over IEEE 802.11e Wireless Local Area Networks, a prioritization mechanism that categorizes different partition types to different priority classes according to the calculated distortion within one Group of Pictures. In the proposed scheme, video streams have been encoded based on the H.264 codec with its data partition enabled. The dynamic scheduling scheme based on Enhanced Distributed Channel Access has been configured to differentiate the data partitions according to their distortion impact and the queue utilization ratio. Simulation results show that the proposed scheme improves the received video quality by 1dB in PSNR compared with the existing Enhanced Distributed Channel Access static mapping scheme.

Keywords: Data Partition, Enhanced Distributed Channel Access, Video streaming, Quality of Service (QoS)

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1. Introduction

IEEE 802.11 based Wireless Local Area Networks (WLANs) have been widely deployed in recent years. The use of unlicensed spectrum, the availability of low cost devices, and their ease of management has lead to a plethora of WiFi Access Points, used not only in office environments or as public hot-spots but also to connect residential users and their multimedia devices to the Internet. According to the IEEE 802.11 standard, there are two different channel access mechanisms, a centralized one, known as the Point Coordination Function (PCF), and a distributed one, the Distributed Coordination Function (DCF). However, most of the current WLANs are based on the latter, i.e., a CSMA/CA mechanism that only provides with a best effort service, while the PCF mechanism has received relatively little attention from manufacturers.

Although the first physical layer specification supported only 2 Mbps capacity, due to the increasing bandwidth demands extensions were adopted over the years, such that nominal rates of up to 54 Mbps are achievable with IEEE 802.11g. This rate increase has enabled the use of WLANs also for real-time applications, such as e.g. voice over IP, video streaming or video conferencing. However, these delay and bandwidth sensitive applications are properly supported only in over-provisioned scenarios, where the best-effort based scheme of DCF is enough to fulfill the QoS requirements.

Totally, the latest Wireless Local Area Networks (WLANs) has two tendencies: 1) nominal rates of up to 54Mbps are achievable with IEEE 802.11g or 100Mbps with 802.11n; 2) the new channel access scheme to fulfil the QoS requirements, such as the Enhanced Distributed Coordination Access (EDCA). EDCA is an extension of Distributed Coordination Function (DCF) that supports service differentiation through four different Access Categories (ACs), namely voice, video, best-effort and background. These ACs can be configured with different values of the contention parameters, leading to statistical service differentiation. However, the configuration of both mechanisms is left open, as the standard only specifies a simple scheduler to provide Constant Bit Rate (CBR) services for the case of Hybrid coordination function Controlled Channel Access (HCCA) and a set of recommended values of the contention parameters for EDCA [1].

In IEEE 802.11e EDCA, different kinds of traffic flows are allocated to different queues. Each queue is characterized by specific contention window and interframe spacing values, the parameters which control the amount of time the transceiver has to wait before attempting to access the channel for transmission. Because of the different setting of such parameters for each ACs, the result is that the queues are characterized by unfair chances of getting access to the channel. Service differentiation between ACs is achieved by setting different Contention Window (CWmin, CWmax,) sizes, Arbitrary Interframe Space (AIFS) values, and Transmission Opportunity duration limit (TXOP limit). If one AC has a smaller AIFS or CWmin or CWmax, the AC's traffic has a better chance of accessing the wireless channel earlier. Generally, AC3 is reserved for real-time voice, AC2 is reserved for video transmission, and the others (AC1, AC0) for best effort and background traffic.

However, the use of the fixed set of recommended values for the EDCA parameters results in poor efficiency for most scenarios, as the optimal configuration of the channel access parameters depends on the WLAN conditions, including the number of stations and their load [2][3]. Thus, when the WLAN is heavily loaded, the performance of real-time applications, and in particular the delay experienced by video traffic, is severely degraded. Following this observation, previous work proposed to improve video performance by adapting the channel access protocol to the WLAN conditions. These works can be classified as follows:

1) Cross-layer approaches

Most of these approaches classify the frames of a layered-encoded video according to their relevance, and map them to different ACs. In [4], the authors employed a controller to drive the delay to an application-specific reference, by employing packet classification at a newly introduced middleware layer. A. Ksentini et al. [5][6] leveraged the inherent H.264 error resilience tools and 802.11e MAC protocol possibilities, and proposed a cross-layer mapping scheme is shown in **Table 1**. A major disadvantage of these approaches is the static mapping method, no consideration of the queue utilization ratio. In [7], the authors proposed an algorithm to meet the delay QoS requirements of various traffic by dynamic monitoring the 802.11e MAC queues and network conditions. Nafaa et al. [8] proposed a cross-layer MAC design featuring a delay-sensitive backoff range adaptation along with a distributed flow admission control. Some distributed schemes are presented for delay sensitive transmission [9-10]. To minimize the total video distortion, Ref. [9] constructed a general distortion model according to the network's transmission mechanism and propose a distributed scheduling scheme jointly considering channel assignment, rate allocation, and routing; Ref. [10] proposed a distributed media-aware rate allocation, which considering about the the wireless link speeds and video rate-distortion characteristics, as well as traffic contention among neighboring links. These approaches require rather complex interactions between the application and the MAC layers, and moreover they either require specific video sources, or modifications of the protocol stack. Furthermore, these methods need to add some changes to the MAC layer, and these changes are difficult to achieve on the WLAN card.

2) EDCA parameters compliant approaches

These approaches relied on the EDCA standard mechanism and dynamically update the EDCA parameters and/or the video codec behavior based on the observed WLAN conditions [11-14]. In [11], the authors focused on influence of contention window and AIFS, and Ref. [12] focused on dynamic adjusting TXOP to guarantee the QoS performance. Xiao Y. et al. addressed on bandwidth allocation schemes according to contention-based nature [13]. In [14], EDCA configuration was dynamically adjusted the EDCA configuration according to the distortion measurement with the goal of maximizing the video reconstructed quality. Their major drawback is that they are based on heuristics and lack analytical support, and hence do not guarantee optimized performance. Furthermore, for the Internet of Things, L. Zhou presented a multidemdia traffic classification, and designed a new and efficient media-aware security framework for facilitating various multimedia applications [15].

Table 1. Cross-layer mapping scheme

Mapping scheme	Access Categories	Video slice types
IEEE 802.11e	AC_3	audio
	AC_2	All video slice(Parameter Sets, DPA,DPB,DPC)
	AC_1	Best effort
	AC_0	Background
Reference [5]	AC_3	Parameter Sets, DPA
	AC_2	DPB, DPC
	AC_1	DPC
	AC_0	Background

To address the above questions, the paper proposes a dynamic mapping algorithm, which different data partitions in H.264 are dynamically scheduled into different AC according to the calculated importance factor and the EDCA queue utilization ratio. The rest of this paper is organized as follows. In Section 2, we describe H.264 video packets relies on a Data Partitioning (DP) technique at the application layer. Through employing DP, the H.264 encoder partitions the compressed data in separate units of different importance. Then we calculate the importance factor for each data partition within one Group of Pictures (GoP), and each data partition is marked with an importance factor. In Section 3, according to the marked importance factor and the queue utilization ratio, we dynamic specify the marked packet with an AC provided by 802.11e EDCA. The experimental results and analyses are presented in Section 4 to show the performance of the proposed scheme. Finally, Section 5 concludes this paper.

2. The Prior Model of H.264 Video Packets

2.1. Data partitioning in H.264

Data partitioning is an effective application-level framing technique in H.264 standard, which divides the compressed video data into separate units of different importance. Generally, all symbols of MBs are coded together in a single bit string that forms a slice. However, DP creates more than one bit string (partition) per slice, and allocates all symbols of a slice into an individual partition with a close semantic relationship. There are three different partition types in H.264: 1) DPA, i.e., partition A, containing header information such as Macro Block (MB) types, Quantization Parameters (QPs), and Motion Vectors (MVs). This information is the most important because if it is lost, symbols of the other partitions cannot be used. 2) DPB, i.e., partition B, carrying intra Coded Block Patterns (CBPs) and intra coefficients. DPB requires the availability of DPA in order to be useful at the decoding level. In contrast to the inter information partition, intra information can stop further drift and hence is more important than the inter partition. 3) DPC, i.e., partition C, containing only inter CBPs and inter coefficients. Inter partitions are the least important because their information does not resynchronize the encoder and decoder. In order to be used it requires the availability of DPA, but not of DPB.

Usually, if DPB or DPC are missing, the available header information can still be used to improve the efficiency of error concealment. More specifically, due to the availability of the MB types and motion vectors, a comparatively high reproduction quality can be achieved as only texture information is missing.

2.2. Calculating the Importance Factor

In this section, we propose a method to quantify the influence to the video quality of each partition. Firstly, we resume that a video frame is coded into one slice, one slice is divided into three partitions (DPA, DPB, and DPC). For each GoP, which begins with an Instantaneous Decoding Refresh (IDR) frame, let L denotes the size of one GoP. The IDR accesses unit contains information that cannot be partitioned into the three partitions. That is, they contain only the intra picture (coded picture that can be decoded without needing information from previous pictures) where no data partitioning can be applied. Thus, the generated slices (A, B, C, PSC, and IDR) are directed to the Network Abstraction Layer (NAL) with an associated header using an implementation dependent data structure. In this paper, the IDR frame is assumed not lost, only the following L-1 frames are quantified.

Now, we define some notations used in the derivation of the priority model. Let N_f be the pixel number of a frame, let $F(i,m)$ be the original value of m-th pixel in i-th frame, let $F_c(i,m)$ and $F_d(i,m)$ be the reconstructed value at the encoder and decoder respectively. The source distortion $D_s(i)$, channel distortion $D_c(i)$ and total distortion $D(i)$ of i-th frame are calculated under Mean Square Error (MSE) criterion as:

$$D_s(i) = \frac{1}{N_f} \sum_{m=1}^{N_f} [F(i,m) - F_c(i,m)]^2 \tag{1}$$

$$D_c(i) = \frac{1}{N_f} \sum_{m=1}^{N_f} [F_c(i,m) - F_d(i,m)]^2 \tag{2}$$

$$D(i) = \frac{1}{N_f} \sum_{m=1}^{N_f} [F(i,m) - F_d(i,m)]^2 \tag{3}$$

The relationship of $D_s(i)$, $D_c(i)$ and $D(i)$ is:

$$D(i) = D_s(i) + D_c(i) + \frac{2}{N_f} \sum_{m=1}^{N_f} [F(i,m) - F_c(i,m)][F_c(i,m) - F_d(i,m)] \tag{4}$$

When DPA, DPB or DPC of i-th frame is lost, it will influence decoding i-th frame and the following frames. To evaluate the influence factor of different partition, the same error-concealment methods are adopted:

1) in case of DPA of i-th frame is lost, the decoder copies the MBs at the same spatial position of (i-1)-th frame;

2) in case of DPB of i-th frame is lost, the decoder copies the MBs at the same spatial position of (i-1)-th frame;

3) in case of DPC of i-th frame is lost, the decoder exploits the predictive data by resulting the motion vector information from the reference frame.

Let $D(i,j,k)$ denotes the distortion of j-th frame caused by the lost of k-th partition of i-th frame, $1\le i\le L-1, 0\le j\le L-1$, and $k=\{0,1,2\}$. $k=0$ denote as DPA, $k=1$ is DPB and $k=2$ is DPC. To quantify the influence of each data partition of i-th frame upon the recovery quality within one GoP, we define the distortion change $\Delta D(i,k)$ as the distortion difference between two cases: k-th partition of i-th frame is lost and received without error, and the average distortion change $\overline{\Delta D}(i,k)$ within one GoP is defined as the recovery quality metric or the importance factor. Then $\overline{\Delta D}(i,k)$ is calculated as:

$$\overline{\Delta D}(i,k)=\frac{1}{L}\sum_{j=0}^{L-1}[D(i,j,k)-D_s(j)] \qquad k=\{0,1,2\} \tag{5}$$

where $D(i,j,k)=\begin{cases} D_s(j) & 0\le j\le n-1, j\in N \\ D(j) & n\le j\le L-1, j\in N \end{cases}$.

Substituting $D(i,j,k)$ and (4) into (5), we can represent $\overline{\Delta D}(i,k)$ as:

$$\overline{\Delta D}(i,k)=\frac{1}{LN_f}\sum_{m=i}^{L-1}\sum_{p=1}^{N_f}2[F(m,p)-F_c(m,p)][F_c(m,p)-F_d(m,p)]+[F_c(m,p)-F_d(m,p)]^2 \tag{6}$$

Let $\overline{\Delta D}(i,k,0)$ and $\overline{\Delta D}(i,k,1)$ be the average distortion change of the intra and inter-MBs respectively, caused by k-th partition lost, then (6) can be represented as:

$$\overline{\Delta D}(i,k)=\frac{1}{LN_f}\sum_{m=i}^{L-1}[\Delta D(i,k,0)+\overline{\Delta D}(i,k,1)] \tag{7}$$

As mentioned above, the lost of DPA in i-th frame will not influence i-th frame decoding, but also the following frames after i-th frame within one GoP. Then we recursively calculate the propagated influence of the following frames, from (i+1)-th frame to L-frame within one GoP as:

$$\overline{\Delta D}(i,k)=\begin{cases} \overline{\Delta D}(i,k,0)+\overline{\Delta D}(i,k,1)\,|_{F_d(i,p)=F_d(i-1,p)} & k=0 \\ \overline{\Delta D}(i,k,0)\,|_{F_d(i,p)=F_c(i-1,p)} & k=1 \\ \overline{\Delta D}(i,k,1)\,|_{F_d(i,p)=F_d(i-1,q)} & k=2 \end{cases} \tag{8}$$

$$\overline{\Delta D}(i+1,k,0)+\overline{\Delta D}(i+1,k,1)=\overline{\Delta D}(i,k,1)\,|_{F_d(i+1,m)=F_d(i,m)+\hat{E}(i+1,m)} \qquad k=\{0,1,2\} \tag{9}$$

Where $F_d(i+1,m)$ denotes the predictive value of m-th pixel in $(i+1)$-th frame, $\hat{E}(i+1,m)$ denotes the corresponding difference information of m-th pixel. From (8) and (9), using Equation (7), we can calculate the average distortion change within one GoP caused by DPA, DPB or DPC loss respectively.

According to the calculated average distortion change $\overline{\Delta D(i,k)}$, the important factor denoted as IM of each data partition can be categorized to IM_H, IM_M and IM_L as:

$$\begin{cases} IM\_H: & \overline{\Delta D(i,k)} \geq D_1 \\ IM\_M: & D_2 \leq \overline{\Delta D(i,k)} \leq D_1 \\ IM\_L: & \overline{\Delta D(i,k)} < D_2 \end{cases} \tag{10}$$

Then the proposed mapping scheme according to Equation (10) is described as **Table 2:**

Table 2. Proposed cross-layer mapping scheme

Access Categories	Video slice types
AC_3	IDR, IM_H
AC_2	IM_M
AC_1	IM_L
AC_0	Background

3. Dynamic Scheduling Scheme based on Importance Factors

To further utilize the IEEE 802.11e EDCA queues, we focus on the queues' status. As we known, each station provides prioritization through four access categories AC0~3, and each AC has its own transmission queue and its own QoS parameters and backoff counter. A collision within a station is handled virtually, whereby the frame from the highest priority queue involved in the collision is chosen and transmitted to the access medium. This mechanism is known as virtual collision.

EDCA also allows stations to transmit multiple frames without contending again, known as contention free bursting (CFB). CFB is limited by the TXOP limit specified for each service class. Longer limit means that the service class can transmit more frames; hence, it receives better QoS. The order in which the slice units are sent is constant. The first slice units transmitted contain the PSC information, which includes some parameters set related to the encoder configuration and relevant for all pictures in the video sequence. The next slice units transmitted contain the IDR picture. Since IDR frames may contain only I slices without data partitioning, they are usually sent at the start of video sequences (just after the PSC). The slice units following the IDR frames contain one of the three partitions (DPA, DPB, or DPC). In this paper, we simulate the transmission of the H.264 video packets relies on data partition using the static mapping scheme as **Table 1**, and the queue schedule is depicted in **Fig.1**.

As shown in **Fig.1**, parameter sets (i.e. NVB) include SPS (sequence parameter set) and PPS (picture parameter set). The NVB is the highest important information mapped to the highest-priority AC3, so it is scheduled firstly; IDR and DPA information are mapped to AC2, and scheduled secondly; finally DPB and DPC of P frame are scheduled. In this static mapping scheme, video packets are queued into different AC queues, and the high priority queue is not be fully utilized.

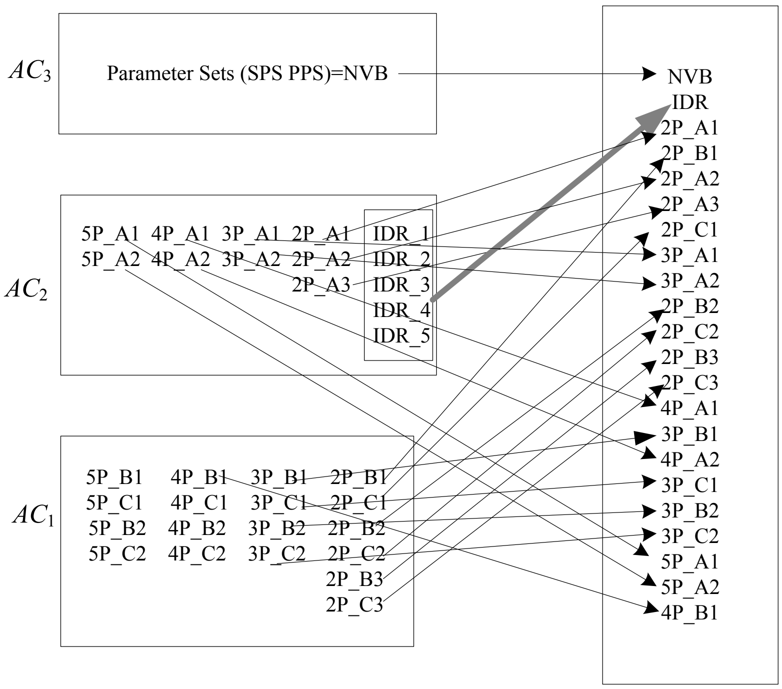

Fig. 1. 802.11e scheduling

To tradeoff the importance factor of video packet and queue length for scheduling, we calculate each queue's average arrival rate and service rate. Firstly, at the sender for each queue $AC_{0\sim3}$, let $\mu_{0\sim3}$ denote the queue average service rate, $\lambda_{0\sim3}$ denote the average data packets arrival rate, then the average service time for each packet is $1/\mu_{0\sim3}$, and the average arriving slot is $1/\lambda_{0\sim3}$, the average queue utilization ratio is $\rho_{0\sim3}=\lambda_{0\sim3}/\mu_{0\sim3}$. When $\rho_{0\sim3}\leq1$, the average arrival rate to all queues is smaller than the average service rate that can be provided to them, therefore the packet can be transmitted in time; otherwise when $\rho_{0\sim3}>1$, the packet must be wait in the queue for transmitting.

Let t_0 denote the time start point, the arriving packets number at $t_1,\ldots, t_k,\ldots$ are $R_{i,1}, \ldots, R_{i,k},\ldots$, and the delivered packets number are $T_{i,1},\ldots,T_{i,k},\ldots$ respectively. The queue's idle time are denoted as $d_{i,1},\ldots,d_{i,k},\ldots$, then the delivered packets number at t_k is $T_k=\sum_{i=0}^{3}\sum_{j=1}^{k}T_{i,j}$, the total arrival packet number is $R_k=\sum_{i=0}^{3}\sum_{j=1}^{k}R_{i,j}$, and the total idle time is $d_k=\sum_{i=0}^{3}\sum_{j=1}^{k}d_{i,j}$. The service rate and arrival ratio for each queue are time-variable, so the α-weighted average sum of μ_i and λ_i which denoted as $\mu_{i,k}$ and $\lambda_{i,k}$ are:

$$\begin{cases} \mu_{i,k}=\alpha\cdot\dfrac{T_k}{\Delta T-d_k}+(1-\alpha)\cdot\dfrac{T_{k-1}}{(k-1)\cdot\Delta T-d_{k-1}} \\ \lambda_{i,k}=\alpha\cdot\dfrac{R_k}{\Delta T}+(1-\alpha)\cdot\dfrac{R_{k-1}}{(k-1)\cdot\Delta T} \end{cases} \quad \alpha\in[0,1] \tag{11}$$

As previously stated, if the average arrival rate $\lambda_{i,k}$ is equal or lower than $\mu_{i,k}$, the packet in this queue can be transmitted timely. According to the mapping scheme shown in Table 2, the highest important video packets are mapped to the highest priority access category AC3, the middle important video packets are mapped to AC2, and the lowest important video packets are mapped to AC1. When the low priority queue is scheduling, the low important packets can "borrow" the higher priority queue's resource if it has idle resource. The available "borrowed" resource is given by

$$\overline{\lambda}_{i,k} = \lfloor \mu_{i-1,k} - \lambda_{i-1,k} \rfloor \tag{12}$$

As the above analysis, on the one hand, different partition types has unequal importance at the application layer; on the other hand, 802.11e can support different QoS requirement for unequal important information at MAC layer, so the video packets can be flexible scheduling. Firstly, the system periodically updates the resource available for each queue. When the video packets are to be send, the important factors of each packet are marked by (10) within one GoP. Then according to the important factor, the video packets are mapped to different queue for transmission.

The specific algorithm is as follows.

1) Initialization: set the time start point t_0, each queue's initial available resource $\lambda_{i,k}$=1;

2) Set time interval= ΔT, calculate the average service rate and average arrival rate of each queue according to (11), calculate the available "borrowed" resource $\overline{\lambda}_{i,k}$ according to (12);

3) Calculate the distortion due to the lost of each data partition within one GoP, categorize the important factor denoted as IM of each data partition according to (10);

4) Schedule video packets to queue AC_3~AC_1;

5) Go back to step 2.

4. Simulation Results and Analysis

In order to evaluate the advantage of the proposed scheme, experiments have been carried out to verify the performance of the proposed algorithm. The wireless network simulation is carried out in Network Simulator-2 (NS-2). For the wireless channel, two-ray ground propagation model is used, and the maximum queue length is 50. The scheduling algortihms described in Sec. 3 have been added to NS-2. The video codec is implemented based on H.264 reference software JM10.2 [14]. The video test sequence "foreman", which contains of 300 CIF frames, is encoded using only I and P frames (each GoP is structured as one I every 16 frames) at 30fps.

The maximum UDP packet size is at 1024Bytes. We include one access point (AP) and five wireless stations sta0~4. The 802.11e MAC parameters for simulations are depicted in **Table 3**.

We simulate a unicast H.264 video transmission utilizing a Basic Service Set (BSS) at 1024Mbps. The video frames are then encapsulated into RTP packets using a simple packetization scheme (one frame one packet). The size of each RTP packet is maximally bounded to 1024Bytes. Additionally, the video server generates back ground traffic (300Kbps) using constant bit rate (CBR) over UDP to increase the virtual collisions. The average distortion of each partition is calculated off-line, and the results are stored in one data file ready for the NS-2 module calling.

Table 3. 802.11e MAC parameters

Access Category	AIFS(*us*)	CW_{min}	CW_{max}	Queue Length	Max Retry Limit
AC_3	50	7	15	50	8
AC_2	50	15	31	50	8
AC_1	50	31	1023	50	4
AC_0	70	31	1023	50	4

The objective function is the reconstructed video quality (the average PSNR of the decoded video sequence). The experimental results shown in **Table 4** depict the packet loss rate (PLR) and reconstruction quality in PSNR when using dynamic mapping algorithm vs. the default EDCA mapping algorithm and the algorithm in Ref. [5] and the proposed algorithm. It can be seen that the default EDCA does not distinguish the importance of each video packets, and all video packets are queued to AC2. Both the algorithm in Ref. [5] and the proposed algorithm differential the importance of the video information, so the PLR of IDR and DPA is zero which is protected well. The encoder's QP=27, the DPB's loss rates are 11.49% and 8.32% respectively when using the proposed dynamic mapping algorithm vs. the mapping algorithm in Ref. [5]; the DPC's loss rate are 18.85% and 16.35%

respectively. The encoder's QP=30, the DPB's loss rates are 11.63% and 9.27% respectively when using the proposed dynamic mapping algorithm vs. the mapping algorithm in Ref. [5]; the DPC's loss rate are 19.04% and 17.61% respectively. The proposed algorithm outperforms the other two algorithms in PLR and the reconstructed quality in PSNR.

Table 4. Comparison of the performance

Video sequence	Performance metric	Default EDCA	Reference[5]		The proposed	
foreman (*QP*=27)	PLR	/	IDR	0.0000	IDR	0.0000
		/	DPA	0.0000	DPA	0.0000
		/	DPB	0.1149	DPB	0.0832
		/	DPC	0.1885	DPC	0.1635
	Average PLR	0.0693	0.0541		0.0273	
	Average PSNR(dB)	35.71	36.42		37.22	
foreman (*QP*=30)	PLR	/	IDR	0.0000	IDR	0.0000
		/	DPA	0.0000	DPA	0.0000
		/	DPB	0.1163	DPB	0.0927
		/	DPC	0.1904	DPC	0.1761
	Average PLR	0.0736	0.0553		0.0311	
	Average PSNR(dB)	33.43	34.15		35.48	

Fig. 1 (a) and (b) represent a final decoded frame when using EDCA, static EDCA and the proposed algorithm, respectively. It is readily realized that the proposed algorithm outperforms both EDCA and static EDCA of Ref. [5].

(a) decoded frame #28, #55, and #88 of Ref. [5]

(b) decoded frame #28, #55, and #88 of the proposed algorithm

Fig. 2. decoded frame of *foreman* sequence

5. Conclusions

As it is important to develop mechanisms that will optimize every aspect of the transmission system and minimize the distortion imposed by channel limitations, this paper proposes a dynamic packet scheduling scheme based on the importance factor of each data partition and the queue length. The novelty of the proposed algorithm is based on prioritization mechanism that categorizes the data partition to different priority classes according to the calculated distortion within one GoP. Then the dynamic scheduling scheme based on EDCA has been configured to differentiate the transmitted packets according to their distortion impact and the queue length. Significant video packets are appointed to high priority access categories while least significant packets to lower categories. Simulation results have shown that the proposed scheme improves the received video quality in terms of PSNR by 1dB, compared with the existing EDCA static mapping scheme.

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