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A novel scheduling algorithm to enhance video quality transmission over LTE networks

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Abstract

Although the popularity of video application has increased exponentially over the past decades. However transmitting such videos over long-Term Evaluation networks (LTE) is considered a difficult task. This is usually attributed to several factors such as the burst of the video content, time-varying channel state and the availability of bandwidth. Numerous downlink scheduling algorithms were proposed lately, most of which aims to improve the quality of service (QoS) by providing lower packet loss ratio and packet delay as well as higher throughput However, excellent video quality for users is not always guaranteed by good quality of service of a network. Therefore, and in order to enhance the quality of service of video delivery in the downlink of LTE network, a novel resource scheduling algorithm was proposed in this paper. The proposed algorithm simultaneously considers the video quality, the throughput and the constrains of (QoS). Based on the simulation results, it can be stated that the proposed algorithm Provides better video quality than other existing algorithms.

Keywords: video quality; LTE networks; resource scheduling algorithm.

1 Introduction

Developing the next generation of wireless communication networks depends mainly on the development of LTE networks. Such networks provide better performance when compared with other systems [1]. It is known that LTE networks utilize SC-FDMA for the uplink, while for the downlink, OFDMA Is used. The available spectrum consists of a number of RBs which are considered as the smallest Resource schedule element [2]. Communication traffic is usually divided into two categories: real-time and non-real-time services. Each category has a different QoS requirements. For instant, real-time services such as voice of IP and video applications cannot be delayed, while non-real-time services such as BE and CBR demands a small packet loss ratio[3].
The MAC layer is usually the place where resource scheduling occurs in LTE networks. Allocating resources efficiently in LTE networks is very important to satisfy multiple users with different QoS requirements. Transmitting videos using LTE networks is considered a difficult task. This is usually related to limited typical characteristics of a video, time-varying channels state and limited available bandwidth. Enhancing LTE networks performance through improving the PLR, throughput and packet delay is the main focus of previous resource scheduler[3–7]. However, almost most of these schedulers don't take into consideration the quality of the received video. In fact, the quality of a video cannot always be guaranteed by good network performance. This is related to the fact that good quality of a video is directly influenced by the number of received packets in addition to network performance.
However, the importance of packets is not being thoroughly considered by previous scheduling algorithms when selecting pockets to transmit. In other words, existing scheduling algorithms cannot guarantee a good video quality because they do not differentiate between pockets based on their importance to video quality. Therefore, and in order to enhance the quality of service of video delivery in the downlink of LTE network, a novel resource scheduling algorithm was proposed in this paper. The proposed algorithm simultaneously considers the video quality, the throughput and the constrains of (QoS). The proposed algorithm redistribute the available resources to packets that are more important to the quality of videos.

2 Previous work

First, all flows that can be scheduled are chosen by the scheduler, then the matric for these flows is computed by the controller at everything transmission time interval (TTI) [4]. The matric of the $i-th$ flow fat the $j-th$ RB is usually indicated by $w_{i,j}$. The flow with the maximum $w_{i,j}$ is assigned the $j-th$ RB by the controller. The $w_{i,j}$ is usually calculated differently based on the algorithm used as follows:

2.1 PE scheduler [4][5]

The Proportional Fair (PF) scheduler is a scheduling algorithm that aims increase the system throughput and to bring fairness among all users. This algorithm is usually appropriate for non-real time services. In this algorithm, the RBs are located by the scheduler taking into consideration the preceding average data rate and the current channel conditions. Thus, the $w_{i,j}$ is calculated as follows:

$$w_{i,j} = \frac{r_{i,j}}{R_i} \qquad (1)$$

where $r_{i,j}$ represents the instantaneous data rate if the $j-th$ RB is given at $the\ i-th$ flow. It is important to note that the MAC module determines the $r_{i,j}$ while taking into consideration the CQI feedback received from the user. While, the estimated mean data rate of $i-th$ flow is denoted as R_i

2.2 M-LWDF Scheduler [4]

The M-LWDF scheduling algorithm is similar to the (PF) scheduling algorithm. In addition, it also takes into account the packet delay as well as giving priority the matric of real-time services. Based on this and for real-time services, the $w_{i,j}$ is determined as follows:

$$w_{i,j} = \alpha_i . D_{HOL,i} . \frac{r_{i,j}}{R_i} \qquad (2)$$

Where $D_{HOL,i}$ represents delay of primal package to be delivered in the i-th's queue, while α_i is determined using the following expression:

$$\alpha_i = -\frac{\log \delta_i}{\tau_i} \qquad (3)$$

Where τ_i denotes for the threshold of $i-th$ flow's packet delay, while δ_i represents the maximum probability of $D_{HOL,i}$ exceeding τ_i. On the other hand, the M-LWDF Scheduler calculates $w_{i,j}$ using Eq. (1) for non- real-time applications.

2.3 EXP/PF Scheduler [4]

EXP/PF Scheduler was also designed to facilitate real-time services. Therefore, and based on this scheduler, $w_{i,j}$ is determined as follows:

$$w_{i,j} = \exp\left(\frac{\alpha_i . D_{HOL,i} - Y}{1+\sqrt{Y}}\right) . \frac{r_{i,j}}{R_i} \qquad (4)$$

Where Y is determined as follows:

$$Y = \frac{1}{M}\sum_{i=1}^{M} \alpha_i . D_{HOL,i} \qquad (5)$$

Where M represents the number of real time users. Similar to the other schedulers, and for non-real time services, $w_{i,j}$ can be calculated using E1. (!).

Due to the importance of resource scheduling in LTE networks, numerous scheduling algorithms have been proposed by many researchers recently, which in most cases try to improve the overall network performance. For example, Nasralla et al [3] tried to improve the QoS of the network by proposing a scheduling algorithm for different traffic classes. Furthermore, Sandrasegaran et a al [6] designed an algorithm that makes optimized choices since it takes into consideration both; the downlink channel state and the delay. In addition, and in order to achieve high transmission efficiency in LTE networks, Wang and Hsieh [7] developed a service differential scheduling algorithm that considers the difference in flows.

On the other hand, many researchers have also tried to improve the quality of received videos in LTE networks by proposing a number of algorithms for this purpose. For instance, Luo et al [1] tried to improve the quality of videos by proposing an algorithm that simultaneously takes into account that fairness, application QoS constraints and system throughput. In addition, Lai et al [8] proposed a scheduling algorithm that takes into consideration the importance of packets on the received video quality. While, Cheng and Mohapatra [9] tried to improve the quality of videos within the delay constraints. Furthermore, Ju et al [10] studied the simultaneous influence of the physical layer, that MAC layer and the application layer on the quality of videos and tried to improve it. Also, Triki et al [11] employed the characteristics of prefetching process as well as users information to propose a novel scheduling algorithm that provides better video quality

Furthermore, Tham et al [12] utilized the OFDMA System to propose a two-level scheduling algorithm for video transmission in LTE networks. Karachontzitis et al [13] divided the pockets into two categories; I packets and P packets, after which they designed a scheduling algorithm to transmit the selected packet. Finally, Nasimi et al [14] developed an optimized algorithm that yields effective resource scheduling for users with different applications.

3 Proposed algorithm

As discussed earlier, the received video quality in LTE network is not being considered by many of the previous algorithms, which only try to improve the performance of the network. Videos are usually transmitted in the form of encoded frames.

Generally, there are three types of these frames; I frame P, frame and B frame. For I frames, the encoding and decoding process is done without out the need to other frames. While for P frames, the production process must refer to the preceding I frame or P frame. As for B frames, the production process must refer to subsequent and former P frames and I frames. Regardless, and when classifying frames based on importance, the quality of videos is more dependent on I frames [15]. Usually, the process of video transmission includes dividing the frames into packets. This means that packets with I frames are considered the most important amongst other packets. However, and although many of the previous algorithms enhance the overall system performance, still and since they do not distinguish packets based on frames, a satisfactory video quality is not always guaranteed.
Therefore, good video quality can be achieved, if the scheduling algorithm considers the Importance of packets. The importance of frames in a scheduling algorithm can be considered using a number of different methods [15–17]. Jung et al [17] used the structure of GOP to distinguish between frames and to show the importance of each different frame. This method will be used in this research. Fig. 1 illustrates the structure of open GOP

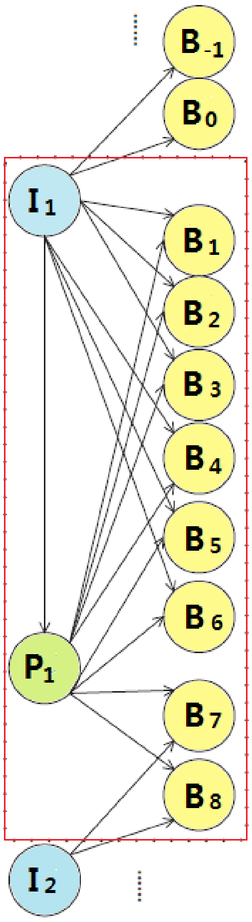

Fig. 1. GOP open structure

The rectangular shown in Fig. 1 represents a GOP structure. As shown, a GOP comprises of a P frame, an I frame and eight B frames. The transmission sequence of the frames is shown by the subscripts. The relationship between the frames is indicated by the arrows. The idea behind the open GOP is that it allows the interaction between the frames of subsequent GOPs. For instance, and as shown in fig. 1, it is possible for B frames from a GOP to refer to an I frame in the following GOP. The influence of losing one frame shall influence other frames. For example; losing I_1 frame influences itself, B_{-1} to B_8 and P_1 frames. On the other hand, losing P_1 frame only influences itself as well as B_1 to B_8 frames. Therefore, it can be concluded the importance of a frame can be quantified by the number of frames that shall be effected if this frame is lost. Based on this, Fig. 2 shows the GOP with the importance of each frame. The number above each frame represents its importance.

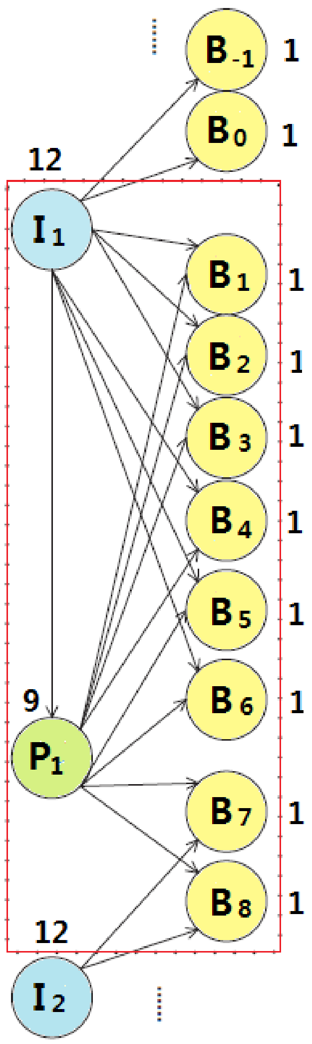

Fig. 2. The importance of each frame

The number above each frame represents its importance. For example, I_1 has an importance number of 12 since it influences all the frames in a GOP as well as tow frame from the subsequent GOP. On the other hand, P_1 frame and B frames have the importance of 9 and 1, respectively.

Based on the above and taking into account the importance of packets, the proposed scheduling algorithm will be introduced here. Also, we can conclude that the importance of frames is predetermined by the structure of the GOP. Furthermore, the importance of a frame determines the importance of its packets. In addition; all its packets of a frame shall have the same importance. The importance of a packet to be scheduled of the $i-th$ flow shall be denoted as I_i. The matric will be higher as I_i becomes larger. This happens if the packet belongs to I frame. The matric is determined as follows:

$$w_{i,j} = I_i.\frac{D_{HOL,i}}{\tau_i}.\frac{r_{i,j}}{R_i} \quad (2)$$

The proposed algorithm simultaneously considers the video quality, the throughput and the constrains of (QoS). Furthermore, unlike the aforementioned EXP/PF and M-LWDF algorithms, and in order to provide a better video quality, the proposed algorithm takes into account the importance of packets by giving them higher matric.

4 Performance evaluation

Herein, the proposed scheduling algorithm will be based on LWIF (Largest Weight Importance First) algorithm. The simulation environment will be illustrated first. Then, the performance results of LWIF with respect to EXP/PF and M-LWDF Will be discussed

4.1 Simulation environment

It is important to note that other background services will not be considered herein. This is because we are only concerned with the quality of video transmission. In this simulation scenario, a single cell with a radius of 1 km will be utilized. The base station will be located at the center of the cell. Users speed shall be taken as 3 km per hour and they will be uniformly distributed within the cell. Also. A resolution of 176*144 of will be adopted for the tested videos. Furthermore, the videos shall be encrypted with a frame rate of 20 frames/s using JM 19.0 reference software. The open-source simulation platform LTE-Sim proposed by Girici et al [5] will be utilized herein to conform the performance of LWIF. Table 1 illustrates all the important parameters of the test scenario.

Table 1. Parameters of the simulation

Parameter	Value
Cell radius	1 km
Carrier frequency	2 GHz
RB number	50
Bandwidth	10 MHz
Modulation scheme	QPSK, 16 QAM, 64 QAM
User speed	3 km/hr
Video traffic	265 kbps
Flow duration	40 s
Max delay	0.1 s
Simulation time	46 s
GOP Structure	IBBBB BBPBB (10 frames)

4.2 Results and discussion

The packet loss ratio of I frames and the system are illustrated in fig.3 and fig.4, respectively. As shown in Fig.3, as the number of users increases, the packet loss ratio also significantly increases and vice versa. The figure also shows that the packet loss ratio of the three algorithms is nearly the same when the number of users in the cell is below 35. However, differences in packet loss ratio between the three algorithms can be seen when the number of users exceeds 35. Furthermore, and since it allocates resources to packets belonging to I frames, the LWIF algorithm shows the lowest packet loss ratio amongst the other algorithms. As for the packet loss ratio of the system. Fig.4 illustrates that when the number of users below 35, the behavior of all three algorithms is approximately the same. However, as the number of users increases beyond 40, a difference starts to appear. Furthermore, the LWIF algorithm also shows the lowest packet loss ratio amongst the other algorithms.

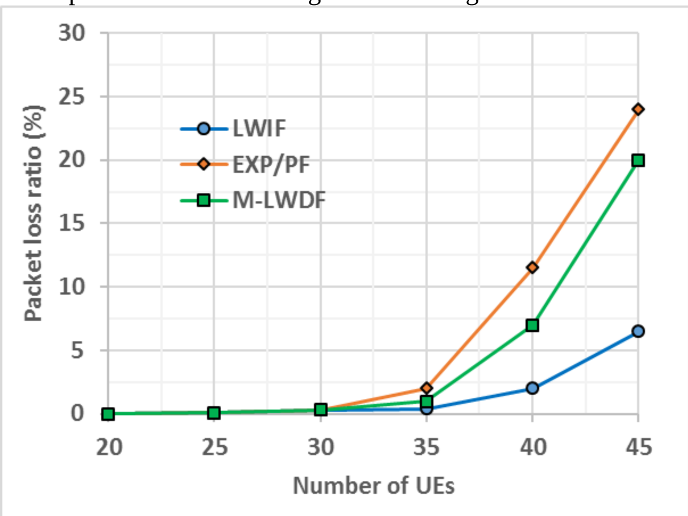

Fig.3. I frames packet loss ratio

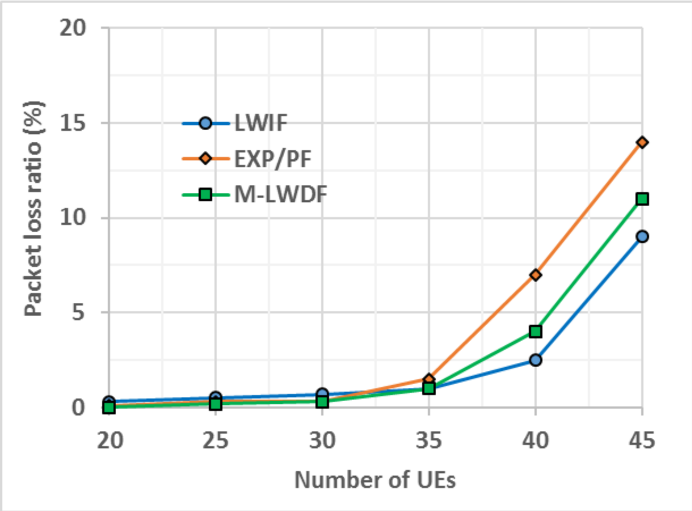

Fig. 4. System packet loss ratio

The performance of the different algorithms in terms of the throughput is illustrated in Fig.5 and Fig. 6. According to Fig. 5 the throughput of I frame for the three algorithms is approximately the same when the number of users is below 35. However, as the number of users increase beyond 35, the behaviour of the three algorithms start to differ. The figure also shows that the LWIF algorithm yields higher throughput than the other algorithms. As for system throughput, similar behaviour to the I frame throughput can also be observed where the LWIF algorithm seems to produce the highest system throughput.

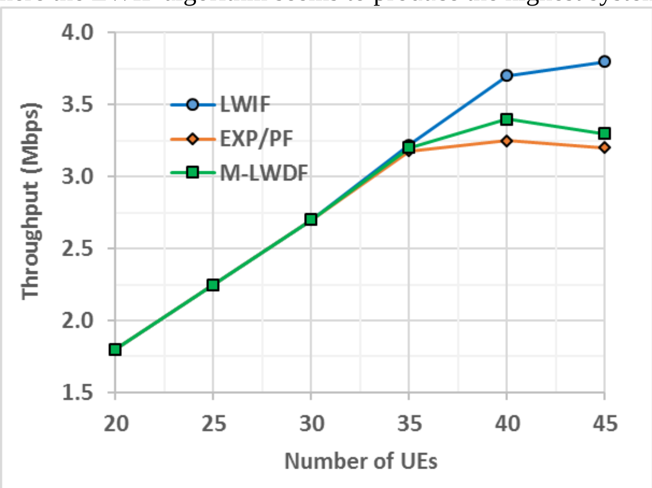

Fig. 5. I frame throughput

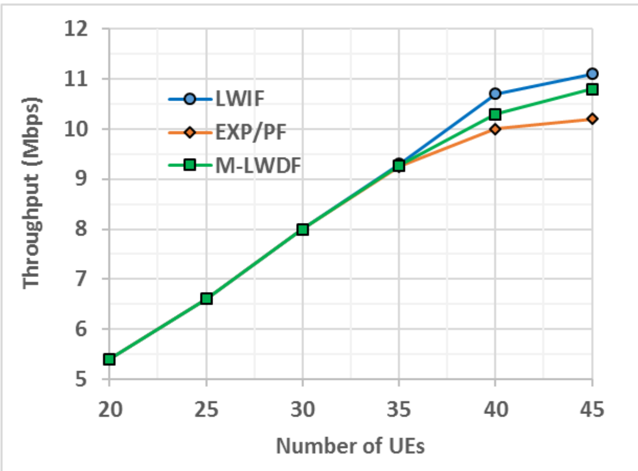

Fig. 6. System throughput

A comparison between the three algorithms used herein regarding the Peak Signal-to-Noise Ratio (PSNR) is given in Fig.7. In general, It can be seen that the (PSNR) decreases as the number of users increases. Based on this figure we can also observe that for a number of users below 30, all the three algorithms show similar (PSNR). However, as the number of users rises above 30, a difference in performance between the three algorithms starts to appear. The LWIF seems to yield the lowest (PSNR) as the number of users increases which means better received video quality. This behaviour can be explained by the fact that light system load is expected when the cell has a few number of users. This means lower (PSNR) and thus higher received video quality. However, when the number of users within the cell increases, the system load becomes very high, and more packets will be lost, thus reducing the quality of the received videos. On the other hand, and because the LWIF algorithm has a low packet loss ratio since It relocates resources to packets belonging to the I frame, It yields a better received video quality then the other algorithms.

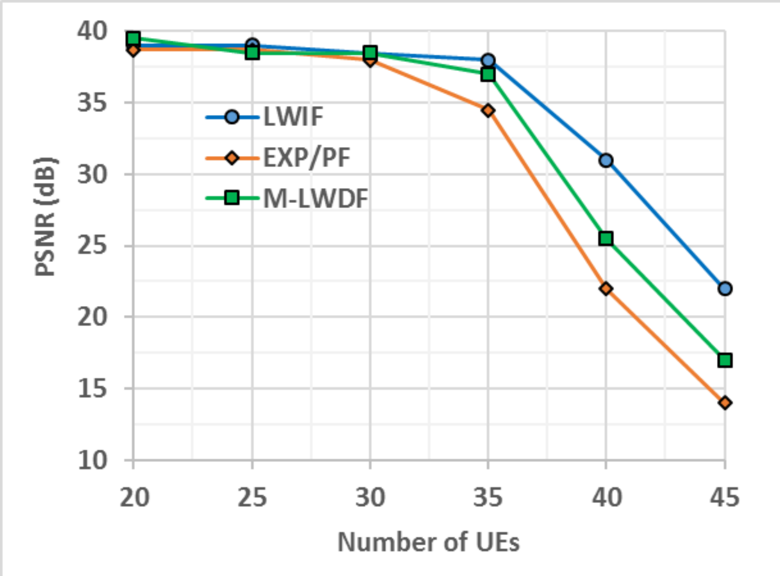

Fig. 7. Comparison of Peak Signal-to-Noise Ratio (PSNR)

5 Conclusions

This paper presents a resource scheduling algorithm that takes into account the quality of received videos over LTE networks. Furthermore, the proposed algorithm simultaneously considers the video quality, the throughput and the constrains of (QoS). To improve the quality of the received videos, the proposed algorithm allocates resources to the packets that has the most influence on the quality of the received videos. Based on simulation results, it can be concluded that the proposed algorithm has yielded a significant improvement to the quality of the received videos, as well as the overall system performance.

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