Exponential MLWDF (EXP-MLWDF) Downlink Scheduling Algorithm Evaluated in LTE for High Mobility and Dense Area Scenario

Ismail Angri[1], Mohammed Mahfoudi[2], Abdellah Najid[3], Moulhime El Bekkali[4]
[1,3]Telecommunication Systems, Networks and Services laboratory - National Institute of Posts and Telecommunications (INPT) Rabat, Morocco
[2,4]Transmission and Data Processing Laboratory (LTTI) - Superior School of Technology - Fez, Morocco

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ABSTRACT

Nowadays, with the advent of smartphones, most of people started to make voice and video conference calls continuously even in a high mobility scenario, the bandwidth requirements have increased considerably, which can cause network congestion phenomena. To avoid network congestion problems and to support high mobility scenario, 3GPP has developed a new cellular standard based packet switching, termed LTE (Long Term Evolution). The purpose of this paper is to evaluate the performance of the new proposed algorithm, named Exponential Modified Largest Weighted Delay First 'EXP-MLWDF', for high mobility scenario and with the presence of a large number of active users, in comparison with the well-known algorithms such as a proportional fair algorithm (PF), Exponential Proportional Fairness (EXP/PF), Logarithm Rule (LOG-Rule), Exponential Rule (EXP-Rule) and Modified Largest Weighted Delay First (MLWDF). The performance evaluation is conducted in terms of system throughput, delay and PLR. Finally, it will be concluded that the proposed scheduler satisfies the quality of service (QoS) requirements of the real-time traffic in terms of packet loss ratio (PLR), average throughput and packet delay. Because of the traffic evolution, some key issues related to scheduling strategies that will be considered in the future requirements are discussed in this article.

Corresponding Author:

Ismail Angri,
Telecommunication Systems, Networks and Services laboratory,
National Institute of Posts and Telecommunications (INPT),
Avenue Allal Elfassi, Rabat, Morocco.
Email: ismail.angri@gmail.com

1. INTRODUCTION

Customer demand for new services in mobile networks, with high quality (QOS) increase from day to day. Due to this exponential increase, operators require a wider bandwidth, high efficiency and low cost [1], [2].

In a dense environment with high-speed UEs, radio resource management is becoming a big problem, so the use of an efficient scheduling algorithm will be mandatory [3].

Several factors influence the QoS of the LTE and LTE-A networks. Among them the transmission channel conditions, the type of services used and the number of radio resources available to each user. The concept of resource block (RB) is that adopted by LTE as a transmission unit. The RB is a block of subcarriers with a number of OFDM symbols, operating in both frequency and time domain [1].

Both TDD and FDD modes are used to operate an LTE network. As can be seen in Figure 1, the LTE frame in the FDD mode has duration of 10 ms, divided into 10 subframes with duration of 1 ms. Each subframe consists of two time slots of 500ns. A number of six or seven OFDM symbols represent a single slot [4].

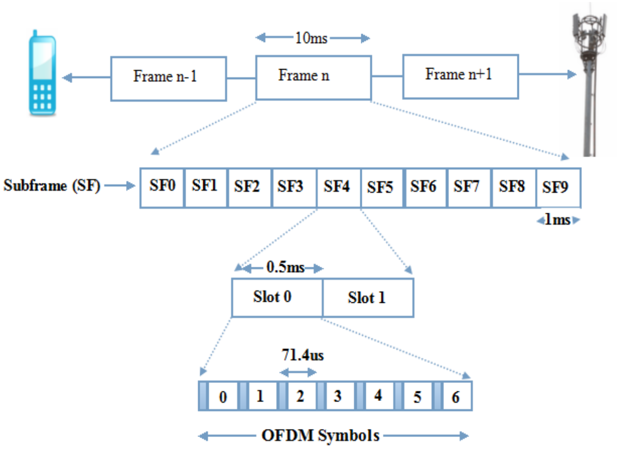

Figure 1. LTE Frame structure [5]

The objectives of LTE are to support high mobility and to avoid network congestion [6]. As in the case of uplinkbands [7], downlink scheduling algorithms must ensure a good sharing of existing radio resources, and especially in the case of real-time traffic (Video and VOIP streams) [8].

The purpose of this paper is to evaluate the performance of the new proposed algorithm in LTE system, named Exponential Modified Largest Weighted Delay First 'EXP-MLWDF', for high mobility scenario, with the presence of a large number of active users.

2. SCHEDULING STRATEGIES

The MAC (Medium Access Control) layer is the responsible layer at the base station of the scheduling process. In LTE, the separation between uplink and downlink scheduling decisions is assured, and the management of both types is independent. A parameter called CQI (Channel Quality Indicator) represents the status of the channel and gives information about its characteristics; this information is used by the scheduler for decision making [9]. At each time period called TTI (Transmission Time Interval), the CQI report is updated [10].

The scheduling strategies in uplink and downlink have been programmed separately in a Multi-cell/multi-user environment in the LTE-sim simulator. These models take into account all the real parameters that influences those decisions such as user mobility, frequency reuse techniques and radio resource management [11].

The new LTE network architecture defined by 3GPP is based on simplicity. The creation of a Full-IP system was made with the aim of improving mainly the throughput and the transmission delay compared to the UMTS networks [12]. A dedicated frequency spectrum for the LTE network can be used to avoid problems of incompatibility with other wireless networks systems [13].

The main protocols configured in the eNb and used in the two levels Control and User Plane are illustrated in Figure 2, in addition to the different functions of the two layers 1 and 2 [14].

The protocol stack for the User Plane consists of multiple sub-layers: PDCP (Packet Data Convergence Protocol) which provides its services to the upper layers, among these services the transfer of user plane data, transfer of control plane data and header compression. RLC (Radio Link Control) used on the radio interface for reliable data transmission. MAC (Media Access Control) which is responsible for the access control to the medium and PHY (the physical layer) which is responsible for the effective transmission of the radio waves [15].

The protocol stack for the control Plane is composed on the PDCP, RLC, MAC, PHY ans RRC sublayers. The scheduling process and the CQI (Channel Quality Indicator) manager that receives the CQI reports (that are very useful for the scheduling decisions) for Downlink traffic are performed by those presented in protocol stack sublayers [16]. The MAC sub layers of the eNb have several objectives. They construct, send, receive and process transport blocks that contain a series of user-plane data from one or more bearers.

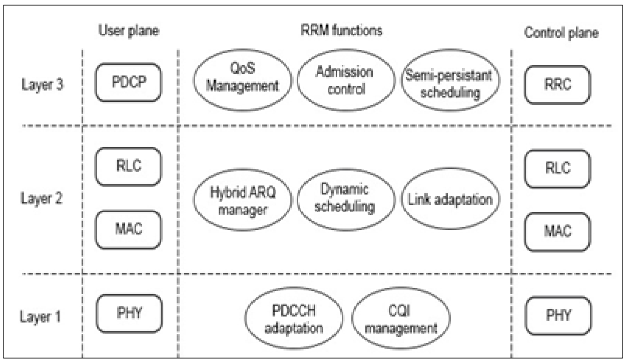

Figure 2. LTE Protocols Stack

In order to optimize the system performance and meet QoS client requirements, radio resources must be assigned to the customer in an efficient manner. And to do this, the MAC scheduler runs the scheduling algorithms that determine how the channels are used in the air interface and that in both downlink and Uplink modes. In Figure 3, a model representation of a simplified packet scheduler in the downlink LTE system is shown.

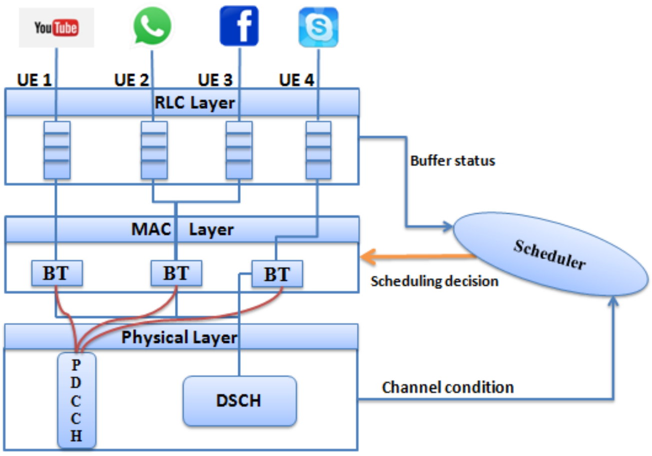

Figure 3. Packet Scheduling Model in LTE System

Different sequences of a specific scheduler are used to calculate the instantaneous metrics assigned to each separated stream. We assume that the metric assigned to stream i on *j-th* sub-channel is defined by *wi,j*. To calculate the metric by each scheduler, two main parameters are mandatory, namely: the available flow rate to the UE on the *j-th* sub-channel and the average transmission rate $\overline{R}_i$ of flow i [17].

In the next equation we give an estimation representation of $\overline{R}_i$. This value is calculated at each TTI using $\overline{R}_i(k-1)$as the average transmission data rate estimated at the *(k-1)-th* TTI and $R_i(k)$ is the rate allocated to *i-th* flow during the *k-th* TTI:

$$\bar{R}_i(k) = 0.8\bar{R}_i(k-1) + 0.2R_i\,(k)\ [17] \qquad (1)$$

In the following, a summary description of three different scheduling algorithms that are used in all simulation scenarios, these are: PF as well as EXP-PF and MLWDF, In addition to other well-known algorithms.

2.1. Proportional fair (PF)

With the main objective of ensuring fairness between the different data streams transmitted to each UE and also to achieve a maximum total network throughput, the PF (Proportional Fair) scheduler was introduced to assign the radio resources to different users and this based on the characteristics of the channel as well as the history of the flows rate of the previous transmissions.

For this scheduler, We can define *ri,j* by taking into consideration the CQI value on the *j-th* sub-channel which is sent by the UE who is intended for *i-th* flow. This parameter is calculated using the AMC module. The metric is then the ratio between the instantaneous flow available for *i-th* flow and the medium flow that was calculated at the moment (k-1) [18], [19].

$$w_{i,j} = \frac{r_{i,j}}{\overline{R_I}} \tag{2}$$

2.2. Exponential proportional fairness (EXP/PF)

To promote the real time traffic, The EXP/PF algorithm was introduced. It requires the not exceeding of a defined delay threshold given the criticality of the real-time RT flows with respect to non-Real time NRT flows.Its main goal is the processing of the multimedia services, especially in an Adaptive Coding & Modulation/Time Division Multiplexing (ACM/TDM) system [20].

For real time flows, the metric is calculated by using the following equations [20]:

$$w_{i,j} = exp\left(\frac{\alpha_i D_{HOL,i} - X}{1+\sqrt{X}}\right)\frac{r_{i,j}}{\overline{R_i}} \tag{3}$$

Where $D_{HOL,i}$ is the Head of line Delay, and X is given by [19]:

$$X = \frac{1}{N_{rt}}\sum_{i=1}^{N_{rt}} \alpha_i D_{HOL,i} \tag{4}$$

With N_{rt} is the number of active real time flows in downlink direction.

2.3. Logarithm rule (LOG-Rule)

To give much more QoS support to the network [9]. The metric for the LOG rule is given as:

$$w_{i,j}^{\text{LOG Rule}} = b_i \log(c + \alpha_i D_{HOL,i})\Gamma_j^i \tag{5}$$

WhereΓ_j^iSignifies the channels spectral efficiency with the *i-th* user at the *j-th* RB, for $1 \leq i \leq N$. However it was found that to get much better performance [15], it’s better to declare the constraints αi, bi, and c as follow:

$$\alpha_i = \left[\frac{5}{(0.99\alpha_i)}\right], b_i = \left[\frac{1}{E(\Gamma^i)}\right], c = 1.1 \tag{6}$$

τ_i in the previous equation represents the packet delay threshold for each RT flow at the moment of scheduling.

2.4. Exponential rule (EXP-Rule)

To be more robust, and to have improvements in delay and throughput [15], The EXP rule scheduler metric is defined as follows [21], [22]:

$$w_{i,j}^{\text{EXP Rule}} = b_i \exp\left(\frac{\alpha_i D_{HOL,i}}{c + \sqrt{\left(\frac{1}{N_{rt}}\right)\sum_i D_{HOL,i}}}\right)\Gamma_j^i \tag{7}$$

Where the following constraint's values are the same as Log Rule's parameters:

$$\alpha_i \in \left[\frac{5}{(0.99\tau_i)}, \frac{10}{(0.99\tau_i)}\right], b_i = \left[\frac{1}{E(\Gamma^i)}\right], c = 1 \tag{8}$$

2.5. Modified largest weighted delay first (MLWDF)

The classification of the streams according to their type (Real-time or not Real-time) is used by this algorithm to promote the real time flows which have the best propagation conditions and the highest time, in order to be transmitted at first in the canal. The M-LWDF metric is defined by [17]:

$$w_{i,j} = \alpha_i D_{HOL,i} \frac{r_{i,j}}{\bar{R}_i} \tag{9}$$

Where $r_{i,j}$ and $\bar{R}_i$ have the same signification as cited in Nomenclature chapter and αi is given by:

$$\alpha_i = -\frac{\log(\delta_i)}{\tau_i} \tag{10}$$

αi is defined with considering τ as a time threshold package and δ as the maximum probability that the delay $D_{HOL,i}$ exceeds the threshold time [16].

3. THE PROPOSED EXPONENTIAL MLWDF (EXP-MLWDF)

The channel conditions play an important role in wireless communication systems to maximize the throughput obtained by the user. We define *ri,j* as the current data rate that could be used by the *i-th* user on the *j-th* sub-channel at time *t*. Thus, users who have a better channel condition will get higher priority to send their packages. So we can propose the metric as shown below:

$$w_{i,j} = r_{i,j} \tag{11}$$

Therefore, we need to consider the users who don't have a good channel conditions. Thus, users will be punished. Hence the necessity to consider the estimated average transmission data rate at the *(k-1)-th* Transmission Time Interval (TTI). So the new metric must be:

$$w_{i,j} = \frac{r_{i,j}}{\bar{R}_i} \tag{12}$$

For each real-time data streams and similar to MLWDF algorithm, we define α_i according to the Equation (10).

From the QoS information's sent to the eNodeB by the users we can get the Head of line Delay $D_{HOL,i}$ for the *i-th* user, which is an important parameter that we must take in consideration. Normally to further the users who don't have good channel conditions, the smaller the difference between the deadline delay and the time spend in queue $D_{HOL,i}$, the higher metric must be. This is explained by the term:

$$\frac{\tau_i}{(\tau_i - D_{HOL,i})} \tag{13}$$

If we applied the exponential function to the previous term, the critical conditions can be served:

$$\exp\left(\frac{\tau_i}{(\tau_i - D_{HOL,i})}\right) \tag{14}$$

When we combined all the cited parameters, we obtained the proposed algorithm as defined below:

$$w_{i,j} = \frac{(\alpha_i * r_{i,j})}{\bar{R}_i} \exp\left(\frac{\tau_i}{(\tau_i - D_{HOL,i})}\right) \tag{15}$$

4. SIMULATION, RESULTS AND DISCUSSION

The different performances of our proposed algorithm are tested in comparison with the other algorithms already existing. To do that, an open source tool named LTE-Sim was used. It is a simulator based on different classes programmed in C++ to represent the models of all the techniques and components of a 4G network layers and sublayers. The different classes can be extended to meet the needs of each user [23].

The various aspects necessary for a real simulation of UpLink and DownLink scheduling strategies in a Multi-Cell/Multi-User environment have been well integrated into the software.

Before starting the simulation in the chosen tool, the definition of a real scenario is mandatory; its role is to fix the different parameters and characteristics to simulate. For example, in our case, a Single Cell with Interference scenario was adopted. Our environment contains 3 cells, each one have a radius of 1 Km. Users (which have a defined number between 10 and 100) moves randomly between the cells using the RANDOM_WALK mobility model with a high speed of 120 km/h. They are uniformly distributed in the three cells. The simulation results were established for the period of which the UEs move inside the cell. Each user receives an H.264 Video stream, a VoIP stream, and BE flows modeled by Infinite Buffer.

The purpose of this simulation is to evaluate the performance of our new proposed scheduling algorithm in LTE Network, for this we compared its performances with the well-known algorithms such as the PF, M-LWDF and EXP-PF schedulers [21], by measuring packet latency (the delay), Packet Loss Ratio (PLR) and packet throughput. The simulation parameters are illustrated in the following Table 1.

Table 1. Simulation Parameters

Parameters	Value
Simulation duration	100 s
Flows duration	120 s
Frame structure	FDD
Mobile speed	120 Km/h
Radius	1 km
Bandwidth	20 MHz
Slot duration	0.5 s
Scheduling time (TTI duration)	1 ms
Number of Resource Blocks (RBs)	100
Max delay	0.1 s
Video bit-rate	242 kbps
VoIP bit-rate	8.4 kbps
Minimum number of users	10
Maximum number of users	100
Interval between users	5
Simulation duration	100 s

4.1. The measurement of packet latency (delay)

Latency has a most noticeable influence on Network performance. Especially for conversational services, such as VoIP and Video Flows that require low latency [22]. Other services that benefit from low delay are gaming and applications with extensive handshaking, such as emails.

Latency and TTI (Transmission Time Interval) are two interrelated parameters. It is difficult to improve one of them without the degradation of the other.

4.1.1. The VOIP flows

The Figure 4 demonstrates that the proposed algorithm presents a very low delay and its stable even the increase of the user’s number. The same behavior is observed for EXP-PF, EXP-Rule, LOG-Rule end MLWDF algorithms. For the PF algorithm, the delay shows highest value compared with the other algorithms by the increase of users starting with 45 UE’s.

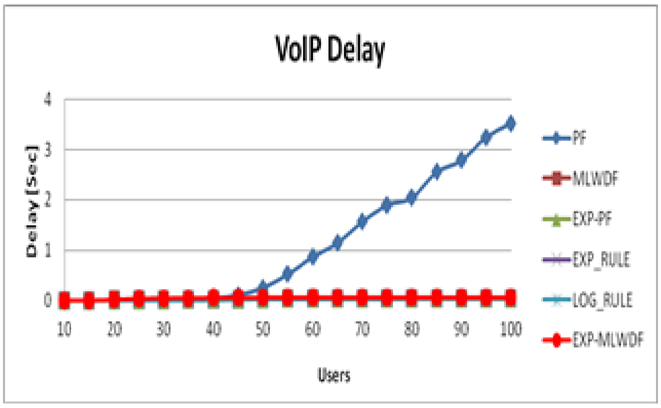

Figure 4. The Delay for VOIP Flows

4.1.2. For video flows

As we can see in Figure 5, The Video delay is very low for the EXP-MLWDF, our proposed scheduling algorithm, even the increment of user's number, comparing with PF and algorithms which presents a higher delay that increase exponentially with the increase of the user's number to get for 100 UE's 15 s which is not acceptable by the norms. The other algorithms present approximately the same behavior as our proposed algorithm.

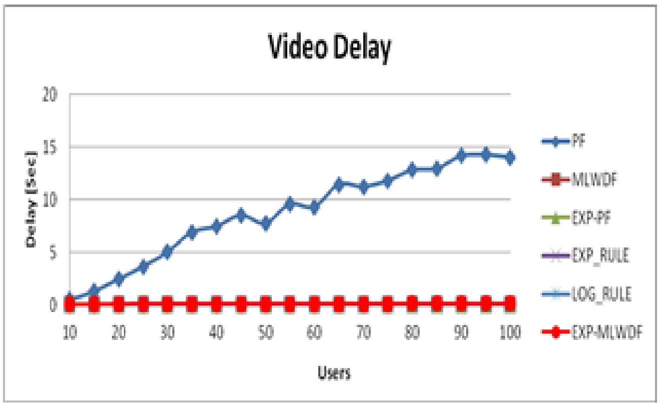

Figure 5. The Delay for Video Flows

4.2. The measurement of packet loss ratio (PLR)

The improvement of PLR estimation is a critical issue, because Packet Loss Ratio has a big effect on the network performance, especially when dealing with the real-time traffic such as VOIP and Video Flows [2].

4.2.1. The VOIP flows

The Packet Loss Ratio has given in Figure 6, it shows that our scheduling algorithm 'EXP-MLWDF' presents a very low packet loss ratio that stay negligible until 50 UEs, starting from 50 UEs, our algorithm continues to present the low value compared with other algorithms in which the PLR starts to increase exponentially with the increase of the user's number, for 100 UE's EXP-MLWDF get very low value about 12% compared with others algorithms which get about 40%.

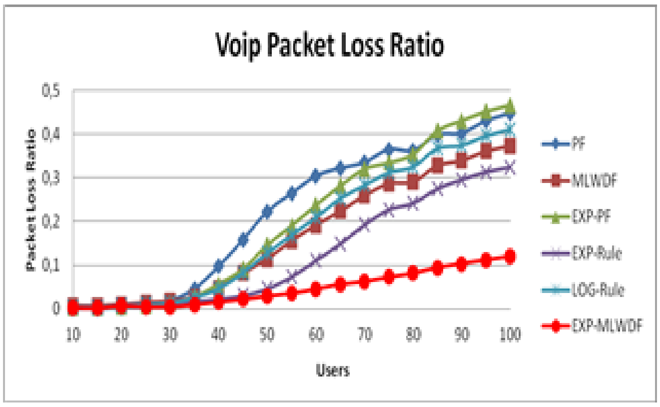

Figure 6. The Packet Loss Ratio (PLR) for VoIP Flow

4.2.2. For video flows

The Packet Loss Ratio for video flows is given on Figure 7, it is noticed that the PLR given by our proposed algorithm is the lowest comparing with other algorithms such as MLWDF, EXP/PF, LOG-Rule, EXP-Rule and especially PF who shows a dramatic increase by the increase of the user's number. In high mobility scenario and with the presence of a big number of users in the cell, the PLR value is very large, about 90 % for all the compared algorithms with the distinction of our algorithm which continue to present the low PLR value.

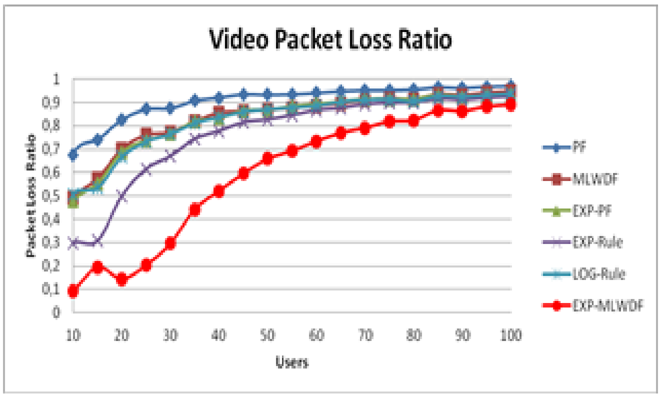

Figure 7. The Packet Loss Ratio (PLR) for Video Flow

4.3. The measurement of packets throughput

The Packets Throughput is measured on the basis of the average success rate of the different packets transmitted to the destination using the appropriate radio channel [2].

4.3.1. For VOIP flows

The packet throughput for VOIP flows increases exponentially with the number of users, and it's the same for all the scheduling algorithms, with the distinction of our proposed algorithm 'EXP-MLWDF' that presents a high throughput. The EXP-PF presents the lower throughput value (see Figure 8).

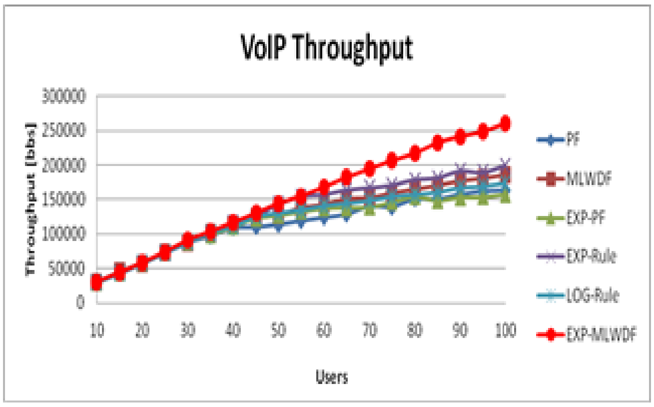

Figure 8. The packets throughput for VOIP Flows

4.3.2. For video flows

Figure 9 represents the Video packet throughput. It shows that the throughput for the entire scheduling algorithms increases as long as the number of users increases until 30 UEs. The proposed algorithm ‘EXP-MLWDF’ presents the very high throughput even the increase of the user’s number, this throughput value starts to decrease starting from 30 UEs from 1 Mbit/s to 600 Kbit/s for 100 UEs. The PF scheduler presents the very low throughput compared with other algorithms.

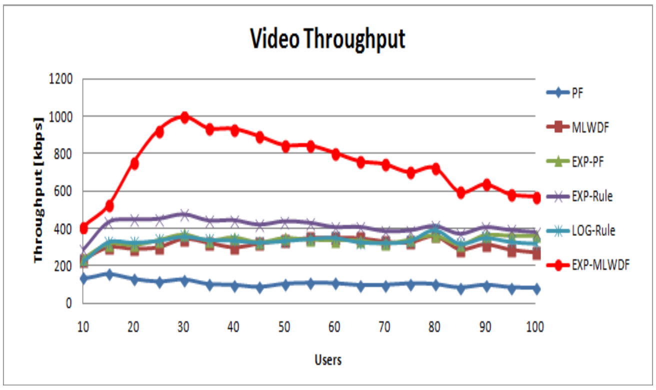

Figure 9. The packets throughput for Video Flows.

5. CONCLUSION

In this paper, our work focused on packet scheduling issues in the downlink of 3GPP LTE networks. We proposed a new algorithm named EXP-MLWDF, and we compared its performances with some well-known algorithms, such as the proportional fairness algorithm (PF), Exponential Proportional Fairness (EXP/PF), the Modified Largest Weighted Delay First (MLWDF), the LOG-Rule and the EXP-Rule, for high mobility scenario with the presence of a big number of users. This comparison is conducted in terms of packet delay, Packet loss ratio ‘PLR’ and Throughput. Simulation results have confirmed that our algorithm is more advanced and satisfies QoS requirements of Real Time services. Our future work will be devoted to propose an algorithm for the Uplink pathway to achieve the best overall system performance.

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BIOGRAPHIES OF AUTHORS

Angri Ismail was born in Akka, Tata, Morocco, on December 19, 1989. He received the Electronics and Telecommunication Engineering degree in 2013, from the Faculty of Sciences and Technics (FST), Sidi Mohamed Ibn Abdellah University, Fez, Morocco. Angri Ismail works as a Telecommunications Engineer at the National Telecommunications Regulatory Agency (ANRT), Rabat, Morocco. PhD student at the National Institute of Posts and Telecommunications, Rabat, Morocco. Email: Ismail.angri@gmail.com

Mahfoudi Mohammed born in 1986 in Sefrou (Morocco), obtained graduate engineer degree in Telecommunications and Networks in 2010 at the National School of Applied Sciences of Fez. Mahfoudi Mohamed worked as Technical support engineer at Huawei Technology, Currently received the PhD in Telecommunications from Sidi Mohamed Ben Abdellah University Fez. E-mail: mahfoudi.mohammed@gmail.com

Najid Abdellah received the PhD. Degree in electronic engineering and the MS degree in Networking and Communication Systems from the ENSEEIHT of Toulouse, France; He has several years of research experiences with ENSEEIHT, ENSTA and INRIA. Dr. Abdellah Najid joined INPT RABAT Morocco as full professor of Microwave and Telecommunications engineering in 2000. He has devoted over 16 years to teaching Microwave engineering; Wireless Networking, Network Architecture, Network modeling courses and directing research projects in Wireless Network performance analysis; Wireless sensor Networking; Microwave and Antennas design. E-mail: najid@inpt.ac.ma

El Bekkali Moulhime received the PhD. Degree in 1991 from the USTL University – Lille 1 – France, he worked in X-band printed antennas and their applications to microwave radar. He is professor in the Electrical Engineering Departement of the Superior School of Technology, Fez (ESTF). He is member of Transmission and Data Processing Laboratory (LTTI). Since 2009, Pr. Elbekkali served as vice President at University of Sidi Mohamed Ben Abdellah (USMBA) Fez, Morocco.