Australian Journal of Basic and Applied Sciences, 9(18) Special 2015, Pages: 48-54

ISSN:1991-8178

Australian Journal of Basic and Applied Sciences

Journal home page: www.ajbasweb.com

Optimum Real-Time Algorithm in Scheduling Video Flows

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ARTICLE INFO

Article history:
Received 12 March 2015
Accepted 28 April 2015
Available online 24 May 2015

Keywords:
Packet scheduling algorithm
LTE Video LTE-Sim

ABSTRACT

An efficient algorithm in allocating resources to active flows is important since it will affect the individual user's throughput and fairness. Thus, it is important to choose an optimal packet scheduler scheme to be used in order to schedule this active flow. In this paper, we have studied five downlink packet scheduling algorithms in LTE-Sim which can be used to schedule real-time traffic such as video. The aim of this study is to determine the most suitable packet scheduling algorithm in order to schedule the video flows. The performance of these packet scheduling algorithms are evaluated based on the performance metric of throughput, delay, fairness and packet loss rate (PLR). Simulation results indicated that FLS outperformed others in all situations. Thus it is concluded that FLS is the most suitable packet scheduling algorithm to schedule video flows.

To Cite This Article: Ku SitiSyahidah Ku Mohd Noh, DarmawatyMohd Ali, SinanGhassanAbid Ali, NurulanisMohd Yusoff., Optimum Real-Time Algorithm in Scheduling Video Flows. ***Aust. J. Basic & Appl. Sci.,*** *9(18): 48-54, 2015*

INTRODUCTION

With the rapid evolution of communication networks and the ever growing capabilities of handsets, the demand for multimedia services is increasing every day. Multimedia services such as VoIP, video telephony and video streaming has their own constraints on Quality of Service (QoS) requirements making the design of the future generation cellular networks is more challenging. Long Term Evolution (LTE) network is developed to respond to this challenge where one of its ability is to improve the QoS. According to (Ericsson, 2014), in first quarter of 2014, the number of LTE subscriptions has reached 240 million and it is predicted to reach 2.6 billion by 2019 which represent around 30 percent of total mobile subscriptions.

LTE is a new standard that has been introduced by the 3rd Generation Partnership Project (3GPP) which is an evolution of the 3G mobile networks towards a packet-optimized system. The aims of the LTE are to reduce latency, increased data rates, improved system capacity and coverage, better battery lifetime and reduced cost for the operator. LTE offers greatly improved data rates, 100 Mbps for downlink and 50 Mbps for uplink and operates in different bandwidths ranging from 1.25 MHz up to 20 MHz (3GPP Technical Report, 2010).

Orthogonal Frequency Division Multiple Access (OFDMA) has been applied in the physical layer of 3GPP LTE system as the multiple access technique for the downlink transmission to transmit data from Evolved Node B (eNodeB) to User Equipment (UE). OFDMA is able to improve the spectrum efficiency, flexible resource allocation, immunity to frequency selective fading and it can overcome the problem of inter-symbol interference (ISI) (Sandrasegaran, K., 2010). On the other hand, Single Carrier Frequency Division Multiple Access (SC-FDMA) is employed in the uplink transmission to increase the UE's battery life (Ratan, J., 2011) and reduce the Peak-to-Average Power Ratio (PAPR) (Muntean, V. H., 2010). In LTE, both Frequency Division Duplex (FDD) and Time Division Duplex (TDD) are supported to separate the uplink and downlink traffic. However, majority of the deployed system is using FDD (Dardouri, S. and R. Bouallegue, 2014).

Scheduling is one of the main features in LTE systems which are performed in the Medium Access Control (MAC) layer. Packet scheduler is in charge of distributing resources among users in a fair and efficient way to maximize the system throughput and fairness. In LTE network architecture, packet scheduler is located at the LTE networks base station, eNodeB to effectively allocate the resources. The function of the scheduler is to maximize the spectral efficiency, thus the impact of the channel quality drop can be reduce or almost negligible.

Authors in (Dardouri & Bouallegue, 2014; Biernacki & Tutschku, 2013 and Kitanov & Janevski, 2013)have compared the performance of

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Proportional Fairness (PF), Modified Largest Weighted Delay First (M-LWDF) and Exponential Proportional Fairness (EXP/PF) algorithms. The performance of M-LWDF and EXP/PF seem comparative in scheduling video flow while PF is found not suitable to be used for real-time flows. On the other hand, the papers of (Afroz, Barua, & Sandrasegaran, 2014 and Sahoo, 2013) compared the performance of Frame Level Scheduler (FLS), Exponential (EXP) Rule and Logarithmic (LOG) Rule algorithms. The results show that FLS outperformed the other two algorithms in scheduling video flow.

This paper aims to investigate the most suitable algorithm (M-LWDF, EXP/PF, FLS, EXP Rule and LOG Rule) to be used in scheduling video flow. An event driven LTE-Sim network simulator (Piro, G., 2011) is used as the simulation tool. LTE-Sim has been chosen because it is an open source network simulator and supports all these packet scheduling algorithms.

The rest of the paper is organized as follows. A brief overview on basic LTE networks and LTE-Sim is presented in Section II. Section III introduces the background and basic principles of scheduling algorithms in LTE. Simulation environment and parameters used are described in Section IV while Section V illustrates the simulation results and discussion. Finally, Section VI concludes the paper.

1. Overview of LTE network and LTE-Sim:

The LTE network follows a general architecture known as Evolved Packet System (EPS) where its primary function is to provide all IP based connectivity. EPS consist of two major components, namely, the Evolved Packet Core (EPC) and the Evolved Universal Terrestrial Radio Access Network (E-UTRAN) as depicted in Figure 1.

EPC composed of five network elements: the Serving Gateway (SGW), Public Data Network Gateway (PGW), Mobility Management Entity (MME), Policy and Charging Resource Function (PCRF) and Home Subscriber Server (HSS). EPC is mainly responsible for mobility management, connection establishment, intra-LTE handover and connecting E-UTRAN to the public Internet. On the other hand, the E-UTRAN is an air interface that provides wireless transmission to UE. Appropriate interfaces that connect the modules are indicated with the lines. The eNodeB is connected to each other by X2 interface and to the EPC by S1 interface.

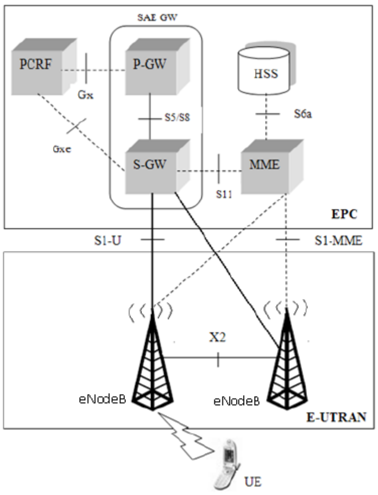

Fig. 1: System architecture of EPS.

The LTE transmission is segmented into frames. Figure 2 shows the LTE frame structure of the Frequency Division Duplex (FDD) for the downlink and uplink sub-frame. A frame is 10 ms long and each frame is divided into 10 sub-frames with 1 ms of length each. The sub-frame is further split into 2 slots where each slot is 0.5 ms long and each slot is divided into a number of resource blocks (RBs). The number of RBs depends on the channel bandwidth. A resource block contains 12 subcarriers and 6 or 7 OFDM symbols. The number of OFDM symbols in a resource block depends on the cyclic prefix (CP) either it is a normal CP (7 OFDM symbol) or an extended CP (6 OFDM symbol).

In the beginning of the scheduling process, the UE determine the Channel Quality Indicator (CQI) index by estimating the instantaneous channel condition and sends a feedback to the eNodeB. Subsequently, this CQI index is use by the eNodeB to select UE with the most suitable modulation and coding scheme (MCS) for spectral efficiency maximization at physical layer. Larger CQI index represent higher level of MCS which means more efficient usage of resources and fewer RB being occupied for transmission. Certain information such as channel quality, resource allocation history, status of transmission queues, buffer state and QoS requirements may be considered by the packet scheduler when making scheduling decision.

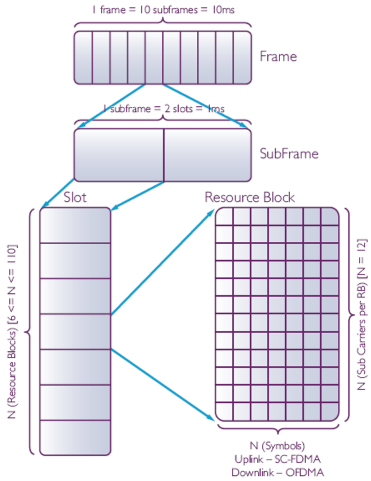

Fig. 2: FDD LTE frame structure.

A general model of the packet scheduling in the downlink 3GPP LTE system is shown in Figure 3. It is observed that a buffer is given to each user in the cell at the eNodeB. Based on the first in first out (FIFO) principle, packets arriving into the buffer are time stamped and queued for transmission. The packet scheduler decides which user is to be scheduled based on the packet scheduling algorithm in each TTI. There is a possibility that a user may be allocated zero, one or more than one RBs at each TTI.

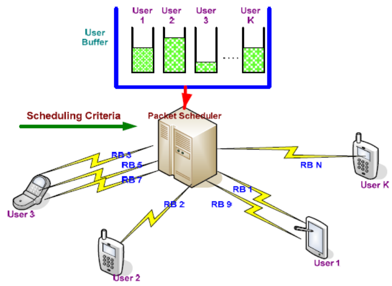

Fig. 3: General packet scheduling model.

LTE-Sim simulator is an open source framework to simulate LTE networks. It encompasses several aspects of LTE networks which include both the E-UTRAN and the EPS. It supports single and multi-cell environments, QoS management, multi-users environment, user mobility, handover procedures and frequency reuse techniques. UE, eNodeB and MME are the network nodes that supported by this simulator. Several types of traffic generators at the application layer have been implemented and the management of data radio bearer is supported. Finally, the well-known scheduling strategies (such as PF, M-LWDF and EXP/PF), Adaptive Modulation Coding (AMC) scheme, CQI feedback, and models for physical layer are supported too (Piro, G., 2011).

2. Packet scheduling algorithms:

The packet scheduling algorithms to be used in the 3GPP LTE should be able to maximize the throughput, satisfy the users' QoS and provide good fairness to the non-real-time users. According to (Basukala, R., 2009.), if the packet scheduler utilizes the CQI feedback from the users when making scheduling decisions, system throughput can be maximized. However, scheduling decisions that rely on channel conditions only is insufficient to support the multimedia applications due to their strict delay requirements. Hence, several packet scheduling algorithms that satisfy these requirements have been developed.

Some of the possible scheduling algorithms that are supported by LTE-Sim are MLWDF, EXP/PF, FLS, EXP Rule and LOG Rule. All these listed scheduling algorithms are classified as channel-aware scheduling algorithm. Channel-aware scheduling algorithm means that the algorithm is considering the channel information when making scheduling decision.

Modified Largest Weighted Delay First (M-LWDF):

M-LWDF algorithm is designed to support multiple real-time data users in CDMA-HDR systems (Ameigeiras, P., 2004) with different QoS requirements. It considers the channel status of a UE and the maximum allowable delay of an application service, adding a metric base to the PF mechanism for the existing Largest Weighted Delay First (LWDF) mechanism (Shin, P. and K. Chung, 2014). The metric for the non-real-time applications are calculated using the PF mechanism, while for the real-time applications such as streaming video and VoIP services. The scheduling isperformed using the metrics calculated by applying the weights of M-LWDF as in equation (1):

$$j^{M-LWDF} = \max \alpha_i \frac{\mu_i(t)}{\overline{\mu_i}} D_{HOL} \quad (1)$$

whereα_i denotes the weight factor while D_{HOL} is the HOL packet delay. $\mu_i(t)$is the data rate corresponding to the channel state of the user *i* at time slot *t*. $\overline{\mu_i}$ is the mean data rate of user *i*.

Exponential Proportional Fairness (EXP/PF):

EXP/PF algorithm can support both real-time and non-real-time services. This algorithm has been designed to increase the priority of real-time flows with respect to non-real-time ones. The average HOL packet delay is taken into account and the EXP/PF metric is calculated as follows:

$$j^{EXP/PF} = \max \alpha_i \frac{\mu_i(t)}{\overline{\mu_i}} \, exp\left(\frac{\alpha_i D_{HOL} - \beta}{1+\sqrt{\beta}}\right) \quad (2)$$

The term$\beta = \frac{1}{N_{rt}}\sum_{i=1}^{N_{rt}} \alpha_i D_{HOL}$ where N_{rt} is the number of active downlink real-time flows. When the HOL packet delays for all the users do not differ a lot, the exponential term is close to 1 and EXP/PF behaves like a PF. If one of the user's HOL delay becomes large, the exponential term overrides the channel state-related term, and the user gets a priority.

Exponential (EXP) Rule:

The EXP rule was proposed to provide QoS guarantees over a shared wireless link. While scheduling the active users in the network, a wireless channel is shared among multiple numbers of users and each user's data arrives to a queue as a random stream where it awaits transmission/service. A scheduling rule in this context selects a single user/queue to receive service in every scheduling instant [10].It gives higher priority to UE with the highest transmission delay or UE that has more packets in its buffer.

$$j^{EXP\ Rule} = \delta_i \exp\left(\frac{\alpha_i D_{HOL}}{1+\sqrt{\theta}}\right) x\, \Gamma \quad (3)$$

where $\theta = \frac{1}{N_{rt}}\sum_{i=1}^{N_{rt}} D_{HOL}$. Γ represents spectral efficiency. According to [15], the optimal parameter, α_i is define as:

$$\begin{cases} \alpha_i \in \left[\frac{5}{0.99\tau}, \quad \frac{10}{0.99\tau}\right] \\ \delta_i = \frac{1}{E[\Gamma]} \end{cases}$$

with τ denotes as delay threshold.

Logarithmic (LOG) Rule:

The LOG Rule algorithm (Sadiq, B.,) is designed to provide a balance in QoS metrics in terms of mean delay and robustness. It allocates service to a user in the same manner as the EXP Rule in order to maximize the current system throughput, assuming that the traffic arrival and channel statistic parameters are available.

$$j^{LOG\ Rule} = \delta_i \log(1.1 + \alpha_i D_{HOL})\ x\, \Gamma \quad (4)$$

The parameters of α_i and δ_i are define as:

$$\begin{cases} \alpha_i = \frac{5}{0.99\tau} \\ \delta_i = \frac{1}{E[\Gamma]} \end{cases}$$

Frame Level Scheduler (FLS):

The FLS algorithm is a two level scheduling scheme. Two different algorithms are implemented in these two levels. A low complexity resource allocation algorithm based on discrete time linear control theory is implemented in the upper level. It computes the amount of data that each real-time source should transmit within a single frame, to satisfy its delay constraint. The PF scheduler is implemented in the lower level to assign radio resources to the users to ensure a good level of fairness[10]. The FLS algorithm is represented as:

$$j^{FLS} = h_i(t) * q_i(t) \quad (5)$$

wherej^{FLS} is the amount of data to be transmitted by the *i*-th flow in *t*-th LTE frame, "*" operator is the discrete time convolution. Equation (5) tells that j^{FLS} is obtained by filtering the signal $q_i(t)$(i.e., the queue level) through a time-invariant linear filter with pulse response $h_i(t)$

3. Simulation environment and parameters:

The video flow configured in LTE-Sim is a trace-based application that sends packets based on realistic video trace files. The selected video flow is encoded at the rate of 128 kbps using the H.264 encoder. In this simulation, the propagation loss model which is composed of path-loss, shadow fading, multipath-fading and the penetration loss is considered. The summarization is tabulated in Table I.

Table I: Propagation Loss Model

Parameter	Value
Path loss	128.1 + 37.6log10(*d*) where *d* is the distance between the UE and eNodeB in km
Shadow fading	Log-normal distribution with 0 mean and 8 db of standard deviation
Multipath fading	Jakes model
Penetration loss	10 db

This paper evaluates five packet scheduling algorithms based on the performance metric of throughput, delay, fairnessand PLR. A single cell with interference delivering the video flows is simulated. In single cell with interference scenario, several cells are created but the simulation is performed only in the central cell. No users are created into the external cells that are only considered as generators of interference. There is also no handover process is performed in this scenario. LTE-Sim simulator is used to perform this analysis.

Table II: Lte Downlink Simulation Parameters.

Parameter	Value
Simulation duration	120s
Flow duration	100s
Frame structure	FDD
Bandwidth	10MHz
Number of RB	50
Radius	1km
Max delay	0.1s
User speed	3km/h
UEs number	From 10 to 50
Video bit rate	128kbps

4. Simulation results and discussion:

This section analyzes the simulation results. The results consisted of performance on throughput, fairness, delay and PLR for the video flows. Throughput is the rate of successful message delivery by a system over a given interval of time while fairness index means every user is receiving a fair share of the system resources.

The video throughput for the algorithms simulated is represented as in Figure 4. As the number of users increased, the throughput also increases. The throughput value delivered is less than the theoretical value calculated for the 10 users (1 video flow deliver 128kbps, thus 10 users will deliver 1.28 Mbps). There are some losses considered in the scenario thus producing the result as in Figure 4. It is observed that FLS is having the best throughput performance followed by EXP Rule algorithm while EXP/PF delivers the lowest throughput. The lowest layer scheduler, instead, allocates resources blocks in each TTI to achieve a trade-off between throughput and fairness(Piro, G., 2011).

The fairness index is illustrated in Figure 5. Fairness among users is implemented using Jain's Fairness Index and the best fairness index value is 1. When the number of users is less than 20, it seems that the fairness value is similar to each other. However, as the number of user increased, thefairness index degrades. It is noticed that FLS has higher fairness index than the others. FLS is a two-level scheduling scheme where PF algorithm is assigned as its lower level scheduler to achieve a high level of fairness among the multimedia flows(Piro, G., 2011).

Delay is defined as how long it takes for a bit of data to travel across the network from one node to another. The allowable value for delay is specified as less than 150 ms (3GPP, 2012). Based on Figure 6, all algorithms are observed to fulfill the delay requirement; however FLS shows the least while M-LWDF has the highest value. Authors (Piro, G., 2011) indicated that the FLS is developed as a two level framework that guarantees bounded delays to multimedia flows which can improve the quality of multimedia services in LTE system.

Packet loss ratio is the ratio of the lost packets during transmission over the number of transmitted packets. The PLR requirement for video streaming service should be less than 1% (Janevski, T., 2003). As shown in Figure 7, the PLR for FLS is the smallest because the value is in accordance to the delay. This is due to the packets in the buffer which is not violating the deadline, thus packets are successfully transmitted.

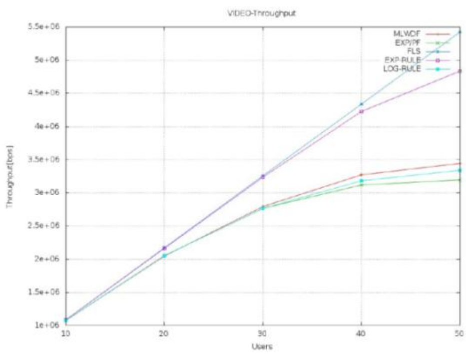

Fig. 4: Throughput vs. number of users.

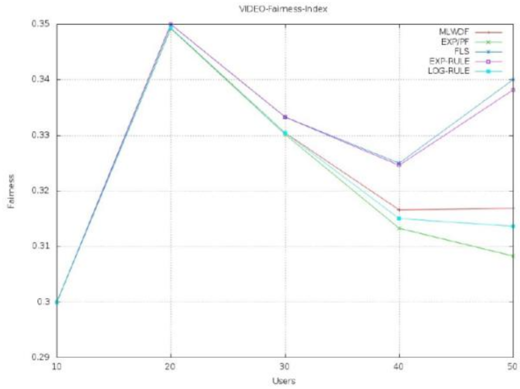

Fig. 5: Fairness index vs. number of users.

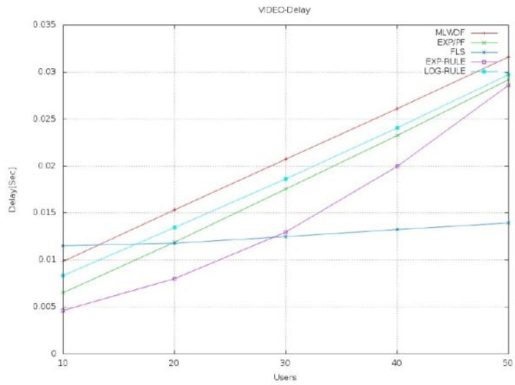

Fig. 6: Delay vs. number of users.

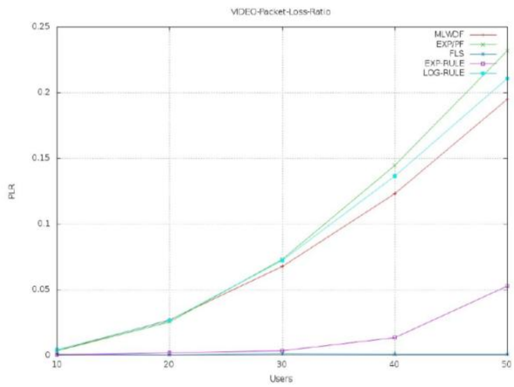

Fig. 7: PLR vs. number of users

5. Conclusion:

This paper evaluates the performance of five packet scheduling algorithm in LTE cellular networks. The performance metric such as throughput, fairness, delay and PLR are analyzed for the pedestrian case. The results show that FLS outperformed other algorithms in scheduling video flow since it has the highest throughput and fairness with the lowest delay and PLR. Hence, it can be concluded that FLS is the most suitable algorithm to schedule video flow. Future research will focus on identifying the optimum real-time algorithm for VoIP flows.

ACKNOWLEDGEMENT

This research was supported by UniversitiTeknologi Mara (UiTM) Malaysia.

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