Study Analysis of Cross QoS Based Scheduler for 3.9G LTE Network

D. Vinayagam, A. Sagaya Selvaraj, A. Jayakumar, S. Radhakrishnan

Abstract—The proposed algorithm prolongs the scheduler from scheduling the Real Time (RT) and Non Real Time (NRT) services based upon their priority required on Quality of Service (QoS). The proposed Cross QoS Scheduling Algorithm (XQSA) is capable of scheduling data, video and voice services over the same wireless channel. The complimentary advantages of both RT (video & voice) and NRT (Best Effort of service, BE) services and cross layering technology is utilized by XQSA which prioritizing services in the scheduler to achieve a significant cell user throughput, a low delay, normalized fairness and a low packet loss ratio. The XQSA adapted the two different scheduling principles together to govern the effective channel utilization. The simulation of the XQSA under multiple cell scenarios for scheduling in the 3.9G LTE (Long Term Evolution) network is done using LTE-Sim tool. In the XQSA policy, the traditional RT and NRT scheduling algorithm are integrated together to support the multi-service scheduling (i.e., Modified Long Weighted Delay First/Proportional Fair (M_LWDF/PF) & Exponential Proportional Fair/Proportional Fair (EXP_PF/PF)). The study analysis of the XQSA is examined experimentally through simulation in terms of throughput, packet loss ratio, delay and cell spectral efficiency and fairness index. The simulation based comparison indicates that M_LWDF/PF and EXP_PF/PF scheduler outperforms PF scheduler especially during RT service. The PF scheduler has high throughput for the NRT service. In all the simulations, the performance level of EXP_PF/PF scheduling algorithm for multi-service scheduling seems to be an optimal solution for guaranteeing required QoS (Quality of Service).

Index Terms—Channel Quality Indicator (CQI), Channel Utilization, Cross Layering, Cross QoS Scheduling Algorithm (XQSA), 3.9G, LTE-Sim, LTE, Multi-service scheduling, Quality of Service (QoS), Spectral Efficiency, User's Fairness.

1 Introduction

THE LTE technology is the evolution of wired broadband network to wireless broadband network with the features of robust and cost effective IP network. The system architecture of LTE network constitutes Evolved Packet Core (EPC), Evolved Node B (eNB) and User Equipment (UE). In the LTE, radio access network constitute of single eNB (network of base stations where packet scheduling is equipped) with multiple UE works on the principle of Evolved Packet System (EPS) which is pure IP based traffic. The LTE technology – wireless broadband network works on the frequency band of 2.6 GHz has a scalable carrier bandwidths ranging from 1.4 MHz to 20 MHz available for each channel. LTE-R8 network (TD-LTE) supports a peak bit rate much less than 1Gbit/s and hence fails to meet the ITU-R requirements for 4G wireless network service (IMT Advanced). So, LTE-R8 network is also referred to as a type of 3G wireless service (3.9G) but often branded as 4G by majority of telecom service providers as it was the first release version of 4G. LTE-A services are expected to release in late 2013 in the telecom market with advanced topology network which enables high spectral efficiency, low latency. The most notable thing in LTE is low transmission cost for every megabyte.

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2 Scope

The major problem multi user scheduling in LTE network is normalized user fairness and optimized radio link level. The radio network users who have poor channel condition are penalized with regard to users with better channel condition. The users with good channel conditions are given better data rate and fairness. User with poor channel condition and lower threshold level has to wait till the channel condition crosses the threshold level. In order to eliminate this problem, the cross layer technology is applied to scheduler and schedule the user based channel quality condition with normalized fairness. performance strategy of cross layer based scheduling algorithm is estimated to find out the best multimedia scheduling scheme with normalized fairness for effective multi-user resource allocation.

3 LTE CQI Model

The downlink scheduling in the LTE network utilizes Channel Quality Indicator (CQI) report sent from the user through Physical Uplink Shared Channel (PUSCH). By utilizing the cross layering technology, the eNB (evolved Node B) receives the updates of user's channel condition periodically or non-periodically using CQI request-response method. The periodic CQI has overhead signaling problem. In aperiodic CQI, the eNB request for CQI report via downlink channel assigned to particular user and user response to the CQI request by eNB for transmitting CQI value, aperiodically via uplink channel (see Fig. 1). The CQI threshold index is scalable from 0-15 corresponds to coding rate, modulation type (QPSK, 16QAM, 64QAM) and bits/resource element.

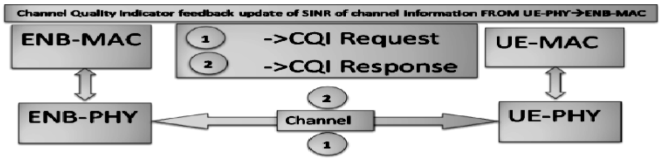

Fig. 1. Request – Response of LTE-CQI updater

The CQI index value zero indicates out of coverage range and its report is utilized by scheduler to distinguish channel quality variation within the reported subset of subcarriers. The CQI report from different users to radio access network (eNB) is used to allocate the short Resource Blocks (SB) to subset of users. The CQI response from user via PUSCH, the eNB can assign SBs and MCSs (Modulation Coding Schemes) through Physical downlink control channel (PDCCH). For every TTI (1 ms), the packet scheduler determines which users are to be scheduled based on a packet scheduling algorithm. The user data rate ($\lambda_f(\beta)$) is obtained by the f^{th} SDFs during the β^{th} TTI and $\lambda_f(\beta-1)$ is the data rate estimation in the previous TTI. For every TTI, the estimation of data rate $\bar{\lambda}_f(\beta)$ as given

$$\bar{\lambda}_f(\beta) = 0.2(4\lambda_f(\beta-1) + \lambda_f(\beta)), \forall f, g = 1, 2, ..., \infty \quad (1)$$

4 Proposed XQSA System Model

The downlink cross layer scheduling policy depends upon the PHY-layer CQI (channel Quality Indicator) and DLL-layer BQI (buffer queue information) is schemes. The proposed XQSA scheduling policy utilizes the combination of PF, M_LWDF & EXP_PF traditional policy along with cross layering feature to enhance user fairness. The M_LWDF and EXP_PF policy schedules periodically the RT-SDFs having delayed sensitive and packet loss tolerant property. The XQSA scheduler policy integrates RT-SDFs and NRT-SDFs scheduler for effective channel utilization. In priority Scheduling policy, the user's SDF (Service Data Flow) is differentiated with bearer flow type for the Service based Priority Metric for each flow (SPM) is assigned to priority index for RT-SDF or NRT-SDF as given Table I (Fig. 2). Finally the XQSA based on SPM and CQI value decides the type scheduler metric to allocate that particular user (Fig. 3).

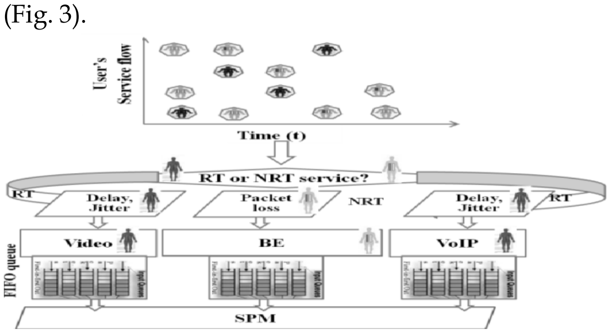

Fig. 2 Priority scheduling policy

The goal of PF scheduler is to maximize the throughput gain as well guarantee normalized fairness by taking into account whether the CQI report and the past throughput is gained or not accordingly.

TABLE I
SPM

Priority Index	Description
1	GBR-Conversational-VoIP call (delay -100ms) -
2	GBR-Conversational-video call (delay -150ms)
3	Non GBR- infinite buffer (BE flow) (delay-300ms)

The PF scheduler metric ($\Re_{f:g}$) is used to calculate the ratio between the data rate available at that instant ($\hbar_{f:g}$) for f^{th} SDFs in the g^{th} sub-channel and the average past data rate (H_f).[8] The instant data rate ($\hbar_{f:g}$) is calculated by using AMC module which considers the CQI report from UE (User Equipment) or user for f^{th} SDFs in the g^{th} sub-channel; and H_f is the total estimated average data rate.

$$\Re_{f:g} = \left(\frac{\hbar_{f:g}}{H_f}\right), \forall f, g = 1, 2, ..., \infty \quad (2)$$

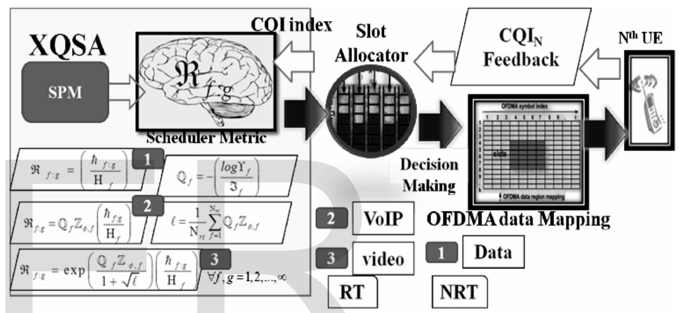

Fig. 3. XQSA system model

The M_LWDF/PF is a XQSA scheduling policy which considers M_LWDF for RT-SDFs and PF for NRT-SDFs. The M_LWDF scheduler schedules the multiple RT-SDFs with best channel quality criterion and high scheduling priority. [7][12] The packet delay probability (Υ_f) is defined as the maximum probability that the delay of the head-of-line Packet ($\square_{\phi,f}$) exceeds the packet delay threshold ($\Im_f$). The priority function ($\square_f$) is the product of packet delay threshold ($\Im_f$) and returns the natural logarithm of packet delay probability (Υ_f).The Delay of the Head of Line Packet ($\square_{\phi,f}$) is the delay of the first packet to be transmitted in the MAC queue length. The M_LWDF scheduler metric ($\Re_{f:g}$) is the ratio of the product of data rate available at that instant ($\hbar_{f:g}$), delay of the head of line Packet ($\square_{\phi,f}$), priority function ($\square_f$) for f^{th} RT-SDFs in the g^{th} sub-channel and the average past data rate (H_f).

$$\Re_{f:g} = \square_f \square_{\phi,f} \left(\frac{\hbar_{f:g}}{H_f}\right), \forall f, g = 1, 2, ..., \infty \quad (3)$$

$$\square_f = \left(\Im_f \log \Upsilon_f\right)^{-1} \quad (4)$$

The EXP_PF/PF is a XQSA scheduling policy which considers EXP_PF for RT-SDFs and PF for NRT-SDFs. [7][9] The EXP_PF is designed to increase the scheduling priority of RT-SDFs with respect to NRT-SDFs, where their head-of-line packet delay is very close to the delay threshold. [12] The parameter N_{rt} is the total number of active downlink RT-SDFs service and the parameter - $\hbar_{f:g}$, H_f, $\square_f$, $\square_{\phi,f}$, Υ_f, $\Im_f$ have the same meaning as already described. In both M_LWDF and EXP_PF policy, if a particular RT-SDF is not transmitted before the expiration or deadline, it is erased from the MAC queue length in order to avoid bandwidth wasting. For NRT-SDFs scheduling, the considered metric is the PF scheduler. For RT-SDFs, the considered metric ($\Re_{f:g}$) is computed by using the following equations:

$$\Re_{f:g} = \exp\left(\frac{\square_f \square_{\phi,f}}{1+\sqrt{\ell}}\right)\left(\frac{\hbar_{f:g}}{H_f}\right), \forall f, g = 1, 2, ..., \infty \quad (5)$$

$$\ell = \frac{1}{N_{rt}} \sum_{f=1}^{N_{rt}} \square_f \square_{\phi,f} \quad (6)$$

4 SIMULATION RESULTS

The XQSA based scheduler is simulated using LTE-Sim simulation tool for RT-SDFs and NRT-SDFs. The simulation utilizes application services: Video flow (440 Kbit/s RT trace file), VoIP G.729 flow (ON (3s)/OFF (6.9s) Markov chain source) & BE flow (greedy source model) are studied in terms of users throughput gain, PLR, APD, FI and CSE. The Path Loss Model for Urban Environment (L_p) = I + 37.6log10(R), where L is the propagation path loss in urban cell channel realization and d (km), is the distance between two nodes (the UE and the eNodeB), I = 128.1 at 2GHz.

TABLE II
INPUT PARAMETER FOR XQSA POLICY

Parameter	Description
Environment	Urban
User scalability	10-50 user/cell
Type of frame structure	FDD
No. of RBs	50
No. of cells/cluster	7 cells
UEs distribution	Uniform distribution
Total no of clusters	3
Cell radius	1 km
Video application	Video trace files (440kbit/s),
VoIP application	(G.729 voice flow) On- Off Markov chain model (8.4kbit/s)
Infinite Buffer application	Ideal greedy source model (BE flow)

The XQSA performance analyses are studied by using M_LWDF, PF, EXP_PF. PF scheduler itself is utilized for the NRT and RT services even though it suits for NRT service only to compare its performance with other schedulers. Then M_LWDF and PF are combined to schedule based on type of service either NRT or RT service. Finally the EXP_PF and PF scheduler is integrated to schedule based on type of service either NRT (BE) or RT (Video, VoIP).This test is also used to obtain the best RT-SDFs and NRT-SDFs scheduler combination in LTE network with users service favorable QoS criterion. Fairness Index (FI) has been computed using Jain's fairness index method. N_{UE} denotes number of users. The number of UEs satisfied with Resource Blocks (RBs) having video and voice flows priority gets the major resource whereas user with best effort service flows had to wait for empty Resource Blocks after assigning Resource Blocks for real time flows. Hence, the PF scheduler flow attains the maximum throughput for SDFs based on channel quality and bandwidth availability.

$$FI = \left(\frac{\sum_{f=0}^{¥} \text{Throughput}_f}{N_{UE} \sum_{f=0}^{¥} \text{Throughput}_f} \right) \quad (7)$$

The Cell Spectral Efficiency (CSE) can be calculated.

$$CSE = \frac{\left(\frac{\text{Goodput}}{\text{Time\_Duration}}\right)}{\text{Bandwidth}} \quad (8)$$

TABLE II (CONTD)

Mobility model	Random walk mobility
Multipath Model	Jakes model
Path Loss Model	Okumura-Hata model
Fairness index	Jain's Model
DL bandwidth	10 MHz per cell
Slot duration	0.5 ms
Type of scheduler	PF, M_LWDF, EXP_PF
Packet loss	10^{-3} (video), 10^{-1}(VoIP),10^{-}(BE)
SDFs duration	100 s
Penetration loss	10dB
Shadowing	Log-normal distribution (μ = 0dB, σ = 8dB)

The EXP_PF scheduling policy for VoIP and video flows results in higher user throughput than PF and M_LWDF scheduler though the numbers of UE's are increased (see Fig.5, Fig.6). Due to the system saturation level, the user NRT-SDFs (BE flows) using PF scheduler has noticeable throughput variations compared with The EXP_PF and M_LWDF (see Fig.7). The PLR value for VoIP application using M_LWDF and EXP_PF scheduler results in higher value than PF scheduler when the cell is charged with increasing users beyond the capacity of the individual cell. Since PF scheduler has delay tolerance property, the PLR value is low when the cell is charged with increasing users (i.e., low delay_intolerable VoIP_flow dropping property of PF scheduler) (see Fig.8). Since the RT-PDFs schedulers (EXP_PF and M_LWDF) are prone to delay sensitivity, an optimal PLR variation is noticed when the cell is charged with user scalability 30 to 50 users. (see Fig.9). For infinite buffer application, PF algorithm strategy results shows the lower PLR value than M_LWDF & EXP_PF, when the cell is charged with increasing users with same HOL packet delays flow (see Fig.10).

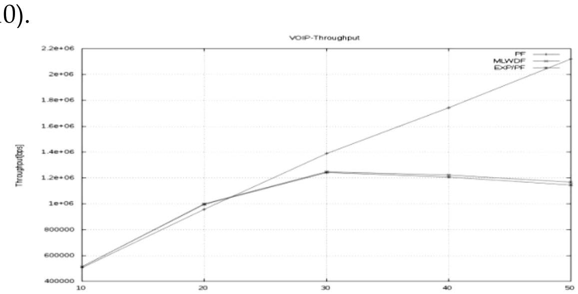

Fig. 4 VoIP: Throughput gain vs. No. of UEs/Cell

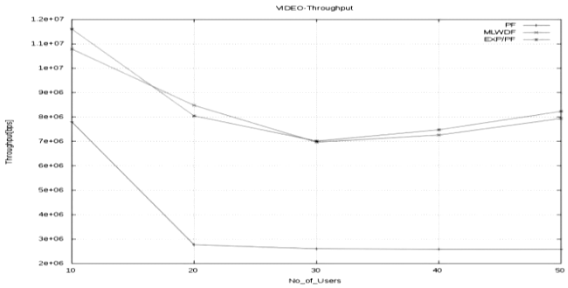

Fig. 5 Video: Throughput gain vs. No. of UEs/ Cell

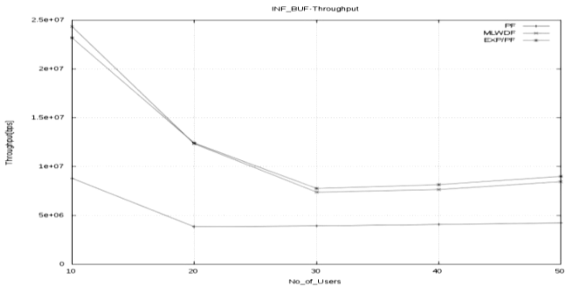

Fig. 6 Infinite-Buffer: Throughput vs. No. of UEs/ Cell

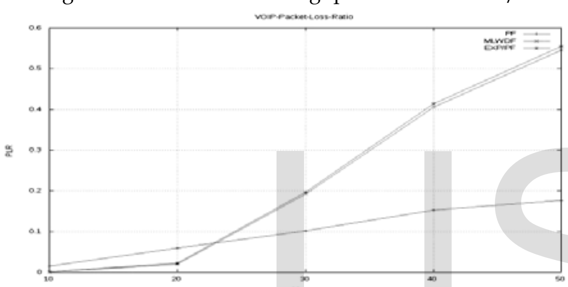

Fig. 7 VoIP: PLR vs. No. of UEs/Cell

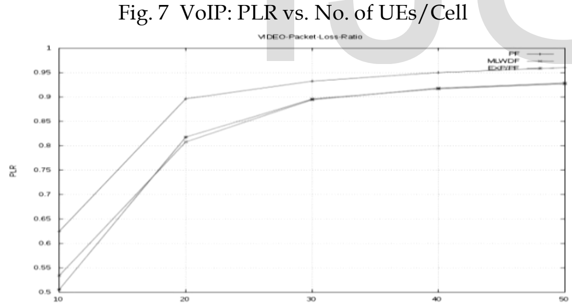

Fig. 8 Video: PLR vs. No. of UEs/Cell

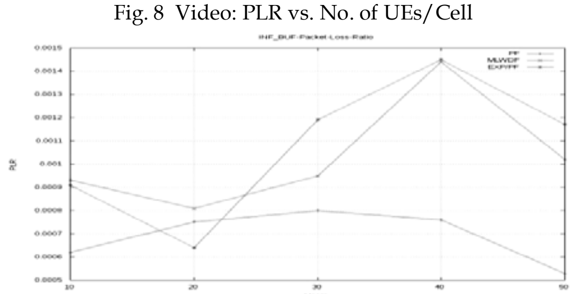

Fig. 9 Infinite Buffer: PLR vs. No. of UEs/Cell

The Users Fairness Index (FI) for the XQSA based scheduler is calculated by using Jain's model (i.e., consideration of the User throughput achieved by each SDF at the end of each simulation). In both VoIP and video flow application, M_LWDF & EXP_PF schedules users with greater throughput, fairness value than PF policy (see Fig. 11 & Fig. 12).

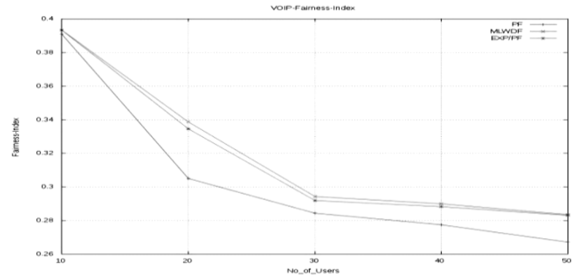

Fig. 10 VoIP: FI vs. No. of UEs/Cell

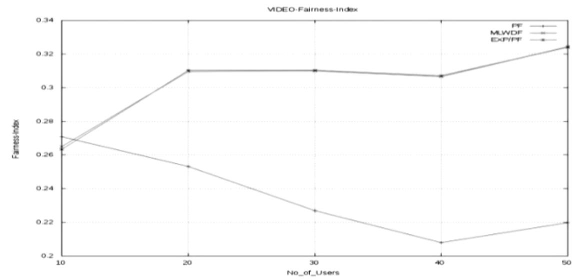

Fig. 11 Video: FI vs. No. of UEs/Cell

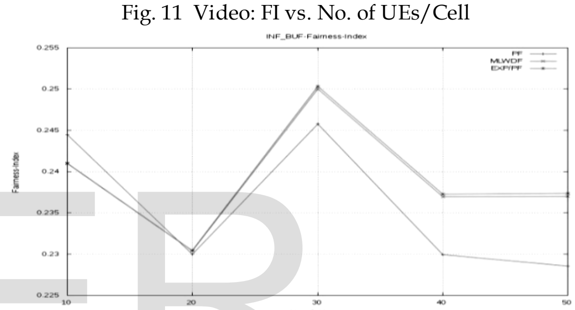

Fig. 12 Infinite Buffer: FI vs. No. of UEs/Cell

Fig. 13 VoIP: APD vs. No. of UEs/Cell

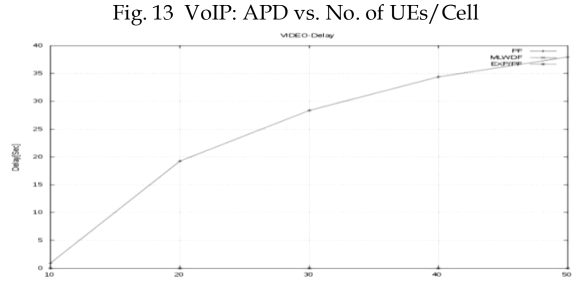

Fig. 14 Video: APD vs. No. of UEs/Cell

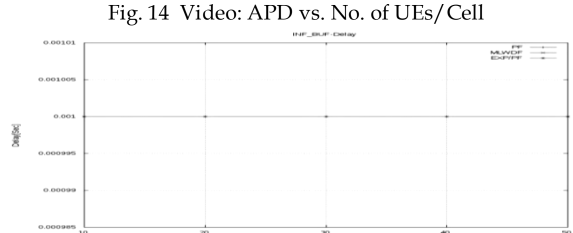

Fig. 15 Infinite Buffer: APD vs. No. of UEs/Cell

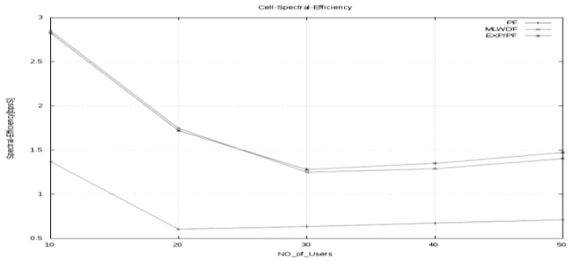

Fig. 16 CSE vs. No. of UEs/Cell

For BE flow generated by infinite buffer application, the M_LWDF and EXP_PF policy depends on channel condition and greedy resource condition. Therefore the M_LWDF and EXP_PF policy results in high fairness value (approx. 0.3) than PF policy when the cell is charged with large users (see Fig. 13). For VoIP and Video application, EXP_PF and M_LWDF presents lower APD (0.02 ms) than PF policy and spontaneously schedules RT-SDFs due to delay sensitive QoS criterion (see Fig. 14 and Fig. 15). Similarly, for Infinite buffer application (BE flow), M_LWDF, EXP_PF, results in constant APD value (0.001ms). (see Fig. 16). The QoS-aware scheduler (M_LWDF and EXP_PF) provides guarantee QoS constraints to a high number of flows than the PF scheduler. Here the initially the CSE at initial stage promote greater spectral efficiency in bps/ Hz (see Fig. 17).

5 Conclusion

From the scheduler analysis, M_LWDF/PF pair scheduling algorithm has greater performance for increasing load applied on comparison with EXP_PF/PF and PF. The adapted M_LWDF/PF and EXP_PF/PF scheduling policy results proved adoptability towards increasing user diversity and channel variation much better than PF scheduling policy. The PF scheduler policy for both RT-SDFs and NRT-SDFs suits best for only NRT-SDFs. The M_LWDF/PF scheduling policy is satisfied with perfect RT-SDFs delay transfer condition through LTE network especially for multimedia services by utilizing the fast channel quality information. Although M_LWDF/PF algorithm promotes both RT-SDFs and NRT-SDFs, this scheduling policy has low user fairness. In M_LWDF/PF algorithm promotes low fairness on user's increasing demand when the users are scalable from high to low APD value based on average radio propagation conditions. Therefore, the M_LWDF/PF scheduling policy does not satisfy the QoS criterion during peak-users situations in LTE network. This EXP_PF/PF scheduling policy promotes users with high throughput, a low APD, a high fairness and a low PLR on peak-users situations in LTE network. The simulation based comparison for RT-SDFs and NRT-SDFs scheduling policy resulted that the EXP_PF/PF outperformed M_LWDF/PF and provides the most favorable solution for users guaranteed QoS criterion.

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