ICIC Express Letters
Volume **11**, Number **1**, January **2017**

ICIC International ©2017 ISSN 1881-803X
pp. **253–260**

A NOVEL NETWORK QUALITY SATISFACTION SCHEDULING IN LTE NETWORK

Yi-Ting Mai[1,*], Jeng-Yueng Chen[2] and Cheng-Tao Yang[3]

[1]Department of Sport Management
National Taiwan University of Sport
No. 16, Section 1, Shuang-Shih Road, North Dist., Taichung City 40404, Taiwan
*Corresponding author: wkb@wkb.idv.tw; wkb@ieee.org; wkb@ntupes.edu.tw

[2]Department of Information Networking Technology
Hsiuping University of Science and Technology
No. 11, Gongye Road, Dali Dist., Taichung City 41280, Taiwan

[3]Department of Computer Science and Information Engineering
National Chi Nan University
No. 1, University Road, Puli, Nantou County 54561, Taiwan

Received June 2016; accepted September 2016

Abstract. *In order to provide high network quality multimedia services, new 4G Long Term Evolution (LTE) MAC layer has adopted the concept of the Quality of Service (QoS) with different classification service levels. The MAC scheduling is an important computing research issue, and some popular researches include how to efficiently allocate the limited radio resources to have good balance in QoS, throughput and fairness. Many conventional scheduling algorithms only considered a factor of rate or delay. In fact, all users may have both different rates and delay requirements according to different services. In this paper, a novel network quality satisfaction scheduling scheme, which can consider the requirement of rate and delay at the same time, is proposed and called MRDUF/FCFS for the LTE downlink environment. Simulation results have shown that the proposed satisfaction scheduling scheme outperforms the conventional scheduling algorithms, including MT, PF, and EDF, in terms of fairness of satisfaction of rate and delay.*

Keywords: LTE, Satisfaction scheduling, Network quality, Resource allocation, Quality of Service

1. **Introduction.** In view of traditional *GPRS (2.5G)* and *UMTS (3G)* network technologies, both the core network *Evolved Packet Core (EPC)* and the radio access *Evolved Universal Terrestrial Radio Access Network (E-UTRAN)* in *Long Term Evolution (LTE)* [1-3] are fully packet-switched model. Furthermore, the 4G LTE technology is designed to work with different bandwidth requirements and to provide a peak data rate at 100 Mbps in the downlink and 50 Mbps in the uplink. To support multimedia service and high bandwidth data delivery, LTE MAC layer supports QoS with different *QoS Class Indicator (QCI)* [4,5] levels. Therefore, some researchers have tried to adopt *Max Rate (MT)* or *Earliest Deadline First scheduling (EDF)* or *Proportionally Fair (PF)* algorithm as LTE MAC scheduling scheme in *evolved NodeB (eNB)* to maximize throughput or allocate a fairness bandwidth respectively. However, based on LTE current QCI priority and QoS requirement in UEs, there is no scheduling scheme to fit different traffic types in a single UE, and our proposed scheme can fit different UE's both rate and delay requirements and improve the fairness in all UEs' traffic.

In LTE network, 3GPP standard has designed QCI priority level to support different traffic types; however, LTE current QCI priority and QoS requirement in UEs' resource allocation is still the traditional policy [5], for example, the max rate algorithm only can achieve maximization throughput without fairness of all UEs' traffic consideration. Some researchers [6,7] had proposed the traffic scheduling schemes or the fairness supporting algorithms to find a balance between different QoS type traffic to avoid starvation at lower QoS level traffic. [8] had proposed a scheme which can support real-time VoIP traffic and dynamically adjust traffic rate to avoid buffer overflow. The authors [9,10] had concerned the computing load issues, and the scheme can divide the schedule processes into Time Domain (TD) and Frequency Domain (FD) for UE traffic QoS support with lower calculation complicated. However, previous schemes might only focus on rate or delay one aspect; to achieve better wireless network quality satisfaction purpose, both rate and delay considerations should be adopted.

The remainder of the paper is organized as follows. An introduction and brief survey of LTE and LTE scheduling is presented in Section 2. The proposed novel network quality satisfaction scheduling in LTE network is presented in Section 2. Performance evaluation with several scenarios is presented in Section 3. Finally, Section 4 concludes this paper.

2. A Novel Network Quality Satisfaction-Based Scheduling Approach.

In LTE network, a basic time unit for packet scheduling and transmission is called a *TTI (Transmission Time Interval)* with length of 1ms. So TTI is the time unit for LTE MAC layer resource allocation. In each TTI, a scheduling decision is made where each scheduled UE is assigned a certain amount of radio resources in the time and frequency domains. The eNB as a scheduler should arrange and allocate resource for connecting UEs in Figure 1. The channel capacity is assumed to be static for traditional MAC scheduling scheme, and it was revised for LTE network environments. In LTE network, an eNB typically selects the *Modulation and Coding Scheme (MCS)* depending on a prediction of the DL channel condition from UEs (as $\mathrm{UE}_1 \sim \mathrm{UE}_\mathrm{K}$ of Figure 1), which is according to the UE's CQI report transmitted (as bottom part of Figure 1). The 3GPP LTE has given a table of reference for the efficiency of each CQI index (CQI ranges from 1 to 15 by modulation type of 64QAM, 16QAM and QPSK) as Table 1. Estimation of the channel capacity depends on the CQI reports from a UE, meaning that different UEs would have different views of the channel capacity. Current scheduling algorithms such as MT, PF and EDF only consider all UEs' rate or delay requirement, and these scheduling schemes cannot fit the individual UE's requirement with different traffic specification. To provide flexible network quality scheduling scheme with lower computing effort, we consider both time and frequency domains with the proposed two steps scheduling scheme as *Max Rate Delay Urgency First (MRDUF)/First Come First Serve (FCFS)*. Our proposed novel MRDUF/FCFS scheme is based on UE's satisfaction to appropriately allocate radio resources for UEs' traffic in LTE network.

2.1. Time domain packet scheduler: MRDUF.

In our proposed scheme, the first step is called MRDUF, the MRDUF scheme will calculate UEs' rate distribution and urgency of the UE delay budget to allocate the priority of each UE traffic, and the calculation Formulas (1)-(3) are as follows:

$$U_{rate,i} = 1 - \min\left(\frac{\overline{r}_\iota}{GBR_i}, 1\right) \tag{1}$$

$$U_{delay,i} = \frac{d_{HOL,i}}{D_{QCI,i}} \tag{2}$$

$$TD\_P_i = \max(U_{rate,i}, U_{delay,i}) \tag{3}$$

$U_{rate,i}$ is the UE_i's traffic rate and $U_{delay,i}$ is the delay level. Moreover, we also add TD_P_i as the priority parameter of UE_i, $\overline{r}_\iota$ is the average bit rate of UE_i in current TTI period, GBR_i is the requirement bit rate of UE_i, $d_{HOL,i}$ is current UE_i's head-of-line in the packet buffer and $D_{QCI,i}$ is UE_i's delay budget of UE_i's QCI level. Using these

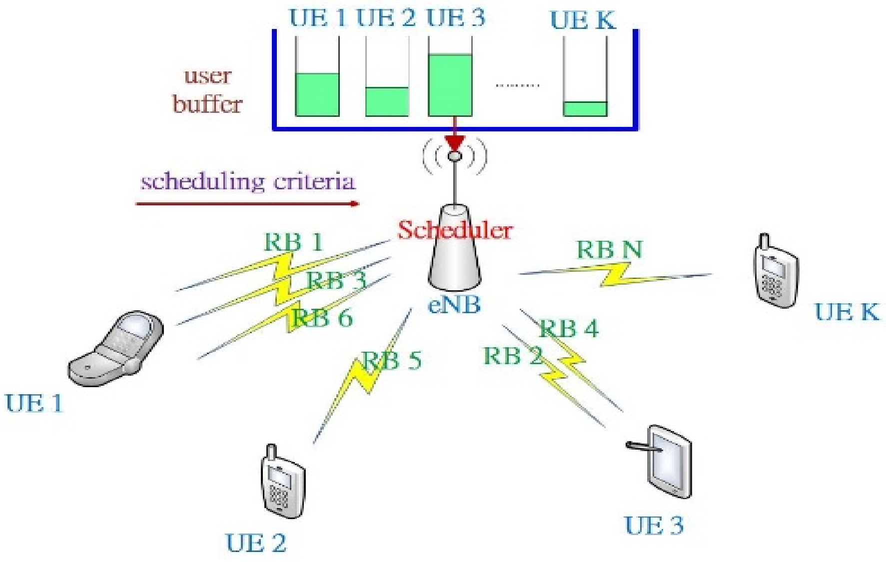


Figure 1. The LTE MAC scheduling diagram

Table 1. LTE CQI table by 3GPP

CQI index	Modulation	Approximate code rate	Efficiency (bits/RE)
0	No Tx	–	–
1	QPSK	0.076	0.1523
2	QPSK	0.12	0.2344
3	QPSK	0.19	0.3770
4	QPSK	0.3	0.6016
5	QPSK	0.44	0.8770
6	QPSK	0.59	1.1758
7	16QAM	0.37	1.4766
8	16QAM	0.48	1.9141
9	16QAM	0.6	2.4063
10	64QAM	0.45	2.7305
11	64QAM	0.55	3.3223
12	64QAM	0.65	3.9023
13	64QAM	0.75	4.5234
14	64QAM	0.85	5.1152
15	64QAM	0.93	5.5547

formulas, the larger TD_P value is, the higher emergence level is. So bigger gap between current rate and requirement rate or delay approaching delay budget will raise the value of TD_P. Furthermore, we design a *Virtual Scheduling List (VSL)* to put how many packets from different UE's traffic in a TTI period, the VSL one TTI delivery capacity as $VSL\_Threshold$, and the calculation Formula (4) is as follows:

$$VSL\_Threshold = N_{RBG} * \left(N_{OFDM}^{TTI} - N_{OFDM}^{Ctrl}\right) * 12(subcarriers) * Eff(CQI_{\max}) \quad (4)$$

In TTE network, two RBs as the Resource Block Group (RBG), so the N_{RBG} is the number of RBG in a TTI period. The number of OFDM symbol is N_{OFDM}^{TTI} in a TTI period, the number of OFDM symbol is N_{OFDM}^{Ctrl} in the control channel, and then the $Eff(CQI_{\max})$ is the best CQI's efficiency. To calculate each UE's TD_P value could sort the priority sequence, and a UE traffic buffer with the largest value of TD_P can have the chance to select a packet into VSL candidate buffer queue. The procedure of

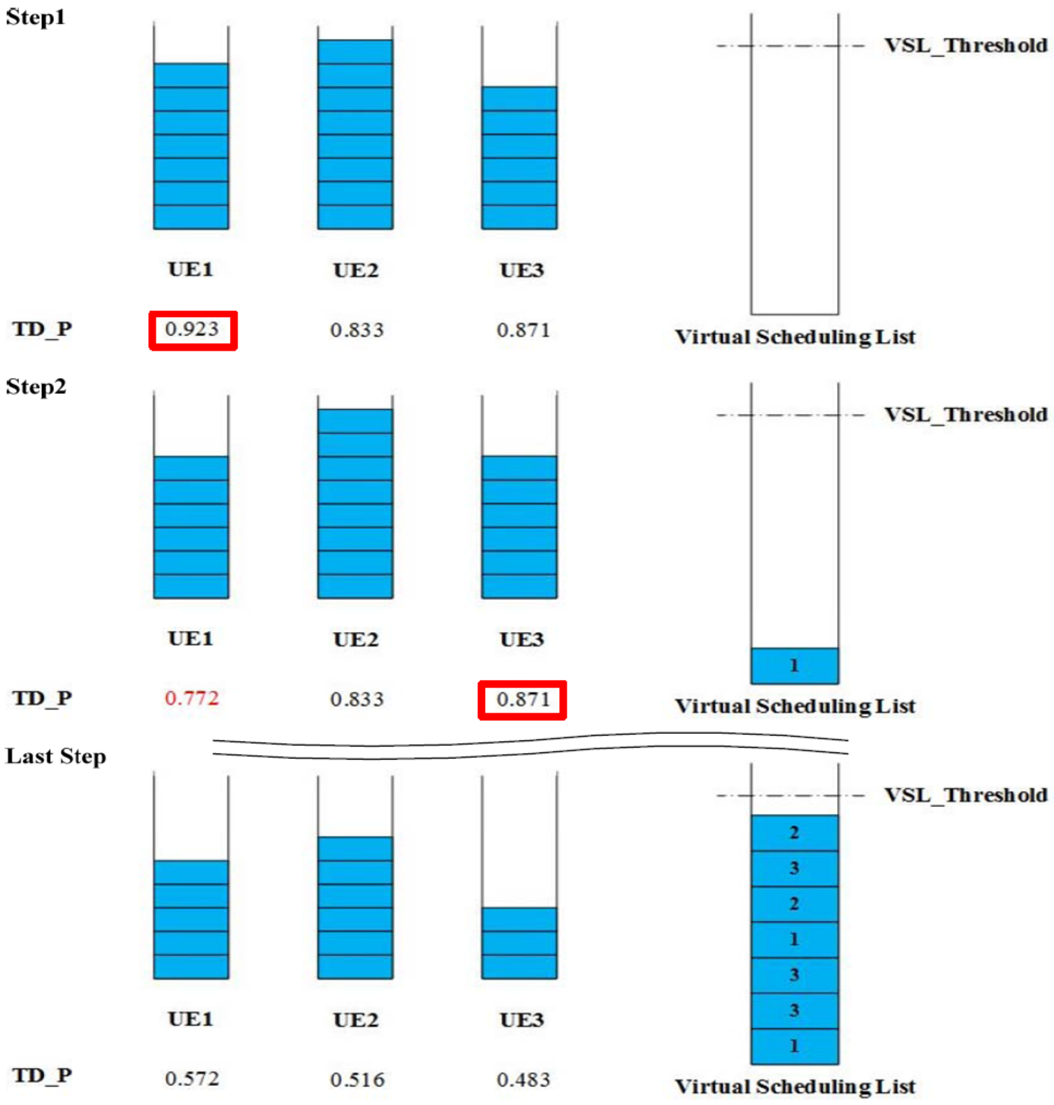


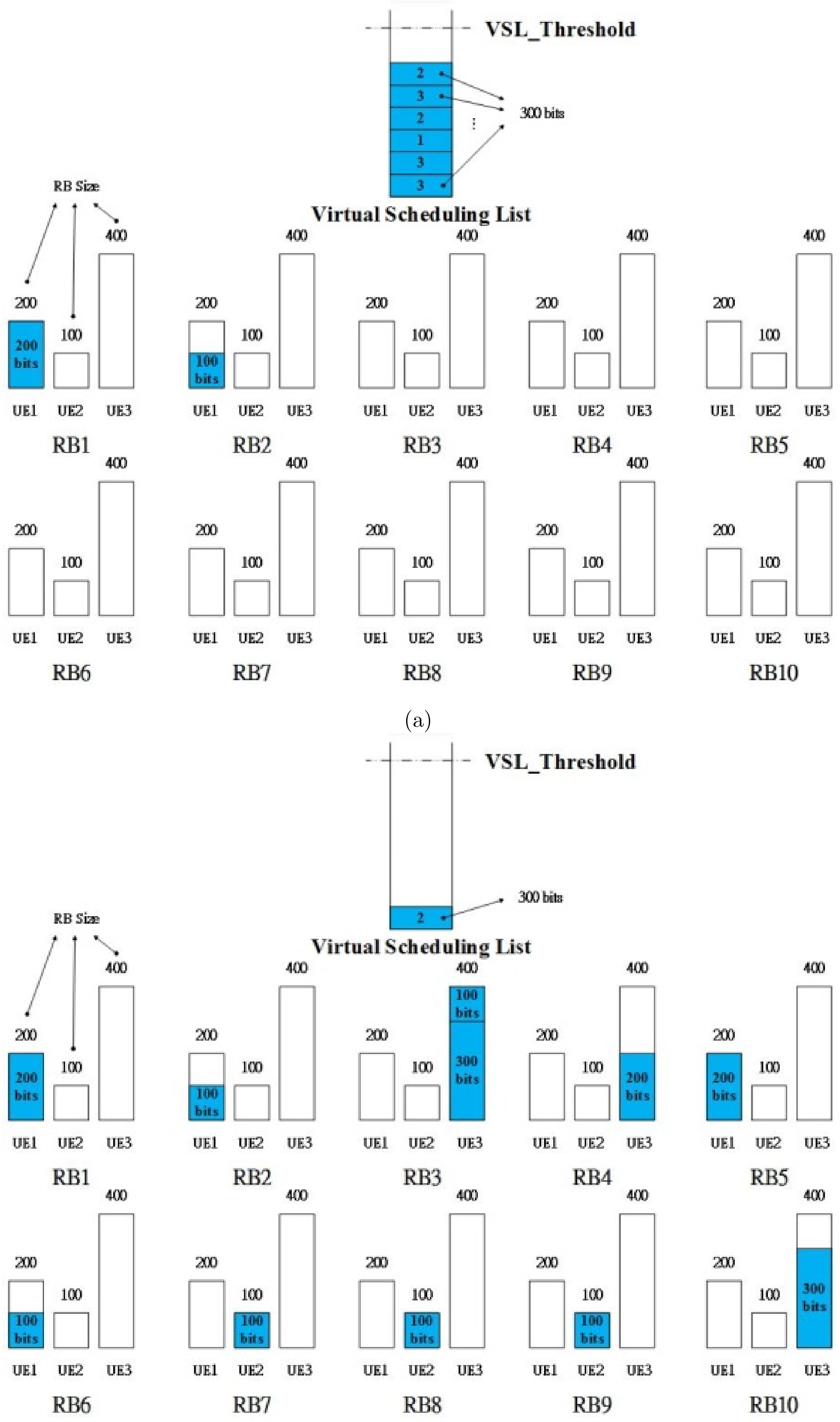
Figure 2. The MRDUF diagram

MRDUF scheme would be continuously run until the next selected UE's packet exceeded the VSL_Threshold as Figure 2. The VSL buffer is the delivery packet list for next step *frequency domain packet scheduler: FCFS*.

2.2. **Frequency domain packet scheduler: FCFS.** Since the VSL is a queue system, our proposed the second step FCFS scheduler should allocate real RB resource according to the VSL queue sequence as Figure 3(a). There are two finished policies, one is no more UE packet in the VSL queue, and the other one is no more free RB space for allocation as Figure 3(b). The two-step mechanisms which have been respectively scheduled from time and frequency domain in consideration with *virtual scheduling list* concept are the detail of our proposed satisfaction-based MRDUF/FCFS scheduling, and it can achieve both rate and delay requirement for different UEs' traffic behavior.

3. Performance Evaluation.

In our simulation environment, there is only one eNB and four real-time traffic types include *VoIP*, *online video*, *online radio* and *video conference* as Table 2. The four types of real-time traffic are designed as uniform distribution, and the detailed simulation parameters are as Table 3. The performance analysis criteria are *Throughput*, *Rate and Delay Satisfaction*, and *Fairness Gain of Rate/Delay Satisfaction*. The definitions of performance criteria are as follows.



(a)

(b)

Figure 3. The FCFS diagram

Throughput: (total received bit in UEs)/(total allocation RBs space).

Rate Satisfaction: (average actual UE's bit rate)/(average UE's requirement bit rate)$*$100%, bigger value would indicate higher rate satisfaction level.

Fairness Gain of Rate/Delay Satisfaction: (SD of MT scheme − SD of other schemes)/(SD of MT scheme)$*$100%, bigger value would indicate fairer rate/delay satisfaction level.

TABLE 2. Traffic flow type

Parameter	**VoIP**	**Online Radio**
Bite Rate	10k bps	10k bps
Packet Size	800 bits	800 bits
Delay Budget	50 ms	300 ms
Parameter	**Online Video**	**Video Conference**
Bite Rate	250k bps	250k bps
Packet Size	8000 bits	8000 bits
Delay Budget	300 ms	50 ms

TABLE 3. Simulation parameters

Parameter	**Value**
Simulation Time	10000 ms
Cell Radius	1.7 km
Number of UEs	24-96
Number of RBs	50
UE Mobility	Random Way Point
UE Speed	Random (15 m/s∼20 m/s)
CQI Reporting Type	Wideband CQI

3.1. **Fairness of satisfaction.** Our proposed schemes can improve both rate and delay fairness satisfaction, and the results are shown as Figure 4 and Figure 5. The PF has the equational fairness gain from light load to heavy load. The EDF can have better fairness gain in heavy load compared to PF scheme. However, our proposed MRDUF/FCFS scheme has higher than 10% gain compared to EDF scheme. So the MRDUF/FCFS outperforms the contrasts especially in heavy.

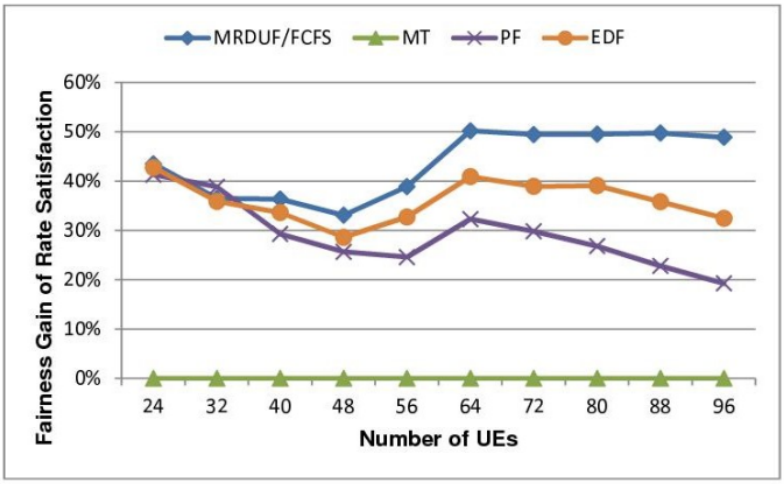


FIGURE 4. Fairness gain of rate satisfaction

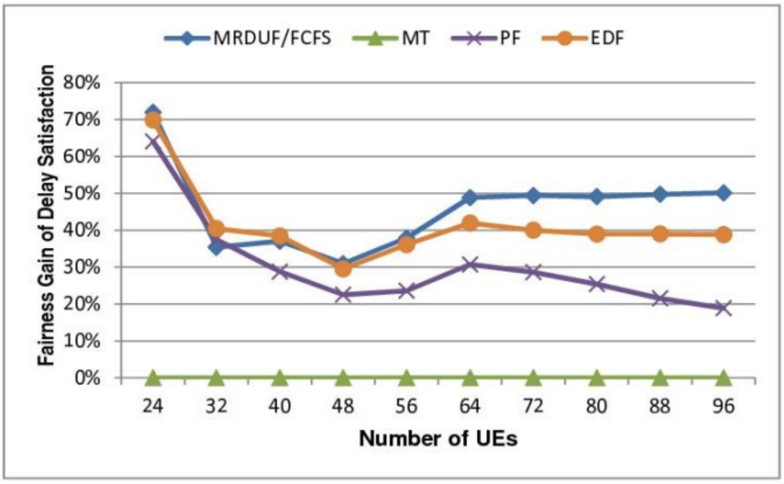


Figure 5. Fairness gain of delay satisfaction

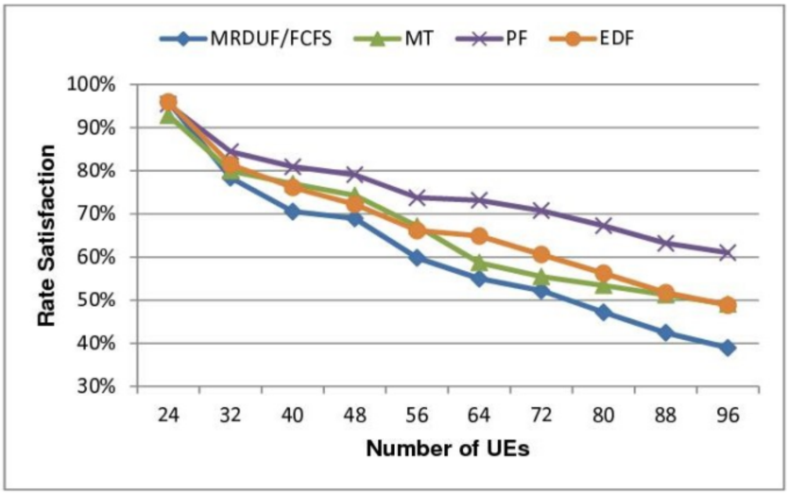


Figure 6. Rate satisfaction

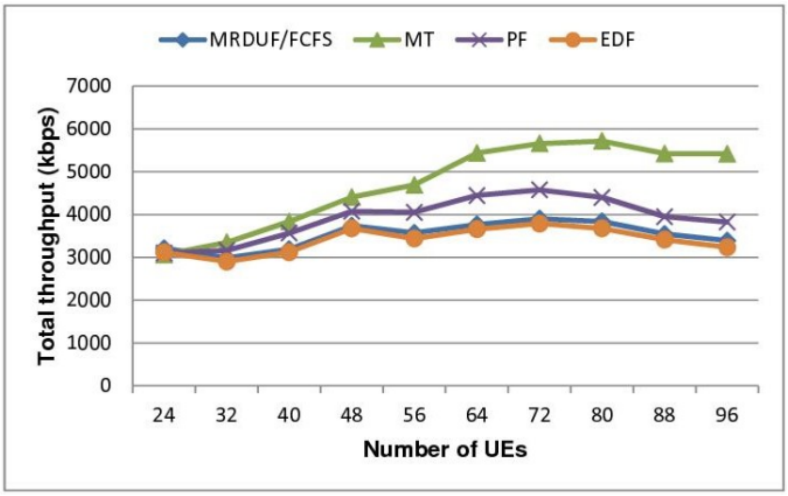


Figure 7. System throughput

3.2. **Rate and delay satisfaction.** In Figure 6, the rate satisfaction is decreasing with increased traffic load. The PF has the best rate satisfaction due to only focusing on per traffic rate requirement, especially the lower bit rate traffic (e.g., VoIP, and online radio) might have 100% satisfaction value with the average calculation benefit effect. However, our proposed MRDUF/FCFS scheme considers not only UE traffic bit rate but also UE traffic delay requirement, and a little bit sacrifice cannot be avoided in rate satisfaction aspect. However, the whole fairness gains have 2-2.5 times compared to PF scheme.

3.3. **Throughput.** In Figure 7, the MT scheme has the best performance due to the maximum throughput specification. The PF should consider the fairness of all UEs' traffic, so the sacrifices cannot be avoided. However, our proposed MRDUF/FCFS concerns not only rate fairness but also delay fairness, and some throughput cannot be improved.

4. **Conclusions.** For current advanced mobile wireless network providers, LTE has attracted attention in the whole world. To find high network quality satisfaction of MAC scheduling in LTE network is a very important research issue, and some traditional scheduling schemes have discussed about this idea in many research articles. A novel network quality satisfaction scheme should consider UE's traffic both rate and delay requirement and concern both two aspects' fairness, and our proposed MRDUF/FCFS scheme can achieve this goal. Moreover, our proposed MRDUF/FCFS scheme can support both real-time and non-real-time UE's traffic requirement and achieve higher fairness. Simulation results have shown that the fairness gain in rate and delay have the best performance even though the rate satisfaction and throughput have less performance. The fairness gain would have 50% gain better than contrasts, and it is very important benefit for network quality satisfaction scheduling aspect. For two-hop structure in LTE-A network, how to design an appropriate scheme for both backhaul link (eNB to RNs) and access link (RN to UEs) resources allocation is also an important research issue for scheduling area in the future.

Acknowledgments. This work was supported in part by the Ministry of Science and Technology, Taiwan, under grant no. MOST-103-2221-E-028-001.

REFERENCES

[1] 3GPP, *Radio Access Network; UTRAN Overall Description*, Tech. Spec. 3GPP TS 25.401, v. 10.2.0, 2011.

[2] 3GPP, *Policy and Charging Control Architecture (Release 11)*, Tech. Spec. TS 23.203 V11.9.0, 2013.

[3] 3GPP, *Physical Layer Procedures (Release 10)*, Tech. Spec. TS 36.213 V10.0.1, 2011.

[4] Roke Manor Research Ltd, *LTE MAC Scheduler & Radio Bearer QoS*, 2011.

[5] Roke Manor Research Ltd, *LTE MAC Scheduler & Radio Resource Scheduling*, 2012.

[6] J.-Y. Chen, C.-C. Yang and Y.-T. Mai, A novel smart forwarding scheme in LTE-advanced networks, *China Communications*, vol.12, no.3, pp.120-131, 2015.

[7] A. Biernacki and K. Tutschku, Comparative performance study of LTE downlink schedulers, *Wireless Personal Communications*, vol.74, no.2, pp.585-599, 2014.

[8] R. Mugisha and N. Ventura, Packet scheduling for VoIP over LTE-A, *Proc. of AFRICON Conference*, pp.1-6, 2013.

[9] T.-M. de Moraes, A.-B. Saleh, G. Bauch and E. Seidel, QoS-aware traffic scheduling in LTE-advanced relay-enhanced networks, *Proc. of Vehicular Technology Conference*, pp.1-5, 2013.

[10] S. Yi and M. Lei, Backhaul resource allocation in LTE-advanced relaying systems, *Proc. of Wireless Communications and Networking Conference*, pp.1207-1211, 2012.