19th International Computer Science and Engineering Conference (ICSEC)
Chiang Mai, Thailand, 23-26 November, 2015

Delay-Aware with Resource Block Management Scheduling Algorithm in LTE

Korn Kaewmongkol, Aphirak Jansang and Anan Phonphoem*
Department of Computer Engineering
Kasetsart University
Bangkok, Thailand
Email: {g5414550018,aphirak.j,anan.p*}@ku.ac.th

***Abstract*—Long Term Evolution (LTE) is a broadband wireless technology that promises to high throughput. In order to simultaneously support several mobile users with real time and non-real time applications, the resource management and Quality of Service (QoS) requirements of delay-sensitive traffic should be carefully aware. In this paper, The Delay-Aware with Resource Block Management Scheduling Algorithm in LTE has been proposed with the delay threshold called C_{value} and the RB ratio of RT and NRT traffic in order to satisfy QoS requirements, especially for the RT traffic. Both delay threshold and RB ratio are used to control queue length and packet delay. The simulation results reveal that the proposed algorithm performs better than the PF algorithm for the average packet delay, the system throughput and the packet loss ratio.**

***Keywords*—LTE, resource block management, packet scheduling, QoS, delay**

I. Introduction

The important characteristics of multimedia application are high bandwidth consumption and delay sensitivity. Nowadays, mobile devices can support social network applications, such as voice and video calls. The increasing number of mobile users requires more bandwidth. However, most current widely deployed wireless technologies, such as 3G and GPRS, cannot support.

Long Term Evolution (LTE) [1], [2] or 4G technology designed for supporting high data rate with various bandwidth range from 1.4 MHz to 20 MHz. The maximum uplink and downlink data rate are 50 and 100 Mbps, respectively. However, users might experience jitter and long delay once the number of users are more than the LTE available resources. Hence, the LTE system requires suitable resource management (RM) mechanisms, located at the eNodeB, for handling traffic of mobile users (UE) as their QoS requirements.

Usually the RM mechanisms focus on the scheduling algorithm based on the channel quality indication (CQI) without packet delay awareness for each particular UE. For general usages, both delay sensitive application traffics, called real time (RT), and delay insensitive application traffics, called non-real time (NRT), simultaneously utilize and compete for available resources.

From previous researches, some scheduling algorithms consider only CQI but not the fairness among UEs. While many concentrate only fairness but ignoring CQI. Some work involve in CQI, fairness and delay factors but no priority concerns for each traffic categories. Some concern about the packet drop history to adjust the resource block but not considering about the packet delay.

In this research, a Delay-Aware with Resource Block Management Scheduling Algorithm in LTE has been proposed. The algorithm utilizes the packet delay constraints as a threshold and divides the suitable RB ratio for different traffic types. The ultimate goal is for reducing RT average packet delay while maintaining the fairness for the NRT packets.

The rest of this paper is organized as follows. In section II, the basic concepts of LTE have been reviewed. Section III shows the related work. In section IV and V, the proposed methods and performance evaluation are described, respectively. Finally in section VI, the conclusion and future work are discussed.

II. LTE overview

LTE system architecture composes of Evolved Packet Core (EPC) and Radio network (E-UTRAN). EPC responses for gateway to Internet, routing among eNodeBs (eNB), QoS and mobility management.

While E-UTRAN, responsible for user and control plane communications, composes of group of eNBs that provide connection from the User Equipment (UE) to the LTE system. The communication from UE to the eNB, called uplink, uses the Single Carrier Frequency Division Multiple Access (SC-FDMA). Whereas the downlink connection, from eNB to UE, uses Orthogonal Frequency Division Multiple Access (OFDMA).

To maintain the appropriate delay, throughput, fairness, and packet loss, an intelligent media access control function is required. In an eNB [2], a Scheduler module, operated at Medium Access Control (MAC) layer, takes care of managing the packet transmission ratio for UEs. Each UE will be allocated with an amount of resources called Resource Block (RB), the smallest unit of resource allocation, for each Transmission Time Interval (TTI).

An LTE frame lasts 10 millisecond (ms) composed of 10 consecutive TTIs. Each TTI lasts 1 ms composed of two time slots (also called RB) with 0.5 ms span. Each RB is 7 OFDM symbols and 180 kHz divided into 12 sub-carriers (84 resource

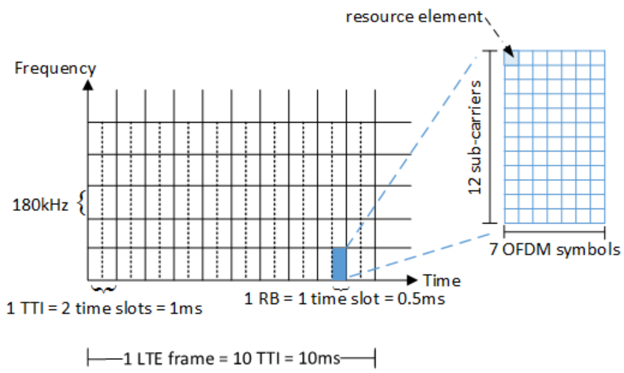


Fig. 1: Radio Resources in Time/Frequency Domain

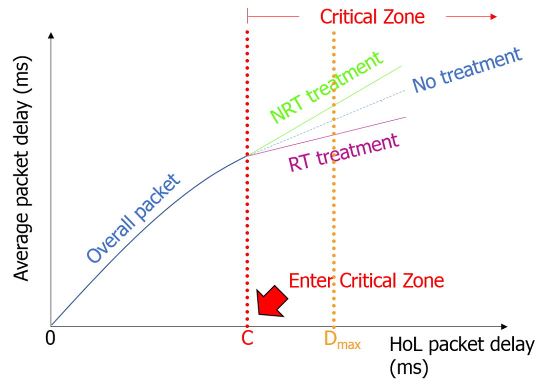


Fig. 2: Critical Zone

elements), as shown in Fig.1. The number of RBs depends on the system bandwidth configuration [2]–[4].

III. Related Work

From the previous work on scheduling mechanisms, the classical algorithms are Maximum Throughput (MT) [2], [5], [6], Round Robin (RR) [2], [5], [6], and Proportional Fair (PF) [2]–[7]. MT focuses on getting maximum throughput without fairness concern. While RR focuses on fairness without system throughput awareness. PF tries to balance between throughput and fairness but not delay awareness.

Based on PF algorithms, many algorithms have been proposed for supporting QoS requirements, especially packet delay constraint for RT traffic. From the proposed enhancing techniques, these algorithms can be grouped according to their techniques as weight function optimization, cross-layer, pro-active, emergency zone management, and RB allocation.

Weight function optimization techniques have been proposed by [3], [5]–[11]. To avoid long packet delay, researches focus on packet priority sorting before transmission by using ratio of head-of-line (HOL) packet delay over the maximum packet delay (D_{max}) as the main parameter.

For users quality of experience (QoE) improvement in video transmission, the cross-layer technique has been developed in [12]–[14]. Packets will be transmitted according to the priority sorting estimated by 1) the video distortion in application layer, 2) instance achievable rate, delay constraint and historical data rate in MAC layer and 3) the CQI from physical layer. Techniques are concentrated only on the RT traffic which might lead to the fairness issue once RT and NRT traffic are coexisted.

A pro-active technique [15] predict the queue length of UE that affects the HOL delay. By using the queue length, some techniques [4], [16] pre-calculate the quota of packets to transmit in an LTE frame for delay violation avoidance.

For the emergency zone management technique [17]–[19], a delay threshold has been used for raising the packet priority as an emergency packet. The goal is to avoid the packet delay violation.

In [20], the RB allocation technique has been proposed. In each TTI, the packet loss rate (PLR) has been used as a parameter for allocating RBs. The technique can reduce the PLR of RT traffic while maintains the fairness for NRT traffic.

In this paper, in order to address packet delay and fairness between RT and NRT, the "Delay-Aware with Resource Block Management Scheduling Algorithm in LTE" has been proposed. The delay threshold and RB ratio are investigated for balancing the system performance and RT packet delay.

IV. Proposed Method

The proposed algorithm initializes the ratio of allocated RBs for RT and NRT (e.g. 70:30 for RT:NRT). Then the algorithm will monitor the HOL packet delay of RT, for each UE, which has been compared with a C_{value} which is an early warning packet delay threshold, in millisecond, before reaching the maximum packet delay (D_{max}) which causes the delay violation, as shown in (1).

$$0 < C < D_{\max} \quad (1)$$

Once the HOL packet delay reaches the threshold C_{value}, the packet is now entering the critical zone, shown in Fig.2. If critical RT packets (N), from all UEs, are over a predefined numbers, X (e.g. X = 2 packets), a certain percentage, W (e.g. W = 10%) of allocated NRT RBs will be reduced and added to the RT. Otherwise, the RB ratio of RT and NRT remains the same as initial. Then the PF scheduling will be deployed.

Normally, for the regular PF [2], [3], all queues from all UEs in each TTI are prioritized based on current potentially achieve data rate (CR) and historical data rate (DR). For the interested k^{th} RB, the priority P_{jk} of the j^{th} queue is derived, for all j, according to (2). The k^{th} RB will be assigned to the queue that has the maximum P_{jk}.

$$P_{jk} = \frac{CR_j}{DR_j} \quad (2)$$

However, not same as the regular PF that has been applied to all queues from all UEs regardless of the RT or NRT traffic, the proposed algorithm applies the PF to RT and NRT separately. The algorithm details are shown in Fig.3.

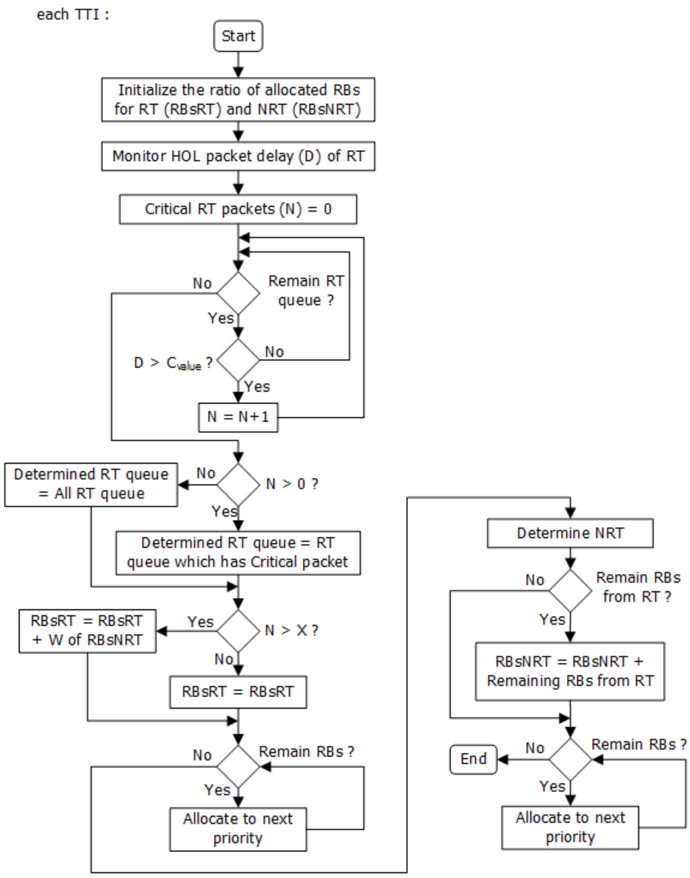


Fig. 3: Proposed algorithm in each TTI

V. Performance Evaluation

In this section, the testing scenario and simulation parameters are described. Then the results and analyze are presented.

A. Simulation Setup

The algorithm has been simulated on NS-3 simulator [21] version 3.19. Testing scenario, shown in Fig.4, composes of a single eNB connected to a remote host via point-to-point connection. The users, UEs, connect to eNB in a single hop manner with two traffic types, RT and NRT.

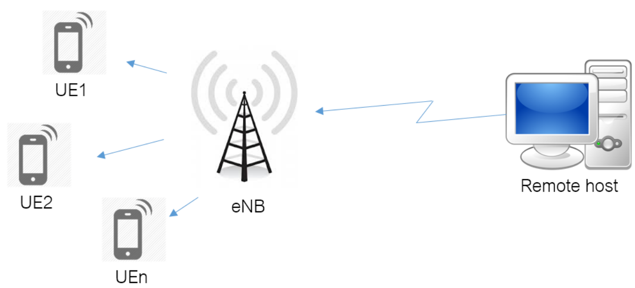


Fig. 4: Testing Scenario

The simulation area is 100x100 m. Each UE will travel in the area by using the 2-D Random Walk mobility model. The simulation parameters for the system are shown in Table I.

TABLE I: Simulation Parameters

Parameter	**Value**
Simulation times	15 seconds
Carrier frequency	5.15 GHz
Downlink channel bandwidth	5 MHz
Number of Resource Blocks	25 (180 KHz per block)
TTI	1 ms
UE Mobility model	RandomWalk2dMobilityModel
Modulation scheme	QPSK, 16QAM, 64QAM
Point-to-point connection	Data rate = 100 Gbps Transmission delay = 10 ms
Maximum Delay for RT (D_{max}) [2]	100 ms

At the remote host, the constant bit rate (CBR) application has been used for generating an UDP traffic with 1024 bytes per packet and 800 Kbps Data rate. The system allocates 20 NRT traffics (20 UEs) run as a background load.

The numbers of 0 to 50 RT traffics will be investigated. Each UE runs only one traffic type, RT or NRT, with infinite buffer size.

For system performance evaluation, firstly, the various C_{value} of 50, 70 and 90 percent of RT D_{max} have been investigated with the fixed RB ratio of 60:40. Then the certain RB ratio of 50:50, 70:30 and 90:10 have been tested with the fixed C_{value} of 70 percent of RT D_{max}.

B. Simulation Results

B.1: C_{value} Investigation

For the C_{value} investigation compared with regular PF, the ratio of RB for RT:NRT is fixed at 60:40 with 20 NRT sessions running as the background traffic. The system has been tested by increasing RT sessions from 0 to 50 sessions. The average packet delay, system throughput, and packet loss ratio of RT and NRT traffic are shown in Fig.5.

For PF algorithm, the average packet delay (end-to-end delay), as shown in Fig.5a, rapidly increases when the number of RT traffic are less than 30 sessions and tends to be stable when there are more than 30. The results for both RT and NRT traffic are the same because the system treats both RT and NRT equally.

While the proposed algorithm treats RT and NRT traffic separately, the results explicitly separate among traffic due to the different RBs allocated and C_{value}. For RT traffic, the average packet delay rapidly increases when the number of RT traffic is less than 30 and slowly increases after that. In case of zero RT traffic, the NRT traffic got fully allocated RBs therefore no longer delay occurs.

RBs are allocated to RT traffic more than NRT traffic while number of NRT traffic are constant at 20 sessions along with the simulation. Thus the average packet delay of RT traffic will normally decrease. In each TTI, if the RBs allocated to the critical RT traffic are not enough, RT will take some RBs from NRT traffic. Therefore, the average packet delay of RT traffic becomes lower compared to NRT. As PF does not distinguish between traffic types and not deal with critical

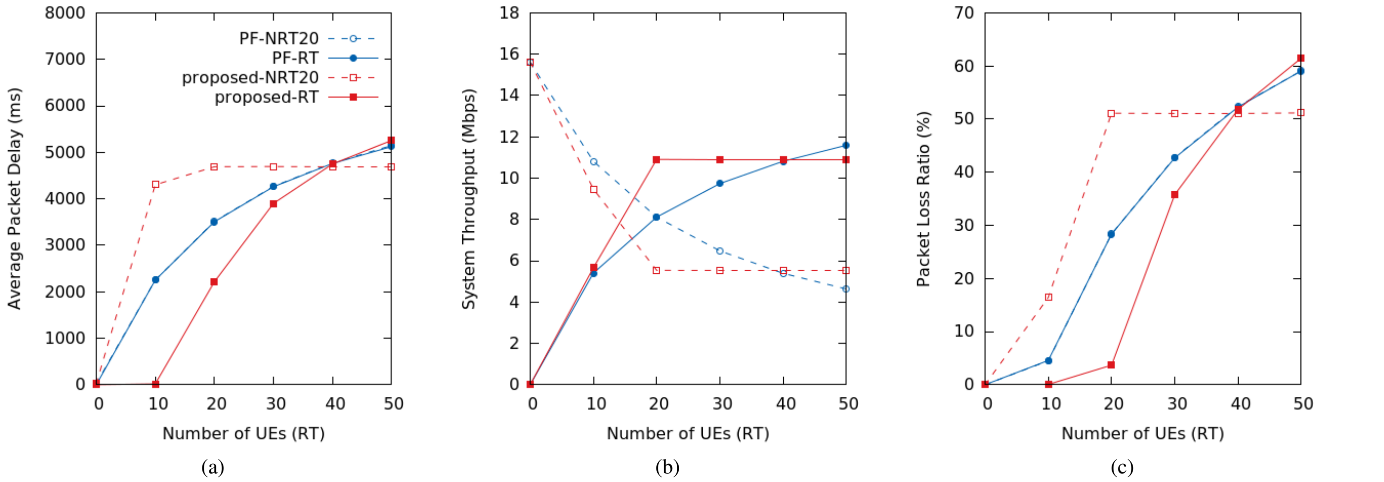


Fig. 5: The results with C_{value} of 50%D_{max}, 70%D_{max} and 90%D_{max} (a) Average packet delay (b) System throughput (c) Packet loss ratio

traffic, the average packet delay of RT traffic in PF is more than in the proposed algorithm.

According to the similar results in average packet delay, the system throughput is also shown in Fig.5b. For the proposed algorithm, throughput of RT traffic rapidly increases when the number of RT traffic is less than NRT. Then it tends to be stable when the number of RT traffic begins to be more than NRT. As RT traffic use more allocated RBs than NRT, RT traffic has more opportunity to transmit than NRT.

In term of packet loss ratio as shown in Fig.5c, PF shows that both RT and NRT traffic rapidly increase when the number of RT traffic is less than the number of NRT traffic and slows down when the number of RT traffic is more than the number of NRT. For the proposed scheme, the packet loss ratio of the RT traffic is less than PF scheme, while the packet loss ratio of NRT traffic becomes more than PF scheme. Packet loss ratio rapidly increases when the number of RT traffic is less than the number of NRT and becomes stable when the number of RT traffic exceeds the number of NRT. The reasons are about RBs allocation and determined critical RT traffic as aforementioned.

However, in Fig.5, there is no significantly different results (only few milliseconds) from various C_{value} of 50, 70 and 90% of D_{max} (as shown only one figure for all C_{value}). Due to only small amount of RBs borrowing process in each TTI, it might be concluded that the C_{value} is not a significantly factor to improve the performance in the testing scenario.

B.2: RB ratio Investigation

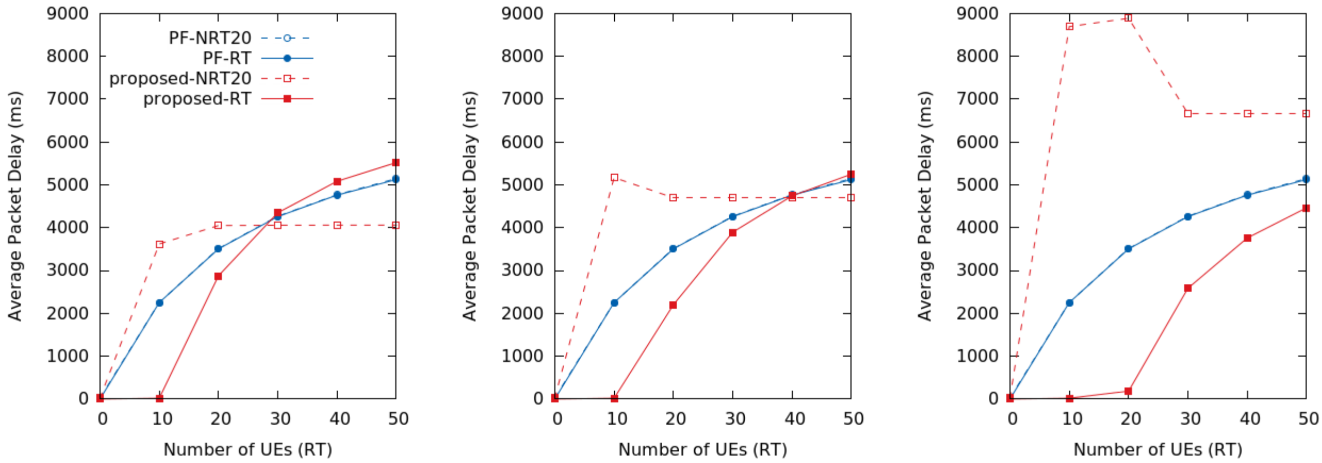
To investigate the effect of RB ratio of RT:NRT, the C_{value} is fixed at 70% of D_{max} with 20 NRT sessions running as the background traffic. The system has been tested by increasing RT sessions from 0 to 50 sessions. The average packet delay, system throughput, and packet loss ratio of RT and NRT traffic are shown in Fig.6 - 8.

For the average packet delay as shown in Fig.6, PF scheme shows that delay for both RT and NRT traffic rapidly increase when number of RT traffics is less than NRT and tends to be stable when number of RT greater than 30. However, for the proposed scheme, the average packet delay of RT traffic rapidly increases when number of RT is less than NRT traffic and slows down until becomes stable when the number of RT reaches 30. Obviously the average packet delay of NRT rapidly decreases and becomes stable when number of RT is greater than NRT.

By observing the effect of RB ratio shown in Fig.6a, 6b, and 6c, allocating more RBs to RT traffic can decrease the average packet delay of RT which is lower than the PF. While the average packet delay of NRT becomes high, especially for the RB ratio of 90:10.

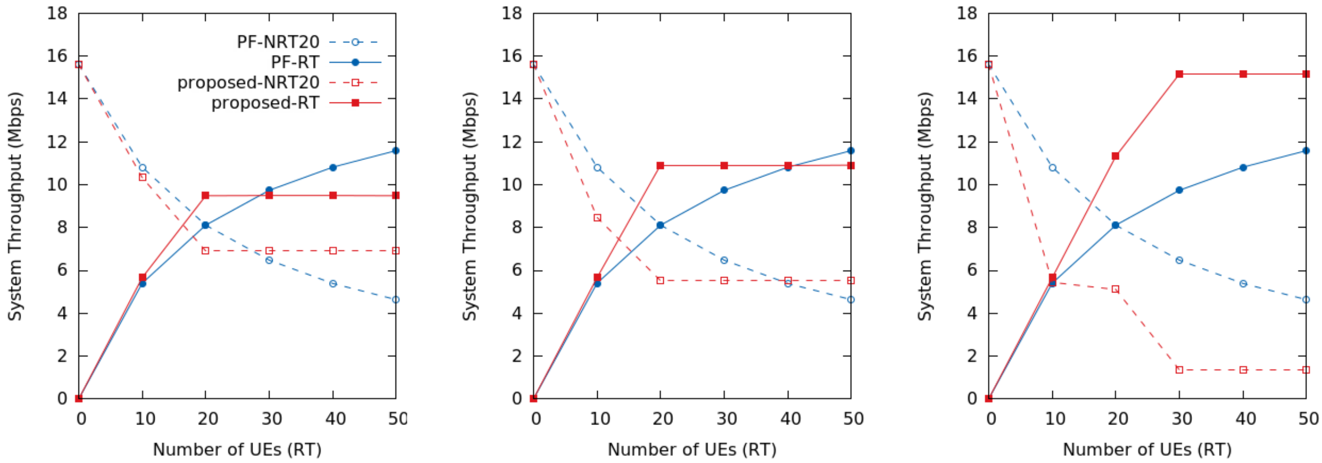
For the system throughput, shown in Fig.7, both PF and proposed algorithm reveal similar results. The system throughput of RT traffic will increase and become stable when the number of RT traffic greater than NRT. While the system throughput of NRT traffic performs oppositely. However, the RT system throughput of the proposed scheme becomes higher than PF for the high RB ratio. As shown in Fig.7a, 7b, and 7c, the more RBs allocation to RT traffic, the more RT system throughput.

For the packet loss ratio, shown in Fig.8, PF shows the increasing of packet loss ratio for both RT and NRT when the number of RT traffic increases. Meanwhile the proposed scheme reveals that the RT packet loss ratio only increases when the number of RT increases, while the NRT packet loss ratio tends to be stable when the number of RT is greater than NRT. As a result of various RB ratios shown in Fig.8a, 8b, and 8c, the high RB ratio for RT can decrease its packet loss ratio, while packet loss ratio of NRT increases and becomes very high for the ratio of 90:10 because there is not enough RBs allocated for the NRT traffic which can lead to high packet waiting time and expired packets.



(a) (b) (c)

Fig. 6: Average Packet Delay, with RB ratio RT:NRT (a) 50:50 (b) 70:30 (c) 90:10



(a) (b) (c)

Fig. 7: System Throughput, with RB ratio RT:NRT (a) 50:50 (b) 70:30 (c) 90:10

VI. Conclusion

Although according to the not significantly effect of the C_{value}, the C_{value} of the proposed algorithm can decrease the average delay of RT, while the delay of NRT is still lower than the PF. Also the system throughput and packet loss ratio of RT are better than the PF while the throughput and packet loss ratio of NRT is quite the same as PF.

The RB ratio also obviously affects the scheme performance. At the RB ratio for RT:NRT of 70:30 seems to be the suitable ratio that can significantly decrease the RT average delay while the NRT average delay is still the same as PF. However, with the high ratio of 90:10, the NRT average packet delay and packet loss ratio are highly affected.

The proposed algorithm has shown that with the threshold and RB ratio, the RT traffic can be treated appropriately. However, the NRT traffic is needed to be degraded as the trade-off

For more realistic situation, defining with fixed value of RB ratio may seem to be not reasonable due to the time varying which might affect the amount of packets in queue, HOL packet delay, CQI feedback, throughput, and number of packet loss for various traffic types. Therefore, in the future work, the system should be able to automatically and properly tune.

References

[1] D. Astely, E. Dahlman, A. Furuskar, Y. Jading, M. Lindstrom, and S. Parkvall, "Lte: the evolution of mobile broadband," *Communications Magazine, IEEE*, vol. 47, no. 4, pp. 44–51, April 2009.

[2] F. Capozzi, G. Piro, L. Grieco, G. Boggia, and P. Camarda, "Downlink packet scheduling in lte cellular networks: Key design issues and a survey," *Communications Surveys Tutorials, IEEE*, vol. 15, no. 2, pp. 678–700, Second 2013.

[3] S. J. Bae, B.-G. Choi, and M. Chung, "Delay-aware packet scheduling algorithm for multiple traffic classes in 3gpp lte system," in *Communi-*

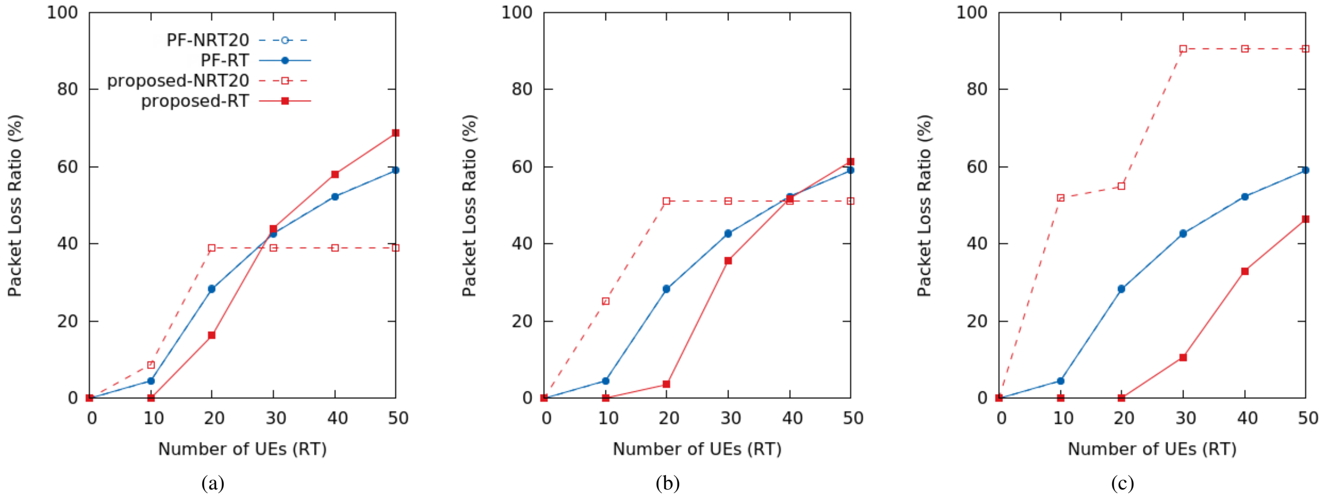


Fig. 8: Packet Loss Ratio, with RB ratio RT:NRT (a) 50:50 (b) 70:30 (c) 90:10

cations (APCC), 2011 17th Asia-Pacific Conference on, Oct 2011, pp. 33–37.

[4] G. Piro, L. Grieco, G. Boggia, R. Fortuna, and P. Camarda, "Two-level downlink scheduling for real-time multimedia services in lte networks," *Multimedia, IEEE Transactions on*, vol. 13, no. 5, pp. 1052–1065, Oct 2011.

[5] H. Ramli, R. Basukala, K. Sandrasegaran, and R. Patachaianand, "Performance of well known packet scheduling algorithms in the downlink 3gpp lte system," in *Communications (MICC), 2009 IEEE 9th Malaysia International Conference on*, Dec 2009, pp. 815–820.

[6] R. Zhang and D. Zhao, "An evolved buffer status aware packet scheduling algorithm for mixed services in the downlink of ofdm system," in *Audio Language and Image Processing (ICALIP), 2010 International Conference on*, Nov 2010, pp. 1531–1536.

[7] D. Wang, R. Soni, P. Chen, and A. Rao, "Video telephony over downlink lte systems with/without qos provisioning," in *Sarnoff Symposium, 2011 34th IEEE*, May 2011, pp. 1–5.

[8] K. Sandrasegaran, H. Ramli, and R. Basukala, "Delay-prioritized scheduling (dps) for real time traffic in 3gpp lte system," in *Wireless Communications and Networking Conference (WCNC), 2010 IEEE*, April 2010, pp. 1–6.

[9] B. Liu, H. Tian, and L. Xu, "An efficient downlink packet scheduling algorithm for real time traffics in lte systems," in *Consumer Communications and Networking Conference (CCNC), 2013 IEEE*, Jan 2013, pp. 364–369.

[10] M. M. Nasralla and M. G. Martini, "A downlink scheduling approach for balancing qos in lte wireless networks," in *Personal Indoor and Mobile Radio Communications (PIMRC), 2013 IEEE 24th International Symposium on*, Sept 2013, pp. 1571–1575.

[11] B. Palit, M. Tyagi, V. Manoja, and S. Das, "A generic real-time traffic scheduler for ofdma based cellular networks," in *Communications (NCC), 2014 Twentieth National Conference on*, Feb 2014, pp. 1–6.

[12] H. Luo, S. Ci, D. Wu, J. Wu, and H. Tang, "Quality-driven cross-layer optimized video delivery over lte," *Communications Magazine, IEEE*, vol. 48, no. 2, pp. 102–109, February 2010.

[13] P. Omiyi and M. Martini, "Cross-layer content/channel aware multi-user scheduling for downlink wireless video streaming," in *Wireless Pervasive Computing (ISWPC), 2010 5th IEEE International Symposium on*, May 2010, pp. 412–417.

[14] M. Nasimi, M. Kousha, and F. Hashim, "Qoe-oriented cross-layer downlink scheduling for heterogeneous traffics in lte networks," in *Communications (MICC), 2013 IEEE Malaysia International Conference on*, Nov 2013, pp. 292–297.

[15] W. K. Lai and C.-L. Tang, "Qos-aware downlink packet scheduling for {LTE} networks," *Computer Networks*, vol. 57, no. 7, pp. 1689 – 1698, 2013. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S1389128613000352

[16] E. M. Ang, K. K. Wee, Y. H. Pang, and S. H. Lau, "Two-level scheduling framework with frame level scheduling and exponential rule in wireless network," in *Information Science and Applications (ICISA), 2014 International Conference on*, May 2014, pp. 1–4.

[17] S. Sun, Q. Yu, W. Meng, and C. Li, "A configurable dual-mode algorithm on delay-aware low-computation scheduling and resource allocation in lte downlink," in *Wireless Communications and Networking Conference (WCNC), 2012 IEEE*, April 2012, pp. 1444–1449.

[18] C. Wang and Y.-C. Huang, "Delay-scheduler coupled throughput-fairness resource allocation algorithm in the long-term evolution wireless networks," *Communications, IET*, vol. 8, no. 17, pp. 3105–3112, 2014.

[19] S. Hendaoui, N. Zangar, and S. Tabbane, "Qos aware pre-emption: A new proposition for lte downlink schedulers," in *Wireless Communications Systems (ISWCS), 2014 11th International Symposium on*, Aug 2014, pp. 744–749.

[20] R. Kausar, Y. Chen, and K. Chai, "Adaptive time domain scheduling algorithm for ofdma based lte-advanced networks," in *Wireless and Mobile Computing, Networking and Communications (WiMob), 2011 IEEE 7th International Conference on*, Oct 2011, pp. 476–482.

[21] The ns-3 simulator website. [Online]. Available: https://www.nsnam.org/