Jurnal Teknologi

Full Paper

PERFORMANCE ANALYSIS OF THE ENERGY CONSUMPTION OF THE SCHEDULING ALGORITHMS IN LONG TERM EVOLUTION LTE (LONG TERM EVOLUTION) NETWORKS

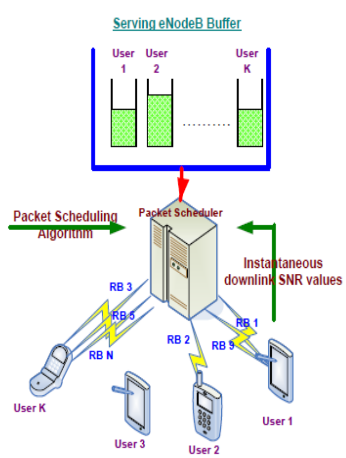
Article history
Received
10 December 2015
Received in revised form
16 January 2016
Accepted
18 February 2016

Nurulanis Mohd Yusoff*, Darmawaty Mohd Ali, Ku Siti Syahidah Ku Mohd Noh

Wireless Communication Technology Group (WiCoT), Advanced Computing and Communication Communities of Research, Faculty of Electrical Engineering, Universiti Teknologi MARA (UiTM), 40450 Shah Alam, Selangor Darul Ehsan, Malaysia

*Corresponding author
2013434872@isiswa.uitm.edu.my

Graphical abstract



Abstract

Energy efficiency has become an important feature in communication systems due to the problem of global warming and lack of energy resources. The impact on global warming caused by wireless communication industries has been gradually increasing, so it is obvious that developing the green communication is significant. In particular, energy consumption in the base stations and downlink transmission are the major areas where significant conservation can be achieved. Thus, the objective of this study is to investigate the performance of the packet scheduling algorithms in the downlink transmission and the energy consumption for video and Voice over IP (VoIP) applications in Long Term Evolution (LTE) systems. In this work, four different scheduling algorithms were analysed namely the Channel and Quality of Service Aware Proportional Fair (CQA_PF), CQA Frequency Fading (CQA_Ff), Priority Set Scheduler Proportional Fair (PSS_PF), and PSS Carrier Over Interference to Average (PSS_CoItA) based on the performance metrics of throughput, delay, energy consumption ratio (ECR) and fairness. The results showed that the CQA algorithm for both methods (CQA_PF and CQA_Ff) outperformed the other algorithms since it has the highest throughput with an increase of up to 25%. Meanwhile, for delay and ECR, the CQA scheduler was the lowest of up to 20% as compared to the PSS scheduler. Thus, it can be concluded that CQA is the most energy efficient algorithm to schedule the video and VoIP applications.

Keywords: LTE, scheduling algorithm, video, VoIP, ns3, energy consumption

1.0 INTRODUCTION

One of the most serious challenges faced by telecommunications network operators worldwide is energy consumption reduction as their networks grew in size, complexity, density, increased energy consumption and thereby increasing energy related Operational Expenditures (OPEX) [1]. The OPEX reductions can be achieved by decreasing the base station (BS) energy consumption [2]. The paper of [3] states that reducing energy consumption is also important to develop green communication besides the strategies of improving user Quality of Service (QoS). As reported by [4], the total energy consumed by wireless access networks in mobile communication network operators is 80%. International Telecommunication Union (ITU) confirmed that the global mobile phone users reached 6 bilion in 2012.

The impact on global warming caused by wireless communication industries has been gradually increasing, so it is obvious that developing the green communication is significant [5].

The theoretical basis of an energy-efficient scheduling policy is mainly due to low transmit power from the base station and user equipment (UE). The bandwidth, channel quality and modulation mode are among of the factors that are influencing the amount of transmit power. In order to minimize the transmit power, the system throughput and fairness among users should be considered as well. In [6], the framework for measuring the energy efficiency is proposed where the power consumption to the throughput ratio was proposed as an Energy Consumption Rate (ECR) metric as in equation (1),

$$ECR = \frac{E}{M} = \frac{PT}{M} = \frac{P}{D^r} \qquad (1)$$

The ECR is defined as the energy per delivered application bit (Joules/Bit), where E is the energy required to deliver M application bits over time T, $D = \frac{M}{T}$ is the data rate in bits per second and P is the power.

The ECR is low if the total transmit power is reduced. Thus, high energy-efficiency can then be achieved. An efficient downlink packet scheduler in the evolved Node-B (eNB) is needed to achieve the best performance metrics of throughput, delay, ECR and fairness.

There are few researchers that focus in reducing the energy consumption at the eNB. This can be achieved by investigating the packet scheduling strategies to achieve better energy efficiency (EE). The researches in [7] have proposed two allocation stages where spectrum efficiency (SE) is traded for EE and QoS . The first stage take care of provisioning the QoS and the second stage is used for improving the EE. In [5] EE is achieved by increasing user's required bandwidth for given data rate under non-full load conditions by trading with SE while authors of [8] have proposed an energy efficient algorithm for low-load conditions. Issues to be taken for Long Term Evolution (LTE) downlink resource allocation is explained in [9] and Energy Reduction Gain [ERG] is the metric used to improve EE.

The spectral efficiency, fairness, and throughput performance of dynamic packet scheduling protocols in the Universal Terrestrial Radio Access Network (UTRAN) LTE has been studied extensively in [10]. However, the performance for energy consumption was not thoroughly considered. The authors in [11] have improved the system gain by exploiting the multiuser diversity gain using the adopt resource scheduling algorithms which can be converted to energy saving. In [12] the authors have proposed a proportional-fair-energy policy available for both low and high load conditions. According to [13], the circuit-level model has been introduced to analyze the effect of the bandwidth, power and modulation schemes on energy efficiency under different channel conditions.

In this paper, the real-time traffic deployment in the downlink transmission was considered since the QoS requirements are stringent. Furthermore, with a large variety of smart mobile devices in the market recently, it is important to study the performance in the downlink because a lot of activities occurred in the downlink transmission. This paper focuses on the Channel and QoS Aware (CQA) and Priority Set Scheduler (PSS) schedulers.

1.1 Channel and QoS Aware (CQA) Scheduler

The Channel and Quality of Service Aware (CQA) scheduler is based on the channel and QoS aware algorithm which performs the Time Division (TD) and Frequency Division (FD) scheduling [14]. CQA sorts the traffic's priority according to the channel condition, head of line (HOL) delay, and Guaranteed Bit Rate (GBR).

In the FD, for each resource block group (RBG) k = 1, ..., K, the CQA scheduler assigns the current RBG to user j that has the maximum value of the FD metric:

$$m_{fd}^{(k,j)}(t) = d_{HOL}^{j}(t).m_{GBR}^{j}(t).m_{ca}^{k,j}(t) \qquad (2)$$

The $m_{GBR}^{j}(t)$ is defined as:

$$m_{GBR}^{j}(t) = \frac{GBR^j}{\overline{R^j}(t)} = \frac{GBR^j}{(1-\alpha).\overline{R^j}(t-1)+\alpha.r^j(t)} \qquad (3)$$

GBR^j is the bit rate specified in the EPS bearer of the flow j, $\overline{R^j}(t)$ is the past averaged throughput calculated with a moving average, $r^j(t)$ is the throughput achieved at the time t, and α is a coefficient such that 0 ≤ α ≤ 1.

The purpose of $m_{ca}^{k,j}(t)$ parameter is to add the channel awareness to the system in order to maximize the capacity by assigning the resources to the flows that can use them more efficiently. Two different metrics were considered: $m_{pf}^{k,j}(t)$ and $m_{ff}^{k,j}(t)$ in the calculation of $m_{ca}^{k,j}(t)$. The m_{pf} is the Proportional Fair metrics which is defined as [15]:

$$m_{pf}^{(k,j)}(t) = \frac{R_e^{(k,j)}}{\overline{R^j}(t)} \qquad (4)$$

where $R_e^{(k,j)}(t)$is the estimated achievable throughput of user *j* over RBG *k was* calculated by the Adaptive Modulation and Coding (AMC) scheme that maps the channel quality indicator (CQI) value to the transport block size in bits.

The other channel awareness metric is m_{ff} [16] which represent the frequency selective fading gains over RBG k for user j and is defined as [15]:

$$m_{ff}^{(k,j)}(t) = \frac{CQI^{(k,j)}(t)}{\sum_{k=1}^{K} CQI(t)^{(k,j)}} \qquad (5)$$

$CQI^{(k,j)}(t)$ is the last reported CQI value from user *j* for the *k*th RBG.

1.2 Priority Set Scheduler (PSS)

The Priority Set Scheduler (PSS) [16] is a channel-aware scheduler that guarantees a predefined bit rate to each user. This scheduler combines the Time Division (TD) and Frequency Division (FD) scheduling in order to increase the spectral efficiency and system capacity.

In the FD scheduler, it allocates a RBG to the UE with the largest metric. In this context, two algorithms have been considered in this work:

- Proportional fair scheduled (PFsch)

$$M^{\wedge}sch_k(t) = \max_{j=1,\dots,N} \frac{R_j(k,t)}{T_{sch_j}(t)} \quad (6)$$

- Carrier over interference to average (CoIta)

$$M^{\wedge}coi_k(t) = \max_{j=1,\dots,N} \frac{CoI[j,k]}{\sum_{k=0}^{N_{RBG}} CoI[j,k]} \quad (7)$$

where $T_{sch_j}(t)$ is similar to the past average throughput of UE j, with the difference that it is updated only when the UE is actually served. $CoI[j,k]$ is an estimation of the signal to interference plus noise ratio (SINR) on the RBG k of UE j. Both PFsch and CoIta are for decoupling the FD metric from the TD scheduler.

2.0 METHODOLOGY

Figure 1 shows a generalized model of the packet scheduling algorithm in the downlink Third Generation Partnership Project (3GPP) Long Term Evolution (LTE) system as illustrated. From this model, each user is assigned a buffer at the serving evolved Node-B (eNB). In packets transmissions, their arrivals into the buffer are time stamped and queued for transmission based on a first-in-first-out (FIFO) basis. The packet scheduler determines which users are to be scheduled in each Transition Time Interval (TTI), based on a packet scheduling algorithm. At each TTI, there is a possibility that a user may be allocated zero, one or more than one RBs [17].

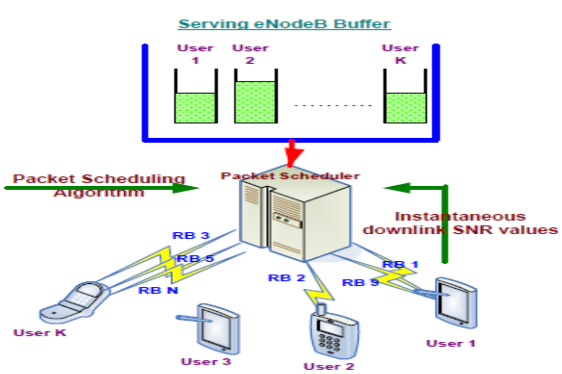


Figure 1 Model of Packet Scheduling in the Downlink LTE [18]

Two traffics, Voice over IP (VoIP) and video are deployed in the network in order to analyse the performance of the scheduling algorithms under consideration. The video application is an MP4 video streamed using Evalvid Server Helper. EvalVid is an open-source project that supports trace file generation of MPEG-4 as well as H.263 and H.264 format videos [18]. In this simulation, the module uses the st_highway_cif.st as the trace file for video traffic. Meanwhile, the VoIP traffic is modelled as ON and OFF duration. ON is the duration of time when the users spend on talking whereby constant packets are transmitted at regular intervals. The OFF duration is the time where the user stops talking and packets are not transmitted [19]. In this simulation, the G.711 encoder was used where it does not perform any compression to ensure the best voice quality. . Table 1 show that the LTE downlink simulation parameters.

Table 1 LTE Downlink Simulation Parameters

Parameter	Value
Simulation duration	50 sec
EnodeB	1
Transmission power for eNB	46dBm
Transmission power for UE	23dBm
Frame structure	FDD
Bandwidth	50 RB (100MHz)
Packet Interval	20ms
Radius	200m
UEs number	From 20 to 100 users
User speed	Constant velocity (3 km/h from the Extended Pedestrian A (EPA) model)
Qos Services	-GBR Conversational VoIP -GBR Conversational video
VoIP codec	G.711
VoIP guaranteed bit rate	12.2 kbps
Video file	St_highway_cif (MPEG-4)
Video Guaranteed bit rate	64kbps
Pathloss Model	Cost231 (Hata Model PCS extension)
Scheduling algorithm	CQA_Pf, CQA_Ff, PSS_Pf, PSS_CoItA

3.0 RESULTS AND DISCUSSION

The simulation was performed using the NS-3 real-time simulator along with the LTE-EPC Network Simulator (LENA) module. This simulator was able to emulate the entire protocol stack of the Long Term Evolution (LTE) standard and most of the wireless network protocols [20]. Four scheduling algorithms were evaluated namely the Channel and Quality of Service Aware Proportional Fair (CQA_PF), CQA Frequency Fading (CQA_Ff), Priority Set Scheduler Proportional Fair (PSS_PF), and PSS Carrier over Interference to Average (PSS_CoItA).

The performance metrics of throughput, delay, energy consumption rate (ECR) and fairness were analysed while a single cell with multiple user equipment (UE) were considered. It must be noted that the inter cell interference is neglected in this study. The fading scenario considered is Extended Pedestrian A (EPA) model in which the user moves with a 3km/h speed [11].

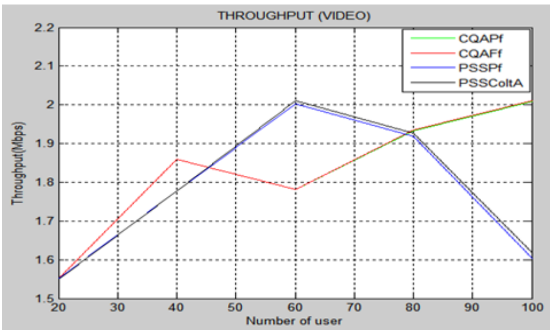


Figure 2 Video Downlink Throughput

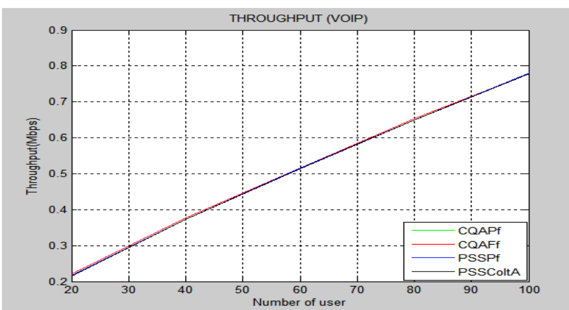


Figure 3 VoIP Downlink Throughputs

Figure 2 shows the video throughput. It can be observed here that when the user is set between 80 and 100, the throughput for both CQA schedulers; CQA_PF and CQA_Ff increased significantly than PSS schedulers. This is because the CQA schedulers were getting more resources in order to meet the requirements of the mixed traffic and hence proved that traffic with tight Quality of Service (QoS) requirement will be given higher priority.

There was no significant variation of throughput delivered for the VoIP flows as shown in Figure 3. This is mainly because the packets associated with voice traffic must be given very high priority and assigned to a guaranteed bandwidth channel in order to ensure that the packet delivery is within an acceptable delay limit [20].

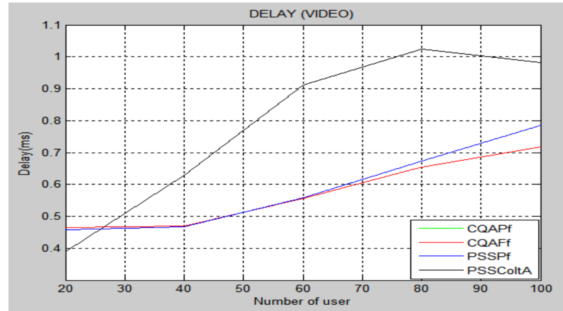


Figure 4 Video Downlink Delay

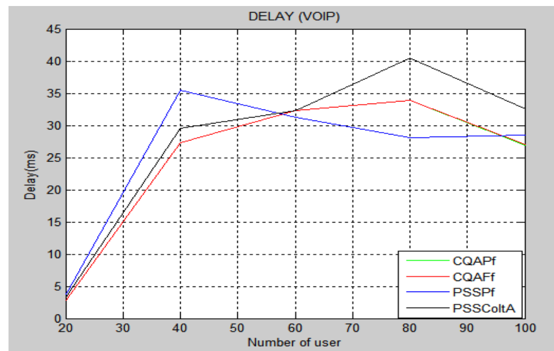


Figure 5 VoIP Downlink Delay

Figures of 4 and 5 demonstrate that video and VoIP flows have longer latency when there are more UEs in the cell. It is obvious here that the delay suffered by both flows is higher when the number of user exceeds 20. In Figure 4, the CQA_Ff scheduler has a 27% lower delay in comparison to the PSS_ColtA when the number of user is set to 100. Meanwhile, the delay for VoIP is shown in Figure 5 where the CQA_Ff scheduler has a 17% lower delay as compared to the PSS_ColtA. The CQA algorithm considers the Head of Line (HOL) delay in allocating the resource block (RB) to the UE thus contributing to a lower delay delivery. However, the delay for PSS_Pf was low when it reaches to 60 users up to 80 users and was not changed until 100 users. This is mainly due to the lowest throughput delivered which is 1.6036 Mbps (Refer toTable 2) which is contributing to low delay.

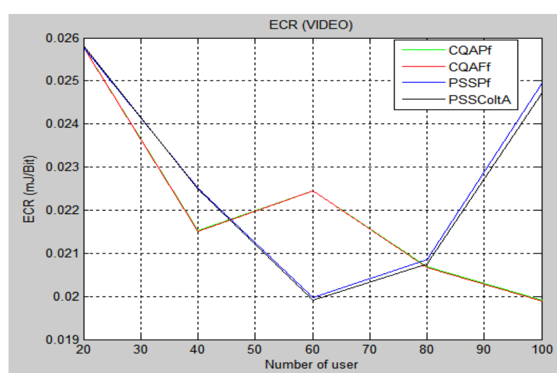


Figure 6 Video Downlink ECR

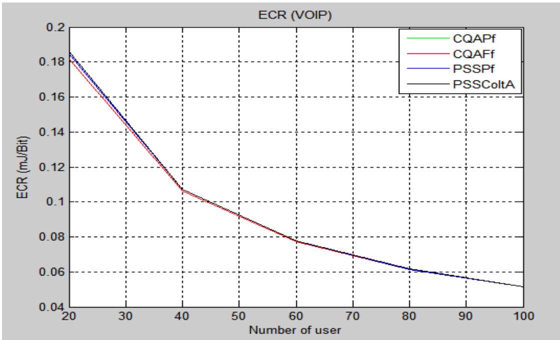


Figure 7 VoIP Downlink ECR

The ECR of video and VoIP are shown in Figures 6 and 7 respectively. Figure 6 shows that the ECR in the CQA algorithm drops drastically which was up to 20% when there were 100 users in the network as compared to the PSS scheduler. This is in accordance to the trade-off between throughput and energy consumption. When the throughput was high, ECR will then decrease. Hence, it can be seen that when ECR value is low, the power efficiency improved. The values for ECR for VoIP in Figure 7 are similar since all algorithms are delivering comparable throughput.

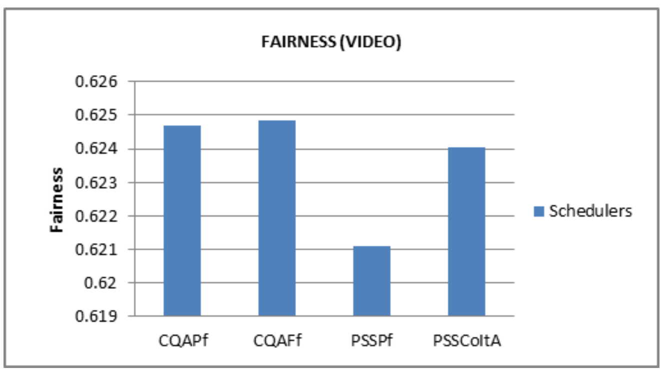


Figure 8 Fairness index comparisons for video

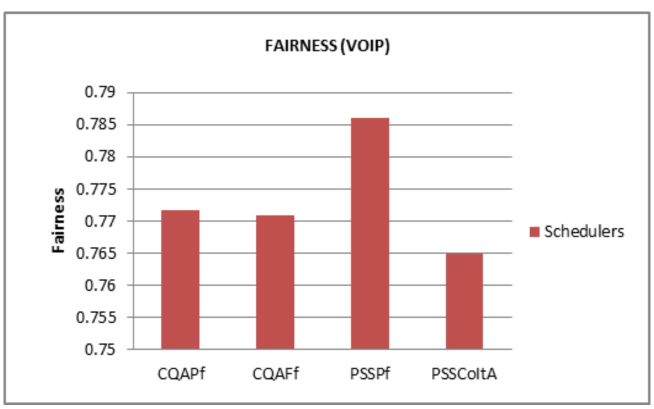


Figure 9 Fairness index comparisons for VoIP

The fairness value of four algorithms for video and VoIP flows are shown in Figures 8 and 9 respectively. The Jain fairness index was used to measure fairness [21]. Figure 9 shows that the fairness index for CQA_Pf and PSS_Pf for VoIP flows increases significantly as compared to CQA_Pf and PSS_Pf in video flow. This is mainly because the VoIP flows are given the highest priority all the time. Table 2 is summarizes the throughput, delay and ECR values for 100 users.

Table 2 Simulation Results Summarization

Metrics	Algorithm	Video	VoIP
Throughput (Mbps)	CQAPf	2.0083	0.7784
	CQAFf	2.0112	0.7776
	PSSPf	1.6036	0.7805
	PSSColtA	1.618	0.779
		Video	**VoIP**
Delay (ms)	CQAPf	0.786	26.902
	CQAFf	0.717	27.084
	PSSPf	0.786	28.457
	PSSColtA	0.982	32.589
		Video	**VoIP**
ECR (mJ/Bit)	CQAPf	0.0199	0.0514
	CQAFf	0.0199	0.0514
	PSSPf	0.0249	0.0512
	PSSColtA	0.0247	0.0513

4.0 CONCLUSION

This paper evaluates the performance of two packet scheduling algorithms in Long Term Evolution (LTE) cellular networks. The performance metric of throughput, delay, energy consumption rate (ECR) and fairness were analysed for the video streaming and Voice over IP (VoIP) applications. The results from simulation showed that the Channel and Quality of Service Aware (CQA) algorithm outperformed the other algorithms in video and voice flow since it has the lowest delay and ECR, delivers higher throughput, and has the highest value for fairness. Hence, it can be concluded that CQA algorithm is the most suitable algorithm to schedule video and VoIP flow. Future research is to include the transmission power of the base station as the scheduling decision in allocating the resources. This is being done by adjusting the power accordingly to the number of users in the network. Higher power will be set when there are more users in the network. On the other hand, low power of transmission is being deployed when there are lower numbers of users in the cell.

Acknowledgement

We are grateful for the MyBrain15 scholarship for financial support during the course of this work to Author 1.

References

[1] Walter Keating. 2011. Reducing Energy Consumption in Access Networks, MEng. Final Report, Appendix B.

[2] Alsharif, M. H., Nordin, R., & Ismail, M. 2013. Survey Of Green Radio Communications Networks: Techniques And Recent Advances. *Journal Of Computer Networks And Communications*. 1-13.

[3] Rui Wang, John, S. Thompson, and Harald, Haas. 2010. A Novel Time-Domain Sleep Mode Design for Energy-Efficient LTE. *Proceedings of the 4th International Symposium on Communications,Control and Signal Processing(ISCCSP)*. 1-4.

[4] Markus Gruber, Oliver Blume, Dieter Ferling, Dietrich Zeller, Muhammad Ali Imran and Emilio Calvanese Strinati. 2009. *EARTH – Energy Aware Radio and Network Technologies. IEEE*. 1-6.

[5] Yali Miao and Kai Wen. 2013. An Energy-Efficient Scheduling Strategy in LTE System. *2013 IEEE 11th International Conference on Dependable, Autonomic and Secure Computing*. 497-501.

[6] ECR Initiative. 2010. Network and Telecom Equipment – Energy and Performance Assessment, Metrics, Test Procedure and Measurement Methodology, Draft 3.0.1.

[7] Rebekka, B., Vinay Kumar B., and Dr. B. Malarkodi. 2015. Radio Resource Allocation with Energy Efficiency-Throughput Balancing for LTE Downlink. *IEEE Sponsored 2nd International Conference on Electronics and Communication System (ICECS 2015)*. 111-115.

[8] Mohammad, R. Sabagh, Mehrdad Dianati, Muhammad A.Imran, and Rahim Tafazolli. 2013. A Heuristic Energy Efficiency Scheduling Scheme for VoIP in 3GPP LTE Networks. *IEEE International Conference on Communications 2013: IEEE ICC'13*. 413-418.

[9] Capozzi, F., Piro, G., Grieco, L. A., Boggia, G., and Camarda P. 2012. Downlink Packet Scheduling in LTE Cellular Networks: Key Design Issues and a Survey. *IEEE Transaction on Vehicular Technology*. 15(2): 678-700.

[10] Kela P., Puttonen J., Kolehmainen N., Ristaniemi T., Honttonen T., and Moisio M. 2008. Dynamic Packet Scheduling Performance in UTRA Long Term Evolution Downlink. *Proceedings of the International Symposium on Wireless Pervasive Computing (ISWPC'08)*.

[11] Han, C., Beh, K. C., Nicolaou, M., Armour, S., and Doufexi, A. 2010. Power Efficient Resource Scheduling Algorithms for LTE. *IEEE Vehicular Technology Conference (VTC Fall)*. 1-5.

[12] Turyagyenda, C., O'Farrell, T., and Guo, W. 2012. Long Term Evolution Downlink Packet Scheduling using A Novel Proportional-Fair-Energy Policy. *IEEE Vehicular Technology Conference VTC Spring*. 1-6.

[13] Shunqing Zhang, Yan Chen, and Shugong Xu. 2010. Improving Energy Efficiency through Bandwidth, Power, and Adaptive Modulation. *IEEE Vehicular Technology Conference (VTC Fall)*. 1-5.

[14] Beh, K. C., Armour, S., and Doufexi, A. 2008. Joint Time-Frequency Domain Proportional Fair Scheduler with HARQ for 3GPP LTE Systems. *Proceedings of IEEE Vehicular Technology Conference (VTC)*.

[15] Bojovic, B., and Baldo N. 2014. A New Channel and QoS Aware Scheduler to Enhance the Capacity of Voice over LTE Systems. *Proc. IEEE 11th Int. Multi-Conference Syst. Signals Devices, SSD*. 1-6.

[16] Mongha, G., Pedersen, K., Kov´acs, I., and Mogensen, P. 2008. QoS Oriented Time and Frequency Domain Packet Schedulers for The UTRAN Long Term Evolution. *Proceedings of IEEE Vehicular TechnologyConference (VTC)*.

[17] Huda Adibah Mohd Ramli, Riyaj Basukala, Kumbesan Sandrasegaran, and Rachod Patachaianand. 2009. Performance of Well Known Packet Scheduling Algorithms in the Downlink 3GPP LTE System. *Proceedings of the 2009 IEEE 9th Malaysia International Conference on Communications*. 815-820.

[18] Arne Lie, and JirkaKlaue. 2007. Evalvid-RA: Trace Driven Simulation of Rate Adaptive MPEG-4 VBR Video. *Multimedia System*. 14: 33-50.

[19] Adi, S. M. Y., Kuokkwee Wee, Ee Mae A, and Mohd. F. A. A. 2015. Performance Study of Channel-QoS Aware Scheduler in LTE Downlink using NS3. *EMERGING 2015: The Seventh International Conference on Emerging Networks and Systems Intelligence*. 44-49.

[20] Weingartner, E., H. vom Lehn, and K. Wehrle. 2009. A Performance Comparison of Recent Network Simulator. *International Conference on Communications*. 1-5.

[21] Xiaowei, Li, Bing, L., Bing, Lan. 2010. Adaptive PF Scheduling Algorithm in LTE Cellular system. *IEEE Information and Communication Technology Convergence (ICTC)*. 501-504.