Software tool for comparing LTE traffic prioritisation algorithms

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The anticipated expansion of LTE subscriptions worldwide, affect the need to improve QoS. This can be done by extending and improving the existing network architecture and implementing new algorithms for traffic prioritisation. In order to determine the best prioritisation algorithm, it is necessary to compare the existing ones. This article presents a software product, with the results of which, a comprehensive comparison of the prioritisation algorithm proposed by the author with four standard ones has done.

Keywords – LTE, scheduler, prioritisation algorithms.

Софтуерен продукт за сравняване на алгоритми за приоритизиране на трафика при LTE технология (Айдън Хъкъ). *Очакваното разрастване на LTE абонаментите в световен мащаб, изисква подобряване качеството на услугите (QoS). Това може да се постигне чрез разширяване и подобряване на съществуващата мрежова архитектура и прилагане на нови алгоритми за приоритизиране на трафика. За определяне на най-добрия алгоритъм за приоритизиране е необходимо да се сравнят съществуващите. Статията представя подобрен софтуерен продукт, за извършване на сравнителен анализ, в който са внедрени различни алгоритми за приоритизиране на трафика, както и този, предложен от автора. В настоящото проучване е направен сравнителен анализ между предложения алгоритъм и четири стандартни – RR, MAX Rate, PF и EXP-PF. За реализиране на сравнението е използван метода с комплексна оценка, за да се избегне субективнистта на автора при оценяване. С цел постигане на оптимални оценки от гледна точка на състоятелност, нормираност и сравнимост са изчислени средна аритметична и средна геометрична комплексна оценка. Получените резултати показват, че за част от използваните критерии за сравняване, предложеният алгоритъм не предоставя най-добри стойности или предоставя съизмерими с тези на останалите алгоритми. Въпреки това, поради широкия набор разглеждани критерии получените комплексни оценки доказват, че предложеният алгоритъм е по-добър от тези, с които е сравнен.*

Introduction

The expected continuous growth of fourth and fifth generation wireless subscriptions requires improving the quality of service [1, 2]. This can be achieved by building new or upgrading and expanding the infrastructure in place to increase throughput, reduce delay and latency, improve accessibility and reliability. Some of these service quality requirements can be satisfied by implementing new traffic prioritisation algorithms. Prioritising traffic based on certain criteria can improve performance metrics for targeted services such as throughput, delay, latency, packet delivery ratio, etc. There are a number of such algorithms - standard and suggested by researchers.

This article discusses Round Robin (RR) [3], MAX Rate [4], Proportional Fair (PF) [5], EXP Proportional Fair (EXP-PF) [6] algorithms and presents an interface, with the results of which, a complex comparative analysis of the algorithms under consideration was made with that proposed by the author [7].

In the previous study [8], a comprehensive comparative analysis was made between the author's algorithm for prioritising traffic in LTE and those proposed by Myo [9] and Akyıldız [10]. The present study performs a complex comparative analysis between the algorithm proposed by the author and standard algorithms for prioritising traffic for LTE technology.

LTE traffic prioritisation algorithms

The scheduler of wireless cellular network’s base station is responsible for prioritising customer traffic, as well as planning and allocating resources between them. There are various standard algorithms for traffic prioritisation, their modifications and suggested by the researchers. The idea behind prioritisation algorithms is to prioritise certain queries, which will improve Quality of Service (QoS) for users. The algorithm proposed by the author, and the standard RR, MAX Rate, PF and EXP-PF are discussed here.

Author's proposal [7] – the suggested algorithm initially prioritises customer requests according to the paid price for a guaranteed service - highest priority is given to the requests with highest paid price. The price is expressed as a value of 0 to 7, where 0 defines the lowest priority and 7 the highest. When subscribers pay the same price, their queries are prioritised according to their distance to the base station - the highest priority is given to UEs who are closest to eNodeB. Remote users have a lower priority because they are closer to the end of the cell and can initiate a handover procedure. If UEs are at the same distance from the base station, mobile user queries are served with higher priority to provide better user experience for these customers. When there are multiple mobile users, their queries are prioritised according to the speed at which they move. Higher priority requests are for UEs who move at higher speeds, because they will pass faster through the serving cell and initiate handover, which will lead to a deterioration in service quality in non-priority servicing of these requests. When there are subscribers who move at the same rate, their requests are prioritised according to the QoS Class Identifier (QCI) requirements of the third generation partnership project (3GPP) standard [11] for the requested service type. The operation of this mechanism is shown in Fig. 1.

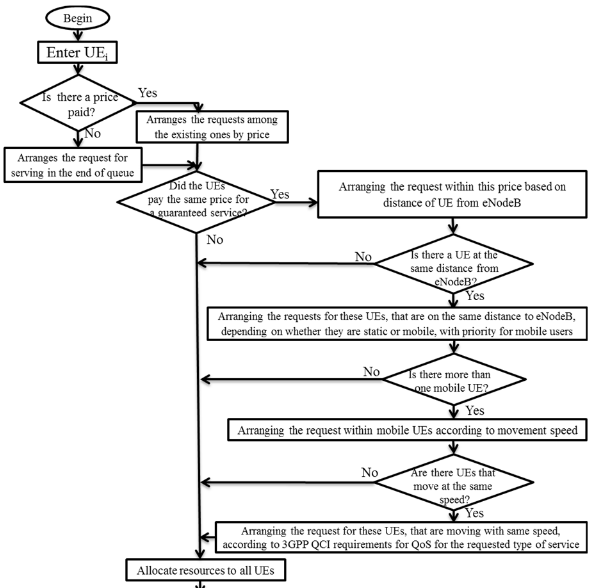

Fig.1. Proposed traffic prioritisation algorithm.

RR [3] - it is a simple cyclic scheduler that allocates resources to users consistently. Distributes network resources to users equally, regardless of the transmit channel conditions. Therefore, the system's throughput is lower than other algorithms. However, this algorithm maintains a relatively good and fair distribution of resources among users (Fig.2.).

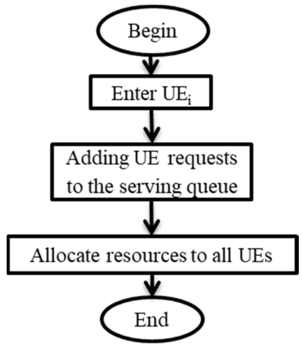

Fig.2. Round Robin algorithm.

MAX Rate [4] - transmits in each transmission time interval (TTI) to the user who has the highest Signal to Noise Ratio (SNR). In this way, users who have attenuation peaks will be scheduled throughout the service time, while others with large attenuations will not be scheduled at all. The Max-Rate algorithm can increase bandwidth, but it completely ignores fair user service (Fig.3.).

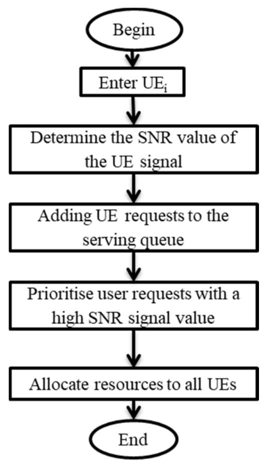

Fig.3. MAX Rate algorithm.

PF [5] - provides balance between fair customer service and overall system throughput. This algorithm works as follows: eNodeB receives channel quality indication (CQI) feedback regarding the required data rate for each user. Then, the changing average bandwidth of each UE in each physical resource block (PRB) in the previous frame is monitored. In time slot t, the algorithm prioritises the UE in the t^{-th} time slot and PRB, which satisfy the maximum relative CQI (Fig.4.).

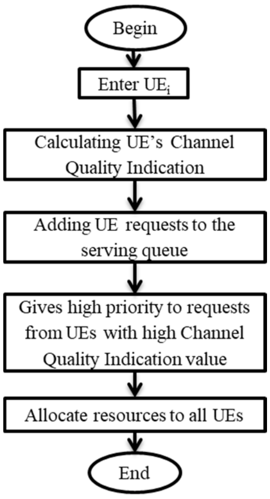

Fig.4. Proportional Fair algorithm.

EXP-PF [6] - EXP properties guarantee bandwidth for real time (RT) services, and PF properties maintain a minimum level of service for non-real time (NRT) services to ensure fairness in services. EXP-PF calculations depend entirely on the type of service prioritised by RT measurements. EXP-PF tries to examine RT streams by strictly maintaining the fairness when applying of PF conditions and recording the average values of the amounts of used queues in which tries to achieve large amounts of throughput by prioritising the flow of large sizes of the queue. A fair allocation of NRT traffic resources and a minimum data rate can be achieved by applying a PF algorithm (Fig.5).

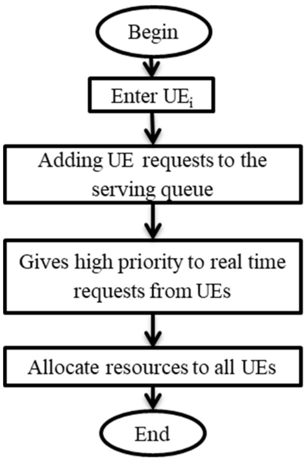

Fig.5. EXP-Proportional Fair algorithm.

Experimental settings and used software tool for complex comparison

The studies and results are based on, the added enhancements, to the simulator proposed in [7]. The interface used to investigate algorithms for prioritising traffic on an LTE network consists of two main forms - a form for adding base stations and information about them (Fig.6.), and a form for adding subscribers to every base station and information about them (Fig.7.-1).

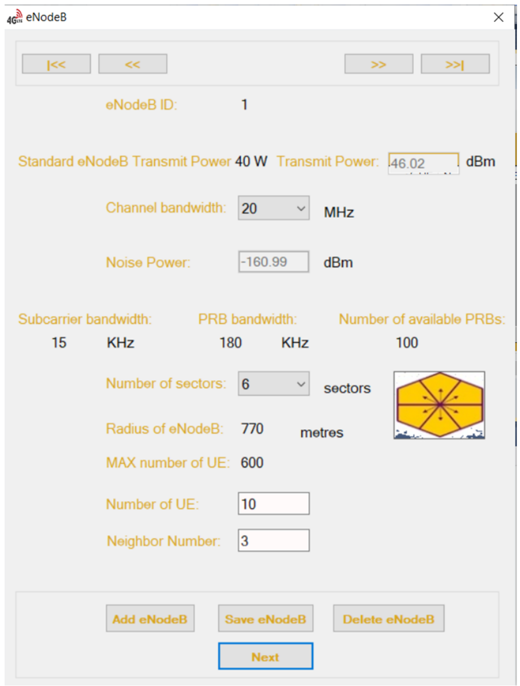

Fig.6. Information for eNodeB.

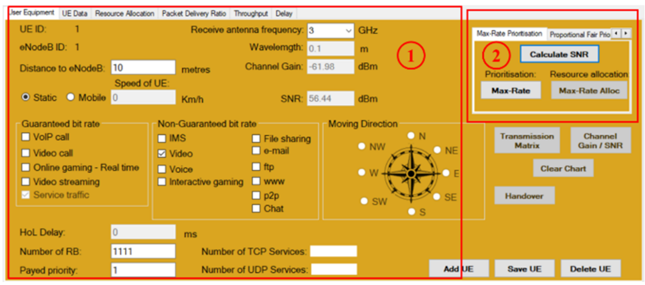

Fig.7. Information for user equipment.

The subscriber form has a section presenting the base stations information entered (Fig.8-1), UEs information (Fig.8-2), a handover simulation (Fig.9-2) and information portion (Fig.9-1), and a section to simulate the implemented algorithms for traffic prioritisation (Fig.7-2).

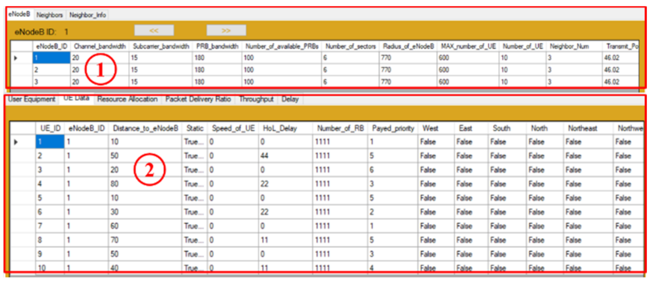

Fig.8. Base station and user equipment information.

The results from simulation tool provides information for a transmission matrix (Fig.10.), throughput (Fig.11.), delay (Fig.12.), packet delivery ratio (Fig.13.), SNR (Fig.14.), and channel gain (Fig.15.) for the consumers, according to the selected for simulation traffic prioritisation algorithm, from the field 2 of Fig. 7.

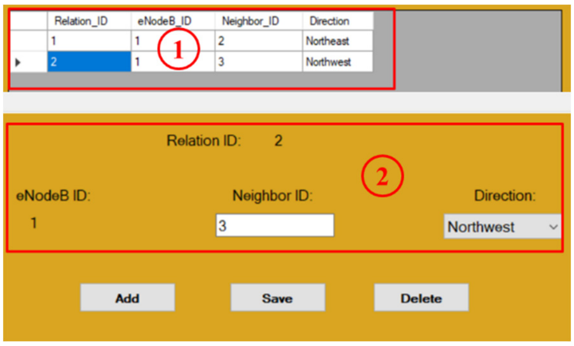

Fig.9. Handover information.

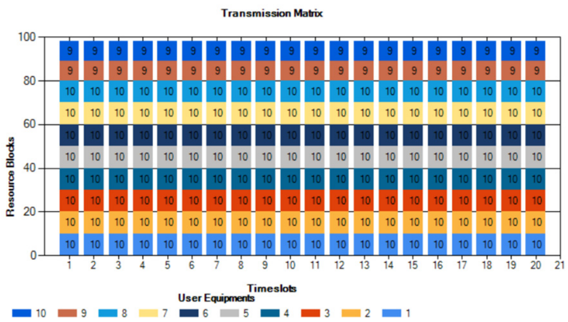

Fig.10. Transmission matrix.

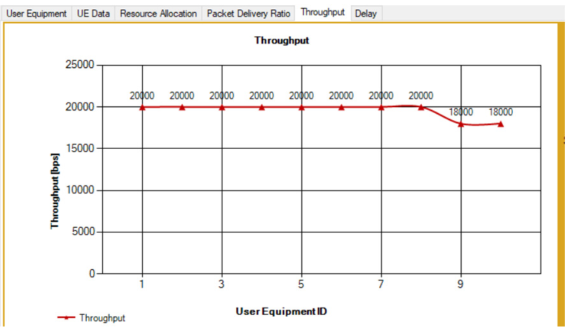

Fig.11. Throughput information

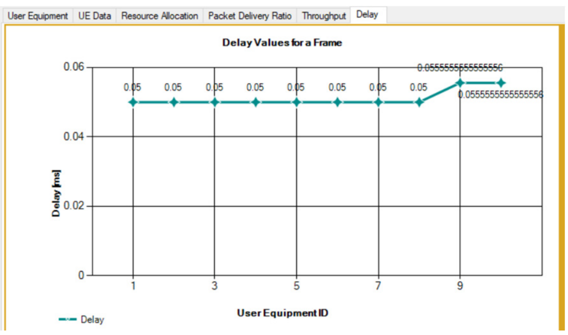

Fig.12. Delay information.

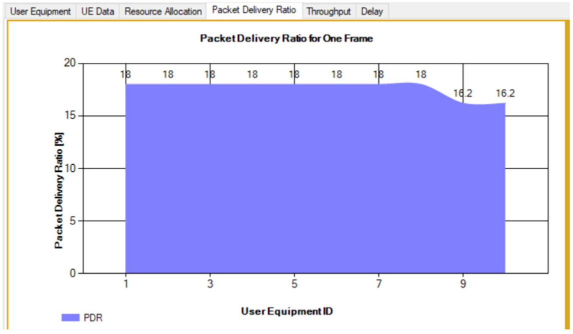

Fig.13. Information for packet delivery ratio.

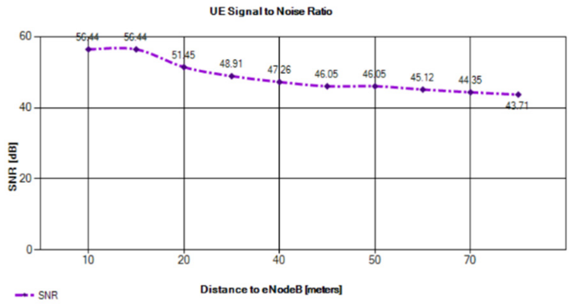

Fig.14. Signal to noise ratio information for user equipment.

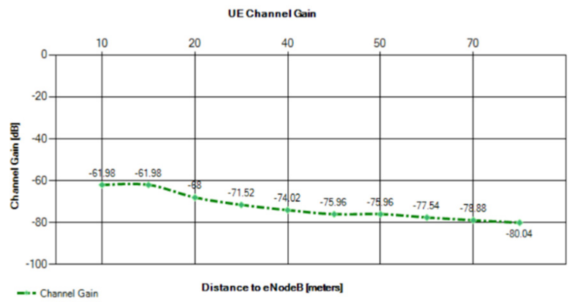

Fig.15. Channel gain information for user equipment.

Since the complex comparative analysis is evaluated under equal criteria, and the influence of handover is not considered, for the current study all tests are performed within one LTE cell. The cell works in 20MHz bandwidth and supports 100 UE's, which are static, and mobile, requiring different types of service and each subscriber requires 10 000 Resource Blocks (RB).

Table 2 presents the points and percentage ratios of the five algorithms for the individual criteria described in [8], on the basis of which the complex assessments are calculated.

For criterion "Respects 3GPP QoS standard" for the surveyed mechanisms is assigned one point for each option that complies with the requirements of the 3GPP QoS standard. The more requirements the standard complies with the mechanism is better.

The points for "Additional parameters for prioritisation" are formed by assigning one point for each prioritisation criterion used different from the standard. This mechanism, which has more prioritisation criteria different than the standard, is better because it can help improve QoS for some subscribers.

In the "RB for serving in next time slot" criterion, the RBs that are left to be served in next time slot for each mechanism are calculated. The lower number of RBs for servicing in the next time slot brings better results.

In the "Resource allocation" row, the scoring is determined according to the RB allocation scheme once the queries have been prioritised - one point for the worst scheme and five for the best.

For the rest of the criteria, the percentage of users who has high, medium, or low priority of the required requests according to the criteria under consideration is determined. Percentage ratios are calculated based on the number of clients whose requests are served with a high, medium or low priority for each criterion. For research purposes, the maximum number of users required queries that are considered for each criterion is 100.

After the absolute values thus obtained, expressed in points and percentage ratios, for each criterion by which the examined mechanisms are compared, relative ones are set. For each criterion, a five-degree scale of relative values is used - "Very bad", "Bad", "Neutral", "Good", "Very good". It is not compulsory all criteria match the same scale for relative values. On the basis of the obtained relative values, the complex assessments are calculated.

Comprehensive comparative analysis of LTE traffic prioritisation algorithms

In order to avoid the subjectivity of the author when evaluating the algorithms under consideration, the method of complex evaluation can be used, presented in [12], [8]. To compute the complex quality indicator, one of the following mathematical dependencies is chosen: quadratic, geometric, arithmetic or harmonic.

The comparison according to the criteria under consideration is based on average arithmetic and average geometric estimation, which are calculated according to the formulas (1) and (2) respectively.

$$R_a = \frac{\sum_{i=1}^{n} b_i \, d_i}{\sum_{i=1}^{n} b_i} \tag{1}$$

$$R_z = \left(\prod_{i=1}^{n} d_i^{b_i} \right)^{\frac{1}{\sum_{i=1}^{n} b_i}} \tag{2}$$

In (1) and (2) the normalised quantitative assessment of i-th indicator is

$$0 \le d_i \le 1, \tag{3}$$

n – number of indicators, and b_i is the i-th weighting coefficient, as

$$\sum_{i=1}^{n} b_i = 1 \tag{4}$$

For the purposes of the study, weight coefficients shall be equal. Since the weighting coefficients are equal, the equations for average arithmetic (1) and average geometric (2) complex estimation are revised, as presented in (5) and (6) respectively.

$$R_a = \frac{1}{n} \sum_{i=1}^{n} d_i \tag{5}$$

$$R_g = \prod_{i=1}^{n} d_i^{\frac{1}{n}} \tag{6}$$

The choice of geometric and arithmetic mathematical dependence is defined as optimal in terms of cogency, normality and comparability. Errors in unit indicators estimates using geometric and arithmetic dependence provide compromise enforcement to the conditions for maximum sensitivity when deterioration of single indicators for quality and minimal sensitivity to errors in their determination. The results of the comparative analysis are presented in Table 1.

According to the results obtained for the complex evaluation, the prioritisation algorithm proposed by the author is better than standard algorithms presented in [3], [4], [5] and [6].

Table 1

Arithmetic and geometric estimations for schedulers under consideration

Evalu-ation	Author's proposal	RR	MAX Rate	PF	EXP-PF
Ra	0.255	0.164	0.182	0.182	0.173
Rg	0.234	0.156	0.166	0.166	0.161

The main advantage of the proposed mechanism is that it fully complies with the 3GPP standard, serves with high priority guaranteed bitrate (GBR) services, allows the internet service provider to implement priority serving for requests from UEs that have paid a higher price for a guaranteed service, as well as requests from mobile UEs, which will reduce losses caused by a handover. This in turn will improve the quality of service for end users.

Table 2

Criteria for comparative evaluation

Criterion		Total	Authors proposal	RR	MAX Rate	PF	EXP-PF
Respects 3GPP QoS standard	**High, Medium, Low (priority)**	GBR-1p; Non-GBR-1p; IMS Streaming-1p; VoIP call-1p; Online Gaming (Real Time)-1p; Video call-1p; Video Streaming-1p; Voice, Video, Interactive gaming-1p; TCP based services e.g. e-mail, chat, ftp, p2p-1p.					
		9	7	2	2	2	2
Additional parameters for prioritisation		Prioritize subscribers who have paid a higher price for a guaranteed service-1p; Prioritize mobile UE-1p; Always prioritize GBR requests-1p; Prioritize Non-GBR requests at a higher percentage ratio-1p; Release the queue from too late for service requests-1p.					
		5	2	1	1	1	2
RB for serving in next timeslot		1 000 000 RB for 100UE served in 100ms	774 000RB	784 000RB	784 000RB	784 000RB	784 000RB
Resource allocation		Round Robin without priority-1; Uneven allocation with more RB for UE with the best instantaneous channel quality-2; Even allocation with respect of UE priority (priority for GBR)-3;Uneven allocation with more RB for UE with high priority (regardless of GBR and non-GBR)-4; Even allocation with UE priority (regardless of GBR and Non-GBR)-5.					
			4	1	5	5	3
Gives priority to UE who paid a high price for guaranteed service	**H**	**H** price-42UE	81%-**H**, 19%-**M**	33%-**H**;38%-**M**;29%-**L**	33%-**H**;38%-**M**;29%-**L**	33%-**H**;38%-**M**;29%-**L**	29%-**H**;40%-**M**;31%-**L**
	M	**M**price-28UE	89%-**M**, 11%-**L**	36%-**H**;32%-**M**;32%-**L**	36%-**H**;32%-**M**;32%-**L**	36%-**H**;32%-**M**;32%-**L**	36%-**H**;28%-**M**;36%-**L**
	L	**L**price-30UE	100%-**L**	33%-**H**;27%-**M**;40%-**L**	33%-**H**;27%-**M**;40%-**L**	33%-**H**;27%-**M**;40%-**L**	40%-**H**;27%-**M**;33%-**L**
Prioritizing UEs closer to the eNodeB	**H**	Closest to eNB-44UE	77%-**H**;23%-**M**	34%-**H**;27%-**M**;39%-**L**	25%-**M**;75%-**L**	25%-**M**;75%-**L**	34%-**H**;34%-**M**; 32%-**L**
	M	Middle of cell-28UE	82%-**M;**18%-**L**	36%-**H**;36%-**M**;28%-**L**	21%-**H**;75%-**M**	21%-**H**;75%-**M**	36%-**H**;32%-**M**; 32%-**L**
	L	Edge of cell-28UE	100%-**L**	33%-**H**;38%-**M**;29%-**L**	100%-**H**	100%-**H**	32%-**H**;32%-**M**; 36%-**L**
Provides priority to mobile users	**H**	**Mo**bile – 50UE	68%-**Mo-H**	34%-**Mo-H**;34%-**St-H**	34%-**Mo-H**;34%-**St-H**	34%-**Mo-H**;34%-**St-H**	34%-**Mo-H**;34%-**St-H**
	M		32%-**Mo-M**;34%-**St-M**	32%-**Mo-M**;34%-**St-M**	32%-**Mo-M**;34%-**St-M**	32%-**Mo-M**;34%-**St-M**	32%-**Mo-M**;34%-**St-M**
	L	**St**atic – 50 UE	66%-**St-L**	34%-**Mo-L**;32%-**St-L**	34%-**Mo-L**;32%-**St-L**	34%-**Mo-L**;32%-**St-L**	34%-**Mo-L**;32%-**St-L**
Provides priority to UEs moving at higher speeds	**H**	**H sp**-70-100km/h-35UE	97%-**H**;3%-**M**	35%-**H**;35%-**M**;30%-**L**	35%-**H**;35%-**M**;30%-**L**	35%-**H**;35%-**M**;30%-**L**	35%-**H**;35%-**M**;30%-**L**
	M	**M sp**-30-50km/h-33UE	97%-**M**;3%-**L**	35%-**H**;30%-**M**;35%-**L**	35%-**H**;30%-**M**;35%-**L**	35%-**H**;30%-**M**;35%-**L**	35%-**H**;30%-**M**;35%-**L**
	L	**L sp**-5-10km/h-32UE	100%-**L**	31%-**H**;38%-**M**;31%-**L**	31%-**H**;38%-**M**;31%-**L**	31%-**H**;38%-**M**;31%-**L**	31%-**H**;38%-**M**;31%-**L**
Gives priority to GBR services	**H**	GBR-50UE	68%-GBR-**H**	34%-GBR-**H**; 34%-non-GBR-**H**	34%-GBR-**H**; 34%-non-GBR-**H**	34%-GBR-**H**; 34%-non-GBR-**H**	68%-GBR-**H**
	M		32%-GBR-**M;** 34%-non-GBR-**M**	34%-GBR-**M**; 32%-non-GBR-**M**	34%-GBR-**M**; 32%-non-GBR-**M**	34%-GBR-**M**; 32%-non-GBR-**M**	32%-GBR-**M**; 34%-non-GBR-**M**
	L	Non-GBR-50UE	66%-non-GBR-**L**	32%-GBR-**L**; 34%-non-GBR-**L**	32%-GBR-**L**; 34%-non-GBR-**L**	32%-GBR-**L**; 34%-non-GBR-**L**	66%-non-GBR-**L**
Gives priority to non-GBR services when larger numbers are demanded	**H**	Non-GBR-52 UE	71%-GBR-**H**	35%-GBR-**H**; 33%-non-GBR-**H**	35%-GBR-**H**; 33%-non-GBR-**H**	35%-GBR-**H**; 33%-non-GBR-**H**	71%-GBR-**H**
	M		29%-GBR-**M**; 37%-non-GBR-**M**	33%-GBR-**M**; 33%-non-GBR-**M**	33%-GBR-**M**; 33%-non-GBR-**M**	33%-GBR-**M**; 33%-non-GBR-**M**	29%-GBR-**M**; 37%-non-GBR-**M**
	L	GBR-48 UE	64%-non-GBR-**L**	32%-GBR-**L**; 34%-non-GBR-**L**	32%-GBR-**L**; 34%-non-GBR-**L**	32%-GBR-**L**; 34%-non-GBR-**L**	64%-non-GBR-**L**
Provides priority to requests for which the maximum delay is high (HoL Delay)	**H**	**H** HoL-70-90ms-40UE	32%-**H**;32%-**M**;36%-**L**	33%-**H**;37%-**M**;30%-**L**	33%-**H**;37%-**M**;30%-**L**	33%-**H**;37%-**M**;30%-**L**	33%-**H**;37%-**M**;30%-**L**
	M	**M** HoL-30-50ms-40UE	38%-**H**;30%-**M**;32%-**L**	35%-**H**;30%-**M**;35%-**L**	35%-**H**;30%-**M**;35%-**L**	35%-**H**;30%-**M**;35%-**L**	35%-**H**;30%-**M**;35%-**L**
	L	**L** HoL-up to10ms-20UE	30%-**H**;40%-**M**;30%-**L**	35%-**H**;30%-**M**;35%-**L**	35%-**H**;30%-**M**;35%-**L**	35%-**H**;30%-**M**;35%-**L**	35%-**H**;30%-**M**;35%-**L**

Conclusions

This article introduces enhanced software product to simulate an LTE cellular network. Using the software provided, it was accomplished a comparative analysis of the proposed algorithm by authors, and four other standard algorithms – RR, MAX Rate, PF and EXP-PF. Studies of the five algorithms have been performed and complex estimates are based on the data obtained. When examining the criteria separately, it can be seen that in the case of criteria “Resource allocation” the proposed mechanism does not provide good results, and according to “Provides priority to requests for which the maximum delay is high (HoL Delay)” there are equal results. The Head of Line (HoL) delay is considered as this is the delay of the first packet to be sent by the UE and it is the most significant [13].

However, in the complex assessment, due to the wide range of criteria considered, the arithmetic and geometric complex estimation proves that the suggested by author algorithm for the prioritisation of traffic in LTE is better than RR, MAX Rate, PF and EXP-PF algorithms.

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