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Performance Evaluation of Enhanced EXPRULE Scheduler for LTE Multi Cell Network

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Abstract: *Nowadays, the demand for high data rate in the Long Term Evolution (LTE) network is rapidly increasing. The vast deployment of real-time services in LTE network increases rapidly. To support such demand, beside the vast update from 3G to 4G, LTE network implements several techniques such as handover and scheduling techniques to support the Quality of Service (QoS) requirements for UEs. One of the challenges in LTE network is the UEs mobility management. The services to UEs shall remain stable while the UEs are moving from one cell to another. In this paper, we analyzed the performance of the proposed eEXPRULE scheduler for LTE network in multiple cell scenario while the UEs are randomly move from one cell to another with different speeds. Extensive simulations are carried out using LTE-Sim simulator. The proposed eEXPRULE improves the performance of video traffic. It improves the video throughput (16%), video PLR (50%), video delay, VoIP delay (62%), and spectrum efficiency over the existing schedulers.*

Keywords: *Downlink packet scheduling, eEXPRULE scheduler, LTE network, QoS awareness, Scheduling algorithm*

INTRODUCTION

The exponential growth of the wireless cellular services consumption has brought demands for rapid simultaneous access to various applications and services, higher capacity, higher speed, and higher data rate, to meet those requirements while guaranteeing the Quality of Service (QoS) requirement, that lead to 3rd Generation Partnership Project (3GPP) proposes the LTE specification. LTE is standardized as 4G by 3GPP. The main feature of LTE is to provide high spectrum efficiency and high QoS mobile broadband to users [1].

Mobility management is a challenging issue in macro multi-carrier deployments, which is a crucial factor for handover process. In LTE network, an User Equipment (UE) can only communicates directly with one Base Station (BS) within a specific coverage area [2]. In the LTE handover procedure, UE has to terminate a current connection in order to establish a new connection. This process may cause an interruption in the UE communication through the network that leads to the QoS degradation [3]. LTE has been implemented several handover techniques to maintain the service continuity while the UEs are moving from one cell to another. In order to handle the UEs movement, LTE has to implement the handover technique in a way that UEs do not experience service interruption and the unnecessary handover should be avoided. LTE uses the Reference Signal Received Power (RSRP) in order to measure the cell coverage from the serving and the neighboring cells. LTE network implements handover whenever the serving cell RSRP decreases to a lower value than the target cell by the predefined hysteresis value for at least a Time to Trigger (TTT) period in the case of coverage based handover. When the UE makes frequent handovers and stays for a small duration of time in the cell, it results in a reduced QoS to the UEs.

PROPOSED SCHEDULER

Since the QoS requirements for real-time (RT) and non-real-time (NRT) are varied in term of delay and data rate, it is necessary to develop an efficient scheduling technique to achieve the QoS requirements for a variety of traffic [4][5]. The following explained the proposed scheduler with higher priorities are allocated to RT traffic in the multi cell scenario.

The proposed eEXPRULE (enhanced Exponential Rule) aims to reduce the overall delay by computing the transmission metric for each traffic, i.e. video, VoIP, and best effort separately, which leads to the UE's throughput increment. The transmission metric for each type of traffic are as follows:

Transmission metric for best effort traffic:

$$\omega_{i,j} = \frac{r_{i,j}}{\bar{R}_i} \quad (1)$$

Transmission metric for VoIP traffic:

$$\omega_{i,j} = \exp\left(\frac{(\alpha_i D_{HoL,i})}{c + \sqrt{\left(\frac{1}{N_{rt}}\right)\sum D_{HoL,i}}}\frac{r_{i,j}}{\bar{R}_i}\right) \quad (2)$$

Transmission metric for video traffic:

$$\omega_{i,j} = \exp\left(\frac{(\alpha_i D_{HoL,i})}{c + \sqrt{\left(\frac{1}{N_{rt}}\right)\sum D_{HoL,i}}}\right) r_{i,j} \quad (3)$$

Where α_i is given as follows, which c is equal to 1:

$$\alpha_i \in \left[\frac{5}{(\tau_i)}, \frac{10}{(\tau_i)}\right] \quad (4)$$

PERFORMANCE EVALUATION

In this section, the performance of the proposed scheduler is evaluated under multi cell scenario and the UEs are in random position and randomly moving within the 4 cells with 120 km/h. The results for the speeds of 3 km/h, 30 km/h, and 120 km/h are compared between the existing and the proposed algorithm in the following section.

SIMULATION SETUP

In this simulation, there are 4 cells with a single eNodeB in each cell. Each eNodeB provides the coverage with the cell radius of 1 km and it communicates with the UEs in 10 MHz bandwidth. The UEs are randomly move within the cells. In this simulation, three types of traffic, i.e. are one video, one VoIP and one best effort flow are executed in parallel by each UE. For the video flow, a trace-based application that emits the packets based on a realistic video trace file with a rate of 242 kbps is used. For VoIP, a G.729 voice stream with a maximum delay of 0.1 s is considered [6]. G.729 is an audio codec with lowest bit rate that squeezes, the digital conversation in the packets of 10 ms length. Due to the low bit rate, it presents the chances for important augment in bandwidth consumption for the existing technology [7]. The Voice flow is a burst application that is modelled with an ON/OFF Markov chain [8]. We run the simulation with multiple UEs in the range of 10 to 80 UEs with a step increment of 10 using the Frequency Division Duplex (FDD) mode.

Table 1. Simulation Parameters

Parameters	Values
Simulation duration	100 s
Flow duration	20
Frame structure	FDD
Cell radius	1 km
UE speed	3 km/h
UE mobility	Random Direction
Number of UEs	80
Bandwidth	10 MHz
Number of RBs	50
Maximum delay	0.1 s
Video bit-rate	242 kbps

Number of cells	4

SIMULATION RESULTS FOR 120 km/h

In this section, the simulation results are presented in order to evaluate the performance of the proposed scheduler in multi cell scenario (4 cells) using LTE-Sim open source simulator. The performance analyses are mainly focused on the RT traffic, i.e. video and VoIP. In order to evaluate the performance of eEXPRULE, we compared the performance of eEXPRULE with the second best scheduler when the network reaches its maximum number of UEs which is 80 UEs.

Figure 1 illustrates the video throughput for several schedulers, the eEXPRULE scheduler has significant improvement compared to the existing schedulers. It improves about 16% of the video throughput compared to the FLS scheduler at 80 UEs. However, the VoIP throughput for all schedulers remained the same and the values are increasing gradually as depicted in figure 2.

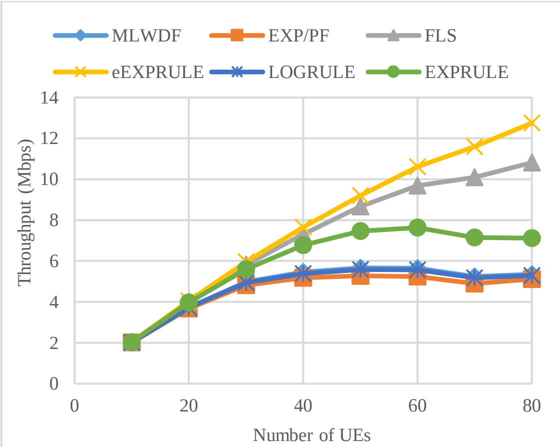

Figure 1. Video throughput

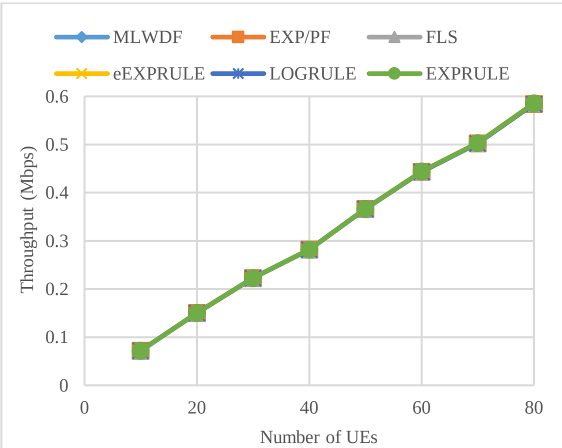

Figure 2. VoIP throughput

Figure 3 illustrates the PLR for video traffic. The eEXPRULE improved the PLR for video by 50% compared to the existing best scheduler which is FLS scheduler and by 72% compared to the worse scheduler (EXP/PF scheduler). The PLR for VoIP traffic is illustrated in figure 4 which is about to zero for 80 UEs same as FLS scheduler.

As shown in figure 5, the packet delay of video flow gradually increases with the increases number of UEs for all schedulers. The eEXPRULE scheduler shows the lowest delay among them. Figure 6 depicts the packet delay of VoIP flow. The result illustrates that the packet delay for FLS and eEXPRULE scheduler maintain almost the same level while the number of UEs increasing. It is observed that the eEXPRULE scheduler is better than FLS scheduler with 62% improvement for 80 UEs.

Figures 7 and 8 illustrate the fairness for video and VoIP flow which calculated based on the Janes fairness index [9]. Figure 7 shows that the video fairness degrades with the increment of UEs. FLS and eEXPRULE scheduler have better performance among them. However, eEXPRULE has better performance compared to the FLS scheduler for 80 UEs.

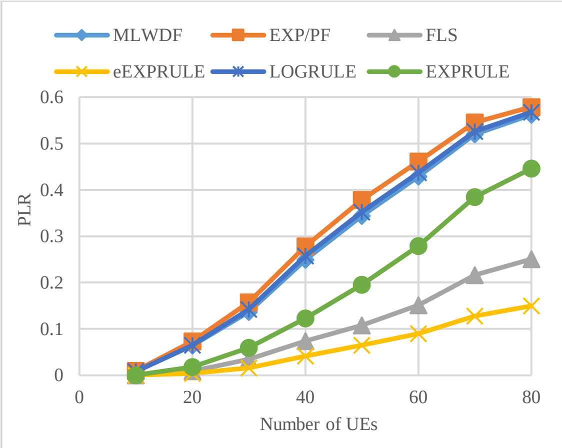

Figure 3. Video PLR

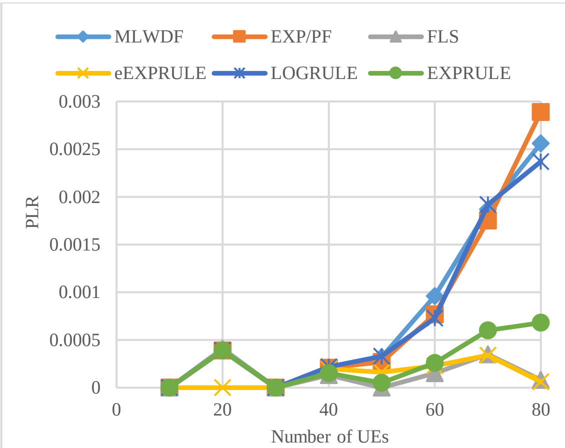

Figure 4. VoIP PLR

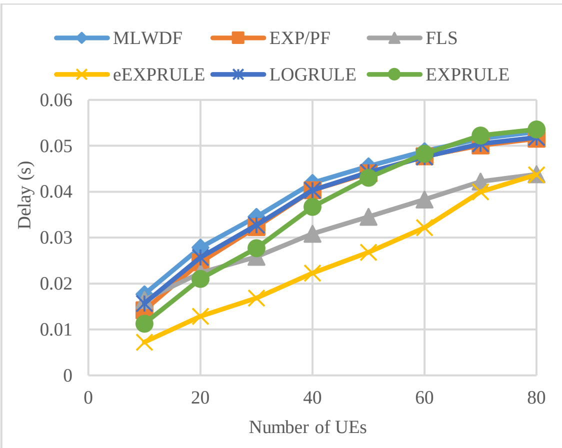

Figure 5. (a) Video delay

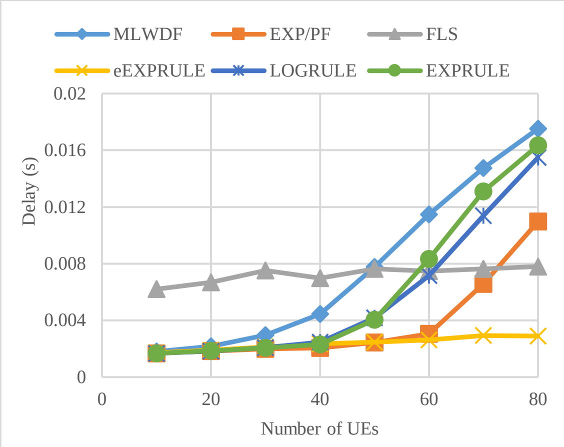

Figure 6. VoIP delay

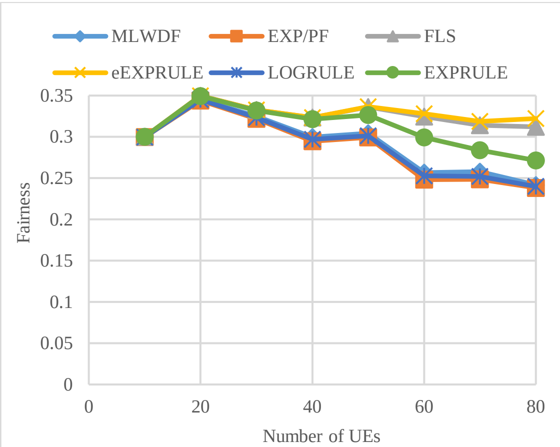

Figure 7. Video fairness

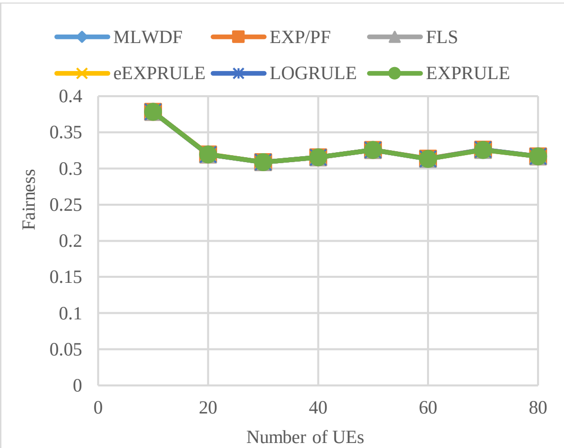

Figure 8. VoIP fairness

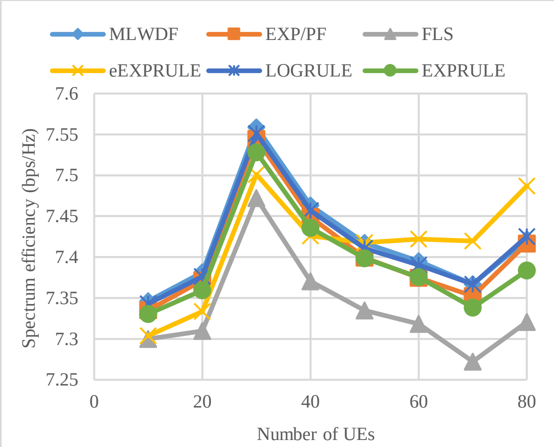

Figure 9. Spectrum efficiency

The spectrum efficiency of four cells with the speed of 120 km/h is illustrated in figure 9. The efficiency increases from 10 to 30 UEs. However, it drops gradually when the number of UEs increased and the same pattern is observed for all schedulers. It can be seen that the eEXPRULE scheduler has a higher spectrum efficiency over the other five schedulers.

RESULTS OF eEXPRULE IN MULTIPLE SPEEDS SCENARIO

In this section, the results for four cell scenario with the UE speed of 3, 30, and 120 km/h are presented. Figure 10 illustrates video throughput, the graph increases gradually with the increment of the UE number. UEs have the same pattern for the three different speeds for the number of UEs below 60. However, when the number of UEs exceeds 60 there is a slight change which can be seen the UEs with 120 km/h has lower throughput. VoIP throughput shown in figure 11. The VoIP throughput increases gradually with the same pattern for the three different speeds which there is no difference for the UE with different speed.

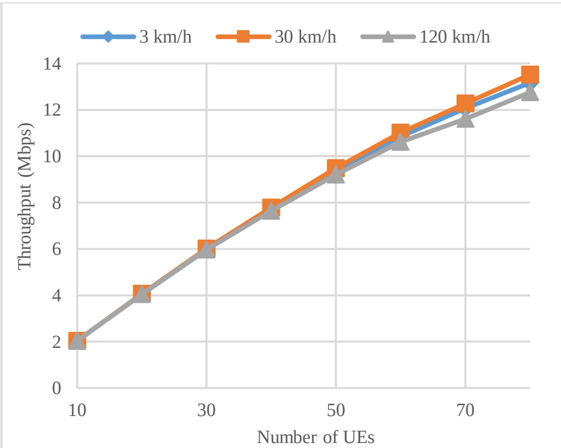

Figure 10. Video throughput

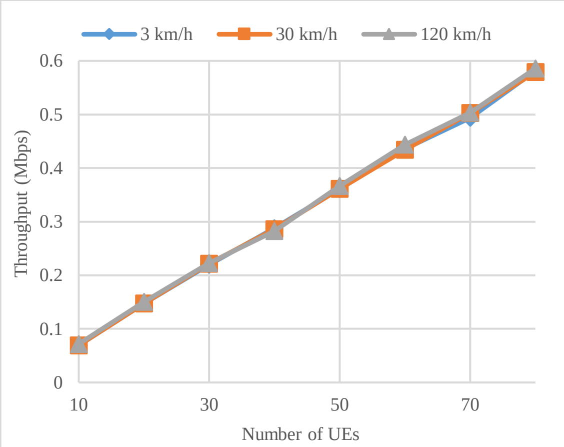

Figure 11. VoIP throughput

Figure 12 shows the PLR experienced by video flows. It shown that the PLR increases with the increasing number of UEs which can be due to the increment in network loads. It can be seen that the UEs with higher speed have higher PLR which can be due to the overhead of the handover from one cell to the other. The PLR for VoIP traffic is illustrated in figure 13. In this scenario, the UEs with the speed of 120 km/h have the average lower PLR.

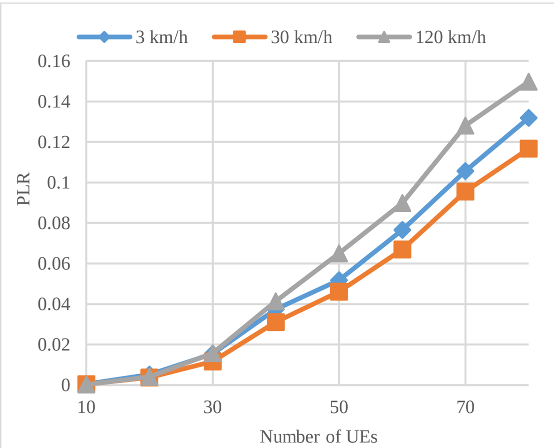

Figure 12. Video PLR

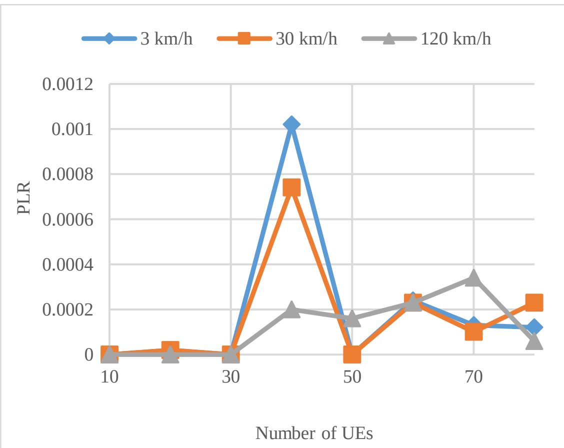

Figure 13. VoIP PLR

Figures 14 and 15 illustrate the video and VoIP delay respectively. The delay for both traffic increases with the increment of the number of UEs with almost the same pattern. In this scenario, UEs with higher speed have slightly higher delay compared to the UEs with lower speed. As mentioned previously, the delay increment is due to increase in the network load.

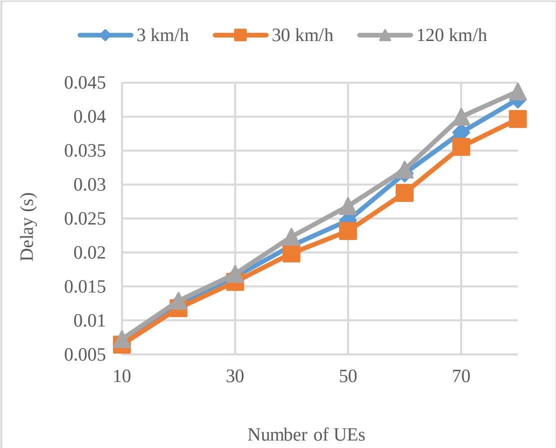

Figure 14. Video delay

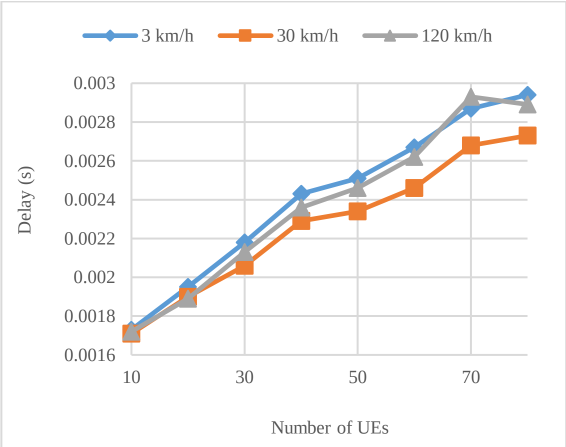

Figure 15. VoIP delay

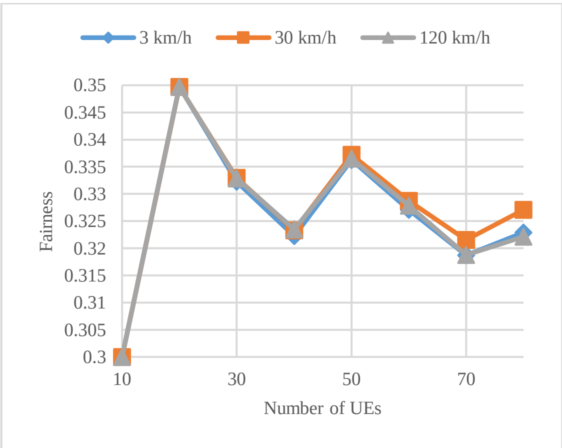

Figure 16. Video fairness

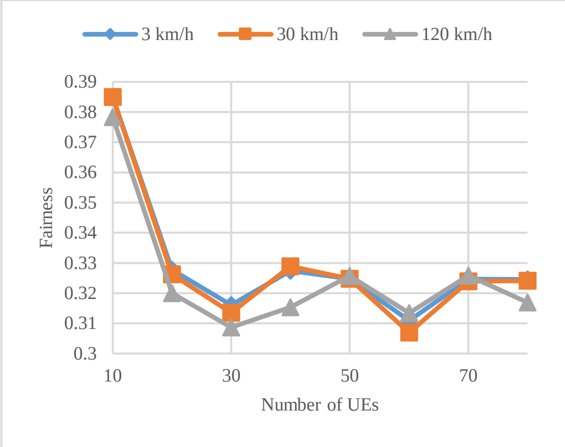

Figure 17. VoIP fairness

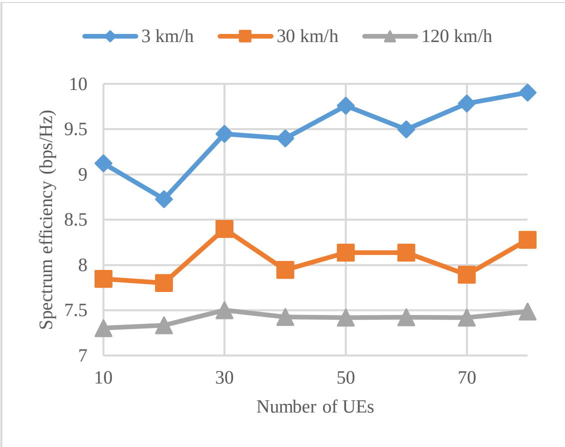

Figure 18. Spectrum efficiency

The results for video and VoIP fairness are shown in figure 16 and 17 respectively. Video flow has the same pattern of fairness which is drops step by step with the increase of UE number.

The spectrum efficiency of four cell scenario with different speed is depicted in figure 18. It can be seen that UEs with higher speed have lower cell efficiency, which is due to cell exchange and handover process within cells and UEs.

CONCLUSION

In this paper, the proposed eEXPRULE scheduler has been evaluated under four cell scenario with multiple UE speeds using LTE-Sim simulator for RT traffics. Extensive simulations are carried out and the results are promising indicated that the eEXPRULE has improved the video throughput (16%), video PLR (50%), video delay, VoIP delay (62%), and spectrum efficiency over the existing schedulers as well as EXPRULE. The proposed eEXPRULE has significant improvement in video throughput, video PLR, video and VoIP delay compared to the existing scheduler.

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