Packet scheduling in LTE mobile network

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Abstract
Selection of proper packet scheduling algorithm is crucial component in QoS provisioning over next generation networks, especially LTE networks which is expected to provide higher throughput with better QoE (Quality of Experience) among the users. A key factor affects the QoS & QoE of LTE networks, is the packet scheduling algorithms used in them.
In this paper ,the performance of most famous packet scheduling algorithms such as Priority Queuing (PQ), Weighted Fair Queuing (WFQ), Round Robin (RR) and First In First Out (FIFO) in LTE mobile networks had been studied.

OPNET modeler 17.1 simulator used to compare the results in different scenarios which contain different applications.

Key Words: Packet scheduling, LTE mobile networks, QoS, OPNET

1 Introduction

The demand for IP packet service is growing rapidly in mobile communication in recent years. IP services enabling multimedia retrieval, web browsing, data download, and ecommerce, etc., will play a more and more important role in the future. Generally, the features of those services require high-speed data rate. Thus 3GPP introduced the 3GPP long term evolution (LTE) standards to the mobile data markets. 3GPP LTE provides high speed wireless communications based on universal mobile terrestrial systems (UMTS)/high speed packet access (HSPA) network technologies on the way towards 4G mobile networks.

However, unfortunately the radio resource is limited and thus needs sophisticated management schemes.

So, there is strong motivation and challenge beyond scheduling procedure and resource allocation in order to improve system performance by increasing spectral efficiency of the wireless interface and hence improve overall network capacity.

The reminder of this paper is organized as follows: Section II shows important components of LTE .Section III network presents QoS in LTE network. Section IV gives brief description of most famous scheduling algorithms.. Section V presents simulation result of this paper study. Finally, conclusions & future works are discussed in Section VI.

2 LTE Network

LTE has introduced a number of new technologies when compared to the previous cellular systems. They enable LTE to be able to operate more efficiently with respect to the use of spectrum, and also to provide the much higher data rates that are being required.

2.1 Simplified network architecture:

Number of nodes reduced from 4 nodes used in W-CDMA (which are NodeB, RNC, SGSN & GGSN) to only 2 nodes (e-NodeB and SAE-GW).
The radio network consists of the E-Node B's which are responsible for scheduling and are interconnected to each other through the X2 interface and connected to the core network (EPC "Evolved Packet Core") through the S1 interface.

2.2 OFDM (Orthogonal Frequency Division Multiplex):

OFDM technology has been incorporated into LTE because it enables high data bandwidths to be transmitted efficiently while still providing a high degree of resilience to reflections and interference. In OFDM, the data stream is distributed over many subcarriers. Each subcarrier will thus have a slow symbol rate and correspondingly, a long symbol time. This means that the Inter Symbol Interference (ISI) is reduced. SC-OFDM for the uplink since the power amplifier in the UE can be manufactured at a lower cost then.

2.3 MIMO (Multiple Input Multiple Output):

One of the main problems that previous telecommunications systems has encountered is that of multiple signals arising from the many reflections that are encountered. By using MIMO, these additional signal paths can be used to advantage and are able to be used to increase the throughput.

3 Quality of Service

As a result of introducing new applications in mobile network and as it is not limited to voice and SMS applications, each application has its own QoS demands to guarantee satisfaction for both of user and mobile operators. In LTE, the QoS is provided by means of a bearer which is responsible for the priority that is given to a packet flow across the LTE network. Bearers are established after the successful authentication and registration of the user in the LTE network.

3.1 Bearer types:

a. Granted Bit Rate (GBR)

GBR requires resources to be reserved for its applications.

b. Non-Granted Bit Rate (Non-GBR)

Bearers are used for services that do not have strict QoS constraints. It is useful for background, interactive traffic classes such as email, web browsing, file download, etc.

3.2 Bearer QoS parameters:

a. QoS Class Identifier (QCI):

is very important in LTE as it defines packet forward treatment at each node, such as scheduling weight, admission control priority, queuing threshold, etc.

b. Allocation and Retention Priority:

This supports to determine relative priority of a bearer over other bearers in case of congestion.

c. Maximum bit rate:

which identifies maximum bit rate supported by bearer.

Below table has example for values of above mentioned factors.

QCI	Bearer type	Application example	Retention Priority
1	GBR	Conversational VOIP	2
2		Conversational Video	4
3		Non-Conversational Video	5
4		Real time Games	3
5	Non-GBR	IMS signaling	1
6		Voice & Video interactive games	7
7		TCP applications (email, FTP , web)	6
8			8
9			9

Table 1

4 Packet Scheduling Algorithms

Packet scheduling is the process of resolving contention for bandwidth. A scheduling algorithm has to determine the allocation of bandwidth among the users and their transmission order. One of the most important objectives of a scheduling scheme is to satisfy the Quality of Service (QoS) requirements of its users while efficiently utilizing the available bandwidth

4.1 WFQ:

It is a generalization of Fair Queuing (FQ). WFQ is a data packet scheduling technique that is used for various size packets, where packets are grouped in flows and each flow has its own weight.

The rate of each flow is determined based on below equation

$$R(i) = R \times \frac{W(i)}{\sum W} \quad (1)$$

It does not take number of packets in each flow into consideration, just care about weight of the flow.

4.2 PQ:

which depends only on priority of class the traffic belongs to without taking into consideration fairness between users

4.3 FIFO:

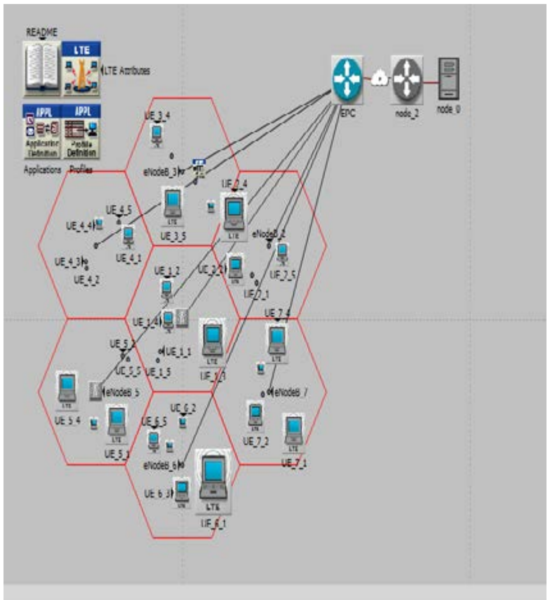
FIFO is the simplest scheduling algorithm. Packets coming from all the input links were en-queued into a FIFO memory stack, and then they were de-queued one by one on to the output link. So it simply queues processes in the order in which they arrive in the ready queue. Since context switches only occur upon process termination, and no reorganization of the process queue is required, scheduling overhead is minimal. Throughput turnaround time, waiting time and response time can be low. No prioritization occurs, thus this system has trouble meeting process deadlines. The lack of prioritization does permit every process to eventually complete, hence no starvation.

5 Simulation Analysis and Results:

LTE network was composed in OPNET which contains 6 cells, each has one NodeB & 5 users. NodeBs connected to Evolved Packet Core (EPC) through E1. EPC connected to IP cloud which connected to router. The router connected to server which supports HTTP applications. Simulation run for 7 minutes.

Applications used by users in this simulation are:

1. HTTP: in "Best Effort" QoS level = 0
2. Voice: in "Interactive Voice" QoS level = 6
3. Video: in "Streaming Multimedia" QoS level =4.



Simulation results:

WFQ: Green grapgh
PQ: Red grapgh
FIFO: Blue grapgh

QoS was assessed by the following parameters in simulation:

5.1 Total download packets in LTE network:

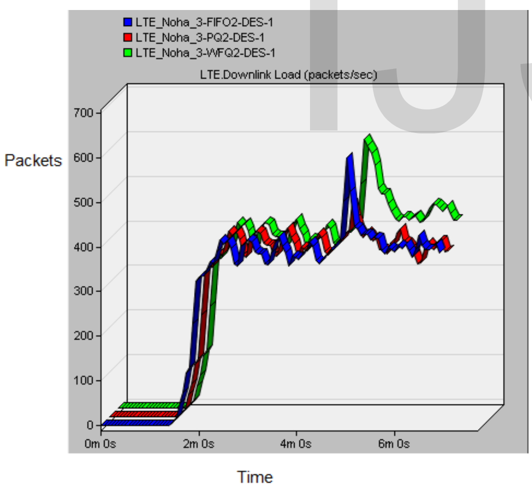


Fig.1 shows that WFQ has the highest rate

5.2 Voice traffic received:

As shown in Fig.2, all scheduling algorithms resulted in same received voice traffic

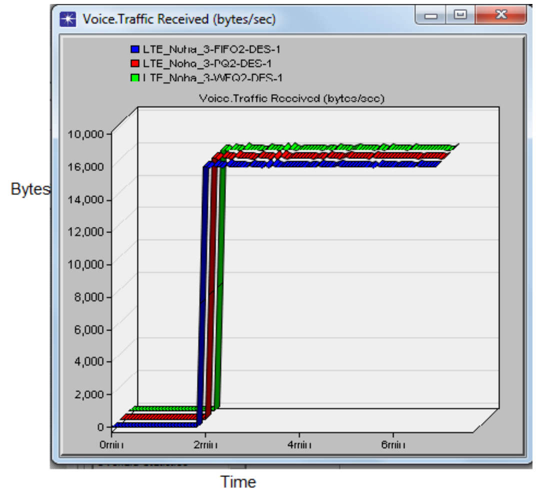


Fig.2 (Voice received byte rate)

5.3 MOS (Mean Opinion Score):

MOS provides numerical measurements of user Quality of Experience in voice telecommunications

MOS score	Mapping score to user(s) satisfaction
4.3 - 5	Very much satisfied
4 - 4.3	Satisfied
3.6 - 4	Many users satisfied
3.1 - 3.6	Many users dissatisfied
2.6 - 3.1	Nearly all users dissatisfied

Table 2

As shown in Fig.3, the 3 algorithms has different values starting from the 5th minute, with PQ silghtly higher than WFQ & FIFO has the lowest values.

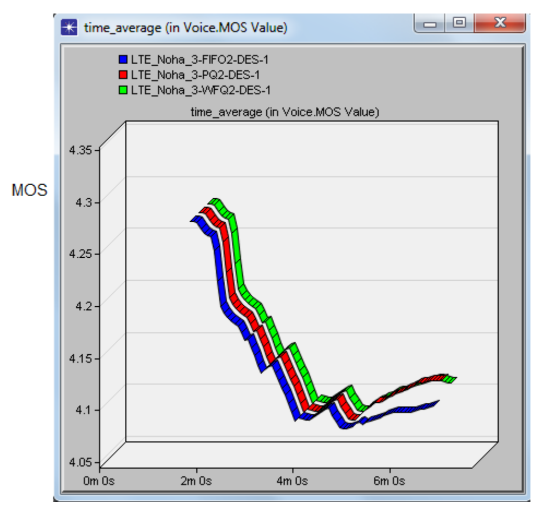


Fig.3 (Average MOS value of Voice)

5.4 Voice End to End Delay :

As shown in Fig.4 PQ has the lowest delay, this is because Voice has the highest priority & PQ take into its consideration only priority of traffic

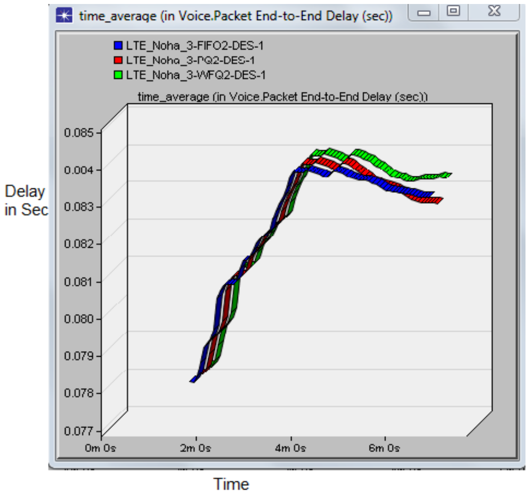


Fig.4 (Time average E2E delay of Voice)

5.5 Voice Jitter:

Jitter is the maximum difference in one way delay of packets over a particular time interval.

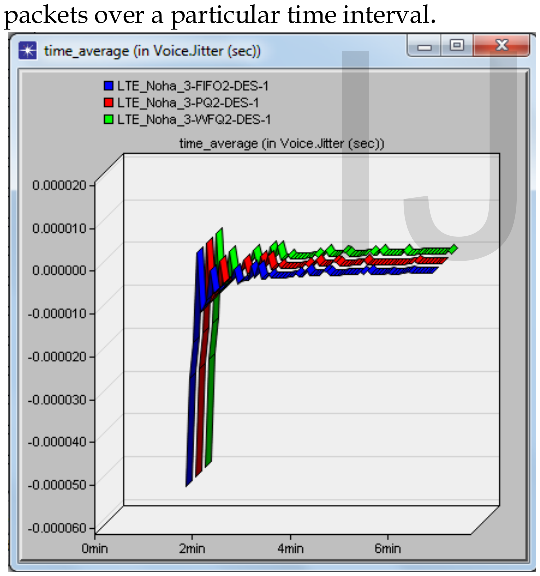


Fig.5 (Time average of jitters rate for voice)

As shown in fig.5, almost all scheduling algorithms results in same jitter

5.6 HTTP: As shown in fig.6, WFQ has the lowest received packet rate

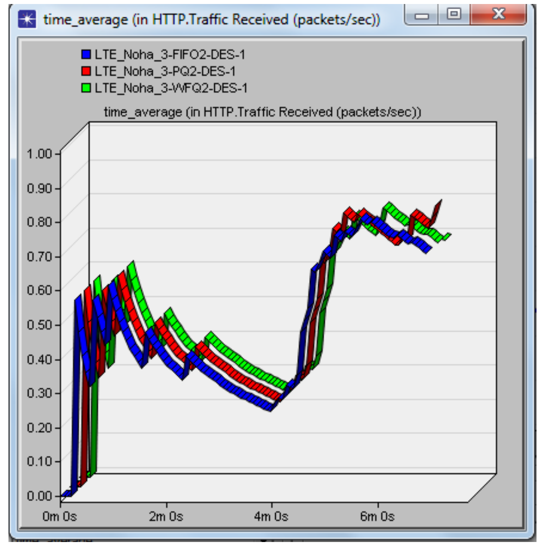


Fig.6 (Average received packet rate of HTTP)

5.7 Video:

As shown in fig.7, WFQ has the highest received byte rate

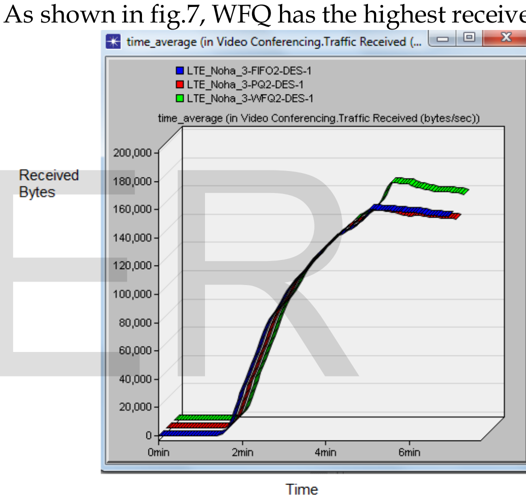


Fig.7 (Time average of received bytes)

5.8 Video End to End delay:

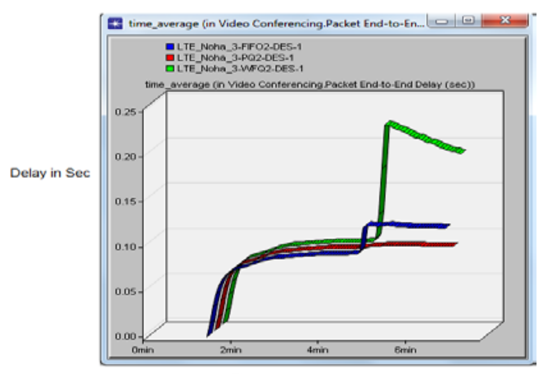


Fig.8 (Time average for E2E delay)

As shown in fig.8, PQ has the lowest E2E delay as Video has the 2nd higher priority in simulation, while WFQ has the highest value as video load is very high & the main target of WFQ to achieve fairness between users.

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6 CONCLUSION AND FUTURE WORK

After analysis and simulation of the three scheduling algorithms in LTE network, it is found that WFQ is the best algorithm to use to achieve both highest downlink load and fairness between users using different applications.
In future work, effect of changing weights of WFQ to be dynamic instead of static & constant weights will be studied. The weights changing criteria should take into consideration Operator revenue as well as QoE from users, with flexibility to change degree of fairness based on above mentioned two important factors to achieve satisfaction of both Mobile operators & Mobile users.

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