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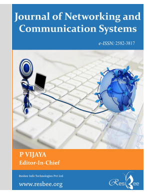

Evaluation Packet Priority Mechanisms over 5G Mobile Network

Mohammed Dighriri

Department of MIS, Saudi Electronic University, Jeddah, Saudi Arabia

Abstract: In wireless networks, enhancing the Quality of Service (QoS) is main purpose of mobile providers. In real-time applications like video monitoring, Mobile networks transport various forms of packet traffic. These applications should have the gain of QoS acclimation. In order to guarantee QoS of mobile networks several Packet Priority Mechanisms (PPMs) are employed at the router. IoT devices are expected to rise considerably over mobile networks 5G a consequence of increasing the capacity and high data rates. These mobile networks face some issues in overload and congestion in Radio Access Network (RAN) because of the massive IoT device packet traffic requiring various levels of QoS requirements. In this article, the method PPMs namely, First-In-First-Out (FIFO), Priority Queuing (PQ), and Weighted Fair Queuing (WFQ) in 5G and 4G networks taking into consideration QoS requirements in IoT and smart systems scenarios are investigated and compared. The three evaluated PPMs were designed over 4G and 5G mobile networks in terms of the user's suitability to enhance the priority order. The results of the OPNET simulation show that the performance evaluation allowed us to draw conclusions on the performance of the three-PPMs and point out the strengths and weaknesses.

Keywords: 5G, IoT, FIFO, Packet Priority Mechanisms, QoS

Nomenclature

Abbreviations	Descriptions
PPMs	Packet Priority Mechanisms
SHS	Smart Healthcare systems
QoS	Quality of Service
PQ	Priority Queuing
TN	Transport Network
PSM	Packet Slicing Model
VCS	Vehicular Communication systems
IMS	Internet Protocol Multimedia Subsystem
RED	Random-Early Drop
NFs	network functions
IP	Internet Protocol
PSM	Packet Slicing Model
WFQ	Weighted Fair Queuing
mMTC	massive Machine Type Communications
HOL	Head of Line
UPIM	User Plane Interface Model
eMBB	enhanced Mobile Broadband
NR	New Radio
RWP	Random Way Point
FPS	Frames Per Sec
FIFO	First-In-First-Out
URLLC	Ultra-Reliable Low Latency Communications
PS	Generalized Processor Sharing

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1. Introduction

Simultaneous applications like video controlling in emergency intelligent systems are critical to obtaining benefit of QoS acclimation by every network. It is extremely vital topresent QoS for priority applications like VCS and SHS [3]. PPMs handle the higher priority of such packets. On the contrary, fewer packets' priority should be managed and conveyed reasonably. As a result, it is a severe task for modeling the PPMs to balance all these standards [5]. Ever since radio sources are important resources and hardly reachable in wireless networks, for that reason, effective employment is necessary. The new communication technologies like LTE, LTE-A, and 5G mobile networks utilize multiple carriers' methods to present enhanced data rates and to make sure maximum QoS demands. Moreover, the minimum radio resource PRB unit is allocable in the 5G mobile networks to a single IoT device. Under favorable channel conditions, the PRB can transmit several kilobytes of data. These several transporters' methods can transmit a large volume of data. On the other hand, regarding IoT communication, both broadband and narrowband applications must be considered to improve the requirements of QoS. In particular, these applications have diverse sizes of data traffic that require QoS specifications like accuracy, real-time, and priority [3]. If one PRB is assigned to a single IoT device for data transmission of just a few bytes, subsequently it may reason severe consumption of radio resources. Furthermore, the diverse kinds of packets must be exploited in the 5G slices technique regarding the network operators presenting a suitable QoS for diverse types of packets priority. Hence, the use of full radio resources and packets priority classification ought to be a perfect solution for data traffic explosion and the priorities fairness.

In this article, the three PPMs namely, PQ, FIFO, and WFO, which have been designed over 4G and 5G networks was compared and investigated. The performance evaluation has been conducted in terms of user's suitability to enhance the priorities order, which takes into consideration data traffics coming from IoT devices and smart systems with QoS requirement such as throughput, load, and delay. The results from my performance evaluation allowed us to draw conclusions on the performance of the three PPMsand point out the strengths and weaknesses. This would help us to design the model of the priorityscheduler at RNs and DeNB cells in 5G mobile networks appropriately.

Therefore, a suitable PPM as a serious partin the scenario of improving QoS over 5G mobile networks is chosen, particularly, soon mobile networks are predictable to face confronts because of the massive number of IoTdevices and their packets with diverse QoS requirements, especially 5G mobile networks are anticipated to present higher bandwidth with the optimal QoE among the IoT devices and users [1]. The most important effect on QoS soon is that there will be billions of IoT devices such as smartphones, SHS, and VCS. They need diverse priorities regarding exploiting the 5G mobile networks, consequently, presenting a comparison of the PPMs applied based on PSM through RNs and DeNB cells in 5G mobile networks. In this article, the executed PSM along with the most outstanding PPMs such as PQ, FIFO, and WFQ in the 5G mobile network is developed. As a result, there is a strong confrontation and motivation beyond packet scheduling mechanisms and radio resource provision to recover the performance of the smart systems by aiding the spectral efficiency of the interface of the mobile network and therefore improving comprehensive network capacity [1].

2. Related Works

In this part of the article, I have investigated and compared PPMs related works of similarresearch, The performance of three PPMs was evaluated, which are PQ, FIFO and WFQ applied over the cells of 4G and 5G mobile networks in terms of user's suitability enhance thepriorities order, which based on IoT devices and smart systems QoS requirements such as throughput, load, latency, and fairness.

This research [2] has shown different transport network PPMs for resource allocation andtheir influence on real-time traffic in LTE mobile networks. The research has useful information in terms of the considerable basics of LTE mobile networks and PPMs for an additional deep research study. The authors have presented how PPMs can manage resources in the transport network, showing a key role in assuring to enhance E2E performance for both VoIP and FTP applications. They introduced a packet-switched system becoming more popular to carry the data; the IMS was developed to make sure QoS for several multimedia services such as VoIP.

This improves the issue with VoIP calls and guarantees that a voice call quality might be as high-quality as the circuit-switched-based voice call [2]. This study has presented different PPMs having various impacts on different servicesunder different traffic scenarios; therefore, they came with the choice of individual priority schemes based on the parameters that are exploited to define the QoS of the several services in theLTE mobile network. The authors [2] have indicated other reviewed research, it has been seen that FIFO and PQ are not suitable for high-speed networks because they tendto drop a great number of packets and reduced the reception of VoIP data, the bursty nature of WFQ does not create it receive any voice traffic, they have fulfilled to present acceptable user performance for services like VoIP, although at the identical time presenting high user capacity, the resources allocation to users have to be cautiously managed, though, the packet priority mechanisms that allocate time slots to users should be cautiously designed. However, in this research, there are some limitations when the authors did not consider simulation to show the results of the density of data traffic at the uplink direction of the access point via small or large cells with high capacity, which can allow them to assess to PPMs and at the similar time assuring VoIP QoS requirements.[2].

In [3] the authors have discussed and demonstrated the performance of diverse PPMs, they considered a hypothetical network topology in the OPNET experimentations. They have designed two routers linked "by a DS1 link and all other links through cells and developed three different packet scenarios, one for each Ppm". Their solution includes three types of protocols: FTP, VoIP, and RTP. In addition, they used a separate server for each data traffic type, and evaluated and compared performance of diverse PPMs. To evaluate their solution, they used metrics such as average E2E delay, average queuing delay, average packet drop rate, and average delay jitter for each priority mechanism scenario. In addition, in their evaluation, they have focused on the impact of using the RED scheme and verified its supremacy over the drop-tail policy, and included the node with protocol FTP packet. The setting was done by exploiting the OPNET simulation attributes profile, these sets include the three PPMs specifications, and they "set the maximum queue size to be 500 packets". They have applied maximum and minimum thresholds as 100 and 200 correspondingly whilst keeping the mark probability denominator ("the fraction of packets dropped while the average queue size is at the maximum threshold") as 10. On the other hand, this study has a disadvantage in terms of the OPNET simulation designed as the authors did not examine the packet at the edges of the LTEmobile network, where the massive density can affect the packet delay and packets dropping [3].

The authors in [4] have presented comparisons of PPMs performance, and have considered the OPNET simulations to assess the responses attained from the Fibre to the home standards. The simulation base model was produced with different protocols including FTP, SMTP

Database, VoIP, RTP servers, and user cells are linked to the network across the passive opticalsplitter in the core networks. The authors have designed the OPNET simulation based on threescenarios of PPMs consisting of FIFO, WFQ, and Deficit Weighted Round Robin (DWRR). They developed all these scenarios to go across the links in the core network [4]. The proposal has been evaluated and the evaluation considered the Ethernet delay, VoIP packet E2E delay, FTP traffic received, and SMTP server traffic received. The total experimentation was run for 180 seconds and the results show that the PPMs have different performances for dissimilar experimentation times in the specified configurations. Nevertheless, this research has some limitations especially as the authors did not consider an OPNET-designed simulation and applied the PQ packet priority mechanism as one of the important PPMs.[4]

Table 1. Related works summary PPMs Comparison

PPMs Comparison				
Research	**Contributions**	**RAT Features**	**Methodology**	**Limitations**
[2]	Comparisons PPMs for resource allocation and their influence on real-time traffic in LTE mobile networks.	LTE-A	OPNET	The authors did not consider simulation to show the results of the density of packets at the uplink direction of the access point via small or large cells with high capacity.
[3]	Comparisons PPMs, they have considered a hypothetical network topology	LTE-A	OPNET	The authors do not examine thepackets at the edges of the LTEmobile network, where the massive density can affect the packet delay and packets dropping
[4]	In comparisons of PPMs performance, they have considered the OPNET simulations to assess the responses attained from the Fibre to the home standards	Fiber networks	OPNET	When the authors do not consider in OPNET simulation designed and applied the PQ PPM as one of the important PPMs.

3. Comparison of Packet Priority Mechanisms

In this part of the article, A novel comparison among PPMs based is proposed on the 5G mobile network PSM, which relies on smart systems. The concept of network slices to differentiate smart systems such as services priority is considered. Therefore, the delay of the packets queuing priority which happens at the output buffer of RNs and DeNBcells in 5G and 4G mobile networks, a priority is dealt with efficiently and evenly by numerous PPMs. Therefore, the fairness and QoS demands are significant features presented by any PPMs such as PQ, FIFO, and WFQ. This article applied PPMs to the classified fairness services priority for the evaluation of QoS in protocols including FTP, VoIP, SMTP, and RTP.These protocols have been applied in OPNET simulation into IoT devices relying on the priority of the packets. Some QoS requirements like delay, load, and throughput for diverse PPMs in the 5G mobile networks are considered in this paper.

3.1 Packet Priority Mechanisms

The three core PPMs used are FIFO, PQ, and WFQ as shown in further detail:

3.1.1 Description of FIFO

The basic approach to transmitting a packet in every network is FIFO. In queue, the first packet is served first in an exact time slot, in spite of any prioritization, security, or evenfairness [6]. Therefore, it is easy to simulate. Nevertheless, it fails to arrive at all other priority customize excluding difficulty FIFO suffers from the "HOL problem that refers to that if the first packet in the queue is blocked for any reason, the remaining is blocked although the link is idle" [6].

3.1.2 Priority Queuing (PQ)

PQ is constructed to deal with the publication of FIFO that does not present any priority to all data traffic or some class. Generally, "PQ assures the best ever service of higher-priority data at each point where it is used" [6]. It presents firm priority to the traffic that is necessary. "Each packet position in one of four queues called as higher, medium, lesser is attained relying on the allocated priority of each packet" [6]. The main drawback of this priority model is that the "lower-level traffic cannot be helped for a long time if the higher priority is generally there" [6]. Hence, the lesser class will be affected by a starving problem which leads to a main packets discard.

3.1.3 Weighted Fair Queuing (WFQ)

It is a queuing method relying on data packet flow and exploited the realization of the GPS model. It is a theoretical model, which maintains well-mannered fairness [7]. Here, 2 ideas are performed flawlessly in WFQ; initial responsive traffic is transmitted to the head of the queue for the reduction of reply time. Subsequently, it divides the remaining bandwidth amid "higher-bandwidth flows in a fair mode" [7]. Generally, WFQ observes that queues do not starve for bandwidth. Every packet has to increase the predictable services. WFQ can observe the advantage "bit marked in the IP packet header of each packet and in order with that marking, it categorizes priority levels of packets, with the development of the dominance value, WFQ allocates more bandwidth to that precise packet to avoid congestion" [7]

3.2 Comparison Transmission Packet Priority Mechanisms

In this part of the article, the advantages and disadvantages of PPMs is presented in terms of transmitting the packets from the source of IoT devices via uplink and downlink of RNs and DeNB cells until they reach the core network of 5G mobile networks. Besides, I have done comparisons of the QoS requirement parameters of the IoT devices in the uplink of the 5G mobile networks as I can see in Tables 2 and 3:

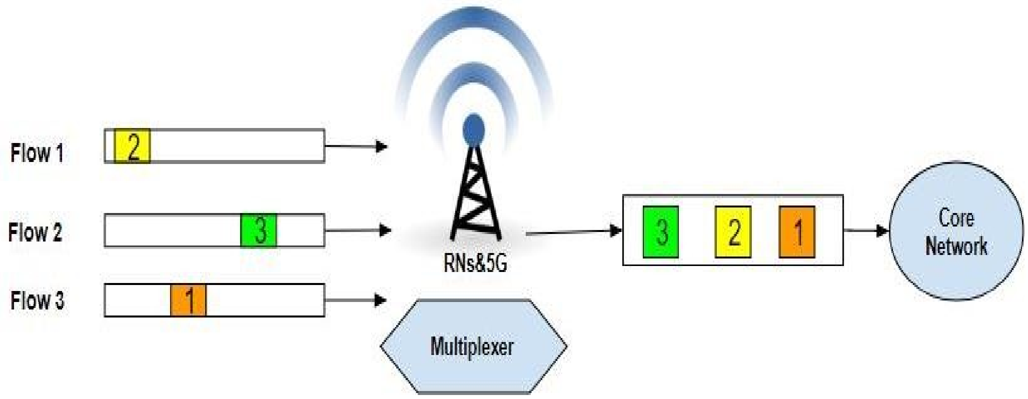

Fig.1. *First-in-First-out model*

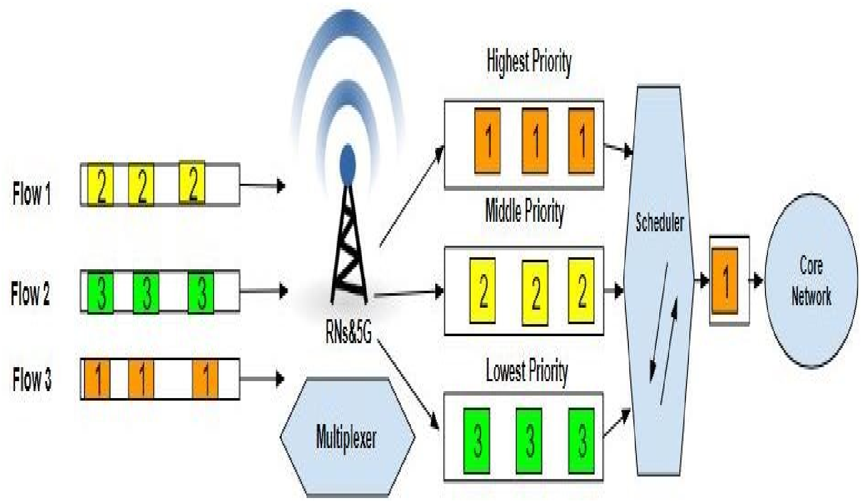

Fig.2. *Priority Queuing model*

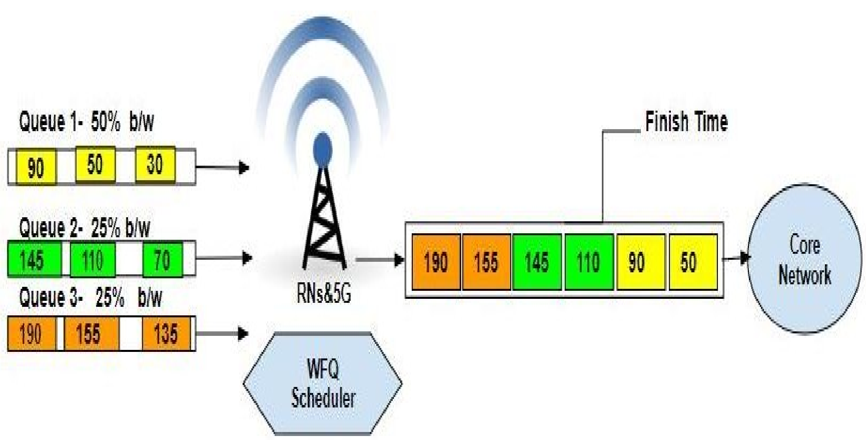

Fig.3. *Weighted Fair Queuing Mechanism*

Table 2. PPMs Transmission Comparison

PPMs	Advantages	Disadvantages
FIFO	• Easy and rapid (one single queue with an easy priority method) • On all platforms it works • In all switching paths it works • In all OS versions it works (above 10.0)	• The unjust distribution of bandwidth amongst several flows • It reasons to starvation (aggressive flows can monopolize links) • It reasons to jitter
PQ	• Presents less-delay propagation to higher-priority packets • It works on most platforms • In all OS versions it works (above 10.0)	• Starvation of lesser-priority classes while high-priority • Classes are congested • Manual configuration of classification on each hop
WFQ	• Easy configuration (Does not need to configure the classification) • To all flows assure throughput • Highly aggressiveflows for drops packets • Assisted on many platforms	• Multiple flows can finish up in one queue • Does not aid the classification configuration • Performance restrictions because of complex classification and priority models

Table 3. PPMs QoS parameters

QoS variables	FIFO	WFQ	PQ
Default on interfaces	>2 Mbps	<=2 Mbps	No
Bandwidth Allocation	Automatic	Automatic	Automatic
Configurable Classes	No	No	Yes
Provides for Minimal Delay	No	No	Yes
No of Queues	1	Dynamic	4
Modern Implementation	Yes	No	No

4. Packet Slicing Model (PSM)

In the proposed PSM model, improving QoS is considered by competent use of 5G radio resources PRBs for IoT and principal idea of the PQ model. Here the PQ model is the suitable PPMs for aiding the several queuing priorities that on the basis of the priority of the packets, initially high priority is transmitted to the output port first, and subsequently, the packets with low priority and etc as exhibited in PSM as illustrated in Figure 4. Therefore, the smart systems environment is designed in 3 levelsof priorities "high *(slice1),* medium *(slice2),* and low *(slice3)",*relying on the packet types as follows:

- The sensitive data is the VCS with highest priority (5 ms)
- The heavy data is the SHS with medium priority (10 ms)
- Smartphone's is well known data with lowest priority (15 ms)

Over a 5G mobile network, aforesaid packets will work in a slicing form in uplink path among RN and DeNB cells on the basis of the UPIM , which is exhibited in Figure 5.

4.1 User Plane Interface Model (UPIM)

The 5G-RAN comprises 2 kinds of NFs From a functional point of view. Here, each and every full radio access functionality is distributed to interrelate with UE over the radio interface: gNBs. It is performed by exploiting the 5G NR interface; as well as ng-eNBs and developing the LTE interface. Aiming at 5G NR gain access, gNBs are associated with the 5G primary network(5GC) by methods of NG ports and might relate to other ng-eNBs and gNBs over Xn ports. To represent modularity and encourage various implementation selections, "3GPP has regulated the F1 interface that functionally divides a gNB into a gNB Central Unit (gNB-CU) for upper protocol layer managing and a gNB Allocated Unit (gNB-DU) for lower protocol layer processing"[8]. A separate gNB is used, if it is distributed into gNB-CU/ gNB-DU or not, and controls the function of one or further 5G (RN) cells. Each 5G cell, is independently recognized by a *cell ID*, and it is assigned with particular radio resources like RF carriers that are operated in a general set of control channels. The 5G (RN) cell interface is being modeled with high flexible OFDM-based waveforms with diverse numerologies (for example diverse subcarrier spacing and cyclic prefix lengths and adaptable time-frequency frame structures like selectable slots durations and dynamic assignment of downlink/uplink transmission direction") [8]. Moreover, the 5G RN cell interface permits forUEs operated through the similar 5G RN cell to be commanded to obtain or communicate utilizing one subgroup of cell resource grid. Finally, this flexibility of 5G cell interface permits UEs with different access types like improved eMBB,mMTC, and URLLC to be at the same time multiplexed over a similar 5G cell, as shown inFigure 5 [9].

5. Simulation Approach

In this section, simulation settings and parameters in an OPNET simulation environment is presented. OPNET simulator tool is a wide and effective simulation package tool with a comprehensive selection of abilities. It enables the prospect to simulate complete heterogeneousnetworks 5G and 4G mobile networks with diverse protocols. The experimented communication network design as illustrated in Figure 6 comprises of 3 RNs cells, DeNB cells in both 5G and 4G mobile networks by applying 32 users and 4 different application servers.

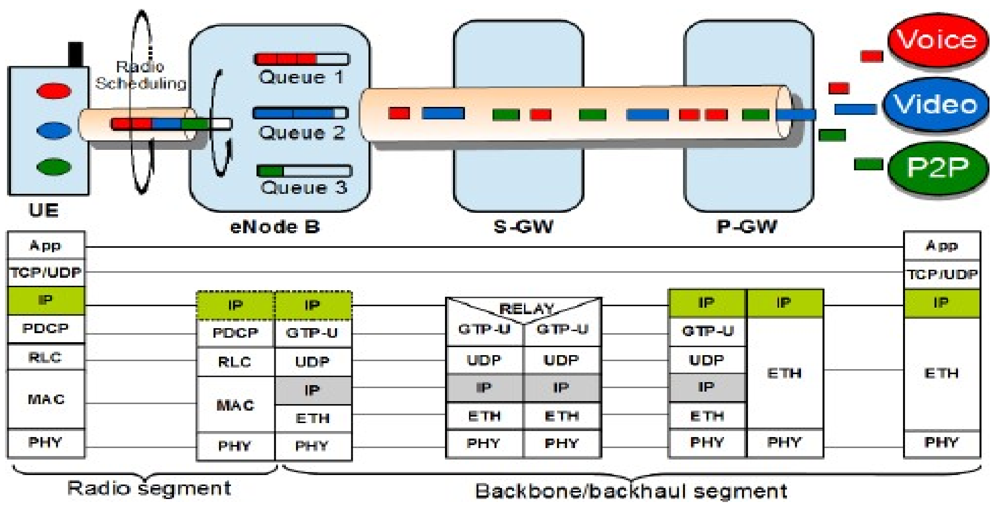

Fig.4.*Packet Slicing Model (PSM)*

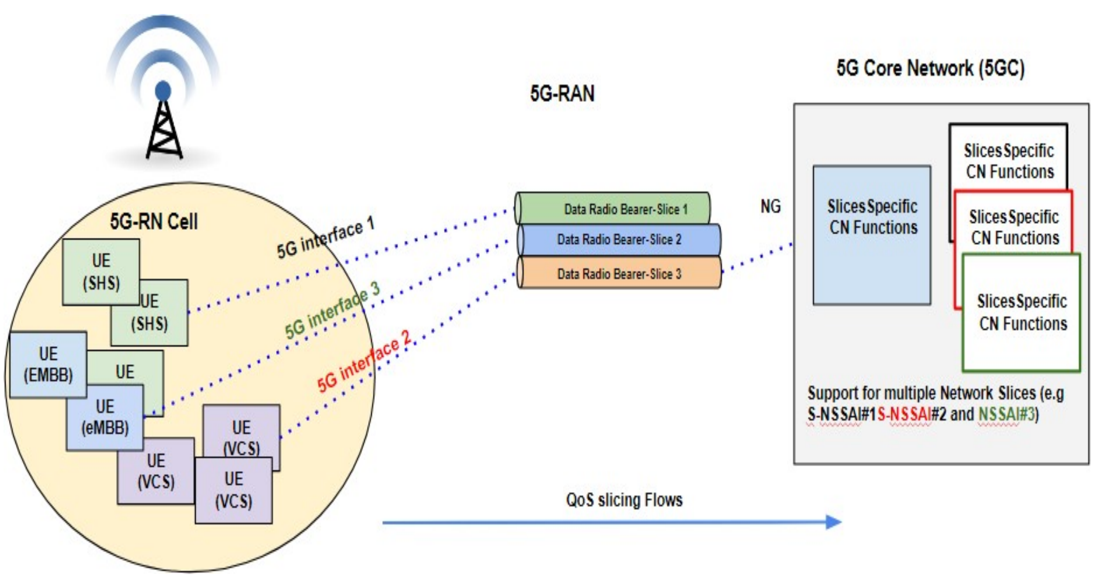

Fig.5. *User Plane Interface Model (UPIM)*

5.1. Simulation Setting

In the simulation setting, the IoT nodes with different protocols are considered which is modified to be suitable along with 5G and 4G mobile network features. The remote server includes FTP, RTP, SMTP, as well as VoIP applications amid the entire smart system. The remote server and the aGW relate to an Ethernet connection with a standard delay of 20 ms. the aGW node protocols include IP and Ethernet. The aGW and Enb nodes (DeNB1, and RN1, RN2, RN3) link over the IP edge cloud (“1, 2, 3, and 4”). QoS Parameters at the TN guarantee QoS parameterization and traffic difference as shown in Figure 6 and Table 4. “The user mobility in a cell is coordinated by the mobility model by updating the position of the users at every single interval. The user’s mobility data is stored on the Global Server (Global-UE-Server). The channel model parameters for the air interface cover slow fading, fast fading models, and path failure”. The experimentation demonstration generally highlights the user plane to implement E2E performance evaluations[10]. Various traffic QoS has presented with the 3GPP standardization.

5.2. Simulation Scenarios

In order to simulate my solution, three scenarios were proposed. The first scenario used(FIFO). The 2nd scenario used (PQ), and 3rd scenario proposed the WFQ as PPMs in 5G and 4G heterogeneous network environments.

5.2.1 Simulation Analysis

In this section, performance of the adopted comparison of three PPMs in 5G and 4G heterogeneous networks is presented. The scenarios have been simulated using PQ, FIFO, and WFQ mechanisms, which are applied to DeNB and RNs cells to link the users (smart systems) by themain server. They were considered to compare the performance of the highest uplink load, throughput, and a lower E2E delay between users using different applications among the three smart systems. The designed these smart systems with four applications, SMTP, FTP, VoIP, and RTP is designed. Also, =three levels of packet priorities for each smart system is stated.

Table 4. Parameters used for simulation

Parameters	Setting
Simulation length	1000 sec
Max. terminal power	23 dBm
eNB coverage radius	“350 m”
Min. Enb-UEs	35 m
Cell layout	1 Enb
	parameters for 5G
5G cell	8*8 antennas
Capability	Enabled
Cloud	Edge could
	parameters for RN
PRBs for RN	To estimate the PRButilization, 3 PRBs are allocated to RN by DeNB.
Type of RN	Fixed
TBS capacity	“1608 bits against MCS 16 and PRBs 5. Existing service rate TBS-overhead (bits/TTI), 1608 (TBS)-352(overhead) =1256bits/TTI”.
RN 1	Adopted by 4 antennas, 10 MHz TDD
RN 2	Adopted by 3 antennas, 5 MHz TDD
RN 3	Adopted by 2 antennas, 3 MHz TDD
Simulated scenarios	FIFO Model, PQ Model, WFQ Model
	General Parameters
Mobility model	RWP
Terminal speed	120 km/h
Frequency reuse factor	1
Path loss	128.1+37.6 log 10 (R). R in km
System Bandwidth	5 MHz
Fast Fading	Jakes-like method
RN PDCP buffer size	5 ms
Slow Fading	“Log-normal shadowing, correlation 1, deviation 8 Db”
UE buffer size	∞
Power control	Fractional PC, α= 0.6, Po= -58 dBm
Applications	SMTP, VoIP, RTP and FTP.
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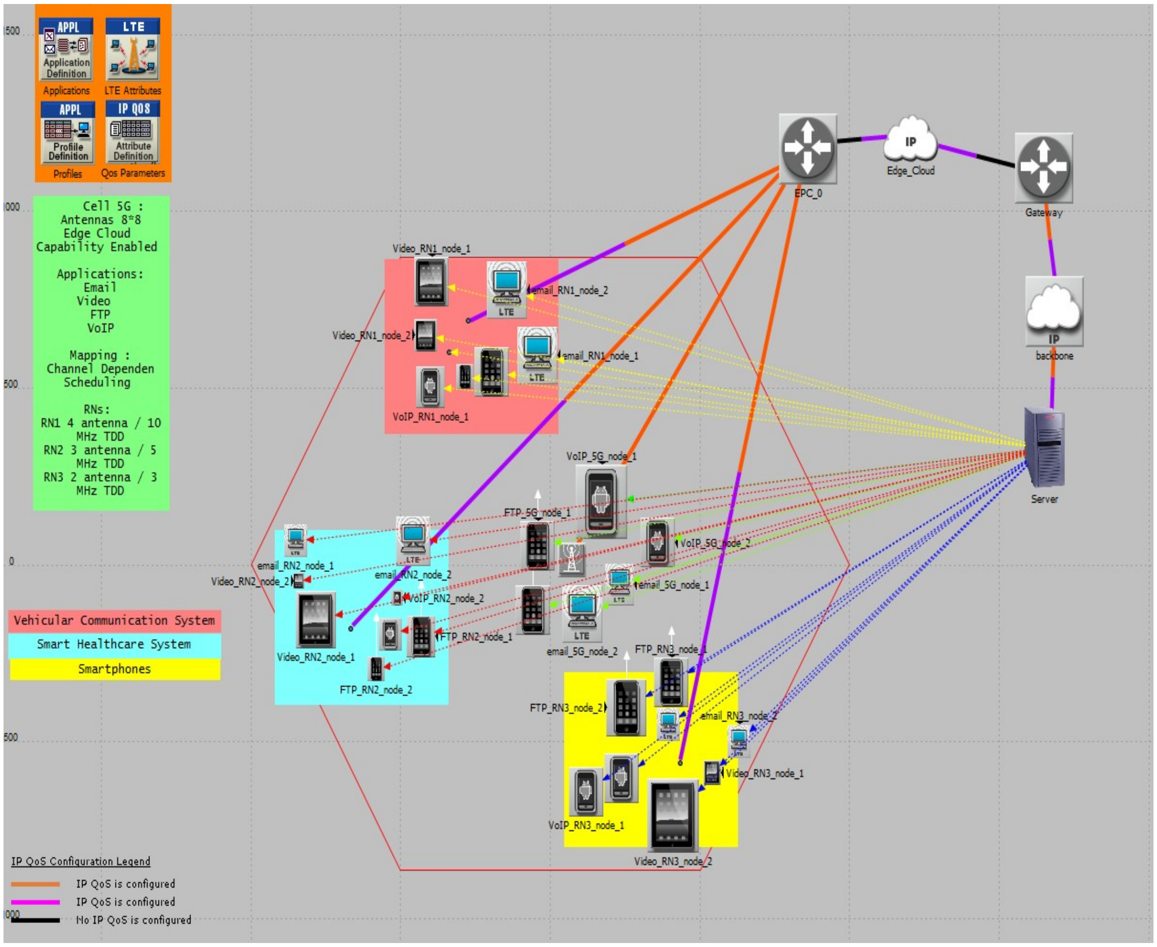

Fig.6. OPNETS PPMs Project

Table 5. Packet priority Mechanism Comparisons

Scenarios	Cells	Application Types
(1) FIFO Model	RNs and DeNB	SMTP, VoIP,FTP &RTP
(2) PQ Model	RNs and DeNB	SMTP, VoIP,FTP &RTP
(3) WFQ Model	RNs and DeNB	SMTP, VoIP,FTP &RTP

5.3. IoT Nodes Performance

The results shown in Figure 7 in the case of SMTP nodes in three smart systems, the FIFO and WFQ models have higher SMTP upload response time compared with the PQ mechanism, which has a lower SMTP upload response time for all smart systems, which is a given indication that FIFO and WFQ mechanisms have supported packets loading from the sources until the final destination of 5G mobile networks. Besides the VoIP node in three smart systemsas exhibited in Figure 8 the PQ mechanism has a slightly lower delay in the E2E VoIP packets than FIFO and WFQ mechanisms, which is supported by the data traffic conveyed from smart systems to reach the main server especially, for the VCS.

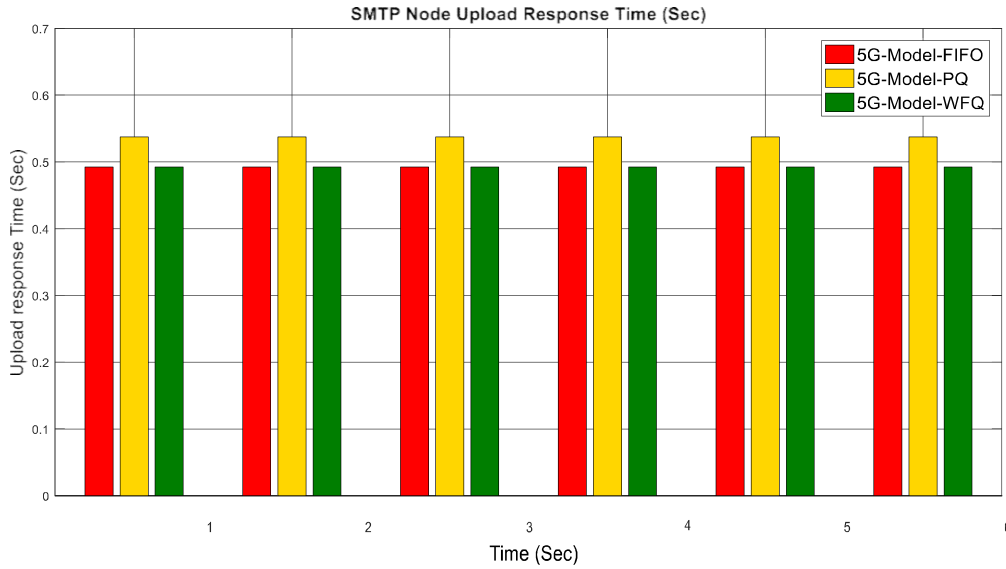

Fig.7. *SMTP Node Upload Response Time*

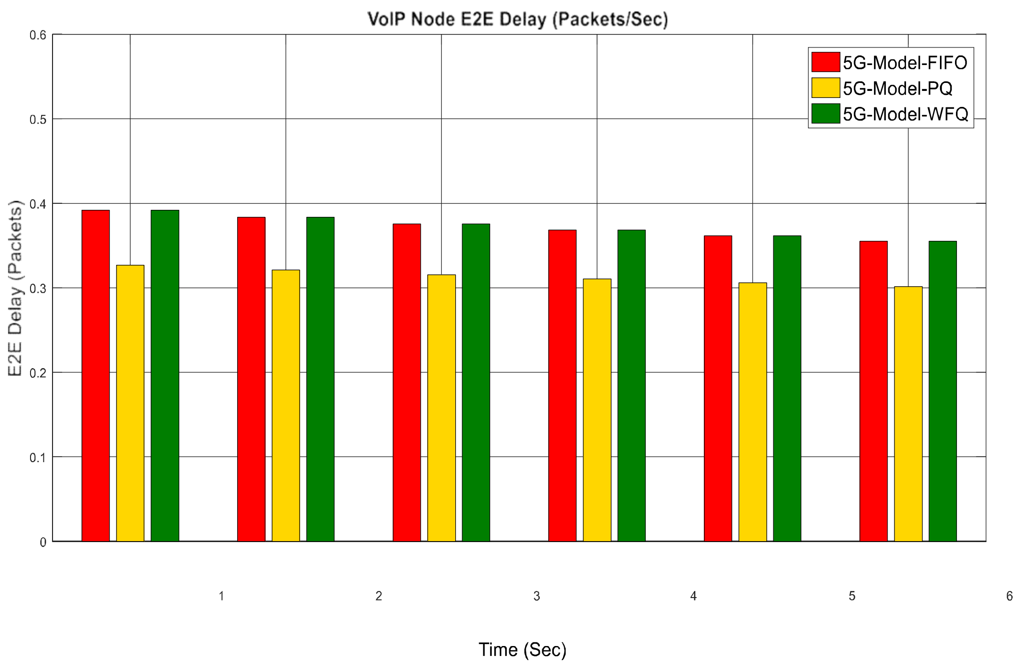

Fig.8. *VoIP Node E2E Delay*

5.4. Cells Performance

In this section, the cell performance by comparing three scenarios on DeNB and RNscells is evaluated. The results obtained are as shown in Figures 9,10, and 11., For example, Figure 10 showsthe results when utilizing the three PPMs over DeNB cells. I found that the PQ mechanism produces a slightly lower processing delay in uplink packets than FIFO and WFQ mechanisms, which have a similar delay in transferring packets from users, which is offered that the PQ mechanism can support packet processing delay lower level and can solve the issue of criticalsmart systems. Moreover, Figure 10 illustrates RNs cells in terms of throughput. The PQ mechanism has the highest values compared to the FIFO and WFQ mechanisms, which can beused to enhance the heavy packets in both VCS and SHS. In addition, in Figure 11, I have usedthese three PPMs over RNs cells. The results show that FIFO and WFQ mechanisms have lower packet loading compared to the PQ mechanism, which has the highest rate of loading. This could be useful to support different smart systems loading requirements such as SHS. Overall, after analysis and simulation of the three mechanisms in the 5G and 4G mobile networks, I found that the PQ mechanism is the best option for PPMs to enhance both the highest uplink of E2E delay and throughput to support a low level of latency in packets demand such as VCS. However, the FIFO and WFQ mechanisms have been observed to enhance packet loading, which can be used for heavy data traffic such as SHS among other smart systems.

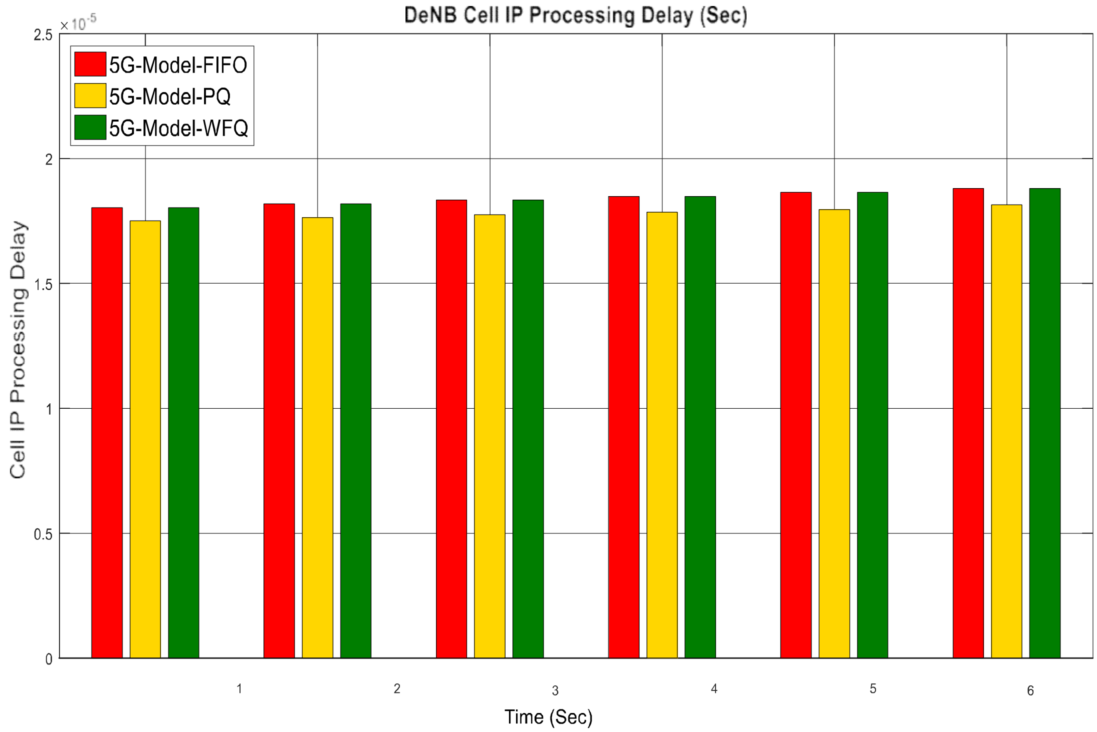

Fig. 9. *DeNB Cell IP Processing Delay*

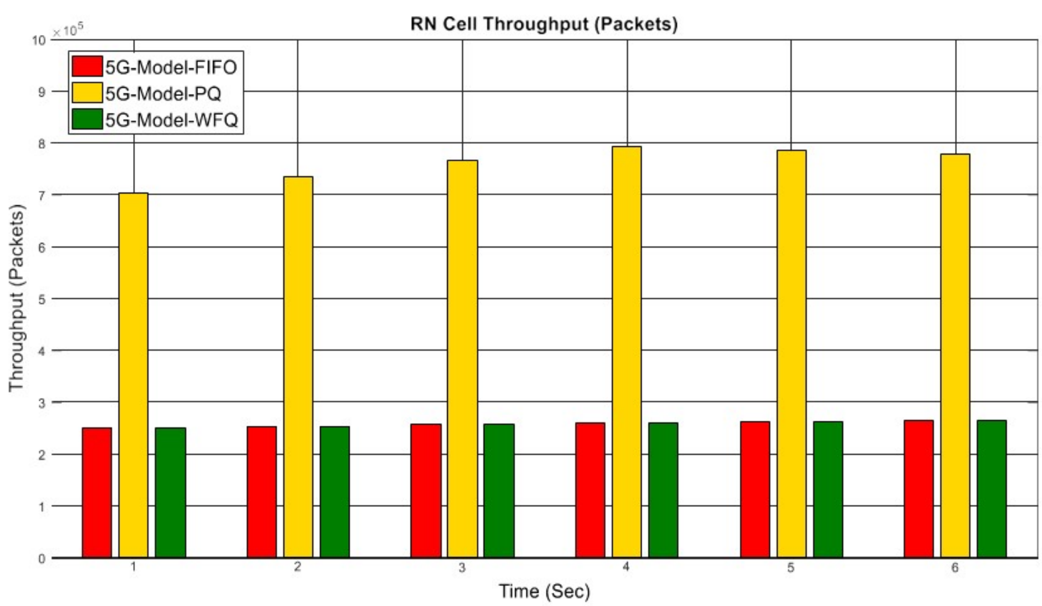

Fig.10. *RNs Cell Throughput*

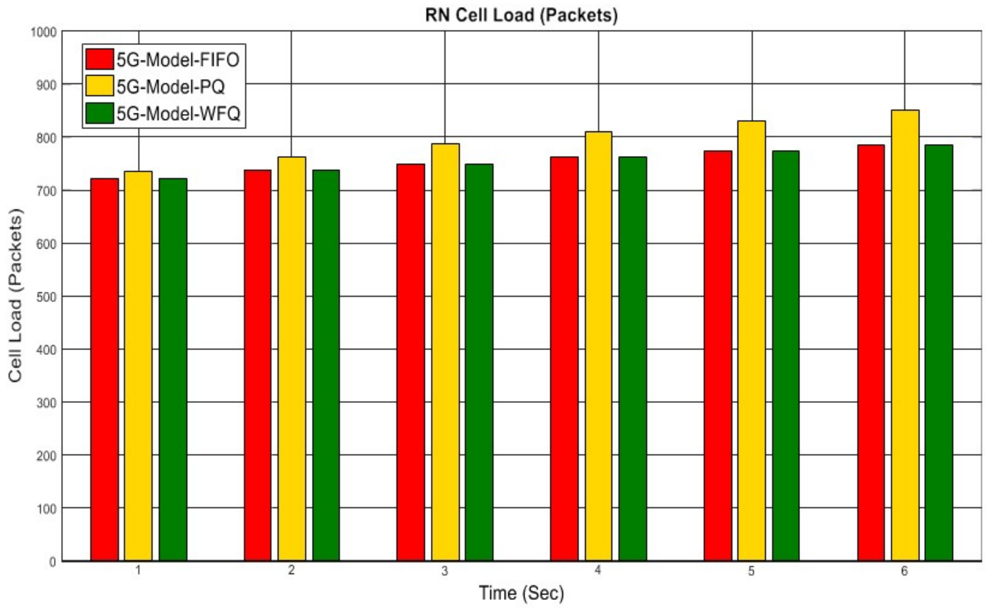

Fig.11. *RN Cells Load*

6. Conclusion

In this article, the PSM over the small cell RNs and the macro cell DeNB within the uplink in 5G mobile networks was proposed. The radio resource utilization for smartsystems over PPMs including FIFO, PQ, and WFQ mechanisms was investigated, my evaluation provides an overview of comparative advantages and disadvantages of priority mechanisms in terms of E2E packets transmission also QoS parameters. Moreover, I have applied and assessed the FIFO, PQ, and WFQ mechanisms over the RNs and DeNB cells through OPNET simulation. my evaluation results show that the PQ mechanism is the most appropriate priority mechanismfor supporting various priorities queuing for different packets, which demand a lower level of latency and throughput such as VCS. Also, the simulation results show that FIFO and WFQ mechanisms have improved packet loading, particularly in heavy packets such as SHS. Overall, these comparisons have been based on smart systems QoS require in a smart city case study to support and help the operations of various systems (e.g., VCS, SHS, and smartphones).my results present opportunities in the future for more research regarding resolving data trafficexplosion and fairness of services area.

Compliance with Ethical Standards

Conflicts of interest: Authors declared that they have no conflict of interest.

Human participants: The conducted research follows the ethical standards and the authors ensured that they have not conducted any studies with human participants or animals.

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