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THE TRANSITION FROM 4G TO 5G BY EMPLOYING FEMTO CELLS PROVEN THROUGH DATA RATE, PLR AND DELAY

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ABSTRACT

This paper introduces the generation five of the mobile systems (5G) utilizing of Femto cells in a single Macro cell of a 4G mobile network. By using three schedulers (Proportional Fair (PF) and its updated version Exponential PF (EXP/PF) besides Maximum Largest Weighted Delay First (MLWDF)), the suggested system has examined three sorts of traffics: Video, VoIP and Best Efforts BE. An enhancement on the overall system moving from 4G to 5G has been shown in the results by adding Femto cells to the main Macro cell. Data rate, packet loss ratio PLR, latency and radio resource allocation fairness are the main parameters that the overall system is judged based on. The simulation findings show that the overall system evaluation is as this: delay and PLR are degraded to decline towards 5G and data rate is boosted even while the number of the system's users is increased. Moreover, fairness in allocating radio resources is also achieved proven through fairness index. So it is counted as one of the efficient methods to introduce the 5G environment where proven through the increment in the data rate, the breadth of the coverage and the reduction in the latency [1].

Keywords: *4G, 5G, LTE-Sim, Macro, Femto, Schedulers, RRM, Data Rate, PLR, Delay & Fairness.*

1. INTRODUCTION

1.1. Background

The Rel10 (4G) is standard for wireless communication of high-speed data for mobile phones and data terminal. It supports at least 200 active data client in every 5MHz cell .Its data rate is about 100 Mbps and it works with IP. It offers increasing of capacity and speed using new modulation techniques [2]. One the other hand, LTE has another name which is 4G. The 4G system can integrate with previous mobile generations such as GSM (Global System for Mobile Communication), EDGE (Enhanced Data GSM Environment) and UMTS (Universal Mobile Telecommunication Service)/HSPA (High Speed Packet Access).Researchers have adopted different methods to improve the LTE system because of the evolution of the telecommunication [3].By concepts such as OFDM (Orthogonal Frequency Division Multiplexing), SC-FDMA (Single Carrier - Frequency Division Multiplexing and Network-based technologies such as Multiple Input and Multiple Output MIMO/ advanced MIMO and Transmission/Reception Coordinated Multi-Point COMP , LTE system is enhanced and introduced LTE Advance (LTE-A).There is another technique to enhance the system based on air interfaces. Particularly, the main aim of this paper is showing the transition from 4G to 5G due to adding Femto cells to a single 4G Macro cell. This is proven through the enhancements showing via the parameters such as throughput, delay, packet loss ratio and fairness index. The other aim is to present the schedulers (algorithms in RRM inside the eNodeB) and compare the performance of each algorithm due to the nature of the selected traffic.

1.2. Heterogeneous Networks (HetNets)

This technique can be considered as a less cost for introducing LTE-A (5G). A mobile network is called a heterogeneous network (HetNet) when a Macro cell has Femto and/or Pico cell(s) within it, whereas a network which consists of only one type of cell (Macro) is known as homogenous. The heterogeneous network is used to improve the spectral efficiency [1][4]. It also increases users' expectations to make the network closer to edge users. HetNets have a lot of advantages by enhancing the voice retain ability, packet accessibility, throughput, mobility, capacity and coverage [5][6]. Mainly, there are two main practical elements: first one is Macro with Pico and the second one is Macro with Femto. Macro cell represents the main cell in the system while Femto and Pico are the small cells. Small cells are less power cells within the main Macro cells with same or different technology [7]. Hence, Femto cell has its own enhanced node B (eNodeB) which uses less power and its name Home eNodeB. In comparison, the standard Macro cell has eNodeB with higher power and the wider coverage area accordingly. Macro, Pico and Femto use the same carrier frequency which, on the other hand, proposes interference challenges. Figure 1 shows a sample of Heterogeneous network.

1.3. Femto Cell

Femto is a small low power base station. Femto range is between 10-50 meters so it is installed in home or buildings. In addition, it is licensed indoor coverage. Femto is a combination of interfaces with existing mobile technologies. When the user starts getting closer to the Femto cell, it will automatically forward its data traffic through Femto cell rather than through the main Macro cell eNodeB. Essentially, the Femto cell is a low output cell power that can route any data over a shorter path to the destination. For example, Femto cell sends users' voice calls through cable or DSL modem placed in a home or a small building, thus letting to save money on phone bills inside their homes by sending them through the technology of Voice over IP VoIP. Femto cell is mainly aimed to increase user throughput and it is simple deployment, prolong handset battery life and more security due to the access policy feature [8].

In 4G and 5G, there are a lot of elements. One of them is evolved node B (eNB) which is responsible for supporting air interface and provides radio resource management functions (RRM). It also has the packet scheduler (PS). Because PS is representing one of the main RRM functionalities, it is very important in optimizing the performance of 4G mobile network. Different packet schedulers have been deployed to efficiently utilizing the mingy radio resources in a 4G network .It is also in charging of data transmissions of the users.
Various packet scheduling algorithms have been proposed considering different sorts of traffics and provided services [1][4][9]. Packet Scheduling (PS) such as Maximum-Largest Weighted Delay First (M-LWDF) and Exponential/Proportional Fair (EXP/PF) are selected in this paper. Scheduling algorithms have been investigated in the downlink 4G system. In this paper, choosing these three types of algorithms will propose a cost effective way to transit from the four generation 4G system to the 5G (Macro cell involved Femto cells). The simulation that is utilized is an open source network simulator called LTE-Sim. The (QoS) quality of service for multimedia services is defined in LTE specification. These three types of scheduling algorithms are used to support Real Time and Non-Real Time application services [9][10].
This paper is arranged as the following: Section II discusses the software and codes that used in this paper. The followed section (III) shows the results after adding the Femto cells to the system by showing the outcomes of the simulation and discussing them. Finally, a conclusion is given in section IV.

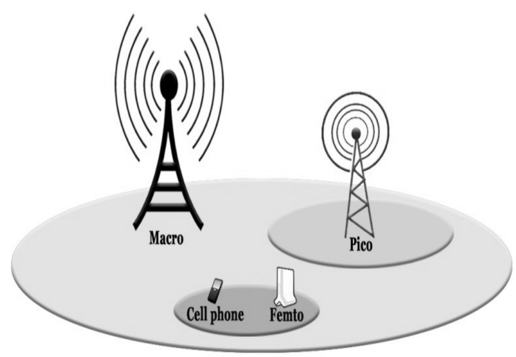

Figure 1: Heterogeneous Network

2. METHODOLOGY

To a clearer understanding of the methodology, it has been divided into three parts.

2.1. LTE-Sim Simulator

Centered According to LTE-Sim; the simulation platform which has been used for getting the results, it was required to have Linux environment ''Ubuntu'' [11]. It is an open source operating system that is used to hold the LTE-Sim simulation program.
LTE-Sim is an open source framework is designed to simulate 4G networks. LTE-Sim has several portions of 4G networks, involving both the Evolved Packet System (EPS) and the Evolved Universal Terrestrial Radio Access (E-UTRAN). It supports a single-Macro cell or heterogeneous multi-Macro cells systems, user mobility, handover capability, QoS management, frequency reuse

techniques, and environment of multi-users [12]. That is the reason why LTE-Sim has been chosen for this paper.

By using the object-oriented paradigm as an event-driven simulator, C++ and shell language (.sh) are the programming languages that used to build LTE-Sim. That ensures modularity, polymorphism, flexibility, and high performance.

To compile LTE-Sim code that is written in C++, Make function has been run that includes the installation code for LTE-Sim as shown in Figure (2). The compiling operation requires nearly 20 minutes if there is no error emerged. The most emerged errors are caused by missing commas in C++ code or editing some of the LTE-Sim part of the code that is required for different simulation requirements.

There are two cases used for Femto cells distributions, 25 (3GPP_5x5_grid) [11] or 40 cells distributed as grids in the single building according to distribution function in LTE-Sim code [16]. This distribution is also proposed by [8] .The number of Femto cells is as aforementioned because Femtos cover only a small area around 10 meters diameter. Hence, to inspect their impact on the Rel10 (4G) Macro cell system, it should be used 25 to 40 Femto cells to cover as much as possible of the main Macro cell coverage area. The case that this paper is selected is that 25 Femto cells in one building in a single Macro cell area. Figure (3) shows the simulation environment using one building with 25 Femto cells in a distance of 4000 meters from the center where Macro eNodeB is located.

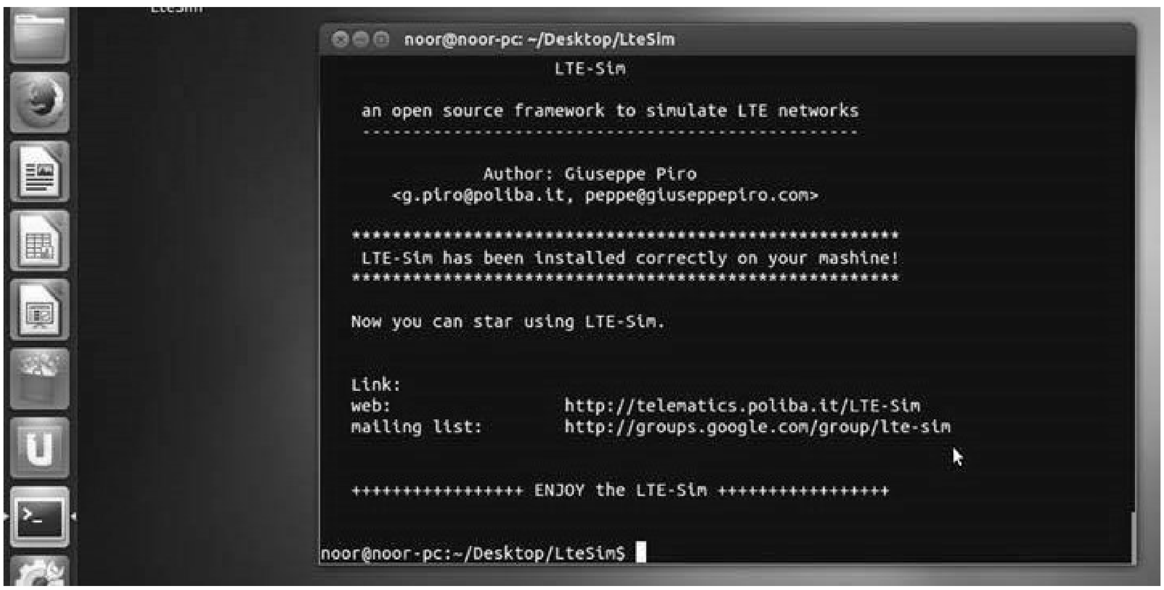

Figure 2: Integrating The LTE-Sim To "Ubunto" By Applying Make Function

2.2. Simulations

The aim of the paper is to compare the performances between two scenarios. The first suggested one is Similar to [1] and [13], Macro cell only representing Rel 10 (4G) system by using three algorithms in the scheduling operation of the downlink (explained in details in section 3.3). The other one is similar to the environment for the first one excluding adding small cells (Femtos) proposing the 5G environment. Hence, the input parameters are considered the same for both scenarios with regarding that Femto scenario requires adding other inputs to create Femto cells. Single Macro cell parameters are seen in Table (1), while Table (2) shows entries for single Macro Cell with Femto cells (25 Femto Cells have been deployed).

To get more accurate results of the simulation by having the average value from five simulations in each case, the total number of simulation's outputs were 75 simulations (for 10 to 50 users) in the coverage area for Macro cell. That is 15 simulations for each type of scheduler (5 for (PS), 5 for (M-LWDF) and 5 for (EXP/PF)) for 10 users. A similar number of simulations for 20, 30, 40 and 50 users' cases for each PS have been conducted.

Total No. Of Simulations = 3 (Schedulers) x 5 (Simulations) x 5 (users' cases, 10 to 50) = 3x5x5= 75. The simulation's files are shown in Figure (4).

Table 1: 4G System Parameters (Single Macro Cell).

Parameter	Value
Simulation time	40 seconds

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Frame structure	FDD
User speed	3 kilo meter/hour
VoIP bit rate	8.4 kilo bit per second
Video bit rate	242 kilo bit per second
Macro cell radius	1 kilo meter
Bandwidth	20 Mega Hertz
Transmission Power	49 dB

Table 2: 5G System Parameters (Single Macro With Femto Cells).

Parameter	Value
Simulation time	40 seconds
Frame structure	FDD
User speed	3 kilo meter/hour
VoIP bit rate	8.4 kilo bit per second
Video bit rate	242 kilo bit per second
Femto cell radius	50 meters
Bandwidth	20 Mega Hertz
Transmission Power	20 dB(Actual Femto Power normally 10 dB)
Activity Ratio	1
Building Type	0
No. Of Building	1
Access Policy	0

2.3. Schedulers

The three aforementioned scheduling algorithms (Proportional Fair (PF) and its modified version Exponential Fair (EXP/PF) in addition to Maximum-Largest Weighted Delay First (M-LWDF)) have been applied in the simulation code. However, LTE-Sim built-in schedulers are six. The reason why there are only three algorithms is that the applications are two types: Real Time (RT) and Non- Real Time (NTR). Each of the selected schedulers is satisfying one of these tested applications. The video application for example, is a real time traffic that could be tested through one of the above algorithms which is created to serve video apps. Figure (5) is the general scheduler model in the downlink at eNodeB of the Rel10 System.

The schedulers were produced to deal with different types of traffics. For instant, the Non Real Time (NRT) traffic in a High Data Rate - Code Division Multiple Access (HDR-CDMA) system is experimented through PF algorithm that was developed to support it [14]. PF provides trade-off between the total system data rate and resource availability (fairness). It takes in a consideration both the experienced channel conditions while assigning radio resources and the past data rate. In comparison, M-LWDF was produced to support multiple Real Time (RT) data users in HDR-CDMA system[15]. In this scheduler, channel variations in allocating radio resources are considered and additionally; in case of video traffic, time delay is considered. Hence, M-LWDF is used in a case that there is a need of different QoS requirements. On the other hand, the scheduler algorithm EXP/PF was proposed as an updated version of PF. It is intended to multimedia applications in the Adaptive Modulation and Coding and Time Division Multiplexing (AMC/TDM) systems and it is used to support mixed types of services: NRT service or RT service [16].

3. RESULTS

The results are gathered from the three type of traffics (Video, VoIP and BE –Best Efforts). The figures that are selected are examples from all the obtained graphs. In other words, they are the most noticeable findings.

3.1. Transition From 4G to 5G Is Proven Through The Data Rate Outcomes

As it is shown from the Figure (5-b), the overall system data rate has been raised to the value (1.8 e^7 bps (18 Mbps) and 1.9 e^7 bps (19 Mbps)) at the point 50 users for the schedulers EXP/PF and MLWDF respectively. In contrast to the same point for the Figure (6-a), the three schedulers approximately reach the same value which is (4.4 e^6 (4.4Mbps)). It has been noticed that due to the PF algorithm doesn't aimed to support Video traffic, it shows the lower data rate value in Figure (6-b). For both Figures (6-a & 6-b), the data rate is increasing while the number of users is increased. This behavior is caused by the effect of scheduling algorithms that provide better resource allocation while more users are added to the system. The outcomes in [17] support the findings for data rate for this paper.

3.2. Transition From 4G to 5G Is Proven Through Packet Loss Ratio (PLR) Results

The better system is the lower the PLR should be. Distributing grid Femto cells should

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reduce the PLR value since the distance between the users and the base stations is shrinking. Figure (7-b) proves that. The PLR value is decreasing from the value (0.2) at point 10 users to the value (0.144) at point 50 users for MLWDF, for example. Generally, PLR value increases while adding more users to the system. Figure (7-a) single Macro cell shows this case using the selected schedulers. Thus, PLR behavior proves that the Femto cells have a positive impact on the PLR value reducing the one that is calculated from deploying Macro cell only.

3.3. Transition From 4G to 5G Is Proven Through Delay Changes

In this part of the simulation, the Femto scenario states lower delay than the Macro scenario. Such results could be deemed as 5G where such behaviour is aimed to be reached. For instance, MLWDF line is decreased while numbers of users are joined to the system. At point 10 users the MLWDF delays is 1.6 ms, whereas at point 50 the delays is 1.4 ms. Even the MLWDF delay behaviour shows a minor difference, the EXP/PF illustrates that more clearly. Figure (8-b) is the delays of the 5G scenario where Femto cells are present. Unlike Figure (8-b), Figure (8-a) explains that the delay in 4G scenario is being worse while more users are joined to the system. This is obvious through the scheduler (EXP/PF) for VoIP traffic. At point 10 users, the latency is 1.6 ms. In contrast, at point 50 users the delay is getting worse where it is increasing to reach the value of 5.5 ms. The oscillation that is shown in Figure (8-b) at points 10,20 and 30 could be caused by the mobility of Femto users inside the building or due to the reattachment process from Femto to Macro or vice versa.

3.4. Fairness Index In Both 4G And 5G

The fairness index is the method that we use to know if the system is fairly allocating radio resource to online users. The applied applications in this paper are Voice Over IP (VoIP), Video and Best Effort traffic (BE - is the rest of available bandwidth). Thus, three graphs of fairness are summated one for each application (20% BE, 40% Video and VoIP 40%). The overall value of the fairness should be 100% ideally (fairness index is 1). Optimum fairness for any system should close to 1. That is why all graphs in (Figures 9, 10, 11-a) are added to comprise Figure (12-a: 4G Fairness index) and similarly (Figures 9, 10, 11-b) present Figure (12-b: 5G Fairness Index). As it is clear that the findings are close to the value of 1 at point 10 users, and then it starts decreasing to the value of 0.8 in both Figures (12-a and 12-b) at point 50 while the number of clients are incrementing. Both cases show a fair system behavior. Moreover, for the 5G considered case that has Femto cells, the fairness index is still under a good condition matching the one obtained from the 4G proposed scenario (both are declined similarly).

4. COMPARESION TO PREVIOUS WORK

A comparison with 4G works can be shown through [1, 13, 16,17and 18], using the similar simulation environment while altering the scenarios and scenarios parameters. The outcomes in [1] shows that while adding two Pico cell to the system, the delay and PLR decreased while the data rate is increased. Macro cell system which represents pure 4G had been enhanced towards the 5G; the 5G standards have been agreed in [19]. Similar outcomes had been shown in [13] where more Pico cell has been added to the system. Using Femto cells (small cells) in [16,17,18] had led to similar essence where the Macro 4G system enhance to present the standardization toward 5G.

5. LIMITATION AND ASSUMPTIONS UNDERTAKEN

It is definitely illogical to add more femto cell to the system to the aim that getting better performance. More cells means more intercell interference ICIC and intracell interference. Similar frequency has been utilized in all the cells in the simulation environment. This leads to more interference in turn more packets' drops. Hence, PLR, and delay will increase and data rate will decrease [8]. For instance as stated in [8], more than 10 Pico cells will reach the system to the steady state while more users were added to the system. Small system degradation will be shown after the 10 Pico cells. Cost is another limitation. More cells add extra cost to the environment. However, the cost of small cells is much better than employing other techniques to reach to the 5G system. On the other hand, schedulers are not utilizing more efficiently from the instant available RRM resource. So that a there are still unused instant carrier component CC that need to be considered.

6. CONCLUSION

To sum up, the overall system is enhanced from 4G proposing the 5G environment. This is

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clearly proven through the data rate, PLR, delay and fairness. Data rate increased from several numbers of Mbps to more than 15 Mbps in all schedulers. PLR shows obvious enhancement by deploying Femto cells in the 4G system. The delay is also improved in which the delay values (in 5G Femto scenario) are declined. Fairness index keeps the value close to 1 in both cases, however, declining smoothly to the value 0.8 while more users are attached to the system. Such improvements propose 5G from Rel10 (4G) mobile environment. The 5G standardization is agreed in [20] so that 100 Mpbs downlink for instance should be reached using different technologies. This paper shows the data rate that is increased toward the 5G direction while the femto cells are adding.

7. FUTURE WORK

Based on the aforementioned limitation and assumptions in section 5, enhanced inter-cell interference cancelation (eICIC) is needed to eliminate the effect of ICIC. The interfernce could be reduced using a method called almost blanked subframe (ABS) could be used to mute some of the small cells instant TTL values to open the space to the main macro cell users. Repositioning small cells, on the other hand, could reduce and elevate the impact of interference. Regarding to the cost, the repositioning could also work in this direction where users will get the expectations of the data rate while the small cells serving them. Finally, with the consideration to the available CCs, researchers would propose new scheduler such as multi-layers resource schedulers. Moreover, Coordinating Multipoint technique CoMP and Carrier Aggregation CA can be used. CoMP could be deployed to benefit from the neighboring small cell to cooperate with each other serving the system user while CA is to reach the best utilization from the available resources.

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8. ACKNOWLEDGEMENTS

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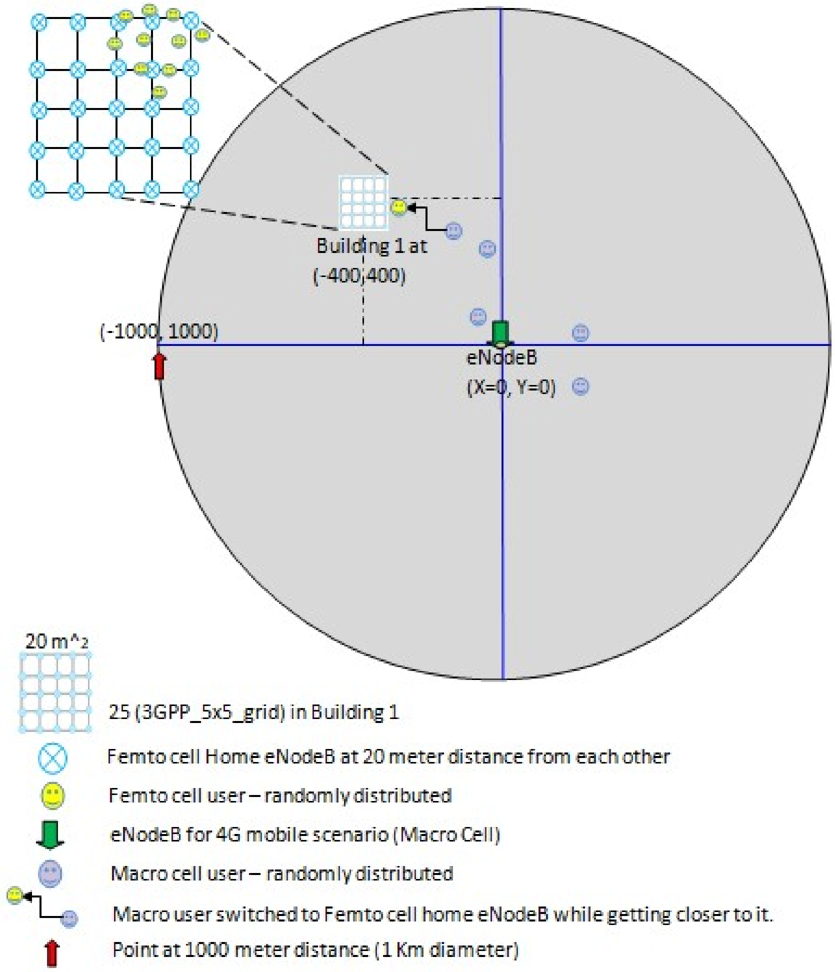

Figure 3: The Simulation Environment Of The 5G

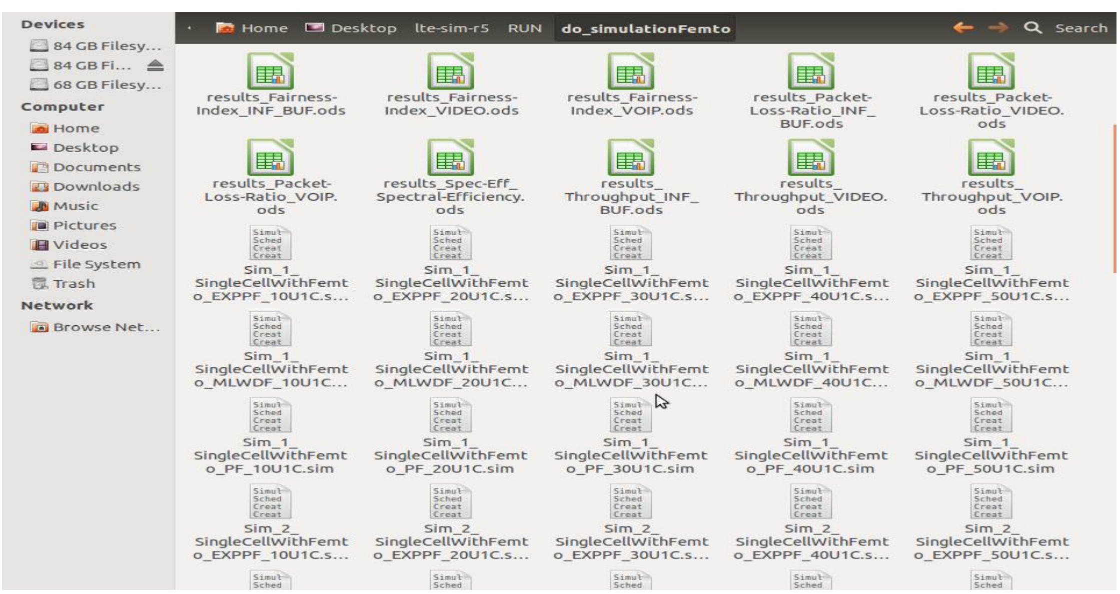

Figure 4: A Portion Of Simulations' Files (Total 75 Simulations' Outcomes)

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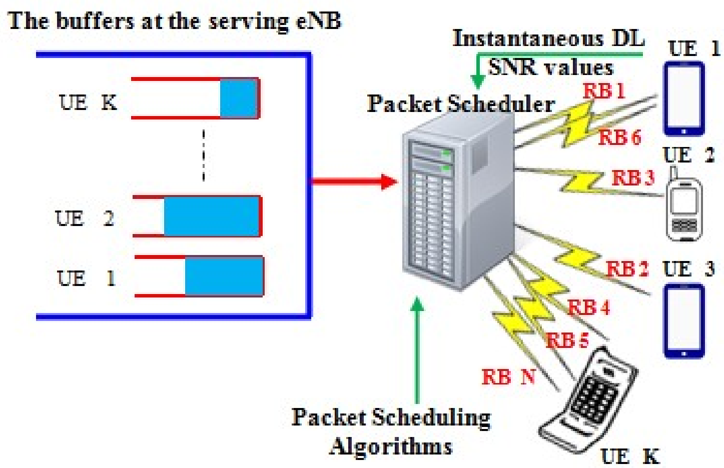

Figure 5: General Scheduler Module In The Downlink At eNodeB Of The Rel10 System [13]

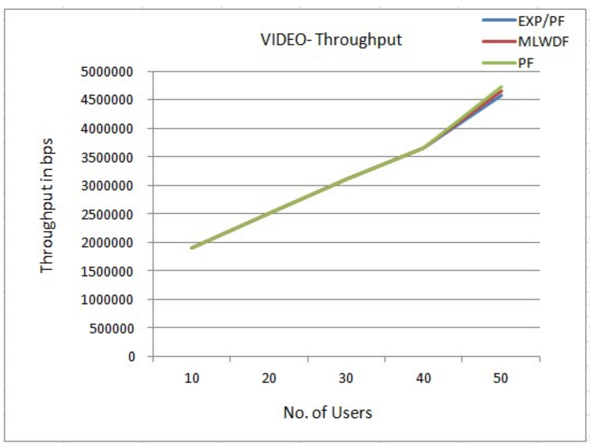

Figure 6-a: Data Rate In A Single Macro Cell (4G System) In Concerning With VIDEO Traffic.

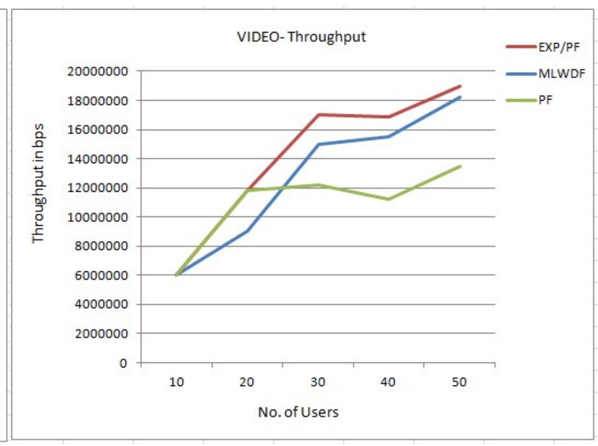

Figure 6-b: Data Rate In Macro Cell Including Femto Cells (5G System) In Concerning With VIDEO Traffic.

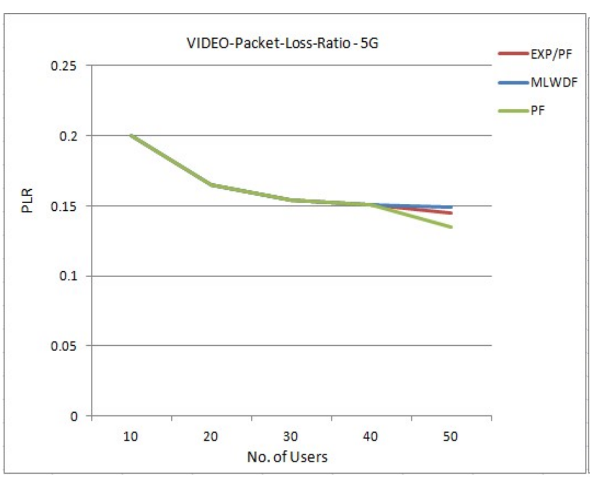

Figure (7-a): Packet Loss Ratio in a single Macro cell (4G System) In Concerning With VIDEO Traffic.

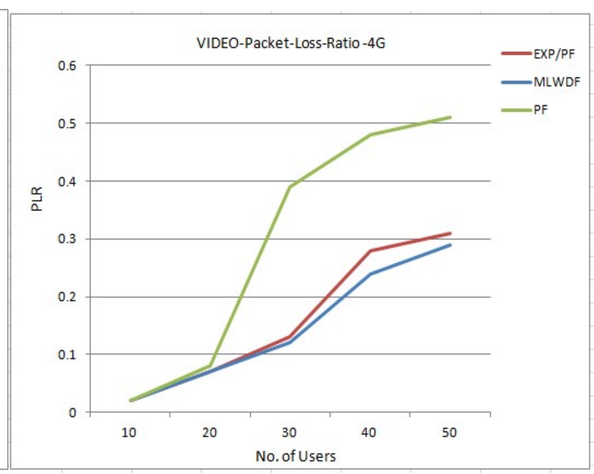

Figure 7-b : Packet Loss Ratio In Macro Cell Including Femto Cells (5G System) In Concerning With VIDEO Traffic.

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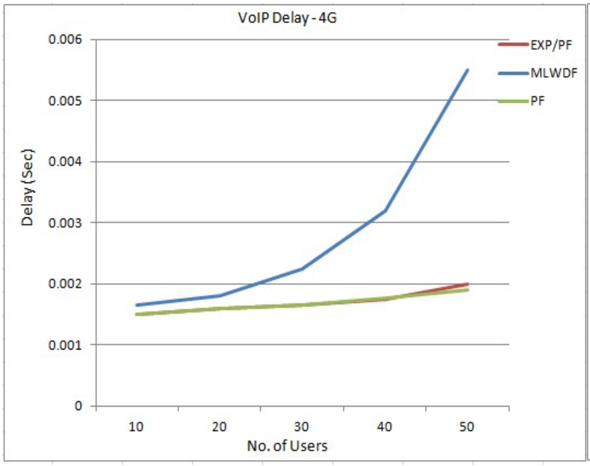

Figure 8-a: *Delay In A Single Macro Cell (4G System) In Concerning With VoIP Traffic.*

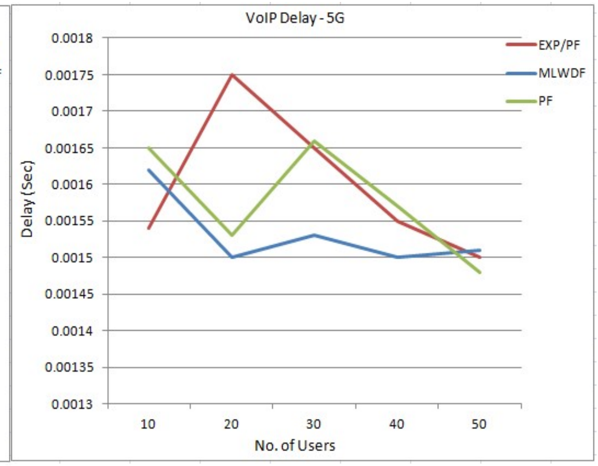

Figure 8-b: Delay In Macro Cell Including Femto Cells (5G System) In Concerning With VoIP Traffic.

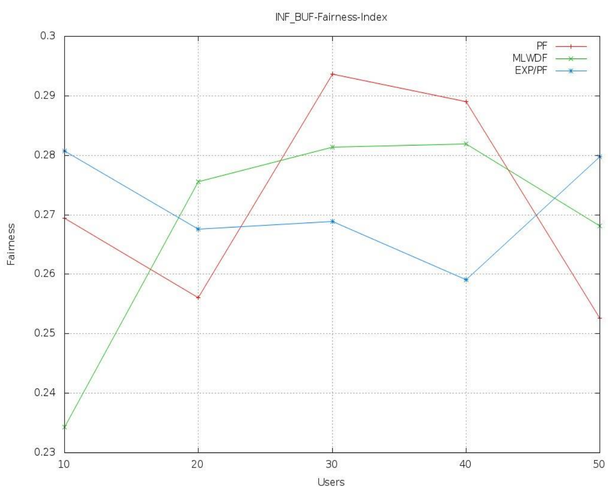

Figure 9-a: Fairness In A Single Macro Cell (4G System) Using INF_BUF (BE Traffic)

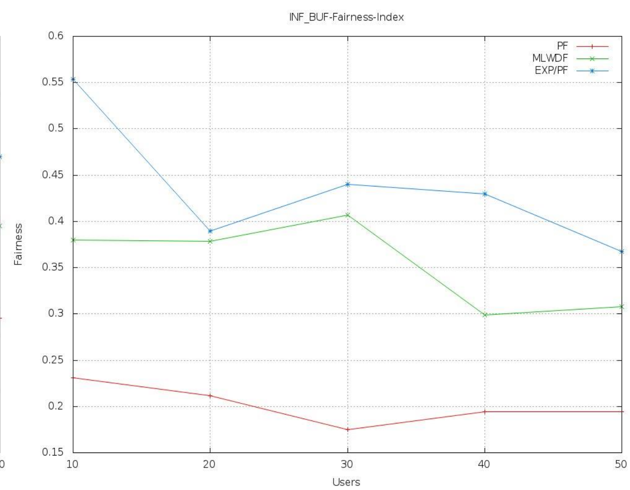

Figure 9-b: Fairness In Macro Cell Including Femto Cells (5G System) Using INF_BUF (BE Traffic)

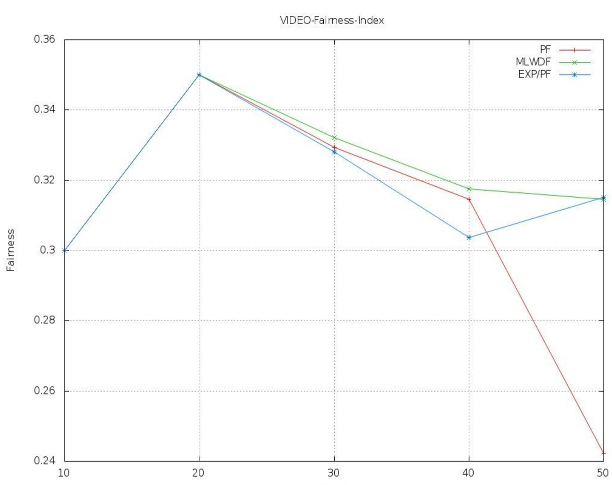

Figure 10-a: Fairness In A Single Macro Cell (4G System) Using VIDEO Traffic.

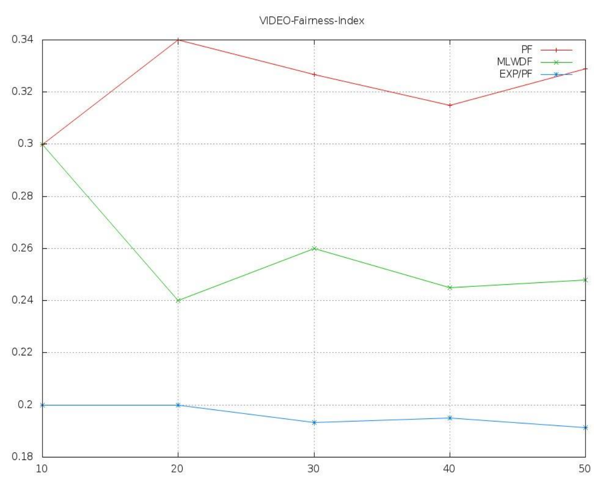

Figure 10-b: Fairness In Macro Cell Including Femto Cells (5G System) Using VIDEO Traffic.

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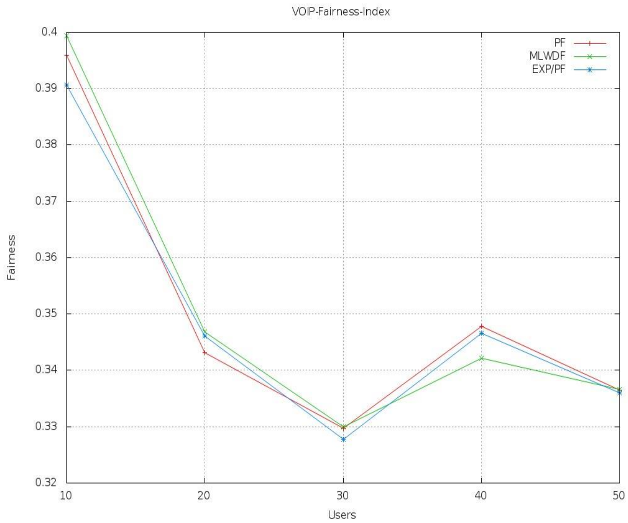

Figure 11-a: Fairness In A Single Macro Cell (4G System) Using VoIP Traffic.

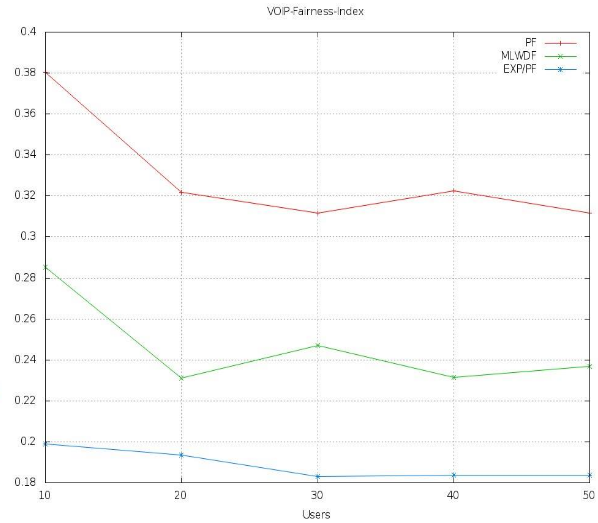

Figure 11-b: Fairness In Macro Cell Including Femto Cells (5G System) Using VoIP Traffic.

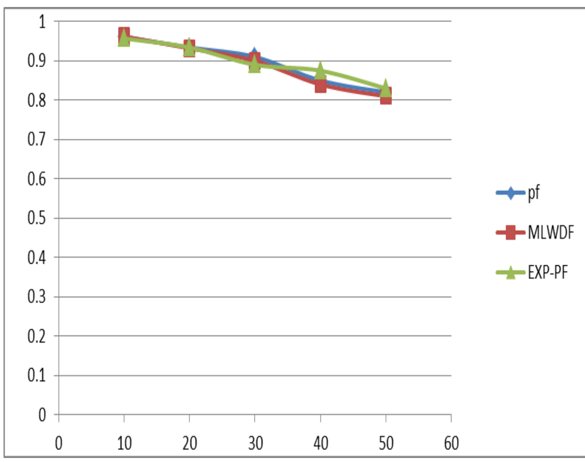

Figure (12-a): The Overall System Fairness Index In A Single Macro Cell (4G System)

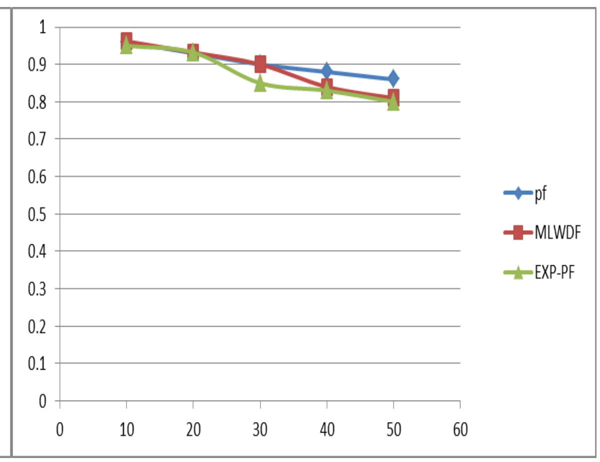

Figure 12-b: The Overall System Fairness Index In Macro Cell Including Femto Cells (5G System)