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Performance Enhancement of Heterogeneous LTE Networks Using EXP/PF Packet Scheduling Algorithm

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***Abstract*— Recently, there has been an increasing demand for Internet access over the mobile devices. To address this, the wireless telecommunication industry defined a new air interface for mobile communications that provides a framework for high mobility broadband services and increase in the overall system capacity. One of the key technology LTE (Long Term Evolution) networks have been introduced in 3GPP (Third Generation Partnership Project) release 8 specifications, with an aim of high-data-rate, low latency and packet-optimized radio access technology. At same time its network architecture has been designed with the goal to support packet-switched traffic with seamless mobility and great quality of service. Since LTE is relatively a new standard it is important to model and analyze the behavior and the performances of LTE Network. The QoS for multimedia services are defined in LTE specification. However, the scheduling algorithms for supporting real time and non-real time application services are not specified. Therefore, different scheduling strategies are proposed. This research work explores the performances of LTE Network for different proposed scheduling algorithms such as Proportional Fair (PF), Maximum- Largest Weighted Delay First (M-LWDF), and Exponential Proportional Fairness (EXP/PF) by using the LTE-Sim network simulator. LTE-Sim is chosen because it is an open source network simulator and supports these scheduling algorithms. The evaluation is considered for a multi cell scenario for different flows such as video and best effort. The performance evaluation is conducted in terms of throughput, delay, and Packet Loss Ratio (PLR). From experimental results it was concluded that all three scheduling algorithms are suitable for best effort flows but EXP/PF is more suitable for video flows.**

Keywords*— *LTE, EXP/PF, WiMAX, TTI, Quality of Service, Scheduling.

I. INTRODUCTION

Developed by 3GPP, LTE is the leading OFDMA wireless mobile broadband technology. LTE offers high spectral efficiency, low latency and high peak data rates. LTE leverages the economies of scale of 3G, as well as the global ecosystem of infrastructure and device vendors, to provide the highest performance in a cost effective manner.

The LTE standard was first published as part of the 3GPP Release 8 specifications. Comparing the performance of 3G and its evolution to LTE, LTE does not offer anything unique to improve spectral efficiency, i.e. bps/Hz. However, LTE significantly improves system performance by using wider bandwidths where spectrum is available (Abed, G. A. et. al., 2012; Iturralde Ruiz, G. M., 2012; Paul, R., 2008). An evolution from 1G to 4G communication technologies is shown in figure 1. As shown in figure 1 LTE belongs to 4G technologies.

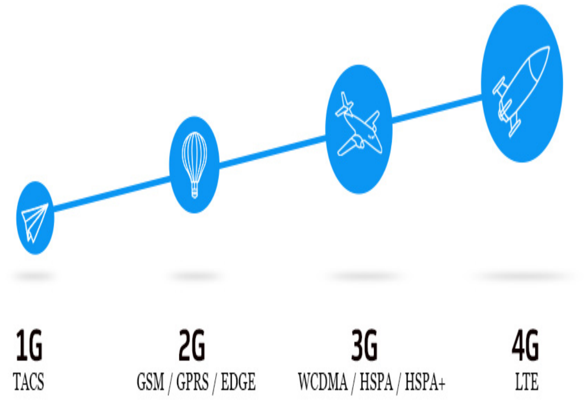

Figure 1: An evolution of communication technologies.

The overall objective for LTE is to provide a significantly increased peak data rates, reduced delay (latency), scalable bandwidth capacity and more multi-user flexibility than the currently deployed networks. It also provides backwards compatibility with existing 3GPP and 3GPP2 technologies (GSM, UMTS, HSPA, CDMA 2000), as well as inter-working with other non-3GPP and non-3GPP2 technologies such as IEEE 802.16 WiMAX (Worldwide Interoperability for Microwave Access), and IEEE 802.11 WLAN (Wireless Local Area Networks), i.e. WiFi (Wireless Fidelity) standard (Araniti, G.,2013; Ekstrom, H., 2009; Ferdosian, N., 2014). The LTE system is not only designed for substantial performance enhancements but also to reduce the cost per bit. Taking the technological point of view what LTE concept makes the number one are the increased data rate, improved geographical coverage and reduced latency. On the other side, the commercial point of view of the LTE promises more competitive business case for the mobile operators and the base network for service providers. Since LTE is relatively new standard it is important to model and analyze the behavior and the performances of LTE Network (Elgazzar, K., 2010; Kela, P., 2008; Tsang, T. 2013).

1.1 Services provided by LTE

The Quality of Service (QoS) for multimedia services is defined in LTE specification. However the scheduling algorithms for supporting services for real time and non-real

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time application are not specified (Lima, F. R. M., 2012; Safa, H., 2012). Therefore different scheduling strategies are proposed. In these scheduling algorithms, a priority value is assigned to each connection regardless its type depending on certain criterion. The connection with the best criteria is scheduled first at the next transmission time interval (TTI). This approach has the advantage of low implementation complexity. However it is difficult to define a single priority criterion, due to the different traffic characteristics and QoS requirements of Real Time (RT) and Non Real Time (NRT). Therefore, it is necessary to use different algorithms for each type of service (RT and NRT).

Since LTE is relatively new standard it is important to model and analyze the behavior and the performances of LTE Network. The QoS for multimedia services are defined in LTE specification. However the scheduling algorithms for supporting real time and non-real time application services are not specified (Liu, F. et. al., 2010; Shakkottai, S. et. al, 2001). Therefore different scheduling strategies are proposed.

1.2 Network Architecture of LTE

Actually, LTE is a path followed to achieve 4G speeds. LTE is a full IP technology used for the mobile broadband services for data transfer and voice calls. Soon it will be used for the Multimedia Broadcast Multicast Service (MBMS). Wireless operators are rapidly expanding their LTE networks to take advantage of additional efficiency, lower latency and the ability to handle ever-increasing data traffic. The core technologies have moved from circuit-switching to the all IP evolved packet core. Meanwhile, access has evolved from TDMA (Time Division Multiple Access) to OFDMA (Orthogonal Frequency Division Multiple Access) as the need for higher data speeds and volumes as increased. LTE network architecture can be divided into two sub networks as shown in figure 2.

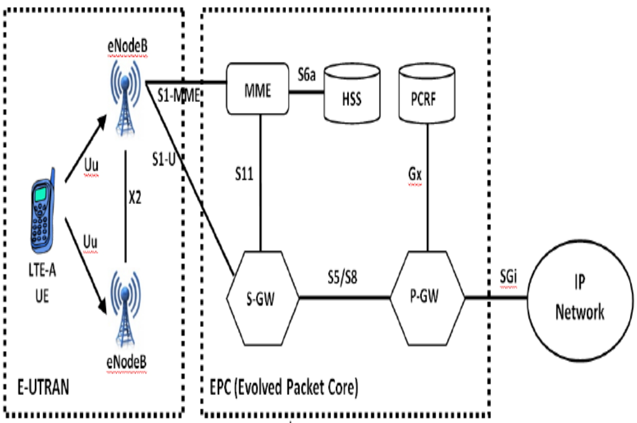

Figure 2: LTE network architecture.

1.3 Goals of LTE

The main goal of LTE is to provide a high data rate, low latency and packet optimized radio access technology supporting flexible bandwidth deployments. At same time its network architecture has been designed with the goal to support packet-switched traffic with seamless mobility and great quality of service.

II. RELATED WORK

Nguyen, Nguyen and Renault (2016) analyzed that the Long Term Evolution (LTE) network have high data rates and fully All-IP architecture. Scheduling and resource allocation are very important tasks in LTE network. A new scheduling scheme which based on the Wideband (WB) E-model, Channel-and QoS-Aware (known as WE-MQS scheduler) for voice traffic in LTE downlink direction was proposed. The proposed scheduling scheme was based on the extension of the WB E-model and the consideration of Maximum Queue Size (MQS) as a factor for the metric. Since this scheduling scheme considers Mean Opinion Score (MOS) values, thus, it gets higher user perception. The simulation results shows that the proposed scheme had the performance which not only satisfies QoS requirements of voice services but also outperforms well-known schedulers such as Frame Level Scheduler (FLS), Modified Largest Weighted Delay First (M-LWDF) and Exponential/Proportional Fair (EXP/PF) schedulers in terms of delay for all the number of user (NU) and Packet Loss Rate (PLR) when the NU is more than 47.

Ferdosian, N., et. al., (2015) considered the resource allocation as a multi-objective optimization problem, covering the performance targets of LTE scheduling. The desired solution which is selecting and scheduling the best candidate bearers was provided by using a throughput aware knapsack algorithm to maximize the desired performance targets. By modifying the Knapsack algorithm to use a throughput aware ranking function the system performance in terms of total throughput can be enhanced in several classes of Quality Channel Indicators (QCI) to the close levels. On the other hand, as much as the Voice over IP (VoIP) traffic is the major volume of the existed wireless communication traffic, they assessed the proposed scheduling solution by comparing the level of the long-term obtained throughput by the VoIP bearers. The simulation results showed that the level of fairness was improved as the particular effect of added normalized throughput metric.

Shojaedin, N., et. al., (2014, June) designed a new scheduler called “Queue MW” (Q-MW) which is tailored specifically to TCP dynamics by giving higher priority to TCP flows whose queue at the base station is very small in order to encourage them to send more data at a faster rate. They implemented Q-MW in ns-3 and studied its performance in a wide range of network scenarios in terms of queue size at the base station and round-trip delay. Simulation results showed that Q-MW achieves peak and average throughput gains of 37% and 10% compared to MW schedulers if tuned properly.

Bendaoud, F., et. al., (2014) surveyed the PS part of the RRM task, which performs the radio resource allocation in both uplink and downlink directions. Several approaches and algorithms were explored to address this need (allocate resources efficiently), the diversity and multitude of algorithms is related to the factors considered for the optimal management of radio resource, specifically, the traffic type and the QoS (Quality of Service) requested by the UE. An art’s state of the radio resource allocation strategies and a detailed study of several scheduling algorithms proposed for LTE (uplink and downlink) were made.

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Capozzi, F., et. al., (2013) provided an overview on the key issues that arise in the design of a resource allocation algorithm for LTE networks. It is intended for a wide range of readers as it covers the topic from basics to advanced aspects. The downlink channel under frequency division duplex configuration was considered as object of study, but most of the considerations were valid for other configurations as well. They surveyed on the most recent techniques is reported, including a classification of the different approaches presented in literature. Performance comparisons of the most well-known schemes, with particular focus on QoS provisioning capabilities, were also provided for complementing the described concepts.
Tamma, B. R. (2012, November) proposed an architecture which addresses several challenges involved in unified heterogeneous network system such as context-aware handover, load balancing and signaling overhead. They also presented comparative mathematical analysis of proposed architecture with respect to the current MIH standard.

Khan, M. F. M. et. al., (2012) provided a review on the vertical handover mechanism focusing mainly on the services provided by the IEEE 802.21 Media Independent Handover Standard. The Handover Execution stage is dependent on the media-specific technology. They also provide a brief discussion to the various approaches used to carry out the handover process depending on the parameters involved in the particular technologies and the handover decision algorithms.

Brueck, S. (2011, November) discussed the need for an alternative deployment model and topology using heterogeneous networks. The concept of LTE-Advanced based heterogeneous networks is about improving spectral efficiency per unit area. Using a mix of macro, pico, femto and relay cells, heterogeneous networks enable flexible and low-cost deployments and provide a uniform broadband experience. To enhance the performance of these networks, advanced techniques are described, which are needed to manage and control interference and deliver the full benefits of such networks. These techniques include cell range expansion, adaptive inter cell interference coordination and interference cancellation receivers.

Damnjanovic, A. et. al., (2011) surveyed current state of the art in heterogeneous deployments and focus on 3GPP LTE air interface to describe future trends. A high-level overview of the 3GPP LTE air interface, network nodes, and spectrum allocation options is provided, along with the enabling mechanisms for heterogeneous deployments. Interference management techniques that are critical for LTE heterogeneous deployments are discussed in greater detail. Cell range expansion, enabled through cell biasing and adaptive resource partitioning, is seen as an effective method to balance the load among the nodes in the network and improve overall trunking efficiency. An interference cancellation receiver plays a crucial role in ensuring acquisition of weak cells and reliability of control and data reception in the presence of legacy signals.

Márquez-Barja, J. et. al., (2011) presented an overview of VHO techniques, along with the main algorithms, protocols and tools proposed in the literature. In addition they suggested the most appropriate VHO techniques to efficiently communicate in VN environments considering the particular characteristics of this type of networks.

Taniuchi, K. et. al., (2009) proposed a novel MIHF (Media-Independent Handover Function) variant, which is renamed interworking (IW) sublayer. IW sublayer provides a seamless inter-RAT handover procedure between UMTS and WiMAX systems. It relies on a new intersystem retransmission mechanism with cross-layer interaction ability providing lossless handover while keeping acceptable delays.

Eido et al. (2005) presented a wavelength allocation algorithm applied to a metropolitan optical packet-switched ring network. Traditional algorithms that provide optimal wavelength allocation generally require excessive computational time even with a small network of 8 to 16 nodes. Therefore, those approaches have proven to be inappropriate for providing a dynamic real time wavelength allocation, which reacts as rapidly as possible to the growth of data traffic. They presented an approach for real time resource allocation (the so-called R2A) algorithm applied to optical packet-switched ring networks. This was based on equivalent bandwidth methods and heuristic iterative algorithm that can be executed in real-time. They also used simulations to evaluate the performance of the network configured according to the wavelength allocation map provided by R2A.

CONCLUSION FROM RELATED WORK

1. The LTE system is not only designed for substantial performance enhancements but also to reduce the cost per bit. Taking the technological point of view what LTE concept makes the number one are the increased data rate, improved geographical coverage and reduced latency. On the other side, the commercial point of view of the LTE promises more competitive business case for the mobile operators and the base network for service providers. Since LTE is relatively new standard it is important to model and analyze the behavior and the performances of LTE Network.

2. Scheduling in LTE networks is still an area of study for researchers. Scheduling is the process of dynamically allocating physical resources to User Equipment (UE) based on scheduling algorithms implemented at the LTE base station. The Quality of Service (QoS) for multimedia services is defined in LTE specification (Li, Z. et. al., 2009; Sokmen, F. I. et. al., 2010). However the scheduling algorithms for supporting real time and non-real time application services are not specified. Therefore different scheduling strategies are proposed. In these scheduling algorithms, a priority value is assigned to each connection regardless its type depending on certain criterion. The connection with the best criteria is scheduled first at the next transmission time interval (TTI). This approach has the advantage of low implementation complexity.

3. It has been observed from related work that packet switched media services are required in case of heterogeneous LTE networks especially with mobile nodes. Actually a well-organized interface is required which can fulfill the requirements of handover between two networks.

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4. Some of the possible scheduling strategies in LTE Networks are Proportional Fair (PF) (Choi, J. G., & Bahk, S., 2007), Modified-Largest Weighted Delay First (M-LWDF) (Ameigeiras, P., et. al., 2004), and Exponential Proportional Fairness (EXP/PF) (Bendaoud, F., et. al., 2014). Proportional Fair (PF) scheduling algorithm was initially implemented in High Data Rate (HDR) networks. It compromises between a fair data rate for each user and the total data rate. Modified-Largest Weighted Delay First (M-LWDF) is a scheduling algorithm that supports multiple real time data users in CDMA-HDR systems with different QoS requirements (Ameigeiras, P., 2004). This takes into account instantaneous channel variations and delays in the case of video service. The MLWDF scheduling rule tries to balance the weighted delays of packets and to utilize the knowledge about the channel state efficiently. Exponential Proportional Fairness (EXP/PF) scheduling algorithm supports multimedia applications in an Adaptive Coding Modulation and Time Division Multiplexing (ACM/TDM) system, which means that a user can belong to a real time service or non-real time service. This algorithm has been designed to increase the priority of real time flows with respect to non-real time ones.

III. METHODOLOGY

It comprises the analysis of methods and principles associated with a specific area of study. LTE-Sim network simulator in ns-2 simulator is used to create simulation for LTE networks. Scheduling algorithm used are PF, MLWDF and EXP-PF. Performance evaluation of these algorithms are performed using two flows namely Best effort and Video flow. In The following section detailed description of proposed methodology is presented.

3.1 Steps Followed

To achieve above mentioned objectives following methodology is opted:

i. Implement scheduling algorithms for heterogeneous LTE networks in a network simulator (ns-2).
ii. Run simulation experiments to analyze the performance of heterogeneous LTE networks for different scheduling algorithms.
iii. Evaluate scheduling algorithms for a multi cell scenario for different flows such as Best effort and Video using LTE-Sim in ns-2.
iv. Conduct comparative analysis of Proportional fair (PF), Modified Largest Weighted Delay First (M-LWDF) scheduling algorithms with proposed Exponential Proportional Fairness (EXP-PF) scheduling algorithm for heterogeneous LTE networks in terms of throughput, delay and packet loss ratio (PLR) for different flows.

3.2 Proposed Scheduling Algorithm EXP/PF

It is an improved version of PF scheduling algorithm. It prioritizes the real time flows with respect to the other ones. It includes following steps.

i. Take data service requests as input.
ii. Check whether request is real time (RT) or non real time (NRT).
iii. Apply respective scheduling metric as given in Eq. 5 in Section 1.2.3
iv. Scheduling metric for EXP/PF gives higher priority to RT service users if their Head of Line (HOL) packet delay approach delay deadline.

3.3. Work Flow

A schematic flow chart for flow of proposed work is shown below in figure 3. It represents how the proposed work is carried out in various phases.

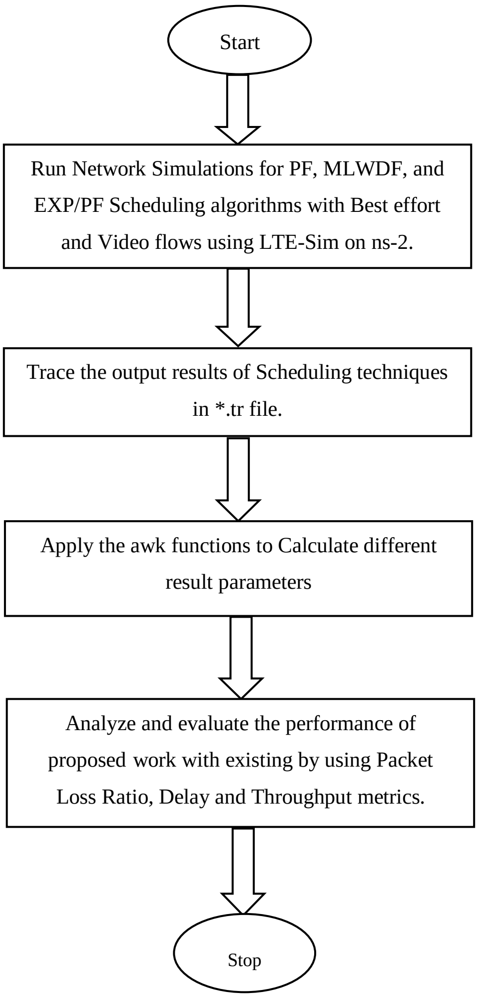

Figure 3: Work Flow of proposed work.

3.4 Scheduling Algorithms

LTE packet scheduling schemes aim to maximize system performance. Performances of scheduling strategies are measured in terms of system metrics, such as throughput, packet loss ratio, packet delay, fairness index, and spectral efficiency (Blough, D. M., 2010). A real-time (RT) application are delay sensitive and requires GBR (Guaranteed Bit Rate) (Piro, G. et. al., 2011; Temino, L. A. M. R. et. al., 2008; Wen, P. et. al., 2007). In contrary, non-real time (NRT) services are less delay sensitive and require high throughput and low error rates (Brehm, M., et. al., 2013; Delgado, O. et. al., 2010). The packet scheduling algorithms being considered in this work are described as follows.

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i) Proportional Fair (PF)

Proportional Fair is a channel-aware/QoS-unaware strategy that takes into account both the CQI and user's past average data rate while allocating resources to the user. The goal of this algorithm was to maintain a trade-off between the fairness and network throughput. It chooses an UE whose metric M is highest. The priority metric, M is given in the following equation.

$$M = argmax \frac{R_i(t)}{\bar{R}_i(t)} \quad (1)$$

and

$$\bar{R}_i(t) = \left(1 - \frac{1}{t_c}\right) * \bar{R}_i(t-1) + \frac{1}{t_c} * R_i(t\text{-}1) \quad (2)$$

where, $R_i(t)$ is the instantaneous achievable transmission rate

$\bar{R}_i(t)$ is the average data rate of user *i* at time *t*.

t_c is the update window size

$\bar{R}_i(t-1)$=0 if user *i* is not selected for transmission at time *t-1*

From Eq. 1, it can be realized that this packet scheduling scheme provides higher priority not only to the users with good CQI but also to the users with low average data rate.

ii) Maximum-Largest Weighted Delay First (MLWDF)

M-LWDF supports multiple RT data users with different QoS requirements. It considers both the CQI as well as the queue status while making scheduling decision. Resource Blocks(s) is/are allocated to a user based on the following priority metric,

$$M = argmax\, a_i W_i(t) \frac{R_i(t)}{\bar{R}_i(t)} \quad (3)$$

and

$$a_i = -\frac{\log \delta_i}{\tau_i} \quad (4)$$

where $W_i(t)$ is the HOL (Head Of Line) packet delay of user *i* at time *t*

τ_i is the delay threshold of user *i* and

δ_i is the maximum probability of HOL packet delay of user *i* to exceed the delay threshold of user *i*.

Here, HOL delay is defined as the time difference between the current time and the time at which the packet arrived. The implementation of this algorithm requires that the packet scheduler at eNodeB time stamps the incoming data packets and keeps track the states of current queue,
particularly queue length.

iii) Exponential Proportional Fair (EXP-PF)

EXP/PF was proposed to support both RT services with different QoS requirements and NRT data services in an AMC/TDM (Adaptive Modulation and Coding and Time Division Multiplexing) system. It is a composite of EXP Rule and PF algorithm. PF properties ensure the maximization system throughput and EXP properties guarantee the delay constraints of RT services. The scheduling metric, M is based on the service type (i.e. RT/NRT) of each user.

$$M = \arg\max \begin{cases} \exp\left(\frac{a_i W_i(t) - a\overline{W(t)}}{1+\sqrt{a\overline{W(t)}}}\right) \frac{R_i(t)}{\bar{R}_i(t)} & i \epsilon RT \\ \frac{w(t)}{P(t)} \frac{R_i(t)}{\bar{R}_i(t)} & i \epsilon NRT \end{cases} \quad (5)$$

and, $$\overline{aW(t)} = \frac{1}{N_{RT}} \sum_{i \epsilon RT} a_i W_i(t) \quad (6)$$

$$w(t) = \begin{cases} w(t-1) - \varepsilon & W_{max} > \tau_{max} \\ w(t-1) + \frac{\varepsilon}{k} & W_{max} < \tau_{max} \end{cases} \quad (7)$$

where, *P(t)* is the average number of RT packets waiting at the serving eNodeB buffer at time *t*

ε and *k* are constants

W_{max} is the maximum HOL packet delay out of all RT service users

τ_{max} is the maximum delay constraint of all RT service users.

PF properties provide higher priority to the user with better CQI but the EXP rule provides higher priority to the user having more data packets in its buffer. EXP/PF gives higher priority to the RT service users if their HOL packet delays approach delay deadline.

3.5 Metrics used for Evaluation of Proposed Work

To analyze the performance of proposed scheduling algorithm, various contexts are created by varying the number of nodes. The following metrics are used to evaluate the performance of the scheduling algorithms. The performance metrics are purposely chosen to show the difference in performance among the different scheduling algorithms. These metrics are the most crucial and common yardstick to measure the overall performance of the network scheduling algorithms. Similar types of metrics were also used in many other comparison related work. The performance metrics are defined as the following:

i) Packet Loss Ratio (PLR)

It is the ratio between the number of packets transmitted by a traffic source and the number of packets received by a traffic sink. It measures the loss rate as seen by transport protocols and as such, it characterizes both the correctness and efficiency of ad hoc routing protocols. It represents the maximum throughput that the network can achieve. A high packet delivery ratio is desired in a network.

PLR = 1 - (number of packets received / number of packets sent) (8)

ii) Average Delay

The packet end-to-end delay is the average time that packets take to traverse the network. This is the time from the generation of the packet by the sender up to their reception at the destination's application layer and is expressed in seconds. It therefore includes all the delays in the network such as buffer queues, transmission time and delays induced by routing activities and MAC control exchanges.

$$\text{Average End to End Delay} = \frac{\sum (\text{Time Received - Time Sent})}{\text{Total Data Packets Received}} \quad (9)$$

iii) Average Throughput

This is the average number of bits arrived per second at destination node. The metric is used as a measure of the reliability of the protocol under different conditions; hence the

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average throughput in the network needs to be higher as much as possible. Factors that affect throughput in MANETs include frequent topology changes, unreliable communication, limited bandwidth and limited energy. A high throughput network is desirable.

$$\text{Average Throughput} = \frac{\text{Number of Data Packets Successfully Received x Packet Size}}{\text{Simulation Time}} \quad (10)$$

IV. RESULTS AND ANALYSIS

In this Section, the results obtained from the implementation of proposed work have been presented. The proposed work has been implemented on LTE-Sim and on NS-2 network simulator. The results obtained are evaluated by using the various performance metrics namely throughput, delay and packet loss ratio (PLR). Performance of Heterogeneous LTE Networks for different scheduling algorithms such as Proportional Fair (PF) and Maximum-Largest Weighted Delay First (MLWDF) was analyzed with proposed scheduling algorithm Exponential Proportional Fairness (EXP/PF) in order to predict the behavior of LTE networks with packet switched media services. The evaluation was performed for a multi cell scenario for different flows such as Best effort, Video and VoIP in ns-2. In this work two scenarios have been taken for creation of simulation environment, which are, Ns-2 and LTE-Sim.

4.1 Results obtained using Graphical Interface of Ns-2

The evaluation is considered for a multi-cell like macro cell and pico cell with interference scenario for different flows such as video and best effort. Under this mobile environment red colored nodes are roaming in macro cell and blue colored nodes are roaming in pico cell. Theses nodes were communicating during movement and trace file was generated for analysis. Heterogeneous networks allow for a flexible deployment strategy with the use of different power base stations like picos, macros etc. to provide coverage and capacity where it is needed the most. A nam file is shown below in Figure 4 for simulated network environment.

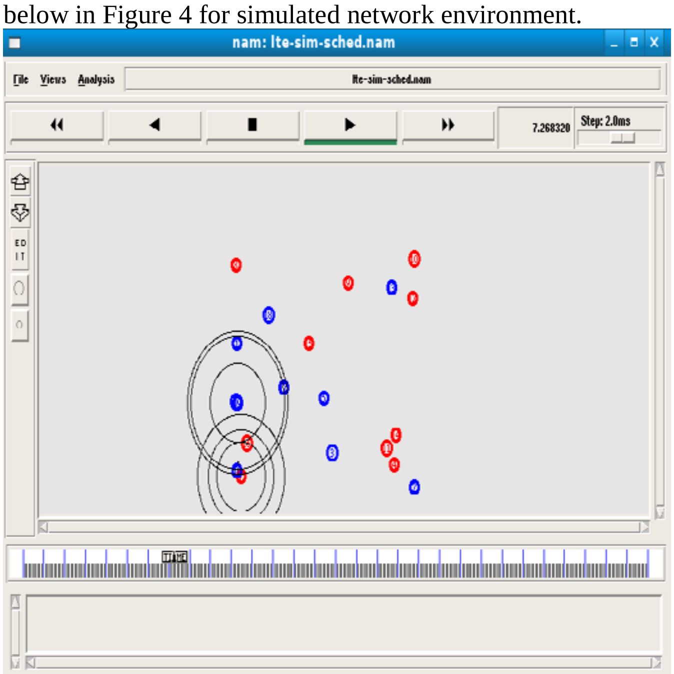

Figure 4: Nam file for simulated environment in ns-2

4.2 Results obtained using LTE-Sim

In LTE-Sim, different scheduling algorithms are evaluated for best effort and video flows for the computation of Packet loss ratio, delay and throughput. The work results on LTE simulator are shown in this section. LTE simulator is accessed using command editor of LINUX operating system. Figure 5 shows the commands of home directory interface. Through this interface, LTE Network simulator is reached by changing the directory path.

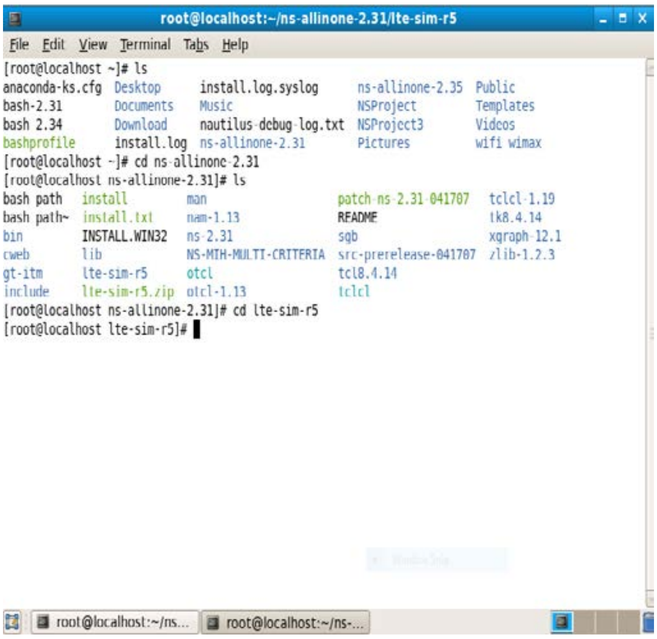

Figure 5: Showing list of commands in home directory

Now, the LTE-Sim directory has been accessed and is ready for further operations. Figure 6 shows the various files of proposed work resided in LTE-Sim folder. These are the files which are used to compute the various results of the proposed work. By using LTE-sim "application/x-executable" link various operations are executed on the simulated network. Furthermore, 13 parameters are used to execute the output file. The description of these 13 parameters is enlisted as:

Parameter 1 → No of Cells: This is the area of tower in one area, here 7 cells are used as 1st input parameter but it can be changed according to the requirement.

Parameter 2 → Radius: This is the radius covered by one cell, in this 1 is used as radius for 2nd input parameter.

Parameter 3 → User equipments: User equipment (UE) is any device used directly by an end-user to communicate. It can be a hand-held telephone, a laptop computer equipped with a mobile broadband adapter, or any other device. The proposed work is preformed for mobile phones only so in this value 1 is used as third parameter.

Parameter 4 → VIOP: This is voice over ip. The work is performed only for video flow and best efforts so in this value 0 is used for this parameter.

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Parameter 5 → Video (0): If video flow is used, the value of 5th parameter will be 1.

Parameter 6 → Best efforts (0): If best efforts flow is used, the value of 6th parameter will be 1.

Parameter 7 → Audio (0): This is audio flow and the work is done on video flow and best efforts soothe value of this parameter shall be 0.

Parameter 8 → Schedule type: - For PF=1, MLWDF=2, EXP/PF=3.

Parameter 9 → Frame structure (CDMD or FDMA): In this work, frequency duplex mode is used, so for this the value of this parameter shall be 1.

Parameter 10 → Speed (3): this is the speed of the device moving from one tower to another.

Parameter 11 → Delay (0.1): This is the max value of delay, Drop otherwise.

Parameter 12 → Bit rate (1): It is measured in bits/seconds.

Parameter 13 →Speed: This is an optional parameter.

The command "./LTE-Sim MultiCell 7 1 1 0 0 1 0 3 1 3 0.1 1 28 >> outputFile" is used to input the 13 parameters in order to generate the output file. Figure 6 shows the graphical representation of the command to input the parameters.

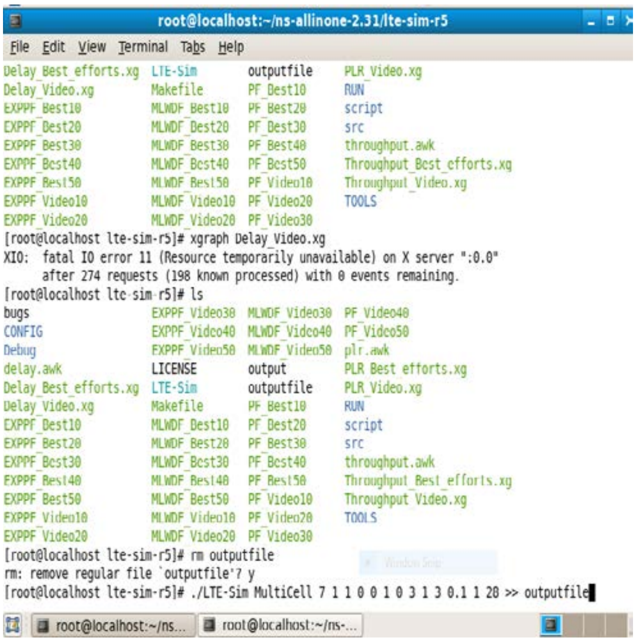

Figure 6: Showing LTE files and input parameters

After the input has been made to the simulator, various output results are obtained. After executing the command shown in figure 6 the output file is generated in given directory. Figure 7 shows the output results obtained. The generated file shows the transferred packets and received packets. On the basis of results obtained, there are 3 files plr.awk, delay.awk and throughput.awk to generate packet loss, packet delay and throughput.

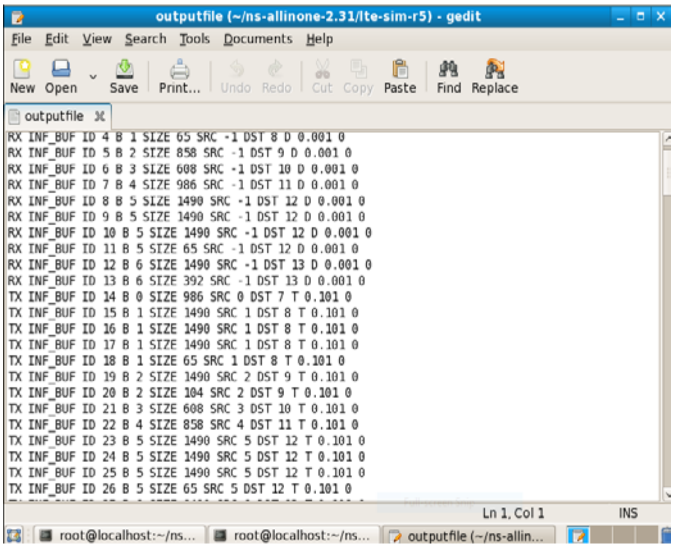

Figure 7: Output file of simulation

In this 30 files have been created using the above flow for video and best effort flow with different speeds and different scheduling type. Different simulation scenarios are created for scheduling algorithms. 10 files of video and best effort flows have been created for each of PF, MLWDF and EXP/PF algorithms. The results obtained for packet loss ratio, delay and throughput shows that the EXP/PF works better than PF and MLWDF scheduling types.

4.3 Result Evaluation

The Comparison of PF, MLWDF and EXP/PF for Best Efforts Flow and Video Flow is done by using three performance metric namely, Packet Delivery Ratio, Throughput and Packet Delay. The results have proven that the proposed EXP/PF is better than the existing scheduling algorithms such as, PF and MLWDF.

4.3.1 Throughput for Best Efforts Flow

At first simulation experiments were performed for PF scheduling algorithm with Best efforts flows. Number of user equipments (UE) was varied from 10 to 50 (i.e. 10, 20, 30, 40 and 50) for performance evaluation in terms of throughput. This process was repeated for other scheduling algorithms i.e. MLWDF and EXP-PF. Simulation results are shown in Figure 8.

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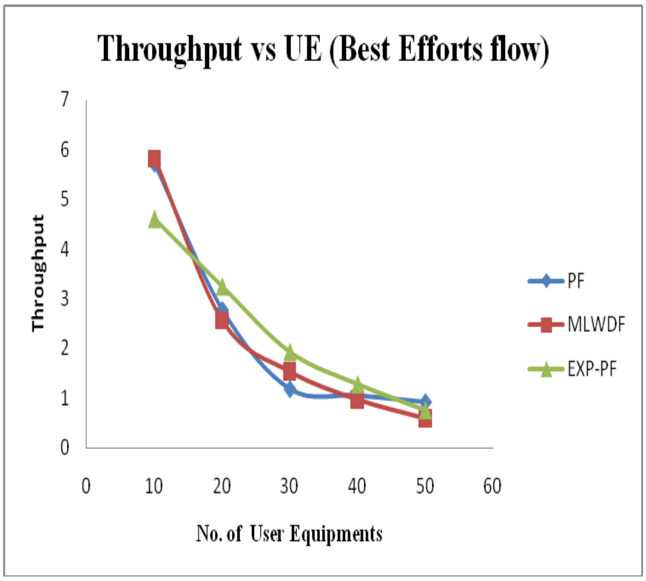

Figure 8: Throughput vs UE (user equipments) for best effort flows.

As observed in Figure 8, EXP-PF performed better with higher number of nodes in LTE network. MLWDF and PF also showed good results with number of user equipments equal to 60.

4.3.2 Packet Loss Ratio for Best Efforts Flow

Here simulation experiments were performed for PF, MLWDF and EXP-PF scheduling algorithm for Video flows. Number of user equipments (UE) was again varied from 10 to 50 (i.e. 10, 20, 30, 40 and 50) for performance evaluation in term of packet loss ratio (PLR). Simulation results are shown in Figure 9.

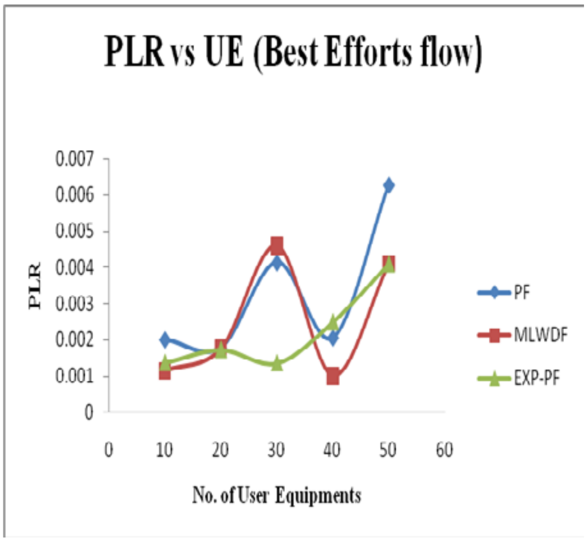

Figure 9: PLR vs UE (user equipments) for best effort flows.

Figure 9 shows average and linear packet loss ratio results for EXP-PF whereas for PF and MLWDF packet loss ratio is non-linear.

4.3.3 Delay for Best Efforts Flow

In this type of scenario evaluation was performed for delay measurement for same configuration as was mentioned in scenario 1 and 2 and it is found to be same for all three algorithms (0.001sec) as shown in Figure 10.

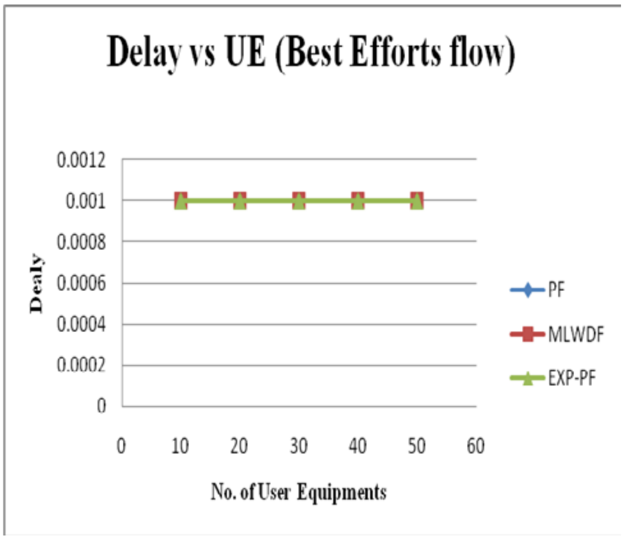

Figure 10: Delay vs UE (user equipments) for best effort flows.

4.3.4 Throughput for Video Flow

It is different from previous scenarios as video flows were used for all three scheduling algorithms. Throughput was observed in different experiments in this scenario. Experiments were performed for all three scheduling algorithms PF, MLWDF and EXP-PF. Simulation results are depicted in Figure 11 below. Throughput value of EXP-PF is higher with number of user equipments more than 30.

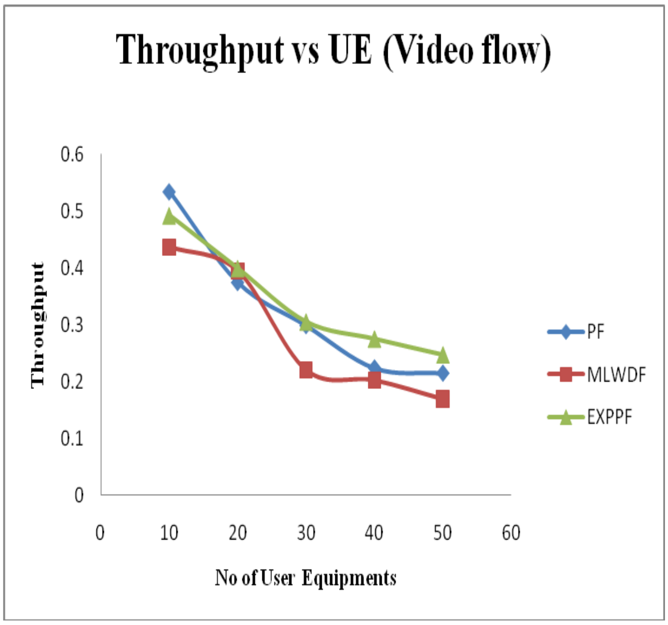

Figure 11: Throughput vs UE (user equipments) for video flows.

4.3.5 Packet loss ratio for Video Flow

Similar experiments were performed for PLR in this scenario. Results are given in Figure 12. EXP-PF and MLWDF showed stable PLR whereas for PF it is high with number of user equipments equal to 40 and fluctuating in general. Proposed algorithm showed very less value of packet loss ratio for video flows as compare to best efforts flows.

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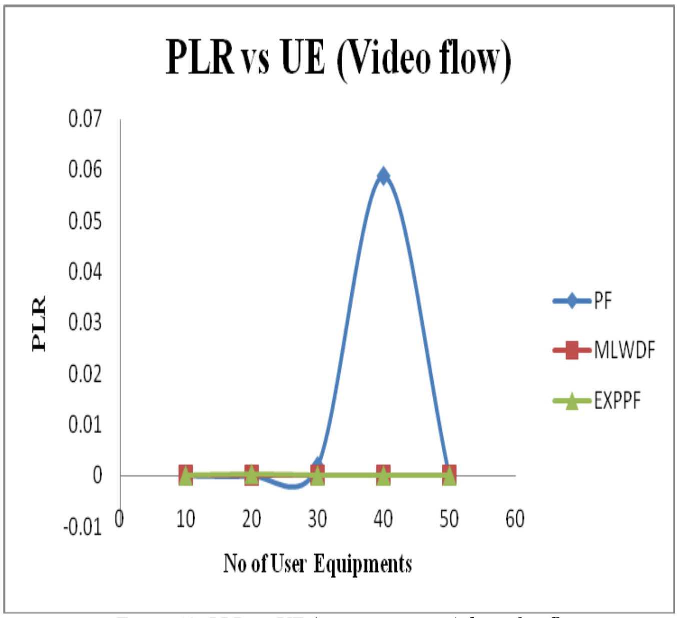

Figure 12: PLR vs UE (user equipments) for video flows.

4.3.6 Delay for Video Flow

Performance evaluation of scheduling algorithms for LTE networks with respect to delay parameter was done for video flows and results are depicted in Figure 13 below. EXP-PF showed better results with comparatively lesser delay values.

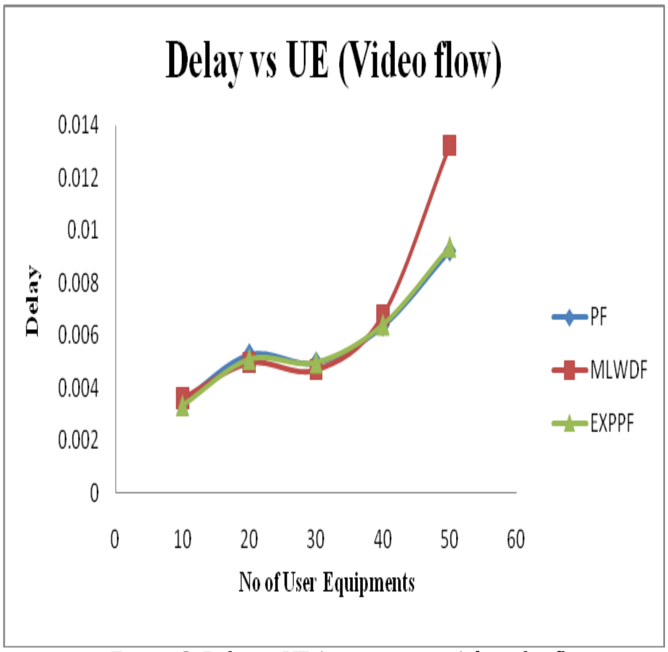

Figure 13: Delay vs UE (user equipments) for video flows.

As EXP/PF algorithm supports both real time (RT) and non-real time (NRT) data services and it gives priority to RT service if delay is near to dead line, it was found suitable for best efforts and video flows especially in terms of throughput. For video flows results are comparatively better while EXP/PF scheduling algorithm was used. Performance of PF algorithm was good for best efforts flows as it is channel aware scheduling algorithm and takes into account both channel quality indicator and user's past data rate for allocation of resources to users but it is not suitable for video flows.

V. CONCLUSIONS AND FUTURE SCOPE

5.1 Conclusions

Performance of resource allocation in LTE networks was evaluated for best effort flows and video flows. Different scheduling algorithms such as Proportional Fair (PF), Maximum-Largest Weighted Delay First (MLWDF), and Exponential Proportional Fairness (EXP/PF) were evaluated by using LTE-Sim network simulator. Finally it is concluded that all three algorithms are suitable for best effort flows, since they exhibit nearly the same performances for best effort flows. On the other hand PF scheduling algorithm is not suitable for video flows due to its high delay, packet loss ratio and low throughput. The MLWDF and EXP/PF scheduling algorithms have better performances for video flows in LTE Networks.

5.2 Future Scope

LTE is expected to satisfy the market needs for next decade. However, user expectations, traffic growth and new services will demand more and more from the network in the future. ITU has already set a project group to study the future requirements within the framework of the IMT Advanced project. LTE-Advanced already fulfills these requirements. Therefore in future investigation of the performances of the scheduling algorithms for LTE-Advanced, as well as other complex algorithms can be explored.

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