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A Quality of Service (QoS) Aware Scheduling Algorithm to Boost QoS of Cell-Edge Users in LTE Networks

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Abstract*: *LTE is the abbreviation of Long Term Evolution. LTE networks are developed to provide enhanced Quality of Service (QoS), as today's cellular world and its high speed multimedia applications demand variety of QoS along with a high speed data rate. Scheduling is a key feature of any network to achieve QoS requirements. The QoS widely depends on the distance of user from the Evolved- Node-B (eNB). The user near eNB experience good QoS and the user far away from eNB experiences poor QoS. The system performance is widely affected due to this. Hence, the ultimate and supreme goal of this research work is to enhance the QoS of the cell edge user and improve network performance. Proposed scheduling algorithm i.e. Improved Extended Modified Largest Weighted Delay First (IE-MLWDF) improves the cell edge throughput along with QoS of the cell - edge users. The paper compares IE-MLWDF with its previous versions namely Modified Largest Weighted Delay First (MLWDF) and Extended - MLWDF in terms of various network parameters. This paper presents a detailed analysis of a scheduling algorithm to enhance QoS of cell edge users to provide better network goals. This algorithm can further be extended or improved to make it more effective.

Index Terms*: *E-MLWDF, EPC, EPS, E-UTRAN, GSM,IE-MLWDF, LTE, MLWDF, Scheduling.

I. INTRODUCTION

LTE is a project named by Third Generation Partnership Project (3GPP) [1]. This is new and advanced level for wireless networks and essentially LTE-A is the upgraded form of LTE [2]. The 3GPP LTE is very flexible radio interface. As per work on the latest release of the LTE standard, the main attention is just to slowly build the routes for the further evolution of LTE, known as LTE-A [3]. The primary objective of this evolution is to reach and even exceed the requirements of International Mobile Telecommunications - Advanced (IMT-A) [11].

Those necessities will include further important advancements in terms of the performance as compared to the current cellular systems [4].

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Wireless communication services have seen a drastic growth, globally, in the past two decades, starting from the analog services right up to the

current digital cellular services [5]. With respect to (w.r.t) the availability and number of subscribers, wireless communication services have surpassed the fixed line telephony services [6][11].

In India itself, as compared to the fixed line communication, the wireless communication penetration is about four times more. Mobile subscribers have increased worldwide, around one billion in less than twenty years [7]. The three most prominent driving forces behind evolution of mobile broadband which led to development and deployment of LTE were the growth in high bandwidth mobile applications like video sharing, IP-TV etc, the increased number of smart phones and the competition among service providers leading to flat revenues. Some more potential key components of LTE evolution lay the foundation for LTE-A and more advanced technologies [8].

II. SYSTEM ARCHITECTURE AND RADIO FRAME FOR LTE / LTE-A

The simple principle behind LTE architecture is its functional decomposition. The features are fragmented into some functional entities. 3GPP has specified a new packet core called Evolved Packet Core (EPC) network architecture to support the Evolved Universal Terrestrial Radio Access Network (E-UTRAN) over a decrease in number of network components [3]. The Service Provider experiences a flawless mobility with LTE architecture. It provides simpler functionality. It reduces connections and also the handovers to other permanent lines and wireless technologies.

Fig 1 shows the logical depiction of LTE network architecture. The LTE architecture is very much analogous to GSM architecture [3]. LTE architecture consists of 2 components: (1) Core Network and (2) Access Network. Access network can be defined as Evolved Universal Terrestrial Radio Access Network (E-UTRAN) [1]. Core network is totally Packet Switched. Evolved Packet Core (EPC) is the Core Network in LTE [8]. The architecture reduces connections and also the handovers to other permanent lines and wireless technologies [2]. The functionalities like access control functions, network management functions and resource management are achieved with the help of core network and access network. An evolved system is formed by E-UTRAN and EPC [3][5].

To expand the system strength, ciphering has been introduced and characterized by using an extra layer to protect security key and other important information. EPC also contains network traffic details and network control units, defining the individuality, uniqueness and civil rights of a user and tracking the activities like authorization, authentication and the accounting server [4].

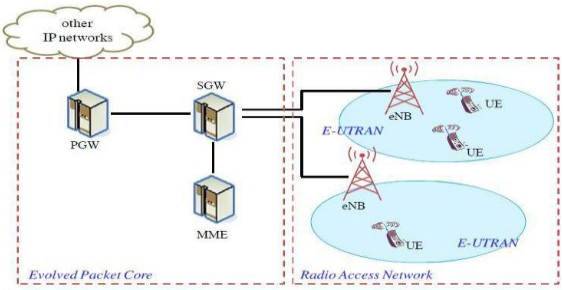

Fig 1

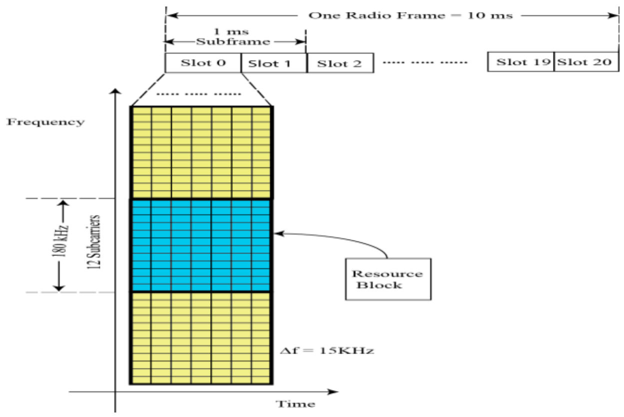

Fig 2

Fig 2 illustrates the LTE radio frame structure. The uplink and downlink data is combined in a radio frame and this frame consists of 10 sub-frames. Each sub-frame is composed of 2 time slots of duration 0.5 ms each and each sub-frame spans over 1 ms, which is called as TTI. 6 OFDM symbols are used for extended cyclic prefix (CP) and 7 OFDM symbols for normal CP. In default configuration, 7 symbols are used [2]. The data transmission in LTE / LTE-A is organized as physical resources which are represented by a time-frequency resource grid consisting of Physical Resource Blocks (PRB) [3][6][9]. The allocation of RBs is performed by a scheduler present at eNB. According to [10], the LTE / LTE-A radio air interface supports Time Division Duplexing (TDD) and Frequency Division Duplexing (FDD) both. In FDD, the allotted bandwidth is fragmented into two parts and simultaneous uplink and downlink transmissions are possible [7][8].

LTE/LTE-A employs Orthogonal Frequency Division Multiple Access (OFDMA) for down-link data transmission whereas SC-FDMA (Single Carrier – Frequency Division Multiple Access) is used for up-link data transmission [7][9]. The transmission from the base station to UE is known as down-link whereas transmission from UE to base station is known as up-link [8]. OFDMA is modified to form SC-FDMA and has similar throughput performance [9]. The new radio access network composed of only one node i.e. eNB which performs all RRM functionalities. The Physical architecture is same for LTE and LTE-A [8].

III. CONCEPT OF SCHEDULING

Scheduling refers to a decision process by which allocation of portion of available spectrum is performed by using specific policies [3]. Scheduling Policies decides how users should be assigned physical resources with given Transmission Time Index (TTI) and which users must wait to the next upcoming TTI to fulfill required QoS and fairness. It is the fact that it is not feasible for every packet to reach at the destination successfully [11]. Therefore, scheduler selects certain data packets on the origin of various algorithms or policies [10].

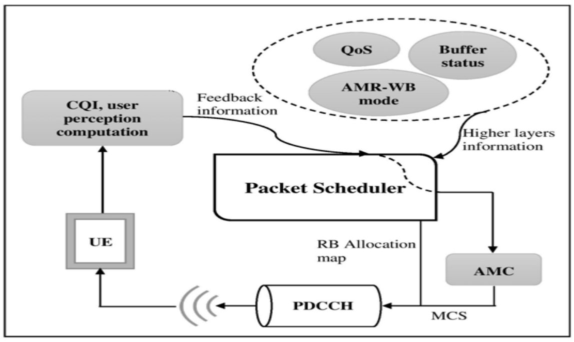

Fig 3

In LTE/LTE-A systems, eNB is the head of taking all scheduling decisions, whether it is up-link or down-link. Time-frequency Resource Blocks (RBs) are shared dynamically between users, so that on a given frequency and at the present time users can experience 'good channel conditions'[5][6]. Scheduler is placed at the Medium Access Control (MAC) layer and it manages the distribution of resources in uplink and downlink. It is based on the key principle of dynamic scheduling, where scheduling decision is taken by eNB. The eNB transmits decision information to the appropriate set of terminals.

IV. SYSTEM MODEL FOR PROPOSED METHOD (IE-MLWDF)

The simulation scenario of the working cell is discussed in this section. In the working cell, there is one eNB at the center of cell and the cell has a radius of 5km. For the ease of algorithm implementation, the cell is assumed to have two regions inner
region having radius Ω and outer region [1]. The UEs are spread or distributed in the cell as shown in figure 4. Down-link channel model is used along with microscopic path loss and negligible fading is considered in the simulation process [4][5]. Different number of UEs is considered in the cell, ranges between 10 and 60. UEs are mobile and have average speed of 5kmph. 900MHz band is utilized. Operating bandwidth is 20MHz .

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The simulation time is set to be 30 seconds. As the total cell area has been divided into two regions, the users outside the inner region of the cell having eNB at a distance greater than Ω are considered as the 'cell-edge users'[1].

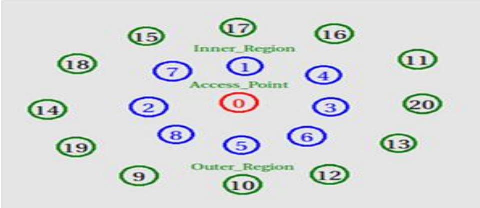

Fig 4

V. FLOW CHART AND MATHEMATICAL DESCRIPTION

Improved-Extended-Modified-Largest-Weighted-Delay-First (IE-MLWDF) is the name of proposed scheduling algorithm. It is a QoS aware algorithm. MLWDF and E-MLWDF scheduling algorithms are older versions of the proposed algorithm. Important expressions and their meanings are as follows:-

Expression	Meaning
m	User
n	Resource Block
r_m	Instantaneous Transmission Rate of User 'm'
M	Averaged Previous Transmission Rate of User 'm'
$D(hol)_m$	HOL delay of User 'm'
δ_m	Probability of Packet Loss for User 'm'
Ω	Inner Circle's Radius
S_m	Transition Probability from Failure to Success for user 'm'
ϵ	Error Probability
$\gamma_{m,n}$	Received SINR of User 'm', RB 'n'
$Z_{m,n}$	Function of Transmission Power of eNB
N	White Noise Power Spectral Density
I	Interference
τ_m	Delay Threshold of User 'm'
R_m	Distance between eNB and user 'm'

Fig 5 shows flow chart of proposed algorithm. IE-MLWDF is an enhanced version of E-MLWDF and the scheduling algorithm that has concern with Delay Threshold of user, HOL delay i.e. difference time between packet arrival and packet transmission for user 'm' and a Utility Function called Weighted Transmission Rate (WTR) that is a ratio of instantaneous throughput of user 'm' to its previous throughput. The distance between eNB and user is calculated with the help of distance formula. The scheme can be interpreted by metric shown in equation (1) where. The Utility Function is described by equation (2).

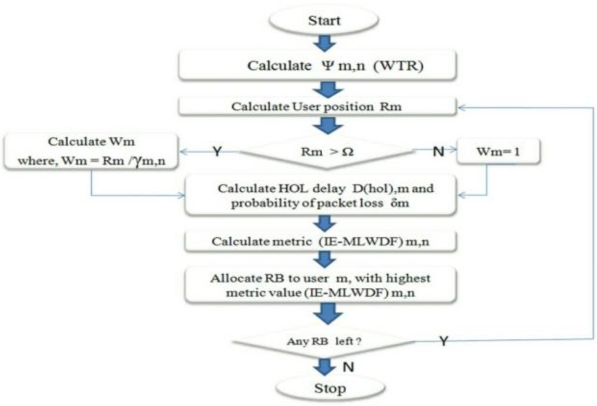

Fig 5

The metric for proposed method can be expressed as:

$$M_{m,n}\ (IE-MLWDF) = \frac{-\log(\delta m\ /Wm)}{\tau m} \times D(HOL)m \times \Psi_{m,n} \qquad (1)$$

Where, Utility function used in metric is defined as:

$$\Psi_{m,n} = \frac{r(t)}{M} \qquad (2)$$

Weight 'Wm' for Rm > Ω (outer region) is given by

$$Wm = \frac{Rm}{\gamma m,n} \qquad (3)$$

Whereas weight for Rm < Ω (inner region) is assumed as 1.

Signal to Interface Noise Ratio (SINR) is given by :

$$\gamma m,n = \frac{Zm,n}{(N + I)} \qquad (5)$$

Probability of packet loss is given by :

$$\delta m = \varepsilon\,(1 - Sm)^{\tau m} \qquad (6)$$

VI. RESULTS AND DISCUSSION

In this research work, with different user traffic the different parameters of IE-MLWDF have been observed. The paper gives a comparison among IE-MLWDF, E-MLWDF and MLWDF. E-MLWDF algorithm uses same queue for all type of data but in IE-MLWDF method, two separate queues are defined for the real time (RT) and non real time (NRT) data. The difference between RT and NRT data is their deadline. Priority of the data is defined separately for RT and NRT data.

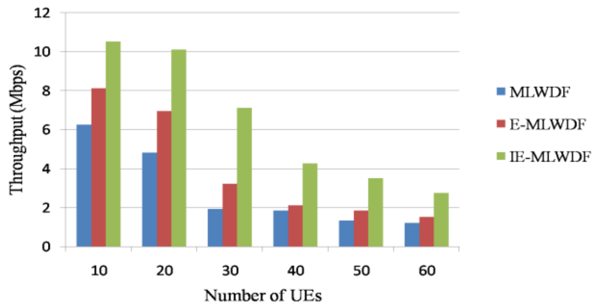

Fig 6

Fig 6 shows comparison of the throughput of cell-edge users w.r.t Number of UEs for MLWDF and E-MLWDF and proposed IE-MLWDF algorithm for different services. As predicted, the cell-edge throughput decreases for all the three algorithms, when the number of users increased in the cell. The cell-edge throughput of IE-MLWDF is observed to be greater than its previous versions. As IE-MLWDF, E-MLWDF algorithms considers such type of parameters that the users located in a cell-edge area with bad channel condition can get priority from the scheduler and receive higher number of RBs as compare to MLWDF, but IE-MLWDF implements two different queues for two different types of data services discussed earlier, the delay and packet loss has been reduced resulting higher cell edge throughput. Also, the users demanding highly time bounded service, experiencing higher delay or user is a cell-edge user then, will get the higher priority and thus the proposed IE-MLWDF algorithm distributes RBs to all users more effectively, depending on their requirements, which enhances the throughput of the cell- edge users. Overall, 50.122 percent and 66.137 percent higher cell-edge throughput has been achieved by the proposed algorithm i.e. IE-MLWDF as compare to E-MLWDF and MLWDF algorithms respectively.

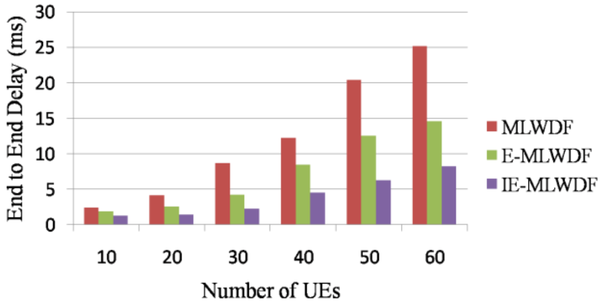

Fig 7

Fig 7 shows graph between end to end delay w.r.t number of UEs. This parameter can be defined as, averaged HOL delay over total simulation time [2]. Overall, 43.971 percent and 64.543 percent decrement has been achieved by the proposed IE-MLWDF algorithm as compare to E-MLWDF and MLWDF algorithms respectively. These outcomes are seen due to the effects of implementation of two queues instead of one queue, which leads the algorithm to reduce the congestion.

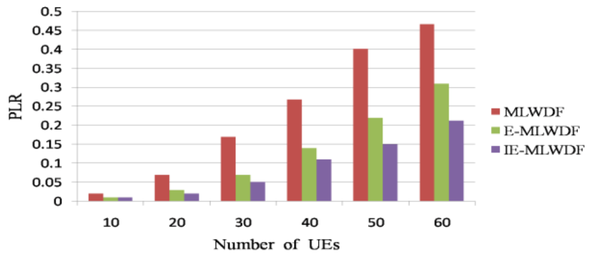

Fig 8

Fig 8 shows the graph of Packet Loss Ratio (PLR) w.r.t number of UEs. In a simple way, it is the measure the percentage of data packets traveling across a physical channel which do not succeed to reach their destination. Overall 24.22 percent decrement has been seen in PLR of IE-MLWDF w.r.t. E-MLWDF and 61.278 percent decrement has been achieved by IE-MLWDF w.r.t MLWDF. The reason behind this outcome is the reduced delay and improved channel conditions.

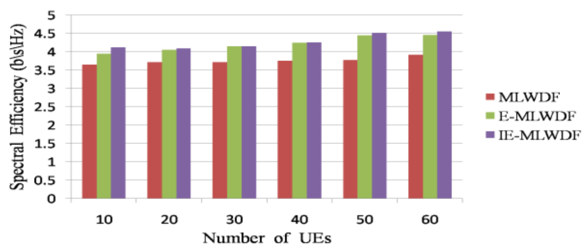

Fig 9

Fig 9 shows the graph of spectral efficiency (SE) w.r.t number of UEs for the three discussed algorithms. SE is the optimized used bandwidth in which maximum data can be transferred with minimum value of transmission errors. SE can also be expressed as the total throughput achieved by all users divided by the bandwidth [10].

The graph demonstrates that IE-MLWDF uses the cell more efficiently as compare to E-MLWDF and MLWDF. IE-MLWDF scheduler avoids the wastage of radio resources by ensuring the proper allocation of RBs. E-MLWDF considers a single queue for all data-types whereas MLWDF uses only few factors like HOL delay, previous throughput which leads to lower SE. Overall, 3.462 percent increment has been achieved by the IE-MLWDF w.r.t. E-MLWDF and 16.03 percent increment in has been observed in IE-MLWDF w.r.t. MLWDF in the parameter.

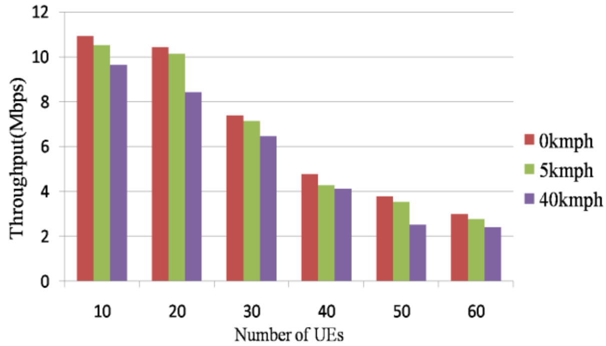

Fig 10

Table 1 : Simulation parameters with corresponding values.

Parameter	PERCENTAGE CHANGE IN PAREMETER OF IE-MLWDF w.r.t. E-MLWDF	PERCENTAGE CHANGE IN PAREMETER OF IE-MLWDF w.r.t. MLWDF
Cell edge user throughput	50.122%	66.137%
End to end delay	-43.971%	-64.543%
Packet Loss Ratio	-24.22%	-61.278%
Spectral efficiency	3.462%	16.03%

Fig 10 shows the effects of changing the average speed of user on the throughput of users located at cell edge is shown for IE-MLWDF algorithm. From the fig 10, static users i.e. users with speed of 0kmph have the throughput greater than the throughput of the non static or mobile users as the users having higher speed suffer from low throughput problem. The pedestrian or very slow speed users can be considered as static users. As the speed of users increase, throughput will decrease showing inverse relationship between user speed and throughput. The static users achieve 5.71 percent more throughput w.r.t. users with 5kmph whereas the static users achieves 9.825 percent more throughput w.r.t. the users with 40kmph. This happens due to the reason that, higher packet loss occurs at higher speed. Longer delay values also affect the throughput.

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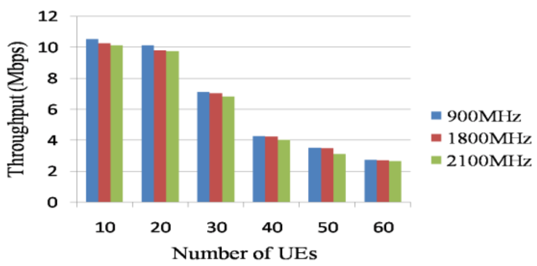

Fig 11

Fig 11 shows graph between cell-edge throughput w.r.t. Number of UEs. The research work implements the IE-MLWDF scheduling algorithm in 3 different frequency bands. The band of 900 MHz achieves 15.32 percent more cell edge throughput as compare to 1800MHz band and 29.169 percent more cell edge throughput has been achieved by 900MHz band w.r.t. 2100MHz band. The reason of this upgraded outcome is that, working in higher frequency band leads to an excessive path-loss as compare to smaller frequency bands, which is degrading the network performance. Here, it important to note that IE-MLWDF algorithm in 1800MHz and 2100MHz bands performs better than its previous two versions in 900MHz band.

Table2: Simulation parameters with corresponding values.

Parameters	(T0Kmph-T5kmph)/T0kmph	(T0Kmph-T40kmph)/T0kmph
Speed	5.71%	9.825%
Parameters	(T900MHz-T1800MHz)/T900MHz	(T900MHz-T2100MHz)/T900MHz
Operating frequency	-15.32%	-29.169%

VII. CONCLUSION

Paper discusses IE-MLWDF scheduling algorithm for LTE network, considering different network parameters like cell edge throughput, end to end delay, PLR, spectral efficiency and effects of changing user speed and operating frequency. The throughput of cell - edge users and spectral efficiency has been increased while end to end delay and PLR has been reduced by using the proposed scheduling algorithm. The proposed algorithm improves cell edge throughput and spectral efficiency by 50.122 percent and 3.462 percent respectively and the method reduces PLR and end to end delay by 24.22 percent and 43.971 percent respectively w.r.t. E-MLWDF. The proposed algorithm improves cell edge throughput and spectral efficiency by 66.137 percent and 16.03 percent respectively and the method reduces PLR and end to end delay by 61.278 percent and 64.543 percent respectively w.r.t. MLWDF. From these outcomes, the conclusion can be dropped that IE-MLWDF algorithm provides a better performance in LTE networks as compare to E-MLWDF and MLWDF algorithm. To get better serving capability, enhanced capacity and improved system performance in future, MIMO can be introduced to this scheduling algorithm. This scheduling algorithm can be extended in 5G networks.

Hence, from the above discussion the proposed scheduling method i.e. IE-MLWDF is very fruitful to improve QoS of cell-edge users in LTE networks.

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