Throughput and Fairness Optimal Scheduling for High Speed Cell Edge Users in LTE Networks

Ch.Rajasekhar, D.Srinivasa Rao, Ch.Venkata Rao, V.B.S.Srilatha Indira Dutt

Abstract*: *Guaranteeing Quality of Service (QoS) to mobile users is the primary aim of cellular broadband system like Long Term Evolution (LTE). Radio resource allocation and scheduling are two important functions in the LTE networks to enhance the quality of service. For increasing the generally user experience, an efficient radio resource allocation and Scheduling algorithm should be used. However, this became a non-trivial task as the demands and requirements of user data changes day-to-day. In these situations, with the limited radio resources, maximum system capacity can be obtained on expense of unfair share of the resources. In this work, high speed cell edge users are considered as they experience poor signal strength and their quality of service degrades when they move away from Evolved-Nodes (e-Nodes). Here, a novel scheduling algorithm has been introduced to extend the cell edge throughput amid during high mobility scenarios. The proposed scheduling scheme will be compared with the conventional schemes like best CQI, RR and PF in terms of throughput and fairness. It is presented that the proposed scheme gives better performance against the conventional ones in the chosen scenario.

Keywords: bandwidth, edge users, fairness, latency, throughput

I. INTRODUCTION

Wireless Internet access was introduced to the world, which led to more mobile phone subscriptions. More attention is required by mobile applications such as media streaming, video conferencing and gaming applications, for which higher data rates are required. Every few years, a new mobile technology built to face the challenges requires more frequency bands. These transitions in the technologies and their infrastructure are called generations. Data services were first available in the second generation. Later after working past a lot of challenges to achieve the needs and higher performance, the Third Generation Partnership Project (3GPP) created High Speed Packet Access (HSPA). The mobile subscribers are increasing due to the increase in the number of smart phones being sold, which, in turn, increases the mobile traffic data. There is a lot of demand on the mobile applications, which then requires higher data rates and low latency. So the 3GPP further started working on Long Term Evolution (LTE), which meets all the requirements.

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It is expected that by 2018, total wireless Internet access traffic [1] will increase to 13,000 Peta bytes per year. The evolution of LTE is governed by the standard developing body 3GPP. LTE is a new radio access technology, where the access network's main requirements are higher spectral efficiency, higher data rates, and shorter round trip time [2].

The access network related to LTE is the Evolved Universal Terrestrial Radio Access Network (E-UTRAN) LTE standards were established by 3GPP as a part of release 8. LTE provides downlink and uplink peak data rates of 300 Mbps and 75 Mbps, respectively. It also provides a latency of 5ms or less in the radio access network. LTE uses both Frequency and Time Division Duplexing whose bandwidths range from 1.4 MHz to 20MHz. Multi Input Multi Output (MIMO) is another important technology used in LTE to enhance the system performance.

LTE uses OFDM in order to evade the multi-path fading problem in downlink transmission. The data is transmitted from the base station to the user terminal through several narrow sub carriers of 180 KHz bandwidth each, without sending all of the data over the complete bandwidth. OFDM offers spectral flexibility and can provide high peak data rates. In OFDM, there is a time recurrence framework, which is partitioned into a number of resource blocks. Here, all the OFDM symbols group together to form the resource blocks. When a user is assigned more resource blocks, then high level modulation is utilized in resources and thereby increases the bit rate. All blocks are allocated to the users by a key operation called a scheduler. Each entry in a resource block is called a resource element (RE). There are different kinds of scheduling algorithms, here two scheduling schemes namely Round Robin (RR) and Best Channel Quality Index (CQI) are considered [3]. In Round Robin scheduling, all the user terminals are equally scheduled without regard for channel quality indication. In Best CQI scheduling, a channel quality indication is sent from the user terminal to the base station as feedback. If the user has good CQI then the resource block is assigned to the client terminal. Before we move to the concept of scheduling algorithms, we must have a clear idea of LTE's requirements such as the physical layer overview of LTE, enabling technologies and their modulation and coding schemes.

All of these concepts are explained in LTE overview. It also explains the modulation schemes and how the resource elements mapping is done.

The related work focuses on the LTE Downlink scheduling algorithms [4], which explains the concept of scheduling and its purpose in the real world. Two scheduling algorithms are introduced here to show how resource blocks are allotted dynamically to the clients.

II. LTE OVERVIEW

Long term evolution architecture mainly consists of two components: E-UTRAN which is a combination of several eNodes and the Evolved Packet Core (EPC) as presented in Fig. 1. To realize the requirements and goals of attaining the mobile broad band communications, LTE should meet the following objectives:

- Peak data rates: LTE should have a peak data rate of 100 Mbps in the downlink and 50 Mbps in the uplink transmission scheme.
- Low latency: Few network components should be used for a radio access network connection. A Mobility Management Entity (MME) is connected to the Evolved Node B (eNB) through an S1 interface, directly, without any controller. Hence, it provides a lower user and control plane latency of 5ms.

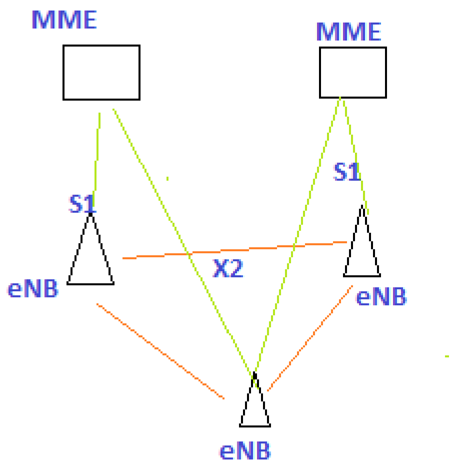

Fig. 1. Flat LTE Architecture

- Lower operating costs: Compared to the 3G wireless network, OFDM based LTE architecture is simple. It has only one element known as eNodeB which is connected to the MME. The radio network controllers are vanished from the Evolved-Universal Terrestrial Radio Access Network (E-UTRAN). Hence, building this network is effortless and has fewer operational costs.
- Bandwidth: LTE operates with bandwidth ranging from 1.4 MHz to 20 MHz, so as to attain high data rates. Both paired and unpaired spectra are utilized to carry the Frequency Division Duplex (FDD) and the Time Division Duplex (TDD).
- Multiple antenna support: The received signal power is directly proportional to the data rate and hence in order to have acceptable data rates, it is recommended to the signal strength. To increase the received signal power more antennae are placed on the receiver side and to increase the transmitter signal power more antennae are placed on the transmitter side. To improve the overall power, multiple antennae have to be placed on both sides. This technique is known as Spatial Multiplexing. This is the concept of Multiple Antenna Connectivity.
- Integration with the other systems: LTE uses all the existing frequency bands of the previous standards, and in addition to those, some more frequency bands are introduced. The regulations of these frequency bands vary in different countries, but they can be used by any service provider which makes a roaming mechanism easy to implement.
- For low terminal speeds, 0-15 km/h yields the better data rates than for higher terminal speeds, such as 350 km/h to 500 km/h. The peak data is 100 Mbps/ 1Gbps for high and low mobility rates respectively.
- Coverage: The coverage area will be around 5 to 100 km. A slight breakdown of throughput and efficiency occurs when a cell size reaches around 30 km.
- Duplexing: There are three kinds of duplex, frequency division duplex (FDD), time division duplex (TDD) and the half- frequency division duplex. Each of these three kinds of duplex is used depending on the particular application. FDD is considered as the migration path for the 3G services and it uses the paired spectrum. TDD is used as an upgrade for the TD-SCDMA.

III. RELATED WORK

The evolution of Universal Mobile Telecommunication System (UMTS) is LTE. LTE aims at higher data rates and better spectral efficiency. Various enabling technologies were developed [5] to achieve these LTE aims, like OFDM and MIMO, as already discussed in the previous section. The performance of the system can be increased by adopting the Radio Resource Management (RRM) in the LTE atmosphere. Sharing the resources, CQI reports and automatic transmission requests are the work done in RRM. In order to satisfy the needs, users should efficiently use the radio resources and several methods are designed to use them. In this section, we are going to talk about most crucial mechanism used in handling the user traffic, which is known as the Packet scheduler [6].

Here we consider the tradeoff between the throughput and the fairness, while allocating these radio resources. In wireless technology, the influence on the channel quality reduces because the packet scheduler aims to maximize the spectral efficiency through successful resource allocation. There is a great instability in the channel quality due to Doppler Effect and the Fading Effect. Due to these effects, OFDM systems adopt the channel aware conditions in order to obtain better channel conditions [7] by assigning the higher priority channel quality to the users.

A. Scheduling factors

- Channel quality indicator: The user gives the channel quality information to base station in the uplink in the form of a four digit number. By using this information, the base station assigns the specific modulation and coding technique and the suitable resource block to the user.

- Buffer status report: When the user has definite data in its buffer it has to inform the base station that there is some data and request a grant from the network to share that data. This is the user's way of informing base station about the data in the user terminal.
- Quality of service: Quality of service is a measure of functionality between the PDN gateway and the user. It defines how the data should be treated in the network. For example, a voice packet is given more priority than web browsing traffic. The user computes the CQI value in the downlink channel and sends it to the base station. The buffer status report (BSR) is also sent to the base station. Based on these factors (BSR, CQI, and QoS), modulation and coding scheme values and the Physical resource block (PRB) mapping are computed and sent to the user.

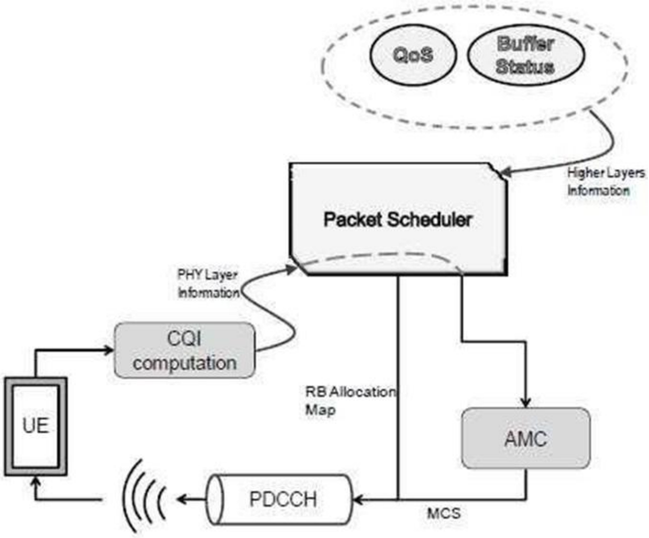

Fig. 2. Packet Scheduler

B. Sequence of operations in a Packet Scheduler

The radio resource management modules interact with the scheduler and this sequence is continuously repeated, as shown in Figure 2.

- The user equipment takes the reference signal and, calculates the channel quality and this is sent to the base station.
- The base station takes the allocation decision by using the channel quality value and fills the resource block.
- The user reads the PDCCH channel payload.

C. Downlink scheduling algorithms

- Best CQI Scheduler

In this algorithm, scheduling [8] is performed by sending the channel quality indicator to the eNodeB. The reference signals are transmitted by the base station (eNodeB) to the user equipment. Then the user equipment calculates the channel quality indicator to assign the resource block to the user equipment. In this scheduling, the users who have the best radio link conditions are assigned the resource block and the others are not assigned the resource block. The client terminals who are at distant from the base station are not assigned the resource block since they do not have the best radio link conditions. The scheduling processes is described in following steps:

1) The base station sends the reference signals to the users.
2) If the channel quality indicator is the highest value, then the resource block is assigned to it; otherwise, it is not.
3) The resource block is given to the user equipment when they have the best CQI.

In this scheduler, there is a maximum amount of throughput and a minimal amount of fairness.

- Round Robin Scheduler

This scheduling scheme, is unaware of channel states, and the allocation of resources is performed regardless of channel behavior. Hence, there will be lower throughput and more fairness. Throughput wise, it doesn't exhibit satisfied levels but provides fairness among all users. The scheduling process [6] is usually carried based on offered resource blocks. The users will be served with resources in order of first come first serve basis. The principle of operation of this round robin algorithm is very easy and fairness is guaranteed.

D. Proposed Scheduling Algorithm

In the previous section, discussed the Best CQI and the Round Robin scheduling, whose algorithms satisfy the throughput and fairness, respectively. Now, in this section new scheduling algorithm is discussed, which is a trade-off between both scheduling algorithms [9]. In a sub- carrier, there are two slot periods to which the resource blocks are allocated by the base station scheduler. According to this algorithm, the first slot allocates the resource blocks to the user satisfying Best CQI scheduling. And the second slot allocates according to the Round Robin Scheduling. Thus, this scheduling algorithm satisfies both throughput and fairness [10].

The figure below represents the proposed scheduling algorithm flowchart. The Base station first checks for the highest CQI value, and the user with the highest value is selected. If there is no highest CQI value, then the scheduler makes the selection at random. All the users with high CQI are selected and scheduled in the first slot period. In the second time slot, all the time slots are scheduled according to Round Robin Scheduling. After the second time slot is done, the process is repeated. The procedural flow of the Proposed Scheduling Algorithm is shown in Figure 3.

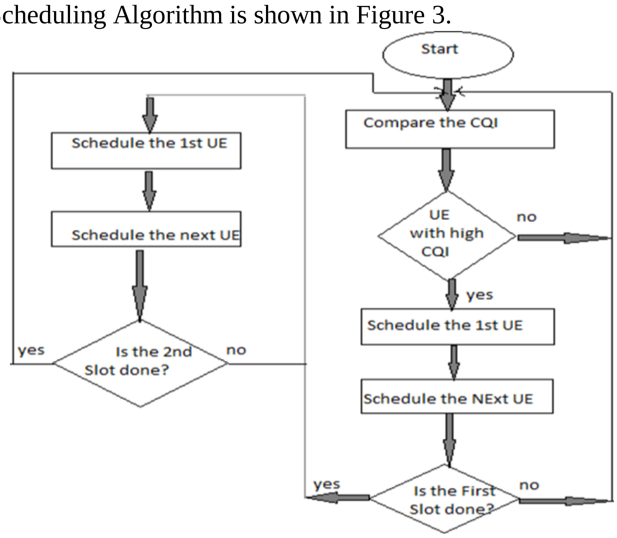

Fig. 3.Proposed Scheduling Algorithm Flowchart

IV. Results and Discussion

In the best CQI algorithm, the BS sorts the users' indices based on their CQI, and allocates the n-th resource block to the user with the highest SNR [dB] at it. In case, there is more than one user with highest CQI at a specific resource block, we select one of them at random, and allocate that resource block to the selected user. This can be seen in the MATLAB code. After the scheduling is done, we calculate users capacities and their channel efficiencies.

For the example, the allocation matrix for the first time slot can be obtained as follows:

```
allcMat =

     0     0     0     0     0     0
     0     0     0     0     0     0
     0     1     0     1     1     1
     0     0     0     0     0     0
     0     0     0     0     0     0
     1     0     1     0     0     0
     0     0     0     0     0     0
     0     0     0     0     0     0
```

A sit can be seen in the first resource block, users 3 and user 6 have the highest CQI (here, 13). So one of the miss elected at random (here the selected user is 6). We have a similar scenario for the other resource blocks. Another representation of the allocation matrix can be made in an array form of size Rb × 1. In this way each element of the array shows the index of the user which that resource blocks is allocated.

```
a_transpose =

     6     3     6     3     3     3
```

With such representation we can show the scheduled users for different time slots in a better way. We can observe that the resource blocks are allocated only to users 3 and 6 because they have the highest CQI among the users. This indicates that by using the best CQI algorithm there is a chance that some users cannot use network resources. In the round-robin scheduling algorithm we start with the first user, and we allocate the first resource block to it. Then we move to the second user, and we allocate the second resource block to this user. We continue this process until we have no resource blocks left, or until we have no users left. In case the number of resource blocks is greater than the number of users, we start over with user one and allocate the K + 1-th resource block to user 1, and so on. Conversely, if the number of users is greater than the number of resource blocks, in the next time slot we start with a user that has not been scheduled yet (namely userk= Rb+ 1).The allocation array can be obtained as follows:

```
a_transpose =

     1     2     3     4     5     6
```

If we continue for more time slots we will have

```
Time slot 1:->
a_transpose =

     1     2     3     4     5     6

Time slot 2:->
a_transpose =

     7     8     1     2     3     4

Time slot 3:->
a_transpose =

     5     6     7     8     1     2

Time slot 4:->
a_transpose =

     3     4     5     6     7     8
```

There are 8 users here, and all the users are allocated in the Round Robin scheduler by allocating first 6 users in the first time slot. When the time slot is totally occupied then it starts allocating the second time slot from user 7, and the allocation continues. The proposed scheduling algorithm combines the ideas of the best CQI and Round Robin scheduling. In this algorithm we use best CQI for odd time slots and round-robin for the even time slots. In this way we can keep the balance between capacity and fairness. The best CQI scheduling is used in the odd time slots and the Round Robin scheduling is used in the even time slots. After the users are scheduled we calculate the capacity, modulation of efficiency of each subcarrier and equivalently of each user for each time slot. If a user is allocated more than one RB, then their capacity would be the sum of the capacity of the RBs, and their efficiency would be the average of the efficiency of all the allocated RBs.

```
Time slot 1:->
a_transpose =

     6     3     6     3     3     3

Time slot 2:->
a_transpose =

     1     2     3     4     5     6

Time slot 3:->
a_transpose =

     3     3     6     3     3     3

Time slot 4:->
a_transpose =

     7     8     1     2     3     4
```

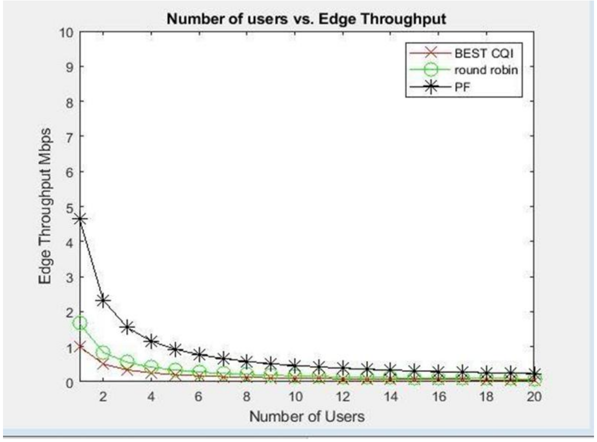

Fig. 4.Edge throughput

The simulated values for the edge throughput performance were represented in Figure 4. The algorithms that are considered here shows almost similar performance and have seen lowering tendency in throughput with increase in number of user equipment. This is mainly due to the lack of RBs for user equipment, when there is significant rise in number users. As seen from the Figure 4, Proportional Fair algorithm functions the maximum rate to the edge users.

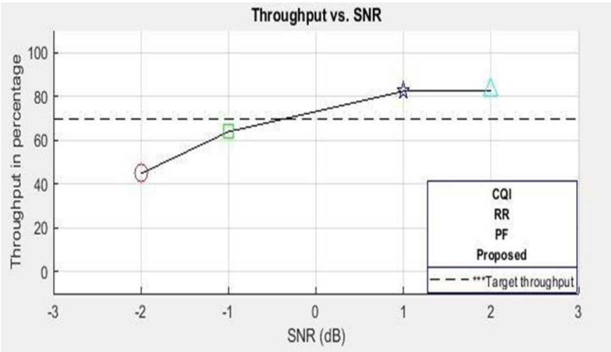

Fig. 5.Throughput Vs SNR

In the Figure 5.it represent the result of the signal to noise ratio to the throughput, the x axes represent the SNR in dB and the y axes represent the throughput in Mbps, a comparison of three algorithms were done to evaluate the system throughput for each. In this scenario the performance of proportional fair are more evaluated compare to pervious scenario. While increasing the SNR it was found that the proposed algorithm has a maximum throughput follow by proportional fair and lastly CQI.

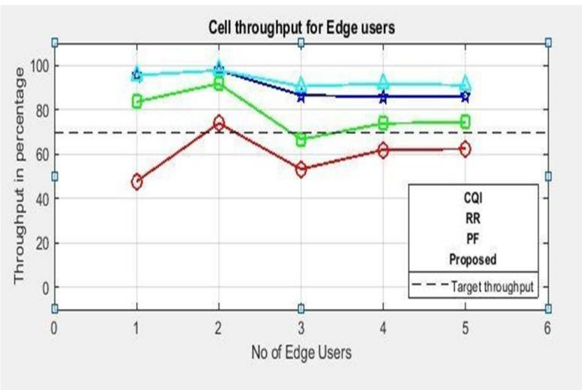

Fig. 6.Cell Throughput

The cell throughput is obtained with the help of channel qualities of the users in the actual wireless network models. Due to this reason, best CQI algorithm gives better throughput since it aids the users based on good channel circumstances as presented in Figure 6. Followed by best CQI, high throughput can be attained by PF and RR schemes.

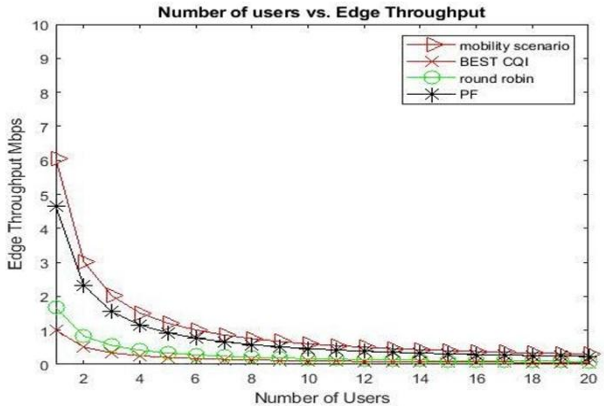

Fig. 7.Edge throughput with mobility scenario

The edge throughput is computed under mobility scenario and is depicted in Figure 7.with the increase in user velocity, there is a decrease in performance variance among the proposed scheme and PF decreases. The proposed scheduler indicates progress with regard to the edge throughput under changing mobility conditions.

V. CONCLUSION

The main objective of this paper is to study the Long Term Evolution Downlink Scheduling Algorithms. In order to know about these scheduling algorithms, details of LTE concepts are required. There are many enabling technologies in the LTE standard that help in improving the capacity of the system and their coverage. OFDM is one of the enabling technologies used in the downlink transmission, where the total bandwidth is partitioned into a number of time-frequency resource elements.

The scheduler is a crucial constituent present in the base station, which helps in allocating the time-frequency resources to the users.

In this work, we devised an improved long term evolution downlink planning algorithm and assessed the throughput and fairness exhibitions of the proposed algorithm with the four distinctive prevailing scheduling methods.

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