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A CQI Based Novel Shared Channel Downlink Scheduler for LTE Networks

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Abstract: ***Long Terrn Evolution (LTE) can be called as the new generation of High Speed Cellular Communication. LTE networks serves as back bone for 4G networks delivering high data transmission speeds and support for Qualisty of Service (QoS). It also ensures the availability of high speed connection, HD Calling, more security and extended support for streaming of HD multimedia content which includes audio and video content. With this much development in the field of mobile communication, another term was coined QoE (Quality of experience) which refers to the overall degree of acceptability of the multimedia content as perceived by the end users. In this paper we introduce a CQI based algorithm to improve the overall QoE while it is being applied on downlink scheduling. Simulation runs proves that CQI has better results as compared to other algorithms based upon parameters such as throughput, SnR and fairness.***

Keywords: QoE, Scheduling, CQI, LTE

I. INTRODUCTION

In view of the recent trends, it is quite clear that wireless communication has emerged as the communication type registering exponential growth in data volume as well as user base. LTE architecture is basically the brainchild of 3rd Generation Partnership Project popularly known as 3GPP which provides high speed Wireless Broadband access upto speeds of 1 Gbps via IP based packet switched network. The high data speeds of LTE networks is very important as the user is churning out extra money for this connection, secondly according to survey done by Accenture [1] 90% of the unsatisfied users, change the ISP instead of complaining about the low data speeds. Now this has quite an impact on the revenues of ISP's offering LTE services. Therefore it is quite important for them to maintain required QoE level.The efficient design and implementation of scheduling algorithms has been the main point of research as it is one of the way to maximize QoE. The target of this work is to make optimum usage of network resources so as to provide high speed data to end users. This optimum usage of network resources is calculated on various parameters to ensure that the data received by the end user satisfies his need of agreed QoS. The various parameters used are throughput, delay and fairness. The deployment of IEEE Standard product can be an added enhancement to solving specific internal issues in the country, as the standard supports QoS multimedia.[20]

II. ISSUES IN LTE NETWORKS

There are many challenges faced by LTE and LTE-A systems hen we discuss about resource management. The first issue is the Multiuser Problem. As the LTE system is spread over a large geographical area and there are several UE's in that area, the major challenge is to serve all the User Equipments (UE) with minimum latency in that cell.

The resource allocation in LTE is done via OFDMA. The users needs to share the bandwidth allocated to the UE in the area to which it is connected. Here the role of scheduling algorithms came into play. Scheduling algorithms increase the efficiency of the system by dealing with each type of traffic differently.

2.1 Aspects impelling the Scheduling Algorithms

One of the main challenges faced while developing scheduling algorithm is the changing nature of the network. There are several variations in the network at any given instance of time which may ultimately result in fluctuating channel conditions, conclusively it is very hard to uphold same modulation process for transmission of data to all UE and LTE system has routed to Adaptive Modulation and Coding Technique (AMC) to overcome this hurdle [2]. It is also significant to recollect that spectral efficiency is not the only factor that needs deliberation while designing scheduling algorithms. The other parameters that require special attention are as follows:

1. Fairness
2. Complexity
3. Signal to Interface plus Noise Ratio
4. Channel Conditions
5. Packet Delay
6. Compatibility support of the algorithm with hardware

Now we will discuss all these parameters in detail to get an idea about the significance of these parameters and their overall impact on the system.

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2.1.1 Fairness: Fairness as a parameter is very difficult to explain and understand as in homogenous LTE system, there are different types of traffic and each type of traffic has its
special need for resources. The challenge lies in the fact that each traffic flow should get required resources and none of the traffic flow should ever come in starvation stage. This definition of fairness does not hold good when we tal about heterogeneous systems. According to some authors, there are two types of fairness. [2]

A) Partial Fairness: Partial Fairness may be defined as the degree of fairness in the same domain. By domain we mean that he similar types of flows. For example if we are taking in consideration only real time flows like audio or video streaming, If we are only concerned about a single type of traffic flow and we are doing justice to that flow, it may be defined as partial fairness. This increases the frequency-efficiency of the unlicensed band, reducing the cost of securing additional frequencies, such as License Assisted Access (LAA), which can satisfy the needs of mobile terminals.[19]

B) Total Fairness: Total Fairness is the measure of fairness if we consider all traffic flows at a single instance of time. For example, in a network, traffic of various classes is transmitting at an instance like video streaming, VoIP, text and audio which can also be termed as heterogeneous traffic; maintaining fairness in terms of resource allocation in this case may be termed as total fairness.

2.1.2 Service Type: LTE has two service types viz. real time and non-real time. This is one of the major advantages of LTE as this coarse classification helps reducing overhead while transmission of data. Real time data has the higher priority as compared to non-real time data. Delay is also a factor which differentiates between real time and non-real time data. Real time data includes VoIP, Video conferencing and streaming. Non-real time data includes web browsing and email.

2.1.3 Channel Conditions: Channel condition is a very important factor that needs special attention while making scheduling decisions. There are a lot of factors that affect quality of channel like path fading, shadow fading, the ever changing distance between UE and eNodeB and congestion. Sometimes external weather conditions lead to packet loss and hence quality of channel is degraded.

2.1.4 Packet Delays: Packet delay is one of the major reasons for performance degradation of the channel. It has a direct effect on real time services like video streaming and VoIP and ultimately the required QoS levels are not achieved. The ideal packet scheduling algorithm should ensure that the packet delay is minimum.

2.1.5 Complexity: Complexity of an algorithm defines that how much time the algorithm will take in determining and sending the packet to its destination. More complex algorithms will lead to more overhead in sending data and will result in unnecessary packet delays.

The algorithm designed should be simple enough so that the output overhead is minimum. In LTE, resource allocation is estimated to be a function of TTI which is normally 1ms so we expect that an optimized algorithm should take less time than TTI.

III. LITERATURE REVIEW

As we all know that OFDMA (Orthagonal Frequency Division Multiple Access) is the base of LTE systems. The main target of all algorithms designed for scheduling is to take advantage of all the qualities of OFDMS for maximization of resource utilization and all the decisions pertaining to resource allocation are taken by centralized scheduler. There are lots of scheduling algorithms which are better and optimized in their own way. We will be discussion some of the scheduling algorithms which have left a great impact on scheduling in LTE. For the sake of clarity, we have classified schedulers according to the type of functionality they offer.

In [3] author discussed Proportional fair scheduling algorithm which is implemented in several high speed wireless networks. The author insisted that this algorithm is an excellent choice for non-real time traffic. The resource allocation is done to User Equipment (UE) strictly based upon channel quality. The aim of this algorithm is ensuring fairness as well as maximizing throughput.

Proportional fair (PF) schedulers were also used by Kwan et al. [4]. Pf is the most commonly used algorithm in 3G networks, so it was thought that is would also work well with 4G systems as well. But the results proved otherwise. The basic reason was the extensive support for real time data in 4G networks and the clause of time sensitivity because of this it generally also termed non elastic service flow. With rigorous experimentation, the authors proved that PF holds good for non-real time data but desired QoS standards are not achieved for real time data and applications.Basukala et al. [5] worked on exponential proportional fairness algorithm (EPF) which has been exclusively designed to support multimedia applications. This algorithm works according to the demand of users. It uses adaptive modulation and coding which adapts according to the resources demanded by the users. It means that this adaptive algorithm provides higher priority to real time applications as compared to non-real time applications. One disadvantage of this algorithm is that it does not hold good while handling buffer delays and its performance is same as of traditional PF algorithm. So as a result of time delay this algorithm is not very extensively used for 4G networks.

Another algorithm was proposed by Park *et al.* [6] which was basically delay based algorithm which was designed especially for real time applications. In this algorithm a concept of Head of Line (HOL) value was also introduced which was very effective in handling real time data. There was only one disadvantage of HOL that when packets exceeded the threshold they got discarded and ultimately resulting in unwanted retransmission and packet loss and hence degradation of QoS.

Ameigeiras *et al.* [7] proposed Maximum-Largest Weighted Delay First Algorithm which supported multiusers in 3G and 4G networks. The main focus of this algorithm was real time data keeping in consideration the current channel quality. This algorithm aimed to support multiple applications with different QoS. This algorithm does not hold good for non-real time data.

Sadiq *et al.* [8] proposed a scheme which proportionally balanced real time and non-real time applications. The scheduling decisions were based upon the length of the queue. But due to very high computational overhead, this scheme was not very successful. Authors used packet delay based max-weight scheduling scheme. The outputs were more optimized as compared to other schemes.

Leinonen *et al.* [9] and Varadarajan *et al.* [10] came up with a scheduling scheme using Round-Robin scheduler. Round Robin is a very traditional technique which has minimum computation overhead. Round Robin technique takes processes in a line and maintains a time quantum in which every process should run and then go to waiting state. Waiting time for processes is reduced to a great extent using Round Robin. On the other side, throughput is degraded by a great extent in this algorithm. It is because of the inability of the algorithm to take into consideration the current channel conditions. The required QoS standards cannot be maintained in an environment where each type of service like VoIP, email, video streaming has its own specific QoS requirements.

The scheduling scheme proposed by Niu *et al*. [11] works on multiuser diversity and frequency. The status of channel is obtained by using CSI (Channel State Information). User classification based upon CSI was used to develop a scheduling algorithm which gets the status of frequency for use in high mobility users and status of multi-user diversity for low mobility users. During experimentation they came to the conclusion that results were better with respect to throughput and PF but it does not handle buffer delays well.

A scheme proposed by Prasad *et al*. [12] was a multi user scheduling scheme which supported multiple users. It was based on the physical layer interface of OFDMA. The results hence obtained were also improved. The main disadvantage of scheme was the computational overhead due to complex algorithms used. A scheduler was proposed by Donthi *et al.* [13] which was best suited for synthetic networks. It was a feedback based scheme which used subband level feedback and user selected subband feedback techniques as described in LTE. The disadvantage of the algorithm was that it often lead to wrong determination of rate for some resource blocks by the scheduler.

Work done by Gotsis *et al.* [14] focused on machine to machine communication. M2M is a challenge in itself as here are n number of devices each of different make and use. These devices have different range, frequencies and area of application. In LTE networks, the heterogeneity of these devices has increased to a great extent which poses a direct degradation in QoS in case the communication is not happening as it should be. To cater these problems, the devices were broadly categorized and each pair of communicating devices was treated with a flexible scheduling algorithm. But this resulted in signaling overhead.

Capozzi *et al*. [15] in his research gave an overview of key design and scheduling issues in LTE networks with special reference to QoS provisioning. Authors also very keenly studied and tried to optimize the power costs incurred, by letting the radio devices sleep while maintaining the required amount of QoS on the parameters of bitrate, packet loss ratio and packet delay.

Nyugen *et al.* [16] proposed a multiple component carrier based PF algorithm. This property of LTE systems enables it to boost data rates exponentially. Authors also found that majority of scheduling algorithms were unable to gain full advantage of this feature of LTE. The algorithm proposed by authors provided better packet scheduling than existing algorithms.

Another algorithm was discussed by Tsai *et al*. [17] which took into consideration the QoS required by every service class. This algorithm was made using divide and conquer scheme. First part known as dynamic priority adjustment gave highest priority to users which required real time data by dynamically adjusting frame value in line with QoS requirement of the user. The second part known as Priority based Greedy Algorithm used Greedy approach in order to reach required QoS.

Xu *et al.* [18] proposed an uplink transmission scheme to exploit the very less explored parts of LTE-A systems. This algorithm evaluated LTE systems on Host to Host and Machine to Machine scenarios. This algorithm was also capable of handling power and resource block allocation dynamically. Simulations established a major performance augmentation.

IV. MODEL AND SIMULATION SET-UP

This work focusses on implementing CQI scheduling algorithm. In the past there are several works which implemented CQI scheduling algorithm and the results they got were also on the positive side. The main advantage of CQI is its simplicity, less overhead and the quality of providing feedback. This helps in smooth data transmission because of availability of channel. The earlier works proposed CQI scheduler to be implemented in eNodeB whereas we will be implementing this algorithm at Downlink Shared Channel also known as LTE DL-SCH.

Figure 2 shows a representation of DL-SCH. Here we have installed a scheduler whose function is to schedule the incoming data to various streams so that they can be processed simultaneously. This scheduler will be coded with CQI algorithm as CQI has proven track record of providing satisfactory QoS levels as compared with other algorithms. This scheduler will divide the data stream into many channels according to the priority, the type of traffic and the channel status. Each data will first be brought under CRC check which checks data for any inconsistencies. Then the data is forwarded to code block segmentation and after that it goes to Turbo Coding block. After that rate matching is done, the data is again segregated and forwarded to the channel with respect to the type of data guaranteeing satisfactory levels of QoS.

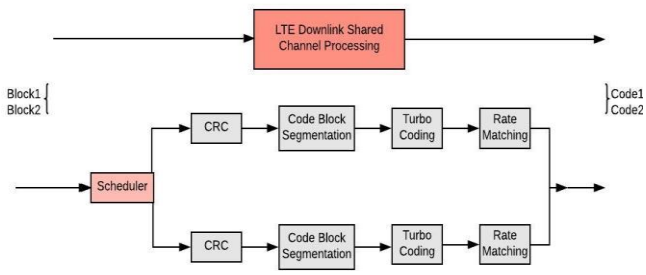

Figure 1: **DownLink Shared Channel Processing**

4.1 Parameters Setting

Table 1 shows the parameters used and the simulations settings for the experimental setup.

Table 1: **Simulation Parameters**

Parameter	Value
Number of Users	100
Number of eNodeB	1
Bandwidth	20MHz
Channel type	Pedestrian and Vehicular
Simulation Length	100 sub-frames
Scheduling Algorithm	CQI
Transmission Scheme	MIMO

V. RESULTS AND DISCUSSIONS

This simulation was performed on a proprietary simulator and the here UE data is transmitted from the co-operating eNodeB and based upon Channel quality reports from the shared channel.

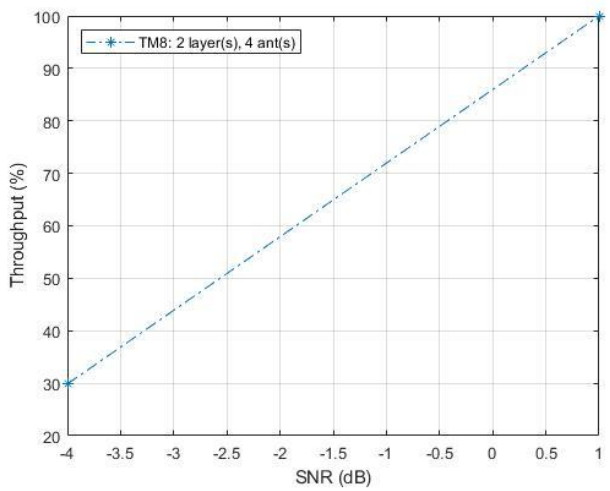

Figure 2: **SnR Vs Throughput**

In this experiment, we have considered four types of data which needs to be transmitted which is audio streaming, video streaming, simple text transmission or web browsing and non- real time data which may include some graphic content. As shown in figure 2, scheduler has divided data into two channels. Now according to the type of data received, the CQI scheduler checks the quality of the channel and forwards the data to the channel which is comparatively free.

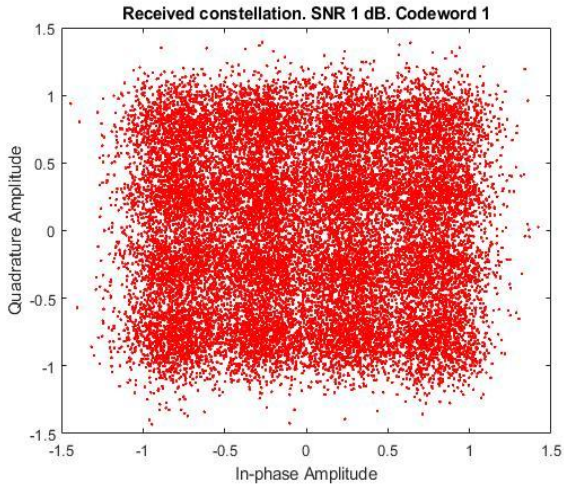

Figure 3: **Amplitude Constellation**

Here in this case when the data has been transmitted, the throughput started from 30% and has shown a gradual increase until the SnR is 1 which is more optimized as compared to other algorithms. The constellation hence formed also gives a fine view about the scattering of data in the channel which is very even in our case.

From the above experiments we have come to the conclusion that CQI is best suited for LTE when applied at shared downlink channel and it does justice to almost all type of data received.

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