Bell Curve Based Resource Scheduling in LTE

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***Abstract*— Scheduling is one of important methods in maximizing data rate and fairness among multiple users. It is very evident that communication system has less number of radio resources in comparison to high number of users. Scheduling method provides best way to allocate minimum resources to maximum users with satisfying all possible communication requirements. The paper discusses a bell curve based resource scheduling algorithm in LTE system. Shape of Bell curve suggests maximum resources allocation to average users whereas fewer resources allocation to low performance users and high performance users. The scheduling method is compared with well known scheduling techniques, such as maximum throughput, round robin, and proportional fairness methods. Results shows suggested scheduling method is comparable with existing scheduling methods.**

Keywords—LTE, resource, fairness, throughput, data rate, scheduling, Bell Curve

I. Introduction

LTE called as "Long Term Evolution" is a fourth generation technology in telecommunication. LTE is a 3GPP standard, which is designed for further evolution of conventional UMTS/HSPDA based third generation telecommunication system. High mobile data usage, high multimedia applications, mobile gaming, web 2.0, mobile TV etc. are main motivation in developing LTE standard. LTE provides high data rate LTE up to 300MBPS in downlink and 75MBPS in uplink. It is a complete packet based switching system working on an OFDM technology.

LTE is not a true 4G technology rather it is a 3.9G technology as it does not complied with recommendation of International Telecommunication Union (ITU). Later, LTE-Advanced (LTE-A) is developed in according to the guidelines of ITU and is called as true 4G technology. LTE-Advanced provides 1GBPS data rate in downlink and 500 MBPS data rate in uplink. Such higher data rate and low latency are achieved in LTE-A by inclusion of new technologies, such as carrier aggregation, coordinated multi point network, MIMO, Relay Node.

LTE resources are divided into number of time (called as OFSM symbols) and frequency (called as sub-carriers) slots. A resource element (RE) is a smallest resource unit having a single sub-carrier in frequency domain and an OFDM symbol in time domain. A resource block (RB) is a smallest resource allocation to user equipment, having 12 sub-carriers and 6 or 7 OFDM symbols. Therefore, a resource block can have 72 or 84 resource elements. LTE supports scalable bandwidths which are 1.4MHz, 3MHz, 5MHZ, 10MHz, 15MHz and 20MHz. Each bandwidth has different number of resource block available i.e. 6, 15, 25, 50, 75 and 100 resource blocks respectively. LTE has five physical downlink channels: those are PBCH, PCFICH, PHICH, PDCCH, and PDSCH channels [1]. PDSCH channel is a shared data channel and PDCCH channel is a control channel. In a span of 1ms TTI (transmit time interval) sub-frame, these channels are allocated over number of resource elements. A radio frame of 10ms includes 10 sub-frames of 1ms. Each sub-frame includes two resource blocks of 0.5ms duration [2]. Figure 1 suggests resource block structure in LTE.

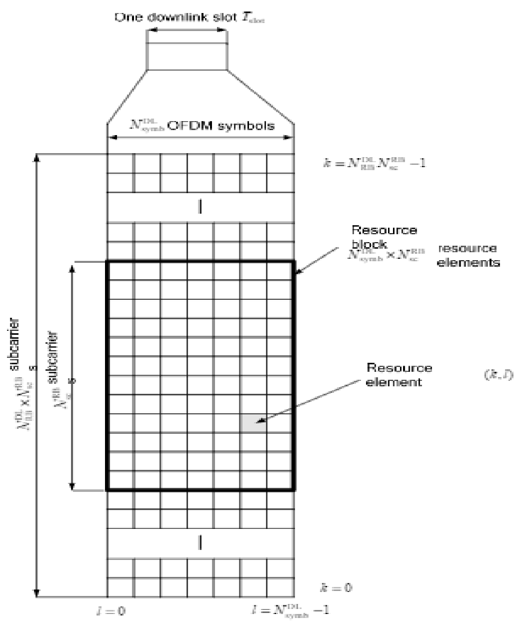

Figure 1: LTE resource block structure

There are number of resource allocation methods are available in literature. Different survey papers suggest [3-5] different scheduling methods utilize in LTE. Figure 2 suggests a general resource allocation block diagram. Radio resource manager (RRM) is a main component for scheduling resources. A packet scheduler or PDSCH scheduler allocates resources based on various parameter considerations, such as channel condition, buffer status, queue length, previous average data rate, fairness, delay etc.

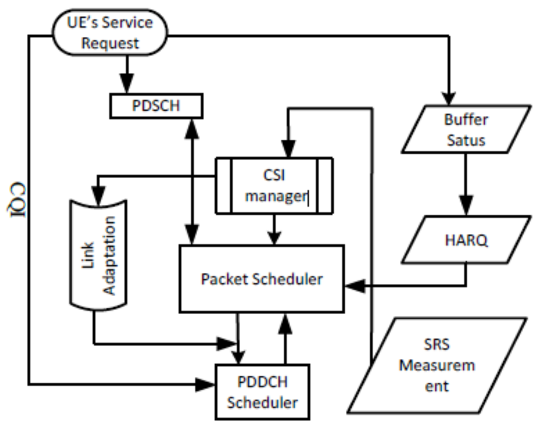

Figure 2: A resource allocation block diagram

Round robin [6] is a basic scheduling method which is completely based on fairness parameter. It does not differentiate users at cell center and users at cell edge. Therefore, it provides maximum fairness to users but it provides very less overall system throughput. Maximum throughput is another basic method in allocation of resources, which is well described in [6-7]. It allocates resource based on current expected maximum date rate. It prioritizes that user who can receive maximum data rate. The following equation (1) is utilized for resource allocation in maximum throughput:

$$PM = \{R_i(t)\} \quad (1)$$

$R_i(t)$ is corresponding to instantaneous throughput of user *i*. This method prioritizes users for allocating resources based on current data rate. Though, this method provides maximum throughput, but it does provide poor fairness. So, users at cell edge would receive minimum resources or null resources using this method. Proportional fairness (PF) is a best technique in delivering of average throughput and high fairness. Proportional fair performance is middle in between round robin and maximum throughput scheduling method. Equation (2) suggests a resource allocation method using proportional fairness technique.

$$PM = Current\ \{R_i(t)\}/\ past\ avg\ \{R_i(t)\} \quad (2)$$

PF method [6-8] allocates resources based on current experienced data rate and past average data rate. This method is widely used in communication system, however it does not suggest resource allocation based on current service classes i.e. real time and non-real time classes. Generalized proportional fairness is another resource allocation method, which is enhanced version of proportional fairness method. There are other methods also present, such as MLWDF (maximum largest weighted delay function) which is based on head of line delay parameter, queue length based resource allocation etc.

Current paper suggests resource allocation based on bell curve. Bell curve is a general performance shape curve, which is utilized in industries or companies for providing employee appraisal performance or incentive. Bell curve fits percentage of appraisal performance of employee in such a way that employs at high end & at low end receives least incentive whereas average employee receives maximum incentive. Further, number of average performer employee is more than number of lower and higher performer employee, so Bell curve can satisfy maximum number of employees. As Bell curve shape is utilized in industries, the Bell curve shape can be utilized in LTE system in allocation of resources. Bell curve shape based resource allocation provides good results. By this method, in LTE system, resources are allocated to average users maximally whereas least resources are allocated high and low users.

II. System Model

A: Bell Curve

A graph that represents density function of the Normal probability distribution is also known as a Normal Curve or a Bell Curve. The Normal distribution requires two parameters, the mean and the standard deviation. The probability density of the normal distribution is given by following equation:

$$f(x|\ \mu, \sigma^2) = \frac{1}{\sqrt{2\pi\sigma^2}}\ e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

Where is μ is median or expectation, σ is standard deviation, and σ^2 is variance. A Normal distribution with a mean μ and a standard deviation σ^2 known as the standard normal distribution is shown in Figure 3.

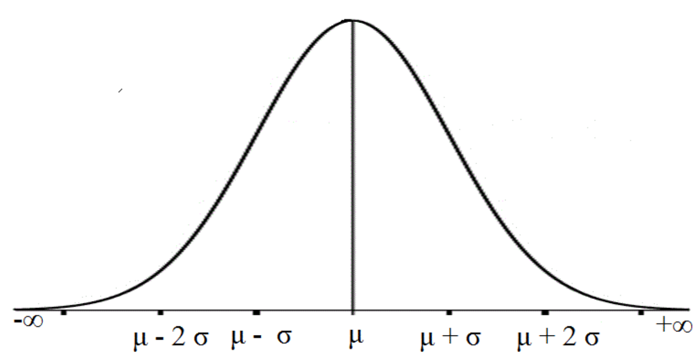

Figure 3: Normal distribution curve (Bell curve)

B: Performance metric for resource allocation

The current resource allocation method is based on date rate received by number of active users. The date rate calculation is possible determining channel quality indicator

(CQI) level. CQI value is dependent of SNR calculation of communication channel [9]. Channel conditions of communication channel is very changeable, so according to channel condition data rate experienced by user in communication medium is also changeable. At a time, different users expect different data rate in communication medium as per corresponding channel conditions. The channel conditions information in terms of CQI level is sent to base station eNodeB.

Table 1 shows relation between channel condition CQI level, code rate, SNR and modulation code.

CQI Index	Modulation Order	Code Rate × 1024	β	SINR threshold (dB)
0	No transmission			
1	QPSK	78	1.00	-9.478
2	QPSK	120	1.40	-6.658
3	QPSK	193	1.40	-4.098
4	QPSK	308	1.48	-1.798
5	QPSK	449	1.50	0.399
6	QPSK	602	1.62	2.424
7	16QAM	378	3.10	4.489
8	16QAM	490	4.32	6.367
9	16QAM	616	5.37	8.456
10	64QAM	466	7.71	10.266
11	64QAM	567	15.5	12.218
12	64QAM	666	19.6	14.122
13	64QAM	772	24.7	15.849
14	64QAM	873	27.6	17.786
15	64QAM	948	28.0	19.809

Table 1: Relation between CQI, MCS, SNR and code rate

As per current method, Bell curve based performance metric for resource allocation is given by following equation (3):

$$PM = \frac{e^{-\frac{\{R_i(t)\}^2}{2}}}{past\ avg\ \{R_i(t)\}} \tag{3}$$

In equation (3), it is considered that median is zero and standard deviation is 1. Further, $\{R_i(t)\}$ is instantaneous data rate of user i and $past\ avg\ \{R_i(t)\}$ is average date rate received by user i in previous TTI(s). Data rate of user i is calculated using following equation (4):

$$R_i(t) = \frac{n_i bits}{symbol} * \frac{n\_symbol}{slot} * \frac{n\_slots}{TTI} * \frac{n\_subcarrier}{RB} \tag{4}$$

In equation (4), number of bits per symbol is calculated, then number of symbol per time slot is calculated, then number of time slots per TTI is calculated and finally number of sub-carriers per resource block is calculated, so equation (4) provides instantaneous data rate of user *i*.

III. Simulation and Results

A: Simulation Environment

In this suggested method, the simulator is based on the MATLAB, which includes LTE system toolbox. According to suggested method, it is considered a LTE cell, in which users are uniformly distributed. In the centre of the cell, the base station eNodeB is positioned, whereas the users are modeled according to a random mobility model. The simulation parameters and the considered traffic model are provided in table 2.

Parameters	Value
Bandwidth	10 Mhz
Number of PRBs	50
Frame Structure	FDD
Cell Radius	1 KM
E-UTRAN frequency band	2.1 Ghz
Simulation Time	10 Sec
UE speed	3KMPH
Path Loss/Channel Model	Typical Urban (pedestrian-A propagation model)
Simulation repetition per scheduler	10
Transmission Time Interval	1000 TTI
Cyclic prefix	Normal
Scheduler	Round robin, Maximum throughput, Proportional fair and Bell curve based scheduler

Table 2: Simulation parameter

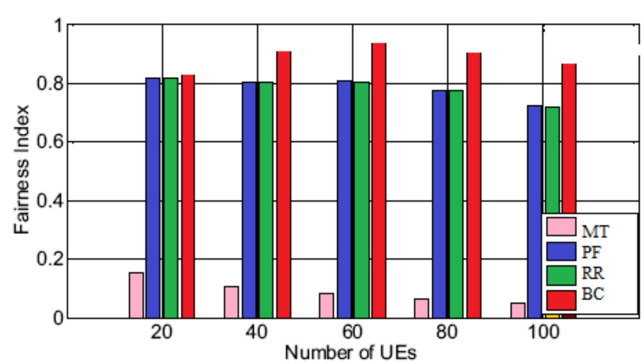

Figure 5: Fairness Index comparison

Figure 5 shows a well comparison between current Bell curve (BC) based resource allocation and other well known methods. It shows, current scheduling method has high fairness in compression to round robin, maximum throughput and proportional fairness methods. As discussed previously maximum throughput method has lowest fairness as comparing to all other scheduling methods.

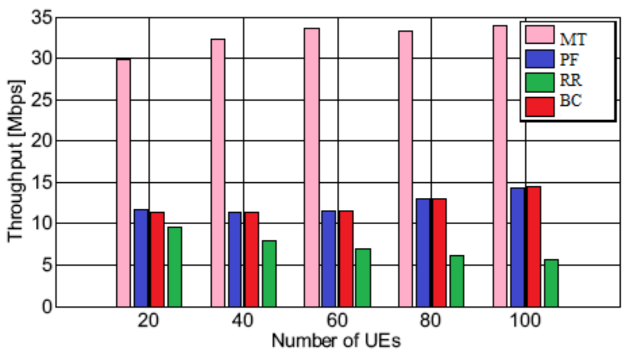

Figure 6 shows system throughputs of different resource allocation methods. Resource allocation based on Bell curve (BC) method provides higher throughput than round robin method but has less throughput than maximum throughput method. Throughput output of current method and proportional fair method are approximately same. Further, it can be say that current method has some higher throughput than proportional fairness method.

IV. CONCLUSION

In this paper, we proposed a novel scheduling algorithm named Bell curve based resource allocation method in LTE system. Radio resources are allocated based on Bell curve based performance determination, in which average users gets maximum resources whereas low end and high end users gets minimum resources. The suggested method provides throughput higher than proportional fairness method and round robin method. Further, it has higher fairness as comparing to proportional fairness method and maximum throughput method. Bell curve based is very simple method in resource allocation and require very less computation time as comparing to other method. From future point of view, the suggested method is also applicable in LTE-advanced system; therefore it is require implementing current method in LTE-advanced system. Further, real time and non real time service classes are equally treated in current method, so it is also require in developing a method which treats real time and non real time service classes differently based on Bell curve shape.

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