A Survey on LTE Downlink and Uplink Scheduling Algorithms

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Abstract— Long Term Evolution is the fastest growing technology in communications that aims to support wide range of network services such as web browsing, video conferencing, social networking, real time gaming, video streaming and so on. For providing multiple network services to user LTE includes some Radio Resource Management (RRM) techniques. In this paper, we provide a brief description of various LTE downlink and uplink packet scheduling algorithm.

List of Acronyms

3GPP	Third Generation Partnership Project
4G	Fourth Generation Wireless
ACM/TDM	Adaptive Coding and Modulation and Time Division Multiplexing
CDMA-HDR	Code-division multiple access high data rate
EXP-PF	Exponential Proportional Fairness Algorithm
EXP Rule	Exponential Rule Algorithm
FLS	Frame Level Scheduler Algorithm
FME	First Maximum Expansion Algorithm
LTE	Long Term Evolution
MAD	Minimum Area Difference Algorithm
OFDMA	Orthogonal Frequency Division Multiple Access
PF	Proportional Fair Algorithm
QoS	Quality of Service
RB	Resource Block
RC	Resource Chunk
RME	Recursive Maximum Expansion
RR	Round Robin
RRM	Radio Resource Management
SC-FDMA	Single Carrier Frequency Division Multiple Access
UE	User Equipment

1. INTRODUCTION

Long Term Evolution is a 4G Communication standard introduced by the 3rd generation partnership project (3GPP) to provide 10 times the speed of regular 3G networks. LTE network targets to provide peak data rates up to 100 Mbps(downlink) and 50 Mbps(uplink) assuming a bandwidth of 20 MHz or equivalently, spectral efficiency levels of 5bps/Hz on the downlink and 2.5 bps/Hz on the uplink. The primary design goals of LTE network are higher downlink and uplink data rates, lower cost-per bit, scalable bandwidth to support wide range of network services like web browsing, video conferencing, social networking, real time gaming, video streaming and so on [6, 9, 13, 14, 16].

2. LTE SCHEDULING

LTE includes some Radio Resource Management procedures to assign resources to the users such that system performance gets maximized. This process of assigning resources to the users is called scheduling. Various downlink and uplink scheduling algorithms are proposed to maximize the performance in terms of system metrics such as packet delay, jitter and throughput [3, 5, 7].

2.1 LTE Downlink Scheduling

In LTE downlink, OFDMA radio access scheme is implemented that divides the entire system bandwidth into sub-bands in the form of subcarriers and assigns subsets of sub-carriers to particular user [5, 9, 13, 14].

In the following section various types of LTE downlink packet scheduling algorithm are discussed.

2.1.1 Proportional Fair (PF) Scheduling Algorithm

The proportional fair scheduling algorithm is designed to support non-real time data service in Code-division multiple access high data rate (CDMA-HDR) System. This algorithm aims to maximize cell throughput while at the same time allocates at least a minimal level of resources to all the users through the scheduling priority [5, 6].

2.1.2 Modified Largest Weighted Delay (M-LWDF) Scheduling Algorithm

The modified largest weighted delay scheduling algorithm is designed to support non-real time and real time data service with different quality of service requirements in Code-division multiple access high data rate (CDMA-HDR) System, due to real time data transfer this algorithm is delay sensitive. This algorithm aims to balance the weighted packet postpone and to degree the performance of the channel to utilize it [1, 5, 6].

2.1.3 Exponential Proportional Fairness (EXP-PF) Scheduling Algorithm

The exponential proportional fairness scheduling algorithm handles both non-real time and real time data service. EXP-PF algorithm is a composite of Exponential Function and PF algorithm. Exponential Function guarantees postpone bound of real time data flow and PF algorithm ensures the maximization of overall throughput. This algorithm is designed to support multimedia applications in an ACM/TDM (Adaptive Coding and Modulation and Time Division Multiplexing) system [5, 8, 9].

2.1.4 Exponential Rule (EXP Rule) Scheduling Algorithm

The exponential rule scheduling algorithm is designed to provide ensured Quality of Service on a shared wireless link. This scheme selects an individual user/queue to get service in each scheduling moment. The packet scheduler enforcing EXP Rule takes into consideration both the channel situations and the condition of queues while taking decision regarding scheduling [1, 8].

2.1.5 Frame Level Scheduler (FLS) Algorithm

FLS algorithm is designed to support real-time data service. It is a two-level scheduling scheme with two separate levels i.e. upper level & lower level. At these two separate levels two different scheduling algorithms are implemented. At the upper level, a less complex resource allocation algorithm based on Discrete Time (DT) linear control theory is applied for calculating the amount of data to be transmitted in a single frame by each real-time user. At the lower level, the proportional fair scheduling algorithm is applied to maximize cell throughput while at the same time allocates at least a minimal level of resources to all the users through the scheduling priority [1, 2, 5, 6, 8].

2.1.6 Best CQI Scheduling Algorithm

Best CQI Scheduling algorithm provides high throughput as well as fairness satisfactorily. This scheduling strategy allocates resources to the users as per their link Quality. For this, users send Channel Quality Indicator (CQI) feedback to the base station. The highest CQI value indicates that the channel has best channel condition and the resources will be allocated to this user. In this scheduling strategy users who are located far away from the base station don’t schedule as well [6, 10, 12].

2.1.7 Round Robin (RR) Scheduling Algorithm

Round Robin scheduling algorithm is a simple algorithm that allocates resources cyclically without considering channel condition. Therefore, it gives great fairness and results in lower system throughput. Each user can take resources for given time period; the first user will take the resources for specific time period, after that resources will be taken back and assigned to another user. The new user will be placed at the end of waiting queue [6, 10, 11].

2.2 LTE Uplink Scheduling

In LTE uplink, SC-FDMA radio access scheme is implemented. As a result it allocates contiguous resource block to particular user in the frequency domain [4, 13].

In the following section various types of LTE uplink packet scheduling algorithm are discussed.

2.2.1 First Maximum Expansion (FME) Algorithm

The main aim of this algorithm is to use the Resource Block (RB) metrics that depend on allocating RB to user A that has best channel condition. Then it expands the allocation of resources in two sides of RB metrics until channel will keeps up its desirable condition as compared to other users. User A is thought to be served whenever other user B having better channel condition is discovered, then no longer resource blocks will be allocated to user A [7, 15, 17].

2.2.2 Recursive Maximum Expansion (RME) Algorithm

RME applies similar principle as FME, but RME performs a recursive search of the maximum. At first, RME assigns RB to UE that has maximum metric value. Then it expands the allocation in both side i.e. right and left-hand side of M until it finds better RB allocation for another UE. Then, the served UE is put into an idle mode, and the algorithm performs recursive step. The algorithm gets terminate when all the UEs are idled or all RBs are allocated. In case all UEs are in idle mode and all RBs have not been allocated yet, the algorithm searches the UEs that have already assigned neighboring RBs, and allocates the remaining RBs between these UEs. [4, 15, 17]

2.2.3 Minimum Area Difference (MAD) Algorithm

MAD assigns resources among various UEs in such a way that it gives the least distinction between the cumulative metric of various users and the envelope-metric, i.e. the greatest metric value for particular RB. When scheduling resources to various UEs, MAD operates at the resource chunks (RCs) instead of RBs. RC is created by one or more contiguous RBs over which the greatest metric values belong to a particular user. Operating with RCs is set up by constructing the metric of size N * NRC, where NRC is the total number of RCs and metric value is figured as the area difference between the envelope metric and the metric of given UE. MAD algorithm shows a modified model of a breadth first search algorithm to the composite of different RCs in Matrix M to reduce the summation of the area difference values in M [15, 17].

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