

A Comparative study of LTE Downlink Scheduling Algorithm

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Abstract-LTE is widely used mobile communication technology. Long Term Evolution (LTE) standard is conceived as an all IP network to achieve higher data rate, low latency, scalable bandwidth, mobility and extended coverage. The network guarantees Quality of Service (QoS) for diverse applications such as VoIP, video and web browsing according to the Third Generation Partnership Project (3GPP) specifications. The Radio Resource Management (RRM) techniques such as packet scheduling algorithm play a vital role in providing such guarantees. The LTE introduces enhanced data link mechanisms to support successful implementation of new data services across the network. This paper presents a survey of downlink scheduling algorithms. The following scheduling algorithms are considered: Round Robin, Proportional Fair, Best CQI, Resource Fair and MaxMin. The comparative analysis of these algorithms is also presented.

Keywords— LTE, downlink scheduling, Round Robin, Proportional Fair, Best CQI, Resource Fair and MaxMin

I. INTRODUCTION

In recent years, cellular networks have been deployed widely, and various multimedia applications have been enabled through the Internet. Furthermore, multimedia contents will be accessed fast thanks to the emergence of the content delivery network (CDN) and content-centric networking (CCN) technologies. Development of mobile communications requires ever higher transmission rates and emerging various multimedia services. The number of applications and services, which require a great number of transmitted data (e.g. searching Internet or using social networks), has been rising. As a result, mobile communication networks of new generations have been developed. New

technologies and systems should provide transmission rates and network capacity that is necessary for these kinds of multimedia services. In this paper, performance evaluation of Long Term Evolution (LTE) system based on different scheduling algorithms is presented. Due to the need of efficient usage of scarce resources, scheduling algorithms become more important area of interest in mobile communication. It is important to use scarce resources effectively in order to increase network capacity and preserve needed quality of data transmission. In this paper following scheduling algorithms were evaluated: Round Robin, Proportional Fair, Best CQI, Resource Fair and MaxMin. Also, a Fractional Frequency Reuse (FFR) method, which represents a new way of resource allocation in LTE systems is evaluated in this paper. Fairness and throughput are used as parameters for evaluation of scheduling algorithms.

In LTE technology this network consists of big number of base stations (eNodeB), which are covering specified area. That area is called region of interest (ROI). Multimedia applications such as voice/video over IP, live streaming, online gaming, and mobile TV require strict quality of service (QoS) and quality of experience (QoE) performance. 3GPP started to work to resolve this issue and introduced the HSPA and later developed the specification for Long Term Evolution (LTE), also known as 4G, which is the most advanced wireless telecommunications technology currently available. LTE will better support real-time multimedia applications such as online gaming and interactive TV. It is expected that in 2014, 80% of broadband users will be mobile broadband subscribers, and they will be served by HSPA and LTE networks [1]. LTE offers network operators the ability to provide increased bandwidth to mobile subscribers, a framework for fixed-mobile convergence through the all-IP network, and vastly increased flexibility in terms of network grooming and configuration. LTE can afford the downlink maximum rate of 100

Mbps using the OFDMA and SC-FDMA to provide better performance in terms of bandwidth, latency, and QoS/QoE. OFDMA has been adopted as the downlink transmission scheme for LTE. OFDM divides the transmitted high bit-stream signal into different sub-streams and sends these over many different sub-channels. A base station in the LTE is called an Evolved NodeB (eNB), and a mobile station is called a User Equipment (UE).

The Media Access Control (MAC) layer controls the authority of users with respect to accessing the media and network resources. In the MAC layer, packet scheduling is an important issue which may have a big impact on the system performance and resource utilization. Due to the scarcity of radio resources and the variation of channel conditions, designing an optimal scheduler for wireless networks is much more difficult and important than wired networks.

In this paper, we evaluate the performance of various downlink scheduling algorithms in the wireless network, in particular, the LTE network when UEs move at different speeds. A few simulation scenarios, e.g., static, pedestrian, and vehicular scenarios using different speeds, are presented for simulation using LTE-Sim [2], one of the open source simulators available for performance evaluation of LTE systems. LTE-Sim is a simulation platform which follows the 3GPP LTE standard. The target cell includes one eNodeB and a variable number of UEs. A realistic scenario was used in the simulation where UEs receive video and VoIP flows as well as best effort flows with infinite buffers.

The paper is organized as follows. Section II summarizes the scheduling algorithms of LTE, and Section III analyzes packet scheduling algorithms for LTE. Section IV evaluates the performance of various scheduling algorithms including PF, M - LWDF, and EXP-PF in terms of packet loss ratio and PSNR. Finally, Section V concludes the paper.

II. ANALYSIS OF DOWNLINK SCHEDULING ALGORITHMS

In this section, we analyze representative scheduling algorithms which are evaluated by simulation in Section IV. Different scheduling methods are shown below.

1. Round Robin (RR): Round Robin [3] algorithm represents the simplest way resource allocation. This algorithm allocates resources cyclically. Scheduler generates a list of active users, who are randomly sorted. After list of user's equipment is generated, resource blocks are allocated to users in order in which

they are sorted in list. After all users have been assigned, the resource allocation starts from the beginning of the list. While allocating resources Round Robin algorithm doesn't consider channel conditions. It can be thought of as one of the fairest algorithms. The scheduler provides resources cyclically to the users without considering channel conditions into account. It's a simple procedure giving the best fairness. But it would propose poor performance in terms of cell throughput. RR meets the fairness by providing an equal share of packet transmission time to each user. In Round Robin (RR) scheduling the terminals are assigned the resource blocks in turn (one after another) without considering CQI. Thus the terminals are equally scheduled. However, throughput performance degrades significantly as the algorithm does not rely on the reported instantaneous downlink SNR values when determining the number of bits to be transmitted.

2. Proportional Fair (PF): A Proportional Fair algorithm was developed and today it is one of the mostly used algorithms. Main purpose of Proportional Fair algorithm is to balance between throughput and fairness [8] among all the UEs. It tries to maximize total [wired/wireless network] throughput while at the same time it provides all users at least a minimal level of service. Proportional Fair algorithm assigns resources to users, who have relatively the best channel conditions. The resources are assigned to a user with the relative best channel condition. Resources are assigned according to the expression [3].

PF was originally developed to maintain NRT service in code division multiple access high data rate (CDMA-HDR) system. The scheduler can affect PF scheduling by allocating more resources to a user, comparatively with better channel quality. This is done by giving each data flow a scheduling priority that is inversely proportional to its anticipated resource consumption. This gives high cell throughput as well as fairness satisfactorily. Thus, Proportional Fair (PF) scheduling may be the best option.

3. Best CQI: This scheduling algorithm is used for strategy to assign resource blocks to the user with the best radio Best CQI to the user will have the highest CQI on that RB. The MS must feedback the Channel Quality Indication (CQI) to the BS to perform the Best CQI. In order to perform scheduling, terminals send Channel Quality Indicator (CQI) to the base station (BS). Basically in the downlink, the BS transmits

reference signal (downlink pilot) to terminals. These reference signals are used by UEs for the calculation of the CQI. A higher CQI value means better channel condition. Best CQI algorithm takes into account current state of channel. Current channel state is expressed by channel quality indicator (CQI) parameter. Better channel state is described with higher values of CQI. Best CQI algorithm assigns resources to users with highest CQI value, which means that user is located in part of channel with best conditions. Due to that users can achieve high throughput. When resources are allocated using Best CQI algorithm high capacity of the whole system can be accomplished. Best CQI algorithm can be expressed from [3].

The whole cellular network structure can be divided into a radio access network (RAN) and a core network (CN), which makes it impractical to enhance each part independently. The LTE project in 3GPP was focused on enhancing the UMTS Terrestrial Radio Access (UTRA) and optimizing 3GPP's overall radio access architecture. Another parallel project in 3GPP was the Evolved Packet Core (EPC), which was focused on the CN evolution with a flatter all-IP, packet-based architecture. Figure 1 shows the LTE system structure

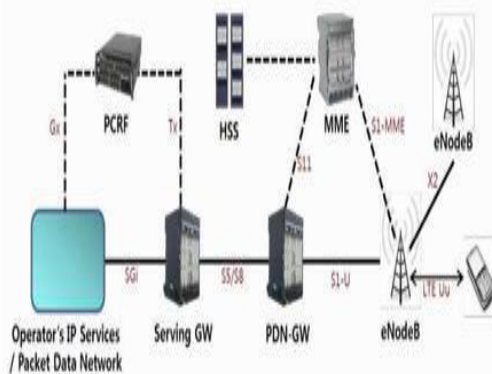


Figure1: LTE System Architecture

Downlink and uplink transmissions are possible using different transmission schemes in LTE. A scalable OFDM transmission or multi-access technique is used to allow high spectrum efficiency by utilizing multiuser diversity in a frequency selective channel in the LTE downlink. On the other hand, a scalable SC-FDMA transmission or multi-access technique is used in the uplink since this reduces the peak-to-average power ratio (PAPR) of the transmitted signal [3].

In LTE, resources are allocated by assigning dynamically available time-frequency resource blocks to each of UEs for providing the desired system performance. Channel-dependent scheduling is supported in LTE, and transmission is based on the shared channel structure where the radio resource is shared among different UEs. Therefore, with resource allocation, multiuser diversity can be exploited by assigning resource blocks to the UEs with suitable channel qualities. Moreover, resource allocation in LTE can exploit the channel variations in both the time and frequency domains. LTE has a wide bandwidth, and this property is advantageous for slow-time varying channels, such as in the scenario with low mobility, where taking advantage of channel selectivity in the time domain is difficult.

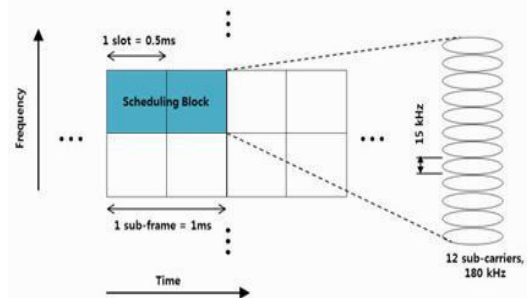


Figure2: LTE downlink time-frequency domain structure

The downlink physical resource is represented as a time-frequency resource grid consisting of multiple resource blocks (RB). A RB is divided into multiple resource elements (RE). A scheduler is a key element in the base station, and it assigns the time and frequency resources to different users in the cell. Therefore, a RB is the smallest element that can be assigned by the scheduler [4].

The scheduler's behavior is closely related to QoE and QoS performance. QoE and QoS are often used interchangeably with respect to service quality management, but they are basically two separate concepts although QoS performance is closely related to QoE performance. QoS refers to a set of technologies that improve performance at the packet level from the network perspective. QoE is the overall performance of a system from the user's point of view. QoE is a measure of end-to-end performance at the services level from the user perspective and an indication of how well the system meets the user's need [5].

IV. SIMULATION RESULTS

In this section, we evaluate the performance of the downlink scheduling algorithms by using the LTE-Sim which is an open source framework for simulating the LTE network. A single LTE cell has a radius of 1 km, one eNB, and several UEs. The eNB provides traffic from GW to UEs. Each of UE runs applications such as voice/video over IP and best effort applications. UEs follow the random direction model, and move at the rates of 0, 3, 30, and 120 km/h, equivalent to static, pedestrian, and vehicular scenarios, respectively

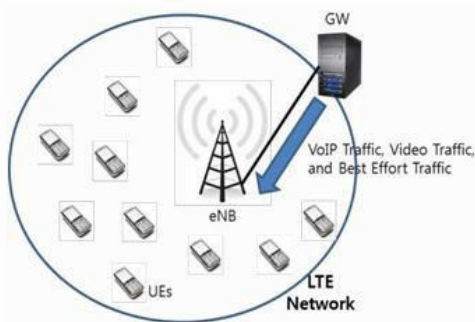


Figure 3. Simulation topology

Parameters	Values
Simulation Time	190s
PHY Layer	Downlink Bandwidth: 5MHz Resource Block: 25 Sub-frame Length: 1ms Target BLER: 10%
Number of UEs	10~100
Cell	Single eNB Radius: 1km
CQI	Full Bandwidth, Measured Period: 1ms
Mobility	Random Direction Speed: 0,3,30,120km/h
Traffic Model	H.264 video at 242kbps G.729 VoIP Best Effort Flow

Table 1 simulation parameter

Table 1 shows the simulation parameters for evaluation of scheduling algorithms, the number of UEs ranges from 10 to 100. Each of UE has three traffic flows provided from GW: video traffic, VoIP traffic, and best effort traffic. The video traffic has the source rate of 242 Kbps, and the traffic is known as trace-based application traffic. That is, generated packets are based on the realistic video trace. Voice data coded with G.729 are created within the VoIP application. On/OFF Markov chain was used as a

model for the voice flow. The ON period has an exponential distribution of 3s as the average value. The OFF period contains a truncated exponential probability density function, where the upper limit is 6.9s with the same average as ON period of 3s [2].

Average user throughput is defined as the amount of data sent successfully for user over a period of time (i.e. one TTI). The Best CQI algorithm. This result is expected, because with usage of this algorithm resources are allocated to user with the best channel state. Those users located in part of channel with the best conditions can achieve highest throughput. Resource Fair and Proportional Fair algorithms have somewhat worst performances than Best CQI algorithm. This is due to their requirement that high fairness needs to be achieved, and because of that lower throughput is achieved. The worst performances are achieved with MaxMin and Round Robin algorithm.

Average throughput of user equipment

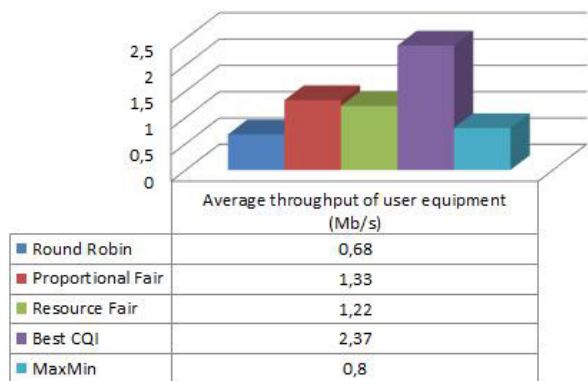


Figure 4. Comparison of average throughput of user equipment based on used scheduler

Fairness is defined as a metrics which determines if resources are shared uniformly between users.

Simulation results show that better improvements are gained by using Round Robin algorithm and FFR than by using Proportional Fair algorithm with FFR, although fairness was improved for a larger percentage in the second case. Also, higher losses are achieved in the second case for average and peak throughput. On the other side, if we compare performances of Round Robin with FFR and Proportional Fair with FFR, better LTE system performances are achieved using Proportional Fair algorithm with FFR

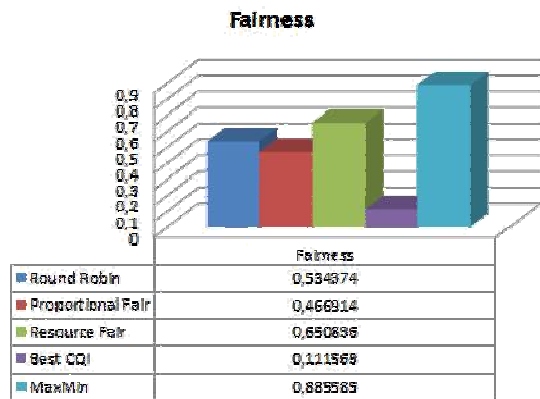


Figure 5. Comparison of fairness based on used scheduler

V. CONCLUSION

In this paper we evaluated LTE systems regarding the used scheduling algorithms. The following algorithms were considered: Round Robin, Best CQI, Proportional Fair, Resource Fair and MaxMin. The following parameters were considered: average throughput of user equipment, spectrum efficiency of user equipment, average cell throughput and fairness in radio resources allocation. Results show that Best CQI algorithm has the best performance in a case of average and peak throughput of user's equipment. On the other side, Best CQI algorithm has the worst results considering fairness of user's equipment. The highest fairness is gained by MaxMin algorithm. This is a new method in the resource allocation. Results show that improvements of throughput and fairness can be gained by using this method with Round Robin algorithm. However, if the results are compared with results of throughput and fairness for Proportional Fair algorithm, then the last scheduling algorithm provides better results.

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