Multi Objective Resource Scheduling in LTE Networks Using Reinforcement Learning

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ABSTRACT

The use of the intelligent packet scheduling process is absolutely necessary in order to make the radio resources usage more efficient in recent high-bit-rate demanding radio access technologies such as Long Term Evolution (LTE). Packet scheduling procedure works with various dispatching rules with different behaviors. In the literature, the scheduling disciplines are applied for the entire transmission sessions and the scheduler performance strongly depends on the exploited discipline. The method proposed in this paper aims to discuss how a straightforward schedule can be provided within the transmission time interval (TTI) sub-frame using a mixture of dispatching disciplines per TTI instead of a single rule adopted across the whole transmission. This is to maximize the system throughput while assuring the best user fairness. This requires adopting a policy of how to mix the rules and a refinement procedure to call the best rule each time. Two scheduling policies are proposed for how to mix the rules including use of Q learning algorithm for refining the policies. Simulation results indicate that the proposed methods outperform the existing scheduling techniques by maximizing the system throughput without harming the user fairness performance.

Keywords: *LTE, Q Learning, Reinforcement Learning, Scheduling Policy, Scheduling Rules, System Throughput, TTI, User Fairness*

1. INTRODUCTION

The increase of mobile data usage and the growing demands for new applications (e.g., mobile television, web browsing, File Transfer Protocol, video streaming, Voice over Internet Protocol) have motivated 3rd Generation Partnership Project (3GPP) to work with LTE (3.9 Generation in Mobile Phones (G)) and LTE-Advanced (LTE-A) (4G), the latest standards of cellular communication technologies.

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Although the previous technologies, such as Global System for Mobile Communications (GSM)/Enhanced Data rates for GSM Evolution (EDGE) (2G/2.5G) and Universal Mobile Telecommunications System/High Speed Downlink/Uplink Packet Access (UMTS/HSxPA) (3G/3.5G), account at present for over 85% of all mobile subscribers, LTE will provide enhanced performance in comparison with the other mentioned ones.

Evolved Universal Terrestrial Radio Access Network (E-UTRAN), the LTE radio access network, offers important benefits for users and operators (Ericsson, 2007): performance and capacity, carrier bandwidths flexibility, self-configuration and self-optimization, improved cell capacity, reduced latency and high mobility. These advantages would not have been possible without some aggressive performance requirements for *Physical Layer* (PHY) and Medium Access Control (MAC) layers such as: enhanced access techniques, time and frequency division duplexing, Multiple-In Multiple-Out (MIMO) systems, smart antennas, spectrum efficiency and intelligent management of radio resources (Ericsson, 2007; Motorola, 2007).

Radio resource management includes transmission power management, mobility management and radio resource scheduling or packet scheduling (PS) (Hussain, 2009). The packet scheduling is a process where the radio resources are assigned to each user in order to offer the requested services in an efficient way. Based on the scheduling rule, which is applied for the entire transmission, each packet is scheduled in every TTI, a time window used to transmit the user requests and to respond them accordingly.

The packet scheduling objective is to maintain a minimum tradeoff between four main utilities: capacity (system throughput, spectral efficiency, cell coverage), Quality of Service (QoS), stability (robustness) and user fairness. The main purpose is to improve the performance of one or more of the above indicators when required by the system, without affecting the performance of other objectives.

By applying one scheduling rule across the whole process depending on various conditions, the balance between objectives could be much affected. The price for satisfying the target objective is reflected in degradation of other performances. The solution is to satisfy every objective by using the most representative scheduling rule at each TTI in order to obtain the overall satisfaction.

In this paper, the tradeoff between system throughput maximization and user fairness satisfaction has been analyzed. There are two main scheduling techniques which are able to maximize one of the above targets: Maximum Throughput (MT) and Round Robin (RR). The RR scheduler allocates radio resources to ensure the best fairness between users without taking the channel conditions into account (leading to the minimum throughput). On the other side, the MT scheduler attempts to allocate resources to the users with the best sub-channel conditions (leading to the maximum throughput), but the fairness between them is badly degraded. Therefore, the described schedulers maximize the throughput-fairness tradeoff.

The first scheduling metric proposed to reduce the throughput-fairness tradeoff was Proportional Fairness (PF) (Kelly, 1997). With PF, users who are already scheduled have small chances to be scheduled in the future, thus ensuring a better fairness with a small degradation of system throughput.

Two scheduler types based on MT and PF utility functions are analyzed in Panigrahi and Khaleghi (2005) in order to improve the fairness index and to maximize the system throughput. The results indicate a better normalized throughput and fairness in comparison with the PF algorithm. A method for throughput maximization with adjustable fairness based on sum utility maximization is presented in Schwarz et al. (2011). Here, the fairness constraint is respected by finding a proper utility function based on Channel Quality Indicator (CQI) probability mass function.

By using cooperative game theory with Shapley value, a new mechanism is proposed in Iturralde (2011) which forms a coalition

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