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Throughput-aware Resource Allocation for QoS Classes in LTE Networks

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Abstract

In LTE systems, multicast services must be delivered efficiently in response to the need for strong QoS support. However, each class of quality services has its own requirements to be satisfied. These quality constraints limit the scheduling flexibility, and the LTE downlink resource allocating algorithms need to assimilate these constraints while trying to maximize system performance in terms of fairness and throughput. This paper addresses this fundamental problem of LTE downlink scheduling by adopting the time-domain Knapsack algorithm over the traffic overload patterns. We fine tune the Knapsack algorithm, to overcome this problem and improve system performance objectives. We demonstrate that more efficient performance can be achieved in terms of fairness index and system throughput, which is evaluated using simulation results.

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Keywords: Long Term Evolution, downlink scheduling, Quality of Service, Knapsack algorithm, fairness

1. Introduction

The Long Term Evolution (LTE) cellular communication system has emerged as a fast-growing prevalent technology, delivering a diversity of mobile broadband services, in the communication market. The LTE specifications have been standardized to utilize Orthogonal Frequency Division Multiple Access (OFDMA) as the transmission scheme, commissioned to carry out the downlink communication[1]. The OFDMA transmission scheme in comparing with the old one (Code Division Multiple Access) provides a key advantage of flexibility for resource allocation decision makers in exploiting frequency diversity[2].

An LTE scheduler is expected to allocate radio resources efficiently to support a high variety of services and maximize system throughput. However, it is a crucial problem to accomplish all targets

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at the same time. Each factor can be supplied at the cost of reducing another one[3]. For example, in response to the strong QoS support, many QoS-aware solutions were introduced which have been revealed to be unsuitable for dealing with throughput and fairness requirements[4].

A flexible QoS-oriented scheduler, divided into Time Domain (TD) and Frequency Domain (FD), was introduced in[5] for real-time video traffic. The proposed algorithm considers arrival rate and head of line packet delay as influential QoS factors for multiuser resource distribution. The authors in[6] described a self-optimization method to the LTE network scheduler in response to the active changes of network conditions and traffic over time and proposed an optimized-service aware (OSA) scheduler. To simplify the complexity of the resource allocation procedure, it has been partitioned into three separate stages: QoS classes identified classification, time domain and frequency domain scheduling. At the first step each bearer is classified into individual QoS class based on its CQI factors. Then the TD scheduler prioritizes the classified bearers according to their QoS data rate requirements and categorizes them into separate prioritized candidate bearers: GBR and Non-GBR. GBR bearers typically carry real-time applications which are sensitive to delay and need to be served with a guaranteed bitrate[7]. OSA algorithm sorts each GBR bearer according to the Head of Line (HOL) packet delay in the buffer of the related bearer.

The ranking function of traditional scheduling algorithms which are only based on the queue's priority, ignoring other metrics, would impose a lack of sufficient intellect over the resource allocation process[8]. In response to this challenging problem, the authors in[9] introduced Knapsack scheduling algorithm with emphasis on overload states. This class-based resource allocation algorithm supports QoS constraints by ordering the bearers using a ranking function calculated based on the multiple metrics, including GBR/Non-GBR class priority, bearer queue status, packet loss and delay. However, since the main volume of the LTE network traffic is real-time services, growing in an explosive manner, especially video and VoIP[10], the fairness issue among these services forms a major challenge as well as QoS support in current networks.

In this work, we propose an opportunistic approach to treat all three desired LTE targets aggregately as a single scheduling problem. Our proposed strategy can be viewed as a theoretical complementary of the work[9]. We formulate the optimization problem of resource apportion and make the ranking function to implement these optimal policies efficiently. The performance of the scheme is evaluated by comparing with Knapsack and Priority only algorithm as reference scheduling schemes. The inter-class and intra-class fairness assessment is done in terms of throughput[11] for VoIP traffic, and the impact of throughput-aware ranking function is evaluated with the help of simulation results.

2. System Model

In the present paper, OFDMA based 3GPP-LTE Downlink system with an E-UTRAN NodeB (eNB) (the base station in LTe networks) is considered. Each OFDMA frame of the LTE radio channel is constructed in the time and frequency domains. It contains ten 1ms sub-frames in time domain and a sub-channel of 12 consecutive same size sub-carriers in frequency domain. A single sub-carrier covers 15 kHz and the sub-channel subsequently 180 kHz of the spectrum. The basic resource unit for mapping the radio resources to active users is named Resource Block (RB). Each RB spans over a 0.5 ms time extent and one sub-channel[12,13]. The resource scheduling process is performed every Transfer Time Interval (TTI) which lasts one ms. We assume 5MHz bandwidth, consisting of 25 RBs in time-frequency domain and 330 active users in a single cell scenario. Here, the set of all users is defined by U ($U = \{1, 2, ..., u\}$) and the set of all RBs by RB ($RB = \{1, 2, ..., rb\}$). U is a collection of the users with different kind and number of bearers (single VoIP, single data, multiple data and VoIP-data) over the mixed-interval-time of normal and overload status. In each overload time interval, 50 users with single data session are added to the existed traffic and they are eliminated at the start of normal status.

Similarly to the algorithms reviewed in[14] it is supposed that the resource scheduling procedure is decoupled between time domain scheduler and the frequency domain scheduler separately, in the way