Review of Application Specific LTE Resource Scheduler

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Abstract –Increasing demand for high data rates in any wireless network environment including Long Term Evolution-Advanced (LTE-A) motivates the researchers to propose efficient resource scheduling. This paper reviews more recent scheduling algorithms for downlink in LTE with specific focus on application specific scheduler such as VoIP, Video Streaming, Interactive Gaming and mobile video conference. It is observed that these application specific downlink scheduler should be QoS aware to adopt the present day multimedia networks. This review will help the researcher to understand and develop more efficient scheduling schemes for real-time applications with efficient radio resource managements in LTE.

Keywords—LTE-A sheduler; Real-time traffic;

I. INTRODUCTION

Long-Term Evolution (LTE) as 4G provides higher capacity and high data speed. The 3GPP is adopting LTE-A as 4G to meet the increasing demands for high data rate mobile network. It is predicted that 4G connections will have the highest share (53 percent) of total mobile connections with more than three-quarters of the total mobile traffic by 2021. The limited radio resources and current mobile network traffic pose great challenges in Quality of Service (QoS) provisioning with efficient radio resources utilization. Even through numerous radio resource scheduler based on different network requirements exist, it is still unknown or unclear how an end user will perceive a delivered real-time service with given a set of QoS parameters.

Data transmission over LTE network uses two physical resources: time domain and frequency domain. Active users in current Transmission Time Interval (TTI) are selected in Time Domain Packet Scheduling (TDPS) whereas Resource Blocks (RBs) to each user is allocated in Frequency Domain Packet Scheduling (FDPS). The scheduling repeats every TTI with execution of two steps: firstly, each user explores the quality of the signal and sends feedback of Channel Quality Indicator (CQI) of the signal status to the station (eNB). Then the eNB uses the information obtained by CQI for the resource allocation decisions.

These schedulers are classified into three general types (i) Channel independent scheduler (ii) Channel dependent without QoS (iii) Channel dependent with QoS. Application specific LTE schedulers are associated under channel dependent with QoS as most of these applications are related to real-time streaming data. This paper explores various QoS aware scheduling algorithms targeting to specific application.

II. APPLICATION SPECIFIC LTE SCHEDULER

The application may be related to multimedia, voice, video, or machine-to-machine communication over LTE network as shown in figure 1. There are several scheduling algorithms targeting to specific application in the literature but review of those does not exists.

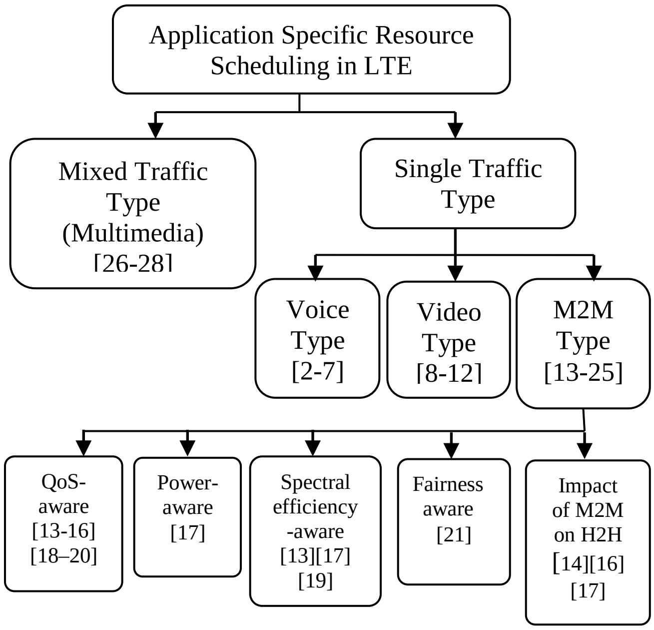

Figure 1: Application Specific LTE Schedulers

A. LTE Scheduler for Voice Data

This section describes downlink scheduling algorithms for voice data over the LTE network with the consideration of user perception. The user perceived quality service called as Quality of Experience (QoE). LTE downlink scheduling based on QoE for VoIP application is given in [2][3] is based on the concept of QoE min where the Mean Opinion Score (MOS) is considered to be at least 3.5 for VoIP Application. The number of users accessing the cell is also optimized. The cross layer based scheduling scheme given in [4] jointly optimized three layers (Application, Medium Access Control (MAC) and Physical) of wireless

protocol stack. Even though the network resource utilization and QoE is optimized through the proposed LTE downlink scheduler, it does not support Wideband (WB) E-model. The metric related to E-model based user satisfaction via MOS is considered to predict user perception for VoIP data scheduling decision in LTE networks [5]. The impact of network jitter on the E-model and Maximum Queue Size (MQS) are not considered here. This idea is extended in [6] based on the WB E-model (predict the
MOS) considering the MQS as an essential and effective factor for the metric.

The main focus of Power saving-semi persistent scheduler (PS-SPS) for voice over LTE (VoLTE) traffic proposed for downlink of LTE-A cell is to reduces the energy consumption of the eNodeB[7]. The traditional SPS (T-SPS) that allocates downlink Physical Resource Block (PRBs) to VoLTE users is modified for energy saving in PS-SPS.

B. LTE scheduler for Video data

QoE-aware optimization downlink scheduling for video traffic flow is given in [8]. Genetic algorithm (GA) integrated with random neural networks (RNN) is applied to maximize QoE of video traffic streaming over LTE networks. The data rates of transmission of streaming video data are adjusted dynamically based on the desiged handover prediction and pre-scheduling mechanism for high quality of service (QoS) provisioning[9]. QoS-aware cross-layer weighted-RR (round robin) downlink scheduler in LTE is given in [10] that consider channel quality, delay-constraints and fair resource block allocation among users to optimize the video data transmission. Modulation and coding scheme with encoding parameters of video data are adjusted dynamically for better video quality. QoE-driven uplink resource allocation in optimistic way is given in [11]. The QoE value for user experience about video contents transmission over LTE network computed using MOS is used to rank video content while base station schedule the resources among contents producers.
The resource scheduling proposed in [12] addresses the challenge if radio resource optimization among heterogeneous group of users according to their propagation conditions wherein users receive the layered video stream within their group at predefined and progressively decreasing service levels.

*C. LTE Schedu*ler for M2M Communications

Development of Machine-to-machine (M2M) communication uses LTE due to the features such as high data rates, low latency, high flexibility and low cost features of LTE. M2M communication generates heavy traffic at uplink and must ensure diversity of service requirements impetus the researcher to develop improved resource scheduler.
QoS aware schedulers for M2M maximize the positive QoS experience per device based on the QoS requirements (e.g. maximum tolerable delay or jitter) of these devices [13-16][18–20].
Power-aware schedulers for M2M minimize the power utilization on uplink per device[17].
Spectral efficiency aware schedulers for M2M ensure the efficient use of resources to maximize the amount of data successfully transmitted [13][17][19].
Fairness aware schedulers for M2M ensure the fairness allocation of RBs among the devices or a group of devices. None of the studied schedulers for M2M have considered avoidance of the starvation problem, where resources are perpetually denied to a device. Scheduler for H2H found in [21] considers this starvation.
Impact of M2M communication on H2H communication in the resource scheduler must be controlled as the of current network traffic greatly affected by large amount of M2M devices and the shortage of shared resources. [14][16][17].
The priority to the devices is given based on delay in [13] without addressing H2H traffic and without ensuring fair resource allocation. Two ways are considered for priority, one consider better channel conditions while other considers less delay tolerant. The first scheduler allocates RBs for a device if its maxi- mum tolerable delay is smaller than the mean delay tolerance of all remaining devices requesting resources divided by two. The waiting time for the devices with denied request is half of their maximum tolerable delays to make a new request. Even through this waiting time mechanism reduces energy consumption, it do not guarantee an efficient use of transmission power. The second scheduler allocates RBs with better channel quality, respecting the contiguity constraint.
Impact of M2M communication on H2H is controlled by resource separation wherein limiting quota of resources for M2M devices are reserved [14]. Within the M2M devices the devices are prioritizes with less delay tolerance yielding unfair resource allocation for devices with more delay tolerant. The resources and transmission power are not used efficiently in this scheduler.
QoS-aware scheduler assigns priority to the device based on critical deadline (time difference between the maximum tolerable delay and the waiting time for receive new resources of a device) and quantity of data to be transmitted from it[15]. It does not address fair allocation, H2H traffic, achieving maximum spectral efficiency, power consumption reduction. This deadline used to group devices in [16] to satisfy the QoS requirements. The priority for group is assigned based on the value of deadline range in that group. Higher value indicates higher priority. H2H devices have higher priority than to

the M2M devices within the group to control the impact of M2M on H2H. Starvation may occur for the devices delay tolerable in a congestion scenario.
Priority to the type of traffic is assigned according to its QoS requirements. Device priority is computed based on the quantity of data in terms of packets in each traffic priority and the traffic priority[18]. Fairness and the impact of M2M on H2H are not addressed here.

Even though channel condition based device priority are computed, the RBs are allocated for the devices with better transmit power [17]. Further this is modified for controlling impact of M2M on H2H and satisfying the QoS requirements wherein separate resources are given for M2M and H2H.
In addition to dedicated resources for M2M, the time interval is divided in two cycle of scheduling [19]. The first cycle prioritizes better channel conditions M2M devices for some time while second cycle selects M2M devices with strict delay tolerance during remaining time. No fair resource allocation is considered.

A predictive resource allocation assigns resources proactively to other devices within a group when one device in a group requests resources instead of waiting for direct request from the other devices[20]. This can reduce latency, but may cause waste of resources.

Numerous devices, sparse transmission, and wide range of applications in Machine-to-machine (M2M) communication add signalling overhead in the control plane making it hard to fulfil QoS requirements. The possible solution to address these issues of M2M communication is based on group-based scheduling (schedule resources among device-groups instead of devices themselves) and time granularity of scheduling (scheduling of time period)[22].
The current traffic level of congestion in LTE network is dynamically adjusted in LTE uplink scheduler given in [23]. IT satisfy QoS, ensure fair resource allocation and control impact of H2H traffic performance. The schemes in [24] adaptively deploy M2M traffic in response to the changing needs of the underlying emergency application with varying adaptation period with respect to speed of change of the allocation requirements.
Scheduling RBs for M2M devices with Qos provision based on groups is discussed in [25]. The clustering of M2M devices are based on their wireless transmission protocols, QoS characteristics and requirements. Binary integer programming problem and a dual problem using the Lagrange duality theory are the basis for resource allocation in LTE-A networks.

D. LTE Scheduler for Mixed Traffic *Type*

Bandwidth and QoS-aware scheduler (BQA) is based on weighted profession fair algorithm for multimedia data transmission over LTE network [26]. The weighted value used to allocate resources is computed form various parameters such as throughput, delay, fairness and QoS requirements of different traffic types.
Resource scheduling in heterogeneous virtual MIMO system at uplink where delay sensitive application is present is discussed in [27] wherein the low complexity user pairing is considered in addition to the resource allocation of heterogeneous users.
QoS-aware resource management mechanism for multimedia traffic report system (QoS-MTRS) discusses the resource scheduler that scheduled the resources according to the degree of importance of the various traffic data considering the channel availability for feasible transmission [28]. Diversity, completeness and overall traffic data value is improved under radio resource limitations.

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