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A Novel Packet Scheduling Scheme for Downlink LTE System

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***Abstract*— Long term evolution (LTE) is the next generation wireless system. There are not many researches for LTE downlink scheduling. It uses orthogonal frequency division multiple access (OFDMA) in downlink. Until now, the goal for the LTE scheduler is achieving the system highest performance, but it will cause to lower priority connection delay or starvation under limited bandwidth resources. Therefore, we design a LTE downlink scheduling scheme and resource allocation strategy which are not only to achieve the system highest performance, but also avoid latency and starvation problem.**

Keywords-LTE; downlink scheduling; QoS; CQI

I. INTRODUCTION

Long term evolution (LTE) is an important technology transfer from circuit switch network to All-IP network architecture [1, 2]. LTE has been identified as a new wireless standard by the 3rd Generation Partnership Project (3GPP) which is using the VoIP to transmit the voice services and packet the data for all services. It could provide the downlink peak rate of 100 Mbps through the OFDMA and SC-FDMA to provide higher bandwidth, lower latency, and better QoS. The Media Access Control layer (MAC layer) in data link layer of Open System Interconnection (OSI) aims to control the authority of user about the accessing media and resource. Scheduler is an important issue in MAC layer for the system performance could be improved by an efficient scheduling algorithm to assign the priority of each user. For this reason, scheduler in MAC layer is the main factor to effects the system performance and resource reusability [3, 4]. Generally, designing scheduler of wireless networks is more difficult and more important than wired networks. It is because of the restriction of the radio resource and variation of the channel condition. The scheduler in LTE aims to maximize the system performance. However, it may decrease the system performance for the latency or starvation of connections with lower priority if scheduler only concerns the high throughput. We propose an efficient scheduling strategy and resource allocation mechanism to maintain high system performance and preserve the proportional fairness of the resource allocation.

The proposed algorithm is called proportional fairness packet scheduling algorithm (PFPS). PFPS will restrictive adjust the priority of the users according to the Channel Quality Indicator (CQI) and allocate the bandwidth according to the variation of the user requests. There are two phases in this algorithm: priority assignment and resource allocation. The services are categorized to Real-Time (RT) Services and Non Real-Time (NRT) Services in priority assignment phase. Each category has its own queue to put the service requests, separately. Otherwise, the emergent queue is used to handle the connections with lower priority which is suffering the latency or starvation. The resource will be applicable allocated according to the upper and lower bound of the current request bandwidth in resource allocation phase. But we do not mention that in this paper.

The paper is organized as follows. The related work is shown in Section II. The proposed scheduling algorithm is described in Section III. Finally, the conclusion and future work are illustrated in Section IV.

II. RELATED WORK

The signal processing is divided into voice and data in LTE. The data is transferred and processed on All-IP network architecture based on packet switching mechanism. The eNodeB has replaced the Radio Network Controller (RNC) in WCDMA system [5]. The major wireless transmission technology of LTE is OFDMA. Besides, the basic architecture of the signal is using OFDM. Multiple Input and Multiple Output (MIMO) could be utilized to improve the transmission performance in LTE. OFDMA inherits the advantages of OFDM and improves the multiplex processing control to increase the average transmission rate. OFDMA efficiently arrange the frequency band by using both Time Division Duplexing (TDD) and Frequency Division Duplexing (FDD). FDD utilizes the symmetrical frequency to access the downlink and uplink data transmission. In the other hands, TDD separates the transmitting and receiving channel by the time vision. The transmitting and receiving channel use the same frequency in different time slot as the subscriber.

Channel Quality Indicator (CQI) is the measurement of the channel quality in wireless networks. The higher CQI value usually indicates the channel has the better channel quality. The CQI of channels could be calculated by Signal-to-Noise Ratio (SNR), Bit Error Rate (BER), Signal to Interference plus Noise Ratio (SINR), and Packet Loss Rate (PLR) [6]. The CQI does not explicitly indicate the channel quality, but rather the data rate supported by the UE given the current channel conditions. So 5-bit CQI value (from 0 to

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30) which higher CQI has better channel quality corresponds to a given transport-block size, modulation scheme, and number of channelization codes [7].

The main purpose of LTE scheduling aims to provide the better resource utilization and channel quality for mobile devices by using the variation of channel. Basically, downlink scheduling algorithms in LTE are similar to the downlink scheduling algorithms in High Speed Downlink Packet Access (HSDPA). Nevertheless, LTE could utilize the variation of channel in frequency domain and time domain due to the OFDMA architecture. The channel signal would be modulated according to the CQI value of each connection between mobile device and eNodeB. CQI also select the appropriate antenna module except calculating the immediately channel quality in frequency domain. MAC layer of LTE is responsible for selecting the size of block, modulation, and antenna assignment. The decision of scheduling is based on TDD mode and then transferring to the PHY layer. Figure 1 introduces the downlink scheduler in LTE system.

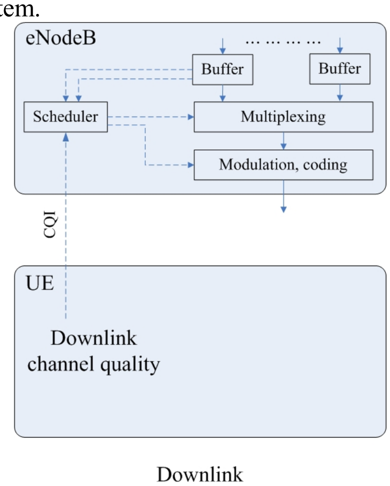

Figure 1. Downlink Shcheduler in LTE.

We introduce three kinds of famous scheduling algorithms: maximum rate (Max-Rate) [7], round robin (RR)[8], and proportional fair (PF)[9]。
Maximum rate (Max-Rate): The priority of each user is assigned according to the CQI value to match the objective of LTE scheduler in MAX-Rate [7]. The higher CQI would be assigned with higher priority. Unfortunately, the low priority will suffer the starvation when the total bandwidth can not satisfy the total requests. Round robin (RR): Round robin allocates the equivalent time interval to each user [8]. It can maintain the fairness of all connections and prevent the starvation but violating the main objective of high system performance of LTE. Proportional fair (PF): The PF algorithm is defined as the Equation (1) and (2) in [9]. It allocates the resource blocks to users according to the comparison of the theoretical assignment and actual assignment.

$$P_i(t) = \frac{r_i(t)}{\overline{R}_i(t)} \quad (1)$$

$$P_i(t) = \frac{r_i(t)}{\overline{R}_i(t)^{\beta_i(t)}} \quad (2)$$

$P_i(t)$ is the priority for user *i* at slot *t*. $r_i(t)$ represents the request data rate. $\overline{R}_i(t)$ is the average data rate of user *i* at time slot *t*. $\beta_i(t)$ indicates the channel with different data rate.

III. The Downlink scheduling scheme

The main objective of this paper aims to design a scheduling algorithm which is adopted by LTE standard. It can not only obtain the high system performance but also maintain the proportional fairness. Each user is allocated the requested resource according to the predefined QoS parameters. Meanwhile, it can avoid the latency and starvation of the lower priority service type connections. This paper proposes the Proportional Fairness Packet Scheduling Strategy for Downlink LTE (PFPS). PFPS is divided into two parts: Priority Assignment and Resource Allocation. But we do not discuss resource allocation. We focus on scheduling scheme in this paper. About resource allocation, we will make effort in future. The proposed PFPS is the scheduling algorithm which is designed on TDD mode and centralized architecture. As shown in Figure 2, PFPS is the frame-based scheduling algorithm. Each frame is organized by 10 subframe [7]. PFPS will access the scheduling procedure before the end of the each frame and finish the scheduling task before the next frame.

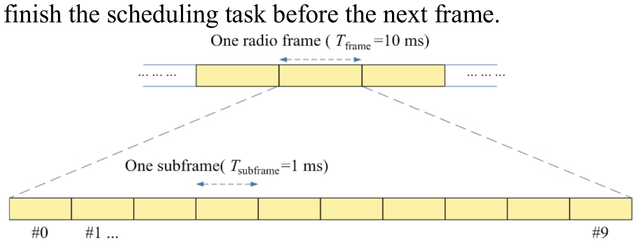

Figure 2. Frame Structure

A. *Proportional Fairness Packet Scheduling Architecture*

The PFPS is the priority-based scheduling algorithm which indicates the transmission ranking by the assigned priority to each connection. PFPS improves the situation of losing guaranteed QoS by dynamically adjusting the priority of the demanded users. The service types are categorized into two types: Real-Time services (RT) and Non Real-Time services (NRT). The RT services will be served firstly. As shown in Figure 6, the priority assignment could be divided into two parts: CQI Ranking and Fairness Control. CQI Ranking is decided by the CQI value of each connection to guarantee the whole system performance by satisfying the requests of all users. Fairness Control promotes the priority level of the lower priority connections to avoid the service interrupts. The Bandwidth Requirement Allocation allocates the resource according to the total bandwidth and the demanded upper bound and lower bound bandwidth.

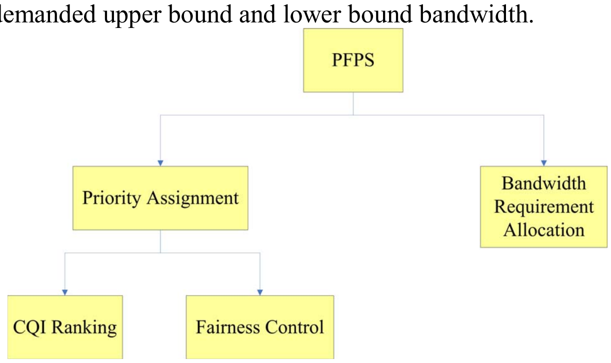

Figure 3. PFPS Architecture

B. Scheduling

Figure 4 is the priority assignment architecture. The emergent queue is involved to satisfy the QoS and prevent the service interrupt of lower service priority in fairness control. The maximum latency and starvation service counter are used to handle the priority promotion of the RT services and NRT services separately.

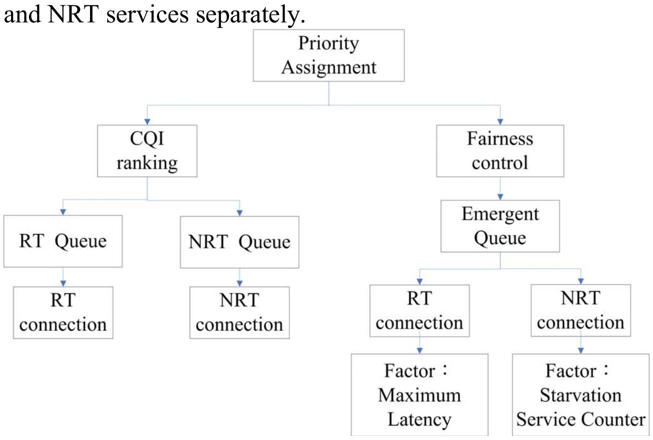

Figure 4. Priority Assignment.

Due to the RT services emphasize the latency problem, the priority assignment of RT services focus on the latency degree to fit in with the requests of QoS. The packet will be put into the emergent queue when it is satisfied the Equation (3). Equation (3) represents the tolerable waiting time is shorter than the length of one frame. The packet will be put into the emergent queue because of the packet needs to be delivered in next frame for satisfying the QoS.

$$\varsigma_i - (T_c - T_i^a(j)) \le T_{fram} \quad \forall i = 1 \ldots N_{RT}, \forall i \in \Omega_{RT} \quad (3)$$

ς_i represents the maximum latency of connection *i*. T_c indicates the system current time. $T_i^a(j)$ is the arrival time of the *j*th packet in connection *i*. T_{frame} is the length of one frame. N_{RT} means the number of RT services in downlink. Ω_{RT} shows the set of RT services in downlink.

The starvation service counter is used to detect the occurrence of the starvation in NRT services. The counter will be added up when the transmission rate is 0 in the last frame. The starvation of the connection is defined as the value of the counter exceeds the threshold η. The connection will be put into the emergent queue to avoid the starvation. Equation (4) indicates that the connection *i* of the m_{th} frame did not been served in the *m*-1 frame if it satisfies the Equation (4). At the same time, the starvation service counter of connection *i* will increase 1. Otherwise, the connection *i* will be put into emergent queue if it satisfies Equation (5) for the service interrupt of connection *i* exceeds the tolerable quantity. $b_i^a(m-1)$ represents the allocated bandwidth of connection *i* in frame *m*-1. $\phi_i(m)$ means the Starvation Service Counter value of connection *i* in frame *m*. The set of NRT service in downlink is shown as Ω_{NRT}. N_{RT} indicates the number of NRT services in downlink.

$$b_i^a(m-1) \le 0 \quad \forall i = 1 \ldots N_{NRT}, \forall i \in \Omega_{NRT} \quad (4)$$

$$\phi_i(m) \ge \eta \quad \forall i = 1 \ldots N_{NRT}, \forall i \in \Omega_{NRT} \quad (5)$$

There are three queues have been used in this paper which are RT Queue (RT_Q), NRT Queue (NRT_Q), and Emergent Queue (E_Q). RT_Q and NRT_Q is used to put the ranked packets of RT services and NRT services separately. E_Q is used to put the packets which are exceeded the Maximum Latency or Starvation Service Counter. The packets are ranked by the CQI value which is divided into 31 levels. Meanwhile, the higher CQI value indicates the higher priority. In RT services, we firstly check the RT services exceed the maximum latency or not. If the RT services do not exceed the maximum latency, the RT services are put into the RT_Q according to the priority value which is assigned based on the CQI value. Else, the RT services will be put into the E_Q. Figure 5 represents the flowchart of RT services determination.

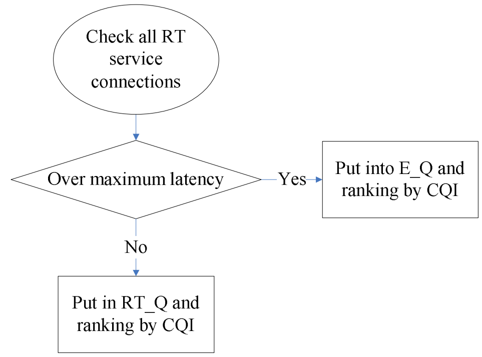

Figure 5. RT Service Determination Flowchart

In NRT services, we firstly check the NRT services exceed the starvation service counter threshold η or not. If the RT services do not exceed the threshold η, the NRT services are put into the NRT_Q according to the priority value which is assigned based on the CQI value. Else, the NRT services will be put into the E_Q. Figure 6 represents the flowchart of NRT services determination.

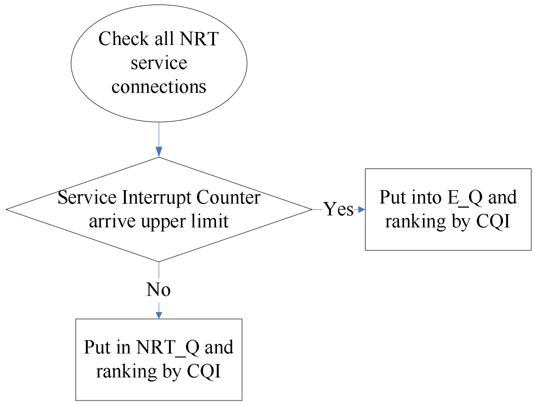

Figure 6. NRT Service Determination Flowchart

Emergent queue is used to put the packets which exceed the maximum latency or starvation service counter threshold. The RT services have the higher priority than the NRT services in E_Q. The RT services and NRT services are ranked according to their own priority separately. As shown in Figure 7.

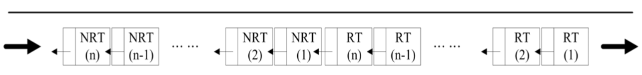

Figure 7. Emergent Queue

IV. CONCLUSIONS AND FUTURE WORK

The efficient wireless resource management and scheduling algorithm can improve the system performance and meet the QoS request of each user. The design of scheduler in LTE has to consider the limitation of wireless resource and variation of the channel quality. The system performance may decrease due to the latency or starvation of lower priority services. In this paper, we propose the PFPS algorithm to maintain the fairness of all services and avoid the latency or starvation. We have two main tasks in future. First, we should consider the resource allocation strategy in variant communication status. And we need to simulate our method to compare with other scheduling scheme in section II.

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