 LTE Downlink Scheduling Algorithm Based on Throughput Optimization

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Abstract. In the downlink resource allocation process, the traditional allocation algorithm only considers the channel index value of the user on a single resource block, but does not deeply consider that the allocated resource blocks interact with each other in the actual data transmission process, which may result in the low utilization of the resource block. Therefore, this paper proposes a new judgment mechanism based on the amount of change of resource block transmission data, which using the value of the actual transmitted data volume caused by the allocation of resource blocks to replace the single user channel status value to ensure that the resource block can play a positive role in the transmission of data. The simulation results show that using the new allocation mechanism can effectively improve the throughput of existing algorithms, and at the same time, it can improve the packet loss rate to some extent.

Introduction

The Long Term Evolution (LTE) employs the technology of orthogonal frequency division multiple access (OFDMA) for its downlink communication and divides spectrum resources into physical resource blocks (RBs). In the downlink scheduling process, the eNB sends a cell specific reference signal (CQI) to each user who needs resource blocks in the cell, and then each user feeds back the CQI value to the eNB which can select an appropriate modulation and coding method to RBs. In addition to taking into account the user's CQI report, it also considers the user's capabilities, the quality of service (QoS) requirements, fairness, and other indicators. The allocation of resource blocks should also consider the complexity. due to the mutual interference, the system often fails to optimize all the indicators.

The essence of downlink resource scheduling is to obtain the metric value according to the network conditions and user requirements, so as to reasonably distribute the RB.

In the classical downlink scheduling algorithm, Reference [1] proposes a max-CQI (also named MT) scheduling algorithm by allocating resource blocks (RBs) to users with the best channel quality indicator (CQI) value.

\[
\text{metric}_i = \arg \max_i (r_i(t))
\] (1)

Where \( r_i(t) \) is the channel rate of user equipment (UE) \( i \) at the current time \( t \). the larger the user's channel quality indicator, the larger the channel rate value at that moment.

Reference [2] proposes the proportional fairness (PF) algorithm, which uses the ratio of instantaneous throughput to past average throughput as the measurement value of the resource block.

\[
\text{metric}_i = \arg \max_i \left( \frac{r_i(t)}{r_i^M} \right)
\] (2)
Where $r_i^M$ is the mean data rate of UE. The literature [3] considers the delay requirements of real-time services and proposes a modified largest weighted delay first (M-LWDF) algorithm, combining weight $\omega$ and the user's HOL packet delay, to allocate resource blocks can effectively reduce the packet loss rate.

$$\text{metric}_i = \arg \max \{ \omega_i d_i(t) \cdot r_i(t) / r_i^M \}$$  \hspace{1cm} (3)

Where $\omega_i = -\log \delta_i / \tau_i$. Here $\delta_i$ denotes the maximum probability that the HOL packet delay exceeds the delay threshold of UE and $\tau_i$ defines the target delay. The literature [4] proposes exponential proportional fair (EXP/PF/PF) algorithm, which introduces the average heading blocking delay to further strengthen the PF algorithm.

$$\text{metric}_i = \arg \max \{ \exp \left( \frac{\omega_i d_i(t) - d_i^M(t)}{1 + d_i^M(t)} \right) \cdot \frac{r_i(t)}{r_i^M} \}$$  \hspace{1cm} (4)

Where $d_i^M(t) = \sum \omega_j d_j(t) / n_R$ and $n_R$ is the number of real-time flows.

However, the vast majority of scheduling methods simply consider the user's revenue on a single resource block without considering the mutual influence between the resource blocks by the user within the same transmission time interval (TTI). Within a TTI, The obtained resource blocks do not use uniform coding method on the resource blocks to perform synthesizes the CQI feedback values of all resource blocks and finally performs a data transmission. This also means that the mere assignment of resource blocks does not necessarily increase the user's amount of information transmission. Instead, it will reduce the overall transmission volume and thus affect the performance of the network. Therefore, aiming at the defects of the existing resource allocation algorithms, this paper proposes a new judgment framework using the change values of the resource blocks obtained by users after resource block allocation to replace the original user channel quality values, then generates a new metric value to allocate resource.

The remainder of this paper is organized as follows: Section 2 proposes the interaction problems in the resource block allocation process, and gives the calculation method of the overall effective channel values for resource blocks in the LTE system. Section 3 uses the change value of the user's actual data transfer amount after the allocation of resource blocks to construct a new metric value for scheduling, and gives a flowchart of resource allocation under the new judgment mechanism. Section 4 gives experimental indicators, results and corresponding analysis, Section 5 summarizes the full-text work, and proposes future research.

**System Model**

**Problem Description**

From the standpoint of a single resource block, the better the channel condition value, it really means that the larger the amount of data transmitted, but in the working mechanism of LTE, the resource blocks obtained by the user within the same transmission time interval (TTI) are not in an independent coding manner. In the process of transmitting information, the eNB will integrate the channel conditions on all the RBs obtained by a certain user, and determine the actual coding method in order. Therefore, there is a problem that although the user obtains the optimal metric value on some resource blocks, the resource block actually causes the coding rate of the entire resource block of the user to decrease, thereby affecting the overall data transmission volume and utilization of the user.

**Modulation and Coding Scheme**

Because different modulation methods have different characteristics, although the low-order modulation method ensures higher reliability, the efficiency of information transmission is lower.
Higher-order debugging methods have higher efficiency, but have higher requirements for channel conditions. Only in good channel conditions can we obtain higher returns. Therefore, LTE introduces an adaptive modulation and coding (AMC). The eNB selects the modulation mode, data block size and data rate through the CQI values fed back by the user.

Within a TTI, the coding method of all resource blocks obtained by the user will be determined by the signal to interference plus noise ratio (SINR). The calculation formula are as follows:

\[ s = \sum_{i=1}^{n} \frac{\sinr_i}{10} / n \]
\[ \text{effvalue} = 10 \cdot \log(-\log(s)) \]

Where \( \sinr_i \) represents the signal-to-interference-noise ratio of a single resource block; \( n \) represents the total number of resource blocks allocated by the user. \( \text{effvalue} \) represents the final effective SINR value of all RBs; From the above equation, it can be concluded that the final effective SINR value of the resource block and the modulation and coding scheme will depend on each resource block.

The New Judgment Framework

The transmission amount of the user resource block is actually determined by the number of resource blocks and the average data amount of the resource blocks. Therefore, Using the change of the total data transmission amount of the user in the TTI replaces the simple channel status value as the priority after allocating the resource block. The judging factors can more directly reflect the role of each resource block, because even if the user obtains the highest priority of the resource block at a certain moment, it may cause the total amount of transmitted data to decrease. Even a certain resource Blocks have a negative impact on all users. This negative effect can also be minimized by introducing changes in the transmitted data. Suppose that the number of resource blocks acquired by a user in a TTI is \( n \), for the next resource block. The judgment method is as follows:

\[ \text{bittrans}_n = \text{GetBit}(\text{effvalue}_n, n) \]
\[ \text{bittrans}_{n+1} = \text{GetBit}(\text{effvalue}_{n+1}, n + 1) \]
\[ \text{data}_\text{change} = \text{bittrans}_n - \text{bittrans}_{n+1} \]

Where \( \text{bittrans}_n \) represents the total amount of data that can be transmitted when the UE obtains \( n \) RBs. The function of \( \text{GetBit()} \) is a corresponding calculation function. The total amount of transmitted data is calculated based on the effective SINR value and the number of resource blocks.

Performance Evaluation

Experimental Parameters

In this section, we evaluate the system performance of the new judgment framework by using LTE-Sim [10], which is an open-source simulator developed for modeling LTE networks. The experiments aim at investigating the new judgment framework in an LTE macro-cell. Table 1 presents the simulating parameters.

| Parameters          | value       |
|---------------------|-------------|
| Time                | 50s         |
| Cell range          | 1 km        |
| Bandwidth           | 10M         |
| Number of UEs       | 30, 40, 50, 60, 70 |
| Moving speed        | 30km/h, 120km/h |
Experimental Results and Analysis

For different moving speeds, the comparison of average throughput of the System shown in Fig 1. From the comparison of images, the increase of MT is the most small because the MT algorithm only considers the channel condition value when performing the allocation, the new framework does not have significant improvement in the algorithm, but it still has a certain effect while the other three algorithms have significant improvement.

![Figure 1. Average throughput of system.](image)

From the perspective of packet loss rate, according to the data in Figure 2, the change of user's channel state is relatively slow when the user is in the process of low-speed movement, so the encoding of resource block obtained by the user is on the average, under the effect of the optimization framework, the amount of data transmitted by the resource block increases, so the packet loss rate has been improved to a certain extent. The user is in a high-speed mobile state of 120km/h. In the next time, the user's channel state transforms more quickly, so compared to the MT algorithm, the other three fairness-based algorithms are less obvious after the optimization to improve the packet loss rate. Due the MT algorithm does not consider the fairness, there are more RBs allocated to the video service, so the packet loss rate has still been greatly improved.

![Figure 2. Packet loss rate of Video service.](image)
In general, it can be proved through experiments that the new framework uses the value of the transferred data volume after resource block allocation as one of the elements of the metric, which in turn minimizes the decrease in the amount of data transmitted due to resource block allocation. As the utilization of resource blocks is improved, the total throughput of the system has been greatly improved. Due to the effective combination of resource blocks, the throughput of both services has been improved.

Conclusion
This paper proposes a framework for optimizing throughput in view of the problem that the previous scheduling algorithm does not consider the interaction of user resource blocks in the resource allocation process. First, according to the modulation and coding characteristics of the LTE resource block, a change value of the actual user data transmission amount after the resource block allocation is calculated, and then the change amount is assigned as a substitute value of the single channel state value. The new framework ensures to a large extent that users will not reduce the actual data transmission volume due to the allocation of a certain resource block, thus effectively improving the throughput. The simulation results show that the new framework greatly improves the throughput of the system, and also improves the packet loss rate under a stable environment, and at the same time ensures that the packet loss rate under complex conditions does not fluctuate substantially.

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