A simple three level downlink packet scheduling to improve throughput in LTE network

Fouziya S. S. H. Shakir\textsuperscript{a)} and Nakkeeran Rangaswamy\textsuperscript{b)}

Department of Electronics Engineering, School of Engineering and Technology, Pondicherry University, Puducherry 605014, India
\textsuperscript{a)} fouziya@pec.edu
\textsuperscript{b)} nakkeeranpu@gmail.com

Abstract: In this paper, a three level scheduling scheme is proposed for Long Term Evolution (LTE) network to enhance the cell throughput while maintaining fairness among User Equipments (UE). At initial level, the users with good channel conditions are scheduled that result in increase in cell throughput. At next level, the users with maximum delay requirements are allocated and at last level the users with long buffer queue are scheduled to maintain fairness among users. The proposed scheme is compared with traditional scheduling algorithms and validated by means of simulation results.

Keywords: LTE, scheduling, QoS, throughput, fairness, delay

Classification: Wireless Communication Technologies

References

1 Introduction

Designing an efficient scheduler is a primary issue for the effective use of limited radio resources. In Long Term Evolution (LTE), the basic unit of resource allocation is named as Resource Block (RB) that can be modulated independently [1]. The important characteristic related to any scheduling algorithm is to guarantee that the necessary Quality of Service (QoS) should be met for a bearer. Many scheduling methods are found in literature for accommodating real time and non real time services [2]. Major studies put forth a balance between user and network related issues in designing an algorithm to get adept results. The main performance metrics for scheduling can be the throughput and level of fairness. In literature, few algorithms focus on achieving fairness among the users and others try to improve the spectral efficiency [3]. Selected algorithms use delay value as a weighting parameter for scheduling in order to satisfy the real time services, but fails to guarantee non real time services [4, 5, 6].

This paper proposes a three level scheduling algorithm to enhance the cell throughput while maintaining satisfied level of fairness and average user delay among users. The performance of the proposed algorithm is compared with the existing algorithms like Proportional Fairness (PF), Modified Largest Weighted Delay First (MLWDF), Exponential rule (EXP rule) and Logarithmic rule (LOG rule).

2 System description

A single cell downlink LTE system is considered with \( K \) active users served by one evolved Node B (eNB). LTE system uses Orthogonal Frequency Division Multiple Access (OFDMA) technology in the downlink, which is highly flexible regarding radio resource management and it has the capability to exploit multi user diversity. The system consists of \( N \) RBs which is determined by the transmission bandwidth \( B \) [1]. The scheduling period spans for two RBs and is termed as one Transmission Time Interval (TTI) and it lasts for 1 ms duration. The radio interface in LTE uses one common shared channel that is shared by all users in the cell. Each User Equipment (UE) sends its channel quality report as a Channel Quality Indicator (CQI) value, by calculating its own experienced Signal to Noise Ratio (SNR), through a feedback channel. This value helps the eNB to choose appropriate Modulation and Coding Scheme (MCS) for that particular UE to achieve minimal bit error rate.

3 Proposed scheduling scheme

The proposed scheduling algorithm improves the aggregate cell throughput while maintaining fairness among UEs. This algorithm works in three levels and at each level it selects the users based on the priority metric and allocates radio resources according to the user’s demand.

**Level 1:** The initial level of this algorithm is to choose users with good channel conditions, to increase the overall cell throughput. Among \( k \in \{1, 2 \ldots K\} \) users, the users having the throughput priority metric \( T_k > T_{th} \) are chosen for allocation, where \( T_k \) is the throughput priority metric of \( k^{th} \) user and \( T_{th} \) is the predefined...
threshold value of that metric. Threshold value is set based on the network operator’s targeted data rate requirements to maximize system throughput.

Let $\mu_{k,n}$ be the data rate achieved by the $k^{th}$ user, $k \in \{1, 2 \ldots K\}$ on $n^{th}$ RB, $n \in \{1, 2 \ldots N\}$ that can be given as,

$$\mu_{k,n} = w \log_2(1 + \frac{p_{k,n}r_{k,n}}{\gamma_{k,n}})$$

where, $w$ is the bandwidth of the system, $p_{k,n}$ is the transmitted power of $k^{th}$ user on $n^{th}$ RB and $r_{k,n}$ is the signal-to-noise ratio achieved by $k^{th}$ user on $n^{th}$ RB.

The average data rate achieved by $k^{th}$ user is given as

$$\mu_{k,avg} = \frac{1}{N} \sum_{n=1}^{N} x_{k,n} \mu_{k,n}, \quad x_{k,n} \in \{0, 1\}$$

where $\mu_{k,n}$ is the data rate achieved by $k^{th}$ user in $n^{th}$ RB and the value of $x_{k,n}$ is one if the $k^{th}$ user is scheduled in $n^{th}$ RB, otherwise it is zero.

The throughput priority metric is given as,

$$T_k = \frac{\mu_{k,n}}{\mu_{k,avg}}$$

The set $\zeta_{\text{max}} = \{1, 2 \ldots K\}$ of users who satisfies $T_k > T_{th}$ are chosen for allocation in descending order of $T_k$. Set $\zeta_1 \in \zeta_{\text{max}}$ with $T_k < T_{th}$, $\forall k \in \zeta_{\text{max}}$ are considered for further allocation in the same TTI, if it has available resources.

Level 2: After allocating users with good channel quality, the proposed algorithm schedules the users having delay priority metric greater than the threshold value. That is, in set $\zeta_1$, the users having $D_k > D_{th}$ are considered for further allocation in descending order of $D_k$. When the packet enters into the buffer of the Medium Access Control (MAC) layer, it is time stamped. The Head of Line (HoL) delay value of a particular packet is measured based on its time stamped value and recent packet processing time. That is,

$$T_{\text{HoL}}^i = T_c - T_{ts}^i$$

where $T_{ts}^i$ is the time stamped value of $i^{th}$ packet, $i \in \{1, 2 \ldots I\}$ and $T_c$ is the current processing time of a packet. Every packet in the buffer will have its own delay budget parameter. The time difference between the packet delay budget parameter ($T_{db}^i$) and its HoL ($T_{\text{HoL}}^i$) delay value is considered as its theoretical departure time ($T_d^i$).

$$T_d^i = T_{db}^i - T_{\text{HoL}}^i$$

This value is used in the calculation of delay priority metric and is given as,

$$D_k = \frac{1}{T_d^i + \frac{L_i^k}{r_k}}$$

where $L_i^k$ is the size of the $i^{th}$ packet of $k^{th}$ user and $r_k$ is the data rate of that user. The set $\zeta_0 \in \zeta_1$ with $D_k < D_{th} \forall k \in \zeta_{\text{max}}$ are considered for further allocation in the same TTI, if it has available resources.

Level 3: After allocating users who have delay requirements, the proposed algorithm schedules the users from set $\zeta_0$ based on buffer priority metric. When the packets enter to the MAC layer they are classified according to the type of service.
and placed in a queue. The number of queues depends on the number of services. Let the system has $J$ queues. The buffer priority metric can be given as

$$B_k = \frac{S_{Jt,i,k}}{S_{TB} \times N_k}$$  \hspace{1cm} (7)$$

where $S_{Jt,i,k}$ is the size of the $j^{th}$ queue excluding the $i^{th}$ packet of the $k^{th}$ user, $S_{TB}$ is the transport block size and $N_k$ is the number of active users. Next instance of scheduling begins from the first level.

4 Simulation results

The performance of the proposed scheduling scheme is examined in terms of cell throughput, fairness index and average delay using an open source simulator, LTEsim [7]. A single cell scenario is considered with a fixed eNB at the center where the users (in the range of 10–60) are uniformly distributed inside the cell. It is assumed that users are moving with a speed of 30 kmph and when they reach cell boundary, new direction is taken towards eNB. It is also assumed that at any instance of time 40% of users receive video service, 40% of users receive VoIP service and 20% of users receive BE service. The buffer at eNB is considered as infinite. The performance is evaluated by varying the number of users. Video flows with source rate of 128 kbps are produced by H.264 trace based coder. Whereas VoIP flows with source rate of 8 kbps are generated by G.729 audio coder. Finally, BE traffic is generated by ideal source that always has packet to send. The main parameters used for performance analysis are given in Table I.

<table>
<thead>
<tr>
<th>Table I. Parameters considered for simulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter</td>
</tr>
<tr>
<td>Bandwidth</td>
</tr>
<tr>
<td>Carrier frequency</td>
</tr>
<tr>
<td>Frame structure</td>
</tr>
<tr>
<td>Channel model</td>
</tr>
<tr>
<td>Path loss</td>
</tr>
<tr>
<td>Penetration loss</td>
</tr>
<tr>
<td>eNB transmission power</td>
</tr>
<tr>
<td>eNB coverage area</td>
</tr>
<tr>
<td>Speed of UE</td>
</tr>
<tr>
<td>$T_{th}$ and $D_{th}$ value used</td>
</tr>
<tr>
<td>Maximum delay</td>
</tr>
<tr>
<td>Simulation duration</td>
</tr>
<tr>
<td>Modulation scheme</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Traffic model</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>
The performance of the proposed algorithm is compared with four existing scheduling algorithms: PF, MLWDF, EXP rule and LOG rule. Fig. 1 shows the aggregate throughput with respect to the different number of users. As LTE uses shared channel for downlink, the aggregate cell throughput decreases as the number of users increases. The decrease in the throughput is also due to many reasons like the type of service of users, increase in control overhead due to retransmission etc.

It is verified by taking random services (i.e., at any instance of time for the chosen number of users, the type of service being served is not fixed) to users for proposed algorithm in the simulation. At initial level, the proposed algorithm increases the throughput by assigning resources to the users that are in good channel condition by using throughput priority metric. However, by providing lower bound to that value, and by giving preference to users with delay sensitive applications, real time users are satisfied at second level. At last level, the users with long buffer queues are scheduled to maintain fairness among users. It is noted from the Fig. 1 that the proposed algorithm outperforms other scheduling algorithm in terms of aggregate cell throughput, while maintaining same level of fairness and average user delay as existing algorithms as shown in Fig. 2. The proposed algorithm provides 11% increase in throughput when compared with the EXP rule algorithm, which performs well among existing algorithms.

![Fig. 1. Aggregate cell throughput for different number of users](image1)

![Fig. 2. Fairness index and average delay for different number of users](image2)
5 Conclusion

A three level scheduling algorithm for the downlink LTE system is proposed to improve the aggregate cell throughput. At initial level, the users with good channel conditions are scheduled which results in an increase in the cell throughput. At next level the users with highest delay requirements are allocated and at last level the users with long buffer queue are scheduled to maintain fairness among users. This algorithm can be used in urban areas that is characterized by high population density, where accommodating more number of users in a given spectrum is very much essential. From the simulation results, it is confirmed that the proposed algorithm outperforms other existing algorithms and provide 11% increase in cell throughput while maintaining same level of fairness and average user delay among users.