

Efficient Packet Scheduler for LTE Downlink with Su-Mimo

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Abstract: Scheduling and Policing are two mechanisms very hard to be co-ordinated in wireless communication systems. In this paper the general frequency domain packet scheduling (FDPS) problem is formalized. The constraint of selecting only one MIMO mode per user in each transmission time interval (TTI) increases the hardness of this problem. Then an approximation algorithm with constant approximation ratio is proposed solving the FDPS problem. The proposed algorithm's performance is then compared with existing efficient packet scheduler termed as the Proportional Fair Scheduler along with the MatLab simulated result.

Keywords: Packet scheduling (PS), Long Term Evolution (LTE), 3GPP, approximation algorithm, proportional fair scheduling

1. Introduction

The technology has been so advanced that all the standardizations put forward is indeed for supporting for the increasing of the system bandwidth. Right from the 1st generation till now, the main ideology and concern was for increased data rates as per user needs. So, the third generation partnership project (3GPP) LTE (long term evolution) standard was introduced with this view.

Providing a transmission speed of 100Mbps in the downlink the LTE can achieve a high peak data rate that scales with scalable system bandwidths, spectrum efficiency and reduced latency. The OFDMA (Orthogonal Frequency Division Multiple Access) has been selected for the LTE DL. In LTE, the system bandwidth is divided into resource blocks(RBs).The packet scheduling done in an LTE network allocates different RBs to individual users according to their channel quality conditions, queuing lengths etc:-.From the 7 modes of LTE, the transmit diversity and spatial multiplexing modes are selected.

The concept of MIMO is used which enhances the need of throughput and efficient spectrum. In the single user MIMO (SU-MIMO), the FDPS is restricted since at most one user can be scheduled over each RB. In OFDMA the resource block allocation is based on the bandwidth, for eg:-. A bandwidth of 1.4MHz has 6 resource blocks with 72 subcarriers occupied, if the bandwidth is 5MHz then there are 180 subcarriers occupied etc:-.The constraint kept increases the hardness of FDPS problem so an approximation algorithm has been proposed. The method of maximization of a submodular function over a matroid is done. Finally, the algorithm is compared with the proportional fair scheduler.

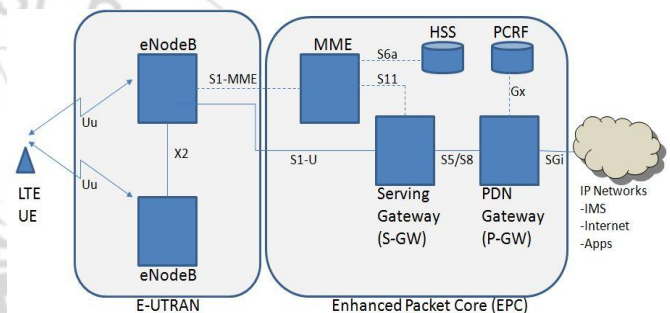


Figure 1: The 3GPP LTE architecture

2. System Model

2.1 Problem Formalization

Let's consider the downlink of an LTE cellular network in which the bandwidth of the system having one base station and n active users is divided into m RBs. The set of all RBs is M ($M = \{1, 2, \dots, N\}$) and the set of all users by N ($N = \{1, 2, \dots, n\}$) the set of the two MIMO modes are L ($L = \{0, 1\}$).The power set of M is A ($A = P(M)$).During each time slot m RBs are allocated to n users by the base station. Each RB is assigned to utmost to one user, and all RBs assigned to one user should belong to one MIMO mode.

Let's define an objective function termed as the profit function for deducing the resource allocated to users. The profit function $p(a, i, j)$ is defined as follows

$$p: A \times N \times L \longrightarrow R \geq 0 \quad (1)$$

where $p(a, i, j)$ indicates the profit gained by assigning a $a \in A$ to user $i \in N$ with $j \in L$ in one TTI. The proportional fair criterion objective must be non-decreasing function such that

$$p(a_1, i, j) \leq p(a_2, i, j) \quad (2)$$

$$p(\emptyset, i, j) = 0 \quad (3)$$

The more resource blocks are allocated the more profit a user obtains. The profit function $p(a, i, j)$ can be expressed as

$$p(a, i, j) = \sum_{c \in a} \lambda_{i,j}^c \quad (4)$$

where $\lambda_{i,j}^c$ is the PF metric value that user I achieves on RB c in MIMO mode j. This metric is the ratio of current data rate of user to the average service rate. If more RBs are allocated the metric sum increases if no RB is allocated then the metric value is zero.

2.2 Proposed System Model

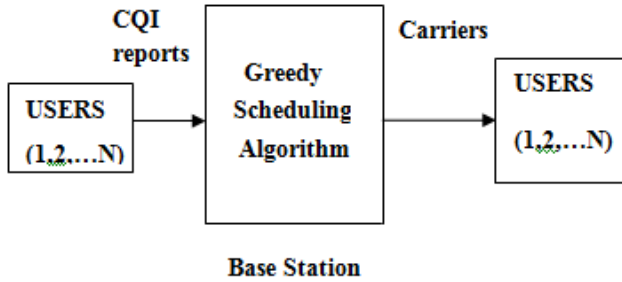


Figure 2. The proposed system model's simple block diagram

Here, the proposed model's block diagram is depicted. It can be deduced that initially a suitable optimal mode is selected by each user. Then based on the channel quality indications of the channels sent to the base station, the users are categorized as high CQI and low CQI. Based on these reports scheduling policies are put forward. This grouping method improves a systems throughput and also guarantees the fairness. Then the Greedy Scheduling Algorithm is implemented for efficient resource allocation which increases the profit function mentioned previously and maintains constant system throughput with speed changes in user mobility and serious fades in channels used.

2.3 LTE DL SU-MIMO PS

The constraint kept causing increase in the hardness of the FDPS problem is as follows.

$$\max_{j \in L} \sum_{(a,i) \in A \times N} p(a, i, j) \cdot x_i^a \quad (5)$$

where x_i^a is a Boolean variable denoting regarding resource allocation to users. Subjected to, for each resource block $x_i^a \leq 1$ and for each user $i \in N$ $x_i^a \leq 1$ where the Boolean variable takes the value either 0 or 1.

3. The Greedy Scheduling Scheme

Here we introduce the greedy scheduling algorithm for LTE DL SU-MIMO. The method is to maximize a submodular function over a matroid which is equal to maximizing the profit function. The algorithm solves the FDPS problem as per the constraints kept.

3.1 The Profit Values of the System

We know that the profit function for the system is $p(a,i,j)$, while considering the profit function can be expressed as

$$p_0 = \sum_{i=0}^n p(a, i, 0) \quad (6)$$

$$p_1 = \sum_{i=1}^n p(a, i, 1) \quad (7)$$

where $p(a,i,0)$ is the profit gained by assigning the RB to user I in MIMO mode 0, which by default we have taken as the transmit diversity and $p(a,i,1)$ is the profit gained by the user in MIMO mode 1 (spatial multiplexing mode). So, clearly p_0 and p_1 denotes the total profit values by a schedule which is valid in corresponding MIMO mode.

3.2 Greedy scheduler

In this scheduling scheme the scheduler selects that group of users which reports the highest channel quality indications. The algorithm for maximizing the profit function can be expressed as

$$\leftarrow \arg \max_{A \subseteq \{a\}} (A \cup \{a\}) - f(A) \quad (8)$$

$$\leftarrow \arg \max_i p_i(A_i) \quad (9)$$

where the functions that is needed to be maximized is depicted.

3.3 Approximation Ratio

The Greedy downlink Algorithm is a 4- approximation algorithm for the FDPS LTE DL problem. Since the approximation ratio 2 is tight the usage of 4 is done. The greedy-sub algorithm uses an approximation ratio of 2. Here let's consider the system as dual scheme (all schedules are in the opposite MIMO modes) of the optimal schedule as follows $\{(a_1^*, 1, 1 - j_1^*), (a_2^*, 2, 1 - j_2^*) \dots (a_n^*, n, 1 - j_n^*)\}$

where (a_k^*, k, j_k^*) implies the set of RBs a_k^* is assigned to user k in MIMO mode j_k^* . The 0 and 1 indicates the 2 modes of LTE DL system.

Therefore the optimal total profit gained is

$$p^* \leq \sum_{i=1}^n p(a_i^*, i, j_i^*) + p(a_i^*, i, 1 - j_i^*)$$

$$= \sum_{i=1}^n p(a_i^*, i, 0) + p(a_i^*, i, 1)$$

$$\leq 2p_0(A_0) + 2p_1(A_1)$$

$$\leq 4 \max(p_0(A_0), p_1(A_1))$$

where $\max(p_0(A_0), p_1(A_1))$ is the return profit value of the greedy approximation algorithm. So, by an approximation ratio of 4 the FDPS problem is solved.

3.4 Time Complexity of the Algorithm

The two equations (8) and (9) are from the greedy downlink algorithm. The time complexity of the algorithm is the total running time of the algorithm. Denoted by T_{GD}

$$T_{GD} = O(nm^2) \quad (10)$$

It can be seen that as the number of users increases the time complexity of the algorithm also increases linearly having given a fixed number of resource blocks. The time complexity depicts that it is equal to the order of the product of square of the m resource blocks and the number of users n

4. Simulation Result

The Greedy Downlink Algorithm is implemented and evaluated in the MATLAB simulator. Also the simulation for proportional fair scheduler is done. The profit function is verified to represent the various scheduling schemes. The proportional fair scheduling scheme allocates resources based on the priority value.

Various other schedulers like Best CQI, round robin scheduler, Max-Min fair etc.-can be implemented and the simulation can be worked out in MATLAB. Among all the schedulers proportional fair is selected as these two are the existing system used for packet scheduling both in the time domain and in the frequency domain. As the proportional scheduler is a scheduling scheme providing fairness to users it's taken into consideration for our work. The implementation of the scheduler is with an approximation ratio of 4. The users based on the priority value are served. Fairness is achieved to a great extent, but the problem that persists is that the scheduling performance are not that stable. Here, the simulation is plotted with the number of user equipments in the x-axis and the average cell throughput (ACT) in the y-axis. The theoretical downlink speed is 100Mbps but practically it's not achievable.

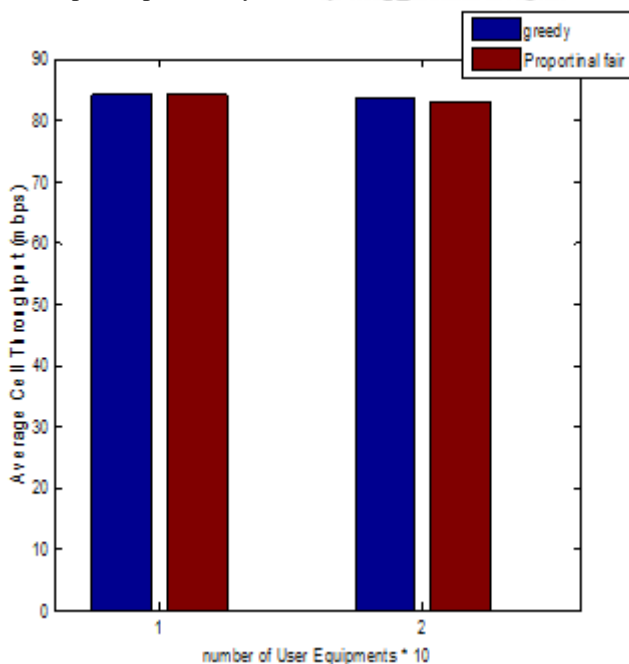


Figure 3: Comparative simulation of Greedy scheduler and proportional fair scheduler

4.1 Performance Evaluation

Here one can observe that when plotted which schedulers' runs well. Two kinds of user speed are set, i.e the walking mode (5 km/h) and the vehicular mode (50 km/hr), respectively. It can be seen that at walking mode the average cell throughput of the greedy scheduler is 84.2000Mbps whereas for the proportional fair scheduler its 84 Mbps. At 50 kmph i.e. the vehicular mode the average cell throughput of greedy scheduler is same 84.2000Mbps and the proportional fair scheduler runs to provide a value of 83.5Mbps.

So, its vivid that in both the walking and vehicular mode the greedy scheduler maintains constant cell throughput whereas as the user mobility increases the performance of the proportional fair scheduler degrades. Even though at present proportional fair scheduler could provide fairness to a system its observed that the balance between fairness and throughput cannot be done for this scheduler. But this balance can be obtained when the greedy scheduler is used.

5. Conclusion

The optimal mode selection and greedy scheduling increase the profit gain with the number of user. The MATLAB simulation results shows that when a comparative study was done the average cell throughput of the greedy scheduler maintains the same whereas the performance of the proportional fair scheduler deteriorates.

6. Future Work

As an ideology, in the near future the concept of finding a new scheduler can be done in which the average cell throughput increases even when the modes varies. Even though greedy scheduler maintains same cell throughput, the data rates are not increased. So, the finding of a new algorithm is to be done in which the data rates can be increased.

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