ISSN: 2321-7782 (Online)
Volume 2, Issue 3, March 2014
International Journal of Advance Research in Computer Science and Management Studies
Research Article / Paper / Case Study
Available online at: www.ijarcsms.com

An Efficient Grouping and Scheduling for Long Term Evolution Downlink

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Abstract: Long Term Evolution (LTE) was standardized by Third Generation Partnership Project (3GPP) in order to improve the spectral efficiency and speed of the cellular systems. Packet scheduling mechanisms and resource allocation plays a vital role in modern wireless systems as they are responsible for the distribution of available radio resources among different users, taking into account channel condition and Quality of Service (QoS) requirements. In this paper, the problem of Frequency Domain Packet Scheduling (FDPS) incorporating Multiple Input Multiple Output (MIMO) technique on the 3GPP Long Term Evolution Downlink (DL) is addressed. For LTE DL MIMO, the constraint of selecting only one MIMO transmission mode (spatial multiplexing or transmit diversity) per user per Transmission Time Interval (TTI) is imposed. Initially, an optimal MIMO transmission mode selection per user in each TTI (1TTI=1ms in LTE) is performed in order to maximize the Proportional Fair criterion. An optimal max weight and greedy scheduling scheme together with grouping method is developed. Simulation results shows that the proposed scheduling scheme together with the grouping method achieves fairly good performance and improves the overall system throughput.

Keywords: Long Term Evolution (LTE), Frequency domain packet scheduling (FDPS), channel quality information (CQI), greedy scheduling, grouping method.

I. INTRODUCTION

The Third Generation Partnership Project (3GPP) Long Term Evolution (LTE) is the latest standard in the cellular systems. The objective of the LTE is to provide better quality of wireless communication with higher data rate, reduced latency and increased capacity and coverage. LTE provides transmission speed up to 100Mbps over a 20MHz channel in downlink [1]. Each LTE Downlink Frame consists of ten sub-frames (10ms in time domain). Each sub-frame is referred to as one Transmission Time Interval (1TTI=1ms in LTE) and consists of two slots, each of 0.5ms (1RB) . In LTE DL, An RB is the basic time-frequency domain resource. A single RB spans over 180 KHz in frequency domain whereas it spans over 0.5ms in time domain. Each resource block comprising of 12 consecutive equally spaced OFDM sub-carriers of 15 KHz each and carries 7 OFDM symbols [8]. The Frequency Domain Packet Scheduling is one of the promising techniques which assign different Resource Blocks to individual users based on their existing channel conditions and the queue length [1].

The task of the eNode-B (base station) packet scheduler is to exploit the RBs to physical channel of different users. To combat the multipath fading, Orthogonal Frequency Division Multiple Access (OFDMA) has been selected for the LTE downlink. In DL OFDMA, Multiple accesses is performed by assigning different frequency portions of the system bandwidth to individual users in both time-frequency domain based on their channel quality information (CQI) [9]. The CQI is the feedback about downlink channel condition delivered by all users to the packet scheduler and is obtained by transmitting reference signal to all users from the base station [2]. Therefore, the scheduler in the base station performs RB to user mapping every TTI according to the scheduling policy [2]. This helps the eNode-B to determine the data rate and to select appropriate modulation scheme and code rate for each user over each sub-frame for downlink transmission [5]. Spatial Division Multiplexing (SDM)

Multiple Input Multiple Output (MIMO) is another promising technology used in LTE to improve the spectral efficieny. LTE DL Transmission supports both Single-User (SU) and Muti-User (MU) MIMO. For SU-MIMO, one or more data streams are transmitted to a single UE to increase the data rate of single user through space time processing. For MU-MIMO, individual data streams are transmitted to different UEs using same time-frequency resources [7]. Different MIMO Transmission mode is incorporated in LTE. In this work, two MIMO transmission mode such as Spatial Multiplexing and Transmit Diversity is considered. Spatial Multiplexing is one of the transmission techniques in which incoming data streams are divided into multiple sub streams and each sub stream is transmitted from each of the multiple transmit antennas [1]. On the other hand, Transmit Diversity is another transmission technique in which data streams are spread across multiple transmit antennas [1]. Transmit Diversity effectively doubles the channel power and improves the signal noise ratio for cell edge users.

In order to achieve high MIMO FDPS gain, initially an optimal MIMO mode is selected for each user in every TTI in order to maximize the proportional fair criterion. Second, grouping method is performed to classify users into two groups based on their CQI report such that group 1 users has higher CQI and group 2 users has lower CQI. Then the selected users in these two groups are transmitted alternatively according to the scheduling policy [2]. The grouping method improves the system throughput and also guarantees fairness and packet loss ratio. After selecting the optimal mode for each user and grouping the users, greedy scheduling scheme is applied to allocate the radio resources based on the CQI report of each user and their current task. The greedy scheduling improves the profit function and system throughput remains constant with the user mobility speed and serious channel fading.

II. System Model

We have considered the cellular network with one base station and 'n' number of mobile users, each assumed to have two transmit and two receive antennas (i.e., Nt = 2, Nr = 2). we also considered two MIMO transmission mode (spatial multiplexing or transmit diversity) that are represented by 0 and 1. At each time slot, eNode-B assign 'R' RBs to 'n' active users. The proposed system model is shown in Fig. 1

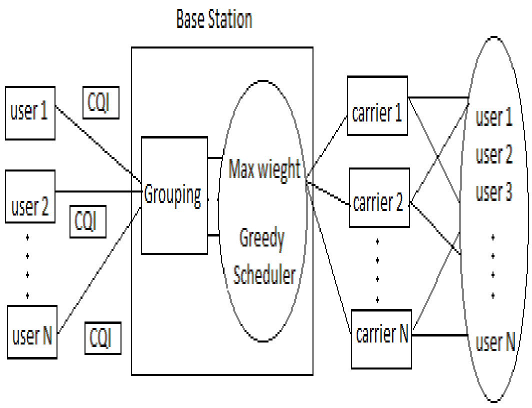

Fig. 1: Proposed System Model

In this work, SU-MIMO is specified in which each RB can be assigned to at most one user or multiple RBs can be assigned to one user belongs to same MIMO mode. We assume the wireless channel is frequency selective fading channel. This fading channel varies with time, frequency and distance between the user and base station. The channel condition may vary for different users and also vary across different RBs.

The set of RBs is denoted by R={1,2,...r} and the power of all RBs can be denoted as [P(R)=C]. The set of users is denoted as N={1,2,...n} and the two transmission mode is denoted as M such that M={0,1} where 0 represents spatial multiplexing mode and 1 represents transmit diversity mode. Let $I^c_i(t)$ be the boolean variable used to indicate whether a set of RBs is assigned to the user i or not.i.e., $I^c_i(t)=1$, if a set of RBs c allocated to the user.

Therefore, the system profit function [1] can be represented as

$$p: C \times N \times M \qquad (1)$$

Where p(c,i,m) denotes the profit gain obtained by assigning c to the user i € N with MIMO mode m € M. The proportional fair criterion objective must be a non decreasing function such that

$$p(c_1, i, m) \leq p(c_2, i.m) \qquad (2)$$

$$p(0, i, m) = 0 \qquad (3)$$

(1) shows that the profit function can be increased by allocating more RBs to the user.

(2) shows that the profit function is zero when no RB is allocated to the user.

The profit function p(c,i,m) can be expressed as

$$p(c, i, m) = \sum_{c \epsilon C} \lambda_{i,m}^{c} \qquad (4)$$

Where $\lambda^c_{i,m} = d_{i,m}/R_i$ is the proportional fair scheduling objective. $d\hat{}_{i,m}$ is the current data rate of user i on RBs with mode m. R_i is the average service rate .If more RBs are allocated, then $d_{i,m} \geq 0$, $R_i \geq 0$ and $\lambda^c_{i,m} \geq 0$.Therefore ,the profit function $\sum \lambda^c_{i,m}$ also increases. If no RB is allocated, $d_{i,m}$=0 and $\lambda^c_{i,m} = 0$. If few RBs are assigned, Ri become smaller and PF objective become larger.

III. LTE DL SUMMIO FDPS

In LTE DL system, SUMIMO FDPS problem is considered with ' r ' RBs and ' n ' users. At each time slot, when a set of RBs c allocated to a user i,then the profit function of the user i is expressed as p(c,i,m). [1] formalised the FDPS problem as

$$max \sum_{(c,i) \epsilon C \times N} p(c, i, m). I_{i,m}^{c} \qquad (6)$$

This shows that the task of SU-MIMO FDPS is to find C×N×M which improves the profit function in each TTI.The objective function is also expressed as

$$p(c, i, m) = Qi \sum_{c \epsilon C} d_{i,m} \qquad (7)$$

$$p(c, i, m) = Qi \min \{Qi, \sum d_{i,m}\}$$

Where Q_i is the queue length of user i and $d_{i,m}$ is the data rate of user i on RBs c in MIMO mode m.The FDPS problem consists of three constraints and they are represented as

$$\sum_i \sum_c \sum_{m \in \{0,1)} I_{i,m}^{c}(t) \lambda i. m(t) \qquad (8)$$

Subject to

$$\sum_i \sum_m I_{i,m}^{c} \leq 1 \qquad (9)$$

$$I_{i,m}^{c} \epsilon \{0,1\} \qquad (10)$$

Constraint (9) shows that one RB is allocated for each user. Constraint (10) shows that only one optimal MIMO mode can be selected for a single user per time instance. Constraint (9) (10) together maximize the objective (7) for each user for each time instance.

IV. GROUPING METHOD

We have assumed that the LTE DOWNLINK consists of ' n ' active users and a single base station. At each time instance, CQI feedback is delivered by individual user to the base station. The users are classified into groups based on their CQI value. For example, ' n ' number of users can be divided into two groups say group1 and group2 such that group1 consists of users with high CQI value whereas group2 consists of users with low CQI value. The appropriate scheduling schemes should be applied to assign the subcarriers to the users on which they have high profit gain. In this work, a greedy scheduling scheme is applied to serve the users selected in the groups alternatively. The grouping method improves the fairness as well as the throughput.

V. SCHEDULING SCHEME

A. Non Decreasing Objective Function

The greedy scheduling scheme is studied for LTE DL SU-MIMO FDPS problem. The aim of this scheduling is to maximize the objective function i.e., profit function must be a non decreasing function. We assumed that the set of RBs and set of users be R and N. Initially, without MIMO mode we may define the valid schedule as

$$\{(c11,1),(c12,1)\ldots\ldots(c21,2),(c22,2)\ldots\ldots$$

$$(cn1,n),(cn2,n)\ldots\} \qquad (11)$$

Without MIMO mode, the profit function is given by

$$p=\sum_{i=1}^{n} p(c,i) \qquad (12)$$

Considering MIMO mode, the profit function can be expressed as

$$p0=\sum_{i=0}^{n} p(c,i,0) \qquad (13)$$

$$p1=\sum_{i=1}^{n} p(c,i,1) \qquad (14)$$

Where p (c,i,0) is the profit gained by assigning the RB to user i in MIMO mode 0. Similarly, p(c,i,1) be the profit gained by assigning the RB c to the user in MIMO mode 1. Obviously, p0 and p1 denotes the total profit gained by a valid schedule in corresponding MIMO mode.

B. Max Weight Scheduling

This algorithm used to schedule the users only with more tasks base on their instantaneous channel condition. Therefore, this scheme is applied to the group 1 which have high CQI value. The max-weight algorithm is choosing the s*(t) at each slot t:

$$s*(t)=argmax_{s\epsilon S}W(S)$$

It improves the fairness as well as throughput

C. Greedy Scheduling

In this strategy, the scheduler selects a user who reports the highest C/I ratio. This provides the maximum possible average throughput .At each time slot, the greedy rule denoted by $\Omega_{\text{max rate}}$ pick a user i which has good channel condition. The Greedy Algorithm [1] for maximizing the profit function can be designed as

$$c \leftarrow \arg\max_{c \in C,\, C \cup \{c\} \in R} \left(f(C \cup \{c\}) - f(C) \right)$$

$$m \leftarrow \arg\max_{m \in \{0,1\}} \left(p_i(C_i) \right)$$

The greedy Algorithm takes the inputs consisting of the N users, R set of RBs and profit function p(c,i,m). The output of the algorithm C0 and C1 where C0and C1 are the valid schedule. The profit gain obtained by the valid schedule are p0(C0) and p1(C1).

VI. SIMULATION RESULTS

The proposed scheme is implemented in MATLAB 12 Simulator. Fig. 3 Simulation shows the Bit Error Rate (BER) obtained using spatial multiplexing Transmission mode.

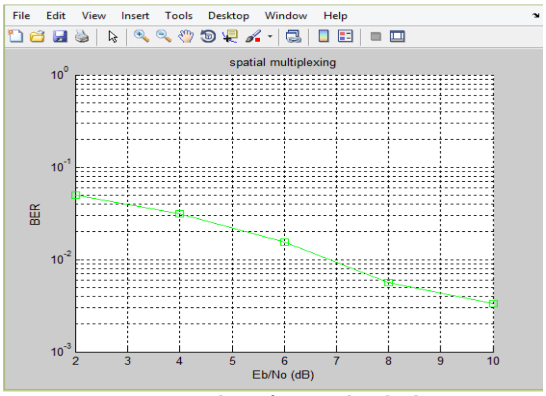

Fig. 3:BER Vs Eb/N0 for spatial multiplexing

Fig. 3 Simulation shows the Bit Error Rate (BER) obtained using Transmit Diversity Transmission mode.

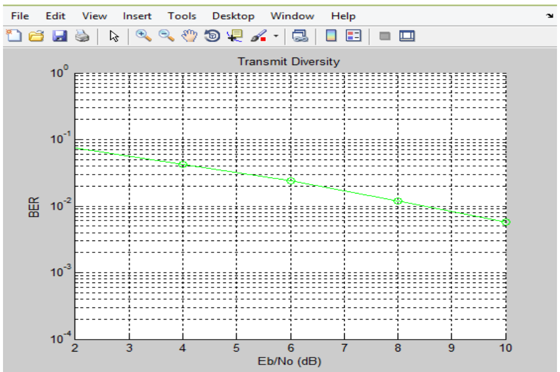

Fig. 4:BER Vs Eb/N0 for Transmit Diversity

The following Simulation results proves that greedy downlink make the profit gain as a non decreasing function. we consider the profit gain is the current data rate $p(c,i,m) = \sum d_{i,m}$ where $d_{i,m}$ is the current data rate of user i by assigning the RB c in MIMO mode m. Fig. 5 Simulation results also proves that the average throughput of the system increases with the number of users.

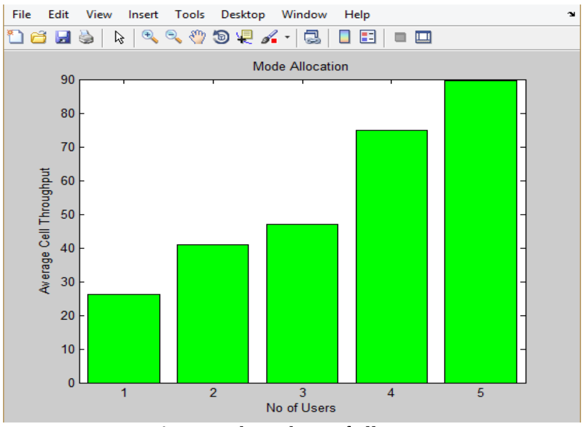

Fig. 5: Average throughput of all active users

VII. Conclusion

The optimal mode selection and greedy scheduling increase the profit gain with the number of user. Simulation results also prove that the average throughput of the system increases with the number of users without degrading due to multipath fading. In wireless environment, some user data may get affected by severe fading. But the greedy scheduler throughput increases with the number of user and still achieves fairly good performance in the presence of serious fading. In Greedy Downlink, the system throughput increases with the increase in number of users.

Acknowledgement

First of all I thank the almighty for giving us the knowledge and courage to complete the research work successfully. Next I express my gratitude to our respected Professor Mrs.L.R.Priya, BE, M.E, (Ph.D) for following us to do research work effectively. Finally, I wish to express my gratitude to my family and my friends, for providing unending support in every aspect possible, to ease my path on this journey.

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