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A novel energy efficient packet-scheduling algorithm for CoMP

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ABSTRACT

The increasing energy consumption driven by striking growths in the number of users and data usage has placed cost reduction and energy efficiency at the forefront of system design. As a step towards incorporating more energy friendly mobile platforms in future networks, 3GPP LTE-Advanced has adopted Coordinated Multi-Point (CoMP) transmission/reception due to its ability to mitigate and/or coordinate inter-cell interference (ICI). However, there is room for reducing energy consumption further by exploiting the inherent flexibility of the dynamic resource allocation (DRA) protocols. Pivotal to the DRA is the packet scheduler that plays central key role in determining the overall performance of the 3GPP long-term evolution (LTE) based on packet-switching operation and provide a potential research playground for optimizing energy consumption in future networks. In this paper, a novel energy-efficient scheduling (EES) is proposed that can achieve power-efficient transmission to the UEs while providing both system energy efficiency gain and fairness improvement. The proposed algorithm is based on a novel scheduling metric focusing on the ratio of the transmit energy per bit and allocates the Physical Resource Block (PRB) to the UE that requires the least ratio of the transmit energy per bit. Through computer simulation, the performance of the proposed EES packet-scheduling algorithm using mixed traffic is compared with the State-of-the-Art (SoTA) packet-scheduling algorithms such as Maximum Carrier-to-Interface ratio (MCI), Proportional Fairness (PF), and Round Robin (RR), which eventually shows the significant improvement.
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1. Introduction

The increasing demand in data and voice services is not the only concern in 4G wireless networks since energy management now plays a critical role. With the enormous and ever increasing growth of high-data-rate wireless services and requirement of omnipresent access, energy consumption of wireless devices is rapidly raising. High-level energy consumption at the base station side usually results in a large operational expenditure [1]. As described in [2], the radio access part single handedly consumes more than 70% of the total energy consumption for many mobile operators. At the user equipment (UE) side, high-level energy consumption brings much discomfort, especially for mobile terminals that are not able to connect to an external power outlet, owing to limited battery capacity and slow advancement of battery technology. Therefore, green radio and energy-efficient design in wireless networks is becoming increasingly important and prompting new waves of research and standard development activities [3]. And also new solutions are required whereby operators can accommodate the expected increasing traffic volume whilst simultaneously reducing their investment in new infrastructure - and significantly reduce their energy bill. Therefore, the EU political agenda, bolstered by the expected growth in mobile data, has identified cost and energy per bit reduction as a stringent design requirement for mobile networks of the future.

The Third Generation Partnership Project (3GPP) community has already taken steps towards reducing the energy consumption in future emerging networking technologies (e.g. Long Term Evolution (LTE)-Advanced [4]) by proposing new energy efficient networking topologies, deployment strategies and modulation technologies. Today's wireless technologies are mostly based on orthogonal frequency division multiplexing (OFDM) system. OFDM can effectively eliminate the intra-cell interference (inside same cell) due to orthogonal subcarrier modulation; and therefore the only major source of interference to handle is inter-cell interference (between different cells). Inter-cell interference (ICI) significantly decreases the achievable throughput of each user as well

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negatively impacts on cell average throughput. Especially, users at the cell-edge areas suffer from serious ICI leading to poor cell-edge throughput. ICI has a large effect on system capacity, particularly when the frequency reuse factor is equal to one. As cell sizes decrease in the future, inter-cell interferences will become more of a problem.

In the framework of 3GPP, many solutions are proposed for LTE to cope with ICI and achieve overall increased cell edge throughout. Relay and Coordinated multipoint (CoMP) are examples of solutions proposed by 3GPP for the LTE-Advanced standard. Although CoMP has added advantages over Relay technologies, as CoMP uses coordination in transmission and reception of signals among different base stations, which helps to further reduce ICI [5]. CoMP transmission and reception techniques utilize multiple transmit and receive antennas from multiple antenna site locations, which may or may not belong to the same physical cell, to enhance the received signal quality as well as decrease the received spatial interference [6]. Using CoMP the cell average and cell edge throughput are boosted, unlike with Relay, which only increases the cell edge throughput. CoMP has already been adopted and standardized by 3GPP in release 11 [7].

Generally, the spectral efficiency (SE) of the cell, the cell edge throughput and the users' fairness are used as performance indicator for CoMP technology. As green communication becomes increasingly important, EE (energy efficiency) is also becoming an important performance criterion for CoMP technology.

1.1. Contributions

The focus of this paper is thus on the downlink CoMP aspects since uplink CoMP technologies tend to have less standardization impact, as receiver processing at the network side can be performed in an almost transparent way to the user equipment (UE) [6]. Most of the conventional schedulers including MCI and PF make decision on the basic on instantaneous channel condition and throughput as key factor of scheduling metric. Nevertheless, new factors should be considered to enhance the system performance such as energy. The transmit energy is insufficient when the radio resources are fully utilized, huge amount of data are required to be transmitted, and most cell-edge UEs have poor channel conditions.

To the best of the authors' knowledge no scheduling metric has been done to allocate PRB CoMP techniques for packet scheduling algorithms in LTE-Advanced which deals with energy. This paper proposes a new packet scheduling method which outperforms several conventional packet scheduling algorithms in terms of throughput, energy efficiency and fairness for MU-MIMO CoMP techniques. This paper aims to find the sub-optimal scheduling techniques for the CoMP scenario in terms of energy efficiency where data throughput also plays a major role. In addition, the computer simulation results show that the use of proposed algorithm provides significant advantages over other channel aware scheduling methods especially in terms of EE fairness where the Gini index (borrowed from the literature of economics) indicates that a much more equal access is granted to the users.

1.2. Organizations

The rest of the paper is organized as follows: In Section 2 we provide the related work. Preliminaries regarding packet scheduling and mixed traffics are described in Section 3. In Section 4, we describe the system model and the signal model. Section 5 presents the proposed energy-efficient packet scheduling algorithm. Performance metrics and the simulation results are given in Section 6. And conclusions are drawn in Section 7.

2. Related work

This section summarizes related works in LTE network in terms of downlink packet scheduling for energy efficiency.

In [8], the performance of an LTE system with various packet scheduling algorithms was studied from an energy efficiency point of view. In this work, the performance of various classical scheduling algorithms such as RR, PF and MCI was used as a basis for the assessment of further innovative energy aware algorithms.

Fig. 1 presents a benchmark of different packet scheduling in terms of EE in LTE system in full queue traffic. This consideration is valid for SoTA schedulers [9], but also serves as a benchmark for evaluating innovative energy aware algorithms which have not been treated so far. As reported in [10] and the results above, it is substantiated that MCI is the best packet scheduling method to have better EE in full queue traffic. Therefore, this conclusion motivates the author of this paper to propose a new energy-efficient

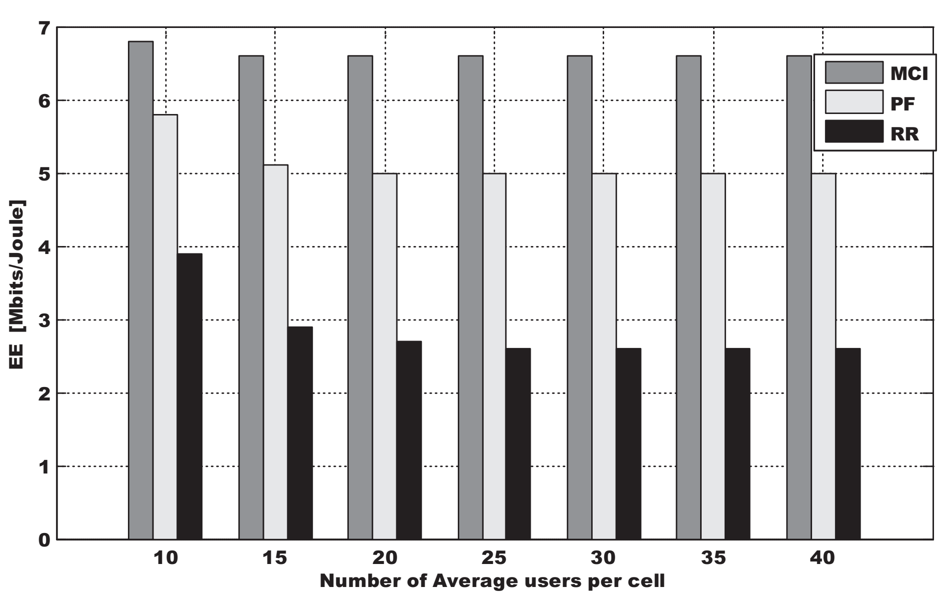

Fig. 1. Comparison of different packet scheduling in LTE-Advanced.

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