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Energy-efficient using GLRT Algorithm for LTE Networks

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ABSTRACT

Long Term Evolution (LTE) has become one of the main cellular technologies to cope with the tremendous demand for higher data rates in mobile communications. Typical LTE base stations are designed to operate continuously at full power to meet this demand, while the diversity of the network load allows however a large exibility in the assignment of resources. Most schedulers are designed with the goal of having been in terms of total throughput or fairness. Nevertheless, the impact on energy consumption is rarely considered. Therefore, it is of paramount importance to develop algorithms that allow base stations to reduce their energy consumption by considering changes in the network load. To tackle this problem, we propose two new scheduling algorithms that exploit the users' channel conditions to reduce the energy consumption. Using a state-of-the-art base station power model, we show that by serving users at time slots when they have favourable channel conditions, and delaying transmissions when they have unfavorable channel conditions, we can use higher modulation and coding schemes that increase the energy efficiency of the base station. Still, we guarantee a minimum Quality of ServiceQoS) by setting a maximum delay time.

Keywords

Energy efficient, cyclic prefix.

INTRODUCTION

Long Term Evolution (LTE) has become one of the main cellular technologies to cope with the tremendous demand for higher data rates in mobile communications [1]. LTE base stations are designed to operate continuously at full power in order to meet QoS of all potentially connected users, regardless of operating conditions. It increases the operational expenses for the network providers as well as environmental impact, which has been a growing concern in the ICT industry in the last years [2, 3].

Most schedulers are designed with the goal of having benefits in terms of total throughput or fairness. For instance, users that have favorable channel conditions or QoS requirements are scheduled with higher priority since otherwise the important performance metrics could be degraded. However, the impact on energy consumption is rarely considered. Therefore, it is a paramount importance to develop algorithms that allow base stations to reduce their energy consumption by considering changes in the network load without sacrificing the minimum QoS requirements. As the base station downlink transmissions are amongst the largest contributors of energy expenditure in cellular networks [4] and focus on the downlink transmissions in this paper.

To tackle this problem, two new scheduling algorithms that exploit the users' channel conditions to reduce the energy consumption in proposed system. Using a state-of-the-art base station power model, by serving users at time slots when they have favourable channel conditions and delaying transmissions when they have unfavorable channel conditions, can use higher modulation and coding schemes that increase the energy efficiency of the base station. Still, we guarantee a minimum QoS by setting a maximum delay time.

SYSTEM MODEL

LTE RADIO INTERFACE

In LTE, a physical resource block (PRB) is the minimum resource allocation unit for a user. It is formed by 12 consecutive subcarriers, or 180 kHz, with a duration of one time slot (1ms). Each scheduled user is assigned

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by the base station a transmission scheme composed of a certain modulation and coding rate. This transmission scheme is based on the channel quality indicator (CQI) fed back by each user, which is computed based on measurements of the reference signals (RS) transmitted by the base station over the whole bandwidth.Based on the RS, users compute the CQI as the index corresponding to the highest modulation and coding transmission scheme that supports a block error rate not exceeding 10%. The CQI measures of both the signal-to-interference-and-noise ratio and the receiver capabilities in a certain PRB [1]. The CQI can take one of 10 possible values as described in Table 1 [5]. After receiving the CQIs of all users, the base station assigns the PRBs to each user with the modulation and coding rate indicated by the CQI. Although the CQI feedback procedure is standardized, the assignment of PRBs to users is the manufacturer's choice of implementation and it is done at each base station independently.

Table 1: SINR and CQI mapping with energy consumption

CQI	Modulation	Coding rate for a 1024 size block	Energy per information bit (J/bit)
1	QPSK	78	5.43
2	QPSK	120	3.53
3	QPSK	193	2.20
4	QPSK	308	1.38
5	QPSK	449	0.95
6	QPSK	602	0.71
7	16QAM	378	0.57
8	16QAM	490	0.44
9	16QAM	616	0.35
10	64QAM	466	0.31

Base station power model

The PRB assignment has an impact on the energy efficiency of the base station. A high modulation order and a large coding rate can transmit more information bits in each subcarrier, hence minimizing the energy consumed per information bit. This can be seen in the last column of Table 1 [6].

To compute the energy per information bit, we use the EARTH power model [4, 7], which is based on the individual power consumption of each of the components forming the transceiver of a base station.

One of the main features of this power model is the scalability it provides based on the network load, allows reducing the energy consumption when the base station is not operating in fully loaded conditions

BASELINE SCHEDULING ALGORITHMS

In this section, the present most common scheduling algorithms used in cellular networks. For assume that each PRB can be assigned to a different user and that the time slot duration is 1ms.

Round Robin [8]

The PRBs are assigned in a circular fashion without taking into account the users' channel conditions. Every PRB is assigned to a different user until all the PRBs are assigned. If more PRBs remain to be scheduled, every user is assigned another PRB, and so on

MAXIMUM CQI (Max-CQI) [8]

Each PRB is assigned to the user which reported the highest CQI in each PRB, maximizing in this way the total throughput. This means that at time slot t, PRB k is assigned to the user that has the highest ratio:

$$i = \arg m \quad r_i^k(t);$$

Where, $_i^k(t)$ is the number of information bits per time slot of user i when using the CQI computed for PRB k. This value can be obtained from Table 1 using the corresponding modulation and coding rate.

Proportional fairness (PF)

This scheduling algorithm presented in [9] sacrifices maximum throughput at the cost of achieving fairness for all the users. With this algorithm, at time slot t, PRB k is assigned to the user i that has the highest ratio:

$$i = \arg m \quad \frac{r_i^k(t)}{(R_i)^{i(t)}};$$

Where, R_i represents the average number of information bits of user i from the assign-ment of PRBs from previous time slots and

$$i(t) = m^s \quad [(m\ 1)(r_i^k(t) r_i^k(t\ 1))];$$

Where,

$$m = \frac{r_i^k(t) r_i^k(t\ 1)}{r_i(t) r_i^k(t\ 1)};$$

and where,$r_i(t)$ is the average number of information bits from all the PRBs assigned to user i in time slot t.

MINIMUM CQI (Min-CQI)

This scheduling algorithm is used only as a bottom line and we assume that it assigns the PRBs to the user which has the lowest non-zero CQI. This results in achieving the minimum throughput and corresponds to assigning PRB k to the user i with the lowest ratio.

Energy-efficient scheduling algorithms

In order to increase the energy efficiency of the base station, we propose two algorithms. The main idea of both is to exploit the users' channel conditions to reduce the energy consumption. Specially, by serving users at time slots when they have favourable channel conditions and delaying transmissions when they have unfavorable channel conditions, we can use mostly higher modulation and coding schemes that increase the energy efficiency of the base station. In our simulations we assume favourable conditions if the CQI reported by a particular user for each PRB is above 5.

Whenever the transmission to a user is delayed, the EARTH power model allows the base station to reduce the energy consumption because of the reduced network load. To avoid starvation of resources for a user with continuously poor channel conditions and to avoid disturbance in the retransmissions, a transmission is delayed only if it is not a retransmission from a previously erroneous packet, and if the user has not delayed transmissions for more than 10 time slots. By setting this maximum delay time, we are able to guarantee a minimum QoS to each user.

Power-based proportional fairness (PPF)

This algorithm is based on the PF approach. However, instead of using the average number of information bits per user, we use the average consumed energy per user. In this way, this algorithm favor’s a high instantaneous rate of information bits and penalizes a high average energy consumption. This means that at time slot t, PRB k is assigned to the user i that has the highest ratio:

$$i = \arg m \quad r_i^k(t);$$

where r_i is the average energy consumed from the assignment of PRBs from previous time slots to user i and where $r^k_i(t)$ is the energy consumed from the assignment of PRB k to user i in time slot t obtained from Table 1 and $r_i(t)$ is the average energy consumed from all the PRBs assigned to user i in time slot t.

Window-based proportional fairness (WPF)

This algorithm considers the period of time that a user has not been served, hence rewarding users that are able to postpone their transmission. Similarly as PPF, it favors the instantaneous rate of information bits, but it rewards a long transmission delay. This means that user i is scheduled if

Table 2: Simulation parameters

Parameter	Value
Number of users	15
Bandwidth	1.4 MHz
Simulation time	2s
Maximum speed	50 km/h
Minimum speed	3 km/h
Channel pro le	ITU pedestrian B
Number of transmit antennas	1
Number of receive antennas	1

Where, T^{i}represent the window of time since the last time slot in which user i was scheduled. The variable n is a factor that tunes the weight of this period of time. In our simulations we set it to 2.

PERFORMANCE EVALUATION

In this section analyze the performance of the baseline and proposed scheduling algorithms in terms of power consumption and throughput using the parameters of Table 2. The power consumption is computed based on the energy per information bit of Table 1 for each assigned PRB, while the throughput is computed based on the rate of information bits obtained from the modulation and coding rate per PRB of Table 1. For our simulations, use a LTE standard-compliant framework and the EARTH power model [4].

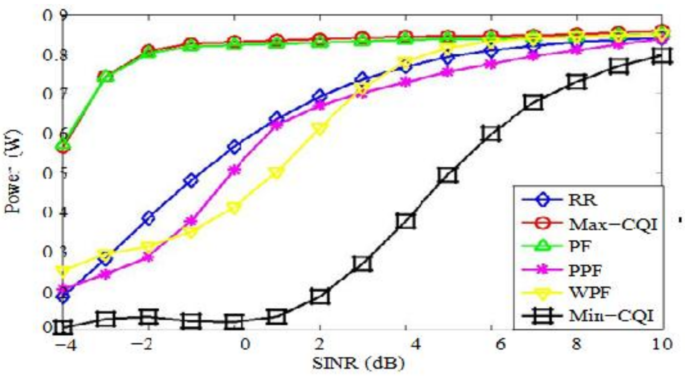

Figure 1: Power consumption of the baseline and proposed scheduling algorithms.

Fig. 1 shows the total power consumption of the base station. Max-CQI and PF lead to the largest power consumption as they both serve users with the highest instantaneous rate of information bits, regardless of the energy consumption. As expected Min-CQI leads to the lowest energy consumption, while RR shows an average performance.

The proposed energy efficient algorithms, on the other hand, are able to drastically reduce the energy consumption of the base station compared to Max-CQI and PF. This comes at the cost of a decrease in the total throughput as seen in Fig. 3. As expected, Max-CQI o ers the largest total throughput as it maximizes the instantaneous rate of information bits. PF o ers a lower throughput as it achieves fairness for all the users by

sacrificing maximum throughput. The proposed energy efficient algorithms over throughput higher than RR for all SNR values and higher than PF for some SNR values

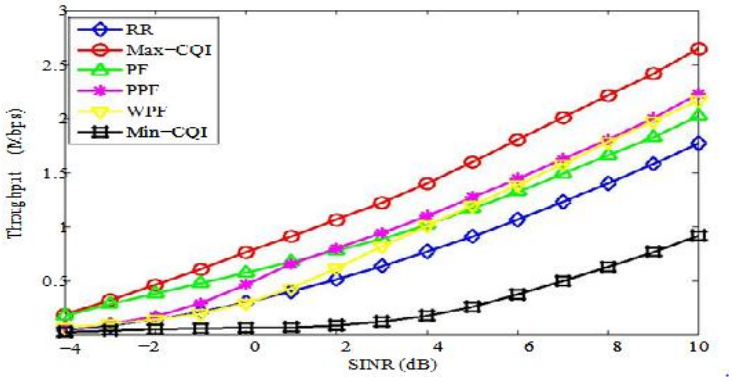

Figure 2: Throughput of the baseline and proposed scheduling algorithms.

Nevertheless, the previous analysis gives no indication of how the throughput is distributed among the users. For this purpose, we plot the cumulative distribution function (CDF) in Fig. 3

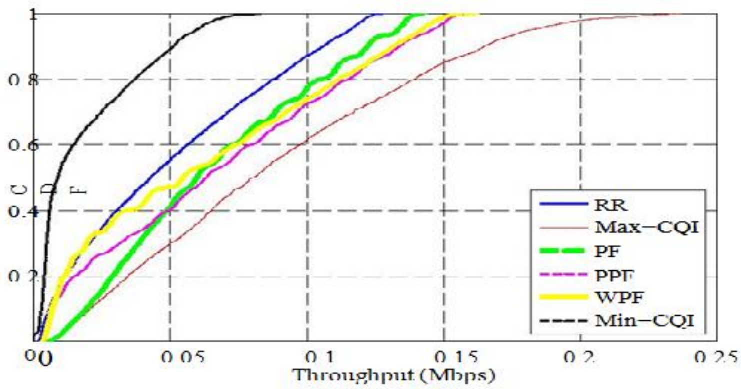

Figure 3: CDF of the baseline and proposed scheduling algorithms.

Evidently, Max-CQI offers the best performance in terms of the probability of achieving a certain throughput, while Min-CQI and RR over the worst performance. PF over the same performance as Max CQI for low throughputwhich shows the fairness achieved by this approach .However, the proposed energy efficient approaches are able to achieve a performance close to Max-CQI for low and high throughput and better than PF for high throughput.

CONCLUSIONS

In this paper, proposed two energy efficient scheduling algorithms for downlink transmission in LTE networks that exploit the users' channel conditions to reduce the energy consumption. Using the EARTH base station power model, we show that by serving users at time slots when they have favourable channel conditions, and delaying transmissions when they have unfavourable channel conditions, we can use higher modulation and coding schemes that increase the energy efficiency at the base station. Still, we guarantee a minimum QoS by setting a maximum delay time. The simulations show that we can drastically reduce the energy consumption with a small sacrifice in total throughput.

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