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A REVIEW OF PERFORMANCE ANALYSIS OF A DOWNLINK LTE SYSTEM USING DIFFERENT RADIO RESOURCE ALLOCATION SCHEMES (RRAS)

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ABSTRACT

Long Term Evolution (LTE), by third generation project partnership (3GPP) is one of the radio access technologies used for delivering broadband mobile services. It is mainly influenced by high data rates, minimum delay and the capacity due to scalable bandwidth and its flexibility. The downlink LTE employs orthogonal frequency division multiple access (OFDMA) as a multiple access technique. The conventional resource allocation method in OFDMA employed different modulation and coding scheme (MCS) on allocated subcarriers to achieve good throughput. But, in the downlink LTE, all scheduling blocks at a given transmission time interval (TTI) to user must adopt same MCS and these brings about constraints in the system and as a result degrade system performance. This paper reviewed several resource allocation schemes for performance analysis in downlink direction for LTE systems. In each of the schemes considered, the suboptimal solution showed a significant performance improvement compared to the optimal solution. A quality of service (QoS) guaranteed resource block(RB) allocation achieved high throughput compared to other schemes considered in this article.

Keywords:LTE, 3GPP, OFDMA, TTI, MCS QoS, RB

INTRODUCTION

The evolution of Long Time Evolution-Advanced (LTE) is as a result of spanning decades of digital transmission access techniques and advances in the digital signal processing methods and technologies (Bahai, 2004). The access technologies and standards implemented in the evolution started from the first digital mobile communication systems GSM (Global System for Mobile Communications) and IS-95 (Interim Standard 95) to the true broadband wireless access systems 3GPP LTE (Long Term Evolution) and WiMAX(Worldwide Interoperability for Microwave Access). The initial access schemes (TDMA, FDMA and CDMA in different variations) converges towards the Orthogonal Frequency Multiplex Division Access (OFDMA) as the only relevant multiple access technology. OFDMA was first introduced as an air interface technology for broadband wireless systems with the WirelessMAN-OFDMA air interface of IEEE 802.16d in 2004. Although initially designed for fixed wireless applications, enhancements for mobility support in IEEE 802.16e transformed WiMAX in 2005 into Mobile WiMAX, and therefore an alternative for the established mobile cellular technologies like UMTS and 1xEV-DO. Consequently, The Third-Generation Partnership Project (3GPP) started in 2005 to develop an evolution of the Wideband CDMA based UMTS standard, called the "Long Term Evolution". 3GPP LTE Release 8 was completed in 2008 which forms the foundation for LTE networks and historical evolution of the wireless access technology is shown in Figure 1 (Adereas *at el*, 2010).

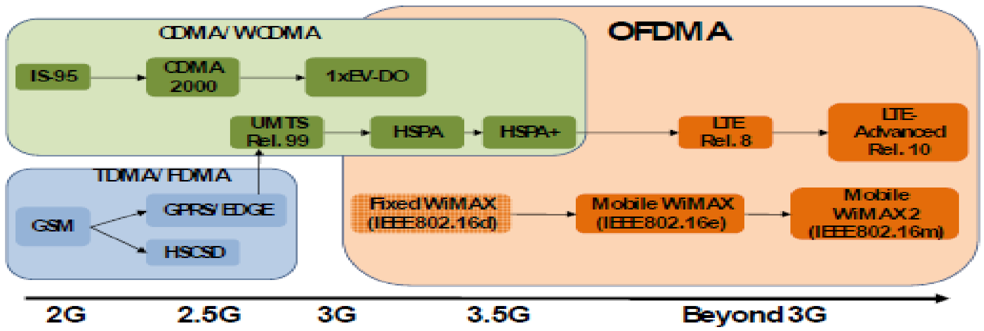

Figure 1: Historical evolution of wireless system towards OFDMA

Minor changes were introduced in LTE through Release 9 in particular the inclusion of femtocells and dual-layer beamforming (Ian *at el*, 2010). The LTE-Advanced which is the backward-compatible enhancement of LTE Release 8 is fully specified in 3GPP Release10.In the context of 4G systems, both the air interface and the radio access network are being enhanced or redefined, but so far the core network architecture(EPC), is not undergoing major changes from the already standardized SAE architecture. Evolved Universal Terrestrial Radio Access Network (E-UTRAN). The core part in the E-UTRAN architecture is the enhanced Node B (eNodeB or eNB), which provides the air interface with user plane and control plane protocol terminations towards the User Terminal (UE) (Ian *at el*, 2010). In this work, a comprehensive downlink performance analysis is carried out for LTE systems using different radio resource allocation schemes (RRAS).

Overview of LTE Frame Structure

The LTE frame structure in as shown in Figure 2, Gadam(2013). The frame duration is 10ms and each frame is divided into subframes of 1ms each. The subframes are further divided into two slots of 0.5ms durations. Depending on the cyclic prefix configuration, each slot has seven and six OFDM symbols in the normal and extended cyclic prefix respectively. In the frequency domain, resources are grouped in units of 12 subcarriers from each OFDM symbol, separated by 15khz and therefore occupying a total of 180khz. One resource block is defined as one of the subcarriers for duration of one slot. The resource block is the main unit to schedule transmissions over the air interface.

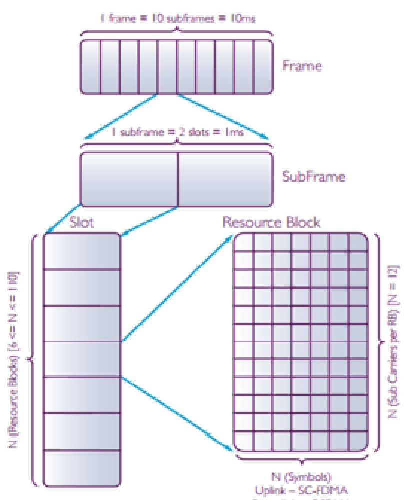

Figure 2: The LTE Frame Structure

The frame structure and its operation based on downlink LTE depends on the concept of physical resource block (PRB). A PRB is defined as consisting of 12 consecutive subcarriers for one slot (0.5msec) in duration. The PRB is the smallest element of resource allocation assigned by the base station scheduler.

LTE RADIO RESOURCE ALLOCATION TECHNIQUES

The need for intelligent resource allocation cannot be over emphasized not only because of the limited nature of the radio spectrum but also because of how it affects the quality of service experienced by the users. The radio resources in this context are those key parameters having to do with radio bearer control (RBC), radio admission control (RAC), load balancing (LB), inter cell interference coordination(ICIC) and so on (Luca, 2009). A considerable amount of literature has been published on the problems of resource allocation in an OFDMA system in recent years. Previous research findings in OFDMA resource allocation focused on scheduling decisions based on the current time instant subject to the current resource constraints. They were not able to utilize the dynamic nature of the wireless spectrum to improve the performance of the communication system. Furthermore, the conventional method of resource allocation in OFDM system is that a user can employ different modulation and coding scheme (MCS) at a given transmission time interval (TTI) on the allocated subcarriers to improve the throughput. In the downlink LTE systems however, all scheduling blocks (SB) allocated to a user must adopt the same MCS at any given TTI. Therefore, the application of conventional resource allocation in LTE results in degraded performance, since MCS must be chosen according to the worst SB [5]. Therefore, due to the constraints discussed above and the complexity of the problem, several researchers focused in developing sub-optimal solutions to the resource allocation problems to improve the overall system performance. Reviews of some RRAS with their performances are discussed in the following subsections.

Adaptive Block-Level Resource Allocation Technique (ABLRA)

Fan *et al* (2011) proposed a resource allocation scheme in LTE that allocates Resource Blocks (RB), Power, and Rate jointly to maximize the network throughput. In this paper, exponential effective signal-to-interference-plus-noise ratio (SINR) mapping (EESM) and mutual information effective SINR mapping (MIESM) methods are used to convert the post-processing SINR to determine an appropriate MCS for RBs with different channel gains. This method uses the modulation and coding scheme (MCS) information in the uplink as a feedback to the base station (BS). Based on the feedback, the BS optimizes RB assignment, power allocation and MCS selection to achieve the highest sum throughput with the limited resources. In order to reduce the complexity of the process, the joint optimization was separated into RB assignment and power allocation. The RB assignment to the users is based on the highest signal-to-interference-to-noise ratio (SINR) or largest MCS index to achieve the highest throughput after relaxing the MCS constraint in LTE. MCS was selected based on power allocation not only to ensure the block level error rate (BLER) performance of RBs with the worst channel condition, but also to exploit the RBs with better channel conditions more efficiently. The relative power was allocated among the RBs' belonging to the same user which is termed as power allocation among RBs' of the same user (PAaRB). The power is then adjusted among users to achieve further improvement and the corresponding MCS is also determined, which is called power allocation among users (PAaUE). Therefore, after completing PAaRB and PAaUE, the power allocation at the RBs of a user can be found. Then, accordingly, new SINR of each user is obtained. Based on the new SINR of a user, MCS corresponds to a user is also found. The MCS indices are used by the base station (BS) to approximate the SINR and it was based on that, the resource allocation scheme was developed to improve the system throughput. Figure 1 depicted the average throughput versus average SINR using Fans' proposal considering SINR and MCS as feedbacks at the same time comparing with the works of Kwan *at el (2009)* using MCS's feedback with 4 users. The average throughput of Fan's method has significant improvement for both feedbacks within-5dB<SINR<25dB while maintaining the same output at low or high SINR as seen from the simulated result in Figure 3.

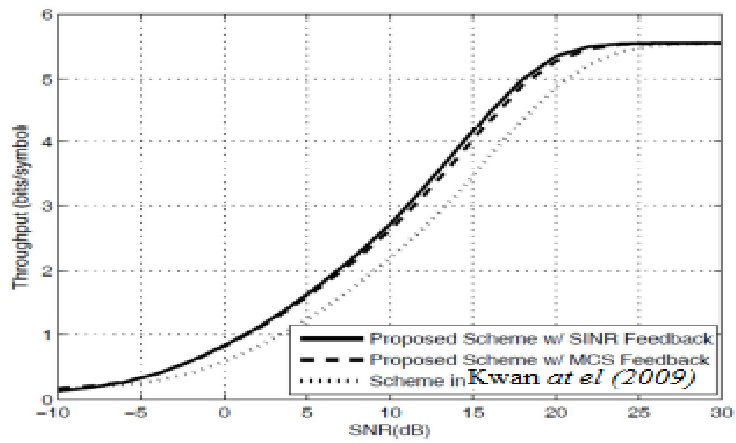

Figure 3: *Throughput Versus SINR For Fan's Scheme And Kwan at el (2009) With 4 Numbers Of Users*

MCS Selection for Throughput Improvement in Downlink LTE Systems (MCSHM)

Jiancun *et al* (2011) investigated MCS selection to maximize system throughput and developed effective MCS selection scheme that dealt with the BLER performance of the RB with both poor and good channel conditions. The joint optimization problem was simplified in the Jiancun's by separating it into RB assignment and MCS selection. Appropriate RBs was assigned to users and then MCS was selected based on the effective packet-level SINR estimated by different ways. Multiple subcarriers in an RB have different channel gains, therefore EESM or other methods were used to find the effective SINR of each resource block and then relate the values of MCS index which was feedback to the base station as Channel quality indicator (CQI). Also, Arithmetic mean (AM), geometric mean (GM), and harmonic mean (HM) of the approximate block-level SINRs on the RBs for each user was exploited which was used to obtain the estimated packet-level SINRs with results in different impacts from these methods. For AM based scheme, the estimated effective packet-level SINR was mainly dominated by the RBs with maximum SINR. For GM based scheme, RBs belonging to the same user were considered. While for the HM based scheme, RBs with minimum SINR were considered. From figure 4, it was shown that the throughput from Jiancun's based MCS selection was improved by 18% compared to the works of Kwan *at el* (2009) when the number of users is 4 and SINR=10dB.

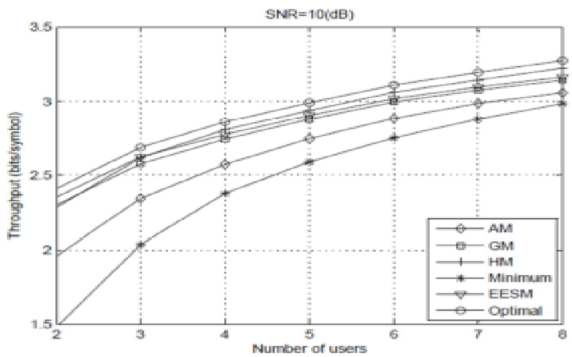

Figure 4: The Jiancun's Scheme

Quality Of Service (QoS) Guaranteed RB Allocation Algorithm for LTE systems (QSRBA)
Guan *et al* (2011) proposed an efficient resource block allocation algorithm which takes into account both the MCS constraints and QoS requirement for the downlink transmission in LTE. The three classical practical resource allocation algorithms namely: max carrier-interference (C/I), round robin (RR) and proportional fair (PF) do not take QoS into
account.. In this method, average channel condition in form of CQI was fedback to the BS from the user which enabled the scheduler to know which MCS to be adopted and be assigned to all the SBs of the same user.

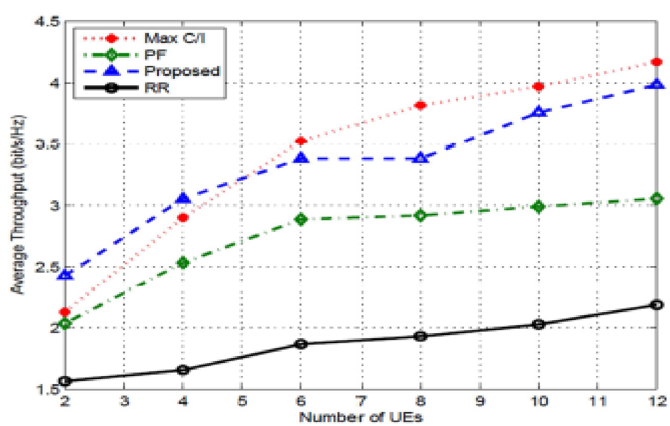

Figure 5: Throughput Of Max C/I, PF, Guan's Scheme And RR Algorithm Versus Number Of Users

The optimization problem in the scheme is complex, which increases exponentially with the number of constraints and variables, but the complexity was reduced by a novel suboptimal algorithm. It mainly comprises of two steps: (i) estimate the number of SBs required by each user based on the ratio of users' minimum rate requirements to its average gain; (ii) with constrain of users' minimum rate requirement, allocate SBs to users according to users' priority. Figure 5 shows that the throughput of Na's scheme is higher than the max C/I algorithm when the number of UEs is small. It may be concluded that max C/I gives the highest performance, but under the assumption that each SB employs different MCS according to their channel conditions. In LTE, max

C/I cannot always provide the best throughput performance because the MCS adopted by each user should be decided by the worst SB allocated to it.

Resource Allocation in an LTE cellular Communication System (RALDL)

Kwan *et al.* (2009) in their work investigated the effect of multi-user diversity in resource allocation to increase throughput of the system. SBs with different channel qualities are assigned to users to achieve overall system throughput maximization.

SBs with highest CQI in group are fed back and the signal requires small bandwidth but at the cost of degraded performance. The LTE adaptive modulation and coding (AMC) is employed to reduce this effect on throughput. The quality of feedback depends on the method adopted. It is assumed that MCS rate increases with CQI index and SBs whose CQI values are not feedback are assigned MCS 1. If MCS are to be assigned to a user, only those blocks with good enough channel qualities or higher can be allocated. SBs with lower MCS index will result in high error rates if selected.

The sub-optimal scheduler is implemented in two stages to reduce the complexity of the algorithm; (i) Selection of best user for each SB and collection of information regarding the set of SBs associated with user. (ii) Selection of the best MCS given the selected SBs for each user. In the case of the optimal scheduler, there are two types of models employed; multi-user optimization and linearized models. In both models MCS,SBs and users are jointly assigned and therefore creating computational complexity. Therefore, sub-optimal scheduler is better than the optimal scheduler due to the decouple selection between SBs and MCS. Figure 6 shows the graph of throughput against

number of users to illustrate the performance of the optimal and sub-optimal algorithms. The average SINRs for all users are set to 10dB. It can be deduced from the graph that, as the number of users increases, the throughput also increase and sub-optimal scheduler, performs better than optimal scheduler.

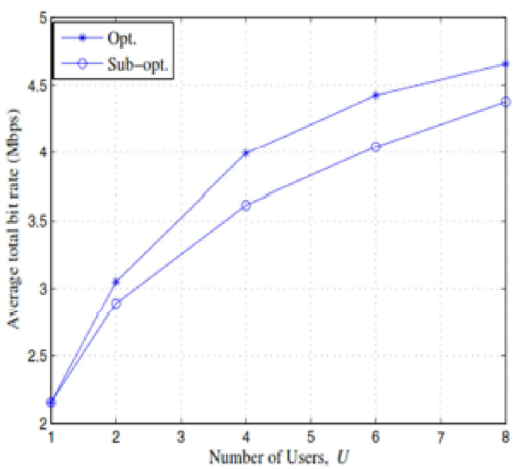

Figure 6: A Graph of Average Bit Rate Versus Number of Users

PERFORMANCE COMPARISON OF THE RESOURCE ALLOCATION SCHEMES AND DISCUSSION

The works of Fan *et al* (2011), Jiancun *et al* (2011), Guan *et al* (2011) and Kwan *et al.* (2009) presented different RB allocation schemes that maximize the overall system's throughput. In comparing their works, the following points were considered; (i) channel estimation method employed, (ii) how the resources are assigned and (iii) the optimization method used and the channel parameters considered. Figure 7 shows the graph for the comparison of the resource allocation schemes considered in this work while Table 1.0 shows summary of the comparison.

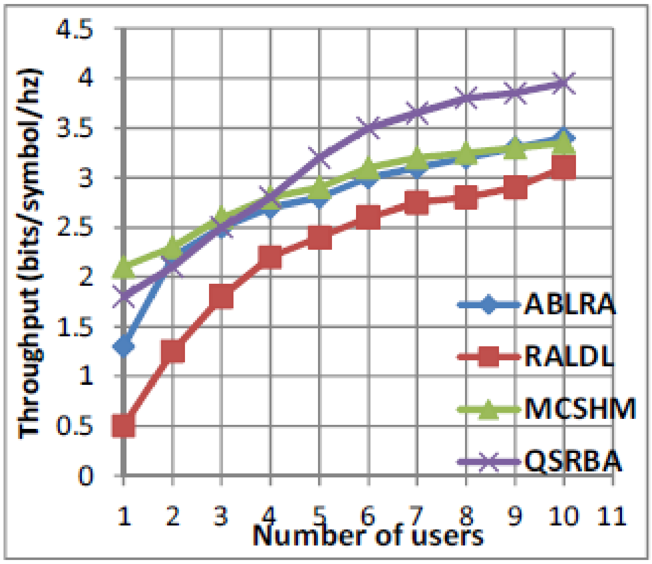

Figure 7: Graph of Comparison of Resources Allocation Methods

Table 1.0: Comparison of The Resource Block (RB) Allocation Schemes

	Fan	Jiancun	Guan	Kwan
Resource Allocation Methods	Optimization of RB and power allocation	RB assignment with MCS using EESM.	QoS guaranteed RB allocation	SBs allocation based on high channel quality to high MCS index
Packet-level MCS index estimation	EESM and MIESM	EESM, AM, GM and HM	Average Channel condition used as CQI index (AM)	CQI index defends on the method used
RB assignment method to users	Based on high SINR or MCS index	Based on high SINR or MCS index	CQI and rate requirement base on channel priority	Based on RBs with good channel qualities or higher
Optimization technique	Sub-optimal, RB assignment and power allocation	Sub-optimal, RB assignment and power allocation	Sub-optimal; SBs estimation per user, and allocation based on priority	Sub-optimal; selection of best user for each SB, and MCS assignment the MCS
Objective	Maximization of network's overall throughput	Maximization of throughput by resource allocation and MCS selection methods	Throughput maximization and QoS guaranteed	To allocate SBs having different channel qualities to users to maximize throughput.
Throughput improved	Increased by 20% when number of users is 4 and SINR is 10dB	increased by 18% with HM based MCS estimation when users number is 4 and SINR 10dB	max C/I has the better throughput as the number of user increases	increased as the number of users increases and SINR set 10dB

Discussion

The authors, Fan *et al* (2011) used EESM and MIESM to estimate the packet-level MCS index for RBs with different channels gains. The effect of channel estimation on the average throughput was investigated by Jiancun *et al* (2011) where they developed EESM, AM, GM and HM effective selection schemes. Guan *et al* (2011) in their work expressed the average channel condition in form of CQI and used it as feedback to estimate the MCS to be used in the scheme. The authors Kwan *et al.* (2009), unlike the previous ones estimated the channel values of those whose feedback messages were not received at the scheduler by assigning MCS 1 to them.The resource allocation methods considered in this work used sub-optimal methods of optimization to maximize their systems' throughput.

CONCLUSIONS

One of the most significant findings that emerged from this review is that the resource allocation scheme with QoS consideration has the highest throughput compared to other schemes as shown in Figure 7. Also, from the resource allocation schemes investigated, the sub-optimal solutions show significant performance improvement with less complexity when compared to the optimal solutions in the downlink LTE.

It is recommended that further research be undertaken on the effects of delay in the uplink feedback and error due to channel estimation on resource allocation for throughput maximization.

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