Combined Radio Resource Management for 3GPP LTE Networks

Modar Safir Shbat
Kyungpook National University/School of Electronic Engineering, Daegu, South Korea
Email: modboss80@knu.ac.kr

Vyacheslav Tuzlukov
Kyungpook National University/School of Electronic Engineering, Daegu, South Korea
Email: tuzlukov@ee.knu.ac.kr

***Abstract*— an intelligent radio resource management (RRM) is the core system of LTE network in order to provide the broadband mobility needs of upcoming years. RRM system will schedule the available radio resources in a best way, so all the users will be served by enough transmission capability and required level of QoS and mobility, and also RRM system will assure that the assigned resources would not interfere with any previous assigned resources. Using aggressive frequency reuse (factor of 1) in LTE network means that the whole frequency spectrum will be available in single eNodeB which creates large effect of inter cell interference (ICI) especially at the edge of the cell. The development of Self Organizing Network (SON) techniques, algorithms and eventually standards is a critical step in LTE femtocell deployments and a great confirmation about the importance of RRM. In this paper different radio resource scheduling algorithms and ICI elimination techniques will be analyzed, and a vision of RRM scheme will be presented based on fulfilling the suggested requirements from RRM system.**

***Index Terms*—3GPP LTE Networks, Radio Resource Management, Self Organizing Network, Inter Cell Interference**

I. INTRODUCTION

The present trend towards the ubiquity of networks and the global mobility of terminals, networks and services will be supported by a diversity of solutions. The exploding growth of the mobile internet and related services in the past few years has fueled the need for more and more bandwidth. In spite of the standardisation progress on new generation cellular networks, several problems remain open and service providers and network operators have complex questions regarding the migration process, requiring fundamental studies. Long Term Evolution (LTE) network promises higher data rates, 100Mbps in the downlink and 50Mbps in the uplink; in addition to LTE has support for scalable bandwidth, from 1.25MHz to 20MHz. All these features are making LTE a very attractive technology for operators as well as the subscribers. The development of Self Organizing Network (SON) techniques, algorithms and eventually standards is a critical step in LTE deployments. 3GPP is standardizing self-optimizing and self-organizing capabilities for LTE and beyond that will leverage network intelligence, automation and network management features in order to automate the configuration and optimization of wireless networks. The SON concept includes the following:

- Self Planning & Self Configuration
- Self Optimization
- Self Testing & Self Healing
- Self Maintenance

Fast review for the SON in LTE network is enough to show the great importance of RRM as a main backbone in its structure.

This paper is organized as follows: the next section II is about different radio resource management schemes; section III discussed the suggested design for the combined RRM in LTE network; section IV the future work and the conclusion is in the section V.

II RADIO ACCESS TECHNOLOGIES (RATs) AND RADIO RESOURCE MANAGEMENT

The LTE system requires optimized signaling as well as optimized radio transmission and radio access network. The radio access network of the LTE system, Evolved UMTS Radio Access Network (E-UTRAN) is agreed to have only one type of node – eNodeB. LTE system prefers UEs to be less intelligent, and allows network to have all control over services and resources. These system features should be considered sufficiently in designing the optimized LTE signaling protocols and radio resources management algorithms [1]. The Evolved Universal Terrestrial Radio Access Network (E-UTRAN) is consisted of evolved Node B's (eNBs) (Figure1) [2], which are interconnected by X2 interface. Each eNB is connected to the Evolved Packet Core (EPC) network by the S1 interface. Our focus is on the eNB which is responsible to host RRM functions like Radio

Bearer Control, Radio Admission Control, Connection Mobility Control and Dynamic Resource Allocation. In the next two types of RRM will be under analysis; the first type is general RRM schemes and the second type is with the consideration of SON requirements.

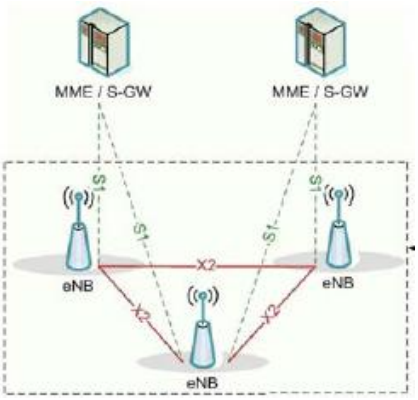

Figure 1. LTE Architecture – Basic RRM.

A. General Resources Scheduling Algorithms

1-Propotional fairness resource allocation algorithm:

Here the priority for each user at each resource block should be calculated first and then the user how has the maximum priority the RB will be assigned to him and the algorithm continues to assign the RBs to the next maximum priorities between the users until all RBs are assigned or all users have been served. This priority of k-th user to be assigned with j-th resource block at time (t) is given by:

$$P_{kj}(t) = RDR_{kj}(t)/R_k(t)$$

Where RDR_{kj} (t) is the requested data rate for the k-th user over j-th RB in time (t) and R_k (t) is the low-pass filtered averaged data rate of the k-th user. The value of RDR is estimated by using AMC (Adaptive Modulation and Coding) selection which is depends on current transmission channel condition. In case of retransmission RDR is different from the one for new resource user request in order to guarantee the successful transmission, so the RDR estimated form is:

$$RDR_{kj} = R_{MCS}(SNR_{AC})$$

Here R_{MCS} is the rate estimation function and SNR_{AC} is the accumulated signal to noise ratio over the transmission channel. In any time interval of scheduling is updated as follows:

$$R_k(t+1) = (1-a)\,R_k(t) + a\,DRD_k(t)$$

Where (a) is the average rate window size and DRD_k (t) is the aggregate data rate for user k at time t.

2-Softer Frequency Reuse based Resource Scheduling Algorithm:

By the aim of reduction of frequency selective scheduling gain loss and to increase the data rate at the cell edge, this scheme is proposed. By this algorithm the frequency reuse factor is 1 at the center and the edge of the cell. The frequency scheduler is working in a way that the cell edge's users have higher probability of using the frequency band with higher power and the cell center's users have the higher probability of using frequency band with lower power. Here the priority is calculated by:

$$P_{kj}(t) = RDR_{kj}(t)/R_k(t)\,F_{kj}$$

This formula is modifications form of the previous algorithm where F_{kj} is the priority factor and can take value between 0 and 1 among the following cases:

User k at cell center, RB j is low power

User k at cell center, RB j is high power

User k at cell edge, RB j is low power

User k at cell edge, RB j is high power

Giving different values to F_{kj} is the way of controlling the resources assignment to users in the edge and center of the cell.

3-Round Robin scheduling Algorithm:

Round robin method is used to allocate the radio resources to users, the first user will be served with the whole frequency spectrum for a specific period of time and then serve the next user for another time period. The previously server user will placed at the end of the waiting queue till to be served again in the next round. All the new resources request also will be placed at the end of waiting queue. This scheme offers great fairness in radio resource assignment among the users but with lowering the whole system throughput.

4-Resource Scheduling Scheme based on Maximum Interference:

By this algorithm all the users in the cell are ranked according to the experienced interference so the user with the worst CQI (Channel quality indicator) will be in the top of ranking and scheduled to assign RBs for him and the turn goes for the user with the next worst CQI to have his RBs. The ranking K can be presented as:

$$K = \arg\max(Y_k(t))$$

Where Y is the vector of experienced interference by The users in the cell in time t.

5- Resource Scheduling Algorithm based on Dynamic Allocation:

The dynamic allocation algorithm is using a kind of signaling process by a small chunks of class traffic smaller than the packet of streaming class traffic are transmitted in the network, this algorithm gives equal allocation of the radio resources but not with the capacity of traffic which can be handled by these physical resource blocks (PRB). This algorithm depends on three main parameters:

M=total number of available PRBs

U=total users to multiplex on a PRB

RB=resource blocks which are assigned to k user. Thus the k user select best PRB from N based on the channel condition.

B. Radio Resource Management for SON in LTE

1-Joint Radio Resource Management [3]:

All operators have to deal with coexistence RATs and the integration between LTE networks and other wireless networks, so the exploitation of the complementarities between technologies through JRRM will be needed. This scheme is based on Reinforcement Learning (RL) [4]. The RRM through smart mechanisms that take jointly into account the resources available in all the RATs to make the appropriate allocations, these are referred to as

Joint RRM (JRRM) or Common RRM (CRRM). The mechanism puts RL agent in each cell which works in Real time independently from the agents in other cells, and it is responsible for distributing the users among the technologies and the decision can be taken either at session initiation, or during session lifetime, which could lead to a vertical handover. In this model if we assume that the reuse factor is 3 the LTE, so that only 8 out of 24 frequency chunks (resource blocks) are assigned to one cell as active. The remaining 16 chunks would be used by neighboring cells.

2-Multi Radio Resource Management [5]:

MRM incorporates a multi-radio resource and mobility management, allowing for intelligent network-centric access selection, seamless handovers and optimized load balancing over a number of different kinds of access networks, including 3GPP and non-3GPP networks. This system consists of three parts; the first one MRM-TE is located on the user terminal and it has to provide inter-system measurement functions and an initial access selection algorithm that is used as long as the terminal has not yet established a connection with the access network. The second part MRM-NET is located in the access network and is associated with all active users within its service area. Last part (MRM-HAM) is the heterogeneous access management function and its main mission is to make access selection decisions based on various input parameters such as link performance, resource usage and availability measurements.

3-Cognitive Radio Resource Management [2]:

The concept idea is to enrich the LTE system with Cognitive features which can be used to provide the system with knowledge that derives from past interactions with the environment. The self-management function of cognitive systems may be introduced in the terminal level, access point or network segment level. The system examines the current operated context has been treated in the past for better and suitable exploitation of experience and knowledge that can be used to produce wiser RRM decisions and actions. Next we must explain the concept of Intra Cell RRM [6], [7]:

Intra-cell configuration includes sub-carrier assignment, power allocation and adaptive modulation. Each one of them is reflected by DSA (Dynamic Spectrum Access), APA (Adaptive Power Allocation) and AM (adaptive modulation) respectively. Multiple sub-carriers are allowed to be assigned to a single user. However, the same sub-carrier isn’t allowed to be assigned in more than one user, and the number of subcarriers that should be assigned to any user depends on many factors parameters like user location, the requested service, user profile and Network Operators (NOs) policies.

4-Dynamic Fractional Frequency Reuse scheme [8], [9]:

In the system a mix of high and low reuse frequency resources (e.g., reuse 1 and 3, respectively) are allowed in each cell. The user’s distance from the cell center is the factor which means the reuse 1 is for the close users from the cell center while the lower reuse resources are assigned to interference-limited users at the cell edge. In the **Down Link FRR:** by the consideration of the distribution of mobile or traffic load the basic idea is the usage of a relative narrowband transmit power (RNTP) indicator, which is exchanged between BSs on the X2 interface [10]. The RNTP is a per physical resource block (PRB) indicator which conveys a transmit power spectral density mask that will be used by each cell. This feature results in arbitrary soft reuse patterns being created across the system. Every cell would have a special subband for generating low interference with its reduced transmit spectral density. Based on the knowledge of which cell is causing the dominant interference in the DL, the scheduler can inquire the RNTP report in that cell to know which subband is being transmitted at reduced power and hence generating less interference, and can choose to schedule mobile in that subband so that it experiences higher SINR. For the Up Link FFR another indicator is used (high interference indicator HII), which is defined per PRB, can be exchanged between cells via the X2 interface to implement uplink FFR [11]. When the HII bit is set to 1 for a particular PRB so it has high sensitivity to uplink interference for this cell; when the HII bit is set to 0 so it signifies that this PRB has low sensitivity to uplink interference and by The exchange of HII reports between cells allows the creation of fractional reuse patterns through uplink scheduling and power control.

III. GENERAL ANALYSIS AND THE DESIGNED RMM SCHEME

A. General Analysis and the Designed RRM Scheme

Different scenarios for RRMs have been introduced, so the analysis of the RRMs in the first section we can find that Scheduling Algorithm based on Softer Frequency Reuse is the best because it utilizes all the tasks performed in the proportional fairness algorithm in terms of the allocation of the resources to users based on their requirement and experienced channel condition in addition to the user location in the center or in the edge of the cell and it can be ideally utilized with semi-static inter cell interference coordination technique. Round robin scheme has the lowest rank for the overall system performance degradation caused by that one user will have all the resources during one time and rest users have to be in waiting queue. Algorithm based on maximum interference suffered by a traffic channel and irrespective of the class of the traffic and its need of the resources, and it also does not consider the position of the channel while scheduling the resources for a user.

B. Combined RMM Scheme

To design an intelligent RRM for LTE networks many issues should be under our consideration, efficient frequency reuse; fairness; QoS; inter cell interference control (ICIC); optimum power allocation; SON requirements and vertical handover.

Auto configuration of the radio parameters is a key feature and reference signal sequences are among the most important radio parameters for LTE, so In order for the UEs to uniquely identify the source of a receiving signal, every eNodeB is given a signature sequence called as Physical Cell ID (PCI).from the LTE specifications of the physical layer (3GPP TS 36.211-840) there are a total of 504 unique physical layer cell identities grouped in into 168 unique physical layer cell identity groups, and each group contains three unique identities.

PCI Planning [12]: the overall PCI is constructed from primary and secondary synchronization IDs as follows:

$$PCI = 3ND_{ID}^{(1)} + ND_{ID}^{(2)}$$

Where $ND_{ID}^{(1)}$ is in the range of 0~167, representing the physical layer cell identity group, and $ND_{ID}^{(2)}$ is in the range of 0~2, representing the physical layer identity within the physical layer cell identity group.

The PCI assignment process has to be has to be as well collision as also confusion free and that can be by using colored graph method [13]. Cognitive softer fractional frequency reuse scheme for CRRM will include the best features of all previous discussed possible schemes and it must be not local kind of RRM which it serves in a single radio network. VHO algorithm should be considered to support seamless services across heterogeneous radio networks. There is a method that makes CRRM embodied as server format in structure related standard and another method that integrates into RRM function. Using Generic Link Layer (GLL) [14] based common radio resource management (CRRM) concept is a dynamic solution for VHO in the suggested RMM; GLL that are physical layer and abstract layer which is located in data link layer works in CRRM server in each LRRM and in mobile node. This layer is reconstructing different quality network signal value from physical layer into one unified format and then transfers it to CRMM server in each heterogeneous network.

IV. FUTURE WORK

Full details about the suggested combined CRRM scheme should provided and deep analysis for the performance must done keeping in mind that as 3GPP LTE proposed that every 1 ms the radio resources should be scheduled which is called TTI in scheduling, and this proposal places a lot of processing load in the eNodeBs, so the way of speeding up the scheduling process should be considered, in addition to utilization of higher order modulation will increase the whole system throughput but it Requires more processing time and efforts on both ends of the transmission process and this issue also must be investigated.

V. CONCLUSION

A wide scan for big variety of radio resource management schemes with analysis for important points for each scheme introduced, and it is clear that huge efforts had been already done for LTE networks' radio resource management, but still this part under many research attempts to improve and develop better performance and optimal RRM scheme in order to enhance bandwidth efficiency and throughput of the network. It

Is obvious that the optimal RRM scheme a combined solution from the coexisted results which belong to the researches that had done till now, and one example is the suggested scheme in this paper which can give a general vision for the futuristic structure of the radio resource management in 3GPP LTE networks.

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