Design Considerations for Radio Resource Management of LTE/LTE-A Femtocells

Ayesha Haider Ali[1] and Mohsin Nazir[2]

[1,2] Department of Computer Science,
Lahore College for Women University, Jail Road Lahore, Punjab, Pakistan 54000.
[1]Email: ayesha.iqbal@gmail.com
[2]Email: mohsinsage@gmail.com

Abstract: In order to improve the wireless network performance, one of the most potential solutions is the use of a number of small size cells called femtocells. One of the facilitating technologies for LTE/ LTE-A (Long Term Evolution- Advance) is the deployment of femtocellular network. As the number of femtocell increases, managing the radio resource becomes challenging due to the co existence of other femtocells and the macro cells. Also with the development of radio access techniques, the radio resource is becoming insufficient. Therefore, it is turning out to be a vital issue that how should the demands for higher data rates with limited resources is met for the evolving 4G network. Radio Resource Management (RRM) techniques involve controlling factors such as transmit power, allocation of channel, handover strategies, guarantee of data rates etc. This paper aims to highlight the RRM considerations with the perspective of LTE/ LTE-A femtocells with OFDMA radio access technology, the broader objective being to emphasize on the importance of efficient RRM techniques.
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1. Introduction

Femtocells or Femtocell Access Points (FAPs), also known as Home Base Stations or NodeB or evolved NodeB (eNB are small base stations installed in homes and their size is like a router (Haddad & Porrat, 2009). They provide exceptional signal coverage to indoor users, and reduce the load on the external macrocell. Femtocells acquired the name because they are much smaller than the standard Macrocell cellular towers. Typically the range of a standard base station may be up to 35 km and a femtocell is in the order of 10 meters (Mavrakis, 2007). The advantages of a femtocell include: Links of higher quality, spatial reuse and increased capacity, improved signal quality due to the use of smaller cells and shorter distance, load sharing with macro cells and reduced infrastructure cost.

FAPs (Femtocell Access Points) are small BSs that are capable of providing wireless indoor coverage to the mobile users using cellular technology and are connected to the core network with the help of broadband internet for example DSL (Digital Subscriber Line) or fiber optic. Femtocells are capable of providing increased capacity and improved signal quality due to the use of smaller cells and shorter distance. Other benefits include load sharing with macro cells and reduced infrastructure cost. Femtocells have filled the gap for indoor environments.

The ever increasing subscriber's demand for higher data rates pursued ITU (International Telecommunications Union) to define future mobile communications standard named IMT-A

(International Mobile Telecommunication-Advanced). The main objective of IMT-A are higher data rates upto 1 Gbps with low mobility and 100 Mbps with higher mobility, improved efficiency in terms of spectrum usage and better user throughput. 3GPP (3rd Generation Partnership Project) has begun to develop LTE-A (Long Term Evolution-Advanced), which is a further development of the LTE, so as to achieve the requirements defined by the IMT-A. It provides more bandwidth (up to 100 MHz). Spectral efficiency will be improved by the use of coordinated multipoint communication and deploying a large number of small BS that is capable of providing capacity which is 1000 times higher than today's networks as depicted in Figure 2 (Nokia-Siemens Networks, 2011).

OFDMA (Orthogonal Frequency Division Multiple Access) is chosen to be the radio access scheme for LTE-A (3GPP, TR 25.814, 2006). OFDMA is derived from OFDM, in OFDMA the sub channels are allocated to different users in same time interval, whereas in OFDM all the bandwidth is allocated to the same user at each time interval. The allocation of sub channels in OFDMA can be optimized by providing opportunistic access to radio resource in order to achieve better performance.

Figure 1: Low-power, low-cost and short-range Femtocells for improved coverage and capacity (http://www.femtoforum.org).

Deployment of FBS in public places is of much benefit to provide higher data rate and improved resource usage to a number of users. Femtocells are different in the sense that they are installed by customers in an ad hoc fashion without any RF planning (Li, et al., 2011).

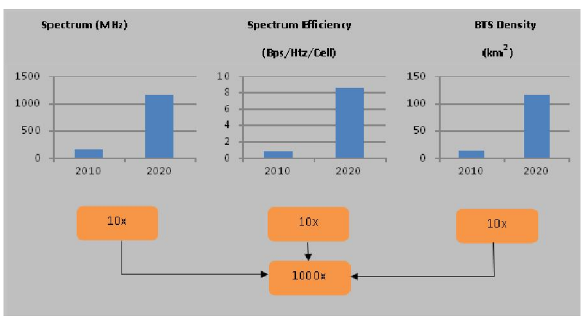

Figure 2: Enhancement in technology will allow 1000 times more data than today (Nokia-Siemens Networks, 2011).

LTE/ LTE-A is likely to become the prominent cellular data provider for the future, thus the integration of femtocells and LTE-A is of great importance (Andrews, et al., 2012). A distinguishing feature of LTE-A is that it provides the femtocell implementation in a distributed manner to meet a number of requirements for providing various services. The FBS is named as Home evolved Node-B (HeNB) in LTE-A. The HeNB has got cognitive capabilities to provide spectrum sensing and management, interference management, handover optimization and so on. Here we have a single macrocell base station named evolved Node-B (eNB)) and a number of eNBs (Huang & Krishnamurthy, 2011).

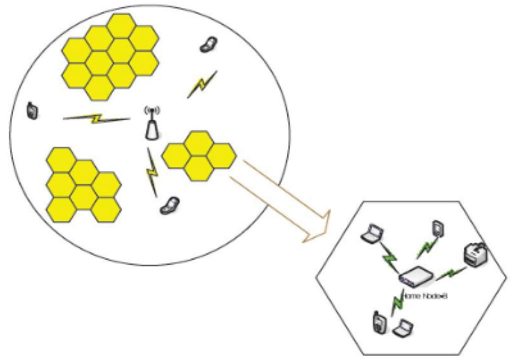

Figure 3: A single eNB with Multiple HeNBs (Huang & Krishnamurthy, 2011).

RRM functionality is a set of algorithms that is used to optimize the utilization of air interface (spectrum) and hardware resources. The purpose of RRM is to ensure the planned coverage for network services, ensure the required QoS and optimize the system usage. RRM policies involve the techniques controlling factors such as transmit power, allocation of channel, handover strategies, guarantee of data rates etc. Also the success of a wireless system depends a lot on the allocated bandwidth and the QoS of the transmission medium (Nazir and Saleemi, 2012). The effciency of resource management between macro and femto network is of great importance because the scarce radio resource has to be effectively utilized for best performance. There is no coordination between these two networks due to which RRM is a challenging task.

In the following section we will discuss different RRM techniques for OFDMA, LTE and LTE-A to emphasize on the various aspects of RRM techniques to utilize the spectrum resource effectively in 4G networks.

2. Radio Resource Management in OFDM/OFDMA Systems

In OFDMA systems, a cross-layer subcarrier and bit allocation algorithm with proportional fairness (CLSBAPF) (Cheng, et al., 2006), considers not only the condition of channel but also the status of queue for each user. The principle idea of using cross-layer is to realize the fact that if a user does not have enough packets to transmit then the resource allocated to this particular user will be wasted. Therefore, in order to use the resources effectively, the condition of each user's buffer should also be considered. The algorithm consists of two steps: 1) users are assigned sub carriers according to the queue length; it is assumed that the power is allocated uniformly to the sub carriers.2) the overall power is also allocated considering the buffer status. The algorithm aims to exploit the throughput of the system with the help of overall power management in proportion with the user data rate.

As the data rate provision moves closer to the next generation, new issues are raising in designing techniques for efficient radio resource allocation. These include the random nature of packet arrival, inadequate buffer space, varying QoS needs and fairness in resource allocation. The concept of cross-layer resource allocation for OFDM systems is considered to be important (Zhang & Letaief, 2004) as it takes into account the condition of the physical channel, the random nature of traffic, QoS requirements, and fairness among users. Timeslots and subcarriers are allocated dynamically and the transmission power is adjusted accordingly.

The uncoordinated dense deployments of femtocells pose several challenges particularly relating to interference in OFDMA RRM. The interference may occur between femtocells and the macrocell, or between various femtocells. Towards addressing this challenge, (Yoon, et al., 2012) has proposed a distributed algorithm named RADION that manages interference across femtocells. RADION's mainstay is to enable femtocells to find the available resources in a distributed manner. The solution takes into account self-organization. As the femtocells are deployed in an unplanned manner, interference will remain an important issue that can limit performance. Various challenges are faced in the design of a distributed resource management framework for the OFDMA based femtocells. It covers challenges regarding Resource Decoupling among the Clients, Resource Decoupling across the Femtocells and Resource Allocation. RADION uses algorithms that allocate resources efficiently and adapts to the changes in network RADION allows the chosen users to reuse the spectrum opportunistically while dividing the resources for the other users in a distributed manner.

In order to avoid interference, an efficient way to optimize the resource usage includes three schemes (Li, et al., 2011): 1) long-term resource management, which is used to assign the spectrum resource for both the macro and femto cells using an adaptive soft frequency reuse (ASFR) to reduce the interference between macro and femto cells; 2) medium-term resource management, in which the resources are allocated to each femtocell. It makes use of self-configuration to adjust FAPs power according to the changes in the environment; 3) fast resource management, which is used to manage resource between various femtocells. A coordinated transmission technique with multipoint is used to allow femtocells to coordinate in order to improve the coverage of the network.

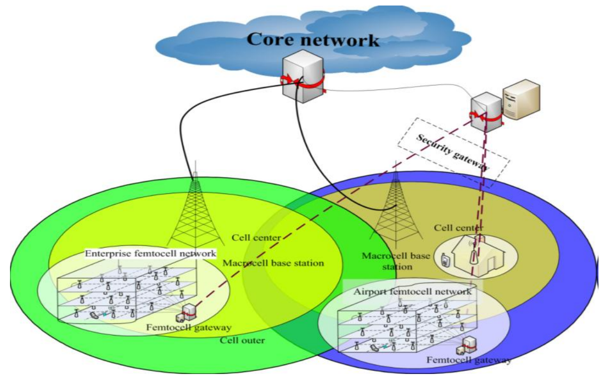

Figure 4: System model showing Macro and femtocell scenario. Each macrocell is divided into two parts; the femtocell may be deployed in any part (Li, et al., 2011).

3. Radio Resource Management in LTE/LTE-A

Although LTE femtocell deployment scenarios provide higher data rate but they pose new challenges in context of interference and RRM. Most of the policies are designed for the classic cellular networks. The femtocells are ad-hoc in nature and this fact limits the complexity of the possible algorithms used. Thus, efficient RRM techniques are important to limit the impact of interference on the performance of femtocells. (Domenico, et al., 2010). A novel RRM algorithm is used that improves the spectrum usage and reduces transmission power usage in the resource blocks allocated in the LTE system. It increases the coverage with interference control.

In (Chen, et al., 2011), a distributed algorithm for the joint optimization of the radio resource is proposed taking into account the heterogeneous cellular network. The authors argue that it is important to use algorithms that are capable of solving 1) channel selection problem, 2) user associations and 3) power control. Self-optimized schemes are required due to the unpredictable nature of the cells and users. This paper targets at designing a distributed algorithm with self-optimization capabilities for small cell networks such as femtocell. Traditionally the macro cell networks aim at optimizing any one of the above 3 elements of the radio resource to improve performance. But this approach is not suitable for femtocells and requires the joint optimization of all the three mentioned factors.

In (Stocchi, et al., 2011), the authors have proposed an algorithm for managing Inter Cell Interference (ICI) in downlink direction in local area, which helps the HeNBs (Home Evolved Node B, that is, femtocell) to work in a self-organizing way. The proposed algorithm uses self-configuration and self-optimization in the form of spectrum selection by the

HeNBs, FSU (Flexible Spectrum Usage) and power control. The objective is to achieve higher throughput and better performance. The FSU algorithm aims to limit downlink ICI for Local Area. The main concept of the algorithm is to divide the bandwidth of the whole system into various chunks called Physical Resource Blocks (PRBs) in accordance with the maximum number of expected cells. These chunks are then assigned to the HeNB that has the priority of transmitting and is therefore called the Priority Chunk (PC) for the HeNB considered. By using the word "priority" it means that the HeNB can use the PRBs that belong to its PC. The considered scenario assumes that the maximum number of cells is already known. In order to avoid the un necessary interference to HeNB a mechanism for power control is used, in which the power used by the HeNB is limited on the PRB that do not belong to its PC.

A femtocell that is closer to macro cell can interfere with its resources. A FBS that is farther from macro BS can reuse the macro resources that are not scheduled for the macro users at that time instance (Sundaresan & Rangarajan, 2009). This concept allows a high level of spectrum reuse in which the femto cell users reuse the resources not in use by the macro users. A location-based resource management can be used to maximize resource usage. As compared to static resource allocation, the resource reuse technique can increase system performance by effectively using the underutilized resources.

4. Design Concerns for RRM

In designing the RRM techniques there are certain factors that are to be considered for best performance and effective resource utilization. The following design factors should be considered in design of RRM techniques:

4.1. Resource allocation opportunistically

As the spectrum is divided into fixed number of RBs, the allocated RBs that are not being used by the neighboring nodes can be reallocated to other users. The FAP can also reallocate some other RBs in case the allocated RBs service shows bad performance. But this type of a solution can be best for scenarios with low traffic levels as the likelihood for free resources is high. In case of dense deployments, the stated solution may not be feasible and can lead to instability because the FBS may jump from one RB to another just to find out the free resources which may result in an unstable state. Thus a solution may be the use of distributed instead of centralized approach in which multiple nodes coordinate to find out the available resources. Thus, resulting in a stable and efficient resource management.

4.2. Resources allocation considering femto to macro interference

One of the limiting factors in LTE/LTE-A femtocells is the interference between the macro and femto cell users. Unlike macrocells, the femtocells deployment is unplanned and ad-hoc in nature and is more likely to cause interference. This fact requires the use of novel solutions for interference mitigation. One solution can be to set aside a portion of spectrum dedicated for femtocells and the remaining for the macrocell deployments. The advantage of this approach is that the interference between macro and femto users can be avoided but this is not a cost effective solution because of the scarcity and high cost of the licensed spectrum. The other solution might be to deploy the femtocell on the same spectrum as that of macro cells. This approach is cost effective and improves the usage of the scarce radio resource. But it may not isolate the effects of femto to macro interference. Thus, requires careful techniques to reduce these interference effects.

4.3. Resources allocation considering femto to femto interference.

In case of dense femto deployment there are scenarios where multiple femtocells may also interfere with each other. This may be the case of enterprise deployment where there are a number of FAPs around causing interference with each other. In such a scenario, RRM techniques taking into account this problem may be helpful. As the resources allocated to one femtocell may have an impact on resources allocated to other femtocells, the frequency and timing of resource allocation is important to avoid such interference. RRM techniques should be aware of this fact and allocate resources keeping in view the resource allocated other femtocells.

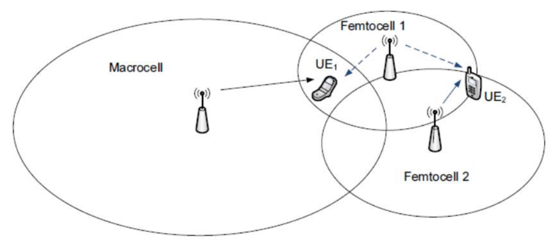

Figure 5: Scenarios involving femto to femto and femto to macro interference (Chen, et al., 2011).

4.4. Transmit power control techniques

The femtocells should have suitable transmit power in order to avoid any interference. If the transmit power is too high, it may result in interference with the neighboring macro and femto cell users. In the same way, if the transmit power is too low it may cause limited coverage than expected.

The RRM approach may involve adjusting the transmit power in a shared and collaborative way. As soon as the femto user causing interference is detected, the FAP can negotiate on the transmit power to be used. If the transmit power is dropped it may lead to the solution of interference problem. But it should be kept in mind that interference management should not be at the risk of performance and coverage degradation.

4.5. Self-organizing capabilities/ Self-Organizing Networks (SON)

As there are dense femtocells deployments, managing resources manually and in a centralized manner may not be feasible and may require huge human resource to achieve the desired objectives. This leads to the need of self-organizing capabilities to manage resources autonomously with least human intervention. Thus the RRM techniques for LTE/LTE-A should support a plug-and play mechanism with auto configuration and adaptation to changing network conditions. The traditional macro networks are deployed using partially static configuration and planning is done through simulations and analysis. But this approach is not feasible in case of femto network due to the increased number of femtocells. Thus, the development of SON techniques, standards and algorithms are an important milestone for LTE-A femtocells.

Table 1 shows a summary of the design considerations for RRM with reference to their need and deployment.

5. Conclusion

This paper focuses on the resource management problem faced in femtocellular networks. The femtocell deployment is different from macrocell which requires addressing resource allocation between femtocells and macrocells to maximize system performance. Resource allocation methods can be utilized to assign some limited resources such as bandwidth and power, in such a manner so as to maximize performance. Therefore, the problem of how to allocate time slots, bandwidth, spectrum etc to different users in 4G networks such as LTE and LTE-A femtocells is challenging. Femto Access Points (FAPs) that are located at the edges of the cell should serve the femto users without any disturbance from the macrocell users (uplink direction). Moreover, there is a need of self-optimized RRM techniques for managing uncoordinated distribution of the femtocells to tackle with the existence of neighboring femtocells. Therefore, it is clear that RRM techniques are required for successful deployment of LTE-A femtocells.

Table 1: Design consideration for RRM of LTE-LTE-A and their need.

Design Considerations	Functionality	Motivation/ Need	Deployment
Opportunistic Resource Allocation	• Centralized/distributed approach. • To find available resources	• Reallocation of RBs. • To overcome problems due to limited service.	OFDMA, LTE/ LTE-A femtocells.
SON	• Self- Organization. • Self-optimization. • Self-Healing.	• Auto configuration. • Adaptation to changes. • Autonomous resource management.	LTE/ LTE-A femtocells.
Interference Management	• Macro-to-femto interference. • Famto-to-femto interference management.	• Frequency Allocation. • Time slot allocation. • Power Control.	OFDMA, LTE/ LTE-A femtocells.
Interference Management with SON	• Interference management for macro-to-femto and femto-to-femto cellular networks.	• To intelligently allocate resources to manage interference. • For interference mitigation with less human intervention.	LTE/ LTE-A femtocells, OFDMA (for femto-to-femto interference management).

References

1. Haddad, Y., Porrat, D., "*Femtocell: opportunities and challenges of the home cellular base station for 3G"*, Proceedings of IEEE Global Telecommunications Conference 2007.
2. Mavrakis, D., "*Do we really need femtocells.*", Vision Mobile 2007.
3. Nokia-Siemens Networks, "2020: Be*yond 4G Radio Evolution for the gigabit experience"*, White Paper 2011.
4. 3GPP TR 25.814, "*Physical layer aspects for evolved Universal Terrestrial Radio Access (UTRA)"*, 2006.
5. Yizhe Li, Zhiyong Feng, Shi Chen, Yami Chen, Ding Xu, Ping Zhang and Qixun Zhang, *"Radio resource management for public femtocell networks"*, EURASIP Journal on Wireless Communications and Networking, Springer Open Journal 2011.
6. Jeffrey G. Andrews, Holger Claussen, Mischa Dohler, Sundeep Rangan, and Mark C. Reed, *"Femtocells: past, present, and future"*, IEEE Journal on Selected Areas in Communications, 2012.
7. Jane Wei Huang, Vikram Krishnamurthy "*Cognitive base stations in LTE/3GPP femtocells: A correlated equilibrium game-theoretic approach"* IEEE Transactions on Comunications, 2011.
8. Nazir, M.; Saleemi, F.*, "Cooperative Cognitive Ecology in Self-organizing Networks: A Review Article,",* International Journal of Computer Science and Information Security, 2012.
9. Peng Cheng, Guanding Yu, Zhaoyang Zhangt, and Peiliang Qiu, *"A cross-layer fair resource allocation algorithm for OFDMA systems",* IEEE International Conference on Communications, Circuits, and Systems Proceedings 2006.
10. Ying Jun Zhang, and Khaled Ben Letaief, *"Adaptive resource allocation and scheduling for multiuser packet-based OFDM networks",* IEEE International Conference on Communication, Networking & Broadcasting 2004.
11. Jongwon Yoon, Mustafa Y. Arslan, Karthikeyan Sundaresan, Srikanth V. Krishnamurthy, Suman Banerjee, *"A distributed resource management framework for interference mitigation in OFDMA Femtocell Networks",* MobiHoc 2012.
12. Yizhe Li, Zhiyong Feng, Shi Chen, Yami Chen, Ding Xu, Ping Zhang and Qixun Zhang. *"Radio resource management for public femtocell networks",* EURASIP Journal on Wireless Communications and Networking SpringerOpen Journal 2011.
13. Domenico, Antonio De, Strinati, Emilio Calvanese, ***"****A radio resource management scheduling algorithm for self-organizing femtocells****",*** IEEE Personal, Indoor and Mobile Radio Communications Workshops (PIMRC Workshops), 2010.
14. Chung Shue Chen, Franc¸ois Baccelli, and Laurent Roullet, *"Joint optimization of radio resources in small and macro cell networks"* IEEE 73rd Vehicular Technology Conference Vehicular Technology Conference (VTC Spring) 2011.
15. Claudio Stocchi, Nicola Marchetti, Neeli and Rashmi Prasad, *"Self-optimized radio resource management techniques for LTE-A local area deployments"*, Wireless Vitae, IEEE 2nd International Conference on Computing & Processing 2011.
16. Karthikeyan Sundaresan and Sampath Rangarajan, *"Efficient resource management in OFDMA femto cells"*, MobiHoc 2009.

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