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Radio Resource Management Issues in 5G Networks – A Review

Naureen Farhan[1*] and Bushra Aijaz[2]

[1] Department of Computer Science, Bahria University Karachi Campus, Karachi, 75260, Pakistan (naureen.bukc@bahria.edu.pk)
[2] Department of Electrical Engineering, Bahria University Karachi Campus, Karachi, 75260, Pakistan (bushraaijaz.bukc@bahria.edu.pk)

Abstract: This review paper presents a study of different techniques that will be used to manage radio resources in a self-optimized and self-organized manner. So that in the approaching 5G networks that are proven to be ultra-dense HetNets comprising of small cells and macro cells the resources will be managed efficiently. In this paper, after discussing various issues and techniques of managing radio resources, finally, the research is resolved by proposing ML clustering technique to manage and categorize radio resources for which LEACH protocol is proposed for low energy consumption in dense networks. Also, the analysis is performed on different parameters that can be controlled and monitored to efficiently manage resource in dense networks. That finally has highlighted the areas that need to be more focused in future Radio Resource Management scenario developments.

Keywords: Received Signal Strength (RSS), Low Energy Adaptive Clustering Hierarchy (LEACH), Mobility Load Balancing (MLB), clustering, machine learning.

I. INTRODUCTION

As there was a time when we were moving from 2G technology towards 3G and that was a complete shift of technology from one era to the other and that was the first milestone in the evolution of technology. Now we are moving into the 2nd era of this evolution as we are now moving from 4G Long Term Evolution (LTE) technology to 5G. The future shift from 4G LTE to 5G will be focused more on self-optimized and self-managed transformation of technology where the networks and devices are more required to be configured and managed on their own, with accurate and improved decision-making capability along with efficient performance.

The advent of 5G technology demands not only better speed, lowered delay and increased capacity of bandwidth but also requires improved functioning on energy efficiency techniques, better spectrum handling, Self-Organized Networks management, Virtualization and moreover better Radio Resource Management (RRM) strategies/techniques. On the other hand, there is much work been done to improve the cellular structure of wireless networks to reduce the delay and interference from the network. We can also predict that based on other researches that future networks will be more kind of hybrid networks where 4G LTE and 5G will be implemented in coordinated manner. Thus, requires new algorithms, techniques and scenarios to be implemented for better coping up with new challenges in the field of technology. [1]

The future networks would be more comprised of low power small cells along with macro cells. The femto / Pico cells will be responsible to collect information/data and transmit it to the base stations (Macro) for further processing. Machine learning algorithms are found to be more robust and workable. For the supervision of resources over network the decision support systems have proven to be very useful when we consider intelligent Decision Support Systems (DSS) using Machine Learning (ML) techniques in obtaining new knowledge or to adapt to the dynamically changing environment. [2]

In accordance with the prior discussion it can be deduced that because of heterogeneity of networks i.e. small cells overlaying the macro cells will result in seamlessly ubiquitous connectivity, improved coverage and capacity of networks due to which cellular traffic will also increase thus will give rise to interference, increased delay, insufficient spectrum, energy and power efficiency issues on top.

The rest of the paper is organized as follows:

Section II focuses on Self Organized Network (SON) mechanism, the need and importance of SON mechanism that can help to optimize performance of network.

Section III discusses radio interference issues, its causes and mitigation techniques that can be used to avoid or mitigate interference caused by dense Heterogenous Networks (HetNets).

Section IV presents different approaches and techniques of performing efficient resource allocation and management in dense networks.

Section V discusses the role of Machine Learning techniques that can be applied in performing effective resource allocation and management in dense networks by using unsupervised learning techniques.

Finally, concluded the review and given a useful paradigm for further future ML techniques that can be used to manage radio resources in wireless sensor networks.

Table 1 Mapping Performance Metrics on Parameters of Load Balancing.

Effect on Performance Metrics	**Parameters for Load Balancing**
Increased Signaling Overhead	User's position
Increased Signaling Overhead	RSS information
Increased Delay	No. of users simultaneously connected to a femtocell
Increased processing time for SON	Ratio of occupied resources
Increased Processing time for SON	Automatic neighbor relations
Improved Transmission Rate	Automatic cell Identity Management
Improved Transmission Rate	Mobility Robustness

II. SELF ORGANIZED NETWORKS (SON) FOR EXPLOSIVELY GROWING RADIO NETWORKS

As the technology is advancing so does the need of communication channels is also exceeding and in the coming days this requirement of interconnected and communicated devices will be increased by tremendous amount, as most of things that will be used by any individual will be a part of internet, thus, requiring more and more communication channels.

SONs are self-healing and self-optimizing networks, in the coming days as the percentage of traffic and calls both outdoor and indoor will be raised too high so there will be the requirement of automated and intelligent self-organized networks which is only possible if the algorithms from Machine Learning (ML) will be applied to intelligently manage and execute in a coordinated manner in a network. In [3] the author has worked on certain mechanisms to evaluate the location and position of indoor femtocell based UEs (User Equipment) through their power level variations due to mobility, and, real time RSS information from mobile terminal which measures UEs measurements through mobile application. Furthermore, to ensure the validity and accuracy of these measurements RSS fingerprint database of indoor environment will be maintained and provide a stable estimation of RSS. Though, it is not mentioned that either the focus is on distributed, centralized or hybrid SON.

A. Parameters for Load Balancing

The mobility load balancing algorithm that can be designed, will based on the parameters as highlighted in the Table 1, the table shows the effect on performance of network changes made by load balancing parameters.

Potential SON function conflicts and resolutions into a real femtocell deployment, to avoid false positives, the UE position information accuracy is very important. Self-optimization is performed by introducing a load balancing mechanism that focuses on indoor environments and temporary overloaded situations.

Thus, Mobility Load Balancing (MLB) will be performing continuous analysis of network, by updating the information after every 5 seconds. [3]

The next focused parameter is the average transmission power variation which is given by Avg. ΔP for each femtocell. Whenever the power of any femtocell rises from the suggested power the load will be shifted to the neighboring femto cell with low power.

Successful transmission rate can alternatively be calculated as rate of transmission failure. Among static users considering real time scenario there is less power variation initially without applying optimization but when the no. of simultaneous connected users reaches the maximum number the load will then be shifted to Femtocells with less load implementing the MLB technique. [3]

III. RADIO INTERFERENCE MANAGEMENT (RIM)

Interference is an important issue when we consider dense networks, as with the increase of traffic density the problems of signaling overhead and data congestion also increase and that leads to interference both indoor and outdoor. Specifically, when we consider small cell networks then due to reduced distance between the Femto Access Points (FAPs) the chances of increased interference rise even more with strong frequencies.

In [4] the two main techniques that are discussed of deployment of FAPs are separate channel and co channel deployments. Separate channel deployment involves a devoted channel allocation to femtocell network whereas, co channel deployment involves shared channels among macro and femto cells within a dense network. Upon analyzing these two techniques we can find out that separate channel will result in reduced interference but is happens to be a costly solution and

nonrealistic considering the high cost of bandwidth assigned to individual access points in dense network. Therefore, co channel deployment is preferred but it requires interference mitigation as there are more chances of femto-macro interference to occur.

Considering the architecture/structure of small cell network in 5G networks, it is deployed in two layers the first and upper layer is the traditional macro cell layer and the lower layer will be of femto access points (FAPs) femtocell layer. Because of implementation of this architecture serious interference issues occurs. These issues can be managed using different techniques and controlling different parameters that would result in reduced interference.

This issue will be mitigated if the upper layer will be implemented based on separate channel deployment and the lower layer will be implemented based on co channel deployment.

A. Interference Mitigation Techniques

Interference Avoidance can be made by using one of the following techniques or a hybrid of any two techniques.

i. Spectrum Splitting
ii. Power Control
iii. Time Hopping
iv. Spectrum Arrangement Schemes

B. Distributed Interference Management

The femto access points (FAP) resolves problems of 5G traffic performance but, gives rise to many optimizing challenges as well. That leads to the major problem of interference which further breaks into two broad categories.

i. Co – Tier Interference
ii. Cross – Tier interference

Interference between femto – femto cells is considered as co tier inference, and interference between femto – macro or femto – Pico is considered as cross tier interference. Radio signals via macro cells are considerably weak in indoors due to path loss, lognormal shadowing and fast fading effects. [4]

Thus, these are the few reasons due to which in near future all the scientists have their eyes on femtocells and millimeter waves. As the data traffic will become ultra-dense and congested. So, it requires some mechanism that would work efficiently in indoor environments. Large cells can be split into small cells through various ways.

As, we discuss about femtocells and macro cells then a topic of major concern under research by many researchers is the issue of proper resource allocation in dense areas within a cell and its neighboring region.

Numerous techniques are used to handle interference in separate channel and co channel deployments. The two approaches that can be utilized for reducing interference includes, ***user centric approach i***n which the focus is on the criteria that the users get all the required resources allocated to verify the user's satisfaction. Whereas, ***the system centric*** approach focuses more on QoS and can be further classified into Radio Adaptive System that maximizes the user satisfaction and Margin Adaptive System that emphasizes on minimizing the transmission power of femto base stations to mitigate interference. [5]

In [5], the author has suggested FERMI (Femtocell Resource Management for Mitigation of Interference) technique, focusing optimized resource allocation more appropriate for commercial purpose rather than residential purpose. Techniques as seen in different research works include frequency splitting technique, clustering algorithms, access control, fractional frequency reuse (FFR) i.e. done by dividing the coverage area into sub zones.

C. Orthogonally Inference Avoidance

Orthogonal frequency division multiple access provides a better solution to mitigate interference because in OFDMA the spectrum is orthogonally sub divided into sub carriers that are further grouped into sub channels providing variations in both frequency and time domain to avoid interference. [11]

An experimental evaluation is conducted in [11] based on system level simulations emphasizing on orthogonal and co channel assignment of channels. The network of two macro cells and many femtocells using Adaptive Modulation and coding scheme closed access method is been used, has resulted in optimally avoiding the interference problems thus, the chances of interference to occur would increase with increased number of users allocated to same sub channel or OFDM symbol.

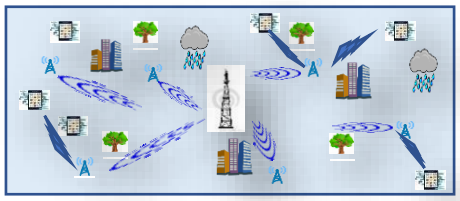

Fig. 1 Macro cell transmitting signal to Small cells and Small cells are successfully transmitting signals to the focused devices providing Quality of Service (QoS) to users.

The orthogonal spectrum fragments assignment will reduce the cross- layer interference and able to work well with low load over the network. Thus, the fragment size should be properly planned to the traffic forecast for each layer.

However, the co-channel deployment efficiently manages the capacity issues, due to larger spectrum availability. But, the problem of cross layer interference persists.

IV. RESOURCE ALLOCATION

Radio resource management has great importance concerning service availability and efficiency, as accurately evaluated hand offs can result in less chances

of interference to occur between devices. There are two approaches ***user centric approach*** in which the focus is more on the user satisfaction providing enough bandwidth to the resources. Whereas, ***the system centric*** approach focuses more on quality of service and it is further classified into Radio Adaptive System that maximizes the user satisfaction and Margin Adaptive System that emphasizes on minimizing the transmission power of femto base stations in order to mitigate interference. [7]

One thing that has been seen in many researches is that the management of resources is preferred to be controlled in automated self-optimized manner rather than preprogrammed or manual. Which can be done by using different distributed algorithms performing joint optimization of radio resources in HetNets. [8]

With the advent of 5G networks to fulfill this requirement of huge number of channels and strong signaling will be fulfilled by using small cell technology i.e. Femtocells. Though in outdoors the need can be fulfilled through macro cells but indoor requirements will be provided using Femtocells.

Femtocells are the newer version of small cells they look much like wireless access base stations, but that's where this similarity ends. This small unit contains the functionality of base stations but over a small package/chip.

In future femtocells will be used along with large cells though; macro cells and picocells are being used now days for communication over large and small distances respectively. The only difference between picocells and femtocells is that Pico cells are linked with a Base Station (BS) whereas; femtocell networks are linked with backhaul internet connection. Femtocells perform well for indoor deployments, as signal strength of macro / Pico cells weakens when it penetrates through walls, also the attenuation increases which eventually effects the received signal strength (RSS).

Small cells are low powered wireless base stations. In future small cells will be used along with large cells though; macro cells and picocells are being used now days for communication over large and small distances respectively. Small cells perform well in indoor environments, as signal strength of macro / Pico cells weakens when it penetrate through walls, also the attenuation increases which eventually effects the received signal strength (RSS). [9]

With the advent of 5G there are 5 main technologies that are emerging:

i. Millimeter wave
ii. Small cells
iii. Massive MIMO
iv. Beam Forming
v. Full Duplex

Millimeter (MM) Waves will allow us to use more and radio devices over the assigned spectrum. According to researches that have been conducted so far, MM wave will include the frequencies that are never used for mobile devices earlier, which includes frequencies from 30 to 300 GHz. But, the major issue with these waves is that, MM waves can't

pass through buildings and other obstacles also there are chances that these waves might get absorbed by rain or plants. And if this happens then it will be very difficult to use MM waves for communication purposes.

This problem can be solved by deploying thousands of low powered small cell Base stations with much closer distances, forming a kind of relay. To transmit signals around the obstacles, which certainly be very useful in cities where, the UE will automatically switch from one BS to another while the device is moving. As shown in Fig. 1.

The deployment of these small cells can be made more effective by introducing massive MIMO to BSs.

As the antennas send out signals in all directions (Orthogonally) and when there will be hundreds and hundreds of ports on antennas then chances of interference between different channels will increase.

To mitigate these interference issues there are different ways to follow, out of which one way is beam forming technique. It's a sort of traffic signaling for cellular devices, which enables the ports to send signals in form of stream to a focused user on different frequencies, which eventually will reduce interference, this can be achieved by using signal processing algorithms. The signals between device and BS will be transmitted in full duplex fashion instead of conventional half duplex transmission of radio waves.

V. MACHINE LEARNING ALGORITHMS TO MANAGE RADIO RESOURCES

Machine learning has proven to be an effective way to build new techniques for self-optimized and self-configured wireless networks. As, wireless sensor networks should be able to adapt rapidly changing conditions of environment [8] and this is only possible when the designing of networks would be more implemented using machine learning techniques to avoid the need of unnecessary redesigning of networks [8]. Thus, it eventually would result in maximum resource utilization and prolonged life of network with dynamic configurations as much as possible along with prompt decision making capability of resources/devices.

Along with functionalities with which the performance and robustness of a network will improve, there are certain drawbacks too of applying Machine Learning techniques on Wireless Sensor Networks (WSNs). [8]

i. Increased performance accuracy of network will eventually demand increased availability of resources and thus would result in high energy consumption, when we speak of highly dense networks.

ii. In WSN the resource management evaluation algorithm will focus more on smaller data samples as compared to the actual scenario where networks are large and dense. Thus, such experimentational results will have smaller error bounds, and thus the algorithm

designer will not have the full control over the algorithm accuracy when applied on large networks.

A. Categorization of ML Techniques

The two broad categories in which we can categorize machine learning algorithms are:

i. Supervised learning
ii. Unsupervised learning

i. Supervised Learning

Supervised learning deals with labelled training data sets, thus, its more focus is on the learned system with known input, output and known parameters used.

Thus, supervised learning techniques in WSNs for resource management can be used for levelling resources, event detection, query processing, intrusion detection and evaluating quality dimensions kind of data. Techniques of Supervised Learning include: [8]

i. K – Nearest Neighbor
ii. Decision Tree Analysis
iii. Networks
iv. Support vector Machines
v. Bayesian Statistics

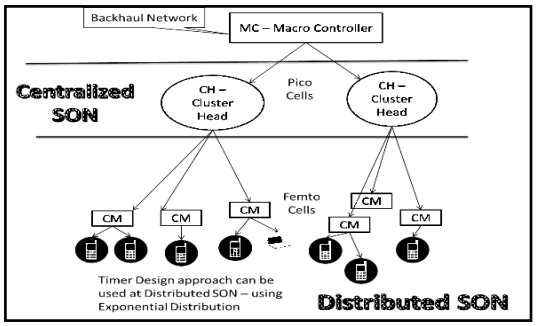

Fig. 2 A Clustered HetNet.

ii. Unsupervised Learning

Unlike supervised learning the unsupervised learning techniques are used to categorize and cumulate unlabeled data based on certain specifications as proposed. Clustering techniques is the most commonly used technique under unsupervised learning approach.

Clustering

When we consider Radio Resource Management in highly dense networks then it demands the availability of such kind of network where most of its operations will be performed in a self-organized and self-optimized manner for lowering the delay component in network communications. Considering ML techniques, the unsupervised Clustering technique can be used to perform clusters in dense networks that are self-managed and self- optimized. Thus, radio resources can be managed efficiently if categorized in form of clusters i.e. cluster based resource allocation mechanism.[5] In this way, the clusters will be assigned cluster heads managing their own cluster respectively, through some self-optimized algorithm. Within every cluster there will be Cluster Heads (CH) that managing and controlling their local cluster resources. Also, this CH will be responsible for assigning resources to FAPs [5]. In Fig. 2, we can see that Macro controller act as a Backhaul Network to provide internet services to the femtocell i.e. through Pico Cells where Pico cells are acting as Cluster heads of individual clusters thus, controlling and managing resource allocation to femto units.

Pico cells are selected as clustered heads due to their increased range when compared with femto cells. Though they require more power and result in more energy consumption when compared with femto units. Thus, to optimize this solution the LEACH Protocol

LEACH can be used to manage clusters and cluster heads. Where, FAP are the Cluster Members (CM) within a single cluster. It is a Time Division Multiple Access (TDMA) based hierarchical Medium Access (MAC) protocol in which the nodes are transmitted to cluster heads and the CHs are responsible for aggregating and managing resources within the clusters. Based on the residual energy level, the cluster heads are formed randomly and takes other nodes in their cluster that are within the energy range of cluster head. Those nodes will then be considered as CM of that cluster. The communication between the CM and CH will performed in TDMA fashion, requiring the CM to be active only in their respective time slot. The CHs will collect information and transfers it to sink in our proposed concept macro controller will act as Sink.

The protocol will work in the fashion as given in Fig. 3, thus, LEACH protocol works in the fashion of rounds; each round comprises of two states the setup state and the steady state [13]. First state is basically the self-adaptive cluster formation mode and the second round is the data transference mode. Second phase is of longer duration than the first phase.

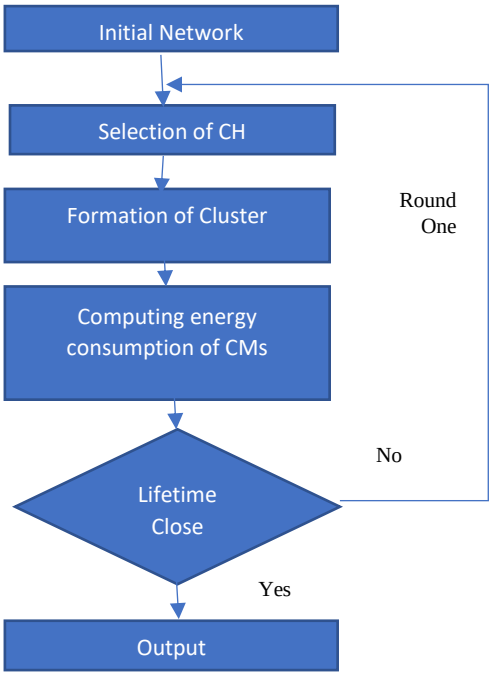

Fig. 3 Flowchart of LEACH protocol.

LEACH protocol randomly selects CH in every round [13] which suggests that there is a possibility that same node will be selected as CH more than once and would exhaust energy quickly than other nodes.

This problem can be resolved if we label data in some way that there will be labeled CHs or CHs of more power would be used to aggregate cluster members. This protocol is proven to increase the lifetime of sensor networks by lowering the energy consumptions and managing the traffic over network in a well-organized manner. Table 2 shows different parameters that are focused in recent research papers to perform clustering based on different techniques. From Table 2 we can analyze that the parameters Delay, QoS, MIMO, Cloud and Energy Efficiency are the less focused areas in managing radio resources for 5G networks.

Table 2 Different Parameters that are focused in different recent researches to perform clustering.

S. No.	Referenced Paper	Year	Delay	Data rate	Capacity	QoS	Mobility	Interference	MIMO / Noma	Beamforming	Clustering	SON	Load balancing	Power	Cloud	Energy efficiency
1	[14]	2014			√	√		√								
2	[15]	2013											√			
3	[3]	2015			√							√	√			
4	[16	2012						√								
5	[17]	2016			√			√								
6	[18]	2013						√					√			
7	[7]	2014			√											
8	[8]	2011		√										√		
9	[11]	2011		√				√		√	√					
10	[13]	2014		√				√			√			√		
11	[19]	2011		√				√		√	√					
12	[20]	2014					√	√		√	√					
13	[21]	2017		√					√					√		
14	[22]	2017		√									√		√	
15	[23]	2014											√			
16	[24]	2017				√	√				√		√		√	
17	[25]	2015			√		√						√			

VI. CONCLUSION

Performing Radio Resource Management in dense HetNets is an effort taking task especially when one wants to achieve optimized performance results. In this research, the overview of few major dimensions is being given that has to be considered while managing resources for HetNets. Among which clustering, an unsupervised ML technique can be used to categorize nodes and manage traffic effectively among nodes. For which, LEACH protocol can be used in combination with few supervised learning techniques i.e. forming a hybrid of techniques to efficiently manage resources over dense networks.

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