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Survey Paper on Combination of LB Optimisation and ICIC in LTE Self-Organizing Networks

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Abstract: With the advances in the cellular networks, which introduces the technologies such as GSM, HSPA, Evolved HSPA, Wimax, Long Term Evolution (LTE), LTE-Advance (LTE-A) the automation of the network management functions will be very helpful in the efficient operation of large communication networks. SON will play major role in minimizing human intervention which in turn reduce management cost and manual errors. There are multiple benefits are defined for SON. Few among them are Self configuration of base station, ANR-Automatic Neighbor Relation, Physical Cell Identifier (PCI) Planning, Load Balancing(LB), Handover Optimization or Mobility Robustness, Random Access Channel (RACH) Optimization, Inter-Cell Interference Coordination (ICIC), energy savings, Coverage and Capacity Optimization (CCO) and Interference Over Thermal Control. In this paper we discuss about the benefits of ICIC feature of SON and related work which happened on this feature of SON.

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INTRODUCTION

In some of the today's mobile wireless network, many elements are configured manually which are error-prone. For a reliable network from planning to maintenance which includes commissioning, configuring and integration are the essential parameters for efficient and reliable network operations. Many times manual tuning process are time consuming, this will act as a bottleneck in rapidly changing network topology. This results in reduction of network performance. Self-Organizing Networks will overcome these limitations and improve the network performance [6].

We have seen a lot of application development during these days, which demanded heavy data rate on mobile networks. We have seen the prolific growth of data traffic due to new generation gadgets and applications. The applications shift the traffic pattern from being data centric to video centric. These above reasons driven development cellular technologies which can provide higher data rates. 3rd Generation Partnership Project(3GPP) LTE protocol is one of the technologies which is developed to provide higher data rate. The higher data rate demand brings the challenge of utilizing spectrum as efficient as possible. One of such approach to utilizing spectrum efficiently is to use LTE heterogeneous networks or small cells. Small cells can be referred to denote femto or picocells. Due to the limited coverage area of these cells, they are called as small cells (femto). Femtos can be used for indoor usage which can cover few tens of meter. With a small improvement of coverage area compare to small/femto cells, pico cells are defined. These pico cells can be used both outdoor or indoor depending upon capacity needs to be provided. The highest covering are cell will be called as macro base station. These macro base station will use high transmission power. Due its high transmission power property of the macro cell, the installation of the macro should be very well planned and executed. Macro cell can create lot of interference to femto/pico. These can be mitigated using almost blank sub-frame. The mitigation or reduction of ICIC is discussed in this paper using sub-band masking techniques.

LTE provide intra-cell orthogonality among the user of the same cell in uplink and downlink direction, due to this inter-cell interference act as main interference source in these kinds of systems.

In LTE, the frequency reuse factor is one, which means neighboring cells can use same available resources simultaneously. Because of this frequency reuse factor inter-cell interference puts limitations on the LTE throughput and efficient usage of spectrum, mainly to the users at cell edge. So to mitigate or cancel the effect of interference, we required a solid mechanism. In LTE, ICIC is a feature used to reduce the inter-cell interference. This paper focuses on inter-cell interference coordination between the cells which are neighbors and can cause interference to each other.

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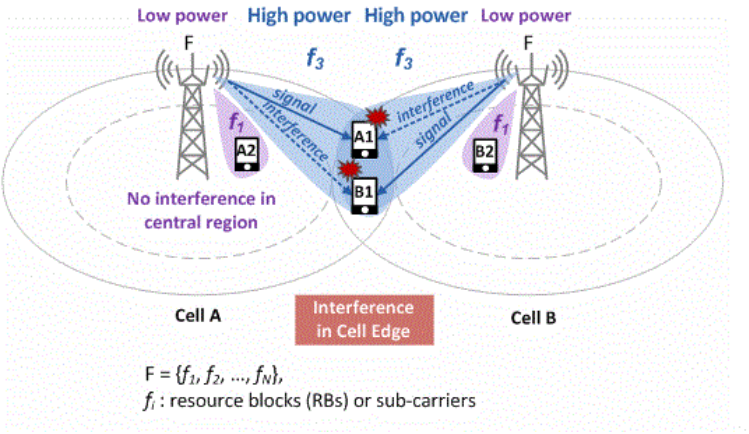

Figure 1: Without ICIC algorithm

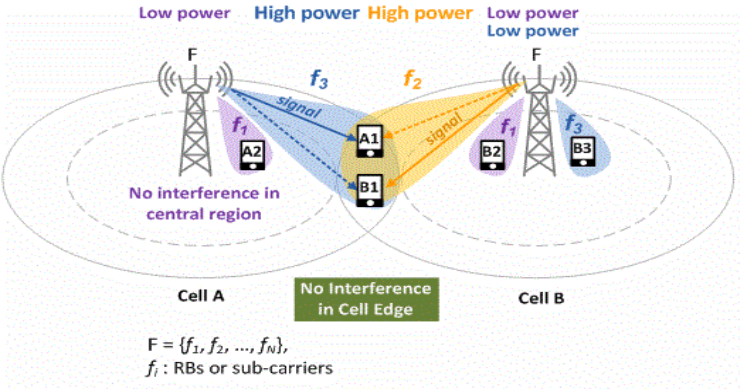

Figure 2: With ICIC algorithm

There are many scenarios exists which can cause interference. Such as one cell is transmitting with higher power than another. Here the user equipment (UE) which attached to the cell, which transmits with low power will get interfered. In another scenario, UEs can connect to a cell which is far in distance compare to other cell, only because the cell which is far is transmitting with more power. Thus, this can lead the underutilization of the cell which is transmitting with low power. This paper also shows how mobility information and loading information can be utilized in inter-cell interference coordination.

Interference is problem in both uplink and downlink direction. In this paper we are discussing about the DL interference reduction. There are multiple papers which will discuss about the UL interference reduction also.

INTER-CELL INTERFERENCE COORDINATION

What causes Inter-cell Interference?

As discussed already, the one of the major cause for reducing data rate is interference. Inter-cell interference can happen when UEs from neighbor cells try to access same resource at the same time. Interference is mainly experienced by cell edge user. If same resources are allocated to UEs which are at cell edge due to their high power of communication these UEs can create interference to each other.

To explain the inter-cell interference we can take example of two neighboring eNBs. Both operating at same frequencies. Each eNB is having a UE which uses same resource. If these two UE are at the center of cell, there will not be any interference to each other. This is because both UE uses low power to communicate with respective eNBs. If both UEs are at cell edge each other can create interference, this is because both will be communicating with high transmission power[9].

The above explanation can be clearly understood using the Figure 1. Where A2 and B2 are located at center of the cell and not creating any interference to each other. Where as in second scenario A1 and B1 are located at cell edge which is creating interference to each other.

From the above example we know that lack of knowledge about each others resources usage among neighboring cell can create interference and interference in turn downgrade the system to great extent. If we assume that each neighboring cells have the knowledge about usage of resource in its neighboring territory, then we can easily reduce the interference noticeable amount.

Now for instance if we assume that we have a intercell interference coordination algorithm, using this algorithm we can give a different resource to cell edge user. Cell A can give same f3 to user A1 and with the help of ICIC cell B can give f2 to user B1. As shown in the Figure 2.

ICIC Frame Work

Release 9 of the 3GPP has defined ICIC feature to coordination among the cell which causes interference to each other. Interference can be reduced by allocating the different resources to UEs belonging to different cells at the same cell edge. The important point here to consider is communication between neighboring cells. How the interference data will be passed between each neighbors. There are multiple approaches suggested by multiple Some suggested using of X2 interface as communication mechanisms. There are other approaches where using of centralized entity to collect the information and take the decision to reduce the interference.

In this paper we will discuss the possible centralized entity which can collect the information form various stake holders which actively participate in the interference creation. Such as eNBs, UEs and some other RF configuration entities.

LITERATURE SURVEY

Inter-cell interference act as one of the prime limiting factor for achieving higher throughput, mitigation and cancellation of this has received huge attention. 3GPP has guided the mitigation of interference but has not given any clear specification which can be followed. Due this point various authors has published many papers on this topic. Our approach here is to have a careful review of each paper.

The authors in [1] provides an overview about inter-cell interference and comparison of methods exists, which are used to mitigate the interference. Specific importance has been given on implementation for LTE. The approach used is a combination of power control, adaptive fractional frequency reuse, inter and intra eNB interference cancellation and opportunistic spectrum access, these can be used to form a ICIC strategy for LTE. ICIC performance can be increased using antenna techniques such as adaptive beam-forming , SDMA, MIMO with new decoding algorithms. This paper has different use cases on fractional frequency reuse.

In [2], authors investigated the self optimizing strategies for interference management in downlink direction of LTE. Major schemes considered are fractional frequency reuse, dynamic fractional load and power control. First and last scheme is based on continuous power control while the remaining is on switching of frequency subbands. In proposed algorithm using the X2 interface, LTE neighbors used to exchange the information. The distributed algorithm uses the information exchanged and closed formulas to achieve performance gain.

As discussed above, there are few papers which discussed about the interference co-ordination scheme in uplink. In [3], the authors present usage of high interference indicator (HII) for uplink interference coordination. HII indicates UL interference to other cell. In earlier ICIC techniques which uses HII, cells suffering from inter-cell interference receives same HII. The proposed approach simplifies two uplink coordination method as a which will improve the spectral efficiency of the system.

In [4] the authors address the problem of ICIC in DL direction of LTE with portraying power level selection of RB as sub-modular game. In this paper the proposal is for semi distributed algorithm based on best response algorithm. With the help of X2 eNBs can select low interference RB allocation.

3GPP has introduced enhance ICIC which will mitigate the interference in heterogeneous networks. In [6] author throws a light on how spectrum used between macros which are transmit with high power and low power picos. The two challenges discussed here are the about the determination of radio resource that macro cell should need to offer pico-cell, And determining which UEs can connect to pico cells Here the author discuss about solving the above two problem with join combination of almost blank subframe and Cell Selection Bias.

In [8] author provide the mathematical formulation for ICIC in 3GPP SON. Author discussed about the importance of ICIC in SON. Author proposed ICIC using autonomic, distributed, context-aware, knowledge-based and policy driven

In [10] authors provided with a overview of heterogeneous networks and how ICIC plays a major role in heterogeneous networks. In this paper release 10 features of the 3GPP has been explained which describe more of almost blank subframes (ABS) on time-domain multiplexing (TDM). There are some overview provide with Carrier Aggregation (CA) which will be used to increase the data capacity of the system.

After investigating carefully, above mentioned literature, we can draw a conclusion to have a common framework, that can support features which are missing, such as subband masking based on the load of the system by the help of self-organization, learning capability.

PROPOSED APPROACH

The approach adopted in this paper will be on centralized approach. Self-Organized Networks (SON) module act as centralized entity which will control most of the RF associations among all the connected eNBs. There can be N number of eNBs connected to SON. Each eNB will provide service to its connected UEs. So SON will be having the complete information about the system.

On a configured basis UEs will send measurement reports, channel quality reports and other RF related information to its

connected base stations. eNBs can send these information to SON on periodic basis or on demand basis.

SON module will collect all the radio related information from its connected eNBs. There will be provision also provided to identify the UE which sent measurements. As the SON has all the information it needed it can apply any algorithm to increase the performance of the system.

As explained above, there can be multiple inputs SON can consider for its own algorithms. For the reduction of interference, identified inputs are Channel Quality Indicator (CQI) reporting and neighbor measurements. CQI is a Medium Access Control(MAC) control element in LTE. This Information Element (IE) will gives detailed information about channel which UE is seeing. Channel quality information will gives a lot of information about channel seen by the UE. If UE is feeling the interference the CQI values will be very bad for that channel. This vital information will be helpful in understanding the radio condition.

One more important parameter is about neighbors information. As we have seen in the example above that the neighbors which are using the same band can create a lot of interference to each other. The neighbor information in LTE can be configured by eNB. UE will read the request and perform the measurements. Depending upon criteria given by eNB, UE generate the measurement report. In the LTE there are number of measurement and reporting criteria defined. Depending upon what kind of report received from UE, a lot of information cab be extracted from reports. Measurement reports will give useful information about the neighboring and serving cell which can be helpful to take the decision that how strong UE can able see other eNBs.

The centralized algorithm will collect above information from connected eNBs, which inturn get these information from respective UEs which are connected to eNBs. The algorithm which present in SON will run for periodically. This algorithm produces a masking value which can be used for subband masking.

Interfering eNBs will be identified, SON will guide the eNBs to mask specific subband which is creating interference. Subband masking value will be passed to eNBs. Masking value will be applied on specific subband. ENB is not allowed to use that subband for transmitting any thing.

CONCLUSION

This paper has provided the overview of inter cell interference and its effect on the LTE and other networks. This article even discussed and reviewed the mitigation techniques used in the industries which can be used in the LTE OFDM technologies, which includes fractional power control, adaptive fractional frequency reuse, adaptive beam forming inter and intra base station interference cancellation.

This article discussed about the possible centralized module which can take advantage of existing methodologies and messages exist in 3GPP to provide a robust inter cell interference algorithm. This module takes the existing KPI (Key performance Indicators) from the eNBs to derive sub-band mask.

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