A Comprehensive Survey on Various ICIC Schemes and Proposed 3G RF Interference Mitigation Techniques for OFDM Downlink on Cellular Networks

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Abstract

The demand for cellular communication services is expected to continue its rapid growth in the next decade, fuelled by new applications such as mobile web-browsing, video downloading, on-line gaming, and social networking. The commercial deployment of 3G. Cellular network technologies began with 3GPP UMTS/WCDMA in 2001 and has evolved into current UMTS/HSPA networks. To maintain the competitiveness of 3GPP UMTS networks, a well-planned and graceful evolution to 4G networks is considered essential [1]. LTE is an important step in this evolution, with technology demonstrations beginning in 2006. Commercial LTE network services started in Scandinavia in December

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Index terms—

1 Introduction

he demand for cellular communication services is expected to continue its rapid growth in the next decade, fuelled by new applications such as mobile web-browsing, video downloading, on-line gaming, and social networking. The commercial deployment of 3G. Cellular network technologies began with 3GPP UMTS/WCDMA in 2001 and has evolved into current UMTS/HSPA networks. To maintain the competitiveness of 3GPP UMTS networks, a wellplanned and graceful evolution to 4G networks is considered essential **??**1]. LTE is an important step in this evolution, with technology demonstrations beginning in 2006. Commercial LTE network services started in Scandinavia in December 2009 and it is expected that carriers worldwide will shortly be starting their upgrades. The main design goals behind LTE are higher user bit rates, lower delays, increased spectrum efficiency, reduced cost, and operational simplicity **??**2]. The first version of LTE, 3GPP Release 8, lists the following requirements:

(1) Peak rates of 100 Mbps (downlink) and 50Mbps (uplink); increased cell-edge bit rates. (2) A radio-access network latency of less than 10ms.

(3) Two to four times the spectrum efficiency of 3GPP

Release 6 (WCDMA/HSPA). (4) Support of scalable bandwidths: 1. **??**5, **??**.5, **??**, **??**0, **??**5, **??**nd 20MHz; support for FDD and TDD modes; smooth operation with and economically viable transition from existing networks. In order to meet these demanding requirements, LTE makes use of multi-antenna techniques and inter-cell interference coordination.

A survey of radio resource scheduling and interference mitigation in LTE. Both are widely recognized as areas which can greatly affect the performance and spectrum efficiency of an LTE network. Inter Cell Interference (ICI) still poses a real challenge that limits the OFDMA system performance, especially for users located at the cell edge. A common Inter Cell Interference Coordination (ICIC) technique is interference avoidance in which the allocation of the various system resources (e.g., time, frequency, and power) to users is controlled to ensure that the ICI remains within acceptable limits. This section present surveys various ICIC avoidance schemes in the downlink of OFDMA based cellular networks and makes use of these classifications to categorize and review various static (frequency reuse (FR)-based) and dynamic (cell coordination-based) ICIC schemes.

A comprehensive survey that investigate such wide range in the area of ICIC as an attempt to resolve ambiguity by providing precise classification in the research community is also presented. For next generation of mobile communication systems; LTE is being standardized by the 3rd Generation Partnership Project (3GPP) ISO; some proposed 3G RF interference mitigation techniques is provided. The trend toward LTE commercial launch in Heterogeneous Network (HetNet) environment and the future plan for LTE -Advanced new releases is highlighted **??**1].

The next generation wireless systems are proposed for Intelligent Transportation System (ITS) and the applications of proposed ITS are intended to use for wideband digital communications such as: broadband wireless internet access digital television, audio broadcasting, and video conferencing, real-time video security, communication for high speed trains. One of the techniques which are proposed for new generation in wireless communication system is OFDM; which is used to transmit data over extremely hostile channel at a comparable low complexity with high data rates. Next generation cellular systems promise significantly higher cell throughput and improved spectral efficiency as compared to existing systems such as GSM, EDGE, and High Speed Packet Access R.7 (HSPA+). For example, system performance requirements for the 3GPP, LTE of UMTS and LTE-A target significant improvements in cell edge spectral efficiency and peak transmission rates that can reach, respectively, 0.04-0.06 bps/Hz/cell, 100 Mbps and beyond **??**2].

In order to achieve these targets, dense frequency reuse of the scarce radio spectrum allocated to the system is needed. Efficient use of radio spectrum is also important from a cost of service point of view, where the number of served users is an important factor. However, as the frequency reuse increases, so does the interference caused by other users using the same channels. Therefore, interference becomes a decisive factor that limits the system capacity, and hence, the suppression of such interference becomes of a particular importance to the design of next generations cellular networks.

2 II.

3 Problem Statement

As a result of several researches has been published, there is no existence to a comprehensive survey that investigates to the wide range of ICIC avoidance schemes. Moreover, there have been several confusions between the various ICI schemes; either in their naming conventions or their operational principles due to the large number of published work in this area. For example: some published work uses the notion of "Partial Frequency Reuse (PFR)" [2] while others use "Fractional Frequency Reuse with full isolation (FFR-FI)"

[3] to refer to the same scheme. Also some published work refers to the well known "Reuse-3" scheme as "Hard frequency reuse" [3], the notion of "Soft Frequency Reuse (SFR)" was originally proposed in **??**2] with a particular definition, whereas in [4] a different scheme was introduced with the same name of "Software Frequency Reuse (SFR)". This raises the need to present a comprehensive coverage of this fast moving field. Also, wireless communications and mobile computing provides the research and development communities working in academic tele-communications and networking industries with a forum for sharing research and ideas. On the other hand, the 3G RF interference in HetNet environment as in Fig. 1 and its mitigation techniques used become a hot research area now for multi-cell interference avoidance in OFDMA systems as no recent new techniques were proposed. The Small cells, Pico cells and femto cells represent a promising solution to enhance network performance with a pervasive coverage at low cost and energy consumption. Small cells stand for small size cells that can be deployed in indoor or outdoor environments and are based on existing or emerging cellular wireless network standards (such as WiMAX, UMTS and LTE). The convergence of wireless communications and mobile computing is bringing together two areas of immense growth and innovation.

4 Previous and Related Work

In this section, a brief review on the main previous survey published researches related to the interference avoidance schemes. In ref.

[3] a performance of a Turbo coded OFDM wireless link is evaluated in the presence of Rayleigh fading for SISO, SIMO, MISO and MIMO system. Data are encoded using turbo encoder then modulated by QPSK or 16 QAM or 64 QAM and further encoded using STBC, and the encoded data are split into "n" streams which are modulated by OFDM and simultaneously transmitted using "n" transmit antennas and the results showed the coded MIMO-OFDM has a significant difference over un-coded schemes, in ref. **??**4], the channel allocation schemes has been classified to three categories: Fixed Channel Allocation (FCA), Dynamic Channel Allocation (DCA) and Hybrid Channel Allocation (HCA).

A summary of the three categories descriptions of channel allocation schemes are: FCA: A set of nominal channels are permanently allocated to each cell for its exclusive use. Where channels can be allocated to cells either uniformly (equal shares) or non-uniformly (based on expected traffic loads) with the option of allowing cells to borrow channels from one another.

DCA: A set of nominal channels are permanently allocated to each cell for its exclusive use. Where channels can be allocated to cells either uniformly (equal shares) or non-uniformly (based on expected traffic loads) with the option of allowing cells to borrow channels from one another. HCA: Presents a mixture between FCA and

DCA where the total number of channels available is divided into fixed and dynamic sets. The fixed set is assigned as in the FCA schemes while the dynamic set is shared by all cells.

While in ref.

[4] four categories are proposed for interference avoidance schemes based on how much it adapts the network to Static Schemes (SS), Low Level Dynamic Schemes (LLDS), Intermediate Level Dynamic Schemes (ILDS) and High Level Dynamic Schemes (HLDS). The results showed that as the degrees of freedom increases the total throughput and 10% throughput increase. A summary of the different categories between interference avoidance schemes.

5 SS:

The best values for the different parameters (power ratio allocated to each user class, number of sub-bands allocated to each user class, frequency allocated to each cell) are determined based on full traffic load scenarios and then these values are kept fixed. LLDS: As the best values for the different parameters may not always be ”best” with different traffic loads, several pre-planned sets of best values for the different traffic loads and varied distributions of users. Given that BSs can know the total number of user and there are reliable and efficient connections between BSs, a scheme can switch based on the traffic load between two or more sets of best values each optimized for a certain traffic load. ILDS: Given the serving user's quantity in each cell and locations of users in its own cell data available to the BSs, BSs calculates the best values for the different parameters to escape the limitation of using one of the pre-planned best value sets in LLDS. HLDS: Require the availability of the channel condition information. It works similarly to ILDS to calculate the best values for power ratio, the sub-band number and allocation of frequency but it also calculates the number of sub-channel to be allocated to each user based on its channel condition.

In ref.

[5], a survey on resource allocation algorithm for downlink of multi-user OFDM system is presented, however a single cell was assumed, thus ICI and ICIC for the downlink were not discussed.

In DCA and based on information used for channel assignment, DCA schemes can be classified either as call-by-call (use only current channel usage conditions) or adaptive (use previous as well as current channel usage conditions), while based on the type of control employed, schemes can be classified either as centralized (a centralized controller assigns channels to users) or distributed (base stations assigns channels to users). Distributed DCA schemes can be either cell based (base stations use local information collected from users and the exchanged information from other base stations) or adaptive (base stations rely only on the signal strength measurements collected locally from its users). Although many claims have been made about the relative performance of each DCA scheme to one or more alternative schemes, the trade-off and their range of achievable capacity gains are still unclear, and questions remain unanswered: How does each dynamic scheme produce its gain? What are the basic tradesoff? Why do some schemes work only under certain traffic patterns? Can different schemes be combined? What is the value of additional status information of the nearby cells? What is the best possible use of the bandwidth **??**2].

IV.

6 Proposed System Model Interference Coordination in Spatial Domain

The channel throughput is determined based on the used Modulation and Coding Scheme (MCS) for a channel (selected based on the Channel Quality Indicator (CQI) reported from the user) as a method for computing and transmitting channel quality information in a multi-carrier communications system which is mapped to the Transport Block Size (TBS) that can be used by using the mapping tables, in a method to perform link adaptation at the radio interfaces. Since different users perceive different channel qualities, a ”bad” channel (due to deep fading and narrowband interference) for one user may still be favorable to other users. Thus, OFDMA exploits the multi-user diversity by avoiding assigning ”bad” channels, which is an important feature in OFDMA. In OFDMA systems, ICI is caused by the collision between resource blocks. With such collision model, the overall system performance is determined by the collision probabilities and the impact of a given collision on the Signal to Interference and Noise Ratio (SINR) associated with the colliding resource blocks. ICIC mechanisms aim at reducing the collision probabilities and at mitigating the SINR degradation that such collisions may cause in order to improve the system performance and increase the overall bit rates of the cell and its cell edge users. Generally, ICIC techniques can be classified into mitigation and avoidance techniques. In interference mitigation, techniques are employed to reduce the impact of interference during the transmission or after the reception of the signal **??**5]. In order to achieve the goal of coordinating transmissions in neighboring cells, IFCO is a powerful tool to solve the problem of ICI in cellular networks and may control over various different resources and variables in the cellular network based on various common input parameters and controllable V.

7 Interference Avoidance Schemes Classifications

A wide range of techniques are presented in order to improve the throughput of the cell-edge users by reducing or suppressing the ICI. Interference mitigation techniques includes:

(1) Interference randomization (where some cell-specific scrambling, interleaving, or frequency-hopping (spread spectrum)).

(2) Interference cancelation (where the interference signals are detected and subtracted from the desired received signal, or if multiple antenna system is employed, the receiver can select the best quality signal among the various received signals) ??6].

(3) Adaptive beam-forming (where the antenna can dynamically change its radiation pattern depending on the interference levels). Interference avoidance schemes represent the frequency reuse planning algorithms used by the network elements to restrict or allocate certain resources (in both frequency and time domains) and power levels among users in different cells. The objective of these frequency reuse planning algorithms is to increase the SINR, and hence, allow the system to support as many users as possible. These frequency reuse planning algorithms must satisfy the power constraint in each cell by ensuring that the allocated transmission power of an Enhanced NodeB (eNB) does not exceed the maximum allowable power. A fundamental concept common to most interference avoidance schemes is to classify users in the cell based on their average SINR to a number of users' classes (also known as "cell regions"). Interference avoidance schemes then apply different reuse factors to the frequency band used by the different classes of users (i.e, to different cell regions). Fig. 3 depicts the various types of interference avoidance schemes.

8 VI.

9 Fractional Frequency Reuse

One of the fundamental techniques to deal with the ICI problem is to control the use of frequencies over the various channels in the network. Frequency reusebased schemes include: conventional frequency planning schemes (Reuse-1 and Reuse-3), FFR, PFR, SFR. Despite their differences, all frequency reusebased schemes need to specify the followings:

(1) The set of channels (sub-bands) that will be used in each sector/cell. (2) The power at which each channel is operating.

(3) The region of the sector/cell in which this set of channels are used (e.g., cell-centre or cell-edge) ??7]. Different schemes define different values and approaches for these various parameters. Accordingly, an identification of a unified structured description for any frequency reuse-based scheme. Such structured description will not only simplify the expression of various schemes, but it will also reduce ambiguity in understanding some of the subtle schemes. To avoid the shortcomings of the conventional frequency reuse schemes, the FFR scheme is introduced to achieve a FRF between 1 and 3. FFR divides the whole available resources into two subsets or groups, namely, the major group and the minor group. The former is used to serve the cell-edge users, while the latter is used to cover the cell-center users ??8].

10 VII.

11 Fractional Frequency Reuse Main Classes

The FFR scheme can be divided into three main classes: PFR: A common frequency band is used in all sectors (i.e., with a frequency reuse-1) with equal power, while the power allocation of the remaining sub-bands is coordinated among the neighboring cells in order to create one sub-band with low inter cell interference level in each sector. SFR: Each sector transmits in the whole frequency band.

However, the sector uses full power in some frequency sub bands while reduced power is used in the rest of the frequency band. IRS: In Intelligent Reuse Schemes (IRS), band allocated to different sectors expands and dilates based on the existing workloads. These schemes start with a reuse-3 like configuration at low workloads which can be changed with the increase of workloads to become PFR, SFR or even reuse-1.

In Fig. 5, represents the FFR based frequency allocation for a typical femto cell system. Total frequency is divided by four frequency sub-bands, a f is allocated for cell -center and f B (f B1, f B2, f B3) is allocated for three sectors in an orthogonal fashion in order to avoid the interference between macro and femto cells. For example, OFDMA in IEEE 802.16m can be considered which allocate Physical Resource Unit (PRU) for macro and femto cell. PRU is composed of 18 subcarriers and 6 symbols, the total number of PRU of OFDMA with 10 MHz bandwidth Will be 48 including Cyclic Prefix (CP). In order to evaluate the total cell throughput, the Shannon's Formula is used as [9]:R=BWlog 2 (1+SNR) (1)

Where, R is the cell throughput and BW is the bandwidth of PRU for each user and SINR for each user can be applied By: In general, frequency reuse schemes are suitable for networks with a static even distribution of loads; however, they lead to significant performance degradation in terms of cell and user throughput when used due to the natural dynamic nature of cellular systems, where there is an unevenly distributed dynamically changing load. Therefore, dynamic frequency allocations are needed in order to cope with the continuous load changes in cells. In cell coordination, interference reduction is realized by real time coordination among all involved cells to avoid that two cell edge UEs in neighboring cells use the same sub-carriers.

12 Power level

Adaptive algorithms are developed in order to efficiently manage the resource utilization among cells without a priori resource partitioning. Coordination between cells can be performed in either a centralized, semi-distributed or distributed fashion. Dynamic ICIC schemes reported in the literature are mostly either semi-distributed or distributed via coordination. A limited number of autonomous distributed ICIC schemes have been proposed, and accordingly, more research efforts are needed in order to develop autonomous schemes that can cope with the nature and needs of the emerging OFDMA-based cellular networks with highly mobile users.

Fig. 6 shows an orthogonal FA scheme. The frequency bands for Macro BS and femto BS can be allocated in an orthogonal fashion in order to avoid the mutual interference between macro and femto BSs. Though macro BS cannot use the full frequency band, orthogonal FA scheme can avoid the co-channel interferences between macro BS and femto BSs.

13 Lte Commercialization Trend

Wireless mobile communications are continuously evolving to respond to increasing needs of quality of service, data rates and diversity of the offered services. Meeting the ever expanding requirements; require innovations in architectures, protocols, spectrum sharing techniques, and interoperability between HetNet networks. This is reflected throughout the research by strongly focusing on new trends, developments, emerging technologies and new industrial standards, providing leading edge coverage of the opportunities and challenges driving the research and development of mobile communication systems.

14 IX.

15 Universal Mobile Access (uma) Femto Cells

Mobile operators have been searching for licensed indoor coverage solutions since the beginning of wireless networks. Unfortunately, the bulk of this opportunity (i.e. residential environments) has been beyond the addressable market for cost and operational reasons. To be successful, a residential licensed access point (i.e. femto cell) solution must include low cost femto cells, a reasonable approach for managing RF interference, and a standard, scalable, IP-based approach for core network integration. Femto cells are important because mobile operators need to seize residential minutes from fixed providers, and respond to emerging VoIP and WiFi offerings. Fig. 7, shows the services provided to operator and subscribers. For operator, benefits will be:

(1) Reduce churn with high quality 3G coverage.

(2) Avoid capital expense by off loading the macro 3G network. On the other hand, subscriber benefits will be:

(1) High performance 3G.

(2) Coverage at home.

Femto cell system is promising to provide cost effective strategy for high data traffic and high spectral efficient services in future wireless cellular system environment. However, the cochannel operation with current Macro networks occurs some severe interference between Macro and Femto cells. Hence, the interference cancellation or management schemes are imperative between Macro and Fem to cells in order to avoid the decrease of total cell throughput. First, we briefly investigate the conventional resource allocation and interference cancellation scheme between Macro and Fem to cells.

Then, a proposal on adaptive resource allocation scheme based on the distribution of Fem to cell traffic in order to increase the cell throughput and also maximize the spectral efficiency over the FFR (Fractional Frequency Reuse) based conventional resource allocation schemes. One of the main concerns for 4G wireless networks is to provide ubiquitous and high speed connectivity to mobile users. Indeed, one notorious limitations regarding wireless coverage is that it is difficult to provide high signal strength for indoor traffic since wireless signals generally have a difficulty in penetrating through many walls. Femto BS devices appeared as a promising solution to complement and enhance traditional macro BS coverage in specially indoor environment.

Moreover, the dense deployment of these femto cells can provide the higher capacity through increased spatial reuse. However, the overlapping of femto BSs and macro BSs in a same operator license band can occur some critical problems linked mainly to interference management. Recent developments from silicon and femto cell access point vendors promise to address the cost and interference issues over the next several years; a solution for core network integration has remained a challenge, as UMA provides standard, secure, scalable and cost effective IP-based access into core mobile service networks, it is now being leveraged to address this challenge. Frequency reuse is one of the most commonly used interference coordination technique, where the whole frequency band is divided into several sub-bands and wisely allocated to a specific area so as to improve signal status at cell edge. Frequency reuse is a common approach to increase data rate of point to multipoint systems.

16 X.

From LTE-a to 4g Future In ref. capability, enabling mobile service provisioning to approach for the first time that available from fixed-line connections. However, market demands typically do not evolve simply in discrete steps; therefore, the future evolution of LTE-A will be a story of continuous enhancement, on one hand, taking advantage of the advancing capabilities of technology, while on the other aiming to keep pace with the expectations and needs of the end users. The likely directions of this continuing enhancement are discussed, and some areas where further technical advancement will be required are identified. In particular, potential measures to enhance the efficiency of spectrum utilization by joint multi-cell optimization, dynamic adaptation of the network to traffic characteristics and load levels, and support for new applications are highlighted. The limited availability of suitable radio spectrum will increasingly impact the future evolution of LTE-A. This is already evident in the carrier aggregation features provided by LTE-A, and it is inevitable that the range of band combinations that have to be supported will continue to increase. Techniques to enhance dynamic load management between carriers according to traffic demand will also become an increasingly valuable tool for ensuring full and efficient use of scarce spectrum resources. Such dynamic techniques are likely in due course to evolve in the direction of cognitive radio solutions, with increasing utilization of spectrum sharing and white space detection as spectrum becomes ever more crowded.

17 XI.

3g RF Interference Mitigation Techniques -self Optimization Network (son) and WCDMA Hetnets

In mobile radio networks with several operators covering the same geographic area, interferences between the frequency channels of the model used in 3G to evaluate the interference between operators is relined so that the simulation results reflect the parameters used for path to reduce the interference between the operators by radiation pattern design of the antennas at the base stations ??9]. The following are proposed techniques can be used to mitigate it.

18 a) Automatic Carrier Selection

In this technique, a frequency list is provided by supervision system named by SCMS, the small cell selects the appropriate frequency for operation during auto-configuration, i.e., once every 24 hrs, that has least interference using Network Listen Measurements (NLM). A suitable hysteresis is added to prevent toggling between carriers and applicable to non-group deployments only. This proposed technique is mainly suitable for the home segment, which removes the need for manual provisioning of carrier frequency and has better coverage and capacity due to the selection of less interfered channel.

19 b) Up link Interference Management

The worst case of Uplink (UL) interference occurs when a small cell mobile handset (UE) comes close to the border of the neighboring small cell macro cell and there is also another UE on the border with both UEs transmitting at high uplink data rates. Aim of this feature is to control small cell UE maximum, UL transmitted Power based on; estimated pathloss between small cell UE and its neighboring Small Cell/Macro cell based upon UE Common Pilot Channel (CPICH) protocol measurements and the neighbor's CPICH transmit power. UL UE maximum transmitted power is updated through Radio Resource Control (RRC) signaling protocol. The mechanism is activated only when following events occur; UL Received Total Wideband Power (RTWP) -checking the uplink interference -is above a threshold of uplink enhanced Dedicated Channel (E-DCH) or high UL data rate is configured on the small cell UE. An Operation & Maintenance defined maximum level of interference that the small cell UE can create into a neighbor cell is implemented. This technique is suitable for all segments and any carrier deployment scenario.

20 c) Continuous Coverage Self-Optimization Based on Admission

In closed access mode, too many Location Area Update (LAU) and Routing Area Update (RAU) attempts from public UEs will trigger a reduction in the pilot power, SON technique to adapt the coverage of the closed access mode Shared Carrier (SC) based on how often non registered UEs are trying to camp on femto or rate at which registered users are performing outgoing handovers. This technique is particularly useful for a SC placed in a sub-optimal location, e.g., next to a window, the technique algorithm runs continuously and can adapt to local traffic variations ??10].

One of the proposed features of this technique is it configurable thresholds for camping rate and handover rate can be targeted and is applicable mainly to home and enterprise segments in shared carrier deployments to minimize impact of downlink RF leakage on non-registered/public users and to minimize signaling resulting from frequents camping requests from non-registered users.

21 d) Outdoor Metro Cell Deployments Challenges

Deployment of small cells in realistic environments poses significant challenges. It is crucial to address these challenges for enabling large scale adoption of small cells in the future.

The myriad of challenges include co-existence schemes with neighboring cells (including small and macro cells), interference management mechanisms (to issues (crucial for efficient deployment of small cells) ensure continuity of service over neighboring small and macro cells), self organizing and self management and optimal network architectures (related to the host radio access technology). Metro Cells can provide additional data capacity in areas of high traffic density in dense urban outdoor areas as macro RF signal levels are generally very high in operator areas deployment of interfaces based outdoor metro cells under an existing interface based macro layer is challenging. Based on simulations and field experience macro cell coverage area can be divided into three zones (red, yellow and green) in terms of suitability for deploying outdoor metro cells on shared carrier, as shown in Fig. **??**, metro cells can be deployed in the Green and Yellow zones, but deployment guidelines need to be followed in order to get good trade-off between performance improvement and interference impacts. Implementation of traffic segmentation is recommended in the Yellow zone in order to maintain Key Performance Indicators (KPIs). Similarly, multiple metro cells deployed in close proximity and configured in a group can offload more users and improve business case in comparison to isolated metro cell deployments Hierarchal Cell Structure (HCS) high mobility detection feature can be implemented on the macro to minimize camping of fast moving idle mode UEs on metro cells Exclusion zone -interference is significant, small cell off load potential is low due to reduced small cell size. Intermediate zone -interference is still significant, but benefits of small cell offload starts to come into play Safe zone -effect of interference is not significant, benefits of small cell offload is maximized. Identification and some challenges related to the design and analysis of ICIC scheme that make interesting future research directions.

22 ? Evaluation Framework and Benchmark

Due to the complexity of the dynamic ICIC problem, most of the performance evaluations are based on simulation models. A principal problem with simulation evaluations during comparing different schemes is the lack of common context, scenarios and evaluation metrics. Accordingly, an evaluation framework and a benchmark are needed to allow researchers to develop and evaluate their ICIC schemes in a sound manner. Such an effort will provide researchers with data sets for unified realistic scenarios (similar to those provided by the European Momentum project for Berlin and Lisbon) that define common realistic conditions, such as: cells layout, number of channels, propagation data, and traffic intensity.

The evaluation framework should provide a unified set of metrics that can be used to evaluate and benchmark various ICIC schemes.

23 ? Wireless Network Cloud (WNC)

Recently, with the emergence of the cloudcomputing technology and other technologies related to wireless infrastructure including software radio technology and remote radio head technology, Wireless Network Cloud (WNC) with Base Station Pooling (BSP) is becoming an interesting alternative network architecture where all eNBs computational resources (enabled by Software Radio) are pooled in a central complexity heuristics algorithms should be investigated as they have the power of obtaining good suboptimal solutions in a computationally efficient way.

24 ? Autonomous schemes

Static schemes suffer from the limitation of being unable to adapt to inhomogeneous traffic load Centralized and semi-distributed schemes are often too heavy for implementations in reality as all the interference information on all RBs has to be gathered at a central controller, which is prohibitively large. Coordinated distributed schemes realization has remained limited largely due to constraints on inter-eNB communication and the latencies involved in information exchange for distributed eNBs. Self-organization is a key factor for the future evolution of mobile networks, due to their increasing complexity and required management efforts. Thus, with the current network architecture and large number of cells, it appears that the future is for autonomous schemes as they can achieve a good ICIC level with no signaling overheads **??**12].

Moreover, they open the way for a more flexible and adapted cell topology as well as for new energy saving methods. Not much research efforts have been

25 ? Heuristics algorithms

An important line of work is to formulate the ICIC problem as an optimization task whose objective is to maximize the multi-cell throughput subject to: power constraints, inter-cell signaling limitations, fairness objectives, and/or minimum bit rate requirements. The problem of resource allocation with dynamic demand is known to be NP-hard. Using an exact method is computationally inefficient as the problem involves extremely large search spaces with correspondingly large number of potential solutions. While optimization models give an insight into the upper bounds of achievable ICIC gains, actually implementing these near optimal mechanisms can be economically and/or technologically infeasible. Thus, various lower reported in developing autonomous distributed ICIC schemes, which makes it an interesting research direction that is worth further investigation.

The demand for cellular communication services is expected to continue its rapid growth in the next decade, fuelled by new applications such as mobile web-browsing, video downloading, on-line gaming, and social networking. The commercial deployment of 3G. Cellular network technologies began with 3GPP UMTS/WCDMA in 2001 and has evolved into current UMTS/HSPA networks. To maintain the competitiveness of 3GPP UMTS networks, a wellplanned and graceful evolution to 4G networks is considered essential. LTE is an important step in this evolution, with technology demonstrations beginning in 2006. Commercial LTE network services started in Scandinavia in December 2009 and it is expected that carriers worldwide will shortly be starting their upgrades. A high-level survey of works on resource scheduling and interference mitigation in 3GPP LTE was presented. These two functions will be key to the success of LTE. The next step in the evolution of LTE is LTE-A, a 4G system which promises peak data rates in the Gbps range and improved cell-edge performance. Important scheduling/interference mitigation related technical issues which require further exploration include:

(1) use of relaying techniques which can provide a relatively inexpensive way of increasing spectral efficiency, system capacity, and area coverage. (2) DL and UL coordinated multipoint transmission/ reception to improve high data rate coverage and cell-edge throughput. For DL, this refers to coordination in scheduling transmissions from multiple geographically separated transmission points.

(3) For UL, this involves different types of coordination in reception at multiple geographically separated points. (4) support for UL spatial multiplexing of up to four layers and DL spatial multiplexing of up to eight layers to increase bit rates. Another general area deserving attention is the design of low-complexity scheduling/interference mitigation schemes which provide near optimal performance. [1] [2]

1

Figure 1: Figure 1 :

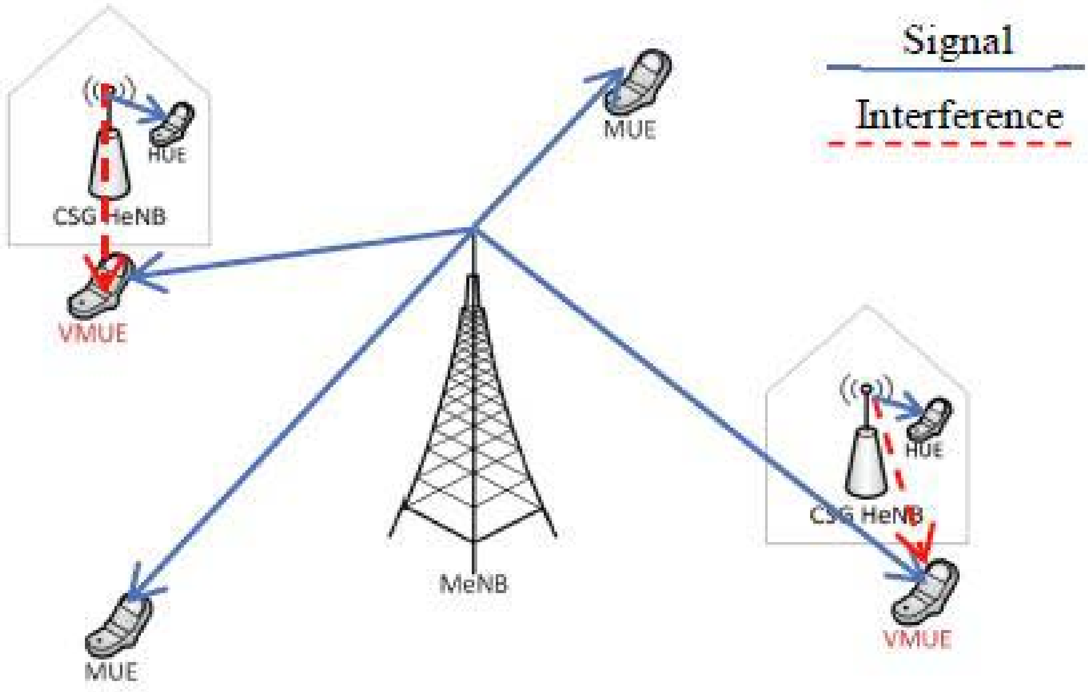

Figure 2:

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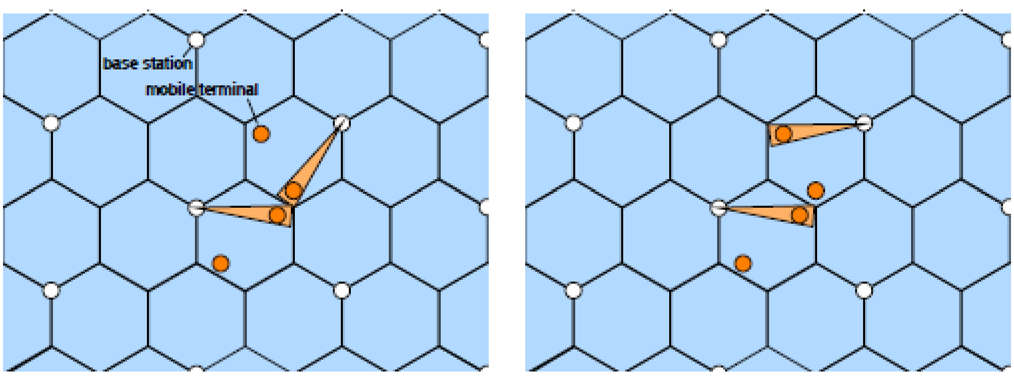

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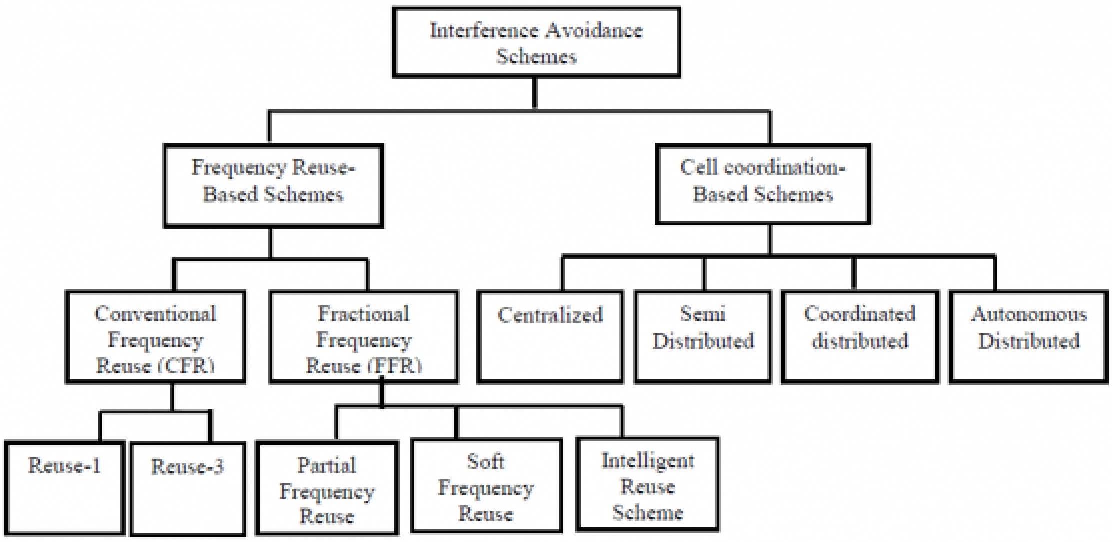
4 

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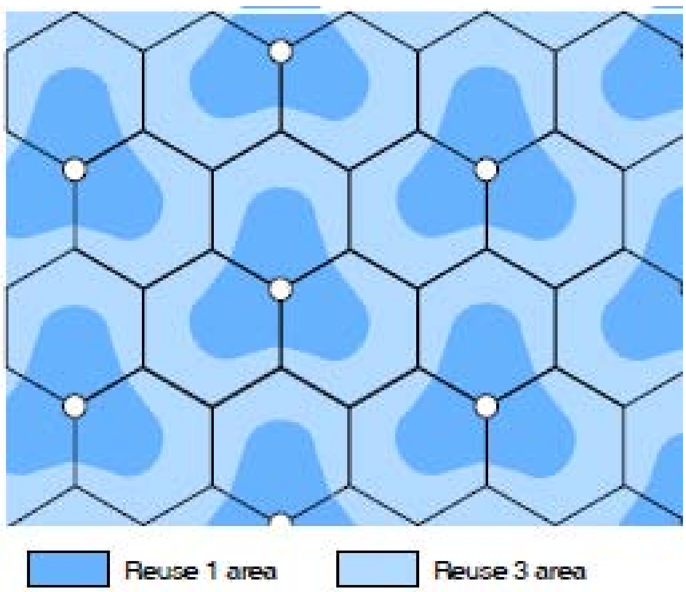
5 

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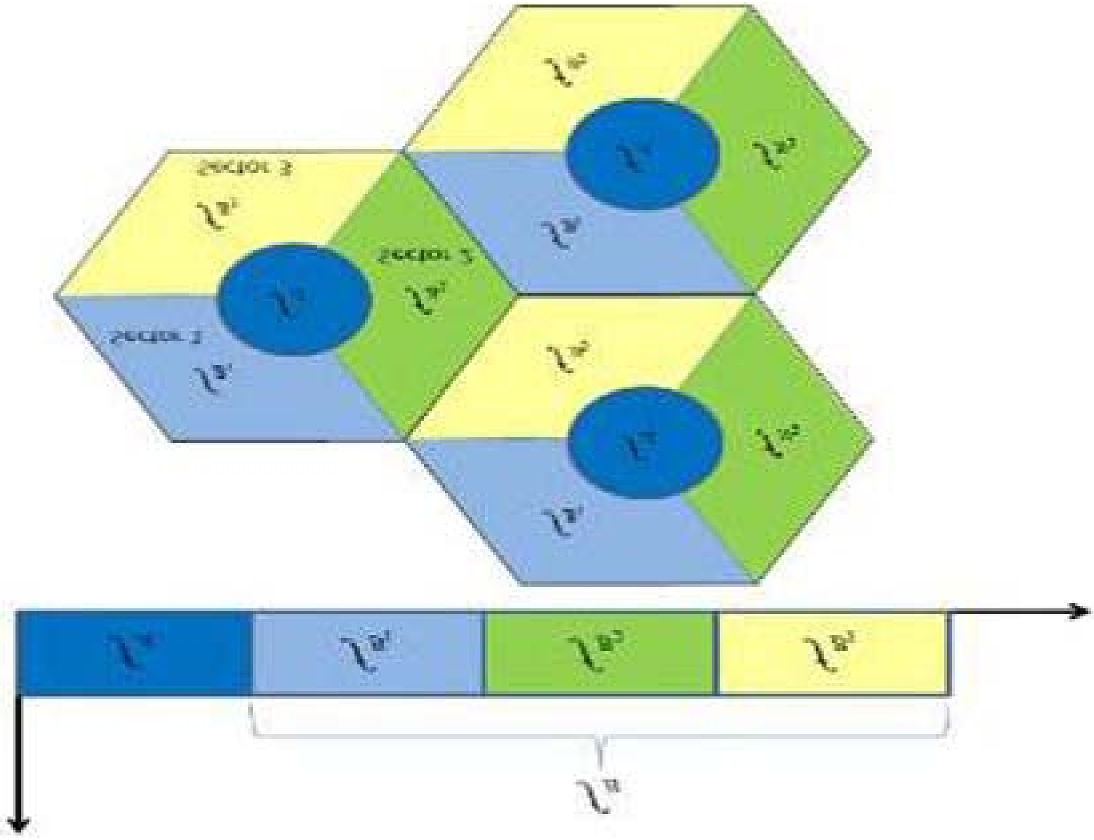

Figure 6: FrequencyA

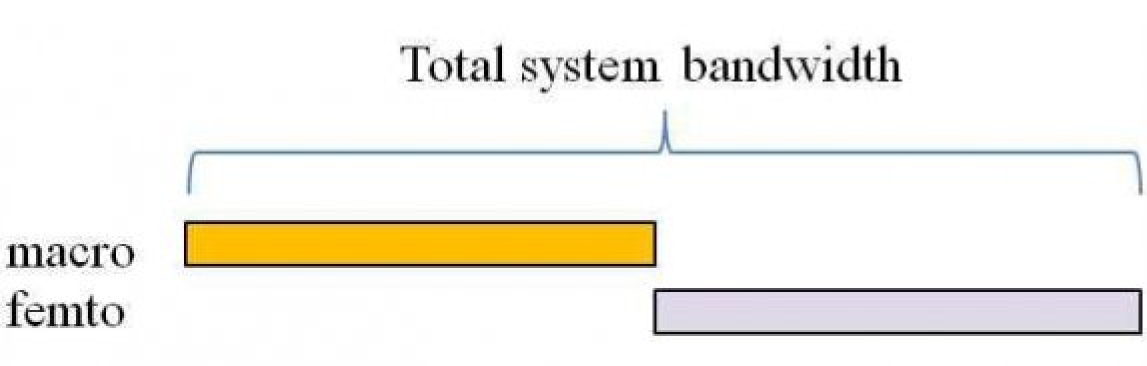

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Figure 7: Figure 6 :

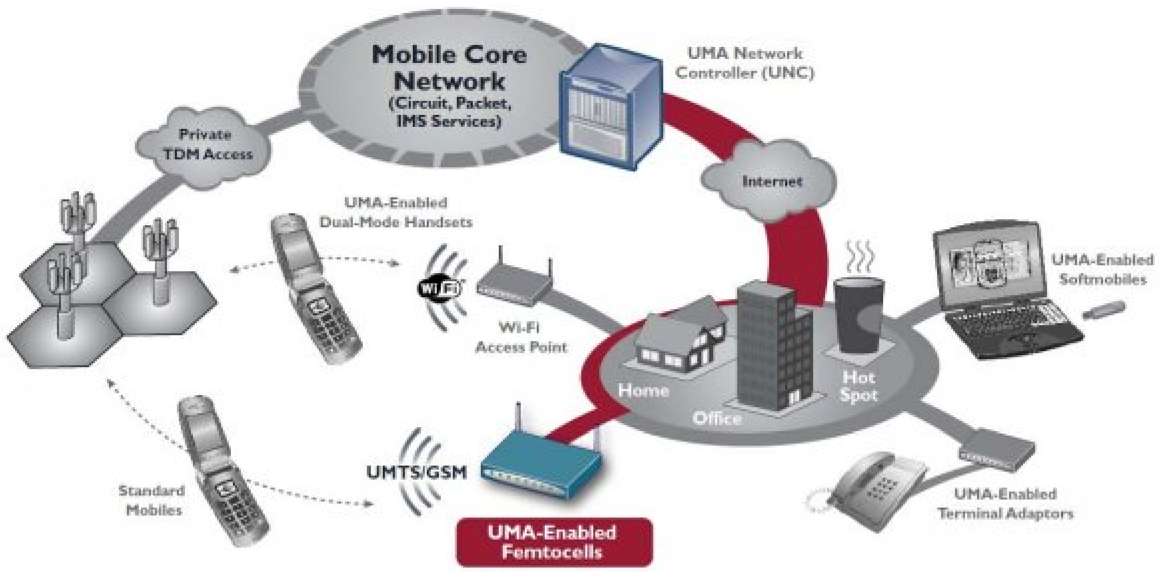

Figure 8: FA

7

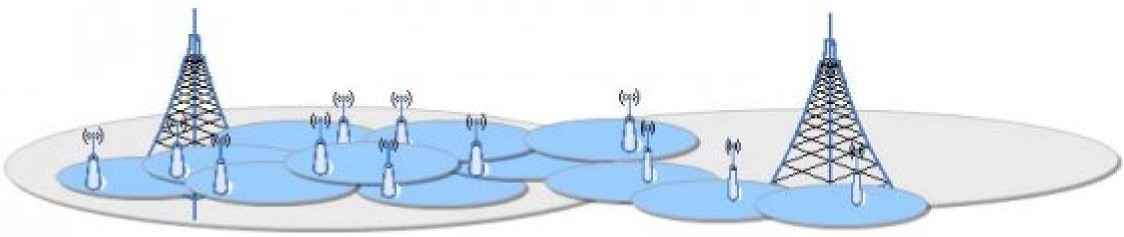

Figure 9: Figure 7 :

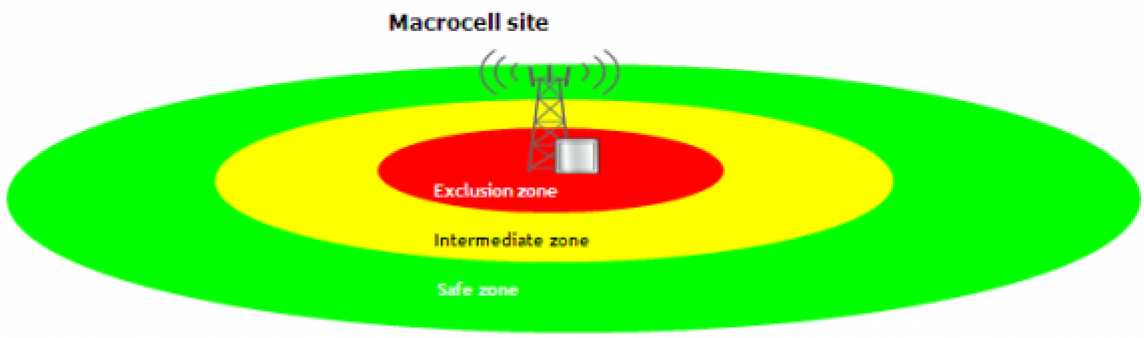

Figure 10: