

Chapter one

Introduction

1.1 Overview:

With the ever-increasing data traffic demand in today's mobile network, immediate solutions for capacity improvement are sought by the operators. Additionally, with up to 80 percent of the traffic being originated from indoors [1] where the current mobile networks are least effective due to high buildings penetration losses, indoor data offloading has become a focus of the industry in the recent years. One attractive solution to offload indoor users' traffic is to deploy small cells such as femtocells. Since small cells are considered as an integrated part of the operator's network, seamless handovers between the small cells and the underlying macrocell network is considered as a key advantage when compared against other alternatives such as Wi-Fi based solutions. Additionally, while operating small cells on a dedicated frequency is a pragmatic possibility, co-channel operation with an existing macrocellular network is technically far more challenging, but is also more rewarding for the operators due to the potentially significantly increased spectral efficiency through spatial frequency re-use [2].

For heterogeneous networks when small cells are deployed within the coverage area of macrocells and if user move from small cell to macrocell handover is required and power control is applied to avoid interference between mobile equipment's.

In hard handover, after the UE establishes a connection to the new cell, it adjusts its power using the open loop power control to communicate to the target cell and radically variation of power is expected.

The situation is slightly different when considering soft handovers. When the user is already connected to all base-stations in the active set, its transmit power is continuously modified through inner-loop control. Since the conservative power control keeps the transmit power of users at a minimum level during the soft handover regime, once the link to the serving small cell base-station is removed, the UE will suddenly need to increase its power. Given that the inner-loop power control modifies the transmit power in small steps. But currently there is no soft-handover support in most small cells products.

1.2 Problem Statement:

For heterogeneous networks, small cells are deployed within the coverage area of macrocells. Here, after handover from a small cell to a macrocell, a user needs to transmit at a much higher power. Such radical and sudden increase of the transmit power of the user who is still located in vicinity of the small cell base-station, introduces a significant uplink interference to the remaining small cell users.

1.3 Aim and Objectives:

This research introduces a challenging problem that is associated to the power control mechanism during the handovers between the co-channel small cells and macrocells in WCDMA networks. The objectives are:

1. To achieve good SIR and high throughput
2. To improve the wireless transmission.
3. To validate the propose method with simulation results

1.4 Methodology:

To avoid unnecessary increase of the transmit power; a timer is activated soon after the CPICH E_c/N_o falls below the Critical Ratio (CR) threshold. Then, if no handover is performed within a predefined time-window (T_w) the power

control will gradually be set back to its normal procedure and the timer is reset. For that particular user, the proposed power adaptation regime will be re-activated only when the measured CPICH E_c/N_0 falls below the quantity observed at the end of the previous timer expiry. This allows static users at the edge of the small cell coverage to transmit at their normal power and eliminates the need for unnecessary power increase.

1.5 Thesis Outlines:

Chapter two will give a background of Wide Code Division Multiple Access (WCDMA) and fundamental of cellular network.

Chapter three discusses the handover, power loop control and Handover Optimization proposed in this research.

Chapter four represents the results of research as graphical results with discussion.

Chapter five: State conclusions and recommendation.

Chapter Two

Cellular Network and WCDMA

2.1 Overview:

The cellular concept arose out of the necessity to share the spectrum which is a premium and a limited resource in mobile communication. It is centered on the ability to control the radio frequency energy within a confined area of space (called a cell) so that the same spectrum can be reused as many times as desired, within each cell. Thus the capacity of the system can be increased by making cells smaller in area and also by sub dividing a cell area into smaller parts (called sectors)[3]. The users in a cell are allowed to get access to the available spectrum by employing a multiple access technique. In cellular mobile communication systems, the widely adopted multiple access techniques are the Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA), and Code Division Multiple Access (CDMA), as described below.

2.1.1 FDMA

In FDMA system, the time frequency plane is divided into N discrete frequency channels, continuous along the frequency axis as shown in Fig. 2.1. Each user is assigned a channel for the entire duration of the user's conversation. Other users can access the channel after the first user's conversation has ended.

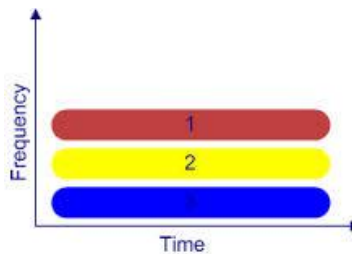


Figure 2.1: Frequency division multiple accesses.

2.1.2 TDMA

In TDMA the time frequency plane is divided into N discrete timeslots, continuous along the time axis as shown in Fig. 2.2. With this technique, multiple users can make use of the band assigned to the communication at different moments of time.

Mixed TDMA-FDMA techniques are used, where the bandwidth assigned to an operator is divided among different FDMA carriers, each of which is shared by the users with the TDMA technique. This technique is used by the second generation digital cellular systems such as Global System for Mobile (GSM) and Personal Digital Cellular (PDC).

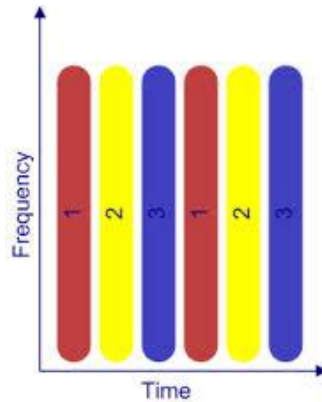


Figure 2.2: Time division multiple accesses.

2.1.3 CDMA

In CDMA system, the signal energy is continuously distributed throughout the entire time frequency plane. Each user employs a wideband coded signaling waveform, as shown in Fig. 2.3. The user data to be transmitted is uniquely coded such that it can be distinguished from those of the other users. Each data bit is subdivided to accommodate the code word in it and as a result this technique leads to spectrum spreading. CDMA is a direct sequence spread spectrum system and is the subject of the present investigation.

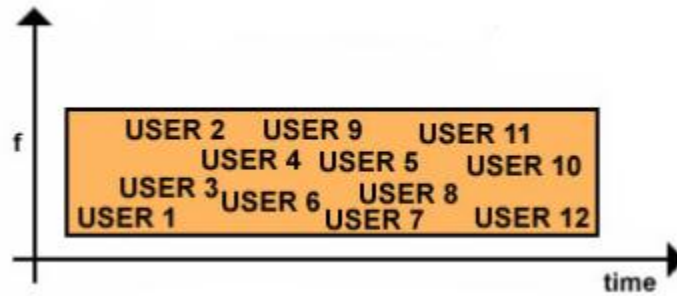


Figure 2.3: Code division multiple accesses.

2.2 Early Cellular Systems

Early cellular systems were all analog systems and need FDMA with Frequency Division Duplexing (FDD). The systems were designed to handle voice and the voice signal was frequency modulated. Part of UHF spectrum was utilized to cover sizable areas where in today do terms could be categorized as macro cells. The capacity was not a main issue in these systems as demand was not great.

2.2.1 First Generation Systems

The first successful cellular mobile communication system was the Advanced Mobile Phone Service (AMPS) developed in USA in 1970s. It used FDMA technology with FDD and employed 20 MHz bandwidth in the 800 MHz region. AMPS at present operates with a 25 MHz bandwidth in each direction over the frequency allocations of 824-849 MHz for the Uplink (UL) (from mobile to base station), and 869-894 MHz for the Downlink (DL) (from base station to mobile). This spectrum is divided into 832 frequency channels leaving 416 channels in the uplink and another 416 channels in the downlink. Some of these channels are used to carry system information and control signal while the rest carries voice and data in analog form. In AMPS, each channel occupies 30 kHz of bandwidth using analog Frequency Modulation (FM). AMPS is among the first generation cellular systems. Although cell division techniques are frequently employed by the first generation system,

reduction of cell sizes below a few hundred meters eventually renders cell division infeasible. Moreover, analog modulation is sensitive to interference from other users in the system, and the voice quality is quite vulnerable to various kinds of noise. As a consequence of these, other means of capacity improvement such as efficient modulation schemes were sought for the second generation.

2.2.2 Second Generation Systems

In the second generation cellular systems, digital technology enabled the use of signal processing techniques to increase the robustness against interference. It also reduced the spectral bandwidth required for each user and hence provided a higher capacity. The second generation systems provide about 3 to 4 times the capacity of the first generation system for the same spectral resource without adding new base stations. Since digital systems are more immune to noise, an Interference-to-Signal (ISR) ratio of about 15 dB is acceptable in digital systems (whereas 18 dB is required for the analog systems under same circumstances). This allowed the use of smaller reuse clusters, thereby increasing the capacity of the system.

The second generation cellular mobile systems were based on Time Division Multiple Access (TDMA) technology, or a combination of TDMA and FDMA. The IS-54 TDMA digital cellular system employs digital voice produced at 10 kbps (8 kbps speech plus overhead), and transmitted with $\pi/4$ differentially encoded Quadrature Phase Shift Keying ($\pi/4$ DQPSK) modulation. The IS-54 system permits 3 callers per 30 kHz channel spacing (30 kHz/10 kbps), therefore, increases capacity three times that of AMPS.

In 1990, Qualcomm, Inc., proposed a digital cellular telephone system based on Code Division Multiple access (CDMA) technology. In July 1993, the

second U.S digital cellular standard (IS-95) was adopted. Using spread spectrum techniques, the IS-95 system provides a very high capacity.

2.2.3 Third Generation Systems

WCDMA Air Interfaces

In principle, all third generation cellular systems have adopted WCDMA as the air interface. However, there are minor differences between the WCDMA air interface adopted by cdma2000 and IMT-2000.

The cdma2000 (USA) within the standardization committee of Telecommunications Industry Association (TIA), the subcommittee TR45.5.4 was responsible for the specifications of the basic cdma2000 scheme. Like for all other wideband CDMA schemes, the goal for cdma2000 has been to provide data rates that meet the IMT-2000 performance requirements. That is at least 144 Kbps in a vehicular environment, 384 Kbps in a pedestrian environment, and 2048 Kbps for indoor office environment. The main focus of standardization has been to provide 144 Kbps and 384 Kbps bit rates with approximately 5 MHz bandwidth. There are two main alternatives currently existing for the down link channel structure of cdma2000. They are the multicarrier and direct spread options. The multicarrier approach maintains orthogonally between the cdma2000 and IS-95 carriers. In the down- link this is important because the power control cannot balance the interfering power between different layers, as it can in the uplink. Transmission on the multicarrier downlink is achieved by using three consecutive IS-95B carriers where each carrier has a chip rate of 1.2288 Mcps. For the direct spread option, transmission on the downlink is achieved by using normal chip rate of 3.6864 Mcps.

IMT-2000 (Europe)

The Europe Telecommunications Standards Institute (ETSI) has been working on the Universal Mobile Telecommunication Services (UMTS), which is to be the European standard for the third generation mobile systems. UMTS will appear as one of the family members within the IMT-2000 family. (Any system/network based on specification that supports the IMT-2000 capabilities and interfaces defined by the ITU will be considered as an IMT-2000 system/network.) ETSI has agreed on UTRA (UMTS Terrestrial Radio Access) as the radio transmission technology for UMTS. This Radio Transmission Technology (RTT), which utilizes WCDMA with FDD for paired frequency bands and a hybrid WCDMA/TDMA with TDD for unpaired frequency bands, has been submitted to the ITU-R as a candidate for IMT-2000. UMTS will utilize the GSM network interfaces as the basis for its network interfaces and proposals. The current GSM network capabilities, which include General Packet Radio Service (GPRS), High Speed Circuit Switched Data (HSCSD), and Customized Application for Mobile Enhanced service Logic (CAMEL), will be enhanced to support UMTS capabilities in terms of services like virtual home environment and multimedia, as well as higher bit rates.

The WCDMA technology in Japan is very similar to that of Europe. The Association of Radio Industries and Businesses (ARIB) in Japan has their technology in line with ETSI's WCDMA. The outcome of the ARIB selection process in 1997 was WCDMA, with both FDD and TDD modes of operation. Since the creation of 3GPP for the third generation standardization framework, ARIB has contributed to 3GPP, in the same way as ETSI has contributed UTRA. In Japan, the IMT-2000 standardization is divided between two standardization organizations: the Association of Radio

Industries and Businesses (ARIB) and the Telecommunication Technology Committee (TTC). ARIB is responsible for the standardization of radio interface while TTC is responsible for the standardization of network interface. In Korea, two wideband CDMA air interfaces are being considered: Telecommunications Technologies Association's standard I (TTA I) and Telecommunications Technologies Association's standard II (TTA II).

The Electronics and Telecommunications Research Institute (ETRI) in Korea has established an R&D consortium to define the Korean proposal for IMT-2000 during 1997 and 1999. The main features of these air interfaces are listed in Table 2.1. TTA II concept is closer to cdma2000 while TTA I resembles WCDMA.

The IMT-2000 system is aiming to be flexible in order to operate in any propagation environment, such as indoor to outdoor, outdoor to indoor, and vehicular environments.

Table 2.1: Parameters of Korean WCDMA Schemes

WCDMA Parameters	TTA I	TTA II
Channel spacing	1.25 MHz / 5 MHz / 20 MHz	20 MHz 10 MHz / 20 MHz
Chip rate	Chip rate 0.92 Mcps / 3.68 Mcps / 14.77456 Mcps	1.024 Mcps / 4.096 Mcps / 8.192 Mcps / 1.384 Mcps
Frame length	20 ms	10 ms
Spreading	Walsh and long codes	Walsh and long codes
Pilot for coherent detection	UL: pilot symbol based DL: common pilot	based UL: pilot symbol based DL: common pilot
Base station synchronization	Synchronous	Asynchronous

2.3 Signal Quality

The signal quality depends on the ratio between signal power and interference power. This is called signal-to-interference ratio (SIR).

$$SIR = \frac{S}{\sum_i I_i} \quad (2.1)$$

Where

I_i Interference from the i_{th} interfering BS.

S received signal power

The received signal power depends on the distance between the transmitter and the receiver.

$$S = P_0 \left(\frac{d}{d_0} \right)^\alpha \quad (2.2)$$

P_0 is the power received at a reference distance d_0 .

α is called the path loss exponent (Typically, $2 \leq \alpha \leq 6$).

2.4 Universal Mobile Telecommunication Services

2.4.1 Network Architecture

As specified by 3GPP, there are two radio interface modes for UMTS Terrestrial Radio Access (UTRA): FDD and TDD [3GPP02a].

Three high-level architecture modules compose the UMTS network [3GPP02a]: User Equipment (UE), UTRAN and Core Network (CN). The UE interacts with the user. UTRAN is responsible for the radio interface, and allows connections to the CN, which is responsible for interaction with external networks, such as other Public Land Mobile Networks (PLMNs), Public Switched Telephone Networks (PSTNs), Integrated Services Digital Networks (ISDNs), and Internet. The structure of the network architecture is presented in Figure 2.4.

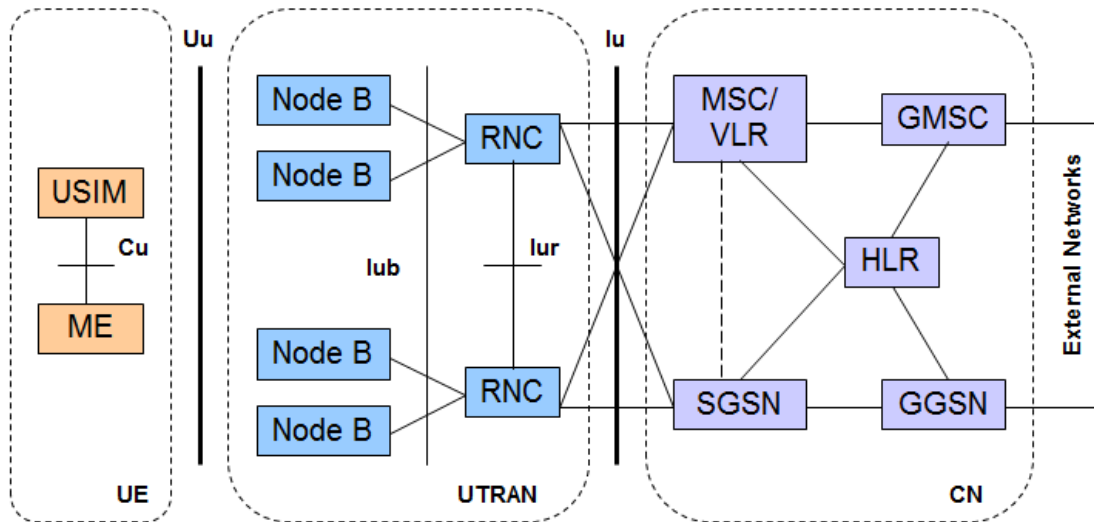


Figure 2.4: UMTS system architecture.

The UE is composed of:

- Mobile Equipment (ME) – responsible for the radio interface over the Uu interface, using WCDMA.
- UMTS Subscriber Identity Module (USIM) – a smart card that stores the subscriber identity, authentication information and encryption keys.

UTRAN elements are:

- Node B – performs the conversion of data flows from the Uu radio interface to the Iub interface, and takes part in Radio Resource Management (RRM).
- Radio Network Controller (RNC) – controls Node Bs and performs RRM, such as code allocation, outer loop power control, packet scheduling, and handover control. The RNC has 3 logic roles: Controlling RNC (CRNC) controls the logical resources of UTRAN access points, Serving RNC (SRNC) ending the Iub and Iu interfaces, and the Drift RNC (DRNC), which is any RNC, other than SNRC, controlling cells used by the Mobile Terminal (MT), being able to perform macro diversity and splitting. The Iur interface allows soft handover (SHO) between Node Bs belonging to different RNCs.

The CN was adapted from the well-known GSM one. In UMTS, CN network elements are:

- Home Location Register (HLR) – database that stores user information, such as allowed services, user location for routing calls, and preferences. Every user of a network must be registered to that network's HLR.
- Mobile Switching Centre/Visitor Location Register (MSC/VLR) – is a network element with two functions: MSC is responsible for switching voice and data connections in the CS domain, the VLR being a database containing all active network users, as well as a more precise location of the UE.
- Gateway MSC (GMSC) – is a switch for connection to external networks-on the CS domain.
- Serving GPRS Support Node (SGSN) – is a switch with the same functions as MSC/VLR, but for connections on the PS domain.
- Gateway GPRS Support Node (GGSN) – equivalent to GMSC on PS domain.

2.4.2 Radio Interface

UMTS uses WCDMA, a wideband Direct-Sequence Code Division Multiple Access (DS-CDMA) spread spectrum air interface, with a chip rate of 3.84 Mcps leading to a radio channel of 4.4 MHz and separation of 5 MHz. The UTRA/FDD frequency bands for Europe are [3GPP05]: [1920, 1980] MHz for UL and [2110, 2170] MHz for DL. WCDMA capabilities include: high bit rates, low delay, QoS differentiation, smooth mobility for voice and packet data, Real Time (RT) voice and capacity capability, and inter-working with existing GSM/GPRS networks.

2.4.2.1 Wide Code Division Multiple Access

WCDMA is a wideband Direct Sequence Code Division Multiple Access (DS-SS-CDMA) system, i.e., user information bits are spread over a wide bandwidth by multiplying the user data with bits -very high bit rates, the use of a variable spreading factor and multi code is supported. The chip rates of 3.84 Mcps leads to a carrier bandwidth of 5 MHz .The wide carrier bandwidths of WCDMA supports high user data rates and have certain benefits, such as multipath diversity. WCDMA supports high variable user data rates; in other meanings the concept of obtaining Bandwidth on Demand (BoD) is supported. The user data rate is kept constant during each 10 ms frame. WCDMA supports two basic modes of operation this modes are Frequency Division Duplex (FDD) and Time Division Duplex (TDD).

Power control, handover is key features in WCDMA air interface. Without power control, a single MT could block a whole cell. WCDMA applies two types of power control: closed loop, to avoid the use of excessive power, and thus, an increase of interference (the near-far problem), and outer loop, to adjust the Signal to Interference Ratio (SIR) of each individual link, instead of defining a SIR target for the worse case, resulting on a waste of capacity. Data from higher layers is carried in transport channels, which are mapped onto different physical channels. Two types of transport channels are defined, 3GPP recommendations [11]: dedicated channels, each one reserved for a single user, and common channels, shared among all users within the cell.

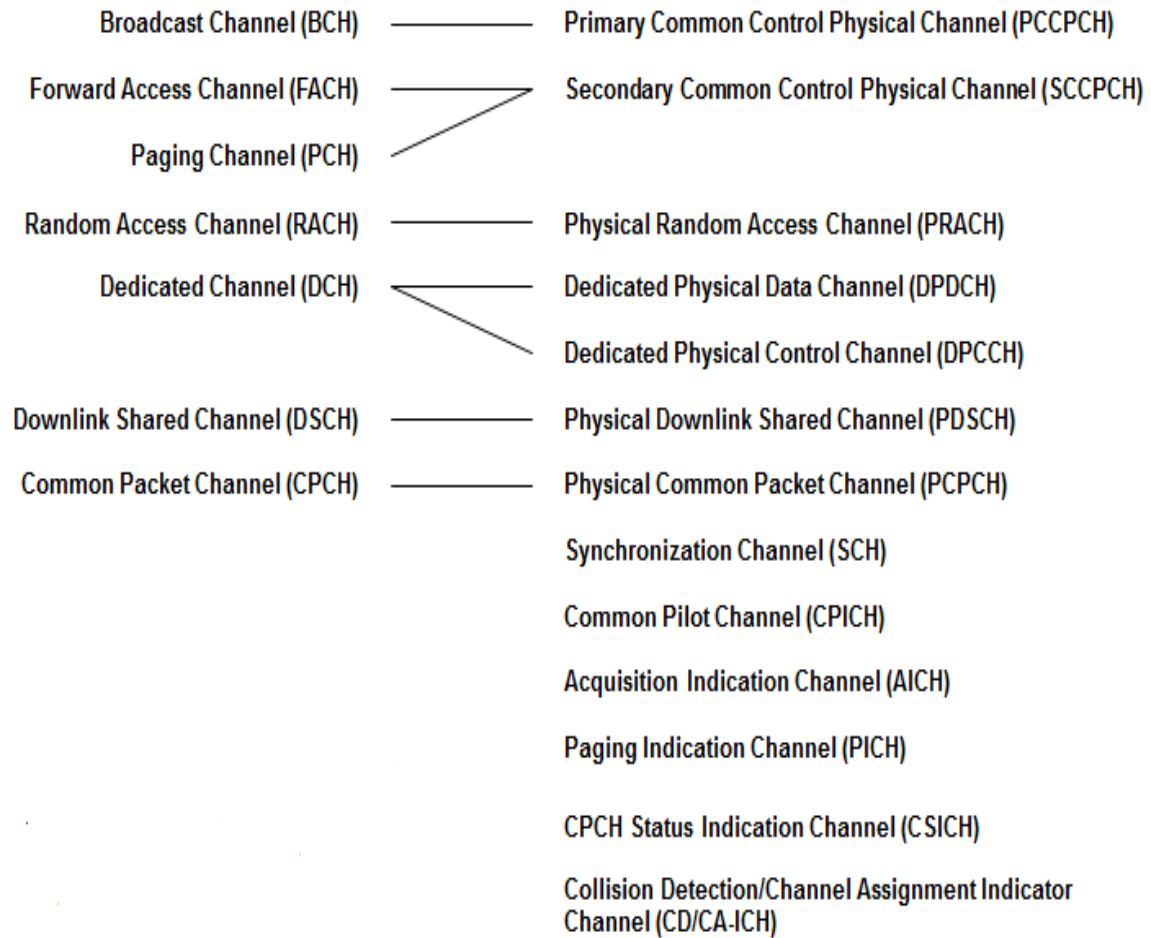


Figure 2.5: Mapping of Transport Channels and Physical Channels.

In UMTS specifications there is only one dedicated transport channel, the Dedicated Channel (DCH), an UL or DL channel responsible for carrying all users' data, including the actual data for the required service, and also higher layer control information. DCH supports fast power control, fast data rate change on a frame-by-frame basis, the use of adaptive antennas, and HO, being mapped onto the Dedicated Physical Data Channel (DPDCH) for user data, and onto the Dedicated Physical Control Channel (DPCCH) for control information. Concerning the common channels, in DL one has the Broadcast Channel (BCH), the Forward Access Channel (FACH), the Paging Channel (PCH) and the Downlink Shared Channel (DSCH) as shown in figure 2.5.

The BCH is used to broadcast system and cell specific information, such as the available random access codes. It is transmitted with high power and low data rate, as it needs to be decoded by all MTs within the Node B's coverage area. BCH is mapped onto the Primary Common Control Physical Channel (PCCPCH). The FACH carries control information for the MT within the cell coverage area, and may also be used for packet data communications. It is transmitted with low data rate, so that it can be received by all MTs in the cell area, and does not use fast power control. It is mapped onto the Secondary Common Control Physical Channel (SCCPCH).

The PCH carries data necessary to the paging procedure, for example, when the network intends to initiate a communication with a specific user. It is always transmitted over the cells where the user is expected to be. Like the FACH, the PCH is also mapped onto the SCCPCH. The DSCH is used to carry dedicated user data and control information, being shared by several users. It supports fast power control and a variable data rate on a frame-by-frame basis, being always associated to a DL DCH. Contrary to the other common transport channels, the DSCH does not need to be received in the entire cell. It is mapped onto the Physical Downlink Shared Channel (PDSCH).

In UL, there are two common transport channels: the Random Access Channel (RACH) and the Common Packet Channel (CPCH) used to carry user packet data. The RACH is used to carry control information from the MT to the network, such as requests to set up connections, and may also be used to transmit small data packets. It is transmitted using open loop power control, and it is mapped onto the Physical Random Access Channel (PRACH). It is transmitted using fast power control, and uses collision techniques in order to avoid collisions when other users are also making packet-based connections.

From the six common channels presented, BCH, RACH, FACH and PCH are mandatory for the basic network operation, DSCH and CPCH being optional. When CPCH is present, four other physical channels, the CPCH Status Indication Channel (CSICH), the CPCH Collision Detection Indicator Channel (CD-ICH), the CPCH Channel Assignment Indicator Channel (CA-ICH) and the CPCH Access Preamble Acquisition Channel (AP-AICH) are needed for CPCH access procedures.

There are also others physical channels, such as Synchronization Channel (SCH), Common Pilot Channel (CPICH), Paging Indication Channel (PICH) and Acquisition Indicator Channel (AICH) that do not carry any transport channel. These channels carry relevant information to the physical layer procedures. The SCH is needed for cell search procedures, the CPICH aids the channel estimation at the MT, the PICH provides efficient MT sleep mode, being operated together with PCH, and AICH indicates to the MT the reception of the random access signature sequence.

2.5 Related Works

Existing literature has been mainly focused on optimization of soft-handovers for traditional macrocell networks without addressing the issues related to the emerging heterogeneous networks [8] [9]. In [10] a power control scheme during soft-handovers is proposed to reduce the error rate of downlink power control commands. Similarly, in [11] a downlink power control method for soft handover regimes is introduced in that the power of each base-station in the active set is proportional to the radio channel between the user and base-stations. Finally, the work in [12] introduces a modified signaling flow when handovers between small cells and macrocells are considered.

In 2012 R. Razavi, C. Androne and H. Claussen show that If the CPICH E_c/N_0 falls below CR, the small cell base-station records the current transmit power of the UE noted as P_{start} . It then commands the UE to adjust its power level PUE such that by the time of the handover, the UE is already at the approximate power level required to communicate to the target macrocell base-station. We shall refer to this power level as P_{target} . This way, the small cell base-station assures that significant rise of the transmit power and sudden decrease of the SIR for the existing small cell users are avoided. P_{target} can be simply estimated by the small cell base-station or more accurately by the UE via path-loss estimation to the target macrocell. Ideally, the user's transmit power, PUE, should be set to P_{target} when CPICH E_c/N_0 equals HR (i.e. when handover is executed)(14).

Chapter Three

Handover in WCDMA

3.1 Overview

Third-generation mobile radio networks, often dubbed as 3G, have been under intense research and discussion recently and will emerge around the year 2000. In the International Telecommunications Union (ITU), third generation networks are called International Mobile Telecommunications-2000 (IMT-2000), and in Europe, Universal Mobile Telecommunications System (UMTS). IMT-2000 will provide a multitude of services, especially multimedia and high-bit-rate packet data. WCDMA has emerged as the mainstream air interface solution for the third-generation networks.

WCDMA allow very high-speed multimedia services such as voice, Internet access and videoconferencing. In order to provide the multiple services, handover is essential for seamless communication. Handover is one of important techniques to improve the system performance. Handover is the mechanism that transfers an ongoing call from one cell to another as a user moves through the coverage area of a cellular. There are two types of handover: hard handover and soft handover. Soft handover is a make-before-break method. Hard handover is a break-before –make method, where a new channel is set up after the release of the old channel. A certain amount of margin may be introduced to eliminate the Ping-Pong effect.

3.2 The Handover Classification In WCDMA System

Handover in WCDMA can be classified hard handover and soft handover. In hard handover based systems such as GSM, the mobile station keeps the connection to only one base station at a time, breaking the connection to the former base stations immediately before making the new connection to the target base station. In soft handover scheme, the new link between the mobile

station and the target base station is built before breaking the old link from the source base station.

Handover in WCDMA system can be classified into intra-frequency handover and inter-frequency handover by channel frequency mobile station uses, if the channel uses the same frequency after handover finishes as that one used before handover proceed, this is called intra-frequency handover, otherwise, if the channel uses the different frequency after handover finishes with that one used before handover proceed, this is called inter-frequency handover [3].

Intra-frequency handover includes intra-mode handover and inter-mode handover, for example, softer handover, soft handover and hard handover, and inter-mode handover between UTRA-FDD and UTRA-TDD [6]. In this research, we mainly analyse the intra-mode handover within WCDMA.

Inter-frequency handover also includes intra-mode, inter-mode and inter-system handover [3]. It is a hard handover by which the link between mobile station and base station is temporarily disconnected. Inter-frequency hard handovers can be used, for example, to hand a mobile over from one WCDMA frequency carrier to another to maximize the use of several carriers per base station.

The intra-mode handover of inter-frequency in WCDMA system is the handover between different frequency channels within one cell or one sector or among macro-cell, micro-cell or pico-cell in a hierarchical network structure in order to improve coverage and capacity or to balance the loading of network [3].

The inter-mode handover of inter-frequency is the handover between WCDMA system and multi-carrier CDMA.

The inter –system handover of inter-frequency is the handover between WCDMA FDD system and another systems , such as WCDMA TDD Or GSM system [3].

3.3 Softer Handover

Softer handover means that mobile station changes its channel from one sector to another sector within one cell. It provides additional diversity gain and doesn't cause extra transmission between base station and mobile station [3].

Fig 3.1 shows a basic softer handover scenario.

In the downlink communication, when a mobile station is in the overlapping area of the two adjacent sectors for one cell of a base station. There are two physical connections between base station and mobile station via two air interface channels, one for each sector separately because WCDMA uses Orthogonal Variable Spreading Factor codes to distinguish different downlink physical channels, this leads to a softer handover to use two separate codes in the downlink direction, so that the mobile station can separate the signals. The mobile station uses Rake receiver method to proceed the received two signals, it's very similar to multipath reception, the only difference is that the fingers needs to generate the respective code for each sector for the appropriate despreading operation.

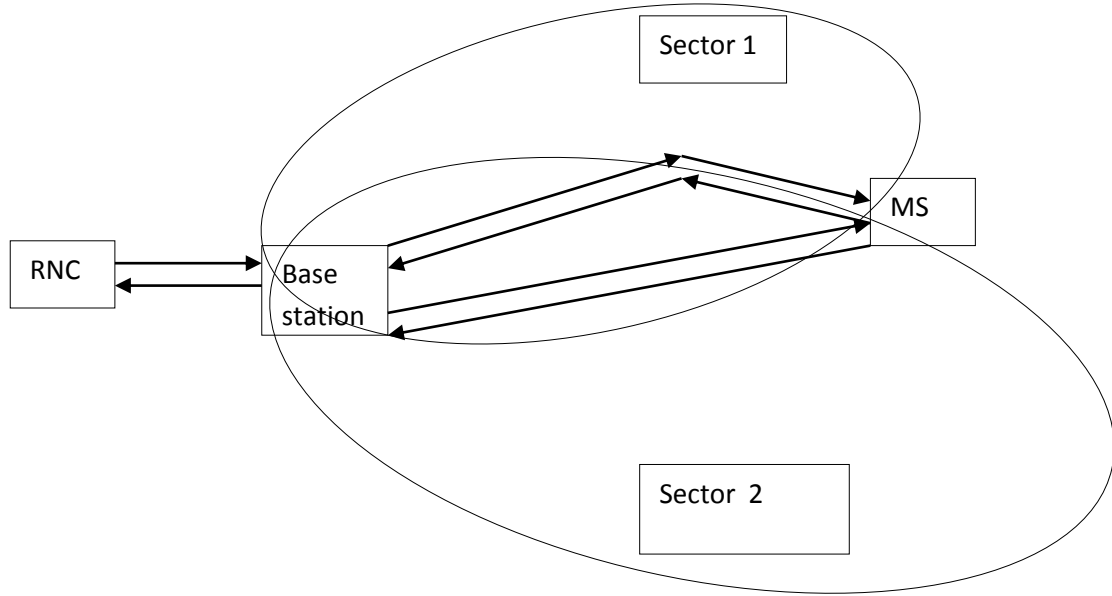


Figure 3.1: Softer Handover in WCDMA.

In the uplink direction, base station uses the same method as mobile station does in the downlink, Rake receiver, to combine the received two signals from two sectors. The two received signals are Maximal Ratio Combined (MRC) in base station. When a user is in overlapping region in Fig. 3.1, if the addition of signal levels received by two adjacent sectors is higher than signal level received by the nearest other-cell sector, the user is in softer handover and is power-controlled by both sectors [4].

The softer handover can improve system performance. In literature [4], the gain obtained by softer handover has been shown. This is due to the fact that in non-overlapping regions, users could transmit lower power compared to those in non-overlapping region, thanks to employing softer handover. Therefore, they cause less interference to other users. The disadvantage of softer handover creates additional interference when increase in the effective receiving angle enlarges overlapping region and causes more interference to the user.

During a softer handover, only one power control loop is active [3].

3.4 Soft Handover

3.4.1 Soft handover principle in WCDMA

In soft handover, a mobile station is allowed to be connected to simultaneously several base stations, which are selected by using relative threshold. Fig. 3.2 show the soft handover principle with two base stations involved. A mobile station enters the soft handover state when the signal strength of neighboring cell exceeds a certain threshold but is still below the current base station's signal strength.

Soft handover in WCDMA is a kind of intra-frequency handover. Soft handover is one of the essential features because of its suitability for CDMA based mobile systems. Therefore, soft handover has become one of the main issues and key challenges for WCDMA system. The two most well-known benefits are fade margin improvement and higher uplink capacity, while the disadvantages include higher downlink interference and more complex implementation. Proper design of handover is one of the main challenges in mobile communications, since it has a great impact on the system performance and capacity [5].

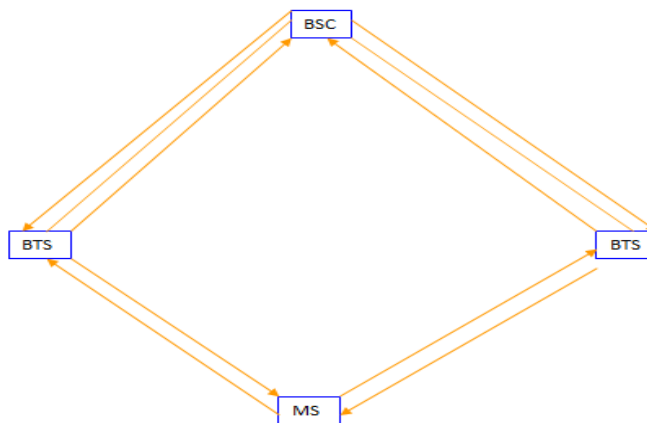


Figure 3.2: Soft handover with two base stations

In the uplink direction, each base station in the active set receives the signal simultaneously from the same mobile station because of the frequency reuse factor of one, then base station decodes the signal, after decoding a frame, the base station sends the frame to Radio Network Controller (RNC), and RNC chooses the base station with the best signal quality on a frame to frame basis and sends the data further, in this respect, it is different with softer handover. In Fig. 3.2, two base stations receive the uplink signal from the mobile station simultaneously and demodulate the signal respectively and pass the signal to the combining point, for example, the base station controller (BSC) [3].

In the downlink direction, mobile station receives signals from certain number of base stations simultaneously and coherently combine them into one signal by maximal ratio combining method since it see them as just additional multipath components. this provides an additional benefit called macro diversity (i.e., the diversity gain provided by the reception of one or more additional signals). In Fig. 3.2, the two base stations in the downlink direction transmit the same information, and the mobile station receives the from the two base stations simultaneously as separate multipath signals and combine them by MRC [3].

3.4.2 Soft Handover advantages

With soft handover technique, when the algorithms and the parameters are designed properly, each MS can potentially use the multiple radio links simultaneously, it may receive its signals from the multiple BSs and in general the same BSs then also receive the signal which is transmitted from the MS. The near far effect is avoided, WCDMA system capacity is substantially improved and the coverage is extended. The coverage size of cell is adjusted dynamically according to the interference from other cells. The system load is balanced among cells; the macro diversity offered by soft handover is

against shadowing fading and fast fading. Soft handover is an essential interference mitigating tool in WCDMA. When the maximum Doppler frequency is 5 Hz, for the required BER= 10^{-3} , the E_b/I_0 is 8.5dB with soft handover, and the E_b/I_0 is 13.1dB without soft handover, the soft handover gain is 4.6 dB.

However, the disadvantage of soft handover is that it creates more interference to the system in the downlink since the new base station now transmits an additional signal for the mobile station, and it needs base station power amplifier resources. It is possible that the mobile station cannot catch all the energy that the base station transmits due to a limited number of RAKE fingers. Thus, the gain of soft handover in the downlink depends on the gain of macro diversity and the loss of performance due to increased interference. In the uplink, it occupies more physical channels, needs more radio resources to be allocated give extra transmission across the interface between the base station and radio network controller, and this is different with softer handover.

3.5 Hard Handover

3.5.1 Intrafrequency hard handover

For the shared channels and common channels, they can't use soft handover; they support hard handover when needed. Decision procedure of this type handover is the same as soft handover controlled by Network Evaluated Handover (NEHO) and RNC, and causes temporary disconnection of the user.

3.5.2 Interfrequency Hard Handover

WCDMA has 20MHz bandwidth, it can be split into smaller multiple bandwidth with different carriers transmission, so each cell in WCDMA network will have multiple frequency carriers. For a hot spot cell, it could have more numbers of frequencies than neighboring cells. Furthermore, in order to give a good coverage, the hierarchical cell structure will be used. For

this kind of structure, micro cells will have different frequency channels than the macro cells overlaying the micro cells.

It is also important for WCDMA to handover between different frequencies; it can be a hard handover within one base station or within one RNC, or between different RNC. So an efficient procedure is needed for this type of handover.

Like GSM or IS-95 system, an efficient method for inter-frequency handover are needed for measuring signal strength and quality on other frequencies while still having the connection running on the current frequency.

A view for inter-frequency handover has been given in reference [6]; it analyzed two methods for inter-frequency measurements in WCDMA.

- Dual receiver
- Slotted mode

While a mobile station employ antenna diversity, dual receiver method means that mobile station has two receiver branches, one receiving branch measures the signal strength and quality on the other frequency while another receiving branch are keeping on transmitting and receiving signals on the current frequency. This is especially suitable for antenna diversity in mobile station.

However it is not easy to have antenna diversity in mobile station by normal antenna. Fortunately, the WCDMA system supports adaptive antenna technique development. It is possible that one of the beam formers of smart antenna in mobile station can be used to catch the signals to measure the signal strength and the quality on other frequency while the other beam formers are used to maintain the connection on the current frequency.

Another method, slotted mode is used for inter-frequency handover measurement in WCDMA. By this way, the information transmitted is

compressed in time domain to give a short Transmission Gap Lengths (TGL) of the channel to measure the signal strength on other frequency, the compressed method. The information are compressed by lowering the data rate from higher layers, or increasing the data rate by changing the spreading factor or reducing symbol rate by code puncturing or by changing FEC rate. Fig. 3.3 shows the basic mechanism of slotted mode:

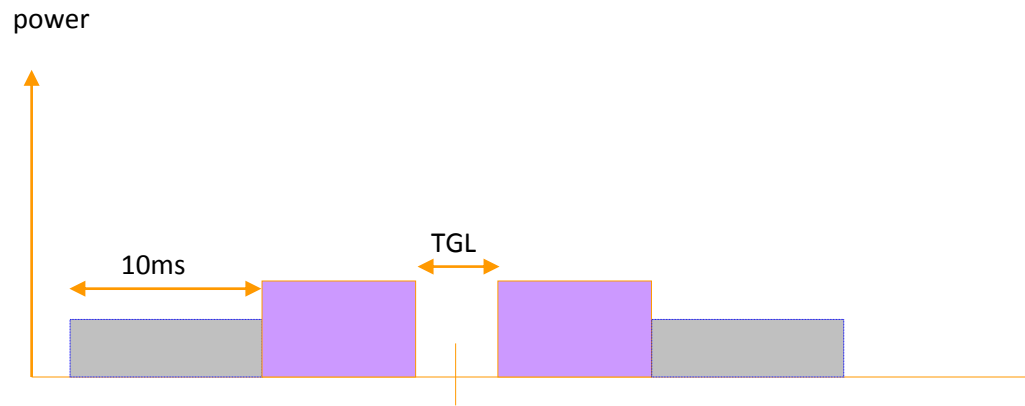


Figure 3.3: Frame boundaries

It is more attractive that mobile stations don't need antenna diversity compared with dual receiver, but there is also a tradeoff between system complexity and the advantage of this method. More detailed information is described for this method in [3].

The inter-frequency handover is a Network Evaluated Handover (NEHO), and the decision algorithm is located in RNC.

3.5.3 Inter-System between GSM and WCDMA

In order to improve the coverage, capacity and balancing load of mobile communication, WCDMA not only supports hard handover between different frequency carriers within WCDMA system, but also support hard handover between WCDMA and other mobile communication system, for example GSM, to offer a worldwide coverage capacity.

Mobile station should be multi-mode in order to support the inter-system handover. In addition the frame timing is critical for this type handover. Two timing methods are shown like that of the inter-frequency handover within WCDMA system mentioned above: slotted mode and dual receiver in reference [6]. A WCDMA terminal can do the measurements either by requesting the measurement intervals in a form of slotted mode where there are breaks in the downlink transmission or then it can perform the measurements independently with a suitable measurement pattern. With independent measurements the dual receiver approach is used instead of the slotted mode since the GSM receiver branch can operate independently of the WCDMA receiver branch.

In WCDMA, handovers are assisted by measurement reports from UEs. The common measurement quantity that is used to trigger handover events is CPICH E_c/N_0 .

Once the CPICH E_c/N_0 quantity associated to the small cell falls below that of the macrocell by at least a Handover Threshold (HT) and stays there for a minimum of a Time to Trigger (TTT) period, the handover occurs. Over time, the small cell base-station is capable of estimating the E_c/N_0 level at which handovers are performed as shown on figure 3.4.

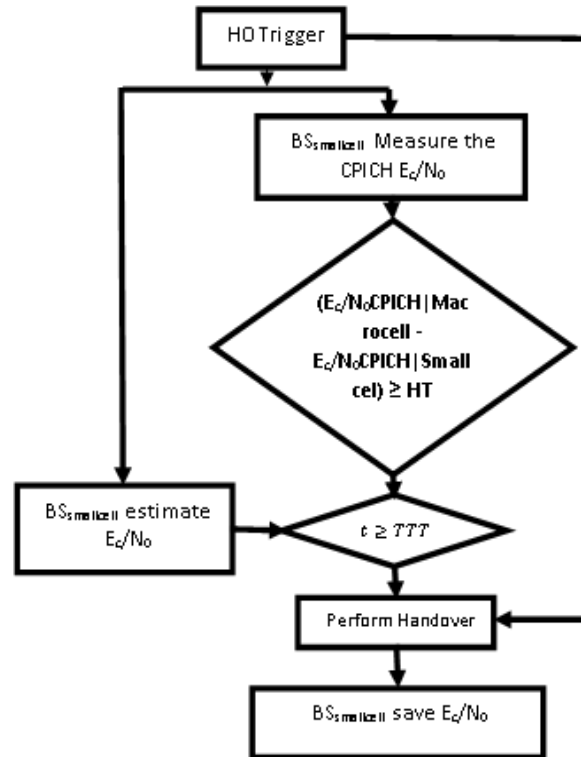


Figure 3.4: WCDMA handover flow chart

3.6 Power control(PC)

Power control is critical in CDMA systems to keep interference under control. Each base station (BS) controls the transmit power of its own users. However, a given BS is unable to control the power of users in neighboring cells; and these users introduce intercell interference, thereby reducing the capacity of the reverse link. Thus, to minimize the total received power in a cell while all users get their minimum required power, the cell should be sectorized such that each sector has the same number of active users.

3.6.1 Uplink open loop PC

First DPCCH power level for the uplink inner-loop PC is started as.

$$P_{UE} = P_{Offset} - CPICH(RSCP) \quad (3.1)$$

P_{UE} is the user equipment power

CPICH(RSCP) CPICH received code power

P_{offset} is power offset and calculated by AC in the RNC and provided to MS during a radio bearer or physical channel reconfiguration.

$$P_{\text{offset}} = CPICH_{\text{power}}^{Tx} + UL_{\text{inter}} + SIR + 10\log(SF) \quad (3.2)$$

$CPICH_{\text{Power}}^{Tx}$ Common Pilot Channel Tx Power

UL_{inter} Uplink interference

SIR is the initial target SIR

SF Spreading factor

3.6.2 Downlink Open loop PC

- The open loop PC is used to the initial power of the downlink channels based on downlink measurement reports.
- The function is in UTRAN and MS.
- A possible algorithm for initial power calculations is

$$P_{Tx}^{\text{Initial}} = R \frac{\left(\frac{E_b}{N_0}\right)_{DL}}{W} \left(\frac{CPICH_{\text{power}}^{Tx}}{\left(\frac{E_b}{N_0}\right)_{CPICH}} - \alpha \cdot P_{Total}^{Tx} \right) \quad (3.3)$$

R user bit rate

$(E_b/N_0)_{DL}$ downlink planned E_b/N_0 .

W the chip rate.

$(E_b/N_0)_{CPICH}$ reported by MS.

α the downlink orthogonality factor.

P_{Total}^{Tx} carrier power measured at the BS and reported to the RNC.

3.6.3 Closed loop PC

Closed loop power control only exists in dedicated channels [7]. It is divided into inner-loop and outer-loop. Inner-loop has almost the same structure in both links. The uplink inner-loop power control adjusts the base station transmit power in order to keep the received uplink signal to interference ratio

(SIR) at a given SIR target, SIR_{target} . The base station (or stations if the mobile is in soft handover) should estimate signal to interference ratio SIR_{est} of the received uplink DPCCH and then generate TPC commands and transmit the commands once per slot according to the following rule:

- If $SIR_{est} > SIR_{target}$, the TPC command to transmit is “0”
- If $SIR_{est} < SIR_{target}$, the TPC command to transmit is “1”

Upon the reception of one or more TPC commands in a slot, the mobile shall derive a single TPC command (TPC_cmd) for each slot. There are two algorithms supported by the mobile for deriving a TPC command. Higher layers determine which of these two algorithms is used.

Chapter Four

Hard Handover Optimization in WCDMA

4.1 Overview

WCDMA is a wideband Direct Sequence Code Division Multiple Access (DS-CDMA) system, i.e., user information bits are spread over a wide bandwidth by multiplying the user data with bits -very high bit rates, the use of a variable spreading factor and multicode is supported. The chip rates of 3.84 Mcps leads to a carrier bandwidth of 5 MHz .The wide carrier bandwidths of WCDMA supports high user data rates and have certain benefits, such as multipath diversity. WCDMA supports high variable user data rates; in other meanings the concept of obtaining Bandwidth on Demand (BoD) is supported. The user data rate is kept constant during each 10 ms frame. WCDMA supports two basic modes of operation this modes are Frequency Division Duplex (FDD) and Time Division Duplex (TDD). Femtocells, by virtue of their simultaneous small size, low cost and high performance, are a potentially industry-changing disruptive shift in technology for radio access in cellular networks. Their small size means that the spectrum efficiency they can attain is much greater than that achievable using macrocells alone. Their low cost means they can be deployed as consumer equipment, reducing the capital load and operating expenses of the host network. And their high performance means that all this can be gained at no loss of service to the customer, and in many cases, owing to the improved link budgets, improved service.

Femtocells are low-power cellular base stations that operate in licensed spectrum. They are typically deployed indoors to improve coverage and provide excellent user experience, including high data rates. Cellular operators benefit from reduced infrastructure and operational expenses for

capacity upgrades and coverage improvements. Femtocells also bring unique challenges, such as unplanned deployment, user installation, restricted access, and interoperability with existing handsets and network infrastructure. Although femtocells may cause some interference to other users in the network, with the use of proper interference management techniques, this can be well controlled.

With the ever-increasing data traffic demand in today's mobile network, immediate solutions for capacity improvement are sought by the operators. Additionally, with up to 80 percent of the traffic being originated from indoors [8] where the current mobile networks are least effective due to high buildings penetration losses, indoor data offloading has become a focus of the industry in the recent years. One attractive solution to offload indoor users' traffic is to deploy small cells such as femtocells see figure 4.1.

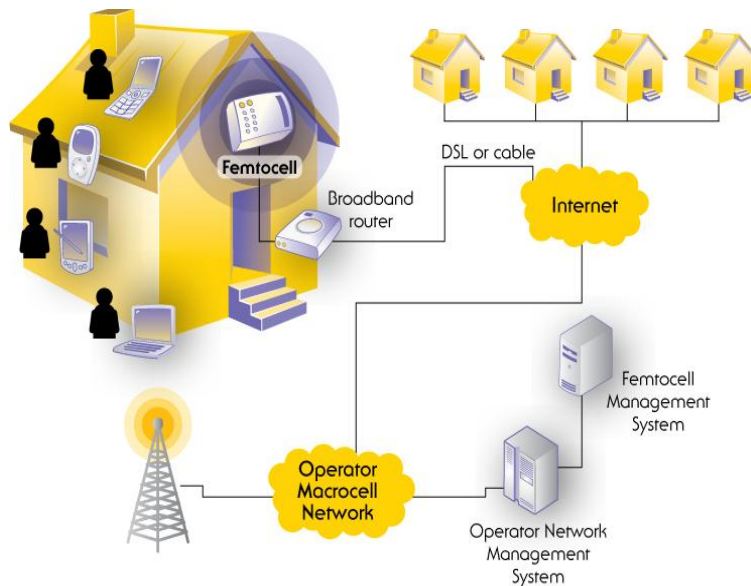


Figure 4.1: Macrocell Network

Since small cells are considered as an integrated part of the operators' network, seamless handovers between the small cells and the underlying macrocell network is considered as a key advantage when compared against

other alternatives such as Wi-Fi based solutions. Additionally, while operating small cells on a dedicated frequency is a pragmatic possibility, co-channel operation with an existing macrocellular network is technically far more challenging [9].

In WCDMA, the uplink inner-loop power control adjusts the User Equipment (UE) transmit power, P_{UE} , in order to keep the received uplink signal to interference ratio (SIR) on that frequency at a given SIR target (SIRT). The base-station estimates the signal to interference ratio (SIRE) of the received uplink Dedicated Physical Control Channel (DPCCH). Then, it generates Transmit Power Control (TPC) commands and transmits the commands to the UE once per time slot. Normally, the TPC commands are binary quantities that are set to '1' if $SIRE < SIRT$ and to '0' otherwise. The 3GPP standard [15] defines two algorithms to determine how TPC commands ought to be interpreted or combined. If the UE receives TPC commands from a single radio link, it can either modify its transmit power in fixed steps in response to every received TPC command (algorithm 1) or wait to receive 5 consecutive TPC commands before adjusting the power (algorithm 2). In case of the latter, a power increase or decrease is executed only if all 5 TPC commands identically recommend a same direction of transmit power change (all increase or decrease); otherwise the power remains unchanged. Evidently, algorithm 2 is more stable but simultaneously slower.

In the case when the UE receives TPC commands from more than one radio link (e.g. during the soft handover regime), it additionally needs to combine TPC commands from different links. In case of algorithm 1 for example, the UE would decrease its power if it receives at least one TPC command with the value of '0' (i.e. Boolean 'OR' operation). This is because it is

sufficient for the UE to communicate to at least one base-station while minimizing the interference to other users.

In hard handover, after the UE establishes a connection to the new cell, it adjusts its power using the open loop power control to communicate to the target cell. The UE's initial transmission consists only of the DPCCH. The details of the initial power configuration after the handover are described in [16]. Adapting the UE's transmit power in that way is not problematic in traditional networks, consisting only of macrocells. The reason for that is because the UE's transmit power is not expected to vary radically after the handover that it is due to insignificant difference between the path-loss from the source and target macrocell Node-Bs. In addition, since macrocells are usually serving relatively large number of users compared to small cells, the increase of a single user's transmit power may not significantly vary the overall interference at a neighboring base-station.

The situation is slightly different when considering soft handovers. When the user is already connected to all base-stations in the active set, its transmit power is continuously modified through inner-loop control. Since the conservative power control keeps the transmit power of users at a minimum level during the soft handover regime, once the link to the serving small cell base-station is removed, the UE will suddenly need to increase its power. Given that the inner-loop power control modifies the transmit power in small steps, it may take a while before the UE can reach an appropriate power level and hence degradation of the user's Quality of Experience (QoE) and dropped calls are possible. The case would be even more significant if algorithm 2 is applied. While, the solution proposed in

this research addresses the problem associated to hard handover, the research focus mainly on the hard handover case since currently there is no soft-handover support in most small cells products (14).

Why open loop power control is needed and how it works?

- ❖ When a UE needs to access to the network it uses RACH to begin the process.
- ❖ RACH is a shared channel on the uplink used by all UE therefore may encounter contention (collision) during multiple user access attempts and interfere with each other.
- ❖ Each UE must estimate the amount of power to use on the access attempt since no feedback from the NodeB exists as it does on the dedicated channel.
- ❖ The purpose of open loop power control is to minimize the chance of collision and minimize the initial UE transmit power to reduce interference to other UE.
- ❖ Instead of sending the whole message, a “test” (preamble) is sent.
- ❖ Wait for answer from NodeB.
- ❖ If no answer from NodeB increase the power.
- ❖ Try and try until succeed or timeout.

Unfortunately, the case of traditional networks not here for heterogeneous networks where small cells are deployed within the coverage area of macrocells as shown on figure 4.1 because the UE's transmit power is expected to vary radically after the handover that it is due to difference between the path-loss from the source and target macrocell Node-Bs. Here, after handover from a small cell to a macrocell, a user needs to transmit at a much higher power. Such radical and sudden increase of the transmit power of the user who is still located in vicinity of the small cell base-

station, introduces a significant uplink interference to the remaining small cell users as shown on figure 4.2.

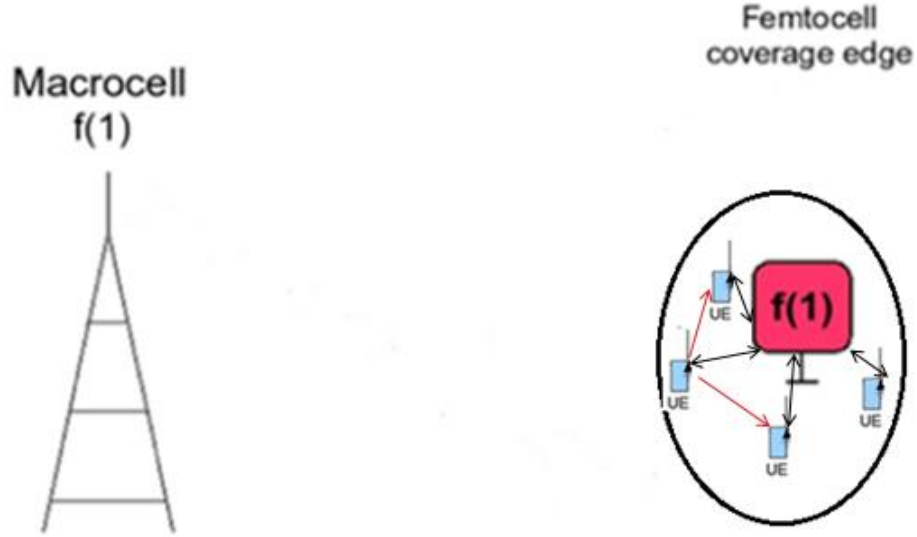


Figure 4.2: HO problem in heterogeneous networks

Figure 4.2 show that a smallcell (eg.femtocell) with four users are deployed within macrocell area and one of users of smallcell that on the edge between macrocell and smallcell cause interference to the other remaining users (because handover is not performed).

4.2 Time-Window based Handover (TWHO) Algorithm

In practice, once the CPICH E_c/N_0 falls below CR, the small cell base-station records the current transmit power of the UE noted as P_{statr} . It then commands the UE to adjust its power level P_{UE} such that by the time of the handover, the UE is already at the approximate power level required to communicate to the target macrocell base-station as shown on figure 3.5.

We shall refer to this power level as P_{target} . This way, the small cell base-station assures that significant rise of the transmit power and sudden decrease of the SIR for the existing small cell users are avoided. Moreover,

P_{target} does not need to be estimated accurately as the finer inner-loop power control mechanism after the handover will adjust any offset. P_{target} can be simply estimated by the small cell base-station or more accurately by the UE via path-loss estimation to the target macrocell. Ideally, the users transmit power, P_{UE} , should be set to P_{target} when CPICH E_c/N_0 equals HR (i.e. when handover is executed).

In this research UE use the equation 4.3 to adjust its power:

$$P_{\text{UE}} = \left(\frac{P_{\text{target}} - P_{\text{start}}}{P_{\text{HT}}} \right) \left(CR - \frac{E_c}{N_0} \right)^m + P_{\text{start}} \quad (4.1)$$

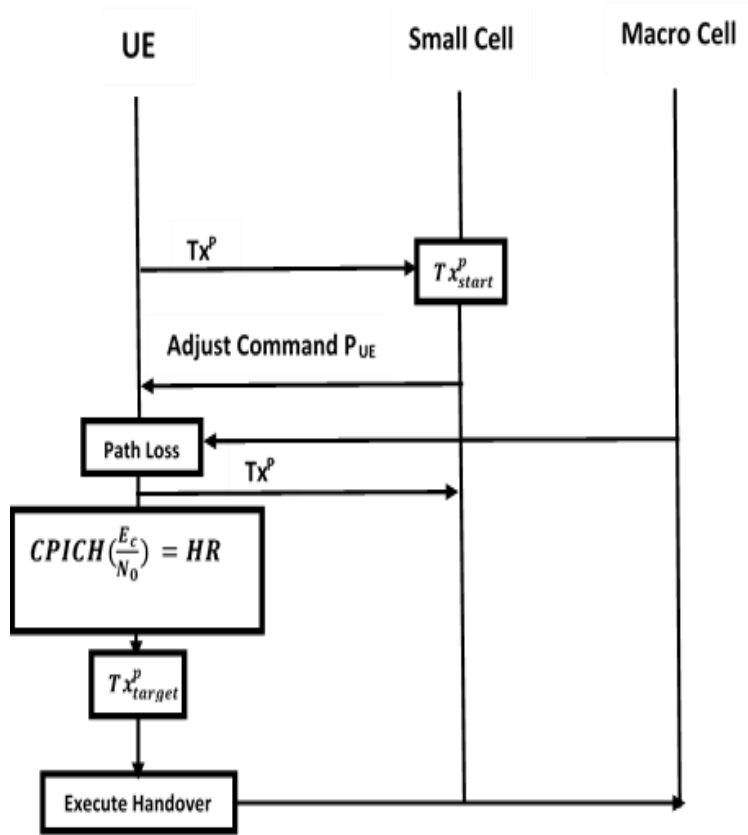


Figure 4.3: Practical Handover flowchart

To avoid unnecessary increase of the transmit power; a timer is activated after the CPICH E_c/N_0 falls below the CR threshold. Then, if no handover is performed within a predefined time-window (T_w) the power control will gradually be set back to its normal procedure and the timer is reset as shown

on figure 4.4, this allows static users at the edge of the small cell coverage to transmit at their normal power and eliminates the need for unnecessary power increase.

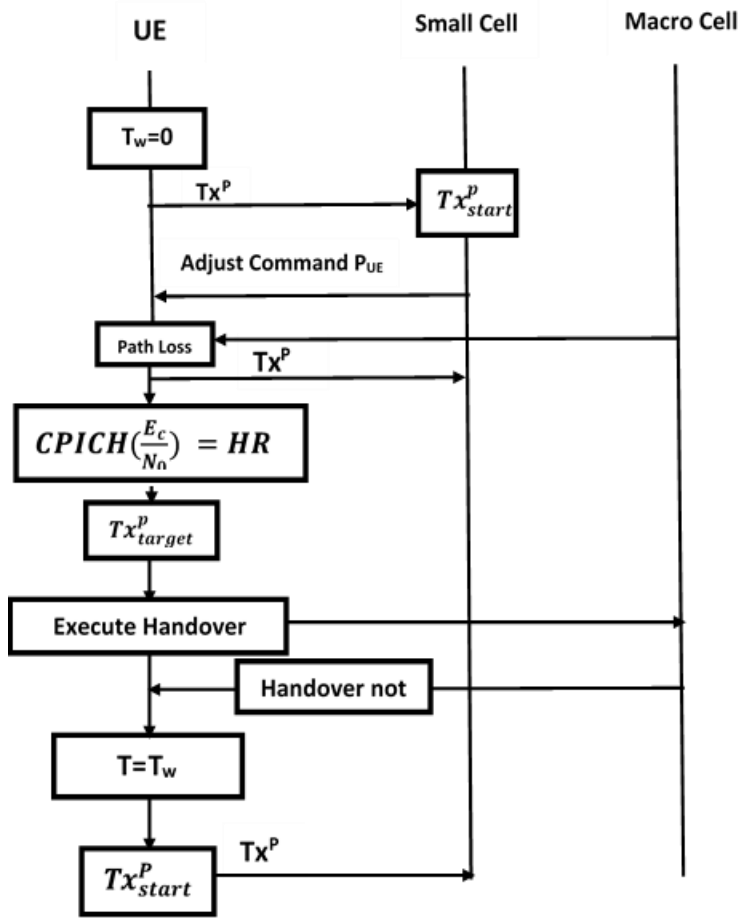


Figure 4.4: TWHO flowchart

In Open loop power control UE use the below equation to adjust its power:

$$P_{UE} = P_{Offset} - CPICH(RSCP)$$

P_{UE} is the user equipment power

P_{offset} is Power Offset

$$P_{offset} =$$

$$CPICH_{power}^{Tx} + UL_{inter} + SIR + 10\log(SF)$$

In this research UE use the below equation to adjust its power [13]:

$$P_{UE} = \left(\frac{P_{target} - P_{start}}{PHT} \right) \left(CR - \frac{Ec}{No} \right)^m + P_{start}$$

$\frac{E_c}{N_0}$ The carrier energy to noise density and its equal to:

$$\frac{E_c}{N_0} = \text{RSCP} - \text{RSSI} \quad (4.2)$$

Where the uplink interference is:

$$\text{UL}_{\text{inter}} = \text{RSCP}_{\text{U1}} + \text{RSCP}_{\text{U2}} + \dots + \text{RSCP}_{\text{U3}} \quad (4.3)$$

And the CPICH received code power:

$$\text{CPICH}(\text{RSCP}) = \text{CPICH}_{\text{power}}^{\text{Tx}} - \text{PL} \quad (4.4)$$

The smallcell path loss [13]:

$$\text{PL}_{\text{SC}} = 30.52 + 36.7\log(d) \quad (4.5)$$

The macrocell path loss [13]:

$$\text{PL}_{\text{MC}} = 11.81 + 38.6\log(d) \quad (4.6)$$

Finally the signal to interference ratio of one the remaining users:

$$\text{SIR} = \frac{\text{RSCP}}{\text{ISCP}} + \text{SF} \quad (4.7)$$

Chapter Five

RESULTS AND DISCUSSION

5.1 Overview

For heterogeneous networks smallcells are deployed within the coverage area of macrocells, if user move from smallcell to macrocell, this user increase its power to perform handoff to serving the macrocell, if no handover is performed, the user introduces significant uplink interference to the remaining small cell users.

This research introduces a realistic and efficient solution to adapt the transmit power of the small cell users during the handover regime to prevent such SIR drops. Simulation results confirm significant performance improvement when using the proposed scheme.

5.2 Simulation Scenario

The simulation scenario consists of a macrocell and smallcell with three small cell users noted as u1, u2, u3.

The rest of the simulation results refer to the scenario when u2 moves from the small cell coverage and handoff to the underlying macrocell, u2 most increases its power to complete the handover to macrocell. Here if handover not execute u2 cause interference to the other small cell users. More specifically, the results capture the SIR drop of u1.

There are factors that impact the SIR drops of u1. The first and most evident factor is the amount of the use's power increase that itself depends on the path-loss difference to the source small cell and the target macrocell base-station. The path-loss for small cell and macrocell was modeled according to the 3GPP recommendations [11].

One of the main parameters that affect the interference interactions between the small cell and macrocell is the effective coverage radius of the

small cell. Figure 5.1 illustrate the relation between smallcell radius and distance from smallcell to macrocell BS.

Additionally, if the small cell base-station is already imposed to high uplink interference (from own or other users) the power increase of a single user may not considerably change the total interference. Finally, the path-loss between the user (at the time of the handover) and the source small cell base-station defines to what extend the base-station is vulnerable to the uplink interference from that user.

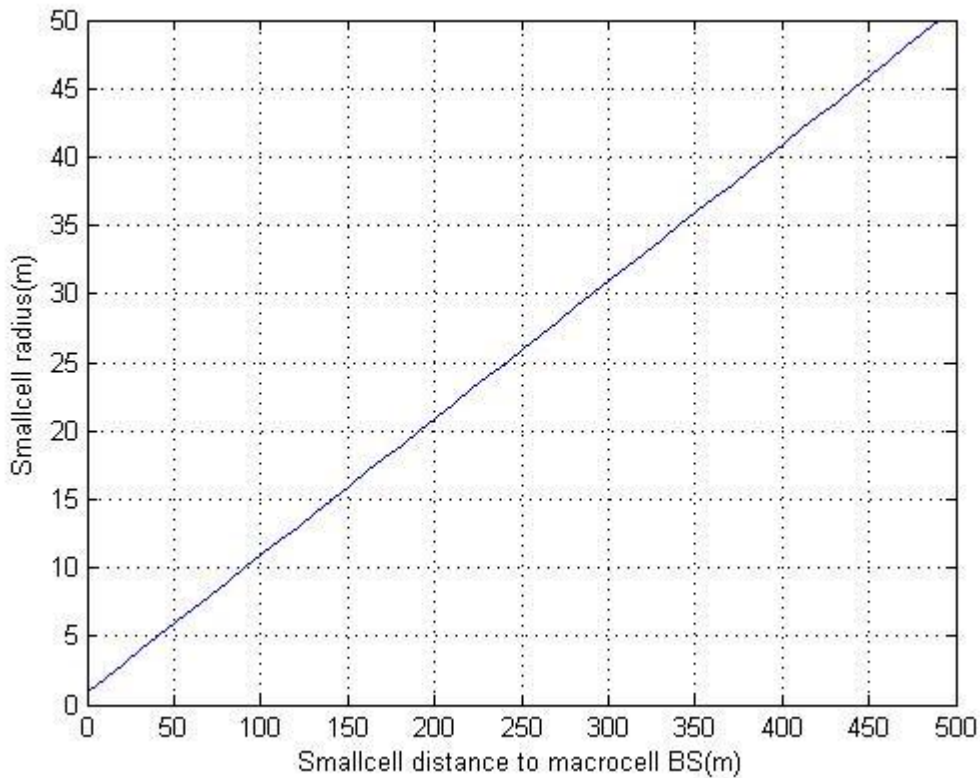


Figure 5.1: Small cell coverage as a function of distance to the underlying macrocell base-station

5.3 Simulation Assumptions and parameters

Key simulation parameters are listed in Table 5.1.

Table 5.1: Simulation parameters

Parameters	Values
No of Macrocell	1
Macrocells users distribution	Uniform
Macrocell BSs total Tx power	20Watt
Macrocell BSs CPICH Tx power	2Watt
Macrocell path-loss model (d is distance in m)	$11.81+38.6\log_{10}(d)$
Macrocells distance	500m
No of small cell users	3
Small cell BSs total Tx power	250mW
Small cell BSs CPICH Tx power	25mW
Small cell BS antenna type	Omni-directional
Small cell path-loss model (d is distance in m)	$30.52+36.7\log_{10}(d)$
Users' power increase/decrease steps	1 dB
Users' antenna type	Omni-directional
Target SIR	6.5 dB
Uplink spreading Factor	128
Users transmit power	24 dBm
Handover Threshold (HR)	3 dB
Mapping order (m)	1
Potential Handover Threshold (PHT)	6 dB

In this research we compare between the SIR of one of remaining users that use the open loop power control (PC) and SIR of one of remaining user that use the Time-Window based Handover (TWHO).

Open loop PC

Here open loop PC mechanism was used to show the effect of handover problem on SIR of u1.

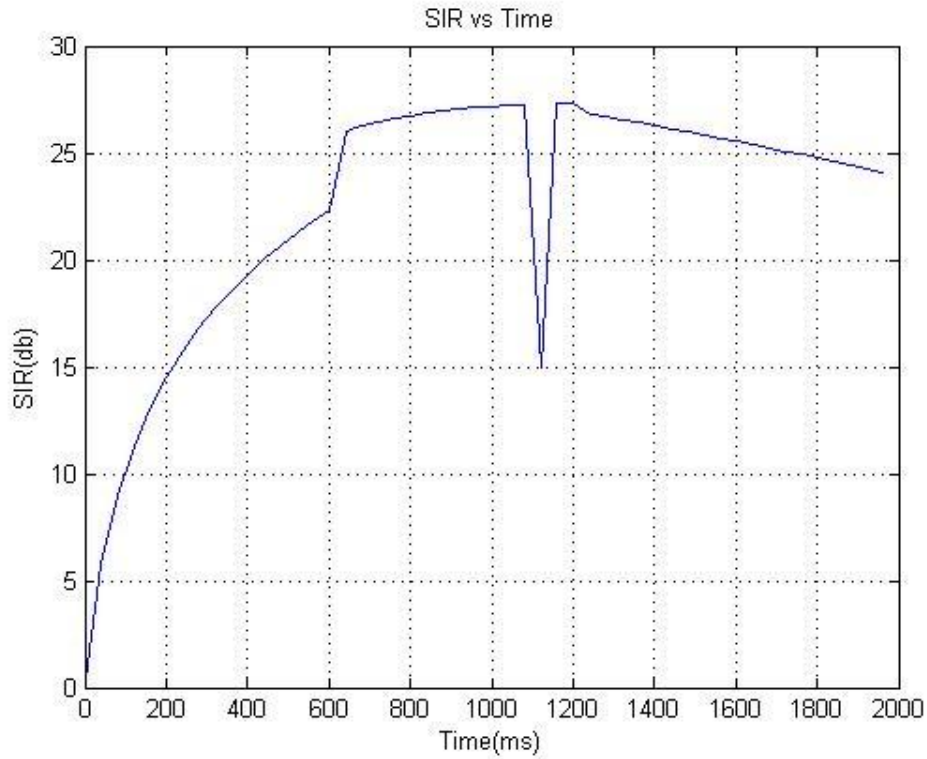


Figure 5.2: SIR of Open Loop PC

Figure 5.2 show that the SIR of u1 in Open Loop PC drop when handover not executed (when u2 causes interference to other user). The SIR drop takes 70ms until it regains its stability, this may be cause drop to user call.

5.4 Time –window HO

Here TWHO mechanism was used to show the effect of handover problem on SIR of u1 on different TW values as shown in figure 5.3 TW = 70ms, figure 5.4 TW = 190ms, figure 5.5 TW = 10us.

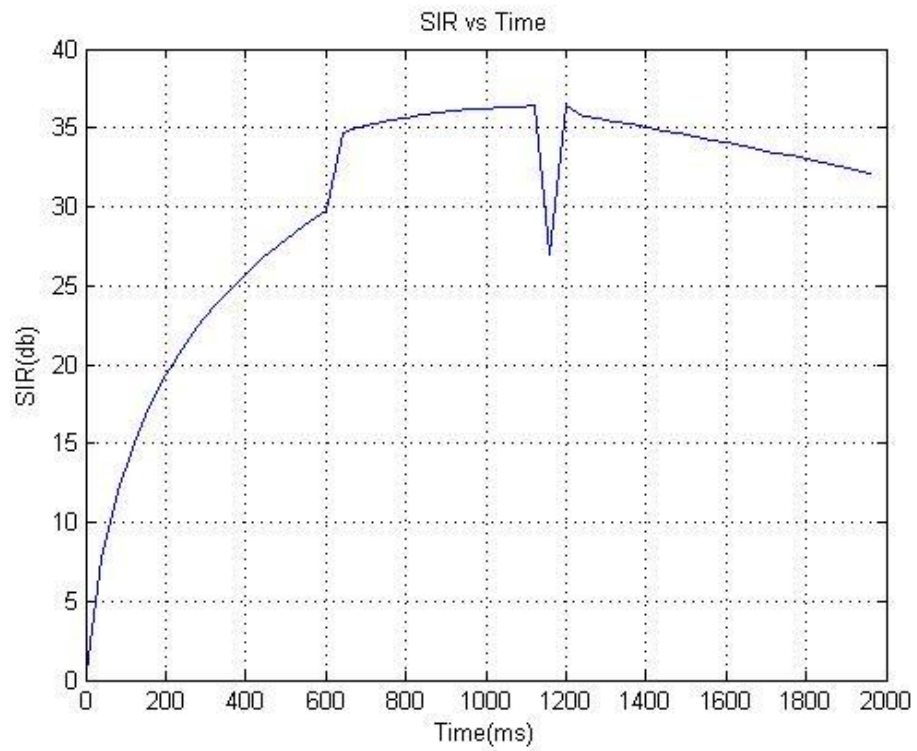


Figure 5.3: SIR of TWHO (TW = 70ms)

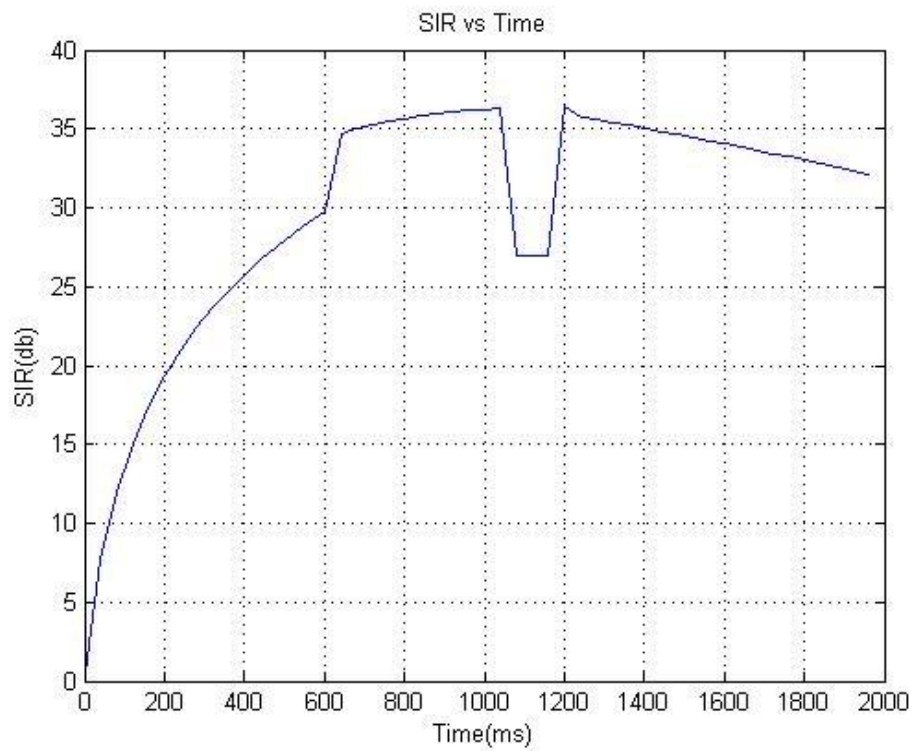


Figure 5.4: SIR of TWHO (TW = 190ms)

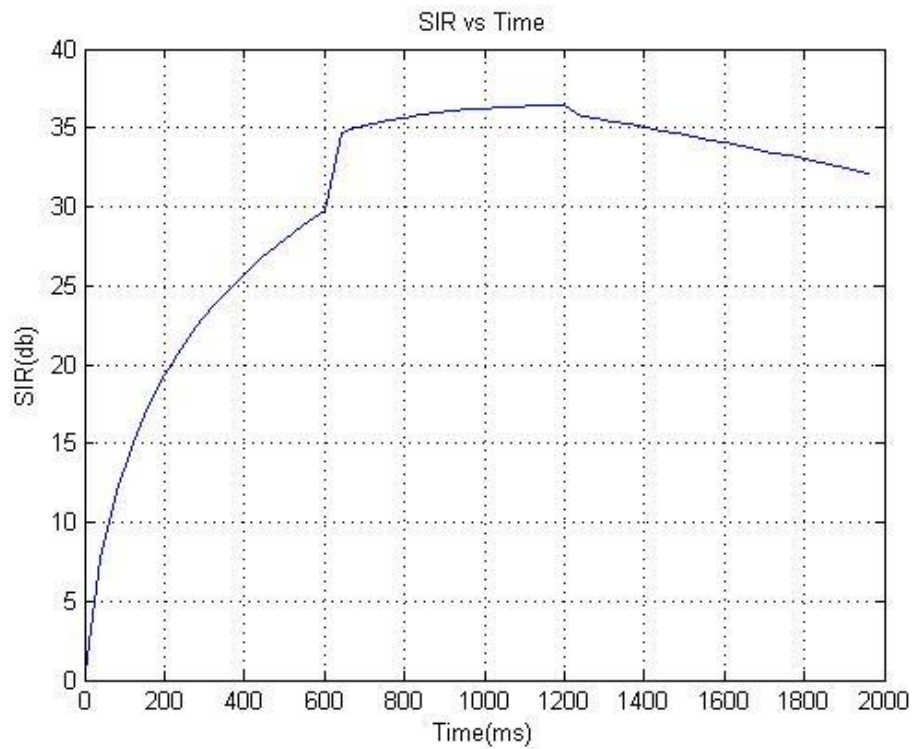


Figure 5.5: SIR of TWHO (TW=10us)

The SIR in Time-Window based Handover (TWHO) not slightly effect by handover problem when TW is very short, the handover problem effect increase with TW decrease and vice versa. In figure 5.4 u1 SIR drop until 190ms this is long time, this long time may be cause drop to the call, by decrease TW as shown on figure 5.3 and 5.5 the drop of SIR take short time, this short time has a legal effect on SIR value.

Chapter Six

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusions

This research investigates a handover problem occurring with current power control during the handover for the co-channel WCDMA heterogeneous networks. The problem is associated with the mismatch between the required uplink transmit power when a user is communicating to small cell and an underlying microcellular base-station. It was shown that the sudden increase of transmit power after the handover causes severe degradation of uplink SIR for existing small cell users. To alleviate the problem, a proposed solution to optimize handover was described.

6.2 Recommendations

It is clear that using Time-Window based Handover technique improves the performance of the WCDMA system. For future work it should be noticed that using TWHO with LTE system so as to reduce the uplink interference.

In another side using techniques of FPGA chips this project can be practical field when these models convert to VHDL language and downloaded in FPGA chip which we know this is called Software Define Radio (SDR) Techniques. The XILINX company provides the converters of the MATLAB to VHDL capability as icons in simulink models so the practical design is very simple after designing these models.

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Appendix

MALAB Code:

```
%SC total transmit power is 24dbm
total_Tx = 24;
%SC CPICH transmit power is 14dbm
CPICH_Tx = 14;
%MC CPICH transmit power is 14dbm
CPICH_Tx_mc = 33;
%SIR about 6.5db
SIR = 36.5;
%spreading factor
SF = 128;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
D=50;
%user equipment transmit power about 24dbm
Pue = 24;
%Critical Ratio
CR = 39;
%Potential Handover Threshold
PHT = 36;
%Mapping Order
m=1;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
t = 1:40:2000;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
PO1=ones(1,50);
Pue_pcl=ones(1,50);
%.....

d1_sc = 10;
%%d1- u1 from SC
d2_sc = 1:D;
%%d2- u2 from sc
for i=1:50
    if(d2_sc(i)>30)
        d2_sc(31)=31;
        d2_sc(30)=30;
        d2_sc(29)=29;
        d2_sc(i)=28;
    end
```

```

end
d3_1 = 1:D;
%%d3- u3 from U1
d3_sc = sqrt(((d1_sc).^2+(d3_1).^2)-
2.*d1_sc.*d3_1.*cos(60));      %%d3- u3 from sc
d2_1 = sqrt(((d2_sc).^2+(d1_sc).^2)-
2.*d2_sc.*d1_sc.*cos(60));      %%d2- u2 from U1
for i=1:50
    if(d2_1(i)>30)
        d2_1(31)=31;
        d2_1(30)=30;
        d2_1(29)=29;
        d2_1(i)=28;
    end
end
dmc_sc = 1:10:500;

for i=1:50
    if(d3_sc (i)>30)
        d3_sc (i)=30;
    end
end

%user2,3 path loss from user1
u2_u1_path_loss = 30.52+36.7*log10(d2_1);
u3_U1_path_loss = 30.52+36.7*log10(d3_1);

%user1,2 path loss from SC
u1_sc_path_loss = 30.52+36.7*log10(d1_sc);
u2_sc_path_loss = 30.52+36.7*log10(d2_sc);
u3_sc_path_loss = 30.52+36.7*log10(d3_sc);

%user 2 path loss from MC
d2_mc = dmc_sc - d2_sc;
u2_mc_path_loss = 11.81+38.6*log10(d2_mc);

%user1 power recieve at SC
Pr1 = Pue-u1_sc_path_loss;
Pr2 = Pue-u2_sc_path_loss;
Pr3 = Pue-u3_sc_path_loss;

%user1 interference power recieve
%Pi1 = Pue-u1_path_loss;
Pi2_1 = Pue-u2_u1_path_loss;
Pi3_1 = Pue-u3_U1_path_loss;

%user2 power in mc area
Pi2_mc = Pue+30-u2_mc_path_loss;

```

```

%user1,2 CPICH recieved code power
RSCP1 = CPICH_Tx-u1_sc_path_loss;
RSCP2 = CPICH_Tx-u2_sc_path_loss;
%.....%

%user1,2 CPICH recieved code power

RSCP2_mc = CPICH_Tx_mc-u2_mc_path_loss;
%.....%
%user2 recieved signal strength indicator
RSSI = total_Tx-u2_sc_path_loss;
CPICH_Ec_N0 = RSCP2+100;%-RSSI;
%.....%

%user2 uplink interference
UL_i = Pr1+Pr3;

%user1 interference
ISSI = Pi2_1+Pi3_1;
SIR_C = Pr2-UL_i+10*log10(SF)-35;
PO = CPICH_Tx_mc+UL_i+SIR+10*log10(SF);
Pue_pc = PO-RSCP2_mc;
%power offset
for i=1:50
    if (SIR_C(i) < SIR)
        if (Pue_pc(i)>(Pr2(i)+1))
            Pue_pc(i)=Pr2(i)+i-30;
            if((i==29))% || (i==30) || (i==31))
                PO(i) = CPICH_Tx_mc+UL_i(i)+SIR+10*log10(SF);
                Pue_pc(i) = PO(i)-RSCP2_mc(i)-70;
            end
        end
    end
    if(SIR_C(i) > SIR)%38.7628
        Pue_pc(i) = Pr2(i);
    end
    %Propose Solution
    if (CPICH_Ec_N0(i)<CR)
        %Pue_pcl(i) = ((10^(Pue/10)-
        10^(Pr2(i)/10))/10^(PHT/10)).*((10^(CR/10)-
        10^(CPICH_Ec_N0(i)/10)).^m)+10^(Pr2(i)/10);
        Pue_pcl(i) = ((Pue-Pr2(i))/PHT).*((CR-
        CPICH_Ec_N0(i)).^m)+Pr2(i);
        if (Pue_pcl(i)>(Pr2(i)+1))
            Pue_pcl(i)=Pr2(i)+i-30;
            if((i==30))

```

```

        Pue_pc1(i) = (((Pue-Pr2(i))-PHT)+((CR-
CPICH_Ec_N0(i)).^m)+Pr2(i))+30;
        Pue_pc1(i) = Pr2(i);
    end
end
end
if (CPICH_Ec_N0(i)>CR)
    Pue_pc1(i) = Pr2(i);
end
end

%user1 uplink interference after power control
ISSI1 = Pue_pc+Pi3_1-20;
ISSI11 = Pue_pc1+Pi3_1-20;
%SIR of user1
SIR=((RSCP1-ISSI1)+10*log10(SF))/4;
SIR1=((RSCP1-ISSI11)+10*log10(SF))/3;
plot(t,SIR1)
title('SIR vs Time');
xlabel('Time(ms)');
ylabel('SIR(db)');
grid;

```