ADAPTIVE POWER CONTROL APPLYING TO FEMTOCELL

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of

Bachelor of Technology
In
Electronics and Communication Engineering

Under the guidance of

Prof. Poonam Singh

by

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2013

Declaration

We hereby declare that this thesis is our own work and effort. Throughout this documentation wherever contributions of others are involved, every endeavor was made to acknowledge this clearly with due reference to literature. This work is being submitted for meeting the partial fulfillment for the degree of Bachelor of Technology in Electronics and Communication Engineering at **National Institute of Technology, Rourkela** for the academic session **2009 – 2013.**

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Certificate

This is to certify that the thesis entitles "**ADAPTIVE POWER CONTROL APPLYING TO FEMTOCELL**" submitted by **Ankit Agarwal (Roll no: 109EC0527)** and **Pravesh Dahal (Roll no: 109EC0528)** in partial fulfillment of the requirements for the award of **Bachelor of Technology** Degree in **Electronics and Communication Engineering** at **National Institute of Technology, Rourkela** is an authentic work carried out by them under my supervision and guidance.

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Abstract

Femtocells are expected to increase network capacity, extend macrocell coverage, and introduce new services. Because Femtocells share the same frequency band with macrocells in many cases, the femtocell base station (BS) must mitigate the interference with macrocells also ensure coverage in customer premises. However, conventional femtocell BS transmit power setting have not adequately accounted for the interference with neighbouring macrocell mobile stations (MSs), leading to small femtocell user throughout. In the paper, we describe an adaptive power level setting scheme i.e. Distributed Power Control algorithm to mitigate the interference of MSs in the basis of the received power levels. In DPC, each pair of transmitter (e.g., an MS) and receiver (e.g., the BS) does not need to know the transmit power or channel quality of any other pair. At each time slot, all it needs to know is the actual SIR it currently achieves at the receiver. Then, by taking the ratio between the fixed, target SIR and the variable, actual SIR value measured for this time slot and multiplying the current transmit power by that ratio, we get the transmit power for the next time slot. This update happens simultaneously at each pair of transmitter and receiver. This is how DPC provides adaptive nature to Femtocell.

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Abbreviation

3G – Third Generation

3GPP- Third Generation Partnership Project

BS – Base Station

CDMA – Code Division Multiple Access

DPC – Distributed Power Control

DSL – Digital Subscriber Link

FBS – Femto Base Station

FCC – Federal Communications Commission

FDMA – Frequency Division Multiple Access

FRF – Frequency Reuse Factor

FUE – Femto User Equipment

GSM – Global System for Mobile Communication

LTE – Long Term Evolution

MBS – Macro Base Station

MS – Mobile Station

MUE – Macro User Equipment

OFDMA – Orthogonal Frequency Division Multiple Access

PL – Path loss

PSD – Power Spectral Density

SINR – Signal to Interference Noise Ratio

TDMA – Time Division Multiple Access

TxPSD – Transmit Power Spectral Density

UE – User Equipment

UMTS – Universal Mobile Telecommunications System

W-CDMA – Wideband Code Division Multiple Access

WiMAX – Worldwide Interoperability for Microwave Access

Introduction

Unlicensed spectrum these days is becoming increasingly scarce, especially those below 3 GHz. The Federal Communications Commission (FCC)'s statistics shows that many frequency bands are being allocated to multiple users, overlapping each other. The two major limitations of wireless communication are range and capacity. Previously, cellular systems were designed for a single application, voice, but presently with the arrival of third-generation (3G) cellular systems, users anticipate better quality of voice, uninterrupted voice calls, clear video images and quick downloads. Femtocells provide a good solution to overcome indoor coverage problems and also to deal with the traffic within Macro cells. They provide reliable and high quality of service to all customers. The capacity problem is critical issue of any Mobile Communication Networks. Even Long Term Evolution (LTE) is called as the 4th Generation of the Mobile Cellular Communication Network it could not make a dot for the Capacity Issue. Most valuable way to increase the Capacity is to split the Macro cell, in other word to use Femtocells in Macro cells. Femtocell is the home base station that any subscribers can buy and set it by themselves easily. Mobile operators only need to consider the radio network cooperation between Femtocell and Macrocell and between Femtocells.

There are few main factors that cause the capacity degradation. One of them is Radio Signal Interference. There are two kinds of Interference in Orthogonal Frequency Division Multiple Access (OFDMA) system. Inter-cell Interference and Intra-cell Interference. And Inter-cell Interference is more critical than Intra-cell Interference.

In this paper, using adaptive power control in Femtocells we determine the appropriate transmit power level to achieve acceptable link performance Femtocells and mitigate Intra-cell and Inter-cell interference to provide appropriate SINR. The interference level can be controlled by transmit power of the reference signal because it is proportional to the maximum transmit power. Conventional transmit power level setting scheme that we applied in this paper is power level setting based on uplink reception power from Macrocell(M.S) using Distributed Power Control(DPC) algorithm.

Outline of Femtocells

Chapter 1

1.1 What are the Femtocells

Femtocells are low power access points which can combine mobile and Internet technologies within our home. The Femtocell unit generates a personal mobile phone signal in the home and connects this to the operator's network through the Internet.

This will allow improved coverage and capacity for each and every user within their home. You can just buy and put a Femtocell access point in your home and feel free having own independent mobile network in your home premise.

Nowadays, Femtocells are widely used throughout the world. According to the ABI Research team there will be 102 million worldwide users on 32 million home base stations by 2011. That is not the surprising thing already, because Femtocells now already reached millions of number with millions of users using it.

The most important role of the Femtocell in the mobile network is increasing the capacity of the entire network.

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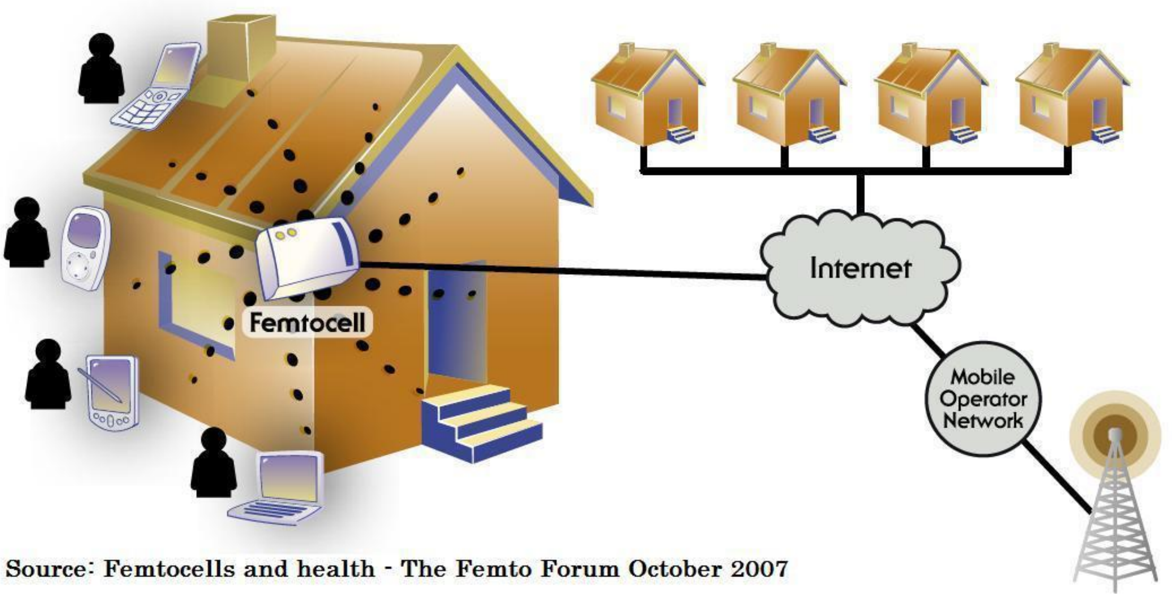

Source: Femtocells and health - The Femto Forum October 2007

Figure 1.1 Femtocell Architecture

These are the following key attributes which distinguishes the Femtocells from other mobile cellular technologies:

Compatible Standardization of the technology: The Standardization of the Femtocells these days is becoming fully compatible with the standard mobile devices and other devices working in the mobile range. Many standard protocols like UMTS, GSM, LTE, Mobile WiMAX, CDMA and other current and future mobile protocols standardized by 3GPP2, 3GPP and IEEE is also very harmonious with Femtocells. The Femto Forum, which is the organization to develop and implement Femtocells throughout the world is highly contributing for the standardization issues. Compatibility with above protocols and technologies can give a chance for Femtocells to give services with more than 3 billion existing devices in worldwide.

Effective use of limited spectrum: The efficiency of limited spectrum is big issues of any operator company. Operating in licensed spectrum allows service providers to provide services with high quality and apart from the any kind of interferences which could worsen the capacity and quality of services.

Raising capacity and independent coverage for users: As pointed above Femtocells not only alleviates the capacity of the network, but also improve the coverage in the home which can allow them to have an independent coverage. Compare to the simple repeaters which are used just increase the coverage, Femtocells can provide a high data rate for limited number of users.

Connection to the mobile operator network: As shown in Figure 1.1 Femtocells connect to the mobile operator network using standard residential broadband connections, including DSL and cable through the internet. The internet connection can be any type of network like dedicated or specific broadband line of mobile operator company or any other internet provider companies. That is the affability point of Femtocells.

Easiness of maintenance: The ordinary subscribers can set up the Femtocells by themselves. That’s why Femtocells can make the operation and maintenance issues easy for mobile network operators. The subscribers can maintain their Femtocells by themselves and only thing to do for mobile service providers is paying attention for cooperation of Femtocells within macro cells and other neighboring Femtocells like interference monitoring etc

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Flexibility of usage: Not only ordinary subscribers set up the Femtocells, but also mobile network operator companies could set up Femtocells purposely in the places where congested or distant areas.

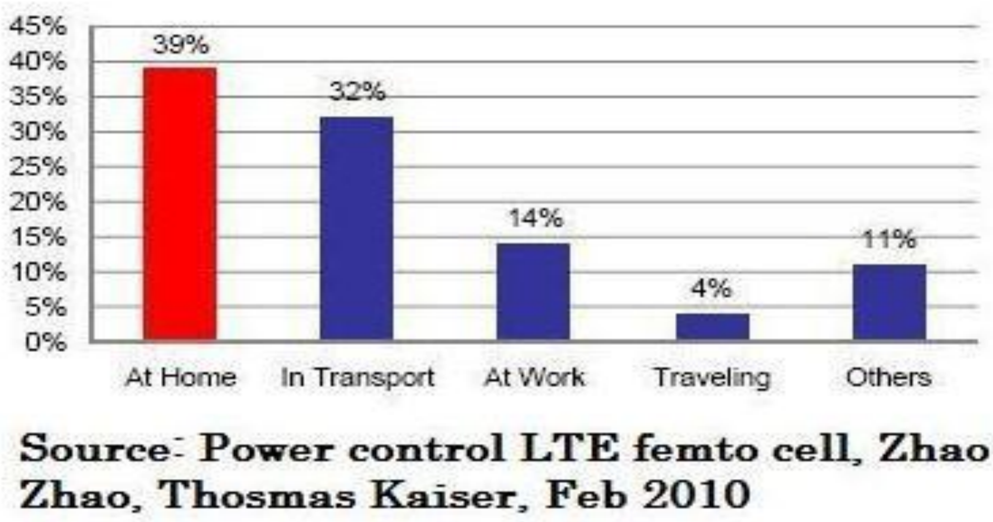
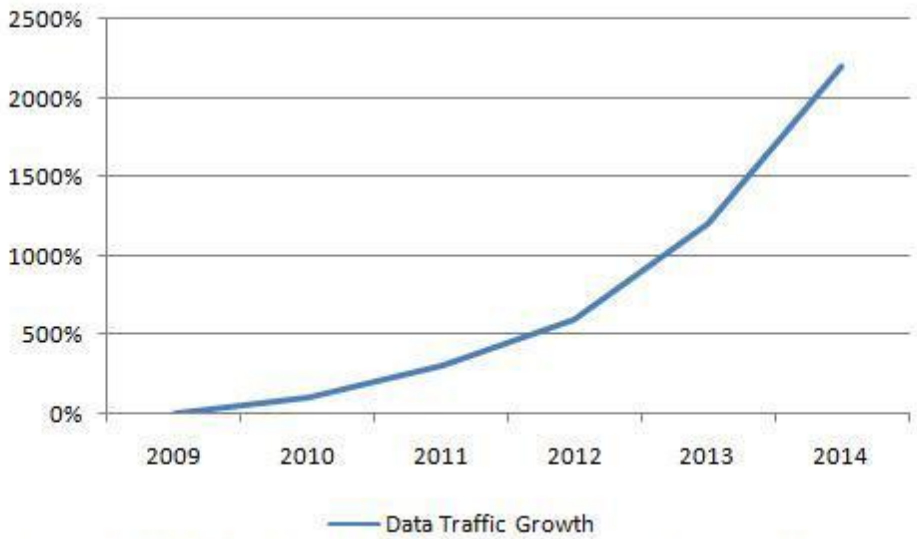


Figure 1.2 Mobile Phone Usage by Location

As shown in Figure 2 the usage of mobile phone at home is much larger than other places. A motivation of using mobile phone at home is high speed data and internet services using mobile phone. Only Femtocells can satisfy such requirements for the subscribers.



Source: The Best That LTE Can Be - Femto Forum White Paper May 2010

Figure 1.3 Data Traffic Growth

In Figure 3 we can see that the growth of the data traffic within recent years. To meet such a continuously increasing huge demand of data traffic mobile technologies should be developed quickly. That’s why everybody wants to develop a fourth generation technology of the mobile cellular network.

1.1.a <u>Advantages for Operator</u>

Deployment of Femtocells proves to be useful for operators in the sense that cost gets optimized along with increased coverage. The subscriber satisfaction improves due to better spatial correlation among capacity need and infrastructure. Reliability of the microcell gets assured as well.

1.1.b <u>Customer’s advantages/disadvantages</u>

User advantages include, low power transmission which results in a extended battery life. Better indoor reception, cheaper services are collateral benefits as well. Overall the bandwidth subscribed for is used more effectively. Initial capital may be high as this technology is somewhat new. Broadband may get congested due to backhauling. IP security is also an issue which must be paid heed to.

1.2 Femtocell Handoff

The ability to seamlessly switch between the Femtocell and the macrocell networks is a key driver for Femtocell network deployment. The handover procedures are fundamentally divided into two phases: handover preparation phase (information gathering, handover decision), and handover execution phase. During the information collecting phase, the transceiver accumulates information about the handover candidates, and authentications are accomplished for safety reasons. In handover decision phase, the best handover candidate is confirmed. Finally, after deciding to perform the actual handover, the mobile station (MS) initiates to connect with a new access point.

1.3 Evolution of Wireless Technology

Characteristics	**2G**	**3G**	**4G**
Frequency Band	350-1900 MHz	1.8-2.5 GHz	2-8 GHz
Bandwidth	200KHz	5-20 MHz	5-20 Mhz
Data Rate	56-115 Kbps	Upto 2 Mbps	Upto 20 MBps
Access	TDMA, CDMA	Wideband CDMA	Multi-carrier-CDMA or OFDM

Table 1

2.1 Definition of path loss

The path loss is the difference (in DB) between the transmitted power and the received power.

Represents signal level attenuation caused by free space propagation, reflection, diffraction and scattering.

Necessary to calculate **link budget.**

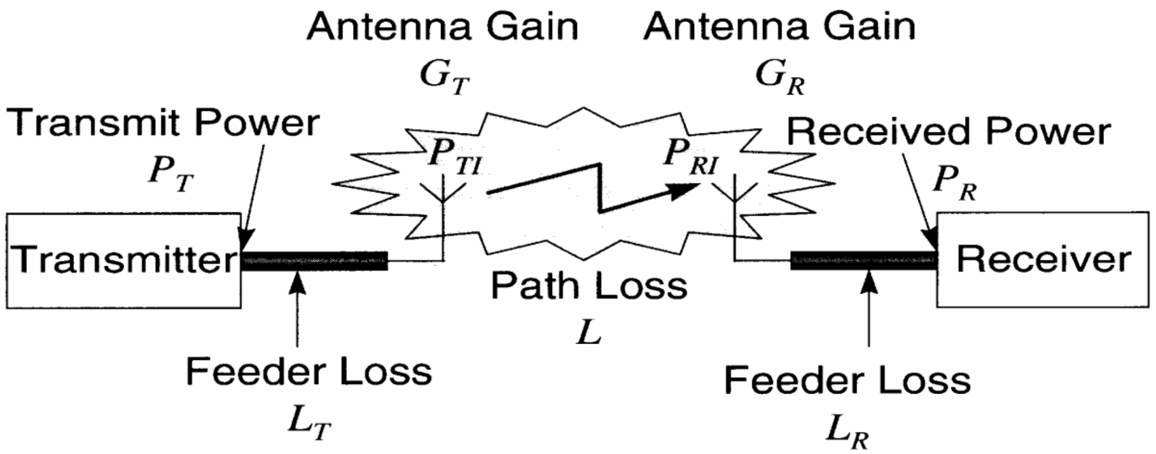


Figure 2.1 Path loss between Transmitter and Receiver

2.1.a Calculating Path loss using empirical model:

Path loss (PL)= $10*n*\log_{10}d[m]+ L_f(n_f)$

Where, n= path loss exponent, 2 (as in free space)

d= distance in meters

$L_f(n_f)$= attenuation

2.1.b <u>Semi Empirical Model</u>

Typical values of Attenuation

Main Wall (Concrete)	15 dB
Inner Wall (Plaster)	5 dB
Window (Glass)	1.5 dB
Door (Wool)	0.5 dB

Table 2.1

2.2 Interference Emerging Circumstances

In OFDMA, User Equipments (UEs) are assigned the different sub-carriers and they are orthogonal on the frequency in one cell. In case of frequency reuse factor (FRF) equals to 1, in order to make the system spectral efficiency better, neighboring cells use the same frequency. If UE transmits data in the same sub-carrier along with another UE of the neighbor cell, it will result to inter-cell interference (frequency collision), which will degrade the bit rate, especially for the UE in the cell edge. According to that situation it could be said that inter-cell interference between neighbor cells could dominate the system performance.

The Uplink interference cases are as illustrated in the Figure 2.2:

FUE to FBS: FUE (Femto User Equipment) in the edge of the FBS (Femto Base Station) premise could interfere to neighbouring FBS uplink.

MUE to FBS: MUE (Macro User Equipment) near the premise of FBS could strongly interfere to FBS Uplink.

FUE to MBS: The FUE which is very near to the MBS (Macro Base Station) could interfere to MBS uplink.

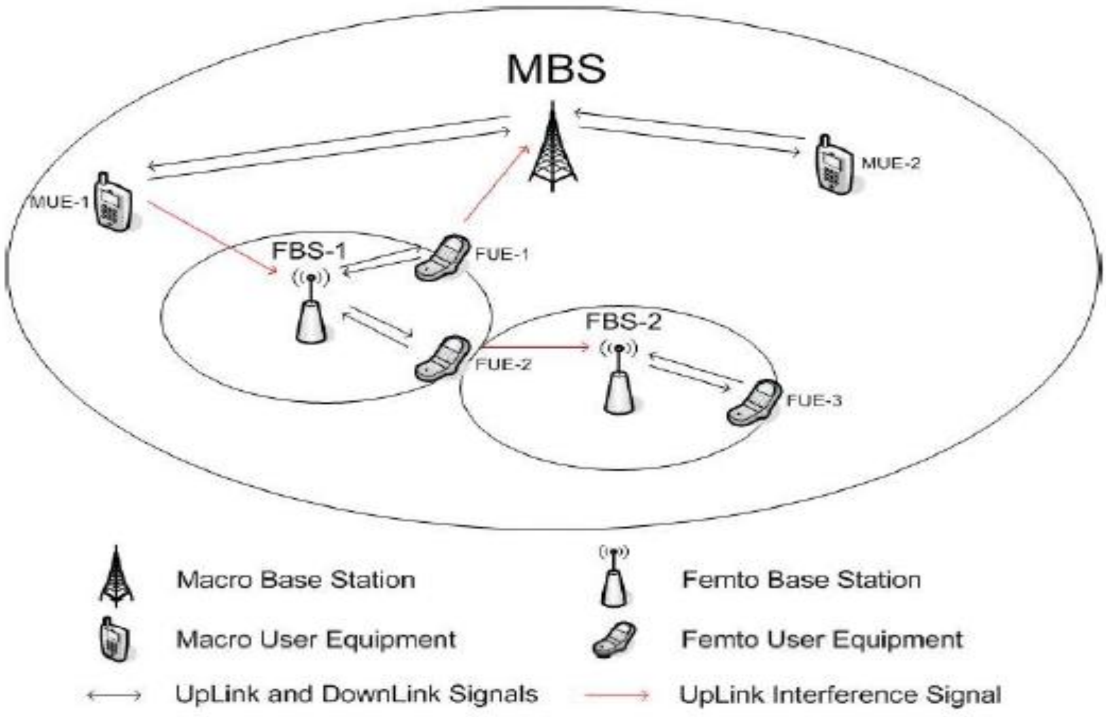


Fig 2.2 interference cases

2.3 The Power Control Techniques

2.3.a ***The Conventional Power Control***

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In Third Generation systems (i.e. WCDMA) every UE (both Femto and Macro users) in one cell uses the total transmission bandwidth. In OFDMA (i.e. LTE), an UE is given certain part of the total transmission bandwidth, so to control UE's transmit power spectral density (PSD) instead of the total power is more practical. The transmit PSD is the same on the assigned resource clusters. The UE total transmission power is calculated as:

*TxPower=TxPSD*M;*

Where M is the number of assigned resource cluster and TxPSD is transmit power spectral density. Conventional power control technique compensates path loss between UE and BS. In the BS all target SINRs are the same level.

$Tx\_PSD\_dBm = min\{Tx\_max, 10log(M) + SINRtar + I\_dBm + PL\_dBm\};$

Where *SINRtar* is Target SINR, *I_dBm* is average uplink interference per resource cluster, *PL_dBm* is Path Loss(that includes shadow fading), *Tx_max_dBm* is UE's max transmit power in dBm.

2.3.b ***UMTS LTE Uplink Power Control.***

UMTS LTE supports a power control scheme that allows for Macro User Equipment to get different target Signal to Interference and Noise Ratio (SINR) instead of the same target SINR according to its path loss to Macro Base Station.

$Tx\_PSD\_dBm = min\{Tx\_max, 10log(M) + SINRtar + I\_dBm + \alpha*PL\_dBm\};$

α is slope parameter which specifies how quickly the target SINR.

For the Femtocell Users, they require more high speed for different data services. That's why a different target SINR is needed for different Femtocell user.

2.4 LTE Uplink Power Control

The Power Control methods of the LTE UL depend on the different schemes and processing on the parameters. Depending on the compensation of slow channel variations or fast channel variations, it is called Fast Power Control and Slow Power Control. And depending on the cooperation to the Base Station, it is called Open Loop Power Control or Closed Loop Power Control.

Open Loop Power Control: The power is set at the mobile terminal using parameters and measures obtained from signals sent by the Femto Base Station (FBS). Here, no feedback is sent to the BS regarding the power used for transmission.

Closed Loop Power Control: The UE also sends feedback to the FBS, which is then used to correct the user Tx power.

2.5 UMTS LTE Uplink Power Control.

UMTS LTE supports a power control scheme which allows for Macro User Equipment to get different target Signal to Interference and Noise Ratio (SINR) instead of the same target SINR according to its path loss to Macro Base Station.

$$Tx\_PSD\_dBm = \min\{Tx\_max,\ 10\log(M) + SINRtar + I\_dBm + \alpha * PL\_dBm\};$$

α is slope parameter which specifies how quickly the target SINR.

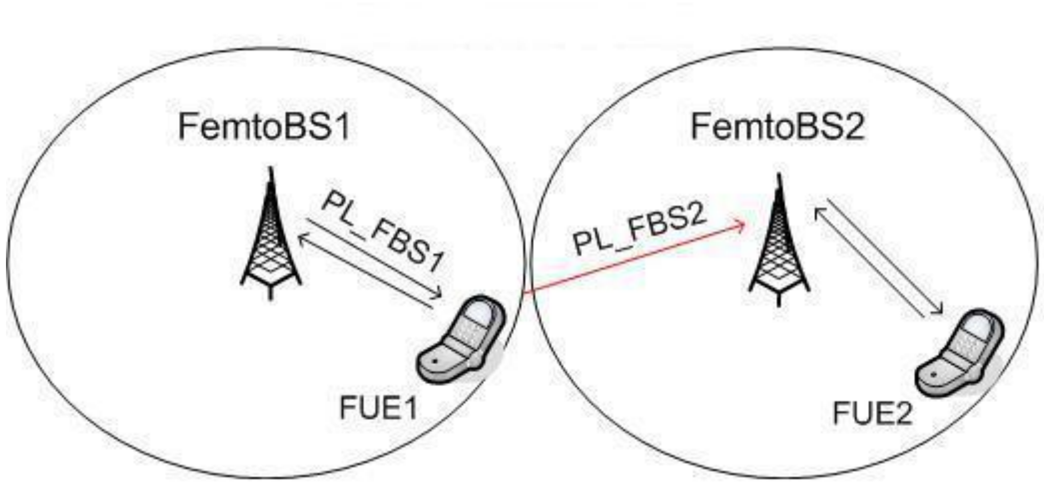

Figure 2.3 Uplink Interference

Table 2.2 Simulation Parameters

Parameter	Values
Number of resource clusters	50 for Femto; 60 for Macro
Carrier Frequency	2 GHz
Path Loss	Hata Model MUE 141.1 + 5.2*log10(d_MUE) FUE 157.4 + 42.9*log10(d_FUE)
Maximum target SINR of UE	25 dB
Max. transmit power	21 dBm
Average Uplink Interference per resource cluster	α=0 when 10dB; α=0.5 when 15 dB α=1 when 20 dB

3.1 Distributed power control

Before we move to a general discussion of the Distributed Power Control (DPC) algorithm, we must first define some symbols.

Consider N pairs of transmitters and receivers. Each pair forms a (logical) link, indexed by *i*. The transmit power of the transmitter of link *i* is p_i, some positive number, usually capped at a maximum value: pi ≤ p_{max} (although we will not consider the effect of this cap in the analysis of the algorithm). The transmitted power forces both the received power at the intended receiver and the received interference at the receivers of all other pairs.

Now, consider the channel from the transmitter of link (i.e., transmitter receiver pair) *j* to the receiver of link *i*, and denote the **channel gain** by G_{ij} .So G_{ii} is the direct channel gain; the bigger the better, since it is the channel for the destined transmission for the transmitter-receiver pair of link *i*. All the other {G_{ij}}, for *j* not equal to *i*, are gains for interference channels, so the smaller the better. We call these channels "gains", but actually they are less than 1, so maybe a better term is channel "loss."

This notation is visualized in Figure below for a simple case of two MSs talking to a BS, which can be thought of as two different (logically separated) receivers physically located together.

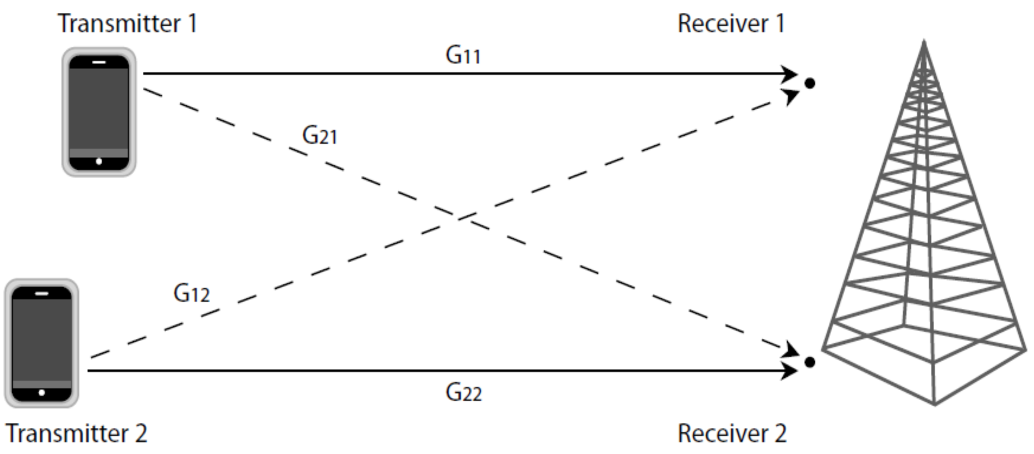

Figure 3.1: Uplink interference between two mobile stations at the base station. We can think of the base station as two (logically separated) receivers collocated. G_{11} and G_{22} are direct channel gains, the bigger the better. G_{12} and G_{21} are interference channel gains, the smaller the better.

Each G_{ij} is determined by two main factors: (1) location of the transmitter and receiver and (2) the quality of the channel in between. G_{ii} is also enhanced by the CDMA spreading codes that help the intended receivers decode more accurately.

The received power of the intended transmission at the receiver is therefore $G_{ii}p_i$. What about the interference? It is the sum of $G_{ij}p_j$ over all transmitters *j* (other than the intended one *i*): $\sum_{j \neq i} G_{ij}p_j$. There is also noise n_i in the receiver electronics for each receiver *i*. So we can write the SIR, a unit-less ratio, at the receiver of logical link *i* as

$$\mathrm{SIR}_i = \frac{G_{ii}\, p_i}{\sum_{j \neq i} G_{ij}\, p_j + n_i}$$

For proper decoding of the packets, the receiver needs to keep up a target level of SIR. We will denote that as γ_i for link *i*, and we want $\mathrm{SIR}_i \geq \gamma_i$ for all *i*. Clearly, increasing p_1 increases the SIR for receiver 1 but lowers the SIR for all other receivers.

As in a typical algorithm we will encounter throughout this book, we assume that time is divided into discrete slots, each indexed by [t]. At each timeslot t, the receiver on link *i* can measure the received SIR readily, and feeds back that number, $\mathrm{SIR}_i[t]$, to the transmitter.

The DPC algorithm can be described through a simple equation: each transmitter simply multiplies the current power level $p_i[t]$ by the ratio between the target SIR, γ_i, and the current measured $\mathrm{SIR}_i[t]$, to obtain the power level to use in the next timeslot:

$$\mathbf{p_i[t+1]} = \frac{\gamma_i}{\mathbf{SIR_i[t]}} \mathbf{p_i[t]}, \quad \textbf{for each i.}$$

We see that each receiver *i* needs to measure only its own SIR at each iteration, and each transmitter only needs to remember its own target SIR. There is no need for sending any control message around, like conveying other users what power level its using. Simple in communication, it is a very distributed algorithm.

This algorithm is also simple in its computation: just one division and a single multiplication. And also it is simple in its parameter configuration: there are actually no parameters in the algorithm that need to be tuned. Simplicity in communication, computation, and configuration is a key reason why certain algorithms are widely adopted in practice.

Intuitively, this algorithm makes sense. First, when the iterations stop because no one's power is changing any more, i.e., when we have convergence to an equilibrium, we can see that $SIR_i = \gamma_i$ for all i.

Second, there is hope that the algorithm will actually converge, given the direction in which the power levels are moving. The transmit power goes up when the received SIR is below the target, and goes down when it is above the target. Which proves that convergence will not happen easily. As one transmitter changes its power, the other transmitters do the same, and it is unclear what the next timeslot's SIR value is going to be. In fact, this algorithm does not converge if too many i are very large, i.e., when too many users request large SIRs as their targets.

Third, if satisfying the target SIRs is the only criterion, there are many transmit power configurations that can do that. If $p_1 = p_2 = 1$ mW achieves these two users' target SIRs, $p_1 = p_2 = 10$ mW will do so too. We would like to select the configuration that uses the least amount of power; we want a power-minimal solution. And the algorithm above seems to be lowering the power when a high power is unnecessary.

3.2 DPC as an optimization solution

In general, “will it converge?" and “will it converge to the right solution?" are the two prime questions that we would like to address in the design of all iterative algorithms. Of course, what “the right solution" means will depend on the definition of optimality. In this case, power-minimal transmit powers that achieve the target SIRs for all users are the “right solution." Power minimization is the **objective** and achieving target SIRs for all users is the **constraint**.

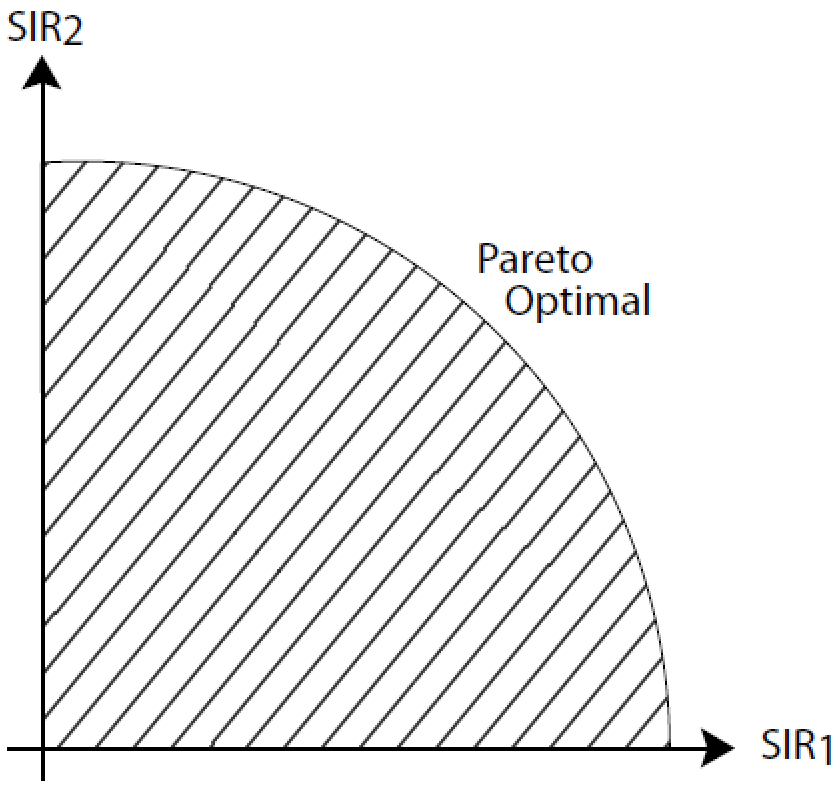

Figure 3.2: An illustration of the SIR feasibility region. It is a constraint set for power control optimization, and picture the competition among users. Every point strictly inside the shaded region is a feasible vector of target SIRs. Every point outside is infeasible. And every point on the boundary of the curve is Pareto optimal: you cannot increase one user's SIR without reducing another user's SIR.

3.3 DPC as a game

Power control is a competition. One user's received power is another's interference. Each player searches for the right “move" (or, in this case, the right transmit power) so that its “payoff" is optimized (in this case, the transmit power is the smallest possible while providing the user with its target SIR γ_i). We also expect that the whole network reaches some desirable equilibrium as each player strategizes. The concepts of “players," “move," “payoff," and “equilibrium" can be defined in a precise and useful way.

We can model competition as a game. The word “game" here carries a technical meaning. The study of games is a branch of mathematics called game theory. If the competition is among human beings, a game might actually correspond to people's strategies. If it is among devices, as in this case among radios, a game is more like an angle of interpretation and a tool for analysis.

In the formal definition, a game is specified by three elements:

1. a set of **players** {1, 2,…,N},
2. a **strategy space** Ai for each player i, and
3. a **payoff function**, or utility function, Ui for each player to maximize (or a **cost function** to minimize). Function Ui maps each combination of all players' strategies to a real number, the payoff (or cost), to player i.

	Not Confess	Confess
Not Confess	$(-1, -1)$	$(-5, 0)$
Confess	$(0, -5)$	$(-3, -3)$

Table 3.1: Prisoner's dilemma. This is a famous game in which there is a unique and undesirable Nash equilibrium. Player A's two strategies are the two rows. Player B's two strategies are the two columns. The values in the table represent the payoffs to the two players in each scenario.

Now consider the two-player game in Table 1.1. This is the famous prisoner's dilemma game. The two players are two prisoners. Player A's strategies are shown in rows and player B's in columns. Each entry in the 2 X 2 table has two numbers, (x; y), where x is the payoff to A and y that to B if the two players pick the corresponding strategies. As you would expect from the coupling between the players, each payoff value is determined jointly by the strategies of both players. For example, the payoff function maps (Not Confess, Not Confess) to -1 for both players A and B. These payoffs are negative because they are the numbers of years the two prisoners are going to serve in prison. If one confesses but the other does not, the one who confesses gets a deal to walk away free and the other one is heavily punished. If both confess, both serve three years. If neither confesses, only a lesser conviction can be pursued and both serve only one year. Both players know this table, but they cannot communicate with each other.

If player A chooses the strategy Not Confess, player B should choose the strategy Confess, since 0 > -1. This is called the best response strategy by player B, in response to player A choosing the strategy Not Confess.

If player A chooses the strategy Confess, player B's best response strategy is still Confess, since -3 > -5. When the best response strategy of a player is the same no matter what strategy the other player chooses, we call that a **dominant strategy**. It might not exist. But, when it does, a player will obviously pick a dominant strategy.

In this case, Confess is the dominant strategy for player B. By symmetry, it is also the dominant strategy for player A. So both players will pick Confess, and (Confess, Confess) is an **equilibrium** for the game. This is a slightly different definition of “equilibrium" from what we saw before, where equilibrium means an update equation reaches a fixed point.

Clearly, this equilibrium is undesirable: (Not Confess, Not Confess) gives a higher payoff value to both players: -1 instead of -3. But the two prisoners could not have coordinated to achieve (Not Confess, Not Confess). An equilibrium might not be **socially optimal**, i.e., a set of strategies maximizing the sum of payoffs $\sum_i U_i$ of all the players. It might not even be Pareto optimal, i.e., a set of strategies such that no player's payoff can be increased without hurting another player's payoff.

4.1 Semi-Empirical Path Loss

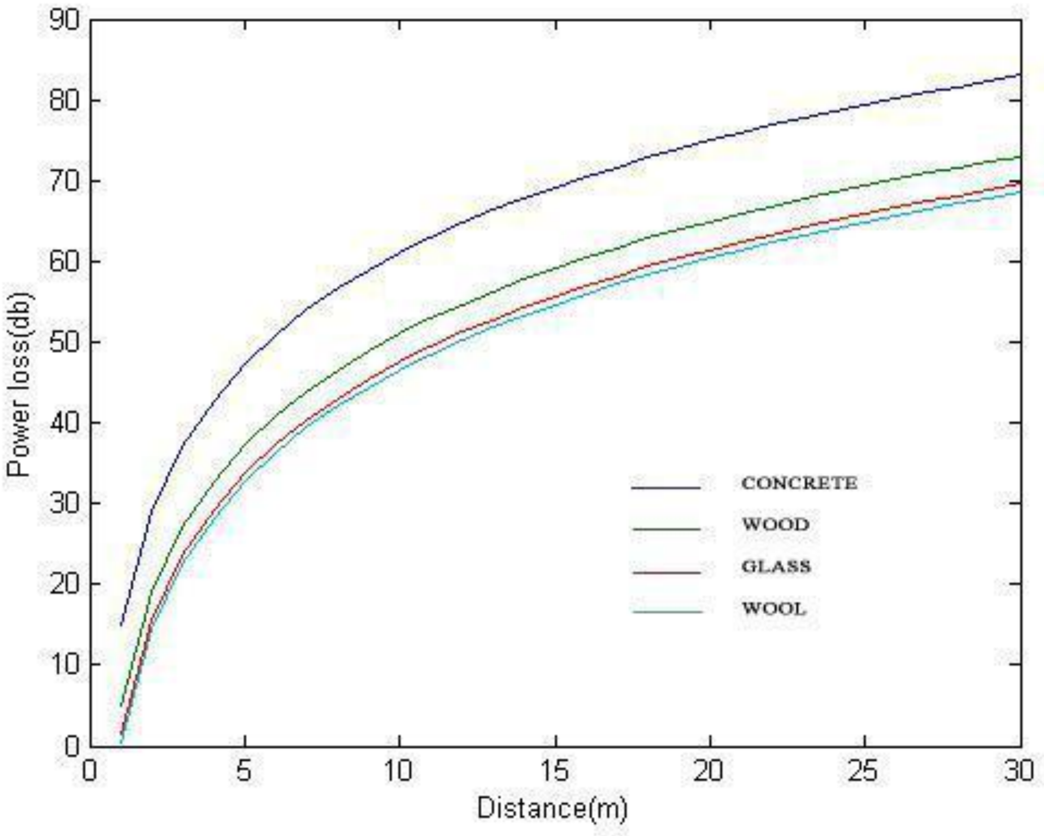

Figure 4.1: *Power loss vs. Transmitter-Receiver Distance*

4.1.a Inference

The signal power loss increases substantially with increase in density of material in between transmitter and receiver. And when the distance between transmitter and base station increases it gradually saturates and becomes steady. The slope is high during smaller distances.

4.2 ***UMTS LTE Uplink Power Control***

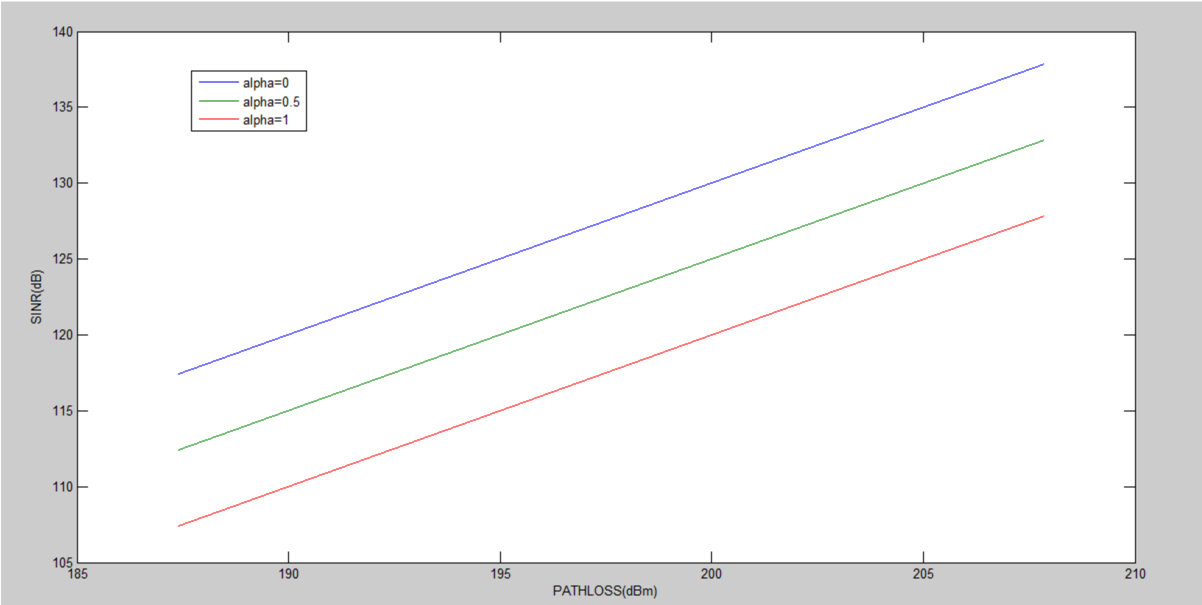

Figure 4.2: *SINR vs. Path Loss*

4.2.a Inference

The SINR of the different path loss is calculated using the both power control techniques. If the slope parameter α equals to 1 in the LTE power control formula, that is the same as conventional power control. And if α equals to 0, then there will be no path loss compensation and there will be high interference in the FBSs. That means, α should get the value of $0< \alpha<1$ for compensation of path loss and good SINR at the FBS. From the simulation result, the received SINR at the FBS is compensated according to slope parameter that has good result when α equals $0< \alpha<1$.

4.3 Adaptive solution using DPC

Suppose we have four (transmitter, receiver) pairs. Let the channel gains $\{G_{ij}\}$ be given in below. We can also represent these gains in a matrix. You can see that, in general, $G_{ij} \neq G_{ji}$ because the interference channels do not have to be symmetric.

Receiver of Link	Transmitter of Link 1	2	3	4
1	1	0.1	0.2	0.3
2	0.2	1	0.1	0.1
3	0.2	0.1	1	0.1
4	0.1	0.1	0.1	1

Table 4.1 Channel gains in an example of DPC. The entries are for illustrating the algorithm. They do not represent actual numerical values typically observed in real cellular networks.

We will use DPC to adjust the power levels. Suppose that the target SIRs are

γ1 = 2:0;

γ2 = 2:5;

γ3 = 1:5;

γ4 = 2:0:

The noise on each link 0.1

The Number of transmitters 4

Using equations of chapter 3 we get following result using above parameters:

update_SIR =

1.4286 2.0000 2.0000 2.5000

update_power =

1.4000 1.2500 0.7500 0.8000

update_SIR =

2.2764 2.3364 1.2821 1.8182

update_power =

1.2300   1.3375   0.8775   0.8800

update_SIR =

1.8270   2.5635   1.5456   1.9798

update_power =

1.3465   1.3044   0.8516   0.8890

update_SIR =

2.0173   2.4006   1.4468   1.9745

update_power =

1.3349   1.3584   0.8830   0.9005

update_SIR =

1.9557   2.4910   1.4893   1.9678

update_power =

1.3652   1.3633   0.8893   0.9153

update_SIR =

1.9820   2.4631   1.4800   1.9820

update_power =

1.3775   1.3837   0.9013   0.9236

update_SIR =

1.9801   2.4798   1.4868   1.9808

update_power =

1.3914   1.3950   0.9094   0.9325

update_SIR =

1.9845   2.4801   1.4882   1.9859

update_power =

1.4023   1.4062   0.9166   0.9392

update_SIR =

1.9871   2.4843   1.4904   1.9876

update_power =

1.4113   1.4151   0.9225   0.9450

update_SIR =

1.9892   2.4868   1.4920   1.9899

update_power =

1.4190   1.4225   0.9274   0.9498

update_SIR =

1.9911   2.4891   1.4933   1.9916

update_power =

1.4253   1.4288   0.9315   0.9538

update_SIR =

1.9926   2.4909   1.4945   1.9930

update_power =

1.4307   1.4340   0.9350   0.9571

4.4 DPC output

4.4.a Plot for SIR vs Iteration

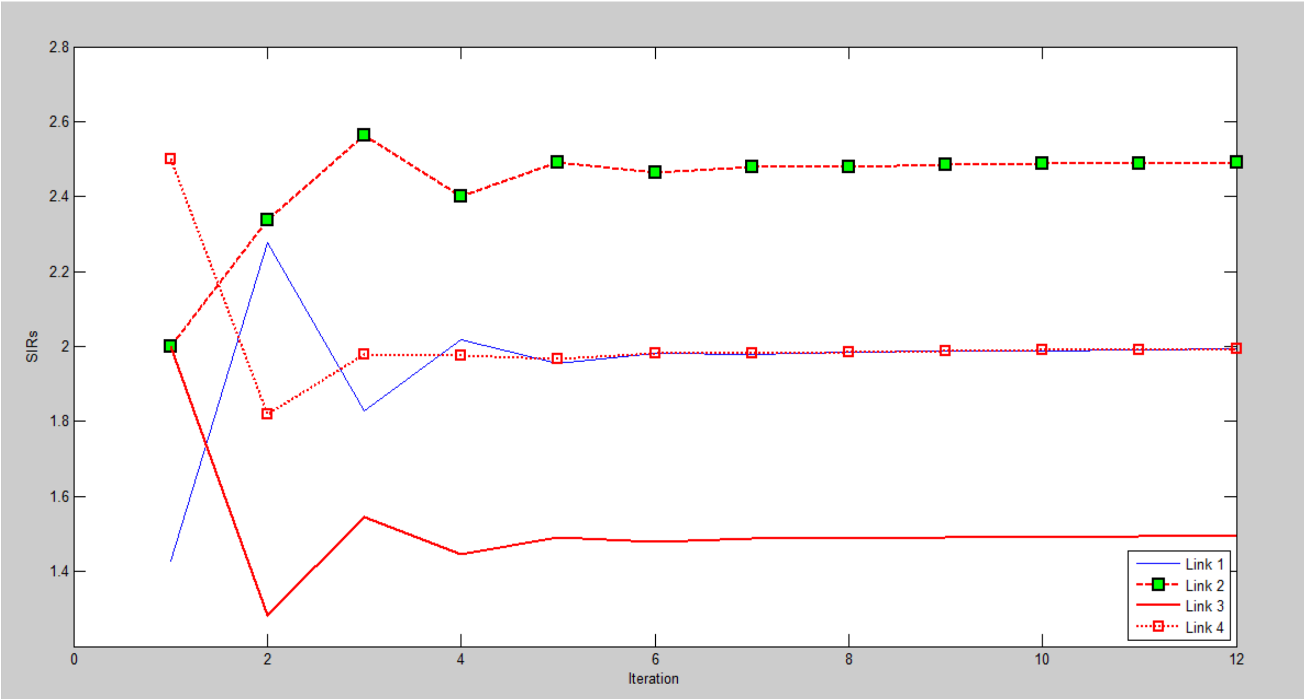

Figure 4.3: SINRs Vs Iteration

4.4.b Plot for Power Vs Iteration

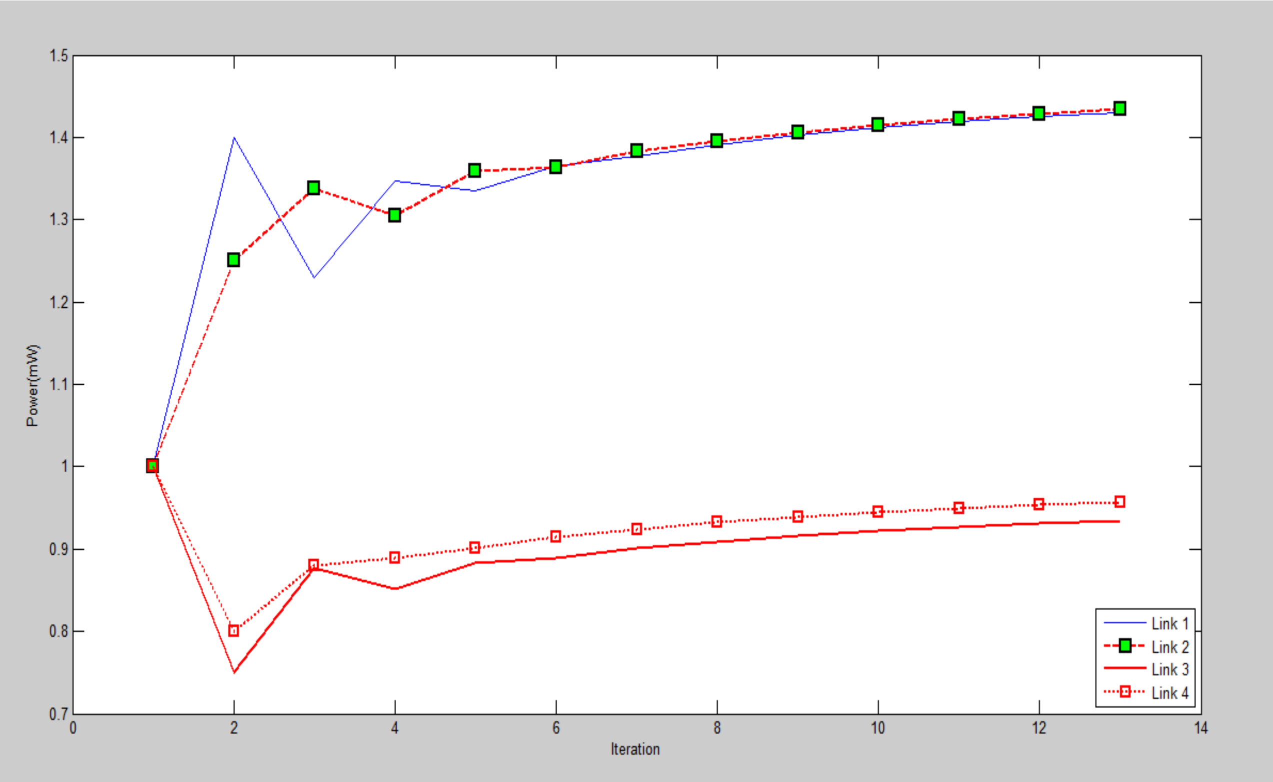

Figure 4.4: Power vs iteration

4.4.c **Inference:**

All the SIRs are now within 0.05 of the target. The power levels keep iterating, taking the SIRs closer to the target. Figure 1.5 shows the graph of power level versus the number of iterations. After about 20 iterations, the change is too small to be seen on the graph; the power levels at that time are

p1 = 1:46 mW;

p2 = 1:46 mW;

p3 = 0:95 mW;

p4 = 0:97 mW:

The resulting SIRs are shown in above Figure. We get very close to the target SIRs, by visual inspection, after about 10 iterations.

Conclusion

- The above simulation gives a definitive view about the range of a Femtocell which is 30-40m.
- The SINR of the different path loss is calculated using the Uplink power control techniques.
- Different users' signals interfere with each other in the air, leading to a feasible SIR region with a Pareto-optimal boundary.
- Interference coordination in Femtocell networks can be achieved through distributed power control with implicit feedback.
- It solves an optimization problem for the network in the form of linear programming.
- By taking the ratio between the fixed, target SIR and the variable, actual SIR value measured for this timeslot, and multiplying the current transmit power by that ratio, we get the transmit power for the next timeslot. This update happens simultaneously at each pair of transmitter and receiver.
- With this algorithm a Femtocell device can adapt itself having fixed target SIR and fixed Channel gains.

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