İSTANBUL TECHNICAL UNIVERSITY ★ INFORMATICS INSTITUTE

SATELLITE UMTS
POWER CONTROL ALGORITHMS

M.Sc. Thesis by
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Department : Telecommunication Technologies
Programme : Satellite Communication and Remote Sensing Programme

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İSTANBUL TEKNİK ÜNİVERSİTESİ ★ BİLİŞİM ENSTİTÜSÜ

UYDU UMTS
GÜÇ KONTROLÜ ALGORİTMALARI

YÜKSEK LİSANS TEZİ

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FOREWORD

I would like to express my deep appreciation and thanks for my advisor Assoc. Prof. Dr. Mesut KARTAL. This work is supported by ITU Informatics Institute.

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Telecommunication Engineer

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ABBREVIATIONS

AAL2	: ATM Adaptation Layer 2
ATM	: Asynchronous Transfer Mode
BCCH	: Broadcast Control CHannel
BFN	: Beam Forming Networks
BSC	: Base Station Controller
BTS	: Base Transceiver System
CCCH	: Common Control CHannel
CDMA	: Code Division Multiple Access
CN	: Core Network
CRNC	: Controlling RNC
CS	: Circuit Switching
CTCH	: Common Traffic CHannel
DCCH	: Dedicated Traffic CHannel
DRNC	: Drift RNC
DTCH	: Dedicated Traffic CHannel
EDGE	: Enhanced Data for GSM Evolution
EIRP	: Effective Isotropic Radiated Power
ETSI	: European Telecommunication Standards Institute
ESA	: European Space Agency
FDMA	: Frequency Division Multiple Access
FER	: Frame Error Rate
GEO	: Geostationary Earth Orbit
GGSN	: Gateway GPRS Support Node
GPRS	: General Packet Radio Service
GSM	: Global Systems for Mobile telecommunications
GSO	: Geo Synchronous Orbit
GTP	: GPRS Tunnelling Protocol
GW	: Gate Way
HLR	: Home Location Register
IMR	: Intermediate Module Repeater
IMT – 2000	: International Mobile Telecommunications - 2000
IN	: Intelligent Networks
IP	: Internet Protocol
ISL	: Inter Satellite Link
ISP	: Internet Service Provider
LEO	: Low Earth Orbit
LHCP	: Left Hand Circular Polarized
LOS	: Line Of Sight
MAC	: Medium Access Control
MAPL	: Maximum Allowed Path Loss
MBMS	: Multimedia Broadcast Multicast Services
MEO	: Middle Earth Orbit
MGW	: Media Gate Way
MM	: Mobility Management
MS	: Mobile Station

MSCS	: Mobile Switching Centre Server
NCC	: Network Control Centre
NLOS	: None Line Of Sight
QoS	: Quality of Service
PC	: Power Control
PCCH	: Paging Control CHannel
PDA	: Personal Digital Assistant
PSTN	: Public Switched Telephone Network
RAB	: Radio Access Bearer
RACH	: Random Access CHannel
RAN	: Radio Access Network
RF	: Radio Frequency
RHCP	: Right Hand Circular Polarized
RLC	: Radio Link Controller
RNC	: Radio Network Controller
RNS	: Radio Network Subsystem
RRC	: Radio Recourse Control
RRM	: Radio Resource Management
SRM	: Satellite Resource Management
SRNC	: Serving RNC
S-UMTS	: Satellite – Universal Mobile Telecommunication System
SGSN	: Serving GPRS Support Node
SIR	: Signal to Interference Ratio
SMS	: Short Message Service
TCP	: Transmission control Protocol
TDM	: Time Division Multiplexing
TDMA	: Time Division Multiple Access
TPC	: Transmit Power Control
T-UMTS	: Terrestrial – Universal Mobile Telecommunication System
UDP	: User Datagram Protocol
UE	: User Equipment
UMTS	: Universal Mobile Telecommunication Systems
USRAN	: UMTS Satellite Radio Access Network
UTRAN	: UMTS Terrestrial Radio Access Network
VLR	: Visitor Location Register
3GPP	: 3rd Generation Partnership Project

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SUMMARY

UMTS – Universal Mobile Telecommunication System is a third generation mobile standard that enables high bit rate data transfer over several mobile phone applications. New generation multi-media products, information technology and telecommunication services that require high QoS and reliable networks, are supported via UMTS. In order to support enough traffic rates with acceptable QoS values over global coverage, new mixed cell architectures are introduced with UMTS. S-UMTS (Satellite UMTS) is a new generation network approach that has mixed cell architecture. S-UMTS enables the use of UMTS air interface protocols via satellite air interface. With this new usage, S-UMTS will be the complementary umbrella cell for T-UMTS (Terrestrial UMTS) coverage areas. Also interconnection will be possible through other IMT-2000 networks with the integration of S-UMTS with T-UMTS core network.

Due to different channel characteristics of satellite and traditional Node B, some modifications on T-UMTS air interface standards are required in the adaptation phase of air interface protocols through satellite air interface. These modifications are mostly applied for compensating high Satellite-Earth signal delays, jitter, Fast Fading, Shadowing, and similar destructive effects of satellite access network.

S-UMTS air interface adaptation objectives are mainly applied on satellite diversity, power control, handover, on board processing, interference scenarios and synchronization issues. Especially for high interference that determines the system capacity, handover and new power control algorithm approaches must be adapted to satellite environment in order to reduce the defects of high delay satellite air interface on radio link channel.

Since the propagation delay reaches up to 240 milliseconds for GSO satellite, the slow signal reactivity becomes a problem in a satellite signalling link. In such a case, traditional transmit power control commands sending and processing frequency will not match T-UMTS power control correction and furthermore it will be destructive. This power control algorithm may also cause unstable and irregular signal power level variation progress, unstable power control loops and over-sampling. These conditions reduce the QoS level that has vital importance for rapid data transfer systems like 3G networks.

According to the latest S-UMTS specifications of Telecommunication Institutes, it is recommended that in the adaptation phase of Power Control Algorithm for S-UMTS, the number of TPC (Transmit Power Control) commands sent in unit time should be decreased, in order to prevent power oscillations, over-sampling and power control loop instabilities. These destructive effects are totally caused by the high delay satellite access network.

In this thesis, the recommended power control algorithm is applied in a S-UMTS access network simulation coded in C++. T-UMTS PC Mode algorithm is adapted to S-UMTS and

the simulation results are investigated considering the variation of drop rates with different input parameters. Additionally, a new approach Adaptive PC Mode algorithm is applied to the simulation process and the results are investigated. In the Adaptive PC Mode, the TPC sending and processing frequency, changes adaptively to the satellite signal level variation, dynamically during simulation progress.

S-UMTS access network simulation results show that, the decrement of the processed TPC commands in unit time, decreases the drop rates rarely, especially in GEO and MEO orbit satellites which have slow tractable power level variation. However, the decrement in processing of TPC commands increases the drop rates in LEO satellites because of the rapid power level variations. Especially high loop delays in low TPC processing rates causes these high drop rates in satellite systems that have rapid signal power level changes. It is observed that with the integration of "Adaptive PC Mode" the drop rates reduced in LEO satellites with the dynamic TPC frequency changes during simulation progress.

In conclusion, the recommended adaptation of power control algorithm for S-UMTS is effective for adjusting the power oscillations in long delay satellite air interface with reducing TPC sending and processing frequency. But it is observed that this frequency reduction is beneficial only for GEO and MEO orbit satellite UMTS systems that have slow power level variations. For LEO satellite UMTS system, new TPC processing algorithms like Adaptive PC Mode can be effective to compensate against to the negative effects of rapid power level variations. So, S-UMTS systems can reach suitable quality of service levels for each orbit type satellites.

UYDU UMTS GÜÇ KONTROLÜ ALGORİTMALARI

ÖZET

UMTS – Universal Mobile Telecommunication System, birçok mobil telefon uygulaması üzerinden yüksek veri alışverişini mümkün kılan üçüncü nesil bir mobil standardıdır. Yüksek servis kalitesi (QoS) ve kesintisiz ağlar gerektiren yeni nesil çoklu ortam ürünleri, bilgi teknolojileri ve telekomünikasyon servisleri UMTS üzerinden desteklenmektedir. Kabul edilebilir servis kalitesi ve küresel kapsama sağlayarak yeterli trafik miktarlarını destekleyebilmek için UMTS ile birleştirilmiş yeni nesil hücre mimarileri tasarlanmıştır. S-UMTS (Satellite UMTS), birleştirilmiş hücre mimarisine sahip yeni nesil bir ağ yaklaşımıdır. S-UMTS, UMTS' de kullanılan hava ara yüzü protokollerinin uydu hava ara yüzünde kullanılması imkânını sağlar. Bu yeni kullanımla S-UMTS, karasal T-UMTS' in (Terrestrial UMTS) kaplama alanlarının tamamlayıcı şemsiye hücresi olacaktır. S-UMTS' in T-UMTS çekirdek ağıyla bütünleşmesi sonucu, diğer IMT-2000 (International Mobile Telecommunications - 2000) ağlarıyla ara bağlantı kurulması da mümkün olacaktır.

Uydu ve UMTS baz istasyonu olan Node B' deki farklı kanal karakteristikleri sebebiyle hava ara yüzü protokollerinin uydu hava ara yüzüne uyarlanması sırasında, T-UMTS standartlarında bazı modifikasyonlar gerekmektedir. Bu modifikasyonlar çoğunlukla uydu giriş ağındaki, yüksek uydu yer sinyal gecikmeleri, jitter, hızlı sinyal düşümü, gölgeleme ve benzeri yıkıcı etkilerin ortadan kaldırılmasını amaçlamaktadır.

S-UMTS hava ara yüzü adaptasyonları çoğunlukla uydu çoğullama, güç kontrolü, çağrının el değişimi, sinyal işleme, farklı girişim senaryoları ve eşleme işlemlerinde uygulanmaktadır. Özellikle, yüksek gecikmeli uydu hava ara yüzünün sinyal üzerindeki yıkıcı etkilerini azaltmak için, sistem kapasitesini belirleyen yüksek girişim oranlarında çağrının el değişimi ve yeni güç kontrolü algoritmaları, uydu sistemlerine adapte edilmesi gerekmektedir.

Yayılım gecikmesinin 240 milisaniyelere çıktığı GSO (Geostationary Orbit) uyduların uydu sinyalleşme linklerinde, yavaş sinyal tepkiselliği ciddi bir sorun oluşturmaktadır. Bu tür durumlarda, geleneksel iletim güç kontrol komutlarının gönderim ve işleme frekansları, T-UMTS sistemlerindeki güç kontrol düzeltme oranını sağlayamamakta, üstelik sinyal seviyesi üzerinde yıkıcı etkiye sahip olmaktadır. Bu geleneksel güç kontrolü algoritmaları kararsız ve düzensiz sinyal güç seviyesi değişimlerine, kararsız güç kontrolü çevrimleri ve kararsız örneklemelere sebep olmaktadır. Bu koşulların oluşması, hızlı veri taşınması özelliğine sahip olan 3G (üçüncü nesil) ağları için çokça önemli olan QoS (servis kalitesi) seviyelerinin azalmasına sebep olmaktadır.

Telekomünikasyon enstitüleri tarafından son yayınlanan S-UMTS spesifikasyonlarına göre, güç kontrolü algoritmasının S-UMTS adaptasyonu sırasında, sinyal gücü salınışları, örnekleme ve güç kontrol çevrimlerindeki kararsızlıkların önüne geçebilmek için, birim zamanda gönderilen TPC (Transmit Power Control) komutlarının sayısı azaltılması gerekmektedir. Bu yıkıcı etkiler yüksek gecikmelere sahip uydu giriş ağı kanal yapısından kaynaklanmaktadır.

Bu tezde, önerilen güç kontrol algoritması, C++ ile kodlanan bir S-UMTS giriş ağ simülasyonu üzerine uygulanmıştır. T-UMTS' de geçerli olan PC Mode algoritması S-UMTS' e adapte edilerek simülasyona uygulanmış ve simülasyon sonuçları farklı giriş parametrelerine karşı ölçülen çağrı düşüm oranlarına göre incelenmiştir. Ek olarak, yeni bir uyarlanabilir PC Mode algoritması yaklaşımı üretilerek simülasyona uygulanmış ve sonuçları gözlemlenmiştir. Uyarlanabilir PC Mode algoritmasında, TPC gönderim ve işleme frekansı,

uydunun sinyal seviyesindeki değişim hızına göre dinamik olarak simülasyonun akışı ile birlikte değişmektedir.

S-UMTS giriş ağı simülasyon sonuçları göstermektedir ki, özellikle izlenebilir yavaş sinyal gücü değişimlerine sahip olan GEO ve MEO uydularında, birim zamanda gönderilen ve işlenen TPC komut sayısındaki azalış, çağrı düşüm oranlarını belirli ölçüde azaltmıştır. Ancak, TPC komutlarındaki azalma, hızlı sinyal gücü değişimlerine sahip olan LEO uydularda, çağrı düşüm oranlarında artışa sebep olmuştur. Hızlı sinyal değişimine sahip ağlarda, servis kalitesinin TPC oranlarının azalışından olumsuz etkilenmesindeki en önemli sebep, TPC sayısındaki azalışın sebep olduğu güç kontrolü çevrim gecikmesindeki artmadır. Simülasyon sonuçlarına göre, uygulanan "Uyarlanabilir PC Mode" algoritmasıyla gelen, TPC gönderim frekansındaki dinamik değişimler ile, çağrı düşüm oranlarının LEO uydularda azaldığını görülmüştür.

Sonuç olarak, güç kontrol algoritmasının S-UMTS için önerilen adaptasyonu, yüksek gecikmeli uydu linklerinin hava ara yüzünde sinyal gücündeki salınışların azalmasında TPC komutlarının gönderim ve işleme frekanslarının ayarlanması ile etkili olmaktadır. Ancak simülasyon sonuçlarına göre gözlemlenmiştir ki bu frekans azalımı sadece yavaş sinyal salınışlarına sahip olan GEO ve MEO uydu sistemlerinde faydalı olmuştur. LEO uydu sistemleri için ise hızlı sinyal seviyesi değişimlerinin olumsuz etkisini yok etmek amacıyla, uyarlanabilir PC Mode gibi yeni güç kontrolü algoritmaları gerekmektedir. Böylece S-UMTS sistemleri, her tip yörünge uyduları için uygun servis kalitesi düzeyine erişebilirler.

1. INTRODUCTION

1.1 Satellite - UMTS Concept Definition

The researches and developments in wireless communications grows rapidly in order to deal with the exponentially increasing data transfer demand produced by the end users. High speed data transfer is necessarily required especially for the new developed Multi Media Services. For this requirement new generation wireless telecommunication networks like 3G and 4G, are developed in order to improve data bit rates. Up to 2000's, traditional 2G systems like GSM, CDMA, GPRS and EDGE served as core networks of countries for wireless data transfer. But after 2003, 3G networks became major wireless data provider for the technology leader countries until today. And now next generation systems 4G networks become live in some of the technology leader countries.[1]

In wireless communication it is a fact that the bottle neck for data transfer speed, is located mostly in air interface. So the researches mainly focused on new access technique. Traditional 2G networks were based on old multiple access techniques TDMA and FDMA. But in 90's CDMA became a popular research area for air interface of wireless networks. In 1998 CDMA2000 was endorsed to be 3G the solution for International Telecommunication Union – ITU. And in 2005 there were more than 200 million commercial CDMA2000 subscribers around the world. [2]

Since CDMA technology become a major technique for access network in high speed wireless communication, it is indispensible to integrate it to other traditional wireless communications like satellite communication. So first in 2002, initial conceptual studies and experiments for Satellite Universal Mobile Telecommunication System - S-UMTS, were underway sponsored mainly by ESA and the European Commission. The main objective for these researches and experiments was to prepare and realize a satellite environment that uses CDMA for the air interface access. [3] Same year, European Telecommunication Standards Institute - ETSI was published "Satellite Earth Stations and Systems – Satellite Component of UMTS/IMT – 2000" (TR 101 865) specification in order to set general aspects and principles for S-UMTS Networks. And the last specification was published at 2007 about "Multimedia Broadcast / Multicast Services (MBMS)" (TR 102 277) by ETSI.

Basically, Satellite UMTS will act as an umbrella cell for Terrestrial UMTS as shown in Figure 1.1. CDMA will be used in order to reach high data transfer rates up to 384 Kbits/s, in the access network between user equipment and satellite or between Intermediate Module Repeater - IMR and satellite. In addition to the ability of providing high rates in data transfer, the satellite component of UMTS (S-UMTS) will play an important role in providing worldwide access to UMTS services. Because satellite systems have the advantage of fast deployment, flexible use, and global coverage, satellites are able to provide telecommunication services in areas where terrestrial networks are economically or technically not feasible, such as the rural areas.

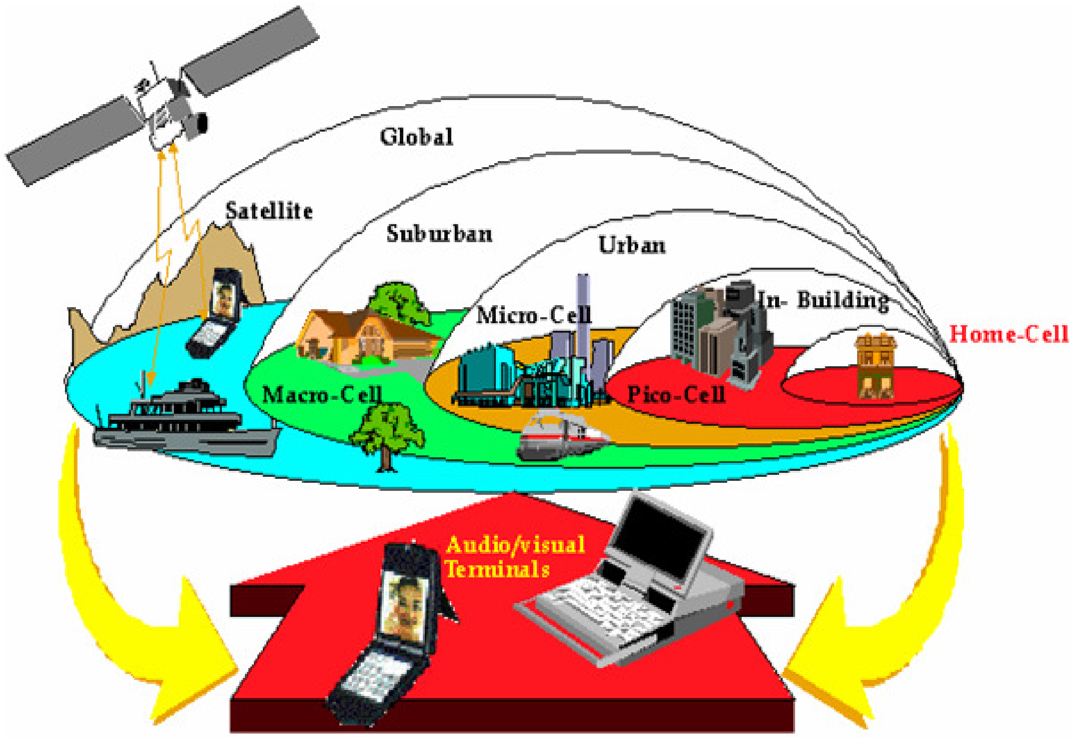

Figure 1.1 : Internetwork roaming – seamless end-to-end service

1.2 Satellite UMTS System Overview

Satellite UMTS System architectures are classified according to the access schemas trough the network. These schemas are Direct Access to Satellite and Indirect Access to Satellite. In Direct Access to Satellite schema, the UE (User Equipment) has communication with T-UMTS Core network directly via satellite environment. So the Radio Resource Management – RRM algorithms like power control, Link adaptation, handover and admission control are all adapted for the long delay communication between user equipment and the satellite. For the terminal equipment site some adaptations are also required which directly affect the cost and potential capability.

Indirect Access schema requires an Intermediate Module Repeater –IMR to provide service to urban or indoor service areas that have no direct line of sight with satellite as shown in Figure 1.2. Between user equipment and the IMR, T-UMTS RRM algorithms are exist, since the air interface behavior is same in T-UMTS and S-UMTS. By the way in indirect Access, user equipment must have the inter system dual mode capability to receive service from both IMR and Satellite.

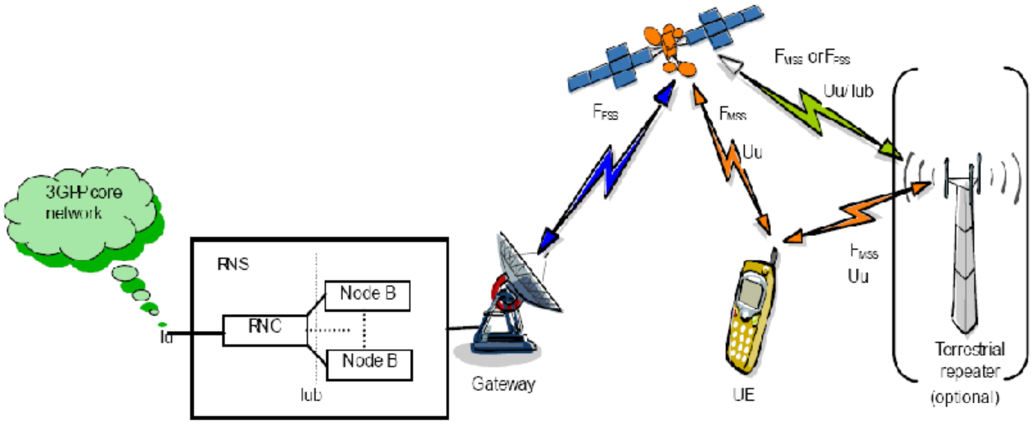

Figure 1.2 : S-UMTS network architecture

In a hybrid network both satellite and IMRs are deployed as seen in the Figure 1.2, attached user equipments communicate with each other via only satellite when there is no signal from IMRs or user equipment is not located in the IMR coverage area. If there is no signal from satellite, then the user equipment will communicate via only satellite. This situation may occur when the UE is not in the LOS (Line of Sight) area. If the UE is in the area of both satellite and IMR coverage then user equipment will be forced to IMR in order to save satellite recourses and UEs own power recourses.

All satellite constellation types can be used for the Satellite - UMTS. Since GEO, MEO and LEO orbit satellites have different radio characteristics depend on their different link properties, link budget inputs will also be regarded on satellite orbit types. S-UMTS has the ability to adapt to several architecture types depending on the throughput requirements. For instance, with Global Beam architecture one satellite can cover a specific area with one spot. And with the multi beam, a satellite can cover more than one coverage area with several spots.

Satellite connects User Equipment with the T-UMTS core network via Gateway Earth Station. The gateway is connected to the Base Station Subsystem which is communicating directly to Mobile Switching Center Server – MSCS. The connection between Gateway and the Base

Station Subsystem can be either TDM or IP. In the near future when the “All IP” evolution finishes in traditional networks, all interfaces in S-UMTS network will be adapted to IP.

1.3 Purpose of Thesis

S-UMTS air interface protocols are mostly based on T-UMTS air interface protocols. Same Radio Resource Algorithms are used in the link calculations. Since the channel characteristics of Cell-UE and Spot-UE are quite different, some adaptations on RRM algorithms are required in order to compensate the characteristic differences. The RRM algorithm, Power Control (PC) is one of the adapted algorithms for S-UMTS. The main reason that PC needs an adaptation, is the long path delay of satellite environment. PC has its own characteristic structure in GSM, CDMA200, Satellite and the wireless other networks.

In this thesis, the corrections on Open-Loop PC, Inner and Outer Closed Loop PC are considered. Especially in the Inner Closed Loop PC, which works between user equipment, gateway and satellite, and the transmit power characteristics are handled. The Outer Closed Loop PC which stands between RNC – Radio Network Controller and the gateway, is added to S-UMTS same in T-UMTS since the air interface of satellite is not included in this interface. One of the most important corrections for S-UMTS is the PC Mode algorithm which is used in setting the frequency of sending and processing TPC’S – Transmit Power Commands in the Inner Closed Loop PC and the Open Loop PC.

In the thesis, the effects of the change in different PC Modes including different Power Control algorithms on the Quality of Service, are handled. The results are compared between different constellation types, LEO, MEO, and GEO satellite orbits. With this comparison best PC Mode is recommended for the S-UMTS PC algorithm regarding on the simulation results. The simulation is based on a network that has random process of event handling with RF area calculations.

One of the other objective of this these is to set an Adaptive PC Mode algorithm approach that effects directly to QoS values with dynamic setting on TPC sending and processing frequencies. With this new algorithm TPC processing frequencies will change dynamically regarding to the power level variation. Obviously the power level variation amount will change related with the constellation type. So another objective of the thesis is to discuss to the different simulation results by applying the PC Mode and Adaptive PC Mode algorithm on different constellation type satellites, in order to reach optimum QoS values in radio interface.

1.4 Problem Description And The Hypothesis

In satellite communication, the Power Control Algorithm of Terrestrial UMTS can't perform the power level correction because of the over-sampling and loop instabilities caused by high path delay of satellite air interface. In order to overcome this problem ETSI recommend to adapt the processing of TPC commands to satellite environment. In T-UMTS, the Power Control algorithm TPC commands are being processed in every TPC slot. Another PC algorithm that is used in T-UMTS, Algorithm 2, is stated in the specification TS 125 214. According to Algorithm 2, TPC buffer collects 5 consequent TPC commands and with processing of these commands, the system decides whether the power control command will up or down. So a combination of 5 slot TPC cycle determines the power steps.

In order to reduce loop instabilities a similar model of Algorithm 2 needs to be used for S-UMTS. In Algorithm 2, processing period is 5 TPC/cycle. But in S-UMTS model, this needs to be increased because, especially in GEO satellite the path delay reaches to 240 milliseconds. If the TPC commands are applied immediately they do not match fast fading correction and furthermore are destructive. TPC processing period needs to be increased up to several slots or frames (1 frame is equal to 15 slots).

In the other hand, increasing the TPC processing period, causes increase in loop delay. For instance if the processing period is 5 TPC cycle, than the exact power control command that is used to set the next power level will be decided in 5 TPC sending time which is equal to 5 loop time. In a wireless network if the signal level variations are high, than the increase in loop delay causes the increase in drop rates. In Figure1.3, t2 and t3 timers indicate the total fading time. If the processing period is increased in order to prevent power oscillation for the networks that have long path delay, than the t1 loop time will increase. And this cause the rising of t2 and t3 which means increase of drop rates in high power level variation networks such as T-UMTS and LEO Satellite networks. But especially in low power level variation systems like GEO, MEO satellite networks, the increase in loop delay do not have such a destructive effect on t2 and t3.

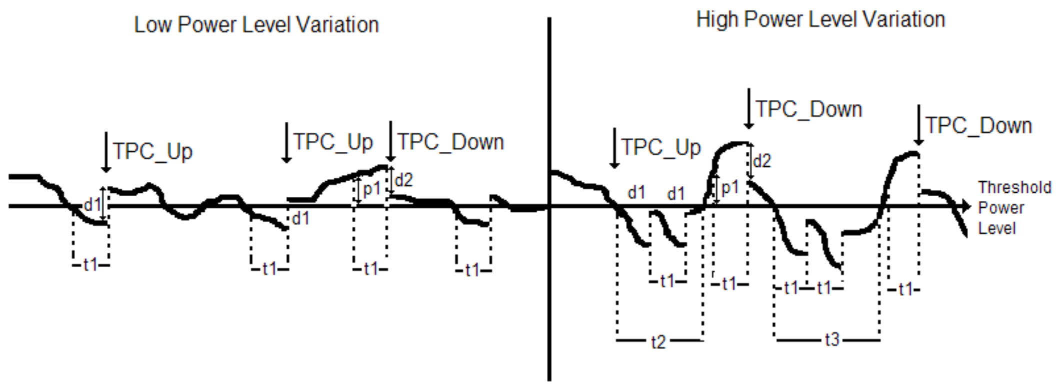

Figure 1.3 : Illustration of signal power level variation

t1: Power Control loop delay.

t2,t3: Total time of the signal level below threshold

d1: TPC_Up Power delta

d2: TPC_Down Power delta

p1: Required power level above the threshold to perform TPC_Down

In addition, Adaptive PC Mode algorithm, stated in third chapter, is a new approach that is used for setting the TPC processing period dynamically with the change of power level. The algorithm takes the power level measurement from the network as input. If the power level change is high in a unit time, then the system decreases TPC processing period. So the loop delay, reduce for a specific time. With the reduction of the loop delay the reactivity of the system becomes better for the rapid power level changes. If the power level change is low in a unit time, then the system, increase TPC processing period. So with less TPC commands, the system became safer against to power oscillations. So the main problem here exists in setting the right balance between being stabile and being more reactive against to fading effects of different link characteristics.

1.5 Simulation Overview

The simulation is a Satellite-UMTS signaling network model coded in C++. In the simulation User Equipments are simulated with random movements and having events at random time on a combination of urban and rural settling model. There are two service areas at that model: A satellite service area called “spot area” and an IMR service area called “cell area”.

The simulation consists of three algorithmic processes: Event Handling Part, Uplink Signal Strength Handling Part, and Downlink Signal Strength Handling Part. On the first part an event queue is constructed by the call initiation, call termination and handover events. Time for event arrivals apply to an exponential process that match with real network behavior (busy hours exist). After these events are processed, the database is being updated by the output values of this event algorithm. And the time progress continues if there is not any other event at that time.

In every simulation progress period, the uplink and downlink RF area calculations of every user equipment that have active call at that time, are being performed. According to the calculation results, if the call has insufficient Quality of Service values, then the call drop event or the handover event occurs according to the signal strength level between UE and the other cell or spot. If the QoS values are suitable, then the system starts the event handling process for the next simulation period time. And then again the RF area calculations start. This chain continues up to the condition that the system time reaches to the simulation end time. After all these calculations and event handling processes finished, the simulation database is being updated. With using to this database values a final network Quality of Service report is built as result output by the system.

2. SATELLITE UMTS SYSTEM DESCRIPTION

2.1 Satellite UMTS Service Network Overview

2.1.1 System description

Third generation mobile system known as Universal Mobile Telecommunications System (UMTS), is a project of International Mobile telecommunications-2000 (IMT-2000). The main purpose of IMT-2000 is to separate wireless telecommunications around the world, regardless of location, network and the terminal equipments. IMT-2000 includes proposals for different types of user equipments that have the ability of establishing connection with terrestrial and/or satellite networks.

Satellite communication systems are known by the expensive node or system costs. But in the other hand it has the ability of serving through an enormous area. The coverage area of satellite spot can change from a town to a continent. In order to use this big advantage for non-satellite networks, new ideas that include a combination of satellite and other new technology networks that have high data transfer rates, are produced. Satellite – UMTS (S-UMTS) is one of these approaches that include the combination of satellite network and the terrestrial network.

The UMTS vision is to integrate the complimentary network elements of satellite and terrestrial mobile systems to provide global coverage and the services. At this point of view, global coverage is the world-wide coverage including all cellular and satellite system, and the services are the bearer services and the Teleservices similar as planned for the fixed telephony. In order to achieve success at this vision objective for Satellite - UMTS, the system has to support same services with the Terrestrial – UMTS within the same range of Quality of Service. The service expectations of S-UMTS are as below in Table 2.1.

Table 2.1 : Services supported by S-UMTS

Information type	Traffic type	Services
Telephony (voice)	Constant bit rate - Real-time	Conversation, telephone-conferencing, Personal real-time services
Messaging (text/data)	Dynamic bit rate - Non real-time	SMS, paging, fax, two-way messaging, e-mail
Web browsing & Wireless Application Protocol (WAP) browsing	Dynamic bit rate - Non real-time	Access to internet
Audio streaming	Constant bit rate - Non real-time	Voice messaging (asymetric), voice over IP (symetric), music on demand

Video streaming, Data streaming, Multicasting	Constant bit rate - Non real-time	TV-on-demand video-on-demand, information retrieval
Real-time video	Constant bit rate - Real-time	Video-telephony, video-conferencing, multy-party games, scanning, telnet.
Data transfer	Dynamic bit rate - Non real-time	Information aquisition from databases
Broadcasting	Constant bit rate Non real-time	Distributing applications without user control "push"
E-commerce	Mostly dynamical bit rate - Mostly non real-time	Transactions, mobile shopping, banking online payment
Location based services	Mostly dynamical bit rate - Mostly non real-time	Location precise traffic information navigation logistics telemetry monitoring
Relay between T-UMTS cells BSs	Mostly dynamical bit rate - Mostly non real-time	Relay of high capacity services from BS to BS. Symetric services except for broadcasting.

From the system point of view, S-UMTS might face with keen competition with other network systems. For instance in the S-UMTS coverage areas, T-UMTS, GSM and GPRS may compete with S-UMTS if they have the same services with same QoS. Broadband satellites that connect T-UMTS networks with each other can also compete with S-UMTS, since S-UMTS has not sufficient capacity to connect T-UMTS islands. In the other hand there may be some cooperation scenarios. For instance, satellite can cover the gabs of T-UMTS coverage area. These gaps are mainly lies around sea, desert or mountain geographical areas. In addition to global coverage international roaming between far end T-UMTS for continuous communication is possible via S-UMTS network. Another cooperation point is in the deployment process of UMTS. Since the S-UMTS deployment is rapid, it may be efficient to provide service for an area that the T-UMTS is in the first step of deployment. S-UMTS can also be used like a backup system to a T-UMTS especially for disaster cases[21].

2.1.2 S-UMTS services and applications

S-UMTS is planned to provide same services with T-UMTS and GPRS systems. But high volume data applications are not expected to be delivered by S-UMTS, because of the nominal QoS values in comparison with T-UMTS. The traffic volume of S-UMTS will probably not deviate very much from T-UMTS. Most handheld terminals will be dual-mode GSM/UMTS, so traditional voice services are not the essence of target market for T-UMTS or S-UMTS. Because of the greater delays and less data rates than in T-UMTS, Multimedia services such as video conferencing are expected to be less user friendly in S-UMTS.

2.1.2.1 Vehicular system services

Vehicular system is one of the main market objectives of S-UMTS. Especially for traveler users, it is important to attach a continuous network in order to gather uninterruptible service. Entertainment, intranet access of companies, navigation and map services, internet and web browsing, message services, customer services and remote information and file transfer diagnosis, E-commerce are some of the vehicular system services.

Since these services has different vehicle usage by customers, it is expected to the generated traffic will vary regarding to the services used. So the operators mostly focus on especially high traffic services not like navigation, customer and remote diagnosis services. Vehicular services can be provided to the end user in two support modes: Broadcast Support and Multicast support.

2.1.2.2 Broadcast service support mode

A broadcast service may consist of single on-going session or several merged sessions over a period of time. The target of a broadcast service message is a part or a whole of a local area network. The reception restrictions of broadcast messages are determined by the end users. But the data that is transmitted in the broadcast service area is defined by the home network environment. An example of a broadcast message can be a welcome message to a network or it can be the application of Mobile TV via UMTS. In the User Equipment perspective, it is important for mobile equipments to adjust the broadcast mode in order to protect itself useless power consumption. In the broadcast serving architecture, the servers are connected to S-UMTS Packet switching system via IN (Intelligent Network). The nodes in packet switching system are responsible for QoS handling, VASP Authentication, Broadcast Area Configuration and the provisioning control. After the switching operation in the core network, the service packets route to the right broadcast service area via USRAN (UMTS Satellite Radio Access Network). Figure 2.1 Illustrates the steps of providing a broadcast message to the end users by the network [5].

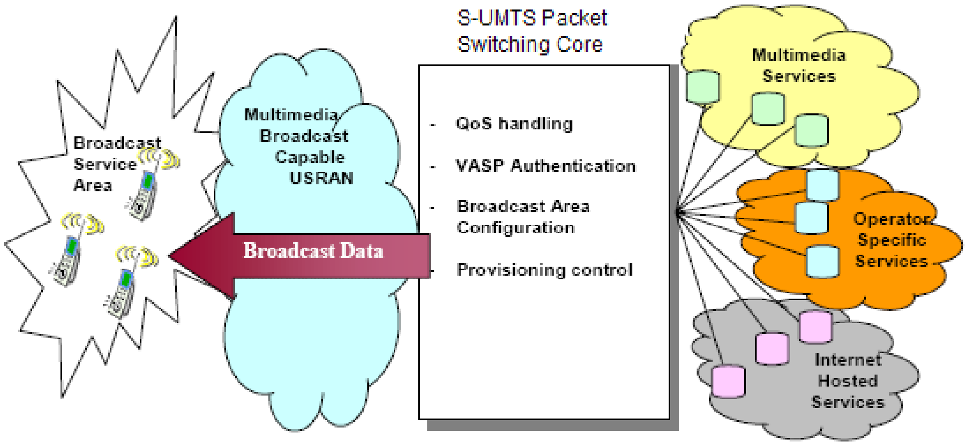

Figure 2.1 : Broadcast mode network

2.1.2.3 Multicast service support mode

In the Multicast Support Mode the service establish a point to multipoint connection between the servers and the users. The data is transferred from a source point which is an operator dependent server to the end users via common radio channels with using the radio recourses efficiently. In the S-UMTS it is an option to use more than one satellite spot as a member of multicast service area group. If user equipment receives multicast service message then it establish more than one session in the same multicast session time period. For instance a service that provide sport match results for the end users, required to establish several connection for the subscription. So the multicast mode is based on a reception and a subscription process unlike broadcast mode. The point to point connections may be provided either by satellite bidirectional link or by the T-UMTS radio network. As in the broadcast mode, multicast mode has the same information path through S-UMTS network. Within the IN carrier, the service messages pass through S-UMTS core network which is responsible with QoS handling, service provisioning, subscription handling, efficient routing, activation and multicast area control. And then according to the message types new sessions establish between S-UMTS core network and the end users with multicast support technique. After the synchronization and activations are terminated, the data stream starts to flow right multicast user group. This flow is shown in Figure 2.2.

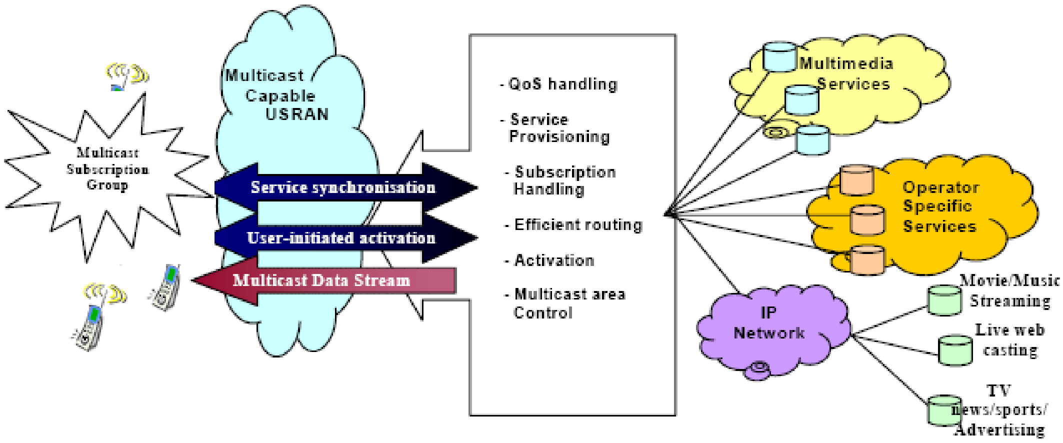

Figure 2.2 : S-UMTS radio and packet core for multicast mode

2.2 Access Network

Satellite UMTS access network consists of satellite and gateways connected directly to T-UMTS Core network. The similar air interface protocols, channel structures and RRM (Radio Resource Management) mechanisms exist in S-UMTS as in T-UMTS. In this chapter, the network architecture, S-UMTS node properties, RRM algorithms, link budget calculations and some specifications are handled.

2.2.1 S-UMTS network architecture

Terrestrial UMTS consist of three main parts: User Equipment (UE), UMTS terrestrial Radio Access Network (UTRAN), and the UMTS core network. UTRAN is divided by two network nodes, Radio Network Controller (RNC) and Node B. Since the communication can be either in data or voice, the core network of UMTS is divided in to two parts. This separation does not exist in radio network. For the data traffic Serving GPRS Support Node (SGSN) and Gateway GPRS Support Node (GGSN) nodes are exist in the core network. GGSN is used to interwork with the remote sites or other Internet Service Providers (ISP) for the internet traffic. SGSN is connected to the RNC via IuPS interface. And the UE connects to UTRAN over the Uu interface as seen in Figure 2.3. For the voice traffic which is still traffic load leader in the market, Mobile Switching Center Server (MSCS) and Media Gateways (MGW) are used with TDM interfaces. In some networks Voice over IP is introduced in order to carry voice traffic between MGWs. So, TDM technology is replacing with IP interfaces which are cost reductive and reliable. This IP networks also support enough QoS rates on today's UMTS networks.

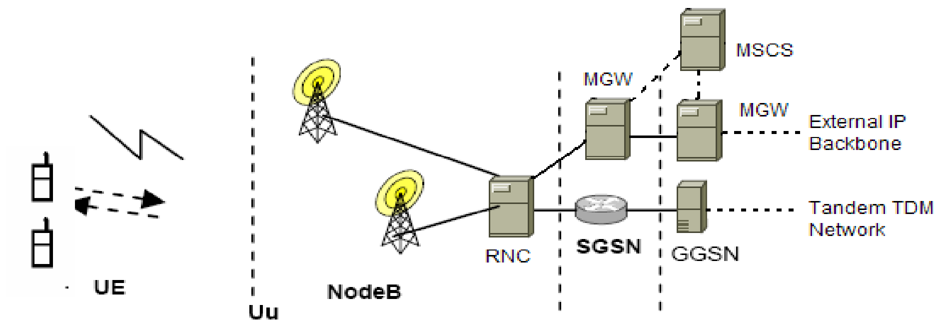

Figure 2.3 : Terrestrial UMTS network architecture

2.2.1.1 Satellite as Node B scenario

Satellite UMTS is similar with T-UMTS in the Core Network perspective. As seen in the Figure 2.4, same core network nodes, SGSN, GGSN, MGW and MSC Server are used. In this architecture the satellite has the same role with Node B in T-UMTS. It completes the connection between UE and the RNC which are geographically unreachable. As mentioned before in some cases that for some places when it is economically or technically unavailable to cover by T-UMTS, S-UMTS may play a complementary role for T-UMTS. As in the traditional satellite networks, satellite will act as a transceiver to provide all radio transmission functions.

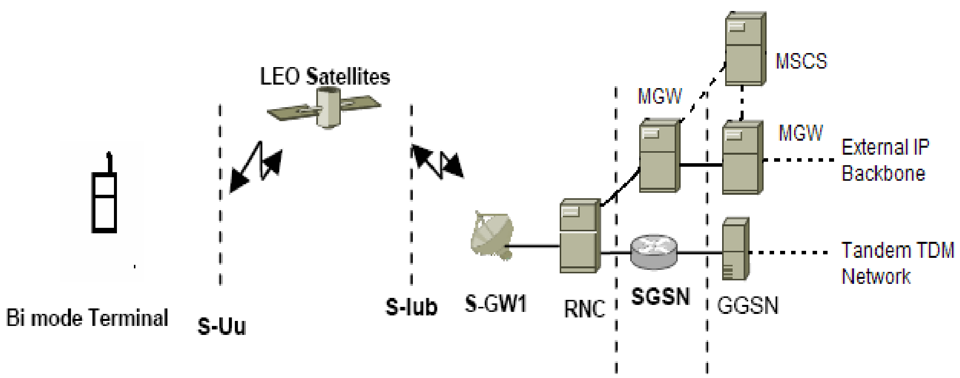

Figure 2.4 : Network architecture in USRAN with satellite as Node B

The fixed part of S-UMTS air interface is composed of AAL2 ATM technology for transport network layer. The radio link control layer (RLC), provides data transfer over the radio interface. RLC sits above the MAC (Medium Access Control) layer which is used to handle to the scheduling of radio bearers with different QoS requirements. It is also responsible of mapping between logical channels and transport channels, and priority handling. Below the RLC, RRC (Radio Resource control) layer stands. RRC is responsible for setting up, releasing and modifying all the lower layer protocol entities. The mapping operation between transport channels and physical channels is in the responsibility of the physical layer. Physical layer controls the use of physical channels at the radio interface.

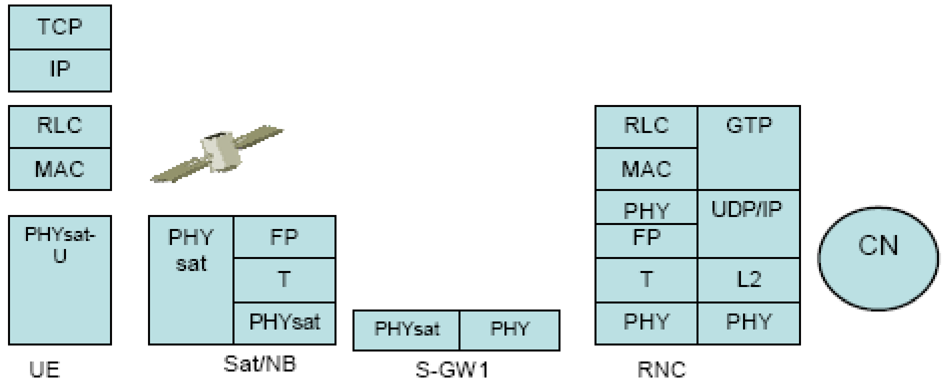

Figure 2.5 : Protocols stack architecture in USRAN with satellite as Node B

For the reliable end to end transport of the traffic, Transport Control Protocol (TCP) is used. GTP, UDP/IP protocol layers are used transfer the TCP IP packet in transparent mode between GGSN and RNC. Since the User Equipment terminal is having the dual mode capability, it can attach both to S-UMTS and the T-UMTS. But especially the antenna type and the battery life time of these terminals differs from T-UMTS terminals.

2.2.1.2 Satellite as RNS scenario

In the cases that T-UMTS has low radio recourses, Satellite as RNS scenario of S-UMTS can be used as a complementary resource. In this case the RNS system including the satellite is used as the RNC node of T-UMTS. Terrestrial Node B and RNC functions are implemented in the satellite. As seen in the Figure 2.6, SGSN and the MGW are connected to satellite via a gateway node. Since the Mobility Management, call control and admission are the functions of RNC, these functions are handled by the satellite. With the implementation of these functions from satellite, it causes new and effective backup recourse for the T-UMTS.

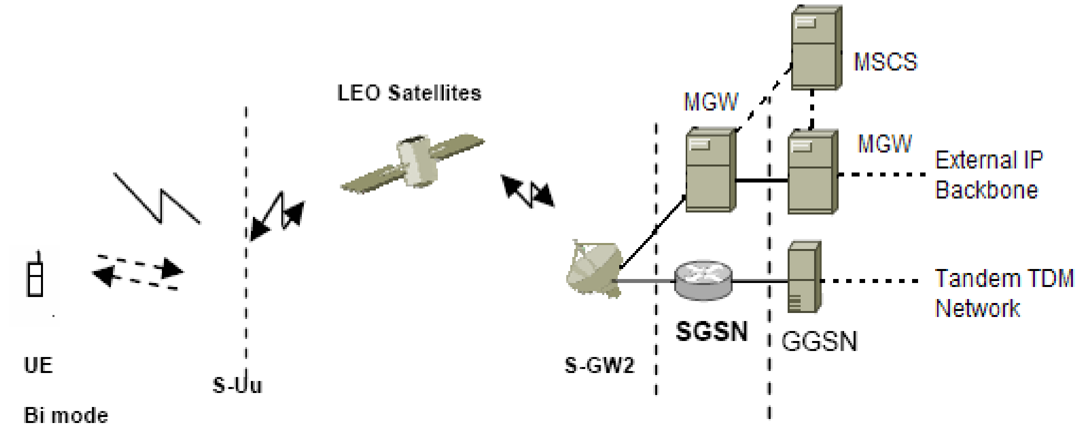

Figure 2.6 : Network architecture in USRAN with satellite as RNS

In Figure 2.5 the protocol structure of Satellite as RNS Scenario is presented. As mentioned before the functions of Mobility Management (MM), are supported by the satellite. As well as MM, other physical layer functions such as MAC, RLC, and RRC layers are supported by the satellite. The communication property directly with terrestrial RNCs, is added to the satellite segment. In the Satellite as Node B Scenario, the signaling messages are processed on the first physical layer. But in the Satellite as RNS Scenario it is planned to process messages up to second MAC layer since the MM messages is to be used. So the MAC layer in the protocol stack is the most important layer for S-UMTS if this scenario is used. For the satellite stack MAC Sat protocol is developed and adapted in order to be interfaced easily with terrestrial network.

2.2.2 S-UMTS node properties

UMTS air interface consists of Node B and User Equipment. If Satellite component is added, then the satellite and the Intermediate Module Repeater are to be included to the air interface. For the comparison of IMR and the Node B, since the coverage areas are similar, the technical properties are also same. But the UE interface properties differ from T-UMTS terminals, due to different channel characteristics of satellite environment.

2.2.2.1 User terminal characteristics

For the satellite networks, previous terminals mainly built and focused for only voice services. But with the introduction of third generations, the terminals are target on enhanced multimedia services that requires high bit rate data transfer with worldwide coverage and roaming development.

User-friendliness, battery autonomy and transportability are the main properties that determine the optimum terminal size. There is an interaction between the user needs and these properties, so with the terminal size. Depend on the transportability, the satellite integrated UMTS technology supports different types of terminals. Pocket phone, PDA, nomadic terminal, modular built-in terminal and plug-in terminal are some of these types.

The pocket phone type is a low cost classic used in second generation networks. With the small dimensions it offers a high mobility but low screen size and battery autonomy. UMTS has higher data rates, and intense source and channel encoding together with power demanding multimedia applications raises energy consumption. So especially for pocket satellite phones that has high power consumption, power control becomes a vital important for continuous mobile communication. As the traditional satellite phones, S-UMTS pocket phones will have the dimensions of around 12 cm by 5 cm, and the weight between 100g and 200g.

Another terminal type is the Personal Digital Assistant (PDA) type which supports new wireless multimedia applications with having greater screen size and more interactive utilities for third generation applications. Since PDA's have bigger size, the battery size is also higher. But in the other hand, due to integrated utilities like camera or speaker, and with the bigger screen size, the energy consumption rise to critical levels. The pocket terminals and the PDAs have the antenna gain of -1,2dBi, EIRP -3dBW, G/T -26,6 dB/K and the data rates in the range of 16kbit/s and 64kbit/s [6].

Nomadic type terminals have the advantage of using radio recourses effective in order to send and receive in high data bit rates. These types have the ability of being used like a laptop PC in the home or office environment with attaching to T-UMTS thanks to the dual mode. Its design gives opportunity of searching satellites with bigger antennas. With the bigger antenna gain the radio resources are being used more economically. Nomadic terminals with integrated antenna has the antenna gain -4dBi, EIRP 2,2 dBW, G/T -20,8dB/K, data rates between 64kbit/s 144kbit/s.

With the modular built-in terminal type it is possible to integrate the equipment parts to mobile vehicles like cars, air planes and boats. The common properties of modular built-in terminals are that they have external power supply and form a combination of antenna, user interface, speaker etc. Since it has an external power supply, the transmit power is less limited. So the transmission capability increases and with that property the terminal communicates with satellite directly even if the transmitted bit rate is high. The modular built-in terminals has the antenna gain of 4dBi, EIRP 15 dBW and the G/T -20,8 dB/K.

In the service point of view the S-UMTS terminals have the capability of support voice and multimedia services crowded places like urban or sub-urban settlements with full duplex mode, if the T-UMTS is deployed. In addition it has the ability to provide broadcast and multicast services in urban areas using S-UMTS for the downlink and T-UMTS for the uplink data transfer.

2.2.2.2 Intermediate module repeater characteristics

Intermediate Module Repeater (IMR) is deployed for S-UMTS to ensure adequate signal reception in urban environments and inside buildings. Since the satellite communication requires the Line of Sight (LOS) transmission, IMR is a good opportunity for the S-UMTS operators to provide UMTS services with LOS requirement as seen in Figure 2.7. There are 5 IMR types for proposed for the S-UMTS: Simple bi-directional IMR, simple unidirectional IMR, simple IMR with a subset of Node B functionality, IMR with Node B functionality, and IMR with Node B and RNC functionalities.

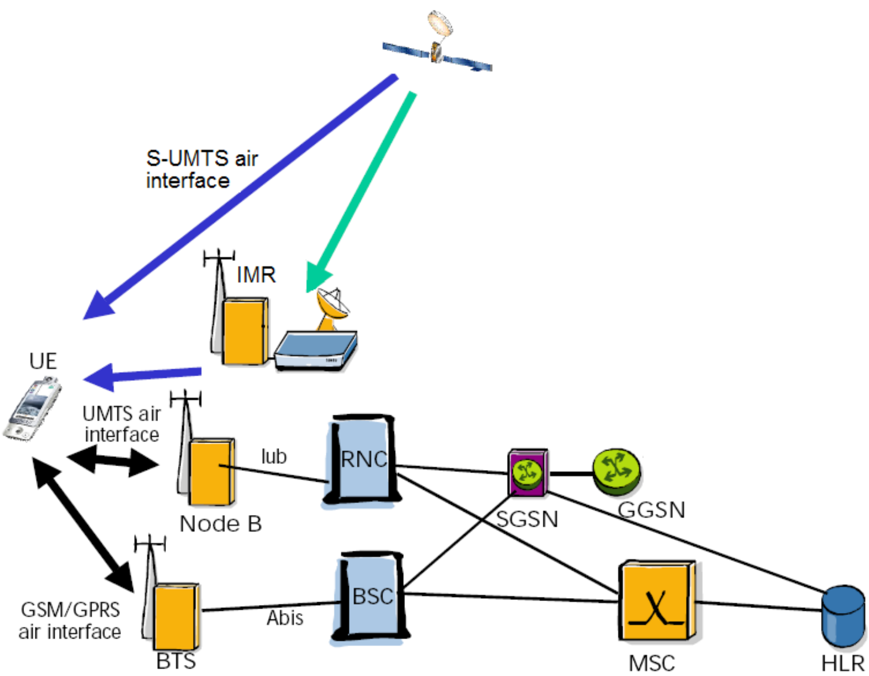

Figure 2.7 : IMR included S-UTMS architecture

For the Simple Bi-direction IMR Type, the IMR acts as it is transparent to Satellite link between satellite and the user equipment. IMR is used to receive, amplify and retransmit the S-UMTS signal. Since the system becomes a multipath for the satellite signal, the UE can use it for the rake receiver. So this is an advantage for the system to enhance the SNIR values of the signal. Another advantage of this type is the low cost, because of the dummy repeaters are being used only for amplify the received signal.

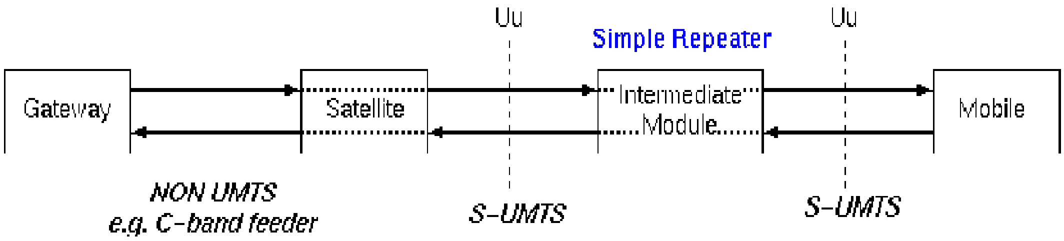

Figure 2.8 : Bi-direction IMR type

It is obvious that the cost of effective handheld terminals for that support full-rate uplink transmission through satellite is high. But this case is used for the rural areas that IMR's are not deployed. In the range of IMR, IMR is used for the uplink transmission. For the rural areas, since in the low data rates SIR are high because the processing gain is high, it is an option to used handheld terminals in the rural areas with acceptable QoS in low data rates. [6]

In the Simple Unidirectional IMR only the downlink transmission is used via IMR. For the uplink T-UMTS is used. Since the IMR is capable of receiving signal only from S-UMTS, the complexity in receiving and transmitting parts. So the costs are greatly reduced in comparison to other IMRs. There is no transmitting through satellite, so power saving is increased in this scenario. In the other hand geographical complement does not exist in this type of IMR usage If T-UMTS used for uplink.

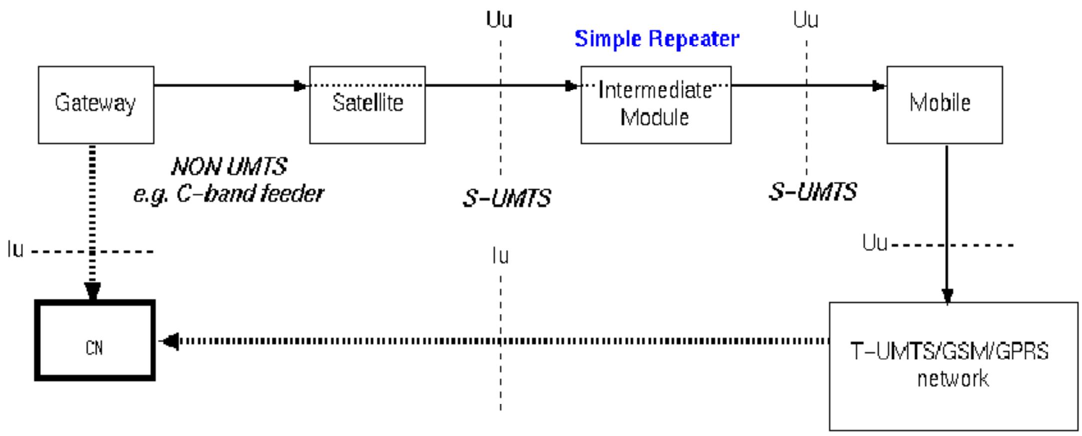

Figure 2.9 : Simple unidirectional repeater

For the simple IMR with a subset of Node B type IMRs, the IMRs act as a Node B for the user equipments in its own coverage area. With some functionalities like Power Control and

Rake Reception, IMR adjust its own radio characteristics between UE and the Node B as seen in Figure 2.9. This is done by the control channels established with every UE and the IMR.

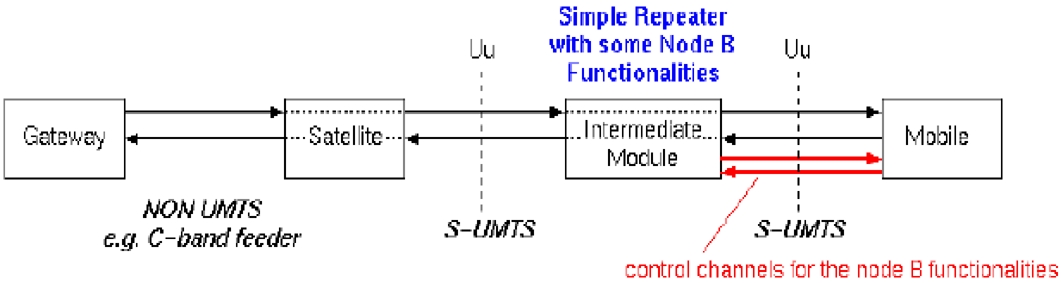

Figure 2.10 : Simple IMR with a subset of node B functionality

So in this case IMR must be capable of processing the control signals which requires extra digital hardware. The cost is high for this need, and can be higher if additional Radio Resources functionalities are added for the IMR. [6]

There is a quite difference between IMR with a subset of Node B functionality type and the IMR with full Node B functionality type regarding the channel structures and the architecture. In the IMR with full Node B functionality, the IMR acts as a complete Node B with supporting all radio resource algorithms as Node B. Since IMR support all RRM functionalities there is no need to receive-amplify-transmit operation between satellite and UE. So the interface between satellite and IMR is a none-UMTS interface. The channel characteristics are the traditional satellite communication characteristics on this interface (do not include CDMA).

Table 2.2 : Overview of different IMR scenarios

IMR type	Advantages	Disadvantages
Simple bi-directional IMR	Creation of a multipath environment, no extra load for UTRAN, good coverage	Terminals needs an expensive satellite transceiver, No fast power control possible
Simple unidirectional IMR	Reduced IMR cost, reduced terminal complexity and cost, fast uplink power control possible, gain from uplink multipath diversity	Extra load for UTRAN, no geographical extension due to limited uplink coverage
Simple IMR with some Node B functionality	Fast uplink uplink and downlink power control possible, multipath combining in both uplink and downlink possible	Higher complexity and cost of the IMRs

IMR with full Node B functionality	Fast uplink and downlink power control possible, multipath combining in both uplink and downlink possible	Higher complexity and cost of the IMRs
IMR with full Node B and RNC functionality	Full UMTS provision, single mode T-UMTS terminal is sufficient	High cost and complexity at the network side

Same aspect exists in the IMR with full Node B and RNC functionalities. On that configuration satellite acts as a tandem between a small UMTS Base Station Subsystem BSS and the UMTS core network. Since the IMR supports Mobility Management MM algorithms, it has the ability to control radio resources by itself on a local network. Today this structure is being used also in GSM for the remote Base Station Controllers (BSC) that are geographically unable to connect with radio link or cable transmission.

As mentioned above different IMR types have some advantages and disadvantages depending on the usage purposes. For all the IMR types from Simple bi-directional IMR to IMR with full Node B and RNC functionality, the complexity is increasing by adding more MM and RR functionalities to the node. This increment brings the cost raise. So for the operator, it is important to well determine the QoS requirements and the service needs in order to balance the cost of whole S-UMTS network.

For meeting the demands of acceptable communication performance, the selection of right RF parameters has a great importance. Below are the ETSI recommendations for a sample IMR RF area parameter values:

Table 2.3 : A sample of recommended wide area IMR RF parameter values

Parameter	Value
Receive frequency (MHz)	1 980-2 010
Transmit frequency (MHz)	2 170-2 200
Feeder link frequency	2 170-2 200; 1 980-2 010 or FSS Band for non-on channel repeaters
Receive polarization	RHCP or LHCP
Transmit polarization	Vertical
Minimum receive power level (dBm)	-78
Maximum receive power level (dBm)	-72
Maximum output power (dBm)	43
Overall EIRP (dBW)	Same as 3GPP Node B
Coverage area (°)	Up to 360° (e.g. 90° per sector)
Assumed height of IMRs (m)	30
Maximum Antenna gain (Tx) (dBi)	15

2.2.2.3 Satellite system characteristics

Regarding to satellite specifications, a complex LEO/MEO constellation is required for a truly global coverage. For a regional or a worldwide coverage within the -70 to +70 latitude range, the GEO constellation satellite is required. But for the urban and indoor coverage areas, additional devices like gap-fillers or boosters are required to achieve acceptable QoS. The satellite system mainly composed of payload and earth station gateway.

2.2.2.3.1 Payload properties

The traditional satellite payloads offer Layer 1 connectivity between spot and the frequency channels by digital or analog processors. Improved regenerative payloads offer advanced performance on connectivity by Layer 2 packet or circuit switching or multiplexing functions over several spots. The enhancement on signal modulation-demodulation and different channel coding-decoding functions are included to the payload for improved link performance. This is because the signal performance requirements are high for the high bit rate data transfer. Saving of radio resources is another issue handled on the payload. Digital regenerative on-board processors support on board multiplexing and buffering of Layer 2 radio resources. The payloads can split in three groups: Transparent Payloads, Hybrid Payloads and Regenerative Payloads.

Transparent Payloads: Transparent payloads have L1 connectivity which is used to amplify the signals with transparent on-board signaling. The payloads with transparent on-board processing are characterized by the connectivity they provide at Layer 1. Depending on the system requirements enough number of spot-beams are used with the advantage of Beam-Forming Networks (BFN).

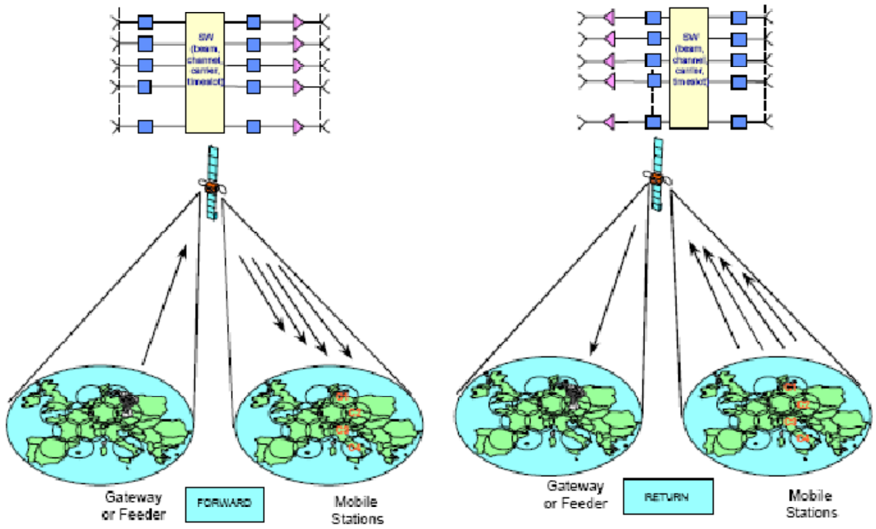

Figure 2.11 : Transparent On-Board processing satellite with multi-beam

Due to the capacity requirements that change from coverage area to area, the ability of shaping network is an important issue. With the help of beam channel regulation, the channels and the carrier allocation can be adjusted for the capacity needs. The multi-beam illustration Figure 2.11 shows the forward and the return link beam allocation from gateway through mobile stations.

The transparent on-board processing satellite with multi-beam architecture support both analog and digital devices with on-board A/D and D/A conversion.

Hybrid Payloads: The main difference between hybrid and transparent payload is the small capacity regenerative processor mounted on board. The hybrid payloads are commonly used for broadcast services. So, mostly the return link is inactive for that one way service. Frequency de-multiplexing, demodulation and decoding operations are performed by regenerative processors. These operations are to carry information including video or data IP datagram. As shown in Figure 2.12 for the regenerative satellites, it is possible to serve multiple user points through multiple service points.

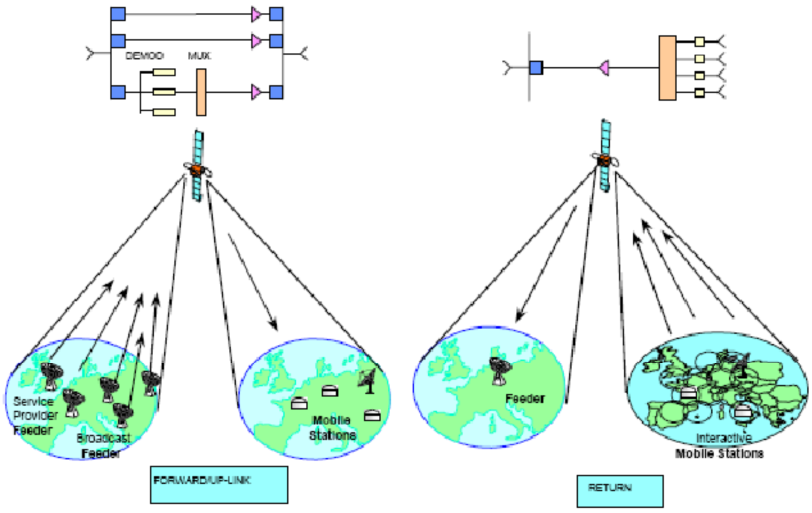

Figure 2.12 : Regenerative bent-pipe forward and backward satellite links

Regenerative payloads: Regenerative payloads are characterized by the demodulation on board. Regarding with the multiple access technique, for different frequency carriers, frequency de-multiplexing is included in order to separate and combine different frequency carriers. The coding techniques and the type of applications differ regarding terminal type. So the payloads on-board decoding must be adapted to several coding schemes. In the regenerative payloads the forward and the backward beams are multiple as seen in Figure 2.12.

The switching technique is another issue for the payloads. After the signals received form spot, they are de-spread, demodulated and decoded on payload. So for the transmit operations they switch to right channels by the switching operation on board which have static or dynamic routing configuration on the system. For the dynamic routing, packet-switching is used. And the circuit-switching is used for the static routing. Especially in the packet switching buffering and prioritizing techniques are used in order to meet the expected QoS requirements of dynamic routing.

For the packet switching payloads, since the packet format and the processing can easily be adapted for different radio environment behavior, it is a great flexibility to improve satellite and radio resources management in a cheap way. As stated in the following chapters the PC Mode algorithm is passed on the change of packet stream and the processing sequence variations that uses this flexibility of payload processing.

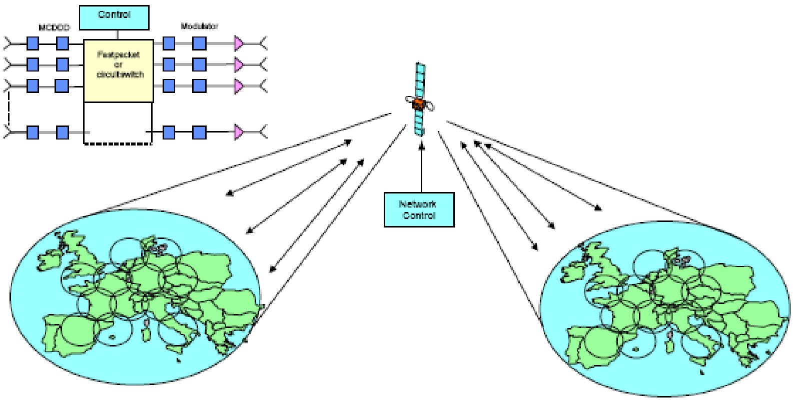

Figure 2.13 : Multi-beam regenerative payload including fast packet or circuit switching

In comparison of these payload types, the bent-pipe with wide coverage type payload has the high connectivity with robust and reliable technology which is friendly to system evolution. But in the other hand these payload types have no routing capability, and have some link budget restrictions. For the case of the bent-pipe with multi-beam payload type, a low routing resolution that the beam is the first degree of connection is possible. Hybrid regenerative and transparent payloads, the advantage of data multiplexing on board which improves satellite capacity in the regenerated link is gained. But in the other hand, increased complexity and the cost dependent on transmission schemes are some of the disadvantages. The link budget and the RF area calculations will be described on Chapter 3.

2.2.2.3.2 Gateway properties

In the S-UMTS architecture GW (Gateway) is interconnected to the CN (Core Network) via Iu (RNC-MSCS/SGSN) interface. If the IMR type is not an IMR with full RNC functionalities, then the GW includes all the Node B and the RNC functionalities and hardware. So, GW is a kind of transition between the CN and the Radio Access Network (RAN).

The RNC node has the ability of radio resource managing and some other user operations like ciphering or applying the security procedures on IP flows. It also maps between the IP QoS and UMTS QoS. Measuring of satellite RF and TCP performance and the adaptation of these measurements to CN requirements are some of other responsibilities of the node RNC. The Node B converts the data flow between the IuB (Node B - RNC) and Uu (Satellite-UE) interface. The main objective of Node B is to manage the power control and the handover procedures together with RNC.

The access network domain provides to the user equipment the radio resources and the mechanisms necessary to access the core network domain. The USRAN contains entities that control the functions related to the mobility and network access. They also allocate or release connections (radio bearers). The USRAN consists of radio subsystems RNC and Node B that performs the GW, connected to the core network by Iu interface. Each RNS includes one RNC and one or more Node Bs.

The Node B in the GW, is a kind of base station. It is the entity that allocates and releases radio channels, partially manages the radio resources, controls the transmission power in the downlink, and converts the data flow between Iu and Uu interfaces. In addition, Node B contains procedures that manage only the physical layer such as coding, spreading, transmission and detection, and physical layer signaling.

The RNC is the main element and the intelligent part of RNS. The RNC controls the use and the reliability of the radio resources. It performs the functions of MAC/RLS layer and terminates the radio resource control RRC protocol. Three types of RNC have been specified: SRNC (Serving RNC), DRNC (drift RNC), and CRNC Controlling RNC.

The SRNC is the entity that holds the RRC connections with the UEs. This entity is the point of connection between USRAN and the core network and is involved in the user mobility management within the USRAN. When user equipment moves in the connection state from a cell or a spot managed by the SRNC to another associated with a different RNS, the RNC of the new cell is called DRNC. The RRC connection is still handled by the SRNC. In this case, the DRNC serves as a simple relay to forward information between the SRNC and the user Equipment.

The CRNC is the RNC performing the control and the configuration of a Node B. This entity holds the responsibility of load control in its own cells or spots, as well as the admission control of and code allocation to new users accessing the system.

S-UMTS GW is a complete interface from physical to access network management between air interface and Iu interface with the physical, medium access control, radio resource management, core network interworking, access point control function and the access network management functions. For the physical function, the GW handles the transmission and the reception of transport channel information flows between two network entities. The multiplexing and de-multiplexing of transport channels and mapping the physical radio resources for signaling flows are some of the medium access control functions. Radio resource management has maintaining function link connections which form the transport and the physical channels. Another GW function is the access control function that handles the connection protocols in the Iu interface between CN and the GW. The responsibility of CN interworking function is the adaptation and control required data between CN domain and S-UMTS access domain.

2.3 Core Network

The properties and the node types of S-UMTS are typically same with T-UMTS. As stated in the previous chapters S-UMTS is differentiated with only satellite air interface environment from the T-UMTS. So the main nodes of T-UMTS like MSCS (Mobile Switching Center Server), MGW (Media Gate Way), RNC (Radio Network Controller) and Node B of T-UMTS exist for S-UMTS.

2.3.1 Network architecture

The core network domain is basically inherited from the GPRS network architecture according to a transition phase, from GPRS to UMTS networks, specified in 3GPP which is the 3rd Generation Partnership Project. The core network consists of physical network entities integrating both circuit and packet-switched domains. The CN domain provides various support functions for services traffic conveyed over the UMTS system. The services correspond to management of user location information, control of network features, and transfer mechanisms for signaling. The core network includes switching functions for circuit-switched services via MSC Mobile Switching Center and the Gateway MSC as seen in Figure 2.14. The HLR (Home Location Register) and the VLR (Visitor Location Register) are the databases responsible for handling, respectively, user subscriptions and terminals visiting various locations. To manage packet data services, the packet domain relies on the SGSN (Serving GPRS Support Node) and the GGSN (Gateway GPRS Support Node), which serve, respectively, as routers and gateways as seen in Figure 2.14. The SGSN and GGSN are involved in the management of session establishment like packet data protocol contexts and in the mobility of data services. In certain cases, mobility management is achieved jointly by circuit-switched and packet-switched domain via the cooperation of the SGSN, GGSN, MSC, HLR and VLR via dedicated interfaces fully described in 3GPP specifications.

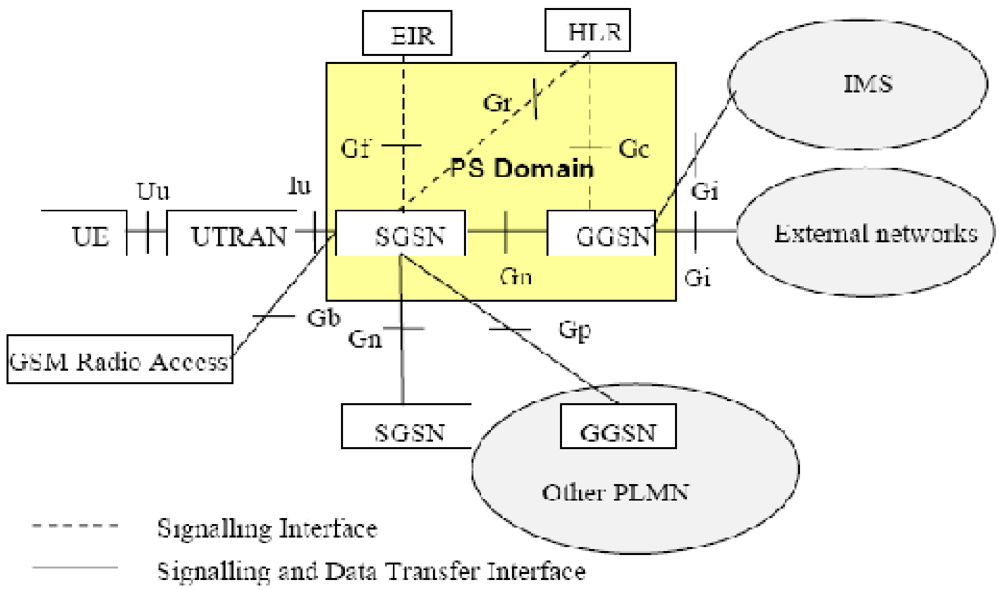

Figure 2.14 : UMTS packet-switching network

The HLR is a database handling maintenance of user subscription data and profiles. This information is transferred to the adequate VLR or the SGSN in order to achieve location and mobility management. In addition, the HLR provides routing information for mobile calls and SMS (Short Message Service).

The VLR is involved in user location updates in the circuit-switched domain (functions inherited from the GSM architecture). It contains subscriber information required for call and mobility management of subscriber visiting the VLR area. The MSC is a switch mainly used for voice and SMS. It is involved, with the public switched telephone network (PSTN), in the establishment of end-to-end circuit-switched connections via SS7 (Signaling System 7). In addition, it is coupled to the VLR to achieve mobility management. The gateway MSC provides switching for CS services between the core network and external CS networks and is involved in international calls.

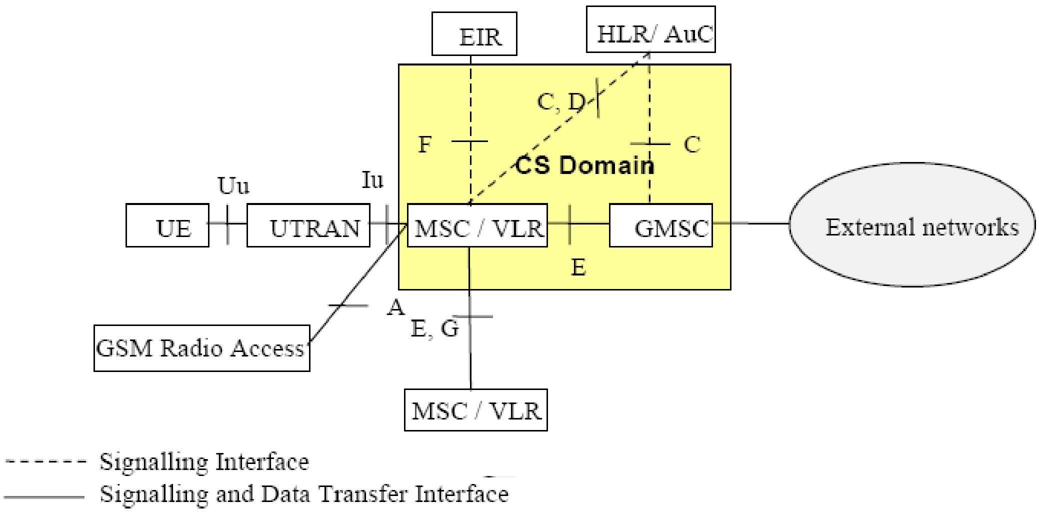

Figure 2.15 : UMTS circuit-switching network

The SGSN plays in the packet domain a similar role to the MSC/VLR in the circuit-switched domain. It handles location and mobility management, by updating routing area, and performs security functions and access control over the packet domain.

The GGSN serves as an edge router in the core network to convey data between UMTS network and external packet networks like internet. In other words, it has in the packet domain the same role that the GMSC does in the circuit-switched domain. The GGSN is involved in packet data management including session establishment, mobility management, and billing like accounting. In addition, the GGSN includes firewall and filtering of data entering the core network in order to protect the UMTS network from external packet-data networks like internet.

2.3.2 S-UMTS – CN integration aspect

The interfacing of the satellite system with the UMTS core network has some different solution depending on the architecture of the satellite network such as GSO, non-GSO, single-hop, double hop, ISL, and non-ISL satellite systems. For instance if the satellite network is a GSO or a non-GSO, the Iu interface must be the same as defined for T-UMTS in order to apply the connection of USRAN to a standard UMTS core network.

Basically, it is not expected that the interface between the access network and the CN includes differences with the terrestrial equivalent. But there are some exception cases regarding of satellite architectures. For these cases the functional analysis of the USRAN, including radio resource control and mobility aspects, has a key factor in the determination of specifications of Iu interface. The functions like handover, between two access network and micro-diversity that need to be related or handled by CN, might be assessed right after performing the functional model. But in the other hand some satellite specific protocols like SRM (Satellite Resource Management), do not need to be supported by CN, since these protocols are directly connected and being managed from NCC (Network Control Center). For the case of needed, it is not expected to be a problem to add a new elementary procedure based the new elementary procedures like messages, timers and information elements defined by current signaling protocols at the Iu interface.

For the QoS point of view, the same model of the USRAN shall be used to assess the performance of the different signaling procedures performed by the satellite access stratum. This demonstrates the Iu protocols execution and performance like delays and overheads, for a specific satellite scenario [18].

3. SATELLITE-UMTS RF AREA PROPERTIES

In this chapter, the RF area properties of new generation S-UMTS, are described. The calculations of RF area, the link budget, and the power control algorithms are used in the S-UMTS radio network simulation described in this section. The radio properties of S-UMTS have the characteristics of both satellite networks and the traditional T-UMTS radio networks.

3.1 Channel Characteristics

Since the access scheme is same, the logical channel characteristics of S-UMTS are similar with radio Terrestrial UMTS. The following logical channel types are defined:

• Common CHannels:

- Broadcast Control CHannel (BCCH);

- Paging Control CHannel (PCCH);

- Random-Access CHannel (RACH);

- Common Control CHannel (CCCH);

- Common Traffic CHannel (CTCH).

• Dedicated Channels:

- Dedicated Control CHannel (DCCH);

- Dedicated Traffic CHannel (DTCH).

These logical-channel types are described in two groups: Control Channels and Traffic Channels[19].

3.1.1 Control channels

BCCH - Broadcast Control Channel (DL)

The Broadcast Control CHannel (BCCH) is a downlink point-to-multipoint channel that is used to broadcast system and spot-specific information. The BCCH is always transmitted over the entire spot.

PCCH - Paging Control Channel (DL)

The Paging Control CHannel (PCCH) is a downlink channel that is used to carry control information to a mobile station when the system does not know the location spot of the mobile station. The PCCH is always transmitted over the entire spot.

RACH - Random Access Channel (UL)

The Random Access CHannel (RACH) is an uplink channel that is used to carry control information from a mobile station. The RACH may also carry short user packets. The RACH is always received from the entire spot.

CCCH - Common Control Channel

This channel type is Bi-directional type channel for transmitting control information between network and UEs. This channel is commonly used by the UEs having no RRC connection with the network and by the UEs using common transport channels when accessing a new spot after spot reselection.

DCCH - Dedicated Control Channel

A point-to-point bi-directional channel that transmits dedicated control information between a UE and the network. This channel is established through RRC connection set-up procedure.

3.1.2 Traffic channels

Traffic channels are used for the transfer of user plane information only.

DTCH - Dedicated Traffic Channel

A Dedicated Traffic CHannel (DTCH) is a point-to-point channel, dedicated to one UE, for the transfer of user information. A DTCH can exist in both uplink and downlink.

CTCH - Common Traffic Channel

A point-to-multipoint unidirectional channel for transfer of dedicated user information for all or a group of specified UEs.[9][20]

3.2 Link Budget & RF Area Calculations

The parameter types of Satellite – UMTS are similar with Terrestrial UTMS. However the values of the parameters differ regarding to the high speed data transfer traffic channels. In this chapter the properties of the link budget parameters and a sample link budget is described.

3.2.1 Cell link budget calculation

Link budget planning is part of the network planning process, using for dimensioning the required coverage, capacity and QoS requirement in the radio network. Since the mobiles power level is limited to 125mW for the voice terminal, UMTS and WCDMA macro cell coverage is uplink limited. Downlink direction limits the available capacity of the cell, as

BTS transmission power typically 20-40W, has to be divided to all users. Both coverage and capacity are interlinked by interference in a network environment. So, by improving one side of the equation would decrease the other side. This makes a tradeoff between different service values for the radio network environment. System is loosely balanced by design. The object of the link budget design is to calculate maximum cell size under given criteria:

- Type of service like data type and speed.

- Type of environment like terrain, building penetration.

- Behavior and type of mobile in speed and max power level.

- System configuration by adjusting BTS antennas, BTS power, cable losses, and handover gain.

- Required coverage probability

- Financial and economical factors by the decision between using of more expensive and better quality equipment or without using the cheapest installation method.
- Match all of those to the required system coverage, capacity and quality needs with each area and service.

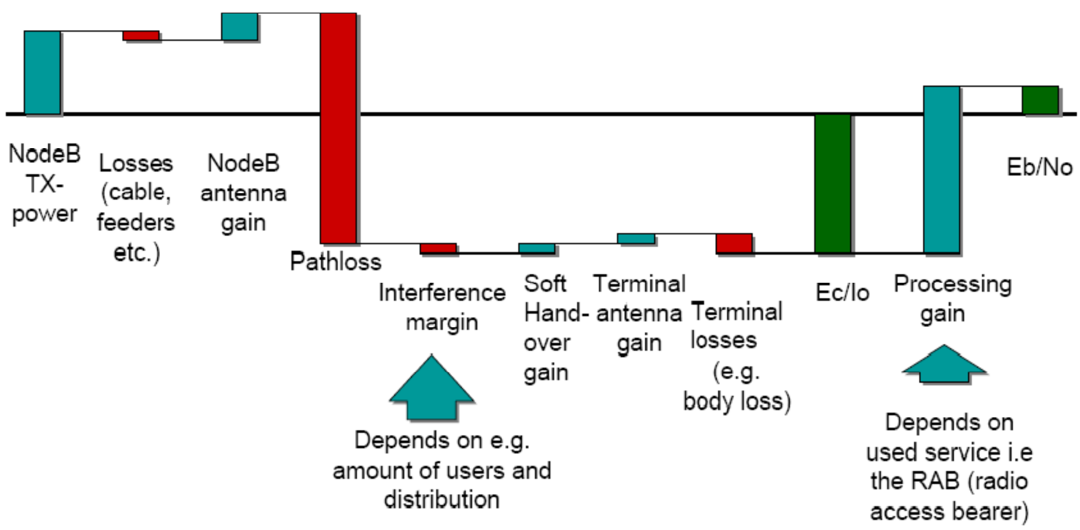

Figure 3.1 : WCDMA cell link budget

In an urban area, capacity will be the limiting factor, so inner city cells will be dimensioned by required Erlangs/km² for voice and data. Even using 25dB as in-building penetration loss into the building core area, link budget would typically allow about 300m cell range, which is a way too much for a capacity purposes. In a rural area uplink power budget will determine the maximum cell range, when typically cells are less congested. A typical cell range in rural areas will be several kilometers depending on a terrain.

A link budget is made in order to find the cell range for different environments. The link budget gives the MAPL (Maximum Allowed Path Loss) in order to meet the requirements for that environment. So the cell range could then found by a simple calculation order after determining MAPL with an acceptable value. As seen in the Figure 3.1, link budget change is a kind of tradeoff impacted by the amount of users, distributions and the used services like RAB (Radio Access Bearer).

For UMTS, link budget calculations have the key factor on determining the network capacity. Due to difference in E_b/N_o requirement, processing gain and receiver sensitivity for each user, the calculated path loss and cell size differ for each user. In WCDMA the node band UE also need to use more power for the demanding users, especially if connecting from a distance for the large path loss.

For the GSM case one user consumes all the available power in the base station during a timeslot. However, in UMTS case, one user consumes the power it requires in order to keep the connection. The available power in UMTS is shared between different users in the downlink.

Table 3.1 : Link budget 384kbps sample data

Characteristics	Parameters	384 kbps data, DL value	384 kbps data, UL value
Target Load		0.75	0.5
Transmitter characteristics	Total transmitter power	20 W	0.25 W
	Transmitter power on TCH	5.666667 W 37.53328 dBm	0.25 W 23.9794 dBm
	TX antenna gain	17.42531 dBi	0 dBi
	TX cable loss	2 dB	0 dB
	TX body loss	0 dB	0 dB
	Transmitter EIRP	52.95858 dBm	23.9794 dBm
Receiver characteristics	RX antenna gain	0 dBi	17.42531 dBi
	Thermal noise density	-174 dBm/Hz	-174 dBm/Hz
	Receiver noise figure	8 dB	5 dB
	Receiver noise density	-166 dB	-169 dB
	Receiver noise power	-100.157 dBm	-103.157 dBm
	Processing gain	10 dB	10 dB
	Required Eb/No	7 dB	3 dB
	Interference margin	6.0206 dB	3.0103 dB
	Required signal power	-97.136 dBm	-107.146 dBm

RX cable loss	0 dB	2 dB
RX body loss	0 dB	0 dB
Diversity gain	0 dB	3 dB
Fast fading margin	0 dB	4 dB
Soft handover gain	1 dB	2 dB
Coverage probability	0.9	0.9
Shadow fading std deviation	6 dB	6 dB
Shadow fading margin	7.5 dB	7.5 dB
Indoor penetration loss	0 dB	0 dB
Allowed propagation loss	143.5947 dB	140.0511 dB

As seen in the Table 3.1 the limiting tradeoff factors are the transmitter EIRP and the allowed propagation loss. After the path loss estimation the boundaries of the cell can be calculated by using the allowed propagation loss as described in the following section. The link budget values are mostly operator dependent. They are set by the radio network planers depending on the radio characteristics of the coverage area. [12]

3.2.1.1 Path loss calculation method

The general pathloss calculation formula is shown in the equation (3.1). All other pathloss calculation models are derived from this equation:

$$P_r = P_t K \left[\frac{d_o}{d}\right]^{\gamma} \quad \textbf{(3.1)}$$

$$PL = K(dBm) - 10\gamma \log_{10}\left[\frac{d_o}{d}\right] \quad \textbf{(3.2)}$$

Where, $PL = P_r - P_t$, and d_o is the reference antenna for far field distance. The following formula gives the unitless constant K:

$$KdB = 20\log_{10}\frac{\delta}{4\pi d_o}. \quad \textbf{(3.3)}$$

γ is the pathloss exponent which varies from 3.7 and 6.5 for urban macro cells and 2.7 and 3.5 for urban microcells depending on different environment. In case of indoor cell, γ has the ranges between 2 and 6. The different values of γ is set in the following pathloss models. Since the propagation environment is so complex that for a network RF calculation, it is difficult to calculate with the real data. So the propagation approximation models are developed.[10][11].

3.2.1.2 Hata-Okumura model

After the measurements are taken from base station and mobile station in 1968 in Tokyo by Okumura, he introduced empirical plots. Later, Hata developed a model similar with Omura's expression which is called "Okumura-Hata" model. Today, Okumura – Hata model is the most common model used in wireless networks especially in UMTS network with some modifications. The initial model was suitable for the frequency rate 500-1500 MHz. In addition the receiver distance is greater than from the transmitter base station antenna which has the minimum height of 30m. The analytical model is shown in the following equation (3.4):

$$PL(urban) = 69.55 + 26.16\log_{10}(f_c) - 13.82\log_{10}(h_t) - C_H + [44.9 - 6.55\log_{10} h_t]\log_{10}(d) \quad \textbf{(3.4)}$$

where C_H is the antenna height correction given the following values for the small and medium sized city:

$$C_H = 0.8 + (1.1\log_{10} f_{c-0.7})h_m - 1.56\log_{10} f_c, \quad \textbf{(3.5)}$$

and for large cities,

$$C_H = \begin{cases} 8.29(\log_{10}(1.54h_m))^2 - 1.1, & 150 \le f_c \le 200 \\ 3.2(\log_{10}(1.75h_m))^2 - 4.97, & 200 \le f_c \le 1500 \end{cases} \quad \textbf{(3.6)}$$

$h_m = h_t$ is the height of the mobile station. For the suburban areas it is modified as follows:

$$PL(suburban) = P(urban) - 2\left(\log_{10}\frac{f_c}{28}\right)^2 - 5.4 \quad \textbf{(3.7)}$$

Hata-Okumura model has the asset that the BS is placed higher than the rooftops and the cells are large. The initial form of Okumura-Hata model stated above is preferred for the first generation systems that have low frequencies with larger cells. For the higher generation wireless networks that have smaller cell size and operating at higher frequencies an extension is developed for the Okumura-Hata model. [10]

3.2.1.3 COST-231 Walfish-Ikegami model

Hata-Okumura path loss model is extended for the large and macro cells that have higher carrier frequencies up to 2 GHz by COST (The European Cooperative for Scientific and Technical). The main COST-231 model has the following equation:

$$\mathrm{PL} = 46.3 + 33.9\log_{10}\mathrm{f_c} - 13.82\log_{10}\mathrm{h_t} - \mathrm{C_H} + [44.9 - 6.55\log_{10}\mathrm{h_t}]\log_{10}\mathrm{d} + \mathrm{C}$$
(3.8)

where C equals to 0 dB for medium cities and suburban areas. For the metropolitan areas it is 3 dB. C_H is the antenna correction which is same as in Hata-Okumura model. The restrictions of this model are the base station height between 30 and 300 m the mobile height around 1 and 10 m the carrier frequency between 1.5 and 2 GHz. Since this model is restricted with large or macro cells, there was still a need for micro and small macro cells which has diameter between 0.02 and 5 Km. For this purpose the group of COST-231 introduce a new model. The restrictions are developed for the frequencies between 800 and 2000 MHz and the base station height between 4 and 50 m. With this model two formulas introduced for LOS and NLOS for $d \geq 0.02$ km:

$$PL = 42.6 + 26\log_{10}(d) + 20\log_{10}(f_c), \quad \textbf{(3.9)}$$

For the NLOS, new loss of signal values added: L_o: free space pathloss, L_{msd}multi screen loss, L_{rts} last roof top loss.

$$PL = L_o + \max(0, L_{rts} + L_{msd}), \quad \textbf{(3.10)}$$

where L_o is calculated as:

$$L_o = 32.4 + 20\,log_{10}\,d + 20\,log_{10}\,f_c. \quad \textbf{(3.11)}$$

L_{rts} requires the width of the street, and the difference between the building height and the height of the mobile station. L_{msd} requires the difference between height of the base station and roof top level. For this case, if the antenna height is less than the rooftop levels, then the performance of this model is not acceptable [10].

3.2.2 UMTS traffic dimensioning

Traffic dimensioning is an important issue for the wireless network extension operation plan. The key factors like terminal penetration for both 2G and 3G, operator market share, subscriber prediction, amount of roamers, user profiles and the service usage per profile are some of the determinants for the network extension. Due to CDMA-characteristics and multi-service nature of WCDMA, without accurate traffic modeling and predictions, the capacity and coverage of the network is difficult to plan. The modeling can be based on the knowledge of GSM/GPRS and internet usage patterns as well as on assumptions of service usage. Predicting the amount of usage and usage locations, is of high importance, because of the fluctuating nature of the traffic simulations with various traffic scenarios needed. User scenarios and profiles should be created together with business planning and should support the selected strategy in the dimensioning.

$$M \approx \frac{n_{subs} n_{pages} Y}{3600 R_{peak} \tau_{session}} = \frac{A_{bps}}{R_{peak} \tau_{session}} \quad \textbf{(3.12)}$$

Equation (3.12) is the traffic calculation formula for the interactive class. In the calculation M is the amount of active users, n_{subs} is the number of subscribers, n_{pages} is the amount of web pages to be downloaded per subscriber, Y is the payload and A_{bps} is the offered traffic. For the maximum RAB bit rateR_{peak}, and for the session efficiency involved overhead and retransmission, $\tau_{session}$ is used.

Supported number of subscriber which is interpreted as network capacity is divided in terms of uplink and downlink that is called Uplink/Downlink Npole. For the uplink case, Npole is the theoretical limit for the number of UEs that a cell can support. At this limit the interference level in the system is infinite and thus the coverage reduced to zero.

$$N_{pole} = \frac{1}{\vartheta(1+i)} \cdot \left(1 + \frac{W}{\frac{E_b}{N_o} R_j}\right) \quad \textbf{(3.13)}$$

$$M_{pole,Uplink} = \left(\frac{1}{1+F}\right)\left(1+\frac{1}{\gamma}\right) \quad \textbf{(3.14)}$$

$$M_{pole,Downlink} = \frac{1}{\gamma(\alpha+F)\left[1+\sum_{b=1}^{AS} \frac{SHO^{(b)}\left(b-1-\Delta^{(b)}\right)}{1+\Delta^{(b)}}\right]} \cdot (1 + G_{dtx}) \quad \textbf{(3.15)}$$

For both uplink and downlink cases γ is the C/I target for the RAB in the linear scale. α is the orthogonality factor of the cell. F is the inter cell interference factor. SHO is the fraction of users that are in soft/softer handover. b is the number of BSs in soft handover. Δ is the system average of soft handover gain. And G_{dtx} is the DTX gain for the DTX enabled systems. [1]

3.2.3 Signal interference ratio

Signal to interference ratio (SIR) is defined as the ratio of the signal power and the total interference power received at the Node B or the satellite spot. The general SIR formula is as follow:

$$SIR = \frac{Signal\ Power}{Total\ Interference\ Power} \quad \textbf{(3.16)}$$

The equation can be extended with the following parameters:

$$SIR = \left(\frac{E_b}{N_b}\right)_j = SF.\frac{P_j}{I_{total} - P_j} = \frac{P_j}{I_{inter} + I_{intra} + P_n} \quad \textbf{(3.17)}$$

For the SIR calculation stated in the equation (15), $P_j$is the received signal power of the user j at Node B or spot. I_{inter} is the interference caused by the intercellular communication. I_{intra} is the interference caused by the intra cellular communication. P_n is the thermal noise which is assumed to be -99 dBm in the downlink and -103 dBm in the uplink for the terrestrial UMTS. And *SF* is the spreading factor which can be calculated as follows [13]:

$$Spreading\ Factor\ (SF\ Processing\ Gain) = \frac{Carrier\ Bandwith}{Information\ Rate} = \frac{Chip\ Rate}{Data\ Rate} = \frac{W}{R} \quad \textbf{(3.18)}$$

Solving for P_j yields:

$$\frac{P_j}{I_{total} - P_j} = \left(\frac{E_b}{N_b}\right)_j \frac{R_j}{W} \quad \textbf{(3.19)}$$

$$P_j = \frac{I_{total}\left(\frac{E_b}{N_b}\right)_j \frac{R_j}{W}}{1 + \left(\frac{E_b}{N_b}\right)_j \frac{R_j}{W}} => P_j = \frac{I_{total}}{1 + \left(\frac{E_b}{N_b}\right)_j \frac{W}{R_j}} = L_j I_{total} \quad \textbf{(3.20)}$$

In determining the interference, system signal quality differs whether if it is in uplink or downlink direction. In the uplink case the target power level at cell or spot is constant and same between different BSs providing service to same coverage areas. In the downlink case, the total transmission power BS is constant and the same between BSs. A BS allocates its transmission power so that all MSs or UEs in the cell or spot have the same SIR. As a result all UEs in a cell or spot have the same Uplink SIR and the same downlink SIR. The uplink and downlink SIR become different between BSs due to the non-uniformity in traffic. [14]

For the uplink case the interference calculation is also used for determining the loading factor for the system dimensioning. I_{total} includes the other users in the cell (N) and the thermal noise can be written as:

$$I_{total} = \sum_{j=1}^{N} L_j I_{total} + P_n \qquad \textbf{(3.21)}$$

All the users in the cell will cause the received power to rise over the unloaded received power like thermal noise. This rise is normally referred to as the noise rise in the cell. This is shown as follows:

$$\frac{I_{total}}{P_n} = \frac{I_{total}}{I_{total} - \sum_{j=1}^{N} L_j I_{total}} = \frac{I_{total}}{I_{total}\left(1 - \sum_{j=1}^{N} L_j\right)} = \frac{1}{1 - \sum_{j=1}^{N} L_j} = \frac{1}{1 - \rho_{UL}} \qquad \textbf{(3.22)}$$

For the equation (3.20) the parameter $\rho_{UL}$is normally referred to as the loading factor. As stated in the equation, the loading capacity of the cell is directly related with the uplink interference produced by the UEs and other interferers. The variation rates are shown in the Figure 3.2. [1]

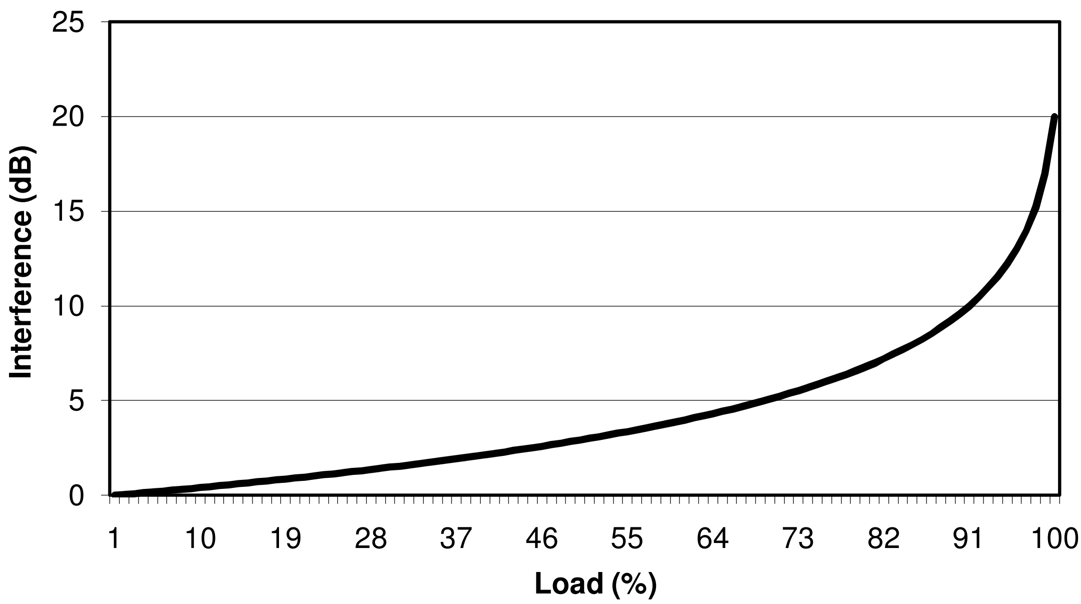

Figure 3.2 : Interference in uplink with the variation of load factor

3.2.4 Spot link budget calculation

For the satellite communication a simple link budget has to be computed for a single link corresponding to the worst case in order to use the radiated power sufficiently. For the worst case a user is affected by propagation impairments is considered. The general formula for the link budget calculation is as follows:

$$\frac{C}{N_o} = P_T G_T \frac{1}{L} \frac{G_R}{T} \frac{1}{k} \quad \textbf{(3.23)}$$

In the equation (3.21), $\frac{C}{N_o}$ is the useful signal to spectral density noise power ratio in dBHz unit. $P_T G_T$is the transmitter EIRP of the transmitter in dBW unit. In the EIRP P_T is the power of the carrier at emission, and the G_T is the antenna gain of the transmitter. $\frac{1}{L}$ corresponds to the path losses like free space loss and the propagation loss in dB unit. In the equations (1),(2) and (3) the parameter L can be calculated for the satellite path loss. $\frac{G_R}{T}$ is the receiver figure of merit in dB/K unit. In the receiver figure $G_R$is the antenna gain of the receiver and T is the system temperature at receiver level.

The computation of the link budget includes both the link between gateway and the satellite, and the link between the satellite and the user equipment. So the total signal to noise spectral density is obtained from the following two links:

$$\left(\frac{C}{N_o}\right)_{Total}^{-1} = \left(\frac{C}{N_o}\right)_{Up}^{-1} + \left(\frac{C}{N_o}\right)_{Down}^{-1} \quad \textbf{(3.24)}$$

$\left(\frac{C}{N_o}\right)_{Total}^{-1}$ is the last total useful signal to spectral density noise power ratio. $\left(\frac{C}{N_o}\right)_{Up}^{-1}$ is the uplink useful signal to spectral density noise power ratio and $\left(\frac{C}{N_o}\right)_{Down}^{-1}$ is the downlink useful signal to spectral noise density power ratio. [15]

For the link budget calculation if the Ka-Band is used, then high interfering signals can affect the transmission links depending on the user locations. Depending on the air conditions the power fade due to atmospheric effects and propagation phenomena can reach tens of decibels like the case, rain event occurs. In addition depending on the satellite spot different antenna gain between the centre and the end of the coverage can reach several decibels.

As seen in the link budget equation (3.21) noise is a factor used in extract the power level from $\frac{C}{N_o}$. In the link, there are lots of noise generator like frequency converter, and power amplifier. In most cases, this noise is sufficiently small compared to signal power and is negligible compared with other noise sources. Thermal noise from ground received by satellite antenna often at 300K, thermal noise generated by the satellite transponder and governed by the low-noise performance of the transponder’s first stage, noise received by the ground antenna in addition to the signal from the

satellite, includes sky noise, atmospheric thermal noise, terrestrial thermal noise, and the thermal noise generated by the ground receiver and governed by the low noise performance of the first-stage amplifier, are some of the noise effects.

Antenna gain is the other characteristic parameter of the link budget. As a definition, the ratio of power radiated per unit solid angle by an actual antenna in a given direction to the power radiated per unit solid angle in the same direction by a reference antenna. On this case if the reference antenna is an isotropic antenna then it is denoted by dBi. Antenna gain is usually taken to mean gain in the direction of maximum radiation if the antenna bean direction is not specified. The general antenna gain formula is as follows:

$$G = \rho \left(\frac{\pi D}{\tau}\right)^2 \quad \textbf{(3.25)}$$

In the equation (3.23), ρ is the aperture efficiency which is between the values 50-70%. D is the antenna diameter and τ is the wavelength. In the logarithmic form the equation is expressed as:

$$[G] = 10 \log(110 \rho f^2 D^2) \quad \textbf{(3.26)}$$

A receive antenna receives noise radio wave in addition to the desired signal. Thermal loss of the antenna will be output as thermal noise. Noise presents a problem in the reception of weak signals as in satellite communications. Noise power is expressed as absolute temperature, Ts. It consists of cosmic noise, noise from lighting, and thermal noise based on atmospheric absorption. Antenna thermal noise: (1-η)T_o, η is antenna radiation efficiency and T_o is ambient temperature. Antenna noise is expressed as:

$$T_a = T_s + (1 - \eta) T_o \quad \textbf{(3.27)}$$

This is called the antenna’s equivalent noise temperature. A major contribution to antenna noise T_a is made by thermal noise from antenna side lobes pointed toward the ground. Efforts are therefore made to reduce side-lobe levels so as to reduce overall noise. [16]

3.3 Power Control Algorithms

3.3.1 GSM power control algorithm

Power control is the algorithm used in wireless communications in order to balance the power, dynamically with the feedback taken by the measurements of received power both from MS and the BTS. Power classes shown in Table 3.2, are used for classification of base stations and MS (Mobile station). The transmission power can also be controlled adaptively. As part of the radio subsystem link control, the MS's transmitter power is controlled in steps of 2dBm.

The GSM transmitter power control has the purpose of limiting the MS's transmitter power to the minimum necessary level, in such a way that the base station receives signals from different MSs at approximately the same power level. For this purpose, sixteen power control steps are defined: step 0 (43 dBm = 20W) to step 15 (13 dBm). Starting with the lowest, step 15, base station can increment the transmitter power of the MS in steps of 2 dBm up to maximum power level of the respective power class of the MS. Similarly, the transmitter power of the base station can be controlled in steps of 2 dBm, with the exception of the BCCH (Broadcast Control Channel) carrier of the base station, which must remain constant to allow comparative measurements of neighboring BCCH carriers by the MSs [7].

Table 3.2 : GSM power classes

Power class	Maximum peak transmission power (W)	
	Mobile station (dBm)	Base station
1	20(43)	320
2	<8(39)	160
3	<5(37)	80
4	<2(33)	40
5	<0,8(29)	20
6	-	10
7	-	5
8	-	2,5

RXLEV and RXQUAL measurement values are used to form transmission power control, and they are defined for the upper and lower thresholds for uplink downlink as seen in the Table 3.3. The adjustable parameters P and N are defined by the Network Management. If the values of P for the last N calculated mean values of the respective criterion (RXLEV or

RXQUAL) are above or below the respective threshold value, the BSS can adjust the transmitter power.

Table 3.3 : Thresholds for transmission power control

Threshold Parameter	Typical value(dBm)	Meaning
L_RXLEV_UL_P	from -103 to -73	Threshold for raising of transmission power in uplink or downlink
L_RXLEV_DL_P	from -103 to -73	
L_RXQUAL_UL_P	-	
L_RXQUAL_DL_P	-	
U_RXLEV_UL_P	-	Threshold for reducing of transmission power in uplink or downlink
U_RXLEV_DL_P	-	
U_RXQUAL_UL_P	-	
U_RXQUAL_DL_P	-	

The transmission power of the MS is reduced if the thresholds U_xx_UL_P of the uplink are exceeded. In the other case, if the signal level is below the threshold L_xx_UL_P, the MS is ordered to increase its transmitter power. When the criteria for the downlink are exceeded in either direction, in an analogous way, the transmitter power of the base station can be adjusted.

Even if the MS or base station signal levels stay within the thresholds, the current RXLEV/RXQUAL values can cause a change to another channel of the same or another cell based on the handover thresholds. For this reason, checking for transmitter thresholds is immediately followed by a check of the handover thresholds as the second part of the radio subsystem link control. If one of the threshold values is exceeded in either direction and the transmitter power cannot be adjusted accordingly the respective transmitter power has reached its maximum or minimum value, this is an overriding cause for handover which the BSS must communicate immediately to the MSC. The power control algorithm flow chart is seen on Figure 3.3[7].

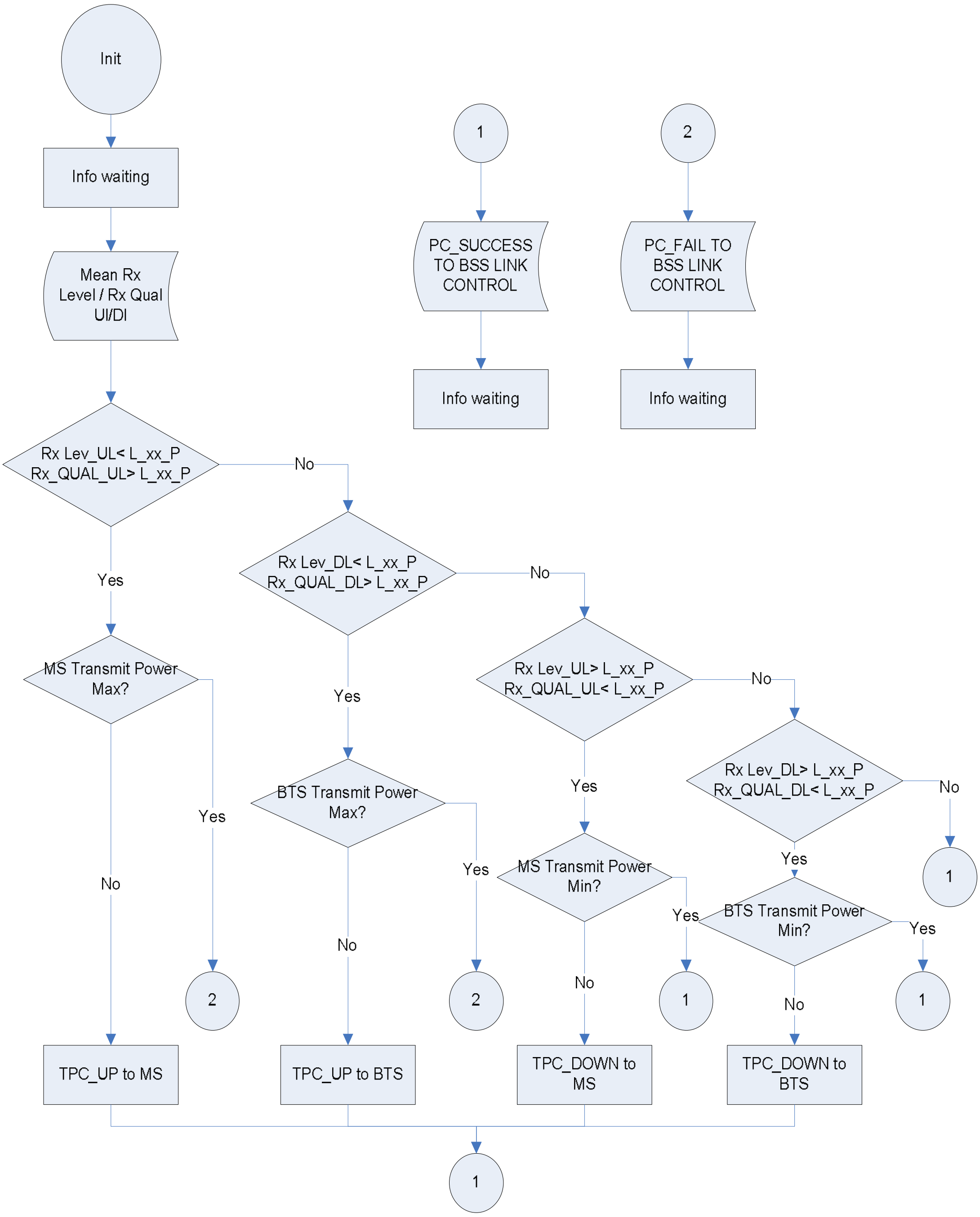

Figure 3.3 : Schematic operation of transmit power control

3.3.2 UMTS power control algorithm

UMTS power control is similar with the PC applied to GSM networks. There are two optional algorithms: Algorithm 1 and Algorithm 2. For the Algorithm 1, the UE receives only one TPC (Transmit Power Control) command for each radio slot. In this case the value of TPC_cmd varies between the values 1 and -1. If the received TPC command is equal to 0, then the value of TPC_cmd is -1. If the received TPC command is equal to 1, then the value of TPC_cmd is 1. In the case of situation that the radio links are in the same radio link set, the UE has the knowledge that some of the transmitted TPC commands in a TPC command combining period are the same. For these cases, the TPC commands from the same radio link set in the same TPC command combining period shall be combined into one TPC command, to be further combined with other TPC commands as described in the following Algorithm 2.

Table 3.4 : Transmitter power control range

TPC_cmd	Transmitter Power Control Range (dB)					
	1 dB step size		2 dB step size		3 dB step size	
	Lower	Upper	Lower	Upper	Lower	Upper
1	0,5	1,5	1	3	1,5	4,5
0	-0,5	0,5	-0,5	0,5	-0,5	0,5
-1	-0,5	-1,5	-1	-3	-1,5	-4,5

For the PC algorithm, Algorithm 2, the received commands are collected in a buffer and then they are processed to decide the next TPC_cmd. This process makes it possible to generate smaller step sizes than the minimum Power Control step size. If all five estimated TPC command are "down" the transmit power is reduced by 1 dB. If all five estimated TPC command are "up" the transmit power is increased by 1 dB. Otherwise the transmit power is not changed. [8]

The UMTS power control algorithm is shown in Figure 3.3 with the combination of the power loops stated in the following chapter.

3.3.3 Power control loops

There are two main loops used for power control: Open Loop Power Control, Closed Loop Power Control. Open loop power control is the ability of the UE transmitter to sets its output power to a specific value. It is used for setting initial uplink and downlink transmission powers when a UE is accessing the network. The open loop power control tolerance is ± 9 dB (normal conditions) or ± 12 dB (extreme conditions).
Inner loop power control (also called fast closed loop power control) in the uplink is the ability of the UE transmitter to adjust its output power in accordance with one or more Transmit Power Control (TPC) commands received in the downlink, in order to keep the received uplink Signal-to-Interference Ratio (SIR) at a given SIR target. The UE transmitter is capable of changing the output power with a step size of 1, 2 and 3 dB, in the slot immediately after the TPC_cmd can be derived. Inner loop power control frequency is

1500Hz. The serving cells estimate SIR of the received uplink DPCH (Downlink Physical Channel) which is used to carry DPCCH (Dedicated Physical Control Channel) and DPDCH (Dedicated Physical Data Channel), generate TPC commands (TPC_cmd) and transmit the commands once per slot according to the following rule: if $SIR_{est} > SIR_{target}$ then the TPC command to transmit is "0", while if $SIR_{est} < SIR_{target}$ then the TPC command to transmit is "1". Upon reception of one or more TPC commands in a slot, the UE derives a single TPC command for each slot, combining multiple TPC commands if more than one is received in a slot. Two algorithms are supported by the UE for deriving a TPC_cmd. The used one of these two algorithms is used, is determined by a UE-specific higher-layer parameters.

Network determines the transmit power of the downlink channel. The power control step size can take four values: 0.5, 1, 1.5 or 2 dB. It is mandatory for UTRAN to support step size of 1 dB, while support of other step sizes is optional. In order to control the network transmit power, UE generates TPC commands, and send them in the TPC field of the uplink DPCCH. After receiving the TPC commands UTRAN adjusts its downlink DPCCH (Dedicated Physical Control Channel), the physical channel on which the signaling is transmitted and DPDCH (Dedicated Physical Data Channel) which the payload as well as the higher layer signaling is transmitted both on the uplink by UE to the Node B and on the downlink by Node B on the UE, power accordingly.

In order to remain the quality of communication at the level of bearer service quality requirement while using as low power as possible, outer loop power control is used. Setting a target SIR in the Node B for each individual uplink inner loop power control is the responsibility of the uplink outer loop power control. According to the estimated uplink quality, this target SIR is updated for each UE (Block Error Rate, Bit Error Ratio) and for each Radio Resource Control connection. With the downlink outer loop power control the UE is able to updating of target SIR required link quality (BLER) set by the network (RNC) in downlink according to different network signal level conditions.

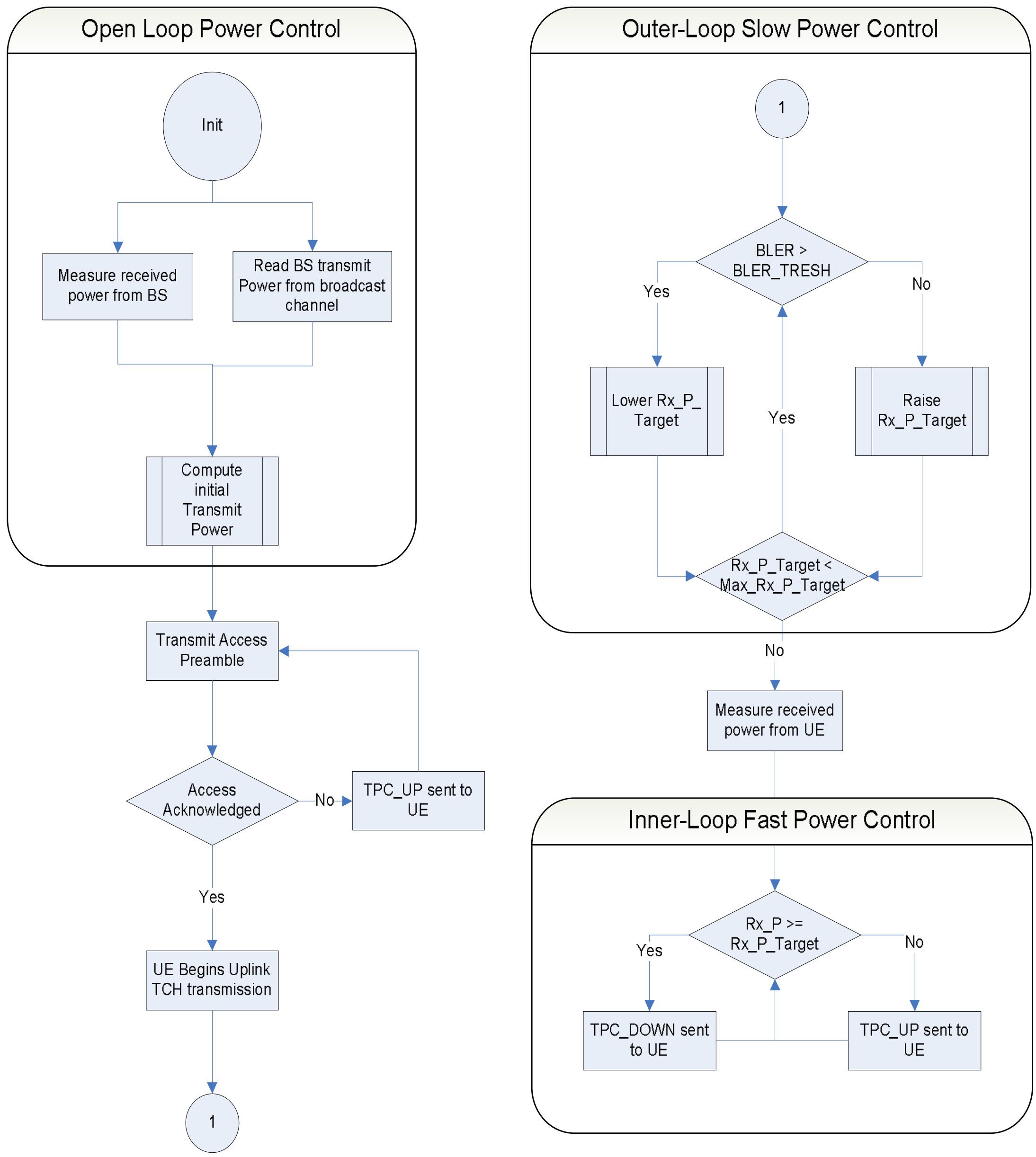

Figure 3.4 : UMTS power control algorithm

One of an important issue is a transmission delay for the satellite communication which is regardless from UE movement characteristic. The delay differs regarding to the satellite constellation. For the GEO satellite the round-trip delay ranging from 250 ms to 280 ms, and 110ms to 130 ms for MEO, and for the LEO constellation 20 ms to 25 ms. It is obvious that in comparison with T-UMTS the propagation delay is higher in S-UMTS, and the capacity is lower due to high frequency consumption in unit coverage area. TCP is used for the transmission control. For such high transmission delays produced by the satellite environment, the effectiveness of TCP is degraded. [6]

3.4 Handover Algorithms

3.4.1 Intra-frequency handover

3.4.1.1 Soft handover

Soft handover is applicable in case of either Intra-satellite spots coverage overlapping for single satellite systems, or inter-satellite spots coverage overlapping for multi satellites system. For the active mode, the UE searches for new spots on the current carrier frequency continuously. This searching process continues with the same way of the initial spot search. The most significant difference compared to the initial spot search is that a UE station gathers a kind of scrambling codes priority list prepared by the network Radio Resource Control. This priority list describes in which order the downlink scrambling codes should be searched for and does thus significantly reduce the time and effort needed for the scrambling-code search. When the neighborhoods of UE are changed the scrambling code priority list is updated regarding of this change.

During the search, the UE measures the received signal level broadcast from neighboring spot, compares them to a set of thresholds, and reports them accordingly back to the gateway which is directly connected to Node B and indirectly connected to the RNC. After the information is gathered from the link measurements the priority list *active set* is updated by the UE station. The *active set* is defined as the set of spots from which the same user information is sent, simultaneously demodulated and coherently combined.

The UE knows the frame offset of the CCPCH of potential soft-handover candidates relative to that of the source spots which are exist in the active set, from the spot-search procedure. This offset together with the frame offset between the DPDCH/DPCCH and the primary CCPCH of the source spot, is used in the calculation of the required frame offset between the DPDCH/DPCCH and the primary CCPCH of the destination spot that is added to the active set when a soft handover is about to occur.

3.4.1.2 Softer handover

Softer handover is the special case of a soft handover between sectors/spots belonging to the same gateway (Node B) site. Conceptually, a softer handover is initiated and executed in the same way as an ordinary soft handover. The main differences are on the implementation level within the network. For softer handover, it is more feasible to do uplink maximum-ratio combining instead of selection combining as the combining is done on the Node B level rather than on the RNC level.

3.4.2 Inter frequency handover

In S-UMTS most of the handovers are performed with using one carrier frequency as in intra-frequency handover. Inter-frequency handover may typically occur when the handover between spots to which different number of carriers have been allocated due to different capacity requirements like hot-spot scenarios. For the handover between spots of different overlapping orthogonal spot layers using different carrier frequencies, the inter frequency handover is used. For the handover between different operators and systems using different carrier frequencies including handover to terrestrial UMTS or GSM system, again the inter frequency system is used.

A key requirement for the support of seamless inter-frequency handover is the possibility for the UE to carry out spot search on a carrier frequency different from the current one. In this process not to affect the ordinary data flow is an important issue.

4. PC ALGORITHMS ON S/T-UMTS

4.1 Objectives

For S-UMTS, power control must necessarily be implemented in order not to waste precious power and system capacity, although the near–far effect in S-UMTS is not as bad as for T-UMTS. Slow (tractable) power-level variations are due to different causes such as satellite motion (path-loss changes), satellite and user antenna gain variations, shadowing, user speed changes, and time-varying co-channel interference. As in T-UMTS, a combination of open-loop for random-access channels and closed-loop power control for connection-oriented channels are required. Closed-loop power control is slower and less responsive to fast dynamics as compared to T-UMTS due to the longer satellite propagation delay, so its design is critical. Some adaptations are implemented on closed loop power control especially in the inner loop power control.

Closed-loop power control is based on two loops working relatively to maintain the desired FER. The inner loop is used to adjust the channel SNIR computed after rake combing and interference mitigation (if applicable) to the target SNIR, which is needed to achieve the target FER. The target SNIR depends on the user bit rate, propagation environment, path diversity, and user speed conditions, all of which change dynamically. Therefore, an outer loop is needed to adapt the target SNIR to match the measured FER to the target FER. However, to compensate with the increased propagation delay in satellite links, algorithm modifications are required in terms of optimization of power control command processing and sending rate, for SNIR estimation, and the operation of mechanization of the inner loop.

The power control sending rate should be reduced to one per frame or several frames as opposed to one per slot, as used in T-UMTS due to the high propagation delay on satellite. Without affecting the frame structure regularity, this regulation avoids oversampling and possible loop instabilities. Another important point is to keep memory of the last power control commands sent, but not yet received because of propagation delay, before deciding for a new power control command. In this way, power-control tracking of slow variations becomes rather insensitive to the satellite orbital height. Clearly, waiting for final decisions would increase the loop delay, but this could be acceptable in MEO/GEO S-UMTS systems where propagation delays might be larger than decoding delay. However, for the networks that have high signal level variations like LEO orbits, increasing the loop delay might results with destructive effects on signal levels and rising the drop rates.

4.2 UMTS PC Algorithms

As stated in chapter 3, 2 kinds of power control algorithm is used in UMTS RRM. According to different air interface properties, Algorithm 2 is adapted for S-UMTS. Especially for LEO S-UMTS networks a new adaptive power control algorithm is designed which is used for changing the transmit power control command sending and processing frequency dynamically and adaptively to the air interface conditions.

4.2.1 PC algorithm 1

Signal to interference ratio is estimated as SIR_{est} from the received uplink DPCH. Then the TPC commands are generated and transmited once per slot according to the following rule: if $SIR_{est} > SIR_{target}$ then the TPC command to transmit is "0", while if $SIR_{est} < SIR_{target}$ then the TPC command to transmit is "1".

TPC_cmd is the parameter used in the power control algorithm which shows the periodic decision of the system. The UE shall add together the values of TPC_cmd derived from each TPC command combining period in which a TPC command is presented. Two algorithms shall be supported by the UE for deriving a TPC_cmd. These two algorithms are determined by a UE-specific higher-layer parameter, "PowerControlAlgorithm", and is under the control of the UTRAN for T-UMTS and it is under the control of USRAN for S-UMTS. If "PowerControlAlgorithm" indicates "algorithm1", then the layer 1 parameter PCA (Power Control Algorithm) takes the value 1 and if "PowerControlAlgorithm" indicates "algorithm2" then PCA takes the value 2.

The step size Δ_{TPC} is a layer 1 parameter which is derived from the UE-specific higher-layer parameter "TPC-StepSize" and, it is under the control of the UTRAN. If "TPC-StepSize" has the value "dB1", then the layer 1 parameter Δ_{TPC} shall take the value 1 dB and if "TPC-StepSize" has the value "dB2", then Δ_{TPC} shall take the value 2 dB. The parameter "TPC-StepSize" only applies to Algorithm 1. For Algorithm 2, Δ_{TPC} shall always take the value 1 dB. After deriving of the combined TPC command TPC_cmd using one of the two supported algorithms, the UE shall adjust the transmit power of the uplink DPCCH with a step of Δ_{DPCCH} (in dB) which is shown as:

$$\Delta_{DPCCH} = \Delta_{TPC}\ x\ TPC\_cmd \qquad \textbf{(4.1)}$$

Algorithm 1 states that when a UE is not in soft handover, only one TPC command will be received in each slot in which a TPC command is known to be present. In this case, the value of TPC_cmd shall be derived as follows [17]:

- If the received TPC command is equal to 0 then TPC_cmd for that slot is –1.

- If the received TPC command is equal to 1, then TPC_cmd for that slot is 1.

4.2.2 PC algorithm 2

In some cases, the UE has the knowledge that some of the transmitted TPC commands in a TPC command combining period are the same. This is the case when the radio links are in the same radio link set. For these cases, the TPC commands from the same radio link set in the same TPC command combining period shall be combined into one TPC command, to be further combined with other TPC commands.

Algorithm 2 makes it possible to emulate smaller step sizes than the minimum power control step specified in the section 4.2.1, or to turn off uplink power control by transmitting an alternating series of TPC commands. When a UE is not in soft handover, only one TPC command will be received in each slot. In this case, the UE shall process received TPC commands on a 5-slot cycle, where the sets of 5 slots shall be aligned to the frame boundaries and there shall be no overlap between each set of 5 slots. Waiting for the sequential 5 time slots, causes to increase loop delay of power control. The value of TPC_cmd shall be derived by setting the first 4 slots of a set to 0 (TPC_cmd = 0). The UE uses hard decisions on each of the 5 received TPC commands for the fifth slot of a set as shown below:

- If all 5 hard decisions within a set are 1 then TPC_cmd = 1 in the 5th slot.
- If all 5 hard decisions within a set are 0 then TPC_cmd = -1 in the 5th slot.
- Otherwise, TPC_cmd = 0 in the 5th slot.

4.2.3 Combining of multiple TPC commands

Combining of multiple TPC commands is performed in two different cases. First is combination of TPC commands of same radio link set. Second is the combination of TPC commands of different radio link sets. Since the UE's have rake receivers which is used to receive information from different radio links at the same time, a UE may receive TPC commands from different links or link sets.

In some cases, the UE has the information of the TPC commands transmitted in a TPC command combining period. This is the case when the radio links are in the same radio link set. For these cases, the TPC commands from radio links of the same radio link set in the same TPC command combining period shall be combined into one TPC command, and is used to combine with different TPC commands in further cases.

If the combination operation will be performed with the TPC commands that are in the different radio link set, then the UE shall make a hard decision on the value of each TPC_i, where i = 1, 2, …, N and N is the number of TPC commands from radio links of different radio link sets which is the first phase of combination. N hard decisions are taken by the UE for each of the 5 TPC command combining periods in the 5 consecutive TPC combining periods.

For the sets of 5 TPC commands, there shall be no overlap between each set of 5 TPC command combining periods. For the first 4 TPC commands combining periods the value of TPC_cmd is zero. After 5 TPC commands combining periods have elapsed, the UE shall determine the value of TPC_cmd for the fifth TPC command combining period. The UE determines the TPC_temp which is a temporary TPC command.

- If all 5 hard decisions within a set are "1", TPC_temp_i = 1.
- If all 5 hard decisions within a set are "0", TPC_temp_i = -1.
- Otherwise, TPC_temp_i = 0.

After these temporary commands are collected, the UE derive a final TPC command which is TPC_cmd from the combination of TPC_temp_i. The combination operation is performed with the function γ that has TPC_temp_i as parameters.

$$TPC_{cmd}(Fifth\, TPC\ combining\ period) = (TPC_{temp_1}, TPC_{temp_2}, ..TPC\_temp_N) \quad \textbf{(4.2)}$$

On this equation TPC_{cmd}can take the values 0, 1 and -1. The function of γ can be in the following combinations [17]:

- $TPC_{cmd} = -1$ if TPC_{temp_i}= -1 for every $1<i<N$,
- Otherwise, $TPC\_cmd = 1$ if $\frac{1}{N}\sum_{i=1}^{N} TPC\_temp_i > 0.5$.
- Otherwise, $TPC\_cmd = 0$.

4.2.4 PC Mode algorithm for S-UMTS

4.2.4.1 DPC mode for T-UMTS

In T-UMTS, there are two DPC (Downlink Power Control) modes which determine the sending and processing frequency of the TPC commands. The DPC_MODE parameter indicates the DPC mode used by the UE. And also the parameter is under the control of UTRAN. The behavior of the system with different DPC_MODE parameters is as follows:

- if *DPC_MODE* = 0 : the UE sends a unique TPC command in each slot and the TPC command generated is transmitted in the first available TPC field in the uplink DPCCH. For that reason UE may delay transmitting generated TPC command to the next available TPC field
- if *DPC_MODE* = 1 : the UE repeats the same TPC command over 3 slots and the new TPC command is transmitted such that there is a new command at the beginning of the frame, unless UE_DTX_DRX_Enabled is TRUE, in which case the UE shall behave as for DPC_MODE=0.[17]

The flexibility in the slot format of radio channels for the TPC bits is being used for the DPC mode. The same DPC_mode parameter is used also in S-UMTS with some adaptations required due to different radio characteristics as stated in the following chapter.

4.2.4.2 DPC mode for S-UMTS

For S-UMTS it is recommended to reduce the number of TPC commands per frame in order to avoid over-sampling and loop instabilities due to propagation delay inherent to satellite systems. The flexibility of the radio time slot structure, allows to the system to configure the radio link so that TPC can be repeated over several slots or frames. In the standards, 3GPP sets two values: 0 (1 TPC per slot) or 1 (1 TPC repeated over 3 slots). It is proposed to extend this value to at least 15 slots, which means 1 TPC per frame up to several frames.

- If DPC_MODE = 0: the UE repeats the same TPC command over 1 frame which is equal to 15 radio slots.
- If DPC_MODE = 1: the UE repeats the same TPC command over 3 frames. So the new TPC command will arrive at the fourth radio frame.
- If DPC_MODE = 2: the UE repeats the same TPC command over 5 frames. So the new TPC command will arrive at the sixth radio frame.

In this thesis the values 3 and 4 for *DPC_Mode* is used with the frame separation 7 and 9 on the S-UMTS network simulation. Reduction of the TPC rate for avoiding power oscillations can be reached with that configuration. So the receiver process and sent only 1 command per frame or more depending on the DPC mode chosen. Capacity loss due to TPC overhead which is significant only for low data rate services, up to 10 % for downlink, can be reduced by adjusting power offset applied to TPC, configured by network radio resource control at link establishment.

4.2.4.3 Adaptive PC Mode Approach

Reduction of TPC commands in unit time causes an increase in power control loop delay. If the network has a rapid change characteristic in signal power level variations, then any decrease in PC command amount in unit time, results with increase in drop rates. The effect of this case is seen in Figure 1.3. Adaptive PC Mode approach is proposed to change the TPC sending and processing frequency dynamically with the network signal level behavior.

Adaptive PC Mode algorithm can be explained by considering two measurement of signal interference ratio taken at time t_1 and t_2 from the system.

0 ≤ DPC_mode ≤ 4, DPC_Mode = Default_DPC_Mode if $SIR_{meas}(t_2) - SIR_{meas}(t_1) < DPC_{Mode_{Change_{Delta}}}$, DPC_Mode = 0 (lowest order value) if $SIR_{meas}(t_2) - SIR_{meas}(t_1) > DPC\_Mode\_Change\_Delta$.

DPC_Mode is the mode chosen at time t_2. *Default_DPC_Mode* is the DPC Mode value chosen at t_2 if the delta of the SIR values taken at time t_1 and t_2 is less than $DPC\_Mode\_Change\_Delta$. $DPC\_Mode\_Change\_Delta$ is a kind of threshold determined by the system in order to set the system signal level characteristics.

The algorithm shows that if the signal level variations are higher than the delta threshold, the system dynamically changes the *DPC_Mode* value to the lowest order (0) such that with the new *DPC_Mode* value, the number of TPC commands generated in unit time is increased. So the system becomes more reactive and sensitive for the rapid changes in signal level. If the signal level changes are less, then the system, the system decides to change the *DPC_Mode* to the *Default_DPC_Mode*. So the system becomes less reactive and less sensitive for the low signal level variations. So the power control loop becomes more stable with less TPC commands in unit time. With that operation the tradeoff between the number of TPC commands and the system stability is provided.

5. SIMULATION DESCRIPTION

5.1 Simulation Objectives

As mentioned in the previous chapter, different signal level variations directly effects Quality of Service figures especially the drop rates of the system. For a satellite network, the characteristic differences of air interface are normally based on different orbit types. So the behavior of Radio Resource Management algorithms, have critical impact on the QoS figures at different orbit types. The main objective of this simulation is to measure the effect of different behaviors of the different type orbits in comparison with normal T-UMTS behavior on the network QoS.

Another significant objective is to test different power control algorithms applied on the T/S-UMTS networks. Especially PC Algorithm 2 and modified DPC_Mode is applied on the test bed. The new approach Adaptive DPC mode is used and the results are compared with ordinary DPC mode of the T-UMTS PC algorithm. With different input parameters the signal level variations are observed and drop rates are measured with simulation results. The simulator has a dynamic structure that includes traffic and mobility models. Testing different RRM algorithms requires accurate modeling of UMTS and satellite link performance.

In conclusion, the adaptation recommendations of RRM algorithms to S-UMTS are set regarding the simulator outputs with adapted inputs to satellite environment. And the effectiveness of the new DPC Mode algorithm on different spot orbit types, is proved with this simulation.

5.2 Simulation Software Structure

The simulation presented in this thesis is a system level simulation includes UMTS air interface having terrestrial and satellite components. The software has three blocks running iteratively by a *while* loop. Some of the parameter initiations are performed with random process and some others are performed by the end of calculations at the start block of the code.

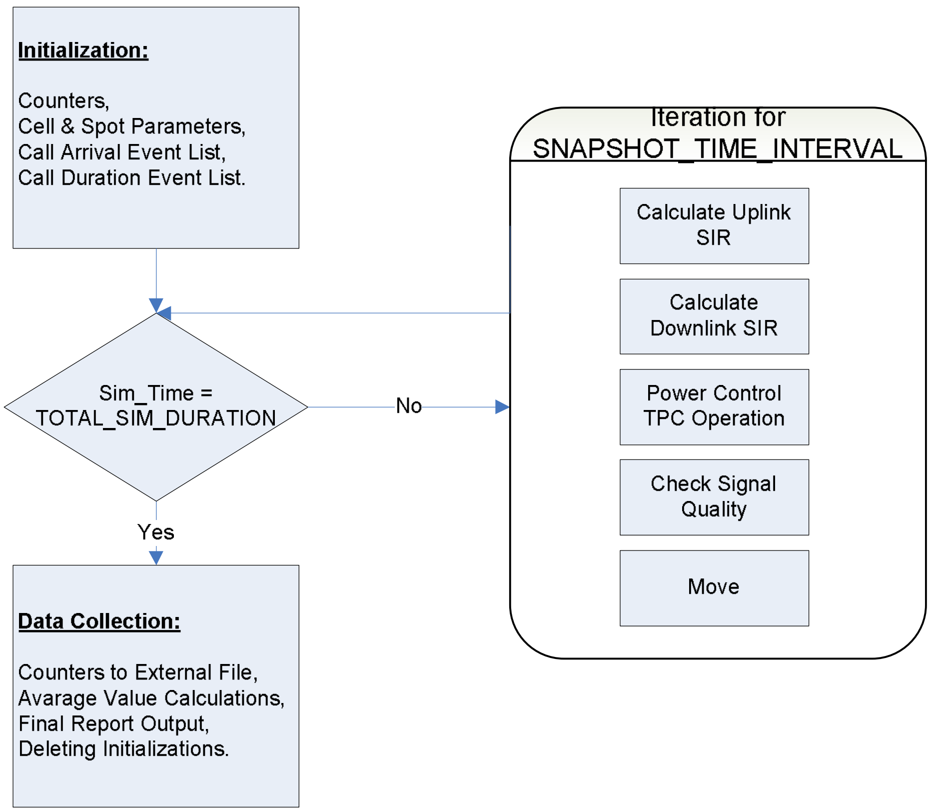

Figure 5.1 : Simulation software structure

As seen in the Figure 5.1, simulation starts with the parameter initiations. Performance counters, Cell and Spot parameters, the event lists including call arrival and call terminations and their specific information like the *UE_no* or *event_time* are initiated at this process. After the initiation is completed, the iteration including calculations of uplink and downlink SIR, power control TPC operations, signal quality checks and move operation, is performed. The number of iteration is depending on the *TOTAL_SIM_DURATION* and the *SNAPSHOT_TIME_INTERVAL*. During the iteration process the outputs of calculations and checks are saved to some counters which will be used at the result phase. After the iteration process is finished, the data collection process is started. During this phase counters are exported to an external output file. Since the result output report is composed of average values of iterative simulations, the average values of output counters are calculated. With these average values the final report is provided by the simulation and the resulting counters and initiations are deleted.

The OOP (Object Oriented Programming) property of C++ is used on the object coding for satellite spot, T-UMTS cell, UEs and the event list. Simulation includes 5 object classes: *Event, Event List, Satellite, Spot Site Database*, and *UE.* All classes have their own attributes and functions.

The class *Event* corresponds to the events in the event list. Three types of events exist in the simulation: *Call Arrival, Call Termination* and *Handover*. Every event is related with a satellite (spot or cell), and a UE. And every event has its identical *event number*, *call duration* and *call id*. The events linked to an *Event List* class. This specific class has some pointers indicating the connected events, *time now* and the *maximum event number* attributes. The operations of Event List class are used to arrange of different events in the list.

The class *Satellite* includes the SIR threshold values, T_x power, requested TPC commands from the system, active calls on the satellite, total R_x power on the satellite, the satellite type whether it is a cell or spot, and the identifiers of the satellite. The functions of the class *Satellite* are used to regulate the attributes and the users attached to the satellite.

The biggest class is the *UE* class which has the responsibility of performing the RF calculations and required quality checks. Class *UE* includes the physical attributes like location in x any coordinates, location and direction angles, some RF properties like T_x power, previous estimated path loss values, received R_x power, TPC Command operations, the signals whether the UE is on call or not, and some identifiers. The functions of class *UE* are used for some calculations especially on uplink and downlink RF area algorithms.

5.3 Simulation Architecture

The simulation space is two circle of radius *DIAMETER_OF_SPOT* and *DIAMETER_OF_CELL*. At the beginning of simulation, the users are placed randomly in the spot or cell area and assigned a random velocity between 0 and *UE_MAX_VELOCITY*. The distribution of the users to the area is exponentially random. That means the population density is high in the center of the circle which present the urban areas. And the population density is low in the far end of the center of the circle which presents the rural areas. The parameter *POPULATION_DENSITY_FACTOR* determines the density rate in the center. For the values 11-13 of *POPULATION_DENSITY_FACTOR*, %85 of the population is in the urban area (center of the spot and cell). For the values 36-38, %40 of the population is in the Urban Area.

The network architecture is composed of two separate coverage area as seen in Figure 5.2. In the urban and suburban area there is an IMR which has the capability of serving to NLOS (Not Line of Sight) areas. The diameter of IMR is about variable 2 Km that changes with the interference density. The RF properties in the IMR coverage areas apply same as in T-UMTS RF area. But in the rural coverage area, the satellite-earth RF area properties exist. Satellite communicates directly with UE where IMR coverage does not exist. Satellite also communicates with the GW in which is connected to Node B and RNC. In the NLOS where satellite communication is impossible, the communication through UEs is provided via IMR.

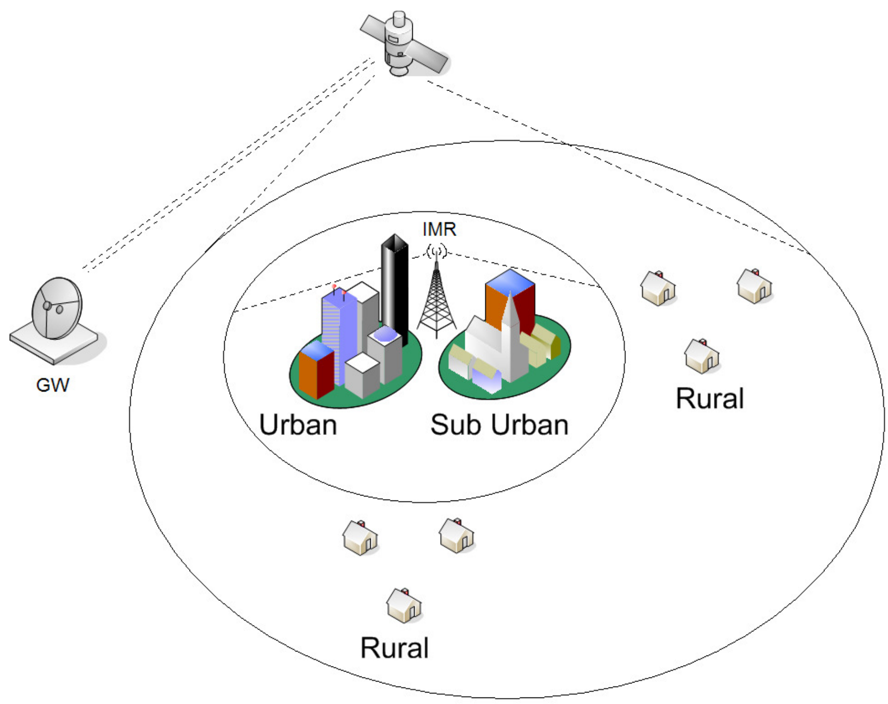

Figure 5.2 : Simulation network architecture

Every repetition step of the mobility update function is 60ms period. And at this period the velocity and the direction of each UE is being updated which is applied in a random process. In each 60 ms period the UE performs a move operation so that the link conditions changes regarding the new location of the UE. At some specific locations there are fading points set, that if the UE place in these points than it encounters with a fading. So the call of the UE may probably drop if the power control mechanism is not enough reactive.

5.4 Algorithm Flow Design

5.4.1 S/T UMTS algorithm blocks

Simulation algorithm is composed of three main blocks: 1 - Event Handling Block, 2 - Uplink Signal Strength Handling Block, 3 - Downlink Signal Strength Handling Block.

In the Event Handling Block, the event list is initiated and ordered with the Call Arrival and Call Termination events regarding to the event time which is determined according to the Poisson Arrival. The algorithm of Event Handling Block is shown in Figure 5.3. The decision of accepting a new call is dependent to the RF conditions of the UE. In this case the Open Loop Power Control which is in charge at initial access in order to set the initial transmit power regarding the estimated path loss, is used. If the RF conditions are not acceptable even if the Open Loop Power Control reaction is taken, then the call is blocked. If the decision of call block is taken than a call termination event is produced and linked to the event list for that time. If the link conditions are suitable then the call continues for the next *SNAPSHOT_TIME_INTERVAL.*

In the uplink and downlink signal strength handling blocks, the checks regarding SIR_{tresh} are performed by the RF area calculations, and the Inner Closed Loop Power control algorithms are performed as shown in Figure 5.4 and Figure 5.5. At the end of both algorithms the *PC_Mode* algorithm is applied in order to determine the TPC sending frequency. If the *Adaptive_PC_Mode* is selected in the initiations, then the *PC_Mode* changes adaptive to link conditions as described in the previous chapter. Finally with the outputs of the calculation the class database is updated. For the uplink signal strength handling block, after the first calculations the SIR level comparison of cell and spot is placed. If UE SIR level from spot is greater than cell even if the UE is attached to spot, then a handover event is added to the event list. Same flow exists if UE is attached to cell.

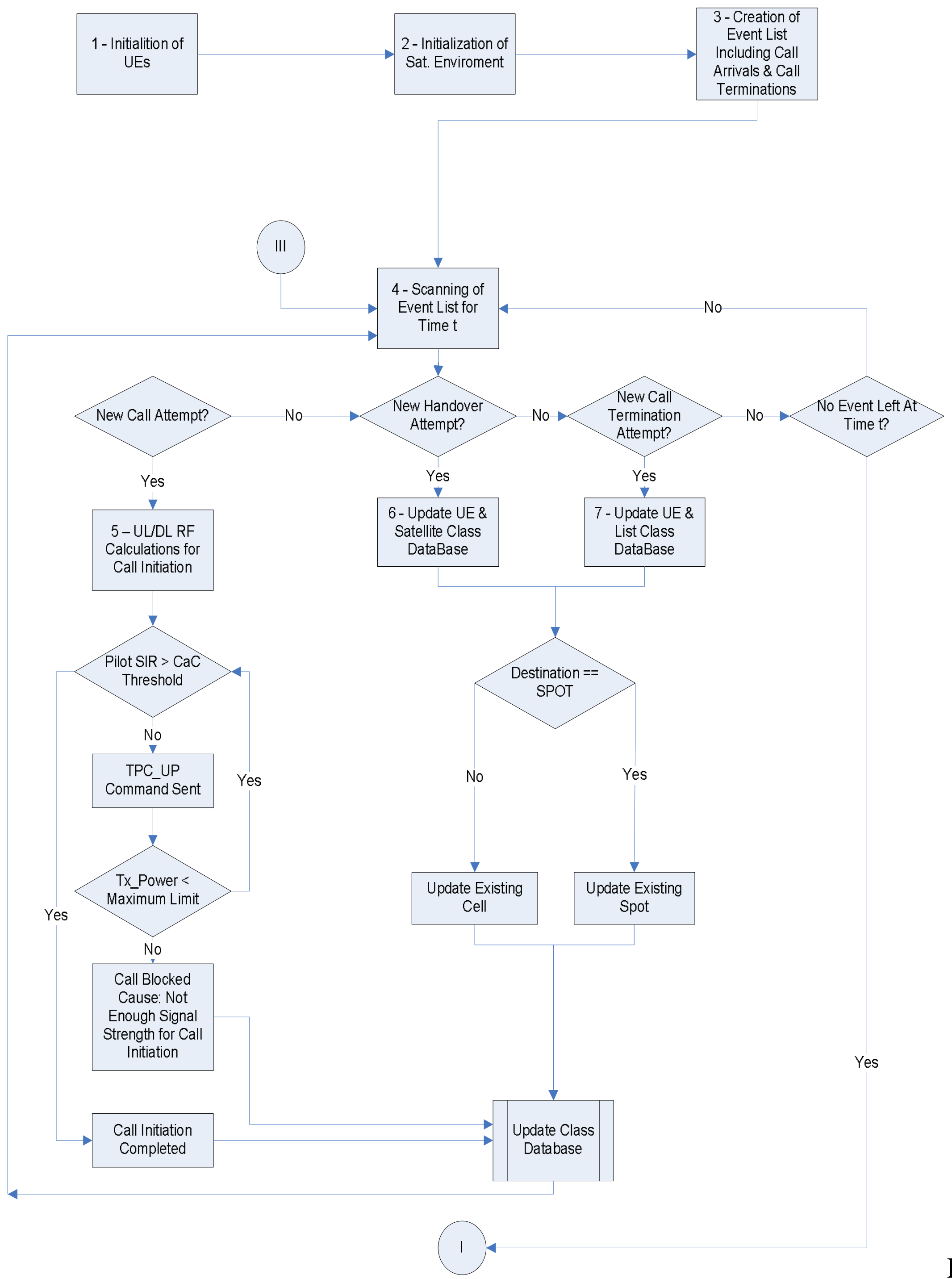

Figure 5.3 : Event handling block

If the handover event is not required than the SIR checks with thresholds, and after the power control and PC Mode reaction is taken regarding SIR values, process continue with downlink calculation. For the downlink calculation the SIR value received from UE at cell and spot is compared. If the value at cell is greater than spot even if the UE is attached to spot, then a handover event is added to the event list. IF the handover process is not required, process continues with SIR comparison with thresholds, power control and PC Mode reactions. After the database is updated with the check results, the process continues with simulation time iteration.

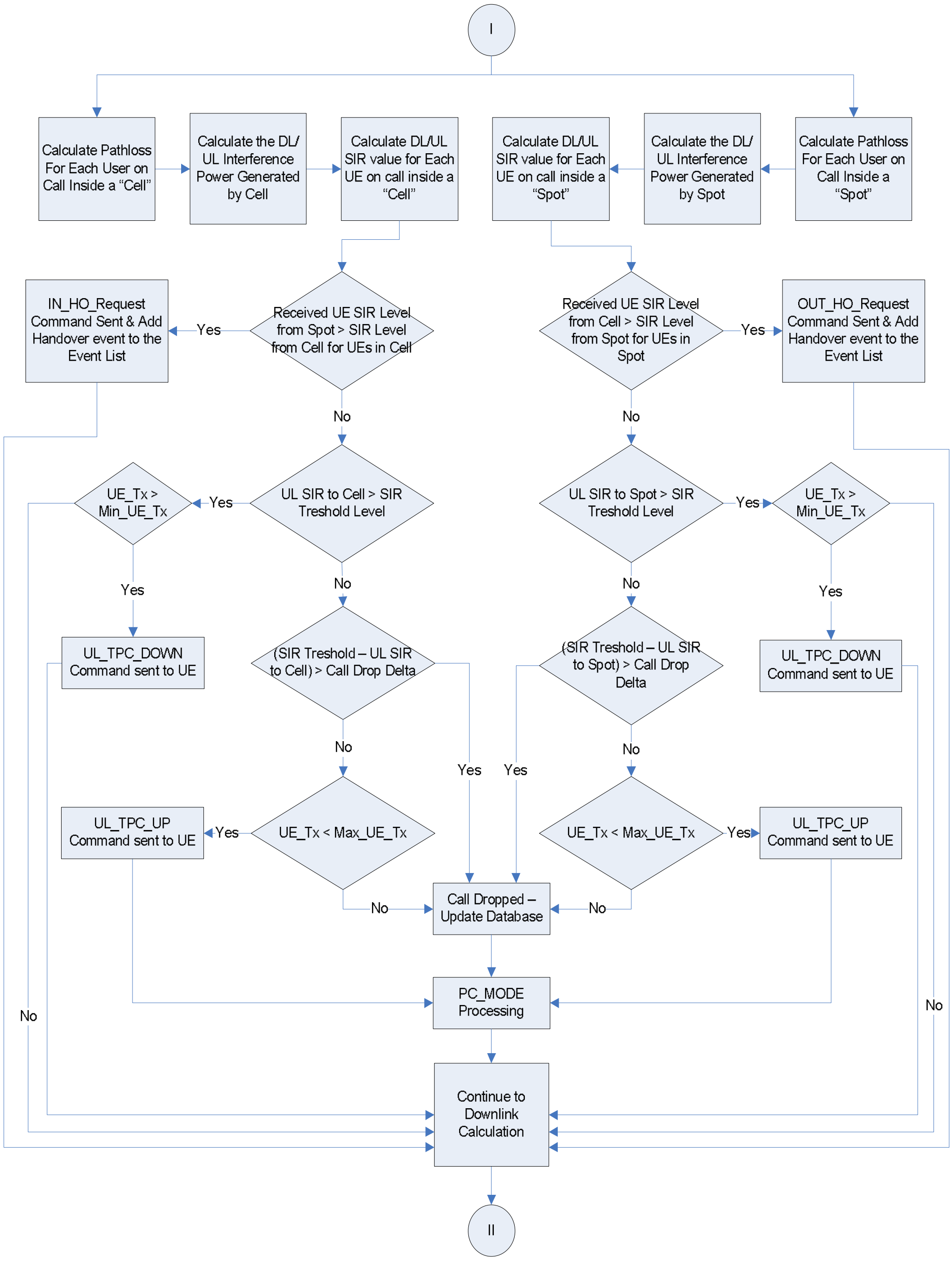

Figure 5.4 : Uplink signal strength handling block

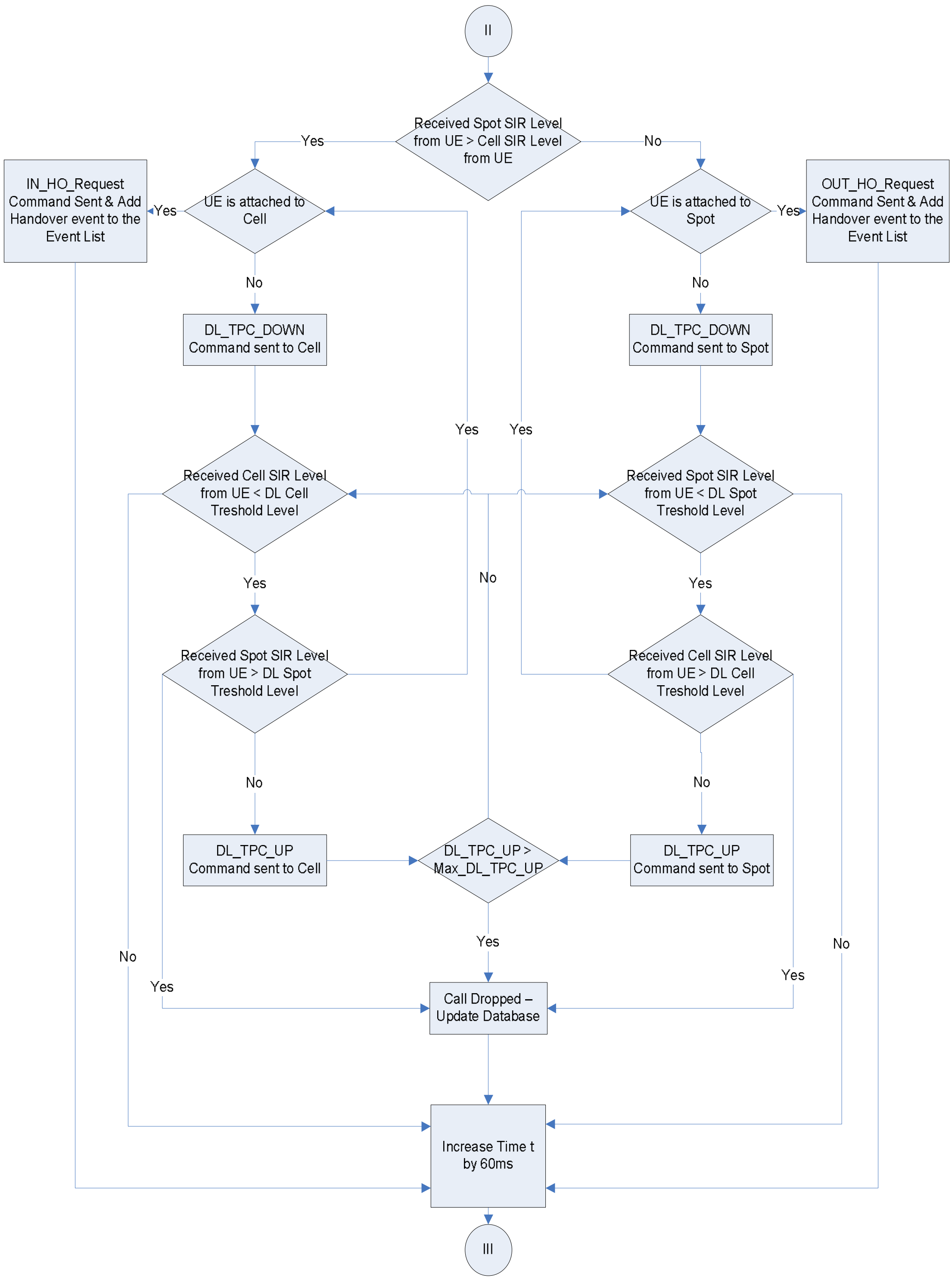

Figure 5.5 : Downlink signal strength handling block

5.4.2 Call establishment and processing phase

In the simulation the well known traffic arrival model Poisson arrival is used. It is supposed that the population of users interacted with the system is infinite but the call rate arrival and the call durations are related of the system state. This assumption exist both in wireless and wire line communication networks since the core network has the same capacity interactions.

The simulation has the number of new call arrivals in a period T follows a Poisson distribution:

$$\lambda = a * T \quad \textbf{(5.1)}$$

$$p_k = P(X = k) = e^{-\lambda}\left(\frac{\lambda^k}{k!}\right), k = 0,1,2 \ldots \quad \textbf{(5.2)}$$

The maximum probability is for k=[λ]. It can be proven that the duration between two calls follows an exponential distribution. In the simulation code the Poisson distribution is used in "Creation of Event List Including Call Arrivals & Call Terminations" part for determining the new call arrival and the call duration time. So in an ordinary day, "the busy hour" is realized in the simulation.

5.4.3 RF measurement and calculation phase

The RF properties of every User Equipment are measured in *SNAPSHOT_TIME_INTERVAL* period which is 60 milliseconds. The calculations are based on the link budget of satellite and terrestrial cell environment. The handover and drop time calculations are based on the signal to interference ratio measurements.

The RF calculations are performed for two separate parts: Cell Link Budget which includes T-UMTS properties and Spot Link Budget which includes S-UMTS properties.

5.4.3.1 Cell link budget

The uplink and downlink link budget for cell includes the following parameters stated in Table 5.1. For the path loss calculation of cell, Okumura-HATA PCS extension (5.3) described in the previous chapter, is used.

$$\begin{aligned}\mathrm{PL} &= 46.3 + 33.9\log_{10}\mathrm{f_c} - 13.82\log_{10}\mathrm{h_t} - \mathrm{C_H} \\ &+ [44.9 - 6.55\log_{10}\mathrm{h_t}]\log_{10}\mathrm{d} + \mathrm{C}\end{aligned} \quad \textbf{(5.3)}$$

In the equation for the system carrier frequency f_c, the parameters DOWNLINK_FREQUENCY and the UPLINK_FREQUENCY are used. The values of the parameters are described in the next chapter. h_t is used for the antenna height of the IMR which is defined with the parameter IMR_ANTENNA_HEIGTH in the simulation. d is the distance of UE to the antenna which changes dynamically with the simulation run time. So the movement of UE results with rapid change in path loss regarding the velocity and the direction of the UE.

Table 5.1 : Simulation cell link budget parameters

Parameters
Tx_Power_of_UE
Tx_Power_of_CELL
Tx_ANTENNA_GAIN_OF_CELL
Rx_ANTENNA_GAIN_OF_CELL
CABLE_LOSS, BODY_LOSS
Rx_ANTENNA_GAIN_OF_UE
Rx_ANTENNA_GAIN_OF_CELL
SHADOW_FADING
INDOOR_PENETRATION_LOSS
DL_Pathloss_for_cell
UL_Pathloss_for_cell

In the link budget the parameter Tx_Power_of_UE and Tx_Power_of_CELL correspond to the total power radiated from the cell and UE antenna. The values of antenna gains, cable and body loss, shadow fading and indoor penetration loss are taken from the ETSI Spec TR 102 058 (2004-11).

For the SIR calculation in each *SNAPSHOT_TIME_INTERVAL* the following SIR formula is used in the simulation:

$$SIR = \left(\frac{E_b}{N_b}\right)_j = SF.\frac{P_j}{I_{total}-P_j} = \frac{P_j}{I_{inter}+I_{intra}+P_n} \quad \textbf{(5.3)}$$

$$Spreading\ Factor\ (SFProcessing\ Gain) = \frac{Carrier\ Bandwith}{Information\ Rate} = \frac{Chip\ Rate}{Data\ Rate} = \frac{W}{R} \quad \textbf{(5.4)}$$

The values for SIR_{tresh} is used in order to determine if a call is dropped or any handover is required from cell to spot or from cell to spot. For *W*, *CHIP_RATE* and for *R*, *BIT_RATE* parameters are used.

5.4.3.2 Spot link budget

The uplink and the downlink link budget is calculated in the simulation with the following parameters:

Table 5.2 : Simulation spot link budget parameters

Parameters
UE_Tx_Power
CELL_Tx_Power
Tx_ANTENNA_GAIN_OF_SATELLITE
Tx_ANTENNA_GAIN_OF_SATELLITE
SATELLITE_FEEDER_LOSS
TRACKING_LOSS
Rx_ANTENNA_GAIN_OF_UE
Tx_ANTENNA_GAIN_OF_UE
downlink_pathloss
uplink_pathloss
BODY_LOSS
EbOVERNo_SAT_NONLINEARIZATION_LOSSES

The ordinary path loss models are not suitable for high delay satellite air interface. So the following general path loss algorithm is used in the simulation as described in the previous chapter:

$$P_r = P_t K \left[\frac{d_o}{d}\right]^{\gamma}, \tag{5.5}$$

$$PL = K(dBm) - 10\gamma \log_{10}\left[\frac{d_o}{d}\right], \tag{5.6}$$

where $PL = P_r - P_t$,and d_o is the reference antenna far field distance. The following formula gives the unitless constant K:

$$K(dB) = 20 \log_{10} \frac{\delta}{4\pi d_o}. \tag{5.7}$$

The parameters of antennas gain, feeder, tracking and body losses and non linearization losses have the values stated in the ETSI Spec TR 102 058 (2004-11). For the SIR calculation same equations (15) and (16) are used for the satellite environment as in the T-UMTS.

For the handover operation soft and softer handover processes are used since there are cell and spot in the architecture. In the soft/softer handover each UE has its own active set which is saved in *CPICH_Table*. In every *SNAPSHOT_TIME_INTERVAL* the CPICH table is updated with the new measurement and calculation results.

5.5 Simulation Parameters

Simulation parameters are composed of the initial input parameters and the result output parameters. The initial input parameters are used in the algorithm flows as inputs for the calculation functions. After these parameters are processed by the calculation functions the results are saved as output parameters. At the end of the simulation the result outputs are collected for a final report which indicates the QoS of the simulation environment. The input parameters are initiated regarding to the recommendations published in the ETSI TR 102 058.

5.5.1 Initial input parameters

The initial input parameters of the simulation are presented in the Table 5.1. The parameters are in three groups. One group is used for the link budget calculations in the algorithm. Second group is used for the other RF area calculations and the third parameter group is used for the Power Control calculations like DPC Mode algorithms. These parameters are reconfigurable in the value ranges specified in the following table.

Table 5.3: Simulation initial input parameters

Parameter	Unit	Value	Explanation
TOTAL_SIM_DURATION	MiliSecond	700000	Simulation duration
MAX_UE_NUMBER		2500	Maximum Number of User Equipments
POPULATION_DENSITY_FACTOR		38	For the values 11-13 %85 of the population is in the Urban Area, for the values 13-16 %75 of the population is in the Urban Area, for the values 36-38 %40 of the population is in the Urban Area.
UE_MAX_VELOCITY	m/s	50	The maximum velocity a User Equipment.
SATELLITE_ORBIT_TYPE		1	1: GEO, 2: MEO, 3: LEO
RURAL_AREA_VELOCITY_FACTOR		5	Coefficient of avarage veloctiy of Rural Area in comparison with urban area.
IMR_ANTENNA_HEIGTH	m	50	Antenna heigth for for IMR
CELL_NUMBER		1	Cell identifier
SPOT_NUMBER		1	Spot identifier
DIAMETER_OF_SPOT	m	200000	Estimated diameter of Spot
DIAMETER_OF_CELL	m	4000	Estimated diameter of Cell

GUARD_POWER	dB	0	Power delta used at the Power Control TPC_Down command process.
PC_ONE_STEP_POWER_CHANGE_UE	dB	1	Power deceraese or increase amount in responce of 1 TPC command. (ValueRange: 1dB - 3dB)
PC_ONE_STEP_POWER_CHANGE_Satellite	dB	1	ValueRange(1dB - 3dB) - Constant is used for power decraese or increase amount in Spots or Cells
SPOT_MAX_TX_POWER	dB	24,6	Only exist for GEO orbital type
CELL_MAX_TX_POWER	dB	16	
CELL_MIN_TX_POWER	dB	5	
SPOT_MIN_TX_POWER	dB	20	
DOWNLINK_FREQUENCY	MHz	2185	Downlink carrier frequency
UPLINK_FREQUENCY	MHz	1995	Uplink carrier frequency
UE_ELEVATION	(°)Degree	42	(Values: 42, 30, 16)
BODY_LOSS 1.0	dB	1	Body loss for User Equipment
EbOVERNo_SAT_NONLINEARIZATION_LOSSES	dB	1	Nonlinearization loss in the downlink satellite link
Rx_ANTENNA_GAIN_OF_CELL	dBi	18	
Tx_ANTENNA_GAIN_OF_CELL	dBi	18	
Tx_ANTENNA_GAIN_OF_UE	dB	0	
UE_FIGURE_OF_MERIT	dB/°K	-24,6	
UE_DL_NOISE_TEMPERATURE	°K	290	
Tx_ANTENNA_GAIN_OF_SATELLITE	dB	0	
CHIP_RATE	Mchips/s	3840	
BIT_RATE	Kbit/s	384	
SNAPSHOT_TIME_INTERVAL	ms	60	Time interval between two consecutive progress time of the simulation algorithm.
REGIONAL_INTERFERENCE_FACTOR	dB	0	Interference factor for downlink, sourced from other existing interferers like adjacent BSs, Adjacent Spot
MAXIMUM_CALL_DURATION	sec	2500	Maximum time that a call can be at on state.
HOURLY_CALL_RATE	calls/hour	5000	Avarage Call amount in one hour
LOGS_ON		1	1 for Sim logs are on, 0 for logs are off
MAX_ALLOWED_SIR_DELTA_FOR_SOFTER_HANDOVER	dB	5	Maximum allowed delta between downlink SIR values of Spot and Cell that is active for an UE

ALLOWED_DL_SIR_DELTA_IN_CELL_BOUNDRY	dB	5	After receiving DL_TPC_up command, cell sets its Tx Power according to ALLOWED_DL_SIR_DELTA_IN_CELL_BOUNDRY.
SATELLITE_FEEDER_LOSS	dB	1	
UE_FEEDER_LOSS	dB	1	
TRACKING_LOSS	dB	1	
ATMOSPHERIC_ABSORPTION	dB	1	
RAIN_ATTENUATION	dB	1	
CABLE_LOSS	dB	1	
SHADOW_FADING	dB	1	
INDOOR_PENETRATION_LOSS	dB	1	
HANDOVER_PROTECTION_VALUE	dB	3	Maximum allowed power delta between source and destination cell before handover performed from source to destination cell.
SIMULATION_REPEAT_COUNT		50	Iteration count of simulation.
UE_TYPE		1	1 - Handheld, 2 - Portable, 3 - Vehicular, 4 - Transportable
TPC_MODE		1	Determines the TPC transfer period. 1 for TPC per 3 frames, 2 for TPC per 5 frames, 3 for TPC per 7 frames, 4 for TPC per 9 frames, 5 for adaptive TPC transfer
DEFAULT_TPC_MODE		3	TPC_mode if not set manually
TPC_MODE_CHANGE_DURATION	ms	15	The protection time after a TPC_Mode changed from existing value.
CALL_DROP_DELTA	dB	3	Maximum allowed power delta between signal strength and call drop signel strength level.
TPC_MODE_CHANGE_DELTA	dB	2	Maximum allowed power delta before TPC_Mode changes in time of TPC_MODE_CHANGE_DURATION

5.5.2 Simulation result outputs

Simulation result outputs are reproduced in every simulation process end. After the event initiations, uplink and downlink calculations the result outputs are produced by the algorithm with using the initial input parameters and with the counters. After the simulation result outputs are produced from the counters, the average values are calculated from the sequentially repeated simulations with the same initial input parameters. After the average outputs are collected, their values are reported for a final display. Table 5.4 shows the collected and reported average output counters and calculation results for the final report. The simulation results for sample inputs are explained in the next chapter by using these output counters.

Table 5.4 : Result outputs reported at the end of the simulations

Output	Explanation
AVG_DROPPED_CALLS_COUNTER_CELL	Dropped calls counter produced in cell.
AVG_DROPPED_CALLS_COUNTER_SPOT	Dropped calls counter produced in spot.
AVG_HANDOVER_TO_SPOT_COUNTER	Counter of handover occured form cell to spot.
AVG_HANDOVER_TO_CELL_COUNTER	Counter of handover occured form spot to cell.
AVG_CELL_TPC_UP_COUNTER	Cell transmit power up counter in the uplink power control phase.
AVG_CELL_TPC_DOWN_COUNTER	Cell transmit power down counter in the uplink power control phase.
AVG_SPOT_TPC_UP_COUNTER	Spot transmit power up in the uplink power control phase.
AVG_SPOT_TPC_DOWN_COUNTER	Spot transmit power down in the uplink power control phase.
AVG_UE_TPC_UP_COUNTER	User equipment transmit power up in the uplink power control phase.
AVG_UE_TPC_DOWN_COUNTER	User equipment transmit power down in the uplink power control phase.
AVG_ESTABLISHED_CALL_AT_SPOT_COUNTER	Total number of establiseh in the spot but not cell coverage area.
AVG_ESTABLISHED_CALL_AT_CELL_COUNTER	Total number of establiseh in the cell coverage area.
AVG_CELL_DROP_RATE	Cell drop rate calculated by the following formula: *AVG_CELL_DROP_RATE* = *DROPPED_CALLS_COUNTER_CELL* / *ESTABLISHED_CALL_AT_CELL_COUNTER* x 100
AVG_SPOT_DROP_RATE	Spot drop rate calculated by the following formula: *AVG_SPOT_DROP_RATE* = *DROPPED_CALLS_COUNTER_SPOT* / *ESTABLISHED_CALL_AT_SPOT_COUNTER* x 101
AVG_BLOCK_RATE_DUE_TO_LOW_SIGNAL_STRENGTH	Total number of blocks at the Open Loop Power Control phase both in spot and cell.

6. SIMULATION RESULTS AND CONCLUSION

The simulation results are composed of signal level variation results, PC Mode results regarding low middle and geostationary type orbit satellites and the adaptive PC Mode performances. These performances are measured by executing the S-UMTS radio network simulations *SIMULATION_REPEAT_COUNT* times with the same parameters described above. After the executions the results are collected and presented in groups.

6.1 Cell/Spot Signal Level Variation Results

Due to long propagation delays, satellite systems are less reactive in comparison with T-UMTS system. The main reason for being less reactive is the slow power level variations in satellite networks. The power level variations in wireless communication, are produced by the UE movement, spot movement (for satellite including cases) and the external causes like atmospheric effects. If the system is tractable which has low signal level change, then the system does not need to be much reactive since the fading situations are not frequent.

In this part of simulation results, the power level change is measured in terms of UE speed and the drop rates. It is assumed that with increase in velocity of UE, the signal level, changes more rapidly. If the signal level is not tractable, the system response against to fading is produced late, so that the signal level stay below signal level threshold for too long time that a call can't maintain its Quality of Services in expected ranges. As a result of this fading the call drops. For the reactivity test of the simulation the following initial parameters in addition to the parameters described in the previous chapter in Table 5.3, are initiated as shown in Figure 6.1. In this case, the spot and the cell drop rates are measured by the change of average UE velocity in the simulation environment. For the test, the simulation is executed for 50 times and the reports are collected. The values shown in Figure 6.1, are the average results of 50 sequential executions of the simulation.

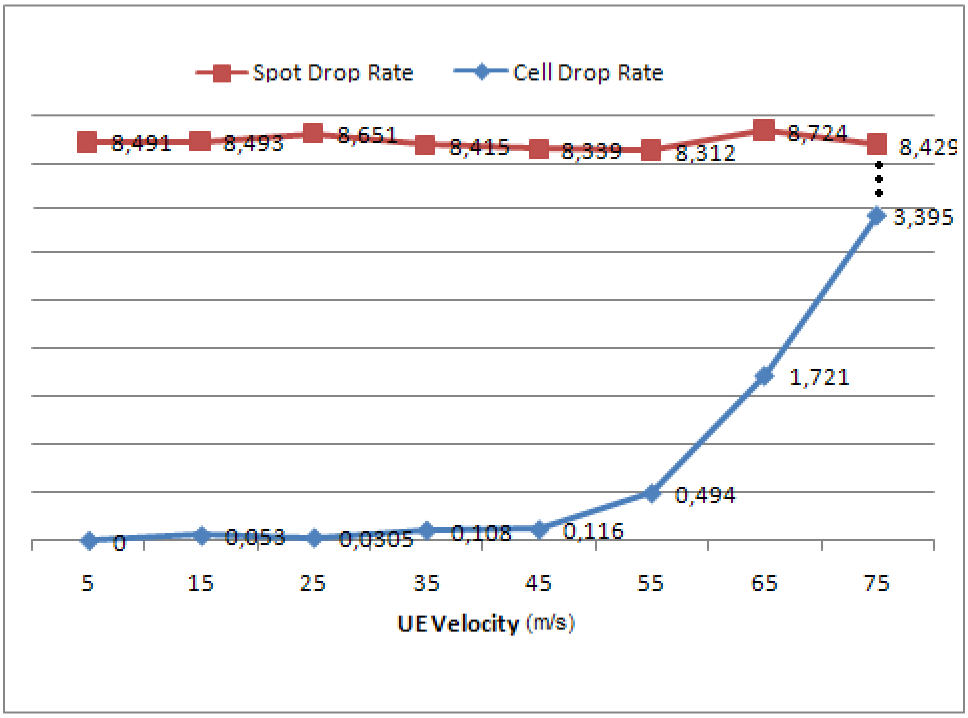

Figure 6.1 : UE velocity – Cell/spot drop rate for LEO S-UMTS

Table 6.1 : Adapted simulation parameters

Parameter	Value
Bit Rate (Kbit/sec)	384
PC_Mode	1
Orbit Type	LEO
Simulation Count	50

The simulation results show that with the rise of average UE velocity in the network, the drop rates increase exponentially in the cell environment. This means that T-UMTS network is very sensitive to rapid signal power level changes in high data rate communication. But for the satellite case change in UE velocity is not enough effective to increase the drop rates as in cell environment. This is because the satellite environment has a long propagation path and the rapid change in UE speed has not any destructive effect on the satellite link.

This chart proofs that the UE behavior is more effective on the cell link than the satellite spot link. So it is deducted that T-UMTS link power has rapid variations and the system must be more reactive with the help of power control. And the satellite link power has slow variations that the reactivity in S-UMTS can be decreased by reducing the TPC commands.

6.2 PC Mode Performance for Different Orbit Types

The different PC Modes are applied in the simulation in order to compare the performances in LEO MEO and GEO orbit satellites in S-UMTS. Additionally the new approach Adaptive PC Mode is applied to the simulation for different orbit types and results are stated.

6.2.1 PC mode on GEO S-UMTS network

Since the satellite environment has a long delay signal path, the TPC sending and processing algorithm of T-UMTS needs to be adapted for the satellite environment as described in the ETSI specs. For this adaptation, the PC Modes are introduced in this thesis and stated in the previous chapter. According to PC Mode algorithm by considering two measurement of signal interference ratio taken at time t_1 and t_2 from the system:

- If *PC_MODE* = 1: the UE repeats the same TPC command over 3 frames. So the new TPC command will arrive at the fourth radio frame.
- If *PC_MODE* = 2: the UE repeats the same TPC command over 5 frames. So the new TPC command will arrive at the sixth radio frame.

If PC_MODE = 3: the UE repeats the same TPC command over 7 frames.

If PC_MODE = 4: the UE repeats the same TPC command over 9 frames.

- If PC_MODE = 5: the PC Mode will change dynamically regarding the following rule:

$0 \leq PC\_mode \leq 4$, PC_Mode = Default_PC_Mode if, $SIR_{meas}(t_2) - SIR_{meas}(t_1) < PC\_Mode\_Change\_Delta$, $PC\_Mode = 1$ (lowest order value) if, $SIR_{meas}(t_2) - SIR_{meas}(t_1) > PC\_Mode\_Change\_Delta$.

The simulation is executed 50 times for each PC_Mode, and the result outputs are collected. The average value of drop rates, TPC sending and processing frequency, and the loop delay of 50 sequential executions are presented in the Figure 6.2. Some of the initial parameters are presented with the figure, the rest of the parameters are initiated with the values in Table 6.2.

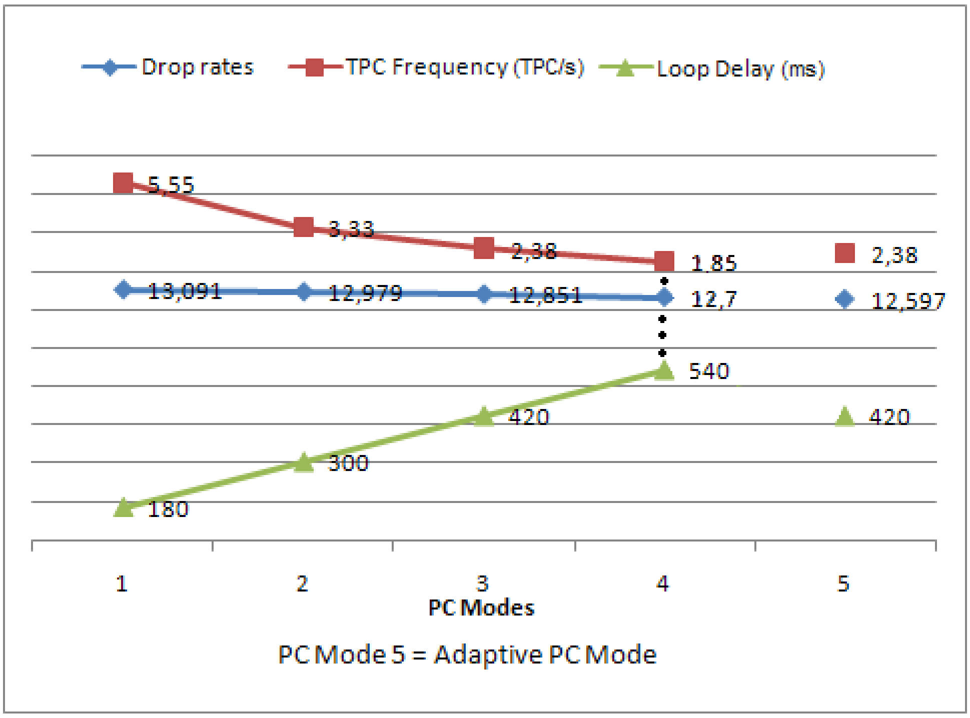

Figure 6.2 : Power control figures for GEO S-UMTS network

Table 6.2 : Adapted simulation parameters

Parameter	Value
Bit Rate (Kbit/sec)	384
Avarage UE Velocity	25
Orbit Type	GEO
Simulation Count	50

The simulation results show that the decrease in TPC frequency cause to decrease in drop rates on the GEO satellite UMTS link. As stated in the specs, the delay to reach the receiver is in the range of 240 ms for GEO satellite, i.e. if applied immediately TPC commands do not match fast fading correction and furthermore are destructive because of the instability in the link power changes. If the TPC commands applied with an increased time interval as in *TPC_Mode* 2 and 3, then this destructive effect is decreased as shown in the Figure 6.2.

Another important result is that, decreasing the TPC Frequency caused an increase in loop delay. The loop delay is the time interval of two consecutive TPC commands sent or processed. If this time interval is increased the reactivity factor may decrease and this has destructive effect on the link. But this destructive effect only exists in the links that have rapid power level variations. In the case of GEO satellite, since the signal variations are slow and tractable, the negative effect of the increment in loop delay, does not have increase effect on drop rates as shown in simulation result. The result of Adaptive PC Mode is discussed in the next chapter.

6.2.2 PC mode on MEO S-UMTS network

MEO orbits are similar with GEO orbits in the link characteristics perspective. The Line of Sight distance is around 38000 km for GEO satellite, 18000 Km for MEO satellite and, 500 - 1500 Km for LEO orbit type satellites. So the propagation delays of GEO and MEO orbits are similar but for LEO orbits, the loop delay and other link characteristics are more likely to T-UMTS cell. For the MEO case of the simulation execution, only the orbit type changed and the rest of the parameters remained same with the previous test as shown in the Figure 6.3.

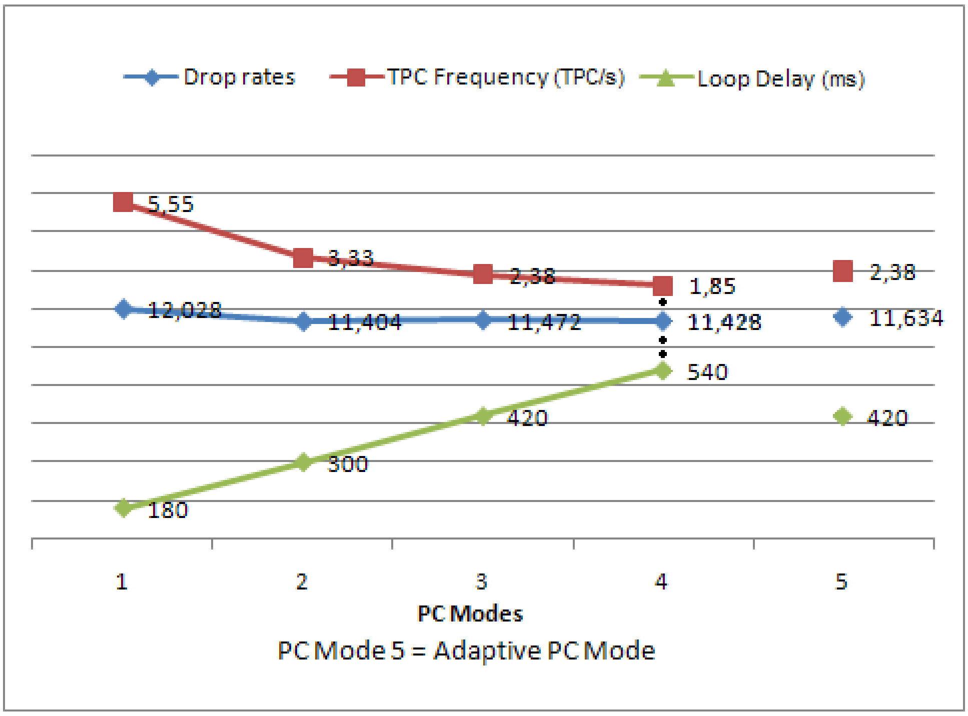

Figure 6.3 : Power control figures for MEO S-UMTS network

The simulation results of MEO network show that the rise of TPC frequency caused a decrease in drop rates similarly with GEO type S-UMTS. Since the number of TPC commands are reduced for unit time, the instability is decreased, so the drop rates are decreased. Especially at *TPC_Mode* 2, 3, and 4 the results show that the decrement in drop rates is not so explicit. Other result is that the loop delay rises with the TPC sending and processing frequency reduction. The result of Adaptive PC Mode is discussed in the next chapter.

Table 6.3 : Adapted simulation parameters

Parameter	Value
Bit Rate (Kbit/sec)	384
Average UE Velocity	25
Orbit Type	MEO
Simulation Count	50

6.2.3 PC mode on LEO S-UMTS network

Since LEO orbits satellites have very low height from earth in comparison with GEO and MEO orbit satellites, the link characteristics are differentiated in terms of propagation delay and fading characteristics. The signal variations in LEO satellites are rapid unlike MEO and GEO orbits. This property of LEO satellite is similar with T-UMTS cell environment.

In this case the drop rates and the loop delay are measured with the TPC frequency change which is in control of *PC_Mode*. The first 4 mode and the adaptive mode are used to measure performance of the power control algorithms as shown in the Figure 6.4.

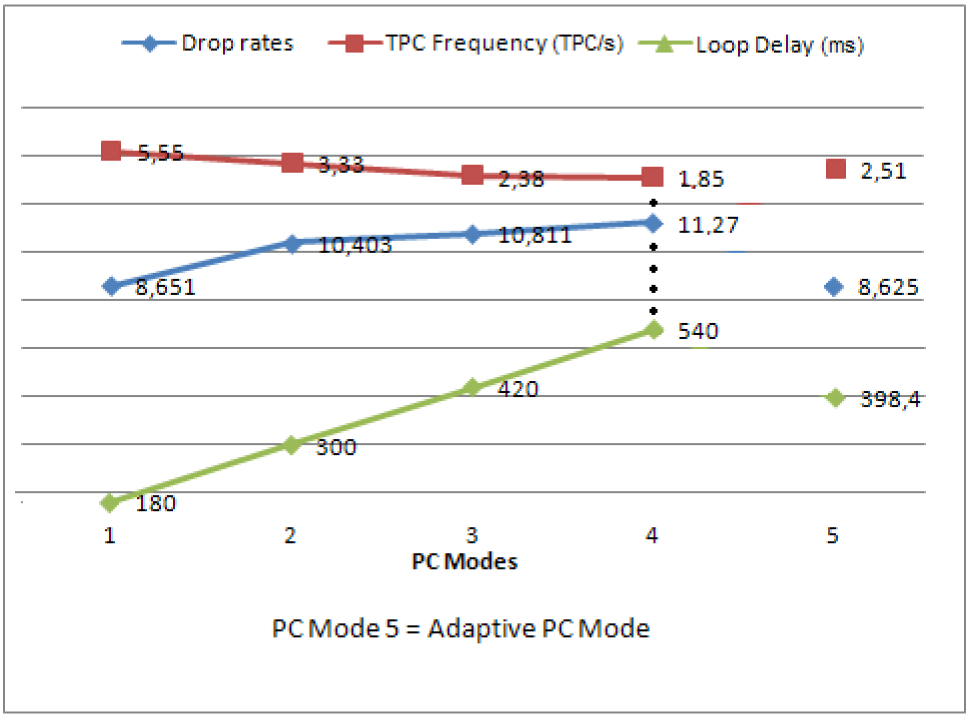

Figure 6.4 : Power control figures for LEO S-UMTS network

The simulation result of LEO type S-UMTS show that, the decrement in TPC sending and processing frequency has the increase effect on drop rates unlike in GEO and MEO type S-UMTS.

Table 6.4 : Adapted simulation parameters

Parameter	Value
Bit Rate (Kbit/sec)	384
Avarage UE	
Velocity	25
Orbit Type	LEO
Simulation Count	50

The most important reason of the increment in drop rates is the higher loop delay on higher order *PC_Modes*. So the common question is "*Why the drop rates is not increased in GEO and MEO type satellites by the loop delay effect?* ". The answer of the question is the effect of rapid signal changes of LEO satellites unlike the slow changes of GEO and MEO satellites. The effect of rapid power change is shown in the illustration Figure 6.5. In the figure while the loop delay t_1 is constant the power level variation is increased in the second phase. So, the total fading time t_2 is equal to t_1 for the first phase, and for the second phase it is increased

($t_2 > t_1$). If any increment in loop delay is t_1 is considered for both phases (low power level variation and high power level variation phases), then the total fading time t_2 must be greater at high power level variation phase. So this negative effect is more explicit in networks that have rapid power level variation characteristics like LEO systems. The negative effects of increasing loop delay for MEO and GEO S-UMTS systems, are negligible since these systems have slow power level variations (tractable systems).

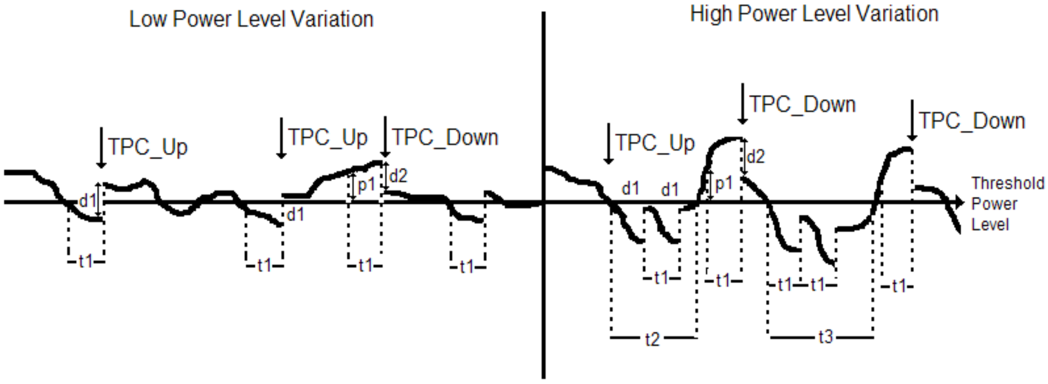

Figure 6.5 : Illustration of signal power level variation

t1: Power Control loop delay.

t2,t3: Total time of the signal level below threshold

d1: TPC_Up Power delta

d2: TPC_Down Power delta

p1: Required power level above the threshold to perform TPC_down

6.3 Adaptive PC mode performance

It is concluded from the previous results that there is a tradeoff between the link stability and the frequency of processing and sending of TPC commands. For the LEO satellite systems, reducing the TPC frequency has destructive effect as seen in the chart. However for the MEO and GEO cases reducing the TPC frequency has a decrement effect on drop rates because of the decrement of link instability.

When the *PC_Mode* 5 is used to apply Adaptive TPC Mode, it is seen from the Figure 6.4 that the drop rates are less than the drop rate of *PC_Mode* 3 which has the same Loop delay and TPC frequency. The reason for that situation is that in the simulation process when the UEs are moving in a steep environment where the propagation scattering is high or the multipath effect exists, the link power changes are rapid. And at that time if the TPC frequency is low than the rapid variations of power level, increases the drop rates. In order to prevent this destructive effect, the Adaptive PC Mode decreases the *PC_Mode* to the values 2 or 1(to *Default_PC_Mode*) that has high TPC sending frequencies, dynamically. By this preventative action the reactivity of the link is increased against to the link power fading for the networks that have high power changes like LEO satellite systems. The effect of Adaptive PC algorithm is less for GEO and MEO satellite systems since these networks have low power level variations.

With the Adaptive PC mechanism, that applied as described above, for the place where the steep index is high also the scattering and multipath effect is high, drop rates become lower for the same loop delay rates. So, the effect of Adaptive PC algorithm is significant for more reactive networks.

6.4 Conclusion

The researches and the simulation results described in this thesis show that, for the third generation satellite networks that allow high speed data transfer, the reactivity and the stability of the system against to power fading of signal, must be well adapted for the satellite environment. For S-UMTS, each of the Radio Resource Management and Mobility Management algorithms need to be adapted for the satellite environment to fulfill the correction and the regulation functions of these management algorithms completely. Especially the adaptation of the Power Control algorithms that has the most significant effect of these regulations on different satellite orbits, is handled on this thesis. The results of simulation are discussed and the new approach, Adaptive Power Control algorithm is introduced in the scope of the thesis.

The reactivity of the system is determined by the power control algorithms applied to adjust the power level dynamically during transmit and receive process of the information. If the transmit and the receive process continues in high bit data rates then the system become more sensitive to link power level fading regarding to the definition of Signal to Interference ratio (equations (3.15) and (3.16)).

The definition of SIR, states that the data bit rate and the value of SIR is inversely proportional. That means if the bit rate is increased than the SIR value is decreased. So for higher bit rates SIR is getting more sensitive for the power fading. It is an important issue to adapt the signal power auto control system for the third generation systems like S-UMTS since these networks have high bit transfer rates.

S-UMTS radio network simulation results show that TPC sending and processing frequency decrement has a positive effect on decreasing the drop rates for the slow networks that have slow power level variations like GEO and MEO systems. This is because the stability of the system is increased with less TPC commands in the long propagation delay environment. For the networks that have rapid link power level variations like T-UMTS and the LEO S-UMTS, the decrement of the number of TPC commands, has a negative effect on decrease of drop rates. As seen in the Figure 1.3, if a network has a rapid change in the link power level states, in order to remain with the same drop rates the system must be well reactive to compensate the power fading with on time power increments. The decrement in TPC commands amount has a positive effect on the reduction of stability, but in the other hand this has a negative effect on the reactivity for the signal fading. This negative effect is more significant on the rapid power variations.

A new approach, Adaptive Power Control that have the effect of increasing reactivity and stability at the same time for the networks that have rapid signal level variations, is introduced at the thesis. By using this dynamic algorithm, the power control mechanism has the ability of changing the TPC commands sending and processing frequency adaptive to signal level variations at the start and during the call progress between the UE and network, dynamically. The simulation results show that with application of Adaptive Power Control the drop rates reduced especially in LEO orbits as shown in Figure 6.4. The reason of this situation is that according to the algorithm, the TPC frequency is increased when the link power is oscillating highly, in order to increase the reactivity of the network. And for the conditions when the power oscillations are low the TPC frequency is decreased. Power level characteristics of LEO satellite is completely match with the behavior of Adaptive Power Control.

All these adaptations in RRM and MM algorithms will be a significant need for future networks that will have higher bit rates. The simulation results and the researches show that the sensitivity of the network is highly affected by the bit rates and the link environments. The maximum bit rate of UMTS is 384 Kbit/s, and for the further systems this rates are increased exponentially. For instance, for the fourth generation systems, the bit rate goes up to

100Mbits/s for low mobility, and 1Gbits/s for low mobility. So the implementation of traditional mobility algorithms on these tremendously high bit rate systems will have a critical issue to reach the expected Quality of Service for the future researches.

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