Master's Thesis

# Enhanced Channel Switching in MBMS UMTS using a Dynamic Power Counting scheme

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## **Abstract**:

In this thesis we propose a novel power based algorithm for switching between ptp and ptm in order to deliver MBMS content with minimum power consumption. Currently traditional technique of UE counting uses only a predefined number of UEs participating in a multicast session to determine when to switch from ptp to ptm and vice versa. We investigate the behaviour of both algorithms in several simulation scenarios with different parameters and finally we determine which are the advantages of the proposed algorithm compared to the UE counting algorithm.

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# 1. Introduction

Over recent years, telecommunications has been a fast-growing industry. This growth can be seen in the increasing revenues of major telecommunications carriers and the continued entry into the marketplace of new competitive carriers. No segment of the industry, however, has seen growth to match that experienced in mobile communications. From relatively humble beginnings, the last 15 years have seen an explosion in the number of mobile communications subscribers and it appears that growth is likely to continue well into the future. Third generation networks are being deployed to replace existing second-generation networks and to provide enhanced services to mobile users. These new networks promise to provide a global wireless infrastructure that will free users from the confines of static communication networks. The ubiquity of the underlying network will allow users to access the Internet from anywhere at anytime. As users adjust to the concept of a ubiquitous communication infrastructure, they will desire to run applications and access services that they currently have available to them on conventional wireline networks.

In particular, one class of application that consumers will likely desire to use on 3G networks are group-oriented applications whereby groups of users can interact with each other. In conventional IP networks, the use of multicast networking techniques is most appropriate for group-oriented applications since multicasting exploits the distribution of group members in the network to minimize packet duplication. The use of multicast in 3G networks, however, is at an early stage of development and is a direction for further research and development.

In this thesis a new algorithm called “power counting” is proposed in order to minimize the loss of power when a number of UEs increase or decrease during multicast sessions. The new algorithm takes into consideration all the drawbacks of previous algorithms and tries to implement a new one which will lead to a more realistic and adaptive power efficient algorithm. This thesis is organized as follows. In chapter 2 we give a detail theoretical framework over UMTS, RRM and Multicast and in chapter 3 we examine Power control in depth. Next the simulator of our results is described in chapter 4 and our results are explained in chapter 5. Finally we offer a conclusion of the proposed algorithm in chapter 6.

# 2. Theoretical Framework

## 2.1 UMTS

With the rapid convergence of mobile cellular telephony and personal digital assistants, customers will want services beyond mere phone calls. Further, mobile carriers will need to find alternative sources beyond traditional voice service charges for maintaining and increasing revenue. As a result, short message, emails, chat and web surfing services have sprung into existence. The next step in the development of wireless services is to improve the current services by providing the capability for integrating multimedia into wireless services. One can easily envision media-intensive applications, such as video conferences and subscription-based music services, which will be launched in the near future. Such services, however, require a cellular system such as proposed in third generation cellular that is capable of providing more bandwidth to the mobile consumer.

The 3G network architecture is designed to support both data and voice applications. The 3G network evolved from earlier 2G and 2.5G networks to provide higher bandwidth to users as well as the ability to access the Internet. One goal of the 3G network was to maintain similarity and compatibility with prior network architectures, such as GSM. Since there are different proposals for 3G network architectures, we shall focus our discussion on the *Universal Mobile Telecommunications Systems* (UMTS).

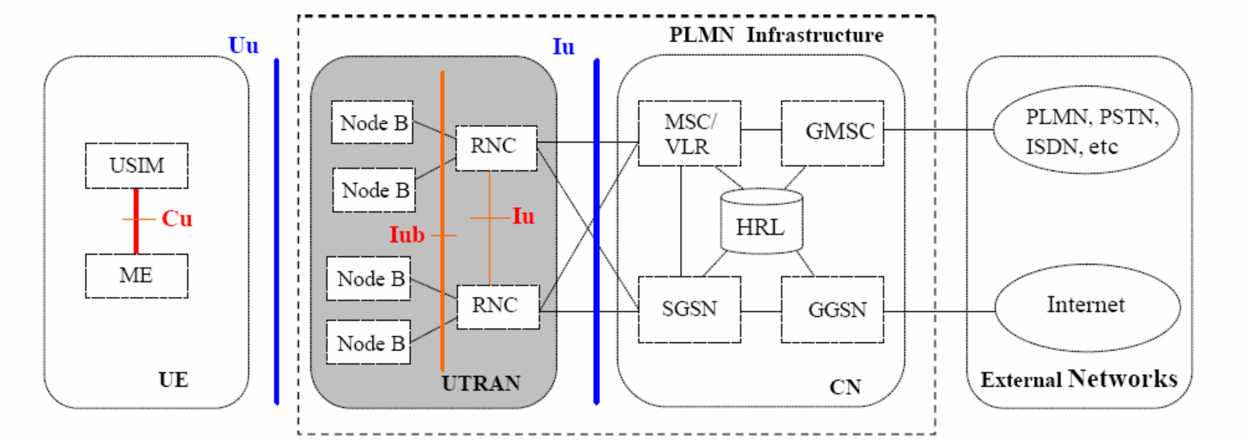

*Figure 1 – Basic Domain splitting of the 3G UMTS Network.*

In *Figure 1*, we present the basic components of a UMTS 3G network. The UMTS 3G network is split into two main domains: first, is the *User Equipment* (UE) domain; and second is the *Public Land Mobile Network* (PLMN) infrastructure domain. The User Equipment domain consists of the equipment employed by the user to access UMTS services. It consists of a radio interface to access the network services. The UE domain includes *terminal* equipment. The PLMN infrastructure consists of nodes that perform the various functions required to terminate the radio interface and to support the telecommunication service requirements of the users. The infrastructure is a shared resource that provides services to all authorized end users within its coverage area. The interface between UE and PLMN infrastructure domain is referred to as "Uu".

We will now explore UE and UTRAN functionalities and after that we will have a more detail description about Protocol structure and logical and transport channels.

### 2.1.1 User Equipment (UE) domain

The User equipment is further split into the *Mobile Equipment Domain* (ME) and *User Services Identity Module Domain* (USIM). The connection point between these two domains is "Cu" reference point. The USIM contains data and procedures needed to identify a specific user. These procedures seek to securely and explicitly identify the user and not the user equipment. In order to accomplish this, information identifying a user is typically embedded in a smart card, such as a SIM card. By associating the smart card to a given user, he is identified no matter which ME he uses.

### 2.1.2 UMTS Terrestrial Radio Access Network (UTRAN)

The UTRAN is the *UMTS radio access network* responsible for managing the mobile user's connection with the CN, and consists of *Radio Network Controllers* (RNC) and *base stations* (Node-B). Its boundaries are the Iu interface to the core network and the Uu interface to the UE. The purpose of the UTRAN system is: (1) to manage system access by performing congestion control and restricting user admission to the network, (2) to manage client mobility and perform any necessary handovers, and (3) to perform radio resource management through measuring channel conditions and applying suitable resource allocation mechanisms. The UTRAN can be further subdivided into several *Radio Network Systems* (RNS). Each RNS is composed of a single *Radio Network Controller* (RNC) and several Node Bs.

### *Radio Network Controller*

The RNC has a function similar to that of the BSC (base station controller) in GSM in the sense that it controls one or more Node Bs. The interface between the RNC and a Node B is named "Iub". The RNC manages all the radio related resources, and performs the following operations :

- Iub transport resources management;
- Control of Node B logical operation and maintenance (O&M)
- System information management and scheduling of system information;
- Traffic management of common cannels
- Macro diversity combining /splitting of data streams transferred over several Node Bs;
- Modifications to active sets; that is the soft handover
- Allocation of DL channelization codes;
- Uplink outer loop power control
- DL power control
- Admission control
- Reporting management;
- Traffic management of shared channels;

RNC can connect to MSC(IuCS) or SGSN (IuPS) via interface Iu.

***Node B***

A Node B is comparable to a base station transceiver in GSM. It may support one or more cells. Functions performed by a Node B include:

- Mapping of a Node B’s logical resources onto hardware resources;
- Transmitting of system information messages according to scheduling parameters given by the RNC;
- Macrodiversity combining/splitting of data streams internal to Node B;
- Uplink inner loop power control
- Reporting of uplink interference measurements and DL power information.

### 2.1.3 Protocol Architecture

*Figure 2* shows the air interface protocol architecture. The air interface is layered into three protocol layers:

- The physical layer (layer 1, L1);
- The data link layer (layer 2, L2);
- Network layer (layer 3, L3).

The physical layer interfaces the medium access control (MAC) sub layer of layer 2 and the radio resource control (RRC) layer of layer 3. The physical layer offers different transport channels to MAC. A transport channel is characterized by how the information is transferred over the radio interface. Transport channels are channel coded and then mapped to the physical channels specified in the physical layer. MAC offers different logical channels to the radio link control (RLC) sub layer of layer 2. A logical channel is characterized by the type of information transferred. Layer 2 is split into following sub layers: MAC, RLC, packet data convergence protocol (PDCP) and broadcast/multicast control (BMC). Layer 3 and RLC are divided into control and user planes. PDCP and BMC exist in the user plane only. In the control plane, layer 3 is partitioned into sub layers where the lowest sub layer, denoted as RRC, interfaces with layer 2. The RLC sub layer provides ARQ functionality closely coupled with the radio transmission technique used.

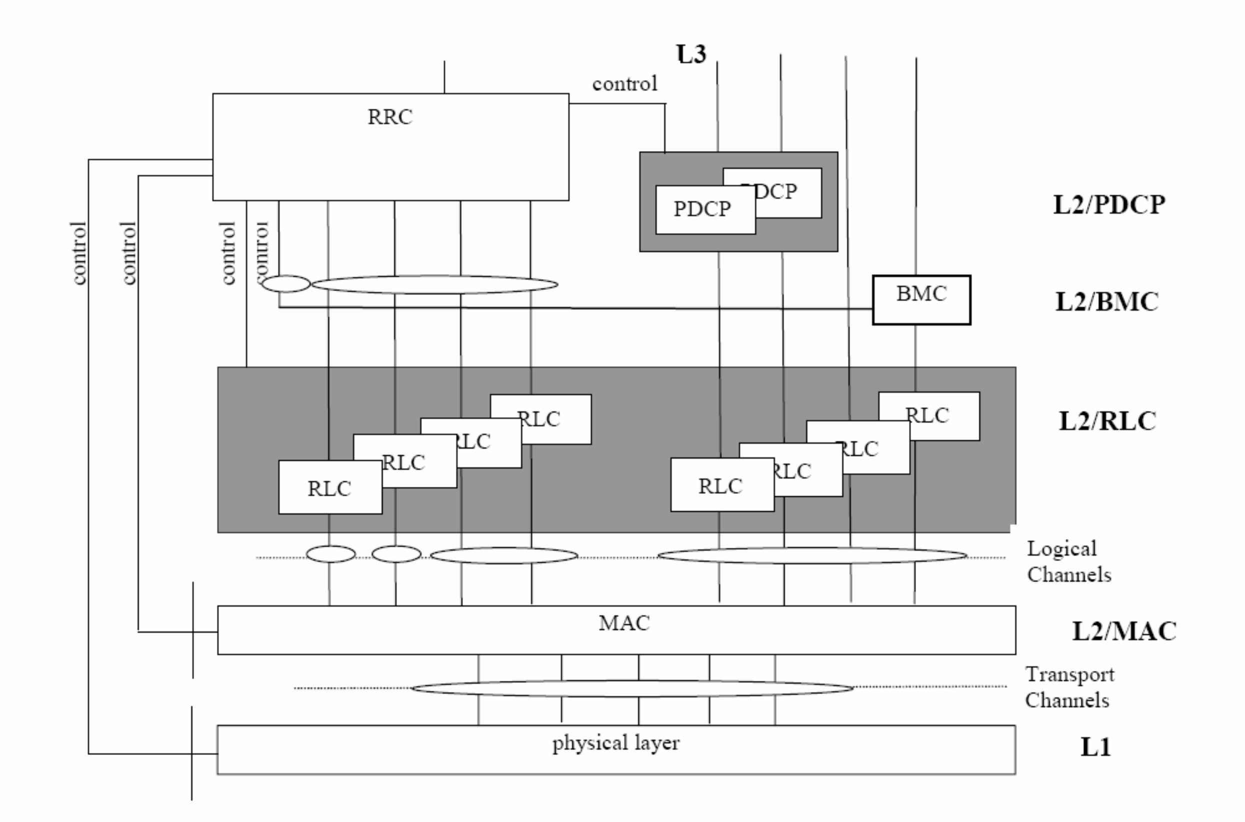

*Figure 2 – Air Interface Protocol Architecture*

### 2.1.4 Logical Channels

The MAC layer provides data transfer services on logical channels. A set of logical channel types is defined for different kinds of data transfer services as offered by MAC. Each logical channel type is defined by the type of information that is transferred. Logical channel types are depicted in *Figure 3*. Logical channels are classified into two groups:

- Control channels for the transfer of control plane information (Table 1)
- Traffic channels for the transfer of user plane information (Table 2 ).

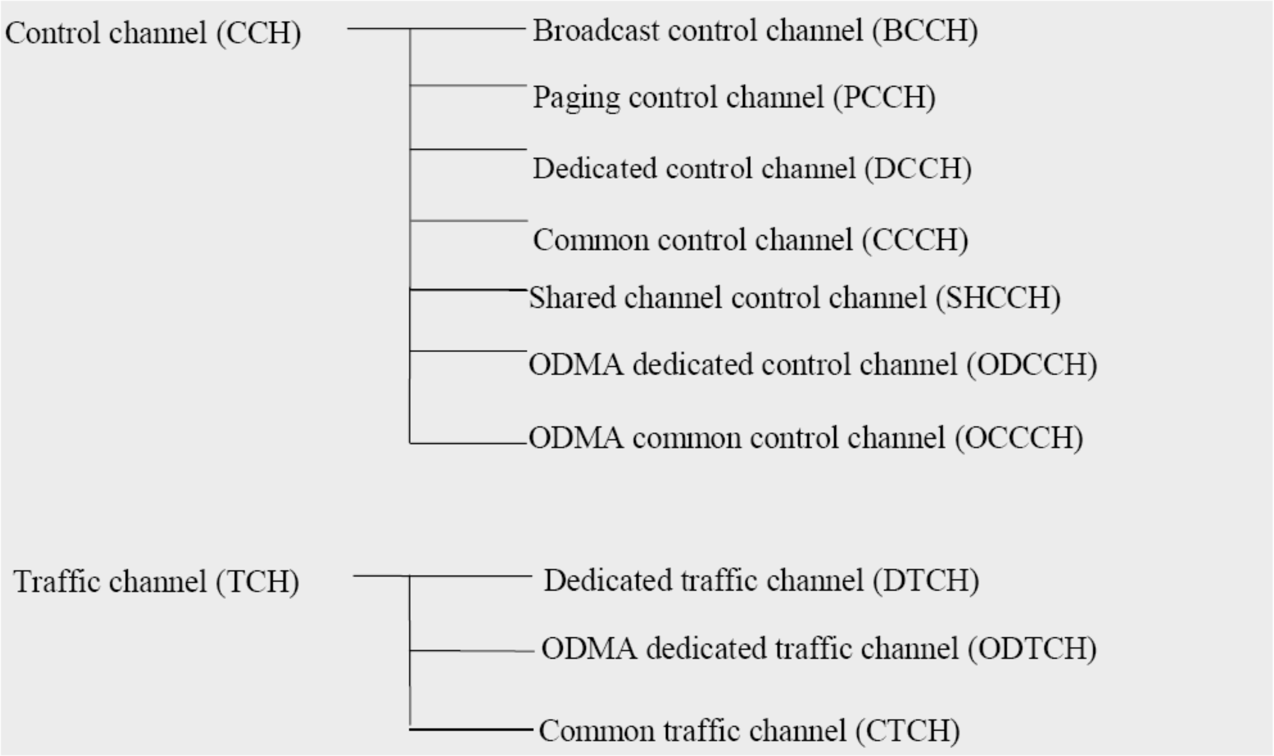

***Figure 3 – Logical Channel Structure***

| | |
|---|---|
| Broadcast control channel (BCCH) | Downlink channel for broadcasting system control information. |
| Paging control channel (PCCH) | Downlink channel that transfers paging information and is used when:<br>• Network does not know the location cell of the mobile station;<br>• The mobile station is in the cell connected state (utilizing sleep mode procedures). |
| Common control channel (CCCH) | Bidirectional channel that transfers control information between network and mobile stations. This channel is used:<br>• By the mobile stations having no RRC connection with the network;<br>• By the mobile stations using common transport channels when accessing a new cell after cell re- |

| | |
|---|---|
| | selection |
| Dedicated control channel (DCCH) | Point-to-point bidirectional channel that transmits dedicated control information between a mobile station and the network. This channel is established through RRC connection setup procedure. |
| ODMA common control channel (OCCCH) | Bidirectional channel for transmitting control information between mobile stations. |
| ODMA dedicated control channel (ODCCH) | Point-to-point bidirectional channel that transmits dedicated control information between mobile stations. This channel is established through RRC connection setup procedure. |

**Table 1 – Logical Control Channels.**

| | |
|---|---|
| Dedicated traffic channel (DTCH) | Point-to-point channel, dedicated to one mobile station, for the transfer of user information. A DTCH can exist in both uplink and downlink. |
| ODMA dedicated traffic channel (ODTCH) | Point-to-point channel, dedicated to one mobile station, for the transfer of user information between mobile stations. An ODTCH exists in relay link. A point-to-multipoint unidirectional channel for transfer of dedicated user information for all or a group of specified mobile stations. |

**Table 2 – Traffic Channels.**

### 2.1.5 Transport Channels

A transport channel is defined by how and with what characteristics data is transferred over the air interface. There exist two types of transport channels:

- Dedicated channels;
- Common channels, listed in *Table 3*.

There is one dedicated transport channel, the dedicated channel (DCH), which is a downlink or uplink transport channel. The DCH is transmitted over the entire cell or over only a part of the cell using beam-forming antennas. The DCH is characterized by the possibility of fast rate change (every 10 ms), fast power control, and inherent addressing of mobile stations.

*Figure 4* shows the mapping between logical and transport channels. The following connections exist:

- BCCH is connected to BCH and may also be connected to FACH.
- PCCH is connected to PCH.
- CCCH is connected to RACH and FACH.
- SHCCH is connected to RACH and USCH/FACH and DSCH.
- DTCH can be connected to either RACH and FACH, to RACH and DSCH, to DCH and DSCH, to a DCH, a CPCH (FDD only).
- CTCH is connected to FACH.
- DCCH can be connected to either RACH and FACH, to RACH and DSCH, to DCH and DSCH, to a DCH, a CPCH to FAUSCH, CPCH.

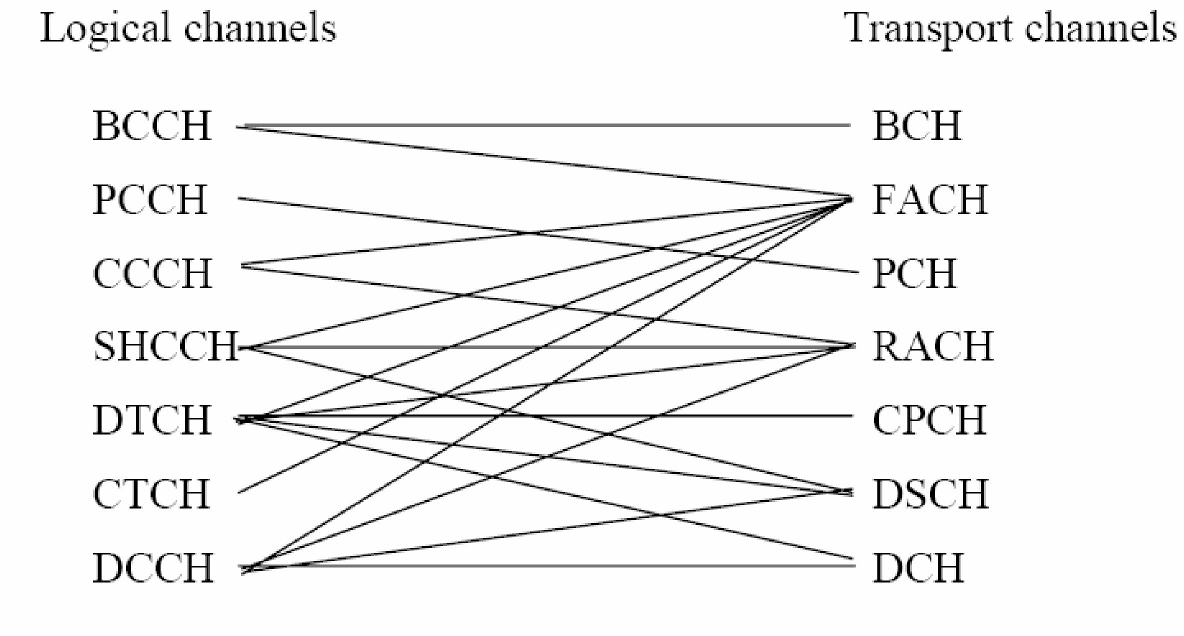

*Figure 4 – Mapping between logical and transport channels.*

| | |
|---|---|
| Broadcast channel (BCH) | Downlink transport channel that is used to<br>broadcast system- and cell-specific information. The BCH is always transmitted over the entire cell with a low fixed bit rate. |
| Forward access channel (FACH) | Downlink transport channel. The FACH is<br>transmitted over the entire cell or over only a part of the cell using beamforming antennas. The FACH uses slow power control. |
| Paging channel (PCH) | Downlink transport channel. The PCH is always transmitted over the entire cell. The transmission of the PCH is associ- |

| | |
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| | ated with the transmission of a physical layer signal, the paging indicator , to support efficient sleep mode procedures |
| Random access channel (RACH) | Uplink transport channel. The RACH is always received from the entire cell. The RACH is characterized by a limited size data field, a collision risk and by the use of open loop power control. |
| Common packet channel (CPCH) | Uplink transport channel. The CPCH is a contention-based random access channel used for transmission of bursty data traffic. CPCH is associated with a dedicated channel on the downlink, which provides power control for the uplink CPCH. |
| Downlink shared channel (DSCH) | Downlink transport channel shared by several mobile stations The DSCH is associated with a DCH. |

**Table 3 – Common Transport Channels**

### 2.1.6 Physical Channels

The transport channels are channel coded and matched to the data rate offered by physical channels. Thereafter, the transport channels are mapped on the physical channels. Physical channels consist of radio frames and time slots. The length of a radio frame is 10 ms and one frame consists of 15 time slots. A time slot is a unit, which consists of fields containing bits. The number of bits per time slot depends on the physical channel. Depending on the symbol rate of the physical channel, the configuration of radio frames or time slots varies.

There are two uplink dedicated physical and two common physical channels:

- The uplink dedicated physical data channel (uplink DPDCH) and the uplink dedicated physical control channel (uplink DPCCH);
- The physical random access channel (PRACH) and physical common packet channel (PCPCH).

The uplink DPDCH is used to carry dedicated data generated at layer 2 and above (i.e., the dedicated transport channel (DCH)). There may be zero, one, or several uplink DPDCHs on each layer 1 connection. The uplink DPCCH is used to carry control information generated at layer 1. Control information consists of known pilot bits to support channel estimation for coherent detection, transmit power-control (TPC) commands, feedback information (FBI), and an optional transport-format combination indicator (TFCI). For each layer 1 connection there is only one uplink DPCCH.

There is one downlink dedicated physical channel, one shared and five common control channels:

- Downlink dedicated physical channel (DPCH);
- Physical downlink shared channel (DSCH);
- Primary and secondary common pilot channels (CPICH);
- Primary and secondary common control physical channels (CCPCH);
- Synchronization channel (SCH).

On the DPCH, the dedicated transport channel is transmitted time multiplexed with control information generated at layer 1 (known pilot bits, power-control commands, and an optional transport-format combination indicator). DPCH can contain several simultaneous services when TFCI is transmitted or a fixed rate service when TFCI is not transmitted. The network determines if a TFCI should be transmitted. When the total bit rate to be transmitted exceeds the maximum bit rate for a downlink physical channel, multicode transmission is employed (i.e., several parallel downlink DPCHs are transmitted using the same spreading factor). In this case, the layer 1 control information is put on only the first downlink DPCH.

The physical downlink shared channel is used to carry the downlink shared channel. It is shared by users based on code multiplexing. As the DSCH is always associated with a DCH, the PDSCH is always associated with a downlink DPCH. For PDSCH the spreading factors may vary from 256 to 4. If the spreading factor and other physical layer parameters can vary on a frame-by-frame basis, the TFCI shall be used to inform the mobile stations of the instantaneous parameters of PDSCH.

Common pilot channel (CPICH) is a fixed-rate (30 Kbps, SF=256) downlink physical channel that carries a predefined bit/symbol sequence. There are two types of common pilot channels, the primary and secondary CPICH, as shown in *Table 4*.

The primary CCPCH is a fixed-rate (30 Kbps, SF=256) downlink physical channels used to carry the BCH. Common control physical channels are not inner-loop power controlled. The primary CCPCH is not transmitted during the first 256 chips of each slot. Instead, primary and secondary SCHs are transmitted during this period.

The secondary CCPCH is used to carry the FACH and PCH. The main difference between the primary and secondary CCPCH is that the primary CCPCH has a fixed predefined rate while the secondary CCPCH can support variable rate. Furthermore, a primary CCPCH is continuously transmitted over the entire cell while a secondary CCPCH is only transmitted when there is data available and may be transmitted in a narrow lobe in the same way as a dedicated physical channel (only valid for a secondary CCPCH carrying the FACH).

| | |
|---|---|
| Primary CPICH | Uses the same channelization code always;<br>Scrambled by the primary scrambling code;<br>One per cell;<br>Broadcast over the entire cell;<br>The primary CPICH is the phase reference for the SCH, primary CCPCH, AICH, PICH. It is also the default phase reference for all other downlink physical channels. |

| | |
|---|---|
| Secondary CPICH | Zero, one, or several per cell;<br>May be transmitted over only a part of the cell;<br>A secondary CPICH may be the reference for the secondary CCPCH and the downlink DPCH. If this is the case, the mobile station is informed about this by higher-layer signaling. |

**Table 4 – Primary and Secondary CPICH**

The synchronization channel (SCH) consists of two sub channels, the primary and secondary SCH. The primary SCH consists of a modulated code of length 256 chips, the primary synchronization code (PSC), transmitted once every slot. The PSC is the same for every cell in the system.

The secondary SCH consists of repeatedly transmitting a length 15 sequence of modulated codes of length 256 chips, the secondary synchronization codes (SSC), transmitted in parallel with the primary SCH. Each SSC is chosen from a set of 16 different codes of length 256. This sequence on the secondary SCH indicates to which of the code groups the cell's downlink scrambling code belongs.

## 2.2 Radio Resource Management

The Radio Resource Management is a responsibility solely taken care of by UTRAN. RRM is located in both UE and RNC inside UTRAN. RRM contains various algorithms, which aim to stabilize the radio path enabling it to fulfill the QoS criteria set by the service (e.g. Conversational, Streaming, Interactive, Background) using the radio path. The RRM algorithms must deliver information over the radio path, which is named UTRA Service. The control protocol used for this purpose is the Radio Resource Control (RRC) protocol.

The RRM algorithms are:

- Handover Control

- Power Control
- Admission Control (AC) and Packet Scheduling
- Code Management.

Next we will give a brief description for each RRM algorithm.

### 2.2.1 Packet scheduling (PS)

The Packet Scheduling controls the UMTS packet access, which is part of the radio resource management functionality in RNC. The functions of the PS are:

- To determine the available radio interface resources for NRT radio bearers.
- To share the available radio interface resources between NRT radio bearers.
- To monitor the allocation for NRT.
- To initiate transport channel type switching between common and dedicated channels when necessary.
- To monitor the system loading.
- To perform Load Control actions for NRT radio bearers when necessary.

Admission Control (AC) and PS both participate in the handling of NRT radio bearers. AC takes care of admission and release of radio access bearers (RABs). Radio resources are not reserved for the whole duration of the connection but only when there is actual data to transmit. PS allocates appropriate radio resources for the duration of a packet call, i.e., active data transmission.

PS is done on a cell basis. Since asymmetric traffic is supported and the load may vary a lot between UL and DL, capacity is allocated separately for both directions.

The cell’s radio resources are shared between RT and NRT radio bearers. The proportion of RT and NRT traffic fluctuates rapidly. A characteristic of the load caused by RT traffic is that it cannot be efficiently controlled. The load caused by RT traffic, interference from other cell users and noise, is called Non-controllable load. The remaining free capacity from the Planned Target Load can be used for NRT radio bearers on a best effort basis, as shown in Figure 5. The load caused by best effort NRT traffic is called the Controllable load.

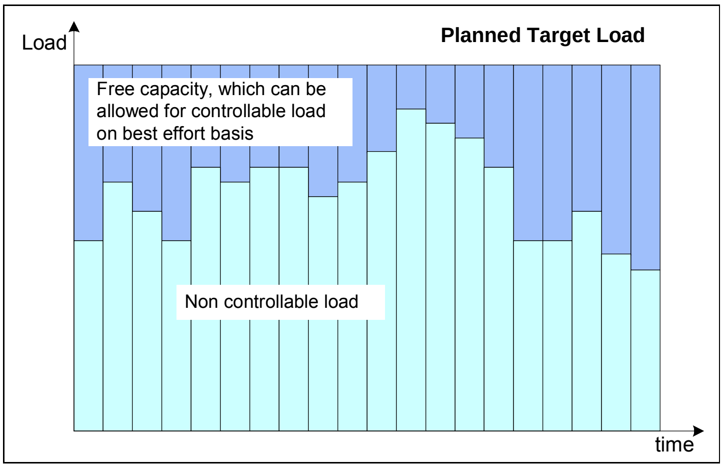


***Figure 5– Capacity division between Non Controllable and Controllable load.***

PS can decide the allocated bit rates and the length of the allocation. In W-CDMA this can be done in different ways, like code division, time division or power based.

### 2.2.2 Call Admission Control

CAC has the main task of deciding whether a new RAB can be admitted and/or a current RAB can be modified. Because of the different nature of the traffic, CAC consists of basically two parts. For RT traffic it must be decided whether a UE is allowed to enter the network. If the new radio bearer would cause excessive interference to the system, access is denied. For NRT traffic the optimum scheduling of the packets must be determined after the RAB has been admitted. The CAC algorithm estimates the load increase that the establishment or modification of the bearer would cause in the Radio Access Network (RAN). Separate estimates are made for UL and DL. The bearer set-up or modification request is accepted, the RAB is established or modified, or the packets are sent, only if both UL and DL admission criteria are fulfilled. CAC will use thresholds produced by RNP. CAC functionality is located in the RNC where all the information is available.

### 2.2.3 Load Control

Under normal circumstances the LC ensures system stability and that the network does not enter an overload state. In order to achieve stability the LC works with the CAC and with the Packet Scheduler (PS). This task is called preventive LC.

Only in special circumstances can the system be found in a situation of overload. When this happens the LC is responsible for reducing the load in a relatively fast way, bringing the system back to the desired state of operation. This state of operation is defined during the RNP process. The LC process is distributed between two types of network elements, the Node B and the RNC.

The actions that can be taken with the objective of reducing the load are:

- Actions for fast LC located in the Node B:
    - Denying the DL or overriding the UL Transmit Power “up” commands.
    - Lowering the reference SIR for the inner-loop PC in the UL.
- Actions for LC located in the RNC:
    - Interacting with the Packet Scheduler and reducing the packet data traffic.
    - Reducing the bit rates of RT users, e.g., voice services.

### 2.2.4 Handover

The basic concept of handover control is that when the subscriber moves from the coverage area of one cell to another, a new connection with the new target cell has to be set-up and the connection with the old cell may be released.

There are many reasons why handover procedures may be activated. The basic reason behind a handover is that the air interface connection between the UE and UTRAN does not fulfil the QoS criteria set for that connection (RAB) and thus the UE or the UTRAN initiates actions in order to improve the connection.

The number of handovers is straightforwardly depended on the degree of UE mobility. It is obvious that the faster the UE is moving, the more handovers it causes to the UTRAN. To avoid undesirable handovers, the UE with high motion may be handed over from micro cells to macro cells. In case of the UE is not moving or moving slowly, it can be handed over from macro cells to micro cells.

The decision to perform a handover is always made by the RNC that is currently serving the subscriber, except for the handover of traffic reasons which in that case the Mobile Switching Centre (MSC) will make the decision. The basic handover process consists of three main phases. These are measurement phase, decision phase and execution phase.

Handover measurement provision is a very important task for the system performance. This is because the signal strength of the radio channel may vary drastically due to fading and signal path loss, resulting from the cell environment (e.g. buildings, mountains) and user mobility. For the handover purposes and during the connection the UE continuously measures the signal strength concerning the neighbouring cells, and reports the results to the Serving RNC (SRNC).

Decision phase consists of assessment of the overall QoS of the connection and comparing it with the requested QoS attributes and estimates measured from neighbouring cells. Depending on the outcome of this comparison, the handover procedure may or may not be trigger. The SRNC checks whether the values indicated in the measurement reports meet the QoS specified for the end-user service. If not, then it allows executing the handover.

Depending on the diversity used in association with handover mechanisms, they can be categorized as hard handover, soft handover and softer handover.

Hard handover means that all the old radio links in the UE are removed before the new radio links are established. Therefore there are not only lack of simultaneous signals but also a very short cut in the connection

Soft handover is performed between two cells belonging to different BSs, but not necessarily to the same RNC. In any case the RNC involved in the soft handover must coordinate the execution to the soft handover over the Iur Interface. Soft handover means that the radio links are added and removed in a way that the UE always keeps at least one radio link to the UTRAN. Soft handover is performed by means of macro diversity, which refers to the condition that several radio links are active at the same time. In a soft handover event, the source and the target cells have the same frequency

Softer handover is a special case of soft handover where the radio links that are added and removed from the Active Set belong to the same Node B. The BS transmits through one sector but receives more than one sector. In this case the UE has active uplink radio connections with the network through more than one sector populating the same BS.

### 2.2.5 Power Control

In mobile communication systems such as 3G systems, which are based on the CDMA technique where all users can share a common frequency, interference control is a crucial issue. This is especially important for the UL direction, since one UE located close to the Node B and transmitting with excessive power, can easily overshoot mobiles that are at the cell edge (the near-far effect), block the whole cell, or even cause interference to UEs in neighbouring cells (inter-cell interference). In the DL direction the system capacity is directly determined by the required code power for each connection. Therefore, it is essential to keep the transmission powers at a minimum level while ensuring adequate signal quality and level at the receiving end. In W-CDMA a group of functions is introduced for this purpose. They are summarised as PC.

PC consists of open-loop PC, inner-loop PC (also called fast closed-loop PC), outer-loop PC in both the Uplink (UL) and the Downlink (DL) directions, and slow PC applied to the DL common channels. The RNP (Radio Network Planning) aspects of the PC functionality and the parameters involved are described next.

Open-loop PC is responsible for setting the initial UL and DL transmission powers when a UE is accessing the network. The slow PC is applied on the DL common channels. The inner-loop PC, adjusts the transmission powers dynamically on a 1500 Hz basis. The outer-loop PC estimates the received quality and adjusts the target SIR (Signal to Interference Ratio) for the fast closed-loop PC so that the required quality is provided. We will have a more detail description for the Power Control Algorithms in next chapter.

## 2.3 Overview in Multicast

Information is delivered over a network by three basic methods: unicast, broadcast, and multicast.The differences among unicast, broadcast, and multicast can be summarized as follows:

- Unicast: One-to-one, from one source to one destination.
- Broadcast: One-to-all, from one source to all possible destinations.
- Multicast: One-to-many, from one source to multiple destinations expressing an interest in receiving the traffic.

Unicast is the term used to describe communication where a piece of information is sent from one point to another point (*Figure 6*). In this case there is just one sender, and one receiver. Unicast transmission, in which a packet is sent from a single source to a specified destination, is still the predominant form of transmission on LANs and within the Internet. All LANs (e.g. Ethernet) and IP networks support the unicast transfer mode, and most users are familiar with the standard unicast applications (e.g. http, smtp, ftp and telnet) which employ the TCP transport protocol.

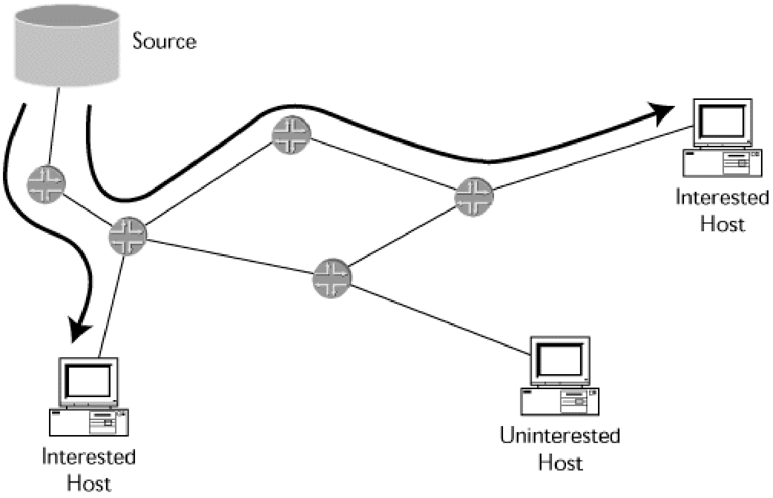


***Figure 6 – Unicast delivery***

Broadcast is the term used to describe communication where a piece of information is sent from one point to all other points. In this case there is just one sender, but the information is sent to all connected receivers.

Broadcast transmission is supported on most LANs (e.g. Ethernet), and may be used to send the same message to all computers on the LAN (*Figure 7*). Network layer protocols (such as IP) also support a form of broadcast which allows the same packet to be sent to every system in a logical network.Television networks use broadcasting to distribute video and audio. Even if the television network is a cable television (CATV) system, the source signal reaches all possible destinations, which is the main reason that some channels' content is scrambled. Broadcasting is not feasible on the public Internet because of the enormous amount of unnecessary information that would constantly arrive at each end user's device, the complexities and impact of scrambling, and related privacy issues.

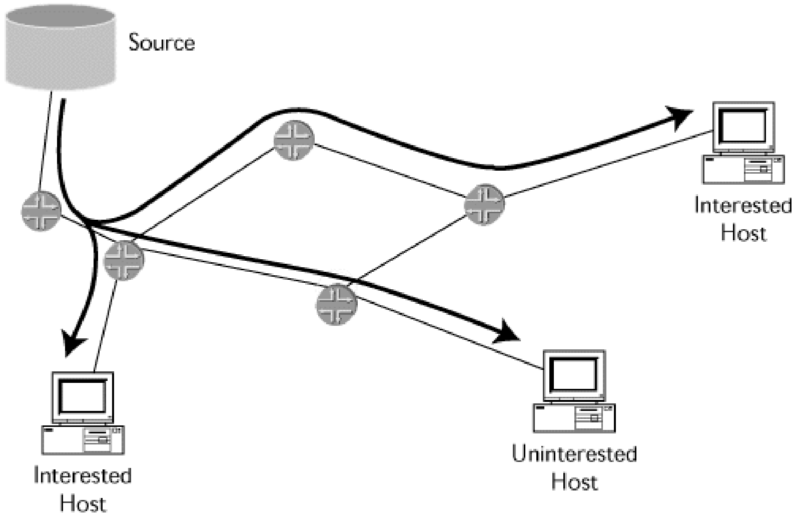


***Figure 7 – Broadcast delivery***

Multicast traffic lies between the extremes of unicast (one source, one destination) and broadcast (one source, all destinations) (*Figure 8*). Multicast is a "one source, many destinations" method of traffic distribution, meaning only the destinations that explicitly indicate their need to receive the information from a particular source will receive the traffic stream.

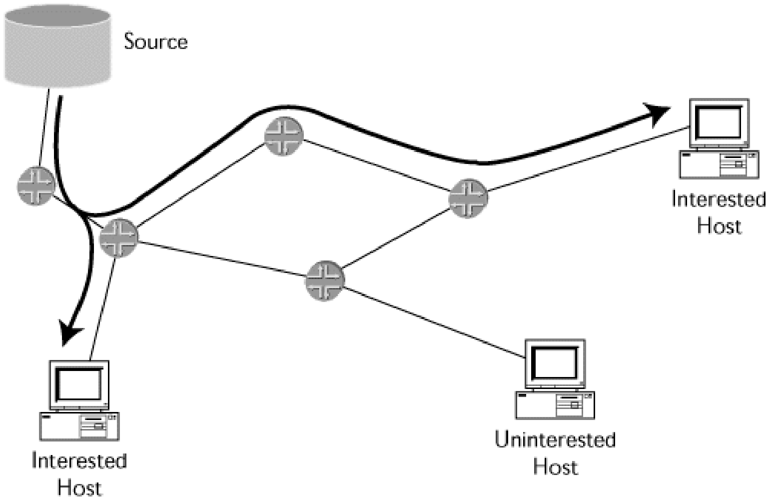


*Figure 8 – Multicast delivery*

Multicast is a clever technique to reduce network bandwidth demand when there are many receivers that want to listen to or view the same source. Instead of sending many streams of packets from the sender, one to each listener, with multicast all of the listeners listens to one and the same stream.

Multicast can be used by applications that require the delivery of packets from one or more senders to a group of receivers. These applications include bulk data transfer (e.g. multicast transmition of a software upgrade from the software developer to the users needing the upgrade), streaming continues media (e.g. audio, video), shared data applications (e.g. a whiteboard or teleconferencing application that is shared among many distributed participants) data feeds (e.g. stock quotes), interactive gaming and so on. One example of an application which may use multicast is a video server sending out networked TV channels. Simultaneous delivery of high quality video to each of a large number of delivery platforms will exhaust the capability of even a high bandwidth network with a powerful video clip server. This poses a major scalability issue for applications which required sustained high bandwidth. One way to significantly ease scaling to larger groups of clients is to employ multicast networking.

As in the case of broadcast, the processing load and the amount of bandwidth consumed by the transmitting host remain constant, regardless of audience size. The network is responsible for replicating the data and delivering it only to listeners who have tuned in to the station. Links that connect to uninterested listeners do not carry the traffic. This method provides the most efficient use of resources because traffic flows only through links that connect to end hosts that want to receive the data.To deliver data only to interested parties, routers in the network build a distribution tree. Each subnetwork  that contains at least one interested listener is a leaf on the tree. When a new listener tunes in, a new branch is built, joining the leaf to the tree. When a listener tunes out, its branch is pruned off the tree. Where the tree branches, routers replicate the data and send a single flow down each branch. Thus no link ever carries a duplicate flow of packets.

We will give a brief description how these mechanisms work.IP multicasting relies on two mechanisms: a group management protocol to establish and maintain multicast groups, and multicast routing protocols to route packets efficiently. The availability of better versions of these protocols is the primary driver behind multicast scalability. Multicast group Protocols (IGMP/MLD) manage packet communication between end stations and their local multicast router, letting them join or leave groups. When group membership is established, multicast packets, identified through a group address in the destination field of the IP header, are forwarded between routers using multicast routing protocols.

Multicast routing protocols construct distribution trees through the network and perform multicast forwarding. Distribution trees define the path that multicast traffic will take through the network to group members. These paths are based on source trees or shared trees. The simplest method is a source tree, with its root at the source and branches forming a spanning tree throughout the network. Because this type uses the shortest path through the network, it's also called a shortest path tree (SPT). Source trees guarantee minimal latency, but require more network resources because a separate branch is used to reach every group member.

Shared trees use a single common root placed at some chosen point in the network. This shared root is often called a rendezvous point. Multicast sources send their traffic to the rendezvous point (RP), which forwards traffic down the shared tree to all group members. Shared trees make more efficient use of network resources, but don't necessarily use an optimal path, which may increase packet latency.

The actions of receivers suggest two basic strategies for protocols to handle joining and pruning branches among a collection of multicast routers:

- Dense mode multicast—The assumption could be made that almost all possible subnets have at least one receiver wanting to receive the multicast traffic from a source, so the network is *flooded* with traffic on all possible branches, then pruned back as branches do not express an interest in receiving the packets, explicitly (by message) or implicitly (time-out silence). This is the *dense mode* of multicast operation. LANs are appropriate networks for dense mode operation.
- Sparse mode multicast—Alternately, the assumption could be made that very few of the possible receivers want packets from this source, so the network only establishes and sends packets on branches that have at least one leaf indicating (by message) a desire for the traffic. This is the *sparse mode* of multicast operation. WANs are appropriate networks for sparse mode operation, and indeed a common multicast guideline is not to run dense mode on a WAN under any circumstances.

Some multicast routing protocols, especially older ones, only support dense mode operation, which makes them inappropriate for use on the public Internet. Others allow sparse mode as well. If *sparse-dense mode* is supported, the multicast routing protocol allows some multicast groups to be sparse and other groups to be dense.

Finally the most popular multicast routing protocol is Protocol Independent Multicast-Sparse Mode (PIM-SM), which is being deployed widely across IP WANs. IP multicast provides an efficient and simple way for enterprise network managers to distribute information and a significant incentive for service providers to deliver affordable public multicast services in the near future.

### 2.3.1 MBMS Reference Architecture (Release 6)

MBMS architecture enables the efficient usage of radio-network and core-network resources, with an emphasis on radio interface efficiency.

MBMS is realised by the addition of a number of new capabilities to existing functional entities of the 3GPP architecture and by addition of a number of new functional entities.

The existing PS Domain functional entities (GGSN, SGSN, UTRAN, GERAN and UE) are enhanced to provide the 'MBMS Bearer Service'. In the user plane, this service provides delivery of IP Multicast datagram’s from the Gi reference point to UEs with a specified Quality of Service. In the control plane, this service provides mechanisms for:

managing the MBMS bearer service activation status of UEs (in the case of multicast)

outsourcing authorisation decisions to the MBMS User Service (i.e. to the BM-SC) (in the case of multicast) providing control of session initiation/termination by the MBMS User Service and managing bearer resources for the distribution of MBMS data (in the case or multicast and broadcast)

A particular instance of the MBMS Bearer Service is identified by an **IP Multicast Address** and an **APN Network Identifier.**

The boundary of the MBMS Bearer Service is the Gmb and Gi reference points. The former provides the control plane functions and the latter the user plane.

A functional entity, the **Broadcast Multicast Service Centre (BM-SC)** provides a set of functions for MBMS User Services. BM-SC functions for different MBMS User Services may be supported from the same or different physical network elements.

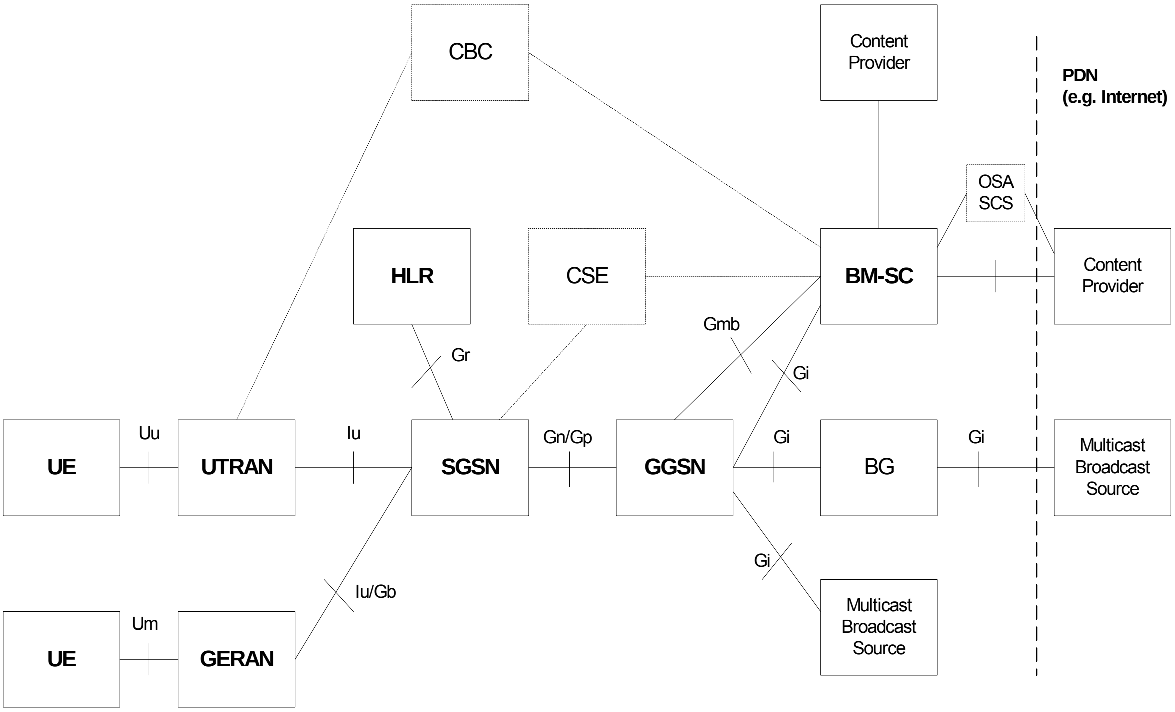


*Figure 9 - Reference Architecture to support MBMS*

### 2.3.2 Multicast Procedures

Reception of an MBMS Multicast service is enabled by certain procedures that are illustrated in the *Figure 10* below.

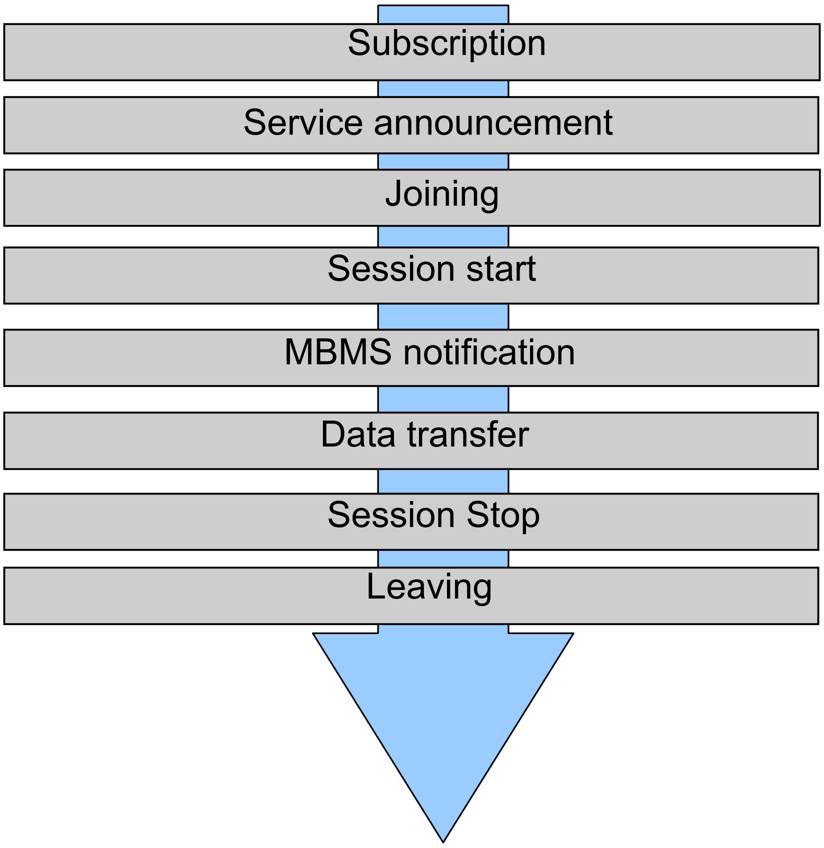


***Figure 10 - Phases of MBMS Multicast service provision***

The phase’s subscription, joining and leaving are performed individually per user. The other phases are performed for a service, i.e. for all users interested in the related service. The sequence of phases may repeat, e.g. depending on the need to transfer data. Also subscription, joining, leaving, service announcement as well as MBMS notification may run in parallel to other phases.

***Subscription***

Establishes the relationship between the user and the service provider, which allows the user to receive the related MBMS multicast service. Service Subscription is the agreement of a user to receive service(s) offered by the operator. Subscription information is recorded in the appropriate database(s) in the operator's network.

***Service announcement***

MBMS service announcement/discovery mechanisms shall allow users to request or be informed about the range of MBMS services available. This includes operator specific MBMS services as well as services from content providers outside of the PLMN. Service announcement is used to distribute to users information about the service, parameters required for service activation (e.g. IP multicast address) and possibly other service related parameters (e.g. service start time).

Operators/service providers may consider several service discovery mechanisms. This could include standard mechanisms such as SMS, or depending on the capability of the terminal, applications that encourage user interrogation. The method chosen to inform users about MBMS services may have to account for the users location, (e.g. current cell, in the HPLMN or VPLMN). Users who have not already subscribed to a MBMS service should also be able to discover MBMS services.

The following could be considered useful for MBMS service announcement mechanisms (not exhaustive):

- CBS
- MBMS Broadcast mode to advertise MBMS Multicast and Broadcast Services
- MBMS Multicast mode to advertise MBMS Multicast Services
- Push mechanism (WAP, SMS-PP, MMS)
- URL (HTTP, FTP)

The details of the MBMS service announcement mechanisms are not specified, but MBMS shall allow the utilisation of solutions using IETF protocols.

### ***Joining***

Joining (i.e. MBMS multicast activation by the user) is the process by which a subscriber joins (becomes a member of) a multicast group, i.e. the user indicates to the network that he/she is willing to receive Multicast mode data of a specific service.

### ***Session Start***

Session Start is the point at which the BM-SC is ready to send data. This can be identified with the start of a "Multicast session" as defined in the Stage 1. Session Start occurs independently of activation of the service by the user – i.e. a given user may activate the service before or after Session Start. Session Start is the trigger for network resources establishment for MBMS data transfer.

### ***MBMS notification***

Informs the UEs about forthcoming (and potentially about ongoing) multicast data transfer.

***Data transfer***

Is the phase when MBMS data are transferred to the UEs. Arrival of the first packet at the GGSN may coincide with Session Start.

***Session Stop***

Is the point at which the BM-SC determines that there will be no more data to send for some period of time – this period being long enough to justify removal of network resources associated with the session. At Session Stop, the network resources are released.

***Leaving***

Leaving (i.e. MBMS multicast deactivation by the user) is the process by which a subscriber leaves (stops being a member of) a multicast group, i.e. the user no longer wants to receive Multicast mode data of a specific service.

### 2.3.3 Broadcast Procedures

An example for the phases of MBMS broadcast service provision is described in the figure below:

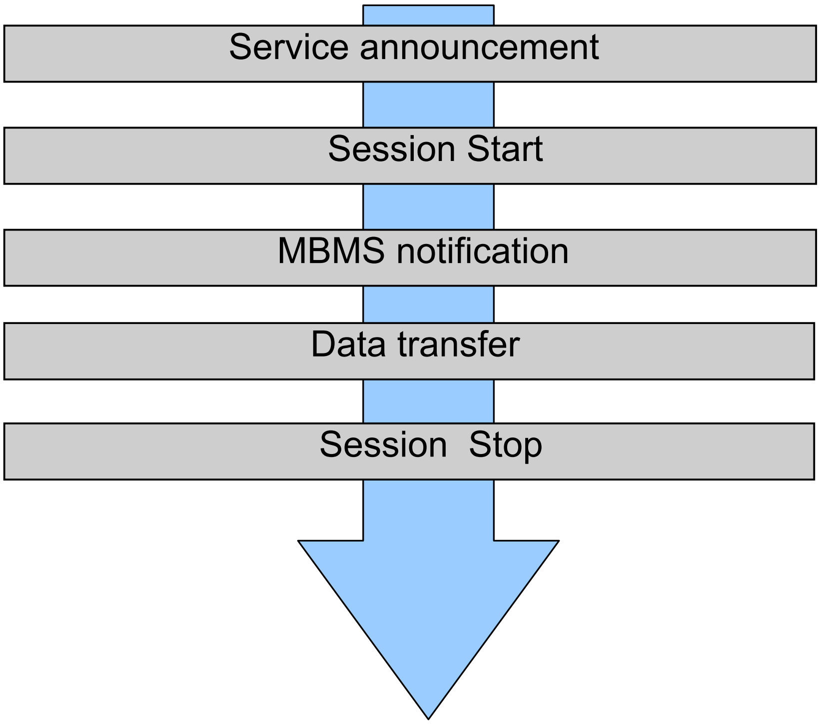


***Figure 11: Phases of MBMS broadcast service provision***

The sequence of phases may repeat, e.g. depending on the need to transfer data. It is also possible that the service announcement and MBMS notification phase may run in parallel with other phases, in order to inform UEs which have not yet received the related service.

**Service announcement**

Informs UEs about forthcoming services. Also see section on Multicast mode.

**Session Start**

Session Start is the point at which the BM-SC is ready to send data. This can be identified with the start of a "Broadcast session" as defined in the Stage 1. Session Start occurs independently of Service Activation by the user – i.e. a given user may activate the service before or after the start of the session. Session Start is the trigger for network resources establishment for MBMS data transfer.

**MBMS notification**

Informs the UEs about forthcoming (and potentially about ongoing) broadcast data transfer.

**Data transfer**

Is the phase when MBMS data are transferred to the UEs.

**Session Stop**

Is the point at which the MBMS application determines that there will be no more data to send for some period of time – this period being long enough to justify removal of network resources associated with the service. At Session Stop, the network resources are released.

# 3. Power Control

## 3.1 Power Control Fundamentals

In Wideband Code Division Multiple Access (WCDMA), power control is employed in both the uplink and the downlink. In the downlink direction the system capacity is directly determined by the required code power for each connection. Therefore, it is essential to keep the transmission powers at a minimum level while ensuring adequate signal quality and level at the receiving end. For the Uplink the main target of power control is to mitigate the near-far problem by making the transmission power level received from all terminals as equal as possible at the home cell. Due to its critical nature in WCDMA ( Because WCDMA is interference-limited), the power control for the connection is applied 1500 times per second.

To manage the power control properly in WCDMA, the system uses two different defined power control mechanisms. These power control mechanisms are:

- Open Loop Power Control (OLCP)
- Closed Loop Power Control (CLPC), including inner and outer Loop Power Control.

These Power Control Mechanisms work together, in order to keep the target SIR in acceptable level. Also these Power Control mechanisms (OLCP and CLCP) working together have considerable impact on the terminal's (UE) battery-life and overall system capacity.

### 3.1.1 Open Loop Power Control

In the Open Loop Power Control the UE adjusts the power based on an estimate of the received signal level for the BS CPICH (Common Pilot Channel) when the UE is in idle mode and prior to Physical Random Access Channel (PRACH) transmission. In addition to that, the UE receives information about the allowed power parameters from the cell's Broadcast Common Channel (BCCH) when in idle mode. The UE evaluates the path loss occurring and based on this difference together with figures received from the BCCH and the UE it is able to estimate what might be an appropriate power level to initialize the connection.

In DL ( which is very essential for our proposed algorithm ) the open-loop PC is used to set the initial power of the DL channels based on the DL measurement reports from the UE. This function is located in both the UTRAN and the UE. A possible algorithm for calculating the initial power value of the DPDCH when the first hearer service is set up is:

$$P_{Tx}^{Initial} = \frac{R \bullet (Eb/No)_{DL}}{W} \bullet \left(\frac{CPICH\_Tx\_power}{(Ec/No)_{CPICH}} - \alpha \bullet Ptx\_Total\right)$$

Equation 1

Where R is the user bit rate, (Eb/No)DL is the DL planned Eb/No value set during the RNP for that particular bearer service, W is the chip rate, (Ec/No)CPICH is reported by the UE, α is the DL orthogonality factor, Ptx_Total is the carrier power measured at the Node B and reported to the RNC and finally CPICH_TX_Power is the Common Pilot Channel transmitted power.

### 3.1.2 Closed Loop Power Control

In contrast with Open Loop Power Control, Closed Loop Power Control is utilized for adjusting the power when the radio connection has already been established. Its main target its to compensate the effect of rapid changes in the radio signal strength (due to the radio path environment, mobility etc.) and hence it should be fast enough to respond to these changes. Closed Loop Power Control, includes inner and outer Loop Power Control.

#### 3.1.2.1 Inner Loop Power Control

In the case of uplink CLPC mechanism, the BS commands the UE to either increase or decrease its transmission power with a cycle of 1.5 KHz (1500 times per second) with a fixed step size. This decision whether to increase or decrease the power, is based on the received SIR estimated by the BS. When the BS receives the UE signal it compares the signal strength with the pre-defined threshold value at the BS. If the UE transmission power exceeds the threshold value, the BS sends a Transmission Power Command (TPC) to the UE to decrease its signal power. If the UE transmission power is lower than the threshold target, the BS sends a TPC to the UE to increase its signal power.

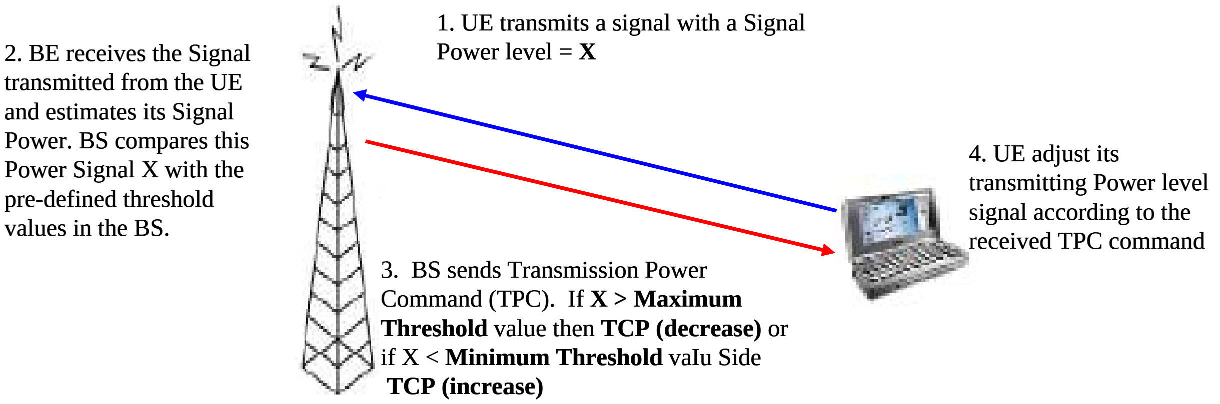


*Figure 12 – Inner Loop Power Control Air*

In the case of downlink CLPC mechanism the roles of the BS and the UE are interchanged. That is, the UE compares the received signal strength from the BS with a predefined threshold and sends the TPC to the BS to adjusts its transmission power accordingly.

The Inner Loop is the fastest loop in WCDMA power control and hence it is occasionally referred to as the Fast Power Control.

### 3.1.2.2 Outer Loop Power Control

The main target of Outer Loop Power Control is to keep the target SIR for the uplink Inner Loop Power Control in an appreciated quality level. Thanks to the macro-diversity, the RNC is aware of the current radio connection conditions and quality. Therefore, the RNC is able to define the allowed power levels of the cell and target SIR to be used by the BS when determining the TPCs. In order to maintain the quality of the radio connection, the RNC uses this power control method to adjust the target SIR and keep the variation of the quality of the connection in control. In fact, Outer Loop Power Control fine-tunes the performance of the Inner Loop Power Control.

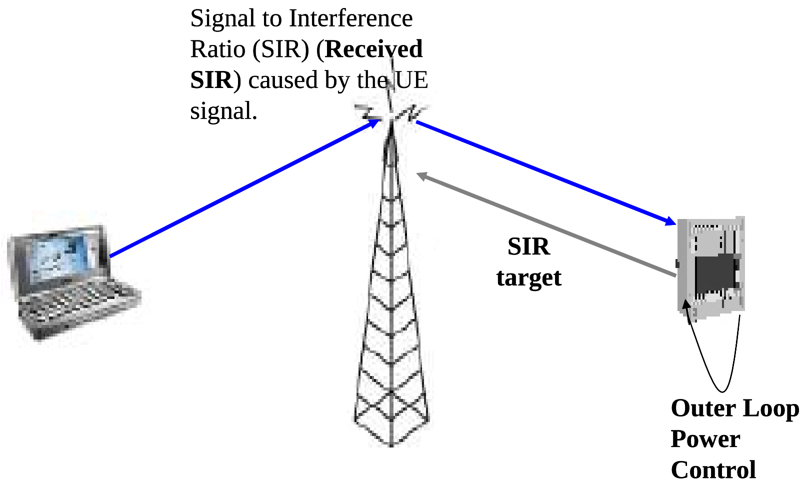


**Figure 13 Outer Loop Power Control**

## 3.2 Power control for MBMS

Here, we would like to review the characteristics of Point to Point (PTP) and Point to Multipoint (PTM) transmission for an efficient multicast transmission.

- PTM transmission (FACH Channel) uses single channel reaching down to cell edge which conveys identical traffic. The transmitted power for this channel is fixed and independent of the number of users, as there is no power control.
- PTP (DCH Channel) transmission uses dedicated channel allocated to each user which conveys identical content. Each channel has the capability of power control, so, the transmission power needs only the necessary strength to reach the UE. More over, because of the independent channel, individual ciphering and QoS control are also facilitated.

PTM is efficient when large number of users are present in the cell, but can be inefficient when used by a small number of users. PTP is efficient when used by a small number of users, but inefficient when used by a large number of users because of radio capacity. It’s just a trading-off relationship.

The number of users is time dependant and can change in accordance to user mobility. So, even though initially the one transmission method is used, it may need a change to the other transmission method soon after for efficient operation.

A central theme of this thesis is to consider what type of condition is preferable for switching from one transmission method to the other. The criteria for the decision of the threshold value for switching has not been satisfactorily addressed till now. A popular approach has been the UE counting algorithm [9]. In this algorithm a predefined number of UEs (threshold value) is used to take a decision for switching from one transmission to another. The threshold is often calculated by assuming that all users are distributed statistically or uniformly in one cell. This is not a realistic approach because of the user mobility and the location of user is not uniformly distributed in the cell, e.g. some users could be located at the cell edge, and some could be close to the Node B. It could also be assumed that all the users are located close to the cell antenna. Lets give an example. The threshold value is set to 10 and the number of the users in the cell is 9, if the criteria to select the PTP or PTM is based on the number of users, the RNC simply selects the PTP because the number of users is below the threshold. In this case, the total transmission power needed may be more than what is expected if all users are located at the cell edge. Similarly, if we consider that the number of users is 11, then the RNC will select the PTM. The power would be wasteful if all the users are located near the cell antenna. It is therefore proposed that the number of UEs criterion alone is not preferable to decide PTP or PTM. In both cases in the example given above, the selection of PTP or PTM should be examined by considering other radio environment criteria as well, as for example power considerations.

Furthermore, other factors, such as signalling load, need to be considered. Switching between channels might add complexity over Iub/Iur and signalling requirements over the air interface.

Another important factor that needs to be examined is the possibility of the ping pong effects (similar to Hard Handover). To illustrate, consider the case just after the threshold is exceeded, and a switch to p2m has been executed. If shortly afterwards, the number of UEs is less that the threshold, for example due to UE mobility or disconnections, a switch would again be initiated. If this continues with the number of UEs just exceeding or just under the threshold then we would have frequent switching, which add considerably to the signalling load in the system. This can be likened to a relay controller, and it is well studied in the controls literature. A common approach to minimise the switching around the threshold value is to consider a hysteresis zone. This will be discussed later. It is worth pointing out that ping-pong effects would cause

- unacceptable signalling load in UTRAN (the SRNCs of the UEs involved could all be different so that Iur is also involved),
- additional signalling load for physical channel reconfiguration via the air interface, and
- Possibly even a further QOS degradation just because of the fact that a switch happens between p2p and p2m.

Next, we propose a new algorithm which takes into consideration all the implications that we discussed above and addresses the drawbacks of the UE counting algorithm, in order to deliver a power efficient, with accepted QoS, reliable multicast content to the UEs.

### 3.3 Proposed Power control algorithm (Power counting algorithm)

Power transmitted in DCH channels is highly dependant on the distance of UEs from the Node-B because of the power control inner loop. The UE counting mechanism ,as explained above, does not take into consideration the average distance of the UEs from the Node-B. If we use scenarios without mobility (static UEs), this algorithm could be very efficient but as we already know mobility is a very critical issue in mobile networks and cannot be ignored: the UEs average distance is variable due to mobility. Thus, mobility is making UE counting inefficient and a threshold based on the number of UEs is difficult and impractical to decide.

Our proposed algorithm ,called power counting , defines a new metric to decide when it is more efficient to use one of the multicast channels..A power threshold instead of a UE threshold is proposed which means that the decision for the switch is depended only on the total power of one of the two channels (p2p with DHC channels or p2m with FACH channel ).

The SDL state diagram of our algorithm is shown in figure 12**Error! Reference source not found.**. When a multicast session begins, all the UE participating in it are in p2p mode because we assume that at the beginning is more likely to have small number of UEs participating in the multicast session rather than large number. After the initiation period ends RNC decides if is better to change to p2m or stays in p2p channel. Next we will demonstrate how our algorithm decides to change from one mode to another taking into consideration only the continuous average of the power over most recent interval of width equal to a “window” of 5sec (moving average). We use moving average in order to minimize the probability of unnecessary switches due to sudden increase of the power in DCH channels. This is a new mechanism among others to help avoid the ping pong effects. The selection of 5 seconds update period is based on the assumption that end Users can make a significant change of there position within that particular interval. This is just an empirical estimation. A different update interval or a dynamic interval could be an enhancement in the future.

Our algorithm is a periodic procedure which with an update period of 5 sec. It is executed in the RNC with power threshold,,instead of UE counting threshold, which switches from one to the other channel (PTP to MTM and vice versa).

The decision steps of the proposed algorithm are listed below.

- If currently p2p channels are used and the total DCH total power is 10% higher than p2m channel then we initiate a switch to p2m channel.
- If we currently use p2m channel and the calculated DCH total power is 10% less than p2m power we initiate a switch to p2p.

In order to eliminate unnecessary ping pong effect and to reduce traffic overheads due to the switch from one channel to another we added a threshold deadzone between the switches equal to 10% of the FACH power. With this threshold interval we achieve:

- 10% power gain for every switch - every time we switch from one channel to another we have 10% power gain, so we don't have to worry about other factors that effect network performance, like traffic overhead, since power gain is far more important.
- power interval of 20% of the FACH power between the switch decisions – If we make a decision to switch to one channel ( from p2m to p2p for example ) it will need 20% of the FACH power to exceed the switch threshold in order to switch back to the previous channel (p2m).This provides us an additional mechanism to avoid ping pong effects.

The selection of the 10% deadzone can of course be made dynamic and dependant on other network state factors, however this is a matter for further research.DCH total transmitted power is the only metric that our algorithm needs to calculate, since the power of FACH channel is known and constant. If we are in p2p mode is easy to calculate the total power of the DCH channels (the power sum of all the channels participating in p2p mode). The difficulty lies in how to find the power of DCH channel when we are in p2m channel since RNC is using FACH to transmit MBMS content. Our approach is to calculate the power needed from DCH channels when we are in p2m channel using the downlink open loop power control, which is located in the RNC and easily accessible.

Open Loop Power Control is an ongoing procedure which is responsible to adjust the power when the UE is in idle mode and prior to Physical Random Access Channel (PRACH) transmission. We use the results of OLPC to find the total power of the DCH channels if the UEs were in p2p mode. As we can see from equation 1 (OLPC equation) all the necessary information to calculate the power is available, so no modifications or additions are required form the network in order to deploy our algorithm.

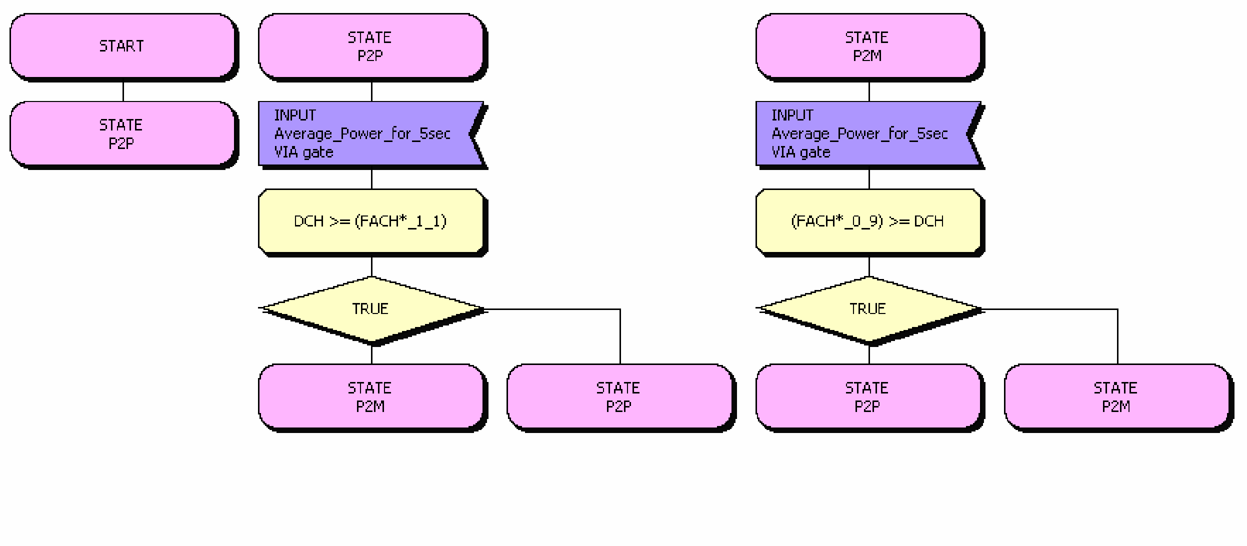


*Figure 14: SDL Diagram of power counting algorithm*

In the next chapter we will demonstrate simulation results for the performance evaluation of our algorithm for many environments.

## 4. Simulation Environment (OPNET)

For the performance evaluation of the proposed scheme we use OPNET simulator in order to simulate different environments. OPNET's UMTS model suite allows you to model UMTS networks, to evaluate end-to-end service quality, throughput, drop rate, end-to-end delay, and delay jitter through the radio access network and the core packet network. It can also be used to evaluate the feasibility of offering a mix of service classes for given quality of service requirements. This model is available as part of OPNET's specialized model library.

OPNET supported node models are grouped in the UMTS and UMTS_advanced object palettes. A short description for each model we use in our simulation is presented in the table below.

| | | |
|---|---|---|
| UE | Umts_station | General client node that includes UE and generic traffic generation functionality. This node can only send traffic to (and receive traffic from) other umts_station nodes served by the same SGSN. |
| Base station | Umts_node_b_adv | Node-B portion of the UTRAN. |
| RNC | Umts_rnc_adv | RNC portion of the UTRAN. |
| CN | Umts_sgsn | Simple CN node—has core network functionality, but does no IP routing. Routes packets to and from umts_station nodes, exclusively. |

**Table 4 – Opnet Models.**

One can configure the UMTS network model to use either of the following configurations:

- UMTS workstation nodes routing application traffic (e-mail, ftp,...) through one or more CN nodes to other UMTS workstation or server nodes, or to workstations and servers running over other technologies, such as Ethernet or WLAN.

- UMTS station nodes sending generic data traffic to other UMTS station nodes though a single SGSN node.

Worth noting that one cannot send application traffic to a UMTS station node, nor can one send traffic generated by a station node to a UMTS workstation or server node. When using the UMTS workstation nodes, one can use the application models to generate traffic as for any workstation node. Using the station and SGSN nodes allows one to configure a traffic generation pattern that is not application-based. This avoids the need to use the application models when one is not interested in application-specific performance in the UMTS network.

The following diagrams illustrate the supported types of UMTS network configurations:

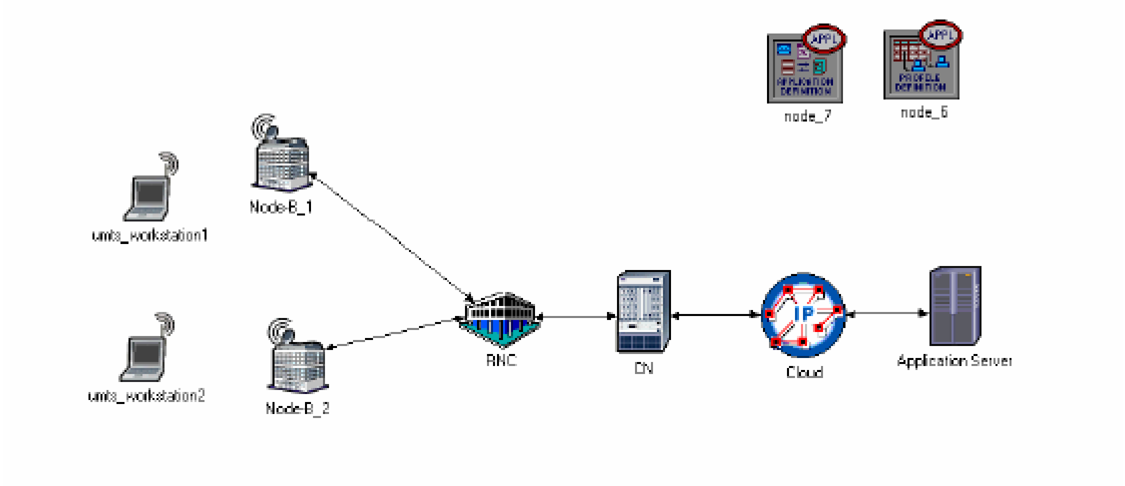


*Figure 15: Simple UMTS Network Using Application Traffic*

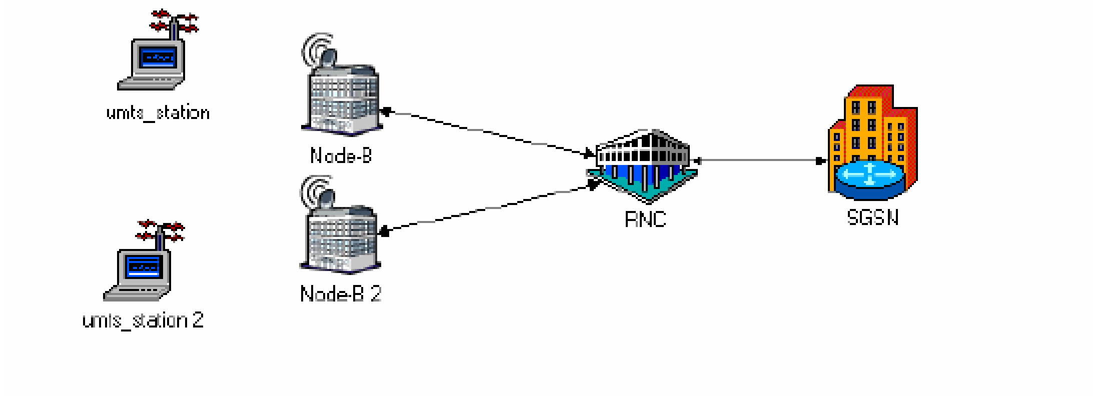


*Figure 16: Simple UMTS Network Using Raw Traffic Generation*

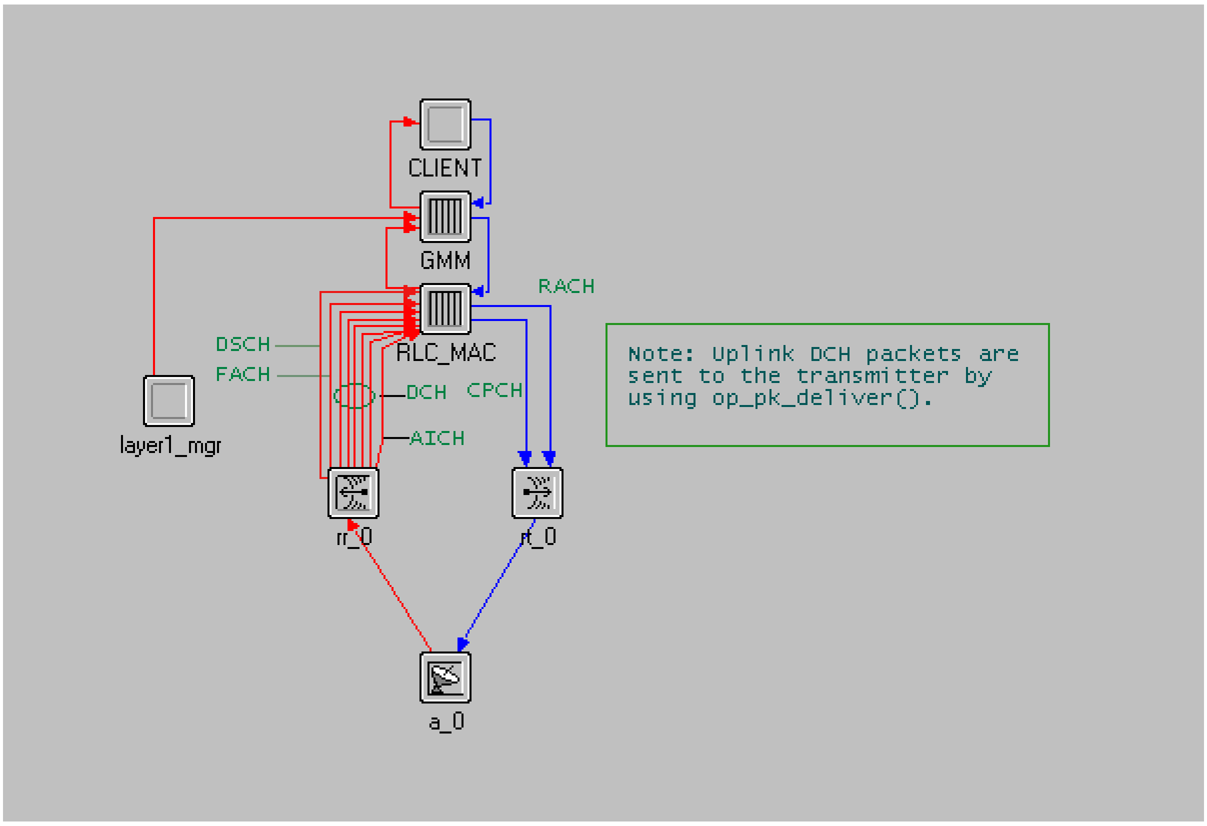
Next we present each model architecture used in our simulations. We will demonstrate only the process models of each node in order to have a more general idea for the structure of each node.

## 4.1 UE Node Model Architecture

The UMTS station model shown in *Figure 17* includes an application layer that feeds directly into the GMM layer. It also includes the RLC/MAC layer, a radio transmitter and receiver, and one antenna.

The GMM layer contains functions from the GMM, GSM, and RRC layers. It has mobility management functions (such as GPRS attach), session management functions (such as PDP context activation), and radio resource control functions (such establishment and release of radio bearers). The RLC/MAC layer contains the RLC and MAC layers. It includes priority handling of data flows, the three types of RLC modes, and segmentation and reassembly of higher-layer packets.

The links between the radio transmitter and the RLC/MAC layer and between the radio receiver and the RLC/MAC layer represent transport channels. On the uplink, there can be one random access channel (RACH), one common packet channel (CPCH), and one dedicated channel (DCH) where signaling and data traffic converges. Each transport channel in the dedicated channel has a unique spread code that distinguishes it from other transport channels. On the downlink, there can be one forward access channel (FACH), one downlink shared channel (DSCH), one acquisition indicator channel (AICH), and one dedicated signaling channel per user, and up to four data channels. The number of signaling and data channels on the downlink is equal to the number of signaling and data channels on the uplink; the exception to this is the DSCH, which has one extra channel. Each channel is assigned a different spread code and traffic on all channels can be sent simultaneously.



Note: Uplink DCH packets are sent to the transmitter by using op_pk_deliver().

*Figure 17 :Ue Node Model*

## 4.2 Base station Architecture

The Node-B node model includes one node_b processor module for each sector it manages. The node_b processor module is connected to an ATM stack, a transmitter module, and a receiver module. Each packet stream between the node_b module and the transmitter represents a downlink channel and each stream between the node_b module and the receiver represents an uplink channel. In the downlink direction, packets are forwarded to the transmitter on the FACH or DSCH streams, or on the dedicated channel DCH.In the uplink direction, all packets travel over the RACH, CPCH (not modeled in the current release), or DCH streams. All DCH packets converge at the DCH input stream, regardless of their channel or spreading code.

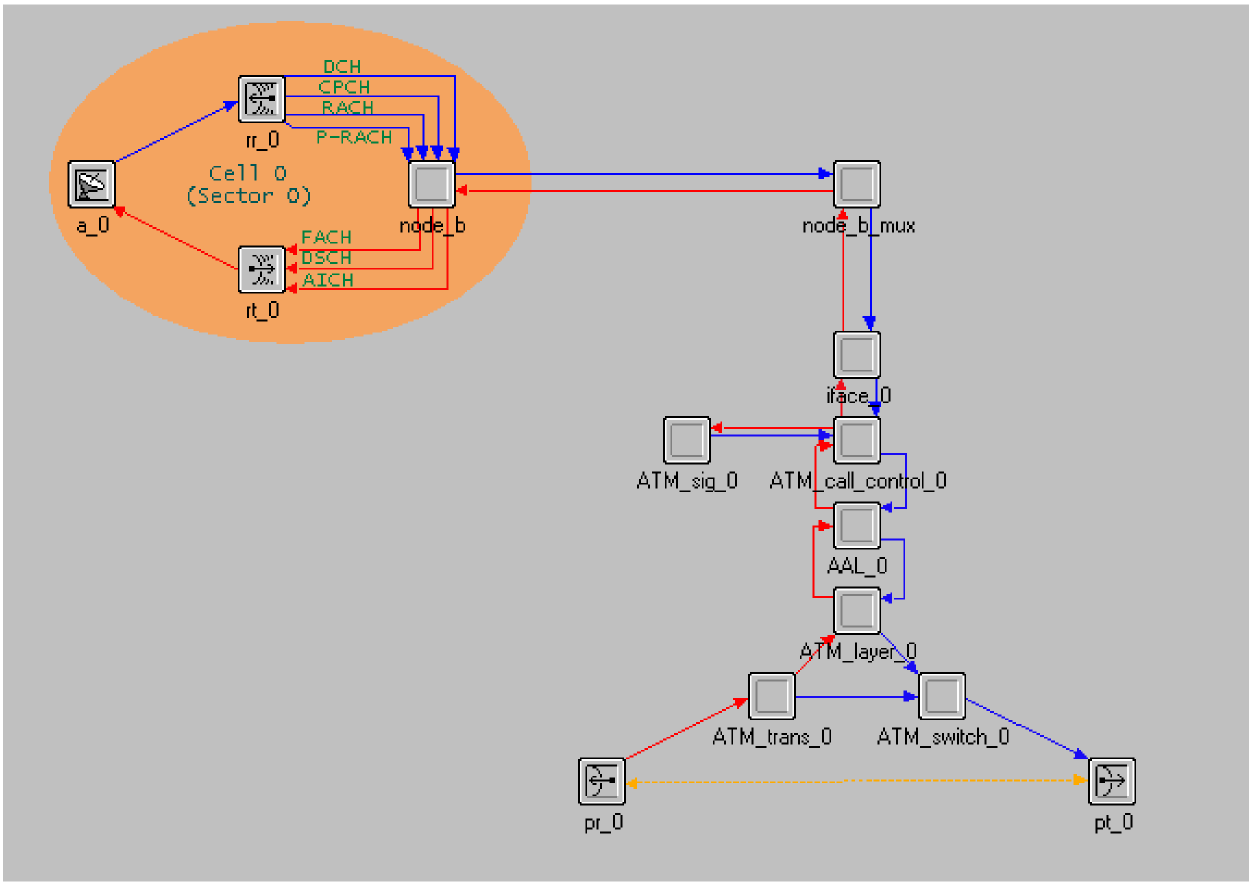


***Figure 18: Node-B node model***

## 4.3 RNC architecture

The RNC Node model consists of a single processor module that runs a process that performs the functionality of the RNC. It has nine ATM stacks attached to it, one of which connects to the SGSN servicing the RNC. The other eight will connect to Node-B ATM stacks. The RNC process model can determine which type of node exists at the other end of any given connection, so the RNC can connect any of these stacks to either a Node-B or SGSN so long as no more than one RNC connects to it and at least one Node-B connects to it. The total number of supported node-Bs can be increased by adding more ATM stacks to the node structure.

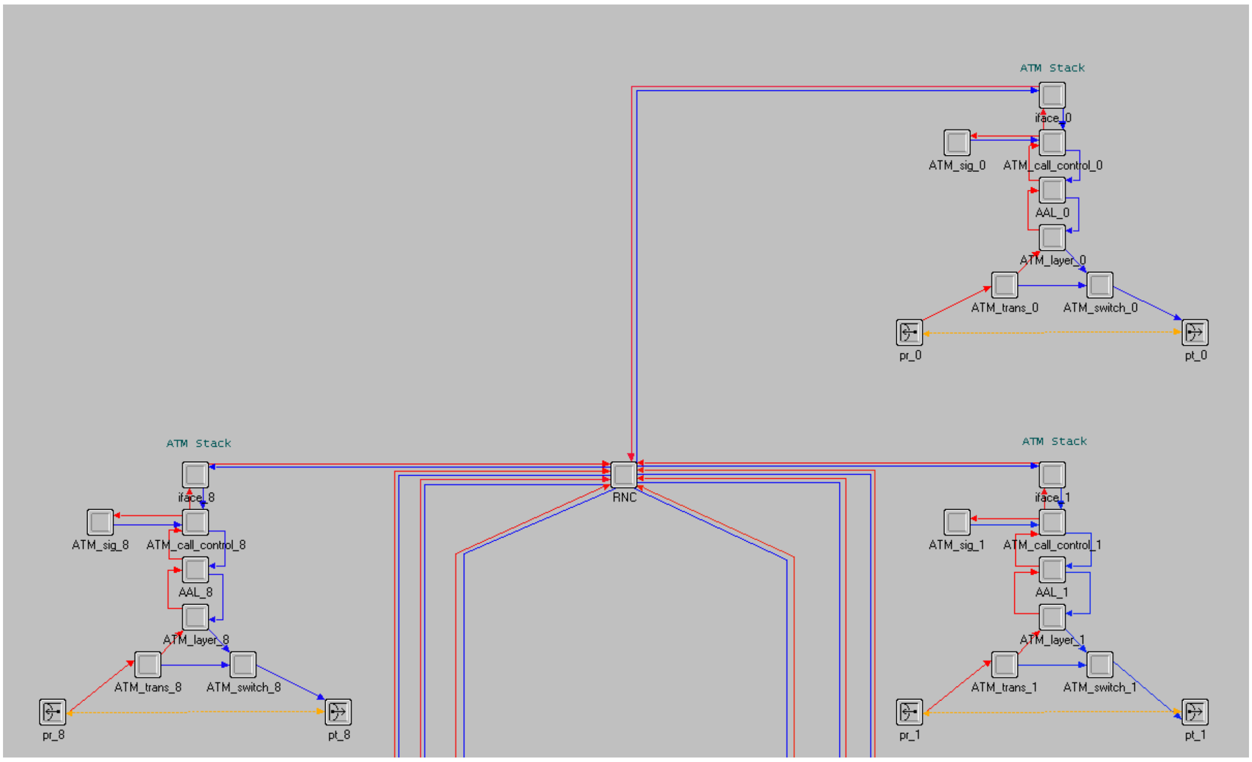


*Figure 19: RNC Node model*

## 4.4 CN architecture

The simple CN node model (*Figure 20*) includes the SGSN module and variable Similar to RNC we have ATM stacks for communications with the RNCs.

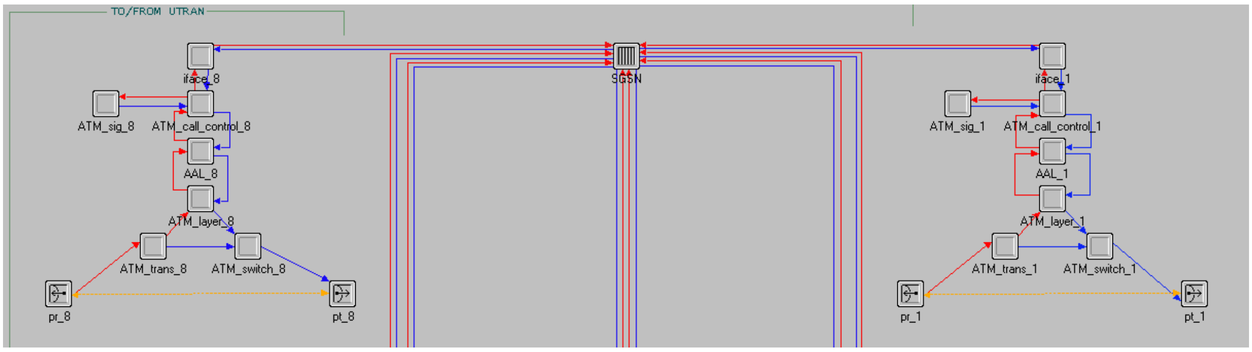


*Figure 20: Simple CN node model*

## 5. Simulation Scenarios and Results

In the process of understanding the behaviour of each channel in supporting MBMS content in a power efficient way we examined several scenarios. We investigate the benefits of power control counting, versus the disadvantages of using UE counting. In each scenario we obtain results which allow us to examine the effects of our algorithm.

In our simulations we use a simple UMTS Network using Raw Traffic Generation (*Figure 16* ) because we wanted to show the performance of our network in terms of power consumption only without considering other factors e.g. the application transmission throughput, delay in the CN or in the  RNC, etc...  We defined a number of UEs in the same cell that generate traffic, called servers, and send to another group of UEs, called clients, in a different cell. Since multicasting in OPNET UMTS model is not supported yet[†] we assume that client UEs belong to the same multicast group and receive multicast content from one server which is represented by several UEs (server UEs in our simulation ).

The number of users and the average distance from Node B are progressively increased. The traffic generated is streaming video and the flow is one way, from the server UEs to the client UEs. The Node Bs are both connected to the same RNC, thus belong to the same RNS (Radio Network Subsystem) and the RNC is finally connected to the CN. Since we want to evaluate only the primary signals and the downlink power between the UEs and the Node Bs, we set the active set size (for soft handover) to be equal to 1. With this we can assume that a UE can be connected with only one Node B at a time and the necessary transmitted power for each UE, in order to have accepted QoS, is taken from one Node-B. This assumption will not effect the performance of our algorithm in real circumstances (with active set equal to 3 ). To the contrary, we add this assumption in order to eliminate the probability of transmitting less power from one Node-B due to soft handover making, our interpretation of the results more accurate, especially when our UEs are in the edge of a cell..For example if we had a number of client UEs at the edge of the serving cell the primary Node-B

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[†] Since the study was initiated a multicast UMTS OPNET simulator, based on MBMS was developed within the IST B-BONE project. It is the intention of the project to contribute these model to OPNET contributed models.

wouldn't have to transmit in maximum power if the active set size was greater than 1, since the combination of the power of the neighborhood Node-B would help the client UE to have acceptable QoS.

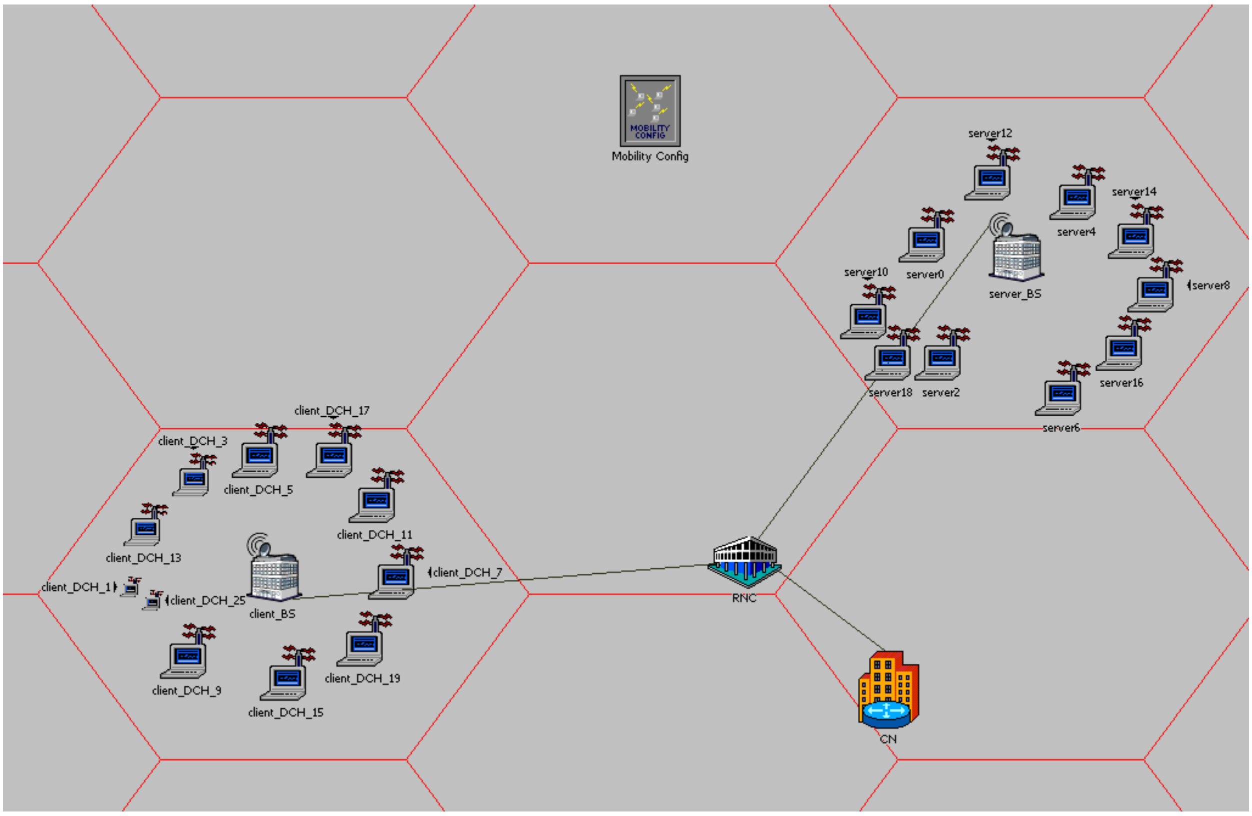


***Figure 21: Simulation Scenario***

Table 5 gives a summary of the possible cell types to be used in the various cell lay-outs.

| **Cell Type** | **Typical Cell Radius** | **Typical Position of Base Station Antenna** |
|---|---|---|
| Macrocell (large cell) | 1km to 30 km | outdoor; mounted above medium roof-top level, heights of all surrounding buildings are below base station antenna height |
| small macrocell | 0.5 km to 3 km | outdoor; mounted above medium roof-top level, heights of some surrounding buildings are above base station antenna height |

| | | |
|---|---|---|
| microcell | up to 1 km | outdoor; mounted below medium rooftop level |
| Picocell | up to 500 m | indoor or outdoor (mounted below rooftop level) |

**Table 5 :Cell types definition**

We will examine a total number of 5 different scenarios in our simulations in order to investigate the sensitivity of the scenarios to the selection of appropriate thresholds for each scenarios:

1. **urban**
2. **dense urban (urban hot-spot)**
3. **suburban**
4. **rural/primary roads**
5. **indoor office**

The description of the different scenarios includes their user density, topology, mobility, cell coverage strategy and propagation models. The propagation models comprise a path loss model and a channel impulse response model. In the path loss model, equations for the mean path loss and values for the standard deviation and decorrelation length of the slow variation (long-term fading) around the mean path loss due to shadowing and scattering are given. In our simulations we assume that the UEs are stable (no mobility ) because one of our metrics is the average distance of the UEs to the Node-B. The distance of each UEs is very critical regarding the power needed from the Node-B in the case of DCH channel, so we keep it stable (i.e. without mobility) in order to allow easier interpretation of the results.

For each scenario we use propagation model and statistics that we create in OPNET simulator.

The statistics include:

- Total Average distance from Node B
- Total Average DCH channel Power Transmitted from Node B
- Total FACH channel Power Transmitted from Node B

- DCH power transmitted for each channel

The propagation models as they defined in [14 ] are :

- Walfish-Ikegamilos
- Vechicular

In the next sections we will give a brief explanation and the results for each scenario stated above.

## 5.1 Signalling

In this section we will investigate the effects in signalling load for switching from one channel to another. Furthermore we will demonstrate the extra overhead caused by DCH channels in the uplink and how much this overhead affects the performance of the network .

Switching between channels requires mechanisms over Iub and Iur and causes signaling load. Each UE, has to receive a reconfiguration message to release the DCH resources in switching from p2p to p2m or to set up a DCH in switching from p2m to p2p. In our first scenario we have a number of users transmitting streaming video to a number of UEs in DCH and FACH channels. The parameters of the scenarios are illustrated in the following table.

| ***Parameter*** | ***Value*** |
|---|---|
| Path loss | Walfish-Ikegamilos |
| Shadow Fading Standard Deviation | 10dB |
| Traffic sent | Streaming video |
| Cell radius | 600m |
| Number of server UEs | 10 |
| Number of client UEs | 10 |
| Average distance | Increasing from 200m to 550m |
| Sectorization | No |
| Cell layout | Hexagonal |
| Transport Channels | DCH and FACH |
| Max Node-B transmitted power | 20W |

**Table 6: Parameters for signalling scenario**

We sent the same traffic to each UE since they belong to the same multicast group starting from 50 sec and continuing up to 150 sec. Next we show the amount of signalling received and sent from two different UEs using FACH and DCH for downlink transmissions. We can see from the figures below that each UE transmits or receives signalling from Node-B at the beginning of the simulation when the UE enters the idle mode and then when the UE connect (receives traffic at approximately 50 sec) or disconnects (multicast session ends at approximately 150 sec) from the Node-B. The connection phase requires higher signalling than disconnecting although the amount of signalling transmitted or received from the UEs is minimal (100 to 200 bits/sec ).

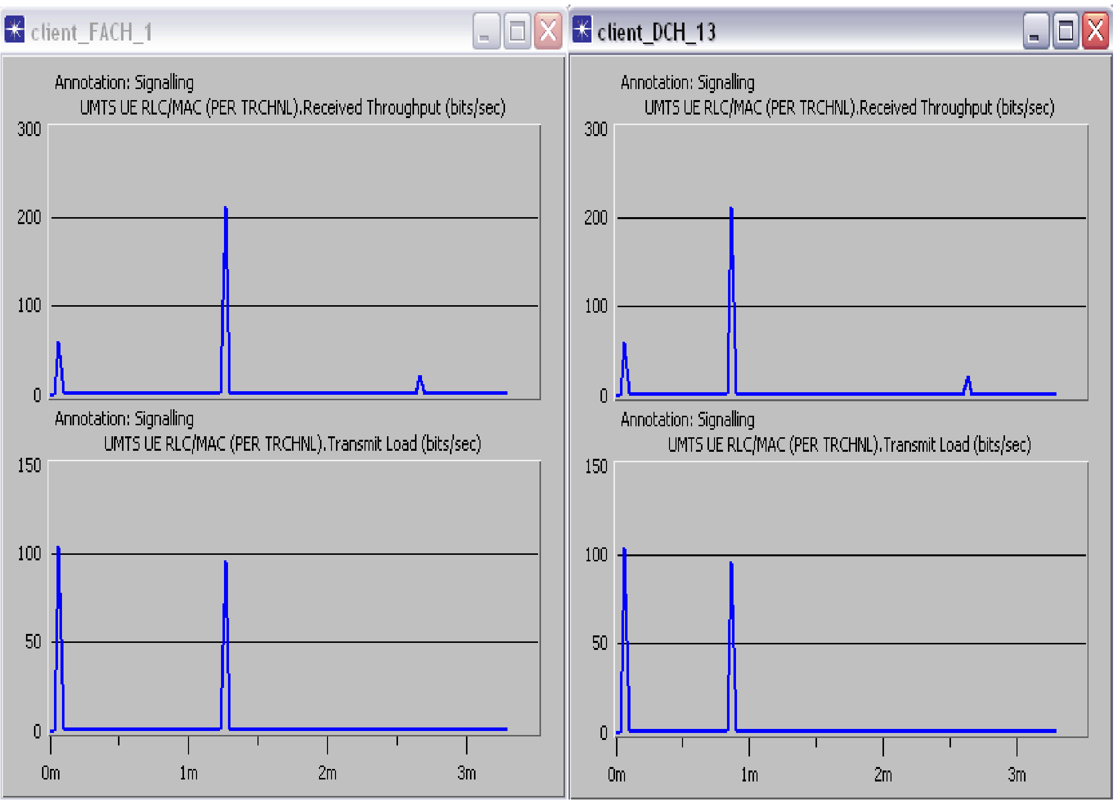
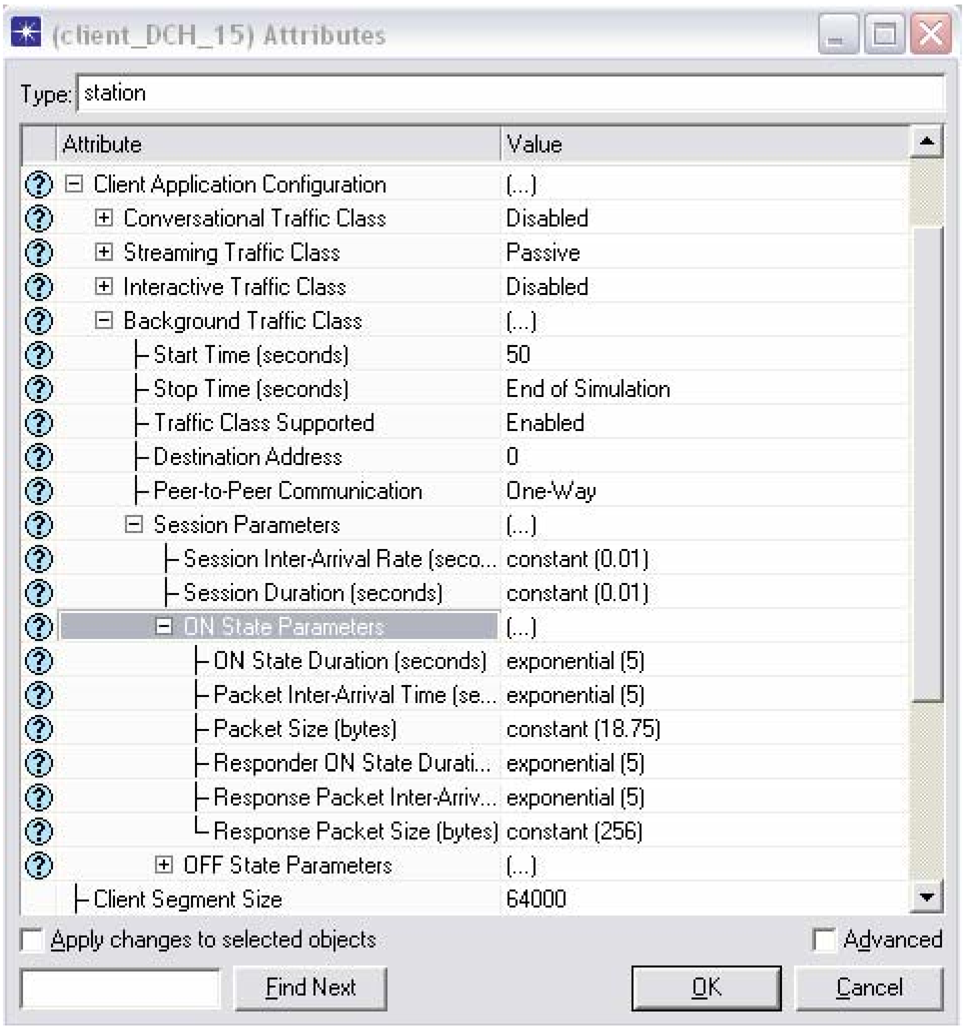


***Figure 22: Signaling overhead in FACH and DCH channels***

To emulate  the signaling caused by uplink Power control commands in the simulation we use background traffic from the client UE to the server UE since OPNET UMTS model does not support inner loop Power Control. The parameters of the uplink traffic are shown in the following figure.



Type: station

| Attribute | Value |
|---|---|
| ⊟ Client Application Configuration | (...) |
| ⊞ Conversational Traffic Class | Disabled |
| ⊞ Streaming Traffic Class | Passive |
| ⊞ Interactive Traffic Class | Disabled |
| ⊟ Background Traffic Class | (...) |
| ├ Start Time (seconds) | 50 |
| ├ Stop Time (seconds) | End of Simulation |
| ├ Traffic Class Supported | Enabled |
| ├ Destination Address | 0 |
| ├ Peer-to-Peer Communication | One-Way |
| ⊟ Session Parameters | (...) |
| ├ Session Inter-Arrival Rate (seco... | constant (0.01) |
| ├ Session Duration (seconds) | constant (0.01) |
| ⊟ ON State Parameters | (...) |
| ├ ON State Duration (seconds) | exponential (5) |
| ├ Packet Inter-Arrival Time (se... | exponential (5) |
| ├ Packet Size (bytes) | constant (18.75) |
| ├ Responder ON State Durati... | exponential (5) |
| ├ Response Packet Inter-Arriv... | exponential (5) |
| └ Response Packet Size (bytes) | constant (256) |
| ⊞ OFF State Parameters | (...) |
| ├ Client Segment Size | 64000 |

*Figure 23: Simulation Parameters for uplink Power Control Signal*

We use constant inter arrival rate and duration of 10ms equal to the radio frame length and packet size of 18,75 bytes because there are 10 bits per uplink DPCCH slot ,as we explain in previous chapter, and 15 slot per frame. This is equal to 150 bits per radio frame which means 18,75 bytes of packet size.

The overhead caused by a single UE is demonstrated in the next figure .It s obvious that in terms of uplink signaling caused by DCH channels the transmitted load does not have any impact in the performance of the network because we have minimal amount of traffic generated (about 100bit/sec). For example if 20 UEs are participating in a multicast session using p2p channel the amount of uplink transmission load for the inner loop power control commands would be only 2Kbit/s which is a minimal quantity.

For the rest of our simulations since we have shown that signaling overhead due to switching between p2p and p2m channels and uplink overhead because of power control commands is minimal we will ignore these two factors and the decision for the appropriate thresholds will take into considerations only the number of client UEs and the average distance.

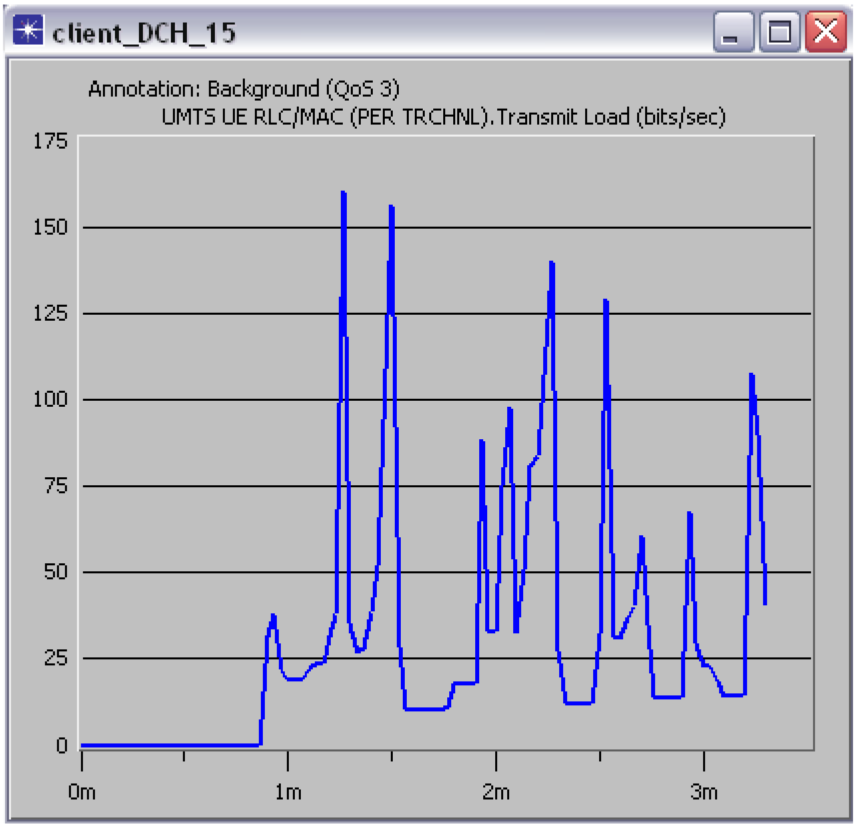


*Figure 24: Uplink overhead due to Power control commands*

## 5.2 Urban Environment

Urban areas are characterized by low vegetation and high building densities. The population density is high, part residential and mainly from the tertiary sector. The urban pedestrian environment considers only the low mobility users in the specified urban area.

The Manhattan-like structure is normally chosen to represent this type of environment. It is composed of a rectangular grid of intersecting streets of 30 m width and homogeneous squared buildings of 200 m side. This is illustrated in *Figure 25*.

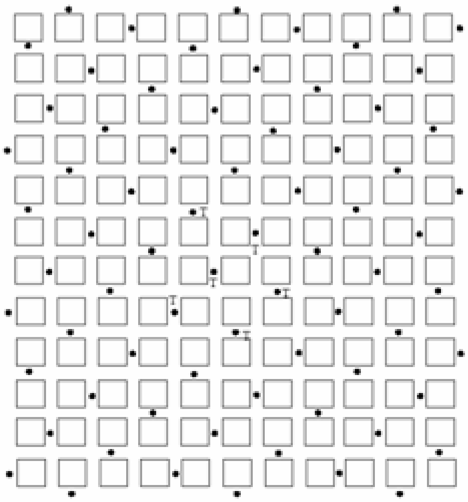
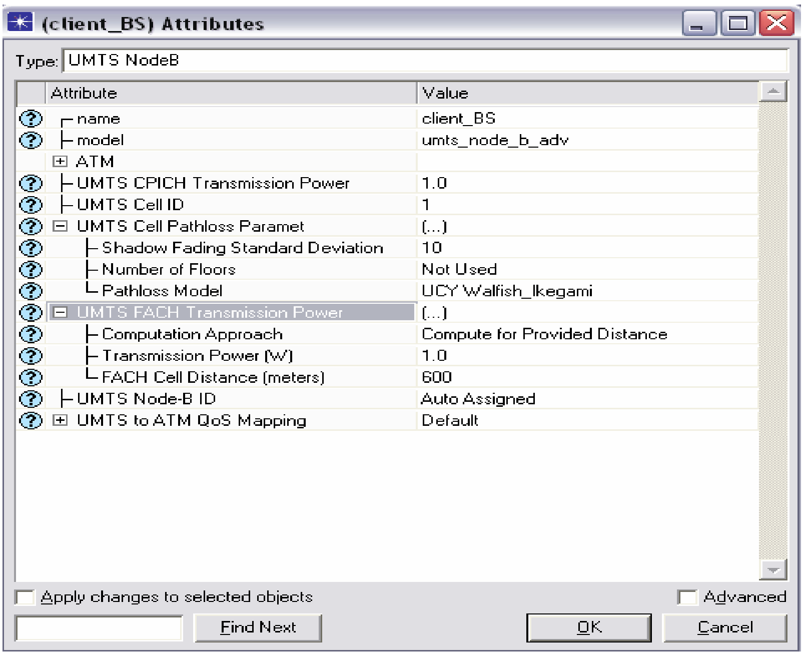


**Figure 25: Manhattan-like urban model topology**

Microcells should be used to be able to handle the high user density. The positioning and dimensioning of these cells in the area to be covered should be carefully studied in order to maximize the capacity and the efficiency. The proposed cell radius is 0.6km and the Walfish-Ikegamilos model is the propagation model (*Figure 26.*



Type: UMTS NodeB

| Attribute | Value |
|---|---|
| name | client_BS |
| model | umts_node_b_adv |
| ATM | |
| UMTS CPICH Transmission Power | 1.0 |
| UMTS Cell ID | 1 |
| UMTS Cell Pathloss Paramet | (...) |
| Shadow Fading Standard Deviation | 10 |
| Number of Floors | Not Used |
| Pathloss Model | UCY Walfish_Ikegami |
| UMTS FACH Transmission Power | (...) |
| Computation Approach | Compute for Provided Distance |
| Transmission Power (W) | 1.0 |
| FACH Cell Distance (meters) | 600 |
| UMTS Node-B ID | Auto Assigned |
| UMTS to ATM QoS Mapping | Default |

☐ Apply changes to selected objects

☐ Advanced

***Figure 26: Urban Pedestrian  parameters***

In the table below  we define all the parameters for the Urban Pedestrian environment.

| ***Parameter*** | ***Value*** |
|---|---|
| Path loss | UCY Walfish-Ikegamilos |
| Shadow Fading Standard Deviation | 10dB |
| Traffic sent | Streaming video |
| Cell radius | 600m |
| Number of server UEs | 10 |
| Number of client UEs | 10 |
| Average distance | Increasing from 200m to 550m |
| Sectorization | No |
| Cell layout | Hexagonal |
| Transport Channels | DCH and FACH |
| FACH transmitted power | 0,36W |
| Max Node-B transmitted power | 20W |

**Table 7: Urban Pedestrian Parameters**

The traffic for all the scenarios is streaming video. We try to find the total power needed for DCH and FACH taking into consideration the average distance of the UE from Node B and the number of serving UEs that belong to the same multicast group. The power of the FACH is predefined according to the cell radius and the propagation model used and is always stable (*Figure 27*) without considering the number of UEs or average distance from Node B . On the other hand for DCH channel when we increase the average distance of the client UEs (10 clients) we can observe that the total power transmitted for DCH channels ( *Figure 28*) is increased.

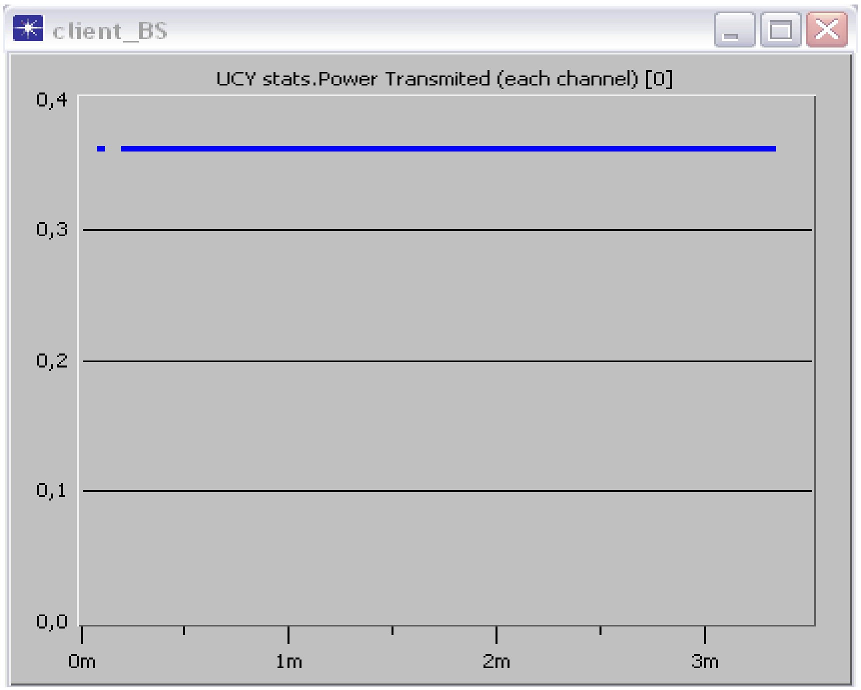


*Figure 27: FACH power for Urban Pedestrian scenario*

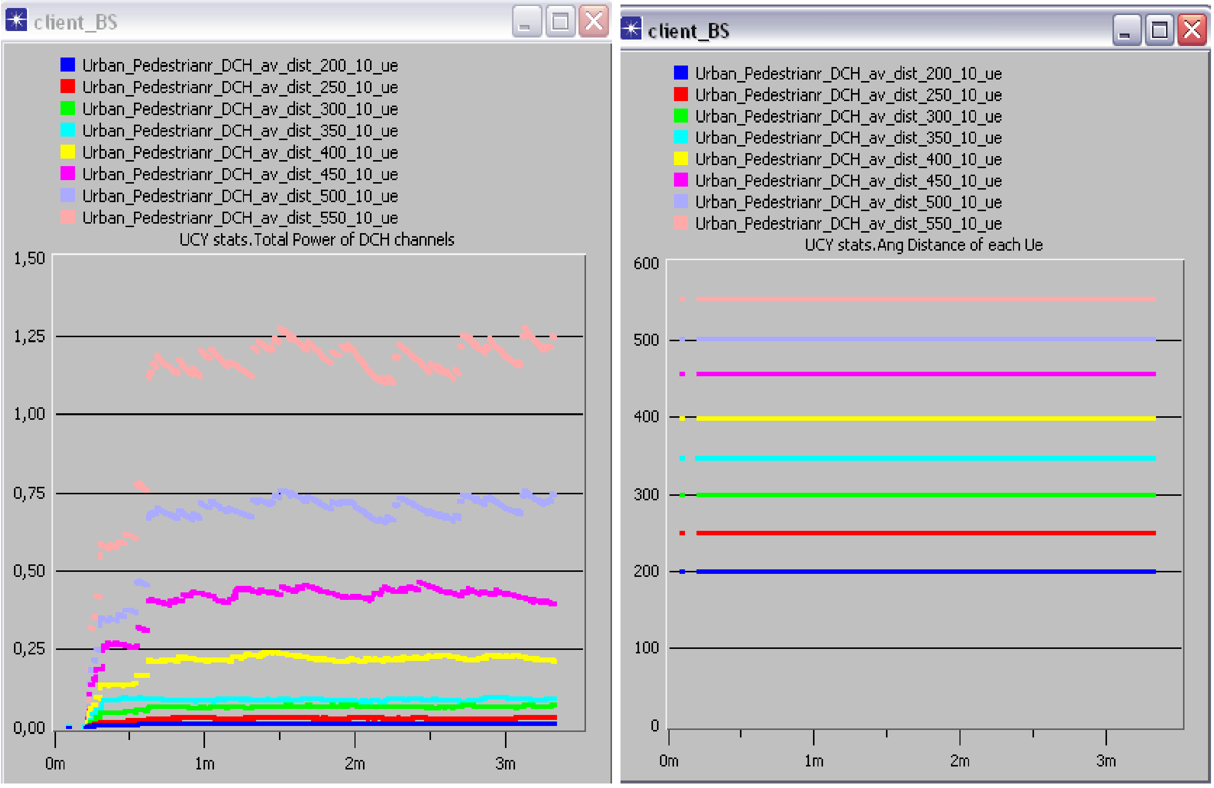


***Figure 28: DCH total power vs average distance for Urban Pedestrian scenario (for 10 UEs average distance increases from about 200 to about 550 metres)***

From the figures above we can see that there is an overall increase to the total power transmitted for the DCH channel. When the average distance of the users is between 200 m to 400 m the power of the DCH channels is below the FACH transmitted power (0,36W) but for distances above 400m the power of the DCH increases dramatically, and near the edge of the cell (550m) the total power of the DCH channels is even three times higher than the FACH power (given the power distance law, this is expected behaviour).

It is obvious that if we use as a threshold the UE count, without taking into consideration the UE distance, the results regarding power consumption in the cell will be inefficient. Next we will demonstrate with some simulation results the benefits of the proposed power counting algorithm. In the first sub scenario we set the average distance per UE to 400m from the Node-B and the number of client UES are set to 10, 11, 12 and 14 respectively.

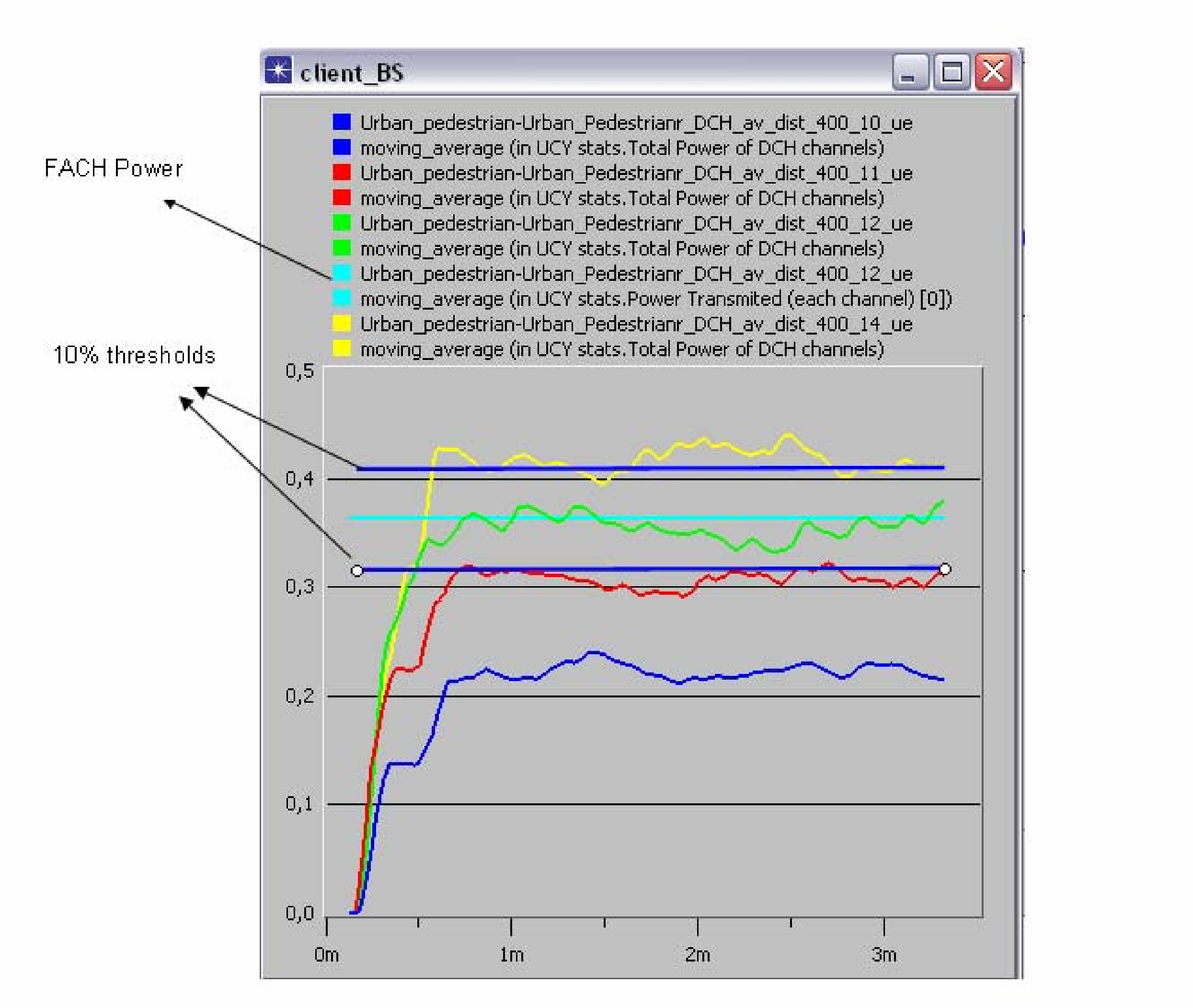


*Figure 29: Moving Average Power for each channel vs number of client UEs at 400m average distance*

Using the power counting algorithm (described in chapter 3) we can see that a switch from DCH channels to FACH is happening when the number of serving UEs is 14 and the gain of the switch is approximately 10% of the power of the DCH channels. Additionally we can have a switch from FACH to DCH channels when the gain is 10% and the number of serving UEs is 11. For this particular scenario with average distance 400m this is the best threshold of power because we accomplish a 10% gain of power when we switch from one channel to the other, and additionally we have an acceptable number of UEs (3 UEs) between the two thresholds in order to avoid ping pong effects.

For the second sub scenario we increase the average distance to 450m and the number of client UES is set to 8, 9, 10 and 12. The results are shown in the figure below.

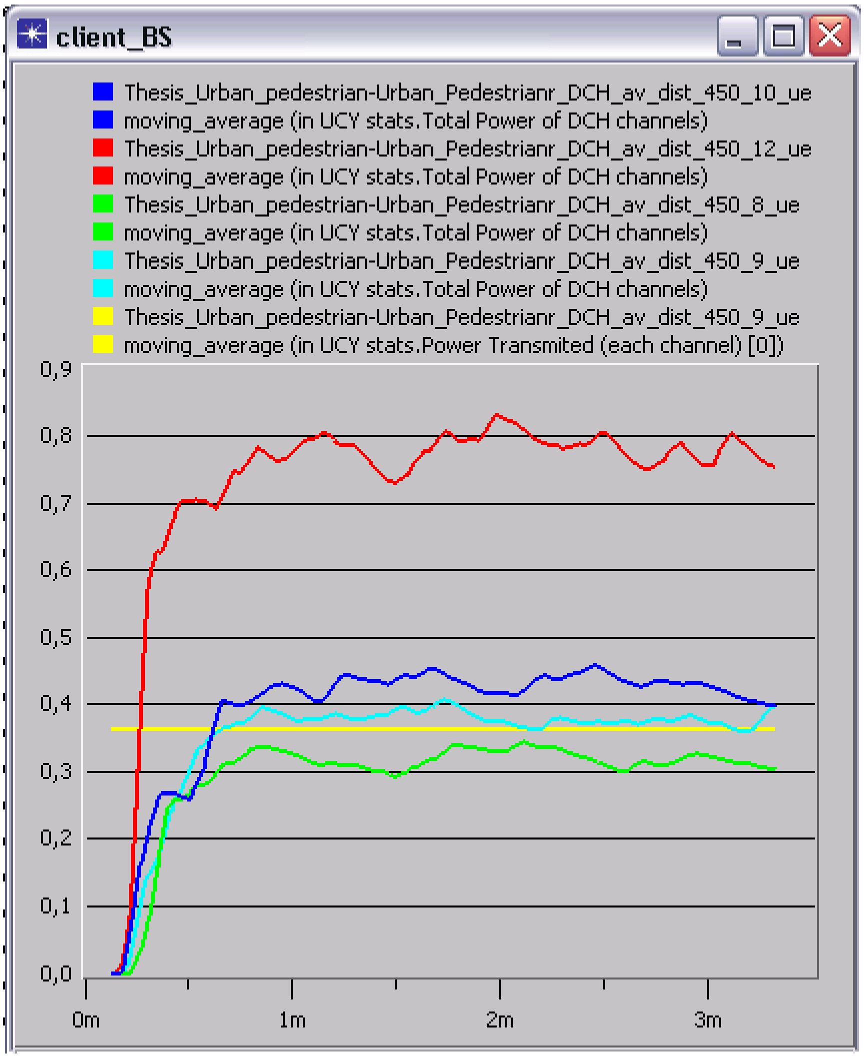


*Figure 30: Moving Average Power for each channel vs number of client UEs at 450m average distance*

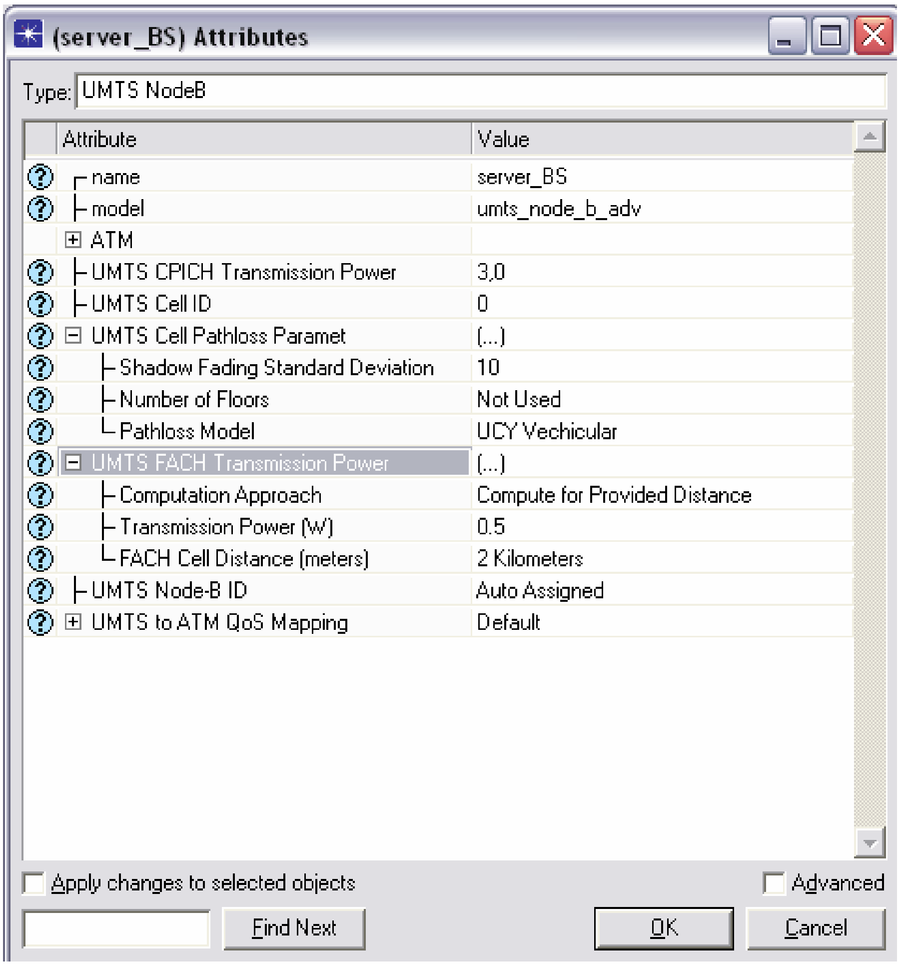
For this scenario we can observe that the switch from p2p channel to p2m happens when the number of client UEs is 10 and respectively for switching from p2m to p2p the number of UEs is 8. Its obvious that for this scenario, we also have 10% gain when we switch from one channel to another, and in addition to that we have an acceptable threshold (2 UEs)  to avoid ping pong effects.

If we were to use the UE counting algorithm instead of the power counting algorithm in our simulations the results would be completely different. From the figures above when the UEs are 400 meter far from the Node B we can estimate that a proposed threshold of UEs for switching from one channel to the other could be set to 12 users since the total power needed for DCH channels is almost the same with FACH transition power. If we were to use the same threshold (12 UEs) when the UEs are located an average distance of 450m far from the Node B (only 50m difference!) we will have a waste of power (reaching up to 55%) since for 12 users if we used UE counting the required power was going to be 0.8W instead of 0.36W (FACH power ) which is the required power for 12 users using power counting algorithm.

Next, we turn our attention to the behaviour of the proposed algorithm in a suburban area.

## 5.3 Suburban

Suburban areas are characterized by medium vegetation and building densities. The population density has a medium value and is essentially residential. The predominant population sector is the secondary one. Little commerce exists. All the necessary parameters for this environment are shown below.



(server_BS) Attributes

Type: UMTS NodeB

| Attribute | Value |
|---|---|
| name | server_BS |
| model | umts_node_b_adv |
| ⊞ ATM | |
| UMTS CPICH Transmission Power | 3.0 |
| UMTS Cell ID | 0 |
| ⊟ UMTS Cell Pathloss Paramet | (...) |
| Shadow Fading Standard Deviation | 10 |
| Number of Floors | Not Used |
| Pathloss Model | UCY Vechicular |
| ⊟ UMTS FACH Transmission Power | (...) |
| Computation Approach | Compute for Provided Distance |
| Transmission Power (W) | 0.5 |
| FACH Cell Distance (meters) | 2 Kilometers |
| UMTS Node-B ID | Auto Assigned |
| ⊞ UMTS to ATM QoS Mapping | Default |

*Figure 31: Suburban parameters*

| ***Parameter*** | ***Value*** |
|---|---|
| Path loss | UCY Vechicular |
| Shadow Fading Standard Deviation | 10dB |
| Traffic sent | Streaming video |

| | |
|---|---|
| Cell radius | 2Km |
| Number of server UEs | 10 |
| Number of client UEs | 10 |
| Average distance | Increasing from 500m to 1700m |
| Sectorization | No |
| Cell layout | Hexagonal |
| Transport Channels | DCH and FACH |
| FACH transmitted power | 0,034W |
| Max Node-B transmitted power | 20W |

**Table 8: Suburban Parameters**

For the Suburban scenario we will try to evaluate the power counting algorithm according to the total transmitted power of each channel. First we will show how total power of DCH channels increases according to the average distance of the UEs (from 500 to 1700m ) with a static number of UEs (10) and next the gain of our algorithm when the UEs average distance is 1500m and 1700 m respectively with variable number of users.

In the figure below we can see how important the average distance is in the total power transmitted of each BS, as we have shown in the urban environment scenario. Particularly when the UEs are placed near the BS (500m, yellow line) the power transmitted is minimal (0,0005W). By increasing the average distance up to 1000m (middle of the cell ) we can observe that the transmitted power has reached the level of 0,008W which is 16 times bigger than the 500m. The results are, as expected, more spectacularly when the UEs are placed near the edge of the cell (at 1700m). We can see that the total transmitted power of the DCH channels is now 0.05W, which is 6 times bigger than the power of 1000m, and 100 times bigger than 500m.

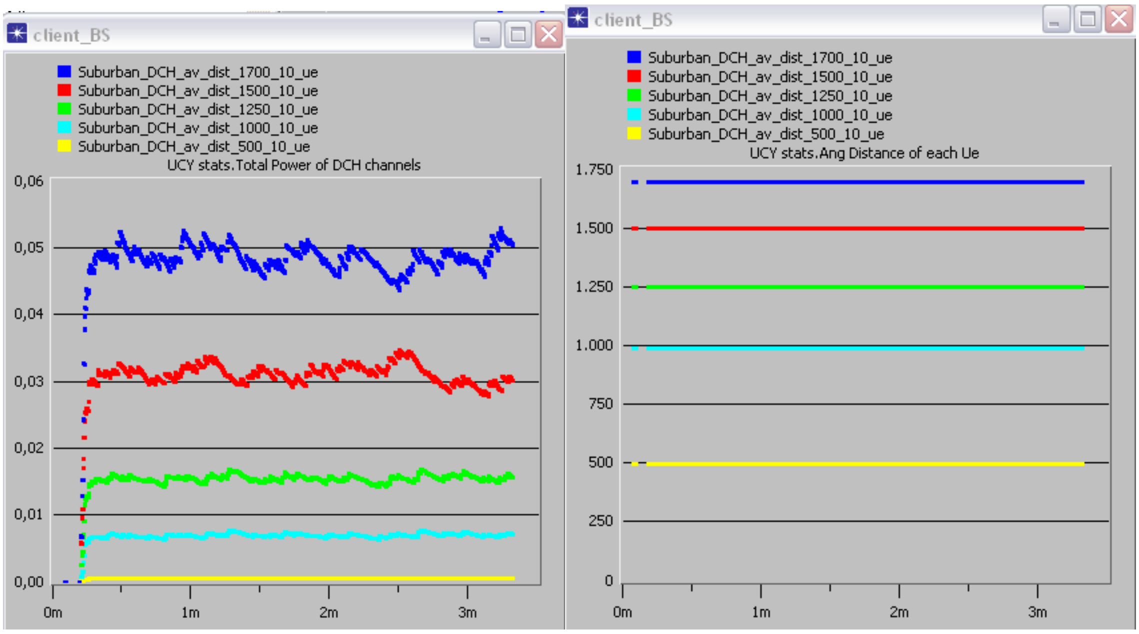


***Figure 32: DCH  total power vs average distance for Suburban scenario (for 10 UEs)***

In figure 33 the power of the FACH channel is presented. As expected the total power transmitted is stable up to 0.034W without taking into consideration average distance or number of users.

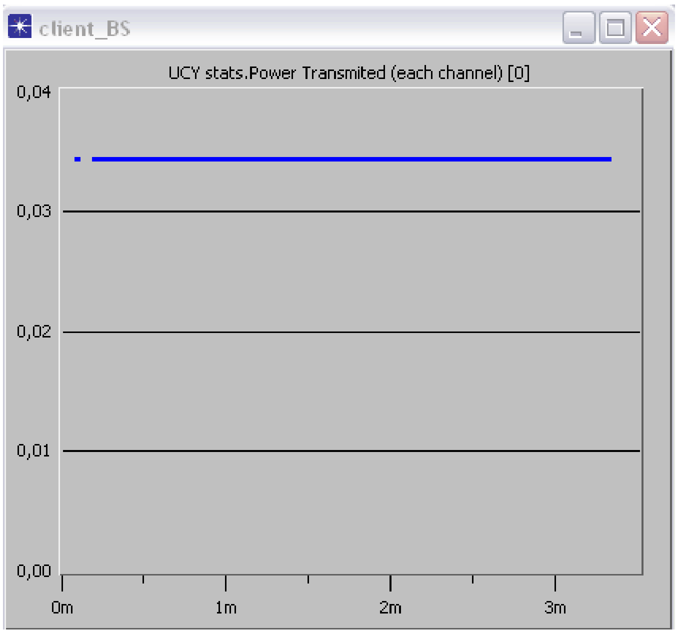


***Figure 33: FACH transmitted power for Suburban***

With the next simulation scenarios we demonstrate how the power counting algorithm determines when the appropriate threshold of power is reached and when to switch from one channel to the other.

In the first sub scenario UEs have an average distance of 1500m from BS with 10 and 11 UEs respectively. In accordance with the proposed algorithm, we can see that when the number of users is 11 and we are using a DCH channel, a switch to FACH is necessary because we reach the 10% threshold of FACH channel. Respectively if we send traffic in FACH and the number of UEs participating in multicast group is 10 a switch to DCH channel has to be made.

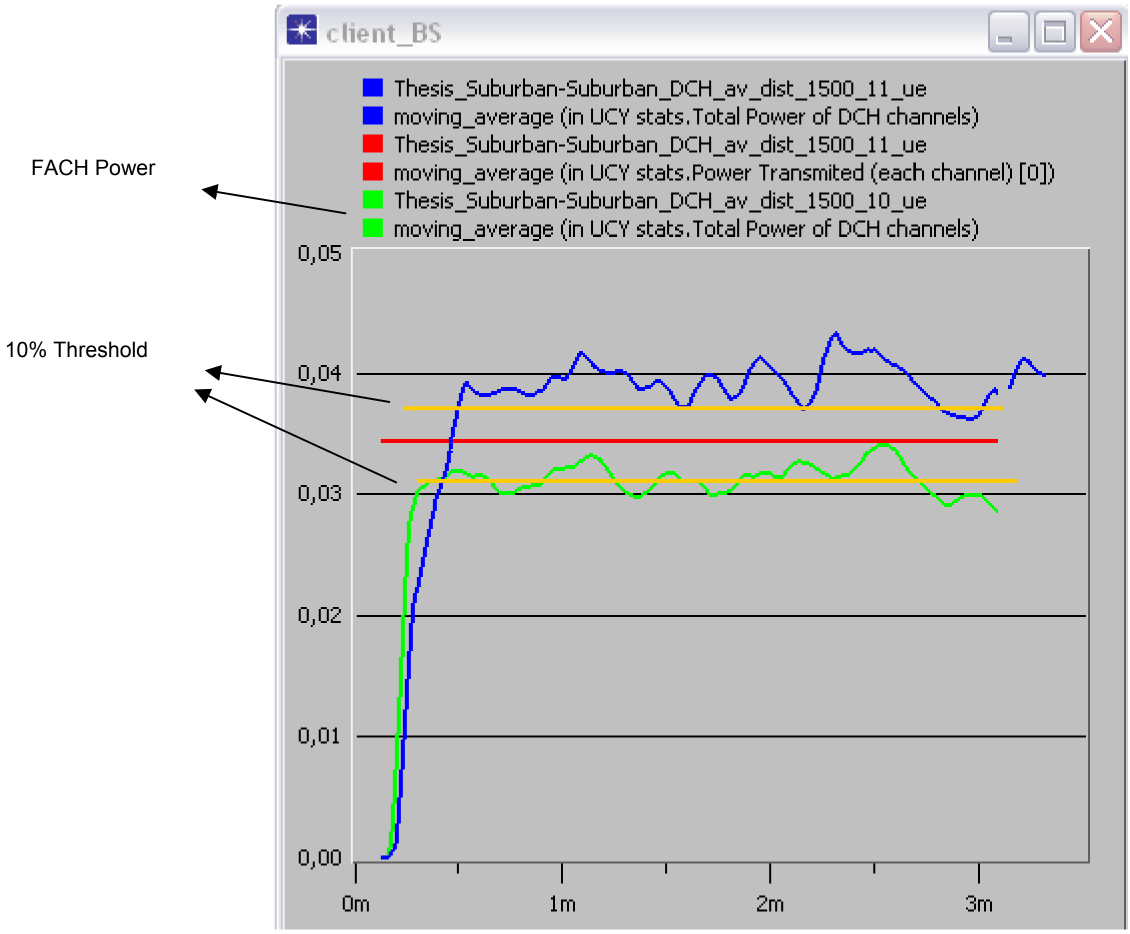
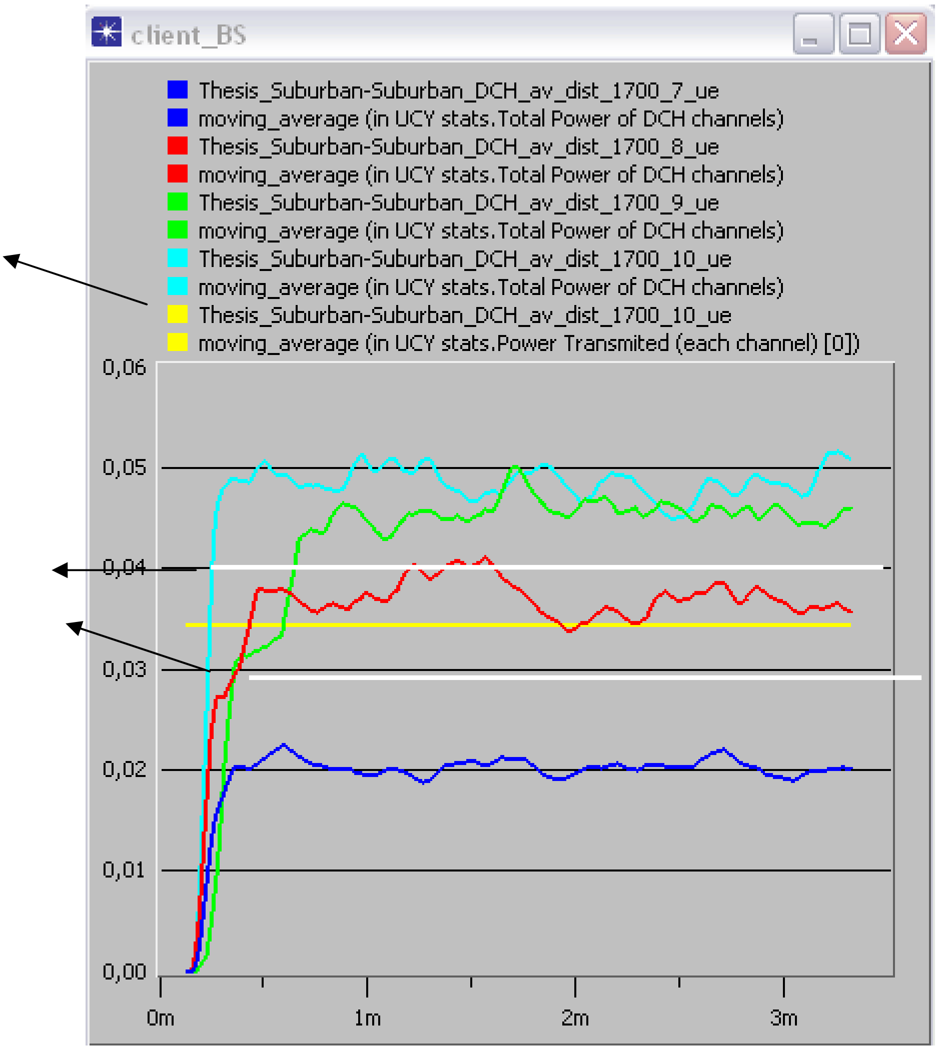


*Figure 34: Moving Average Power for each channel vs number of client UEs at 1500m average distance*

In the second sub scenario we set the average distance to 1700m from the BS and the number of UEs to 7, 8, 9 and 10 respectively. We observe that appropriate thresholds for this scenario are 7 and 8 users for each switchover. When BS transmits in DCH channel and the number of UEs increases to 8 then the algorithm informs the BS to switch to FACH. When BS transmits in FACH and number of UEs is decreased to 7 then the BS is informed to switch to DCH. In this scenario we can see that switching from FACH to DCH channel has a gain of more than 10%( equals to 40%) . This is because in large distances the DCH transmitted power is highly effected and the variation of a single user may change the total transmitted power significantly.



FACH Power

10% Thresholds

***Figure 35: Moving Average Power for each channel vs number of client UEs at 1700m average distance***

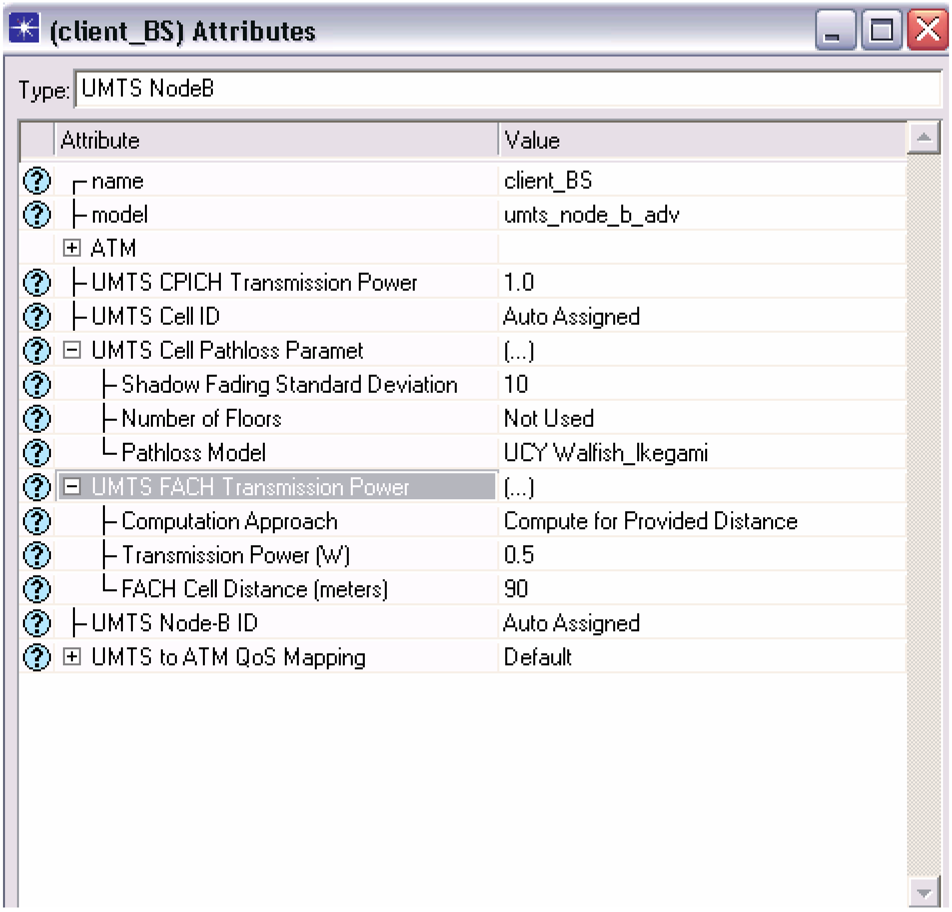
If we use UE counting instead of power counting it is obvious that we will not be able to adjust the variations of the power according to the average distance of the UEs. For example if we decide to use 10 users as a threshold for UE counting (because 10 is the UE number that DCH power is close to FACH power when we have an average distance of ¾ of the cell limits) the algorithm is not efficient when the average distance is 1700m because, as shown in the previous results, the switch has to be made when the UEs are 8. According to the results the wate of power will reach 32% .

Next, we will investigate the behaviour of the algorithm in dense urban conditions.

## 5.4 Dense Urban

This environment corresponds to an area with very high building density, very high buildings with almost no vegetation. Pedestrian users are located on streets and inside buildings and residences. This type of scenario can be easily found in business city centres where the potential user density is extremely high. It is also characterized by low user mobility (mostly pedestrians). The population is essentially from the tertiary sector. The same Manhattan-like structure used for the dense urban environment can also be used for this environment.

Pico cells are used to handle the extremely high user density in some Urban areas. The positioning and dimensioning of these cells in the area to be covered should be carefully studied in order to maximize the capacity and the efficiency. A cell radius of 0,090km is proposed to cover the base station in dense urban scenarios.The selected path loss for this scenario is Walfish-Ikegami model, with antennas below rooftops, log-normally and distributed shadowing (LogF) with standard deviation of 10 dB. We define the above metrics in OPNET using the graphical interface.



Type: UMTS NodeB

| Attribute | Value |
|---|---|
| name | client_BS |
| model | umts_node_b_adv |
| ⊞ ATM | |
| UMTS CPICH Transmission Power | 1.0 |
| UMTS Cell ID | Auto Assigned |
| ⊟ UMTS Cell Pathloss Paramet | (...) |
| Shadow Fading Standard Deviation | 10 |
| Number of Floors | Not Used |
| Pathloss Model | UCY Walfish_Ikegami |
| ⊟ UMTS FACH Transmission Power | (...) |
| Computation Approach | Compute for Provided Distance |
| Transmission Power (W) | 0.5 |
| FACH Cell Distance (meters) | 90 |
| UMTS Node-B ID | Auto Assigned |
| ⊞ UMTS to ATM QoS Mapping | Default |

*Figure 36: Dense Urban parameters for Node-B*

The parameters for this scenario are explained in more detail in the following table.

| ***Parameter*** | ***Value*** |
|---|---|
| Path loss | UCY Walfish-Ikegamilos |
| Shadow Fading Standard Deviation | 6dB |
| Traffic sent | Streaming video |
| Cell radius | 90m |
| Number of server UEs | 10 |
| Number of client UEs | 10 |
| Average distance | Increasing from 50m to 90m |
| Sectorization | No |
| Cell layout | Hexagonal |
| Transport Channels | DCH and FACH |
| FACH transmitted power | 0.000150 W |
| Max Node-B transmitted power | 20W |

**Table 9 – Parameters for Dense Urban**

The following figure presents the dependence of the average distance of the UEs to the average transmitted power of the DCH. The number of users in this scenario was kept at 10 users (as in the previous scenarios) with the average distance variant set from 50m to 90 m. We can see that when the UEs are near the BS (50 m , blue line ) we have the smallest power consumption. As expected, when the average distance of the UEs is increased, we can observe a huge increase of the power especially when we reach the edge of the cell (90 m ,yellow line). At this point we have power consumption almost five times more. The power of the FACH channel (Figure 38) is stable, independant of the average distance or number of users.

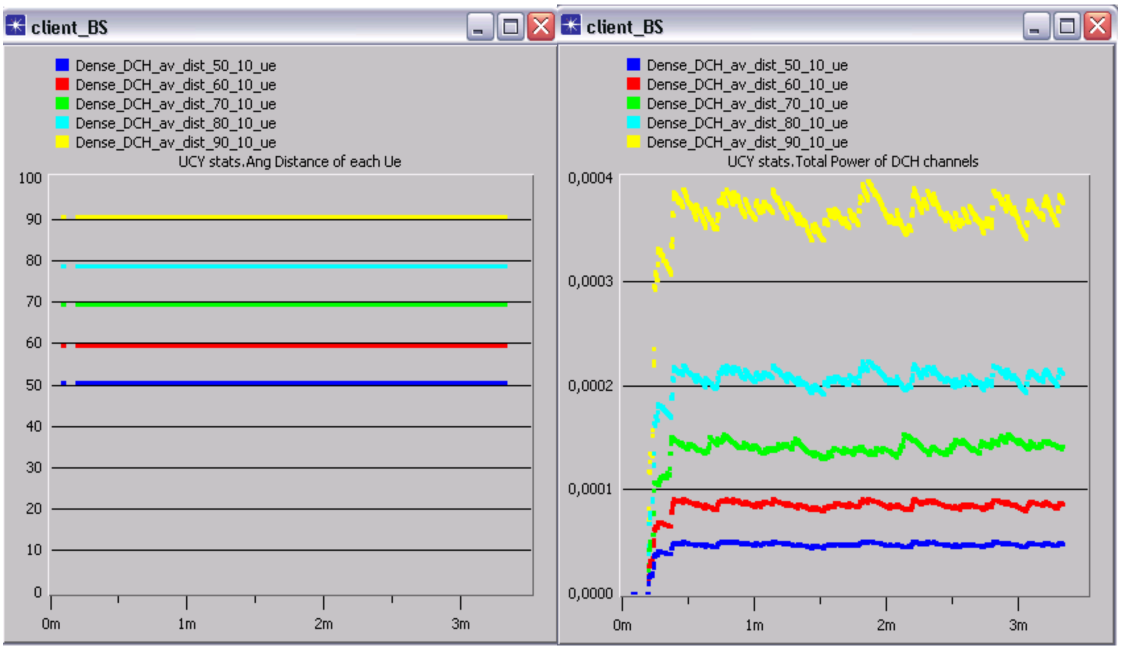


***Figure 37:DCH Power for Dense Urban Vs Average Distance of UEs***

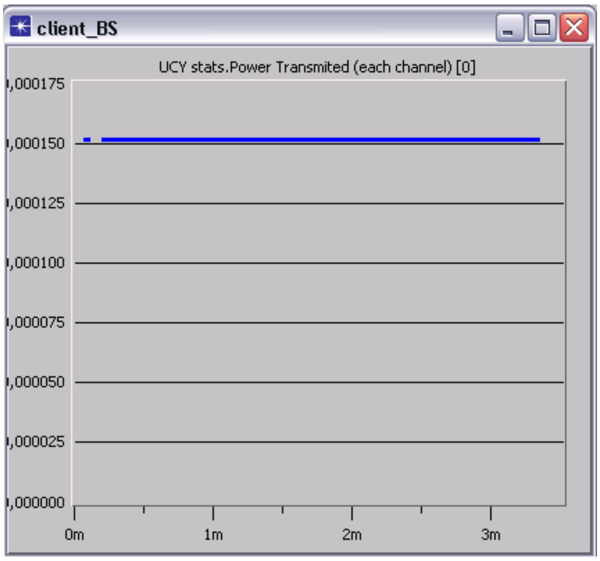


***Figure 38: Fach Transmitted power for Dense Urban***

In the next sub scenarios we vary the average number of users in order to show the advantages of our proposed algorithm. In the first sub-scenario we have an average distance of 70m with the number of users increasing from 6 to 11. As we can see from the figure below when the number of users is 6 or 8 the power consumption is far below the FACH transmitted power. According to the proposed algorithm the switch from p2p to p2m is happening when the number of users receiving traffic is 11. In addition to that the user threshold for switching from p2m to p2p is 10 users. In this sub-scenario we manage to gain a 10 % in each switch but we didn't manage to reduce the ping pong effect because the switch threshold is only 1 user. If the users are increasing or decreasing in a short period of time then we might face the unwanted ping pong effect. Hence, the setting of the threshold, as stated earlier, remains a matter of further research.

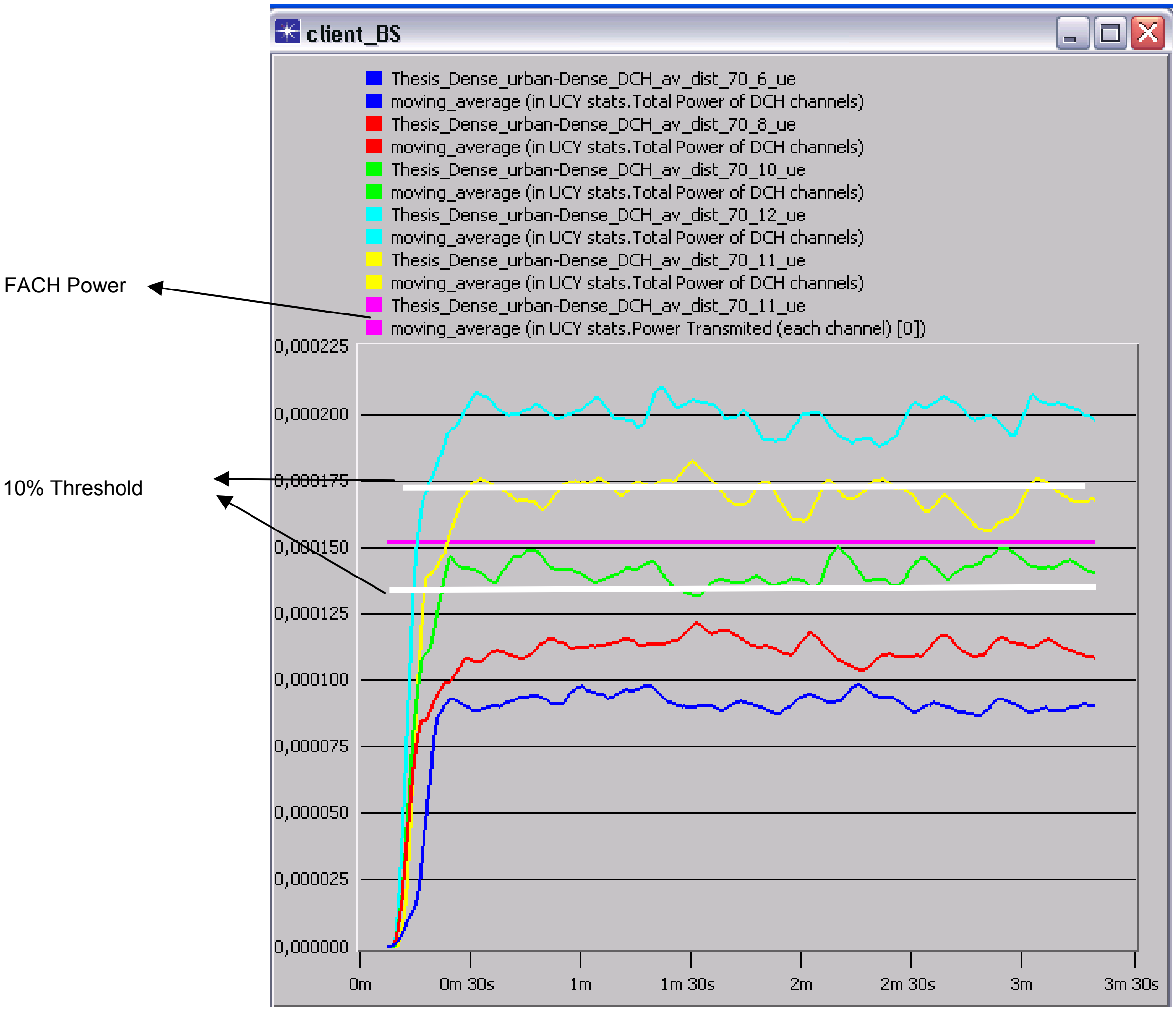


***Figure 39: Moving Average Power for Dense Urban vs number of client UEs at 70m average distance***

In the second sub-scenario the average distance is 90 m (at the edge of the cell) and the number of users is increased form 3 to 5. The number of users is kept small because we are in the edge of the cell and the average power of each user for the DCH channel is the maximum allowed for this cell. From the results for this sub-scenario (Figure 40) we can see that according to the proposed algorithm the switch from p2p to p2m is 4 users, with almost 33% power gain since the average power consumption is approximately 0.00020W. The switch from p2m to p2p is happens when the number of UEs is 3. In this case the average power consumption is 0.00012W which is 53% below the FACH transmitted power. This means that we have better performance since the power gain, in both cases, is higher than 10%. Note that we have the same problem as with the previous sub-scenario with regard to the ping pong effect, which again is not eliminated.

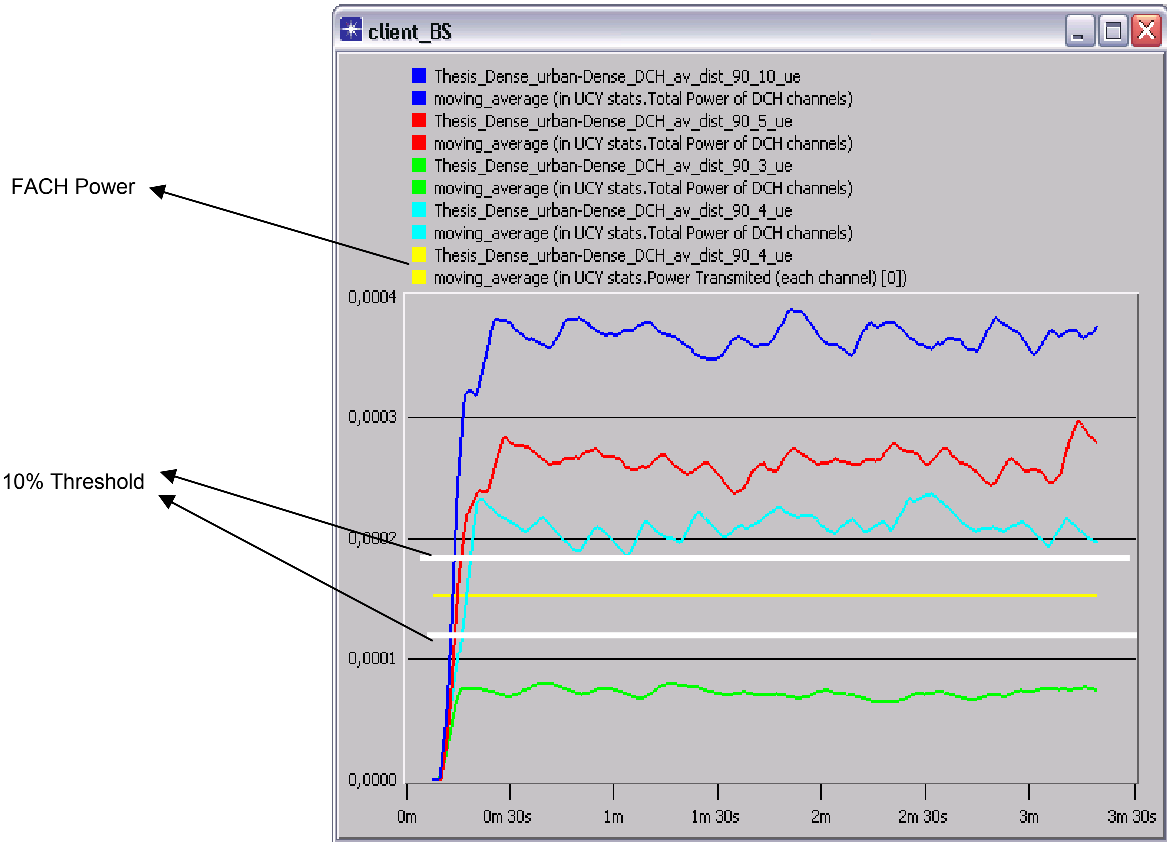


*Figure 40: Moving Average Power for Dense Urban vs number of client UEs at 90m average distance*

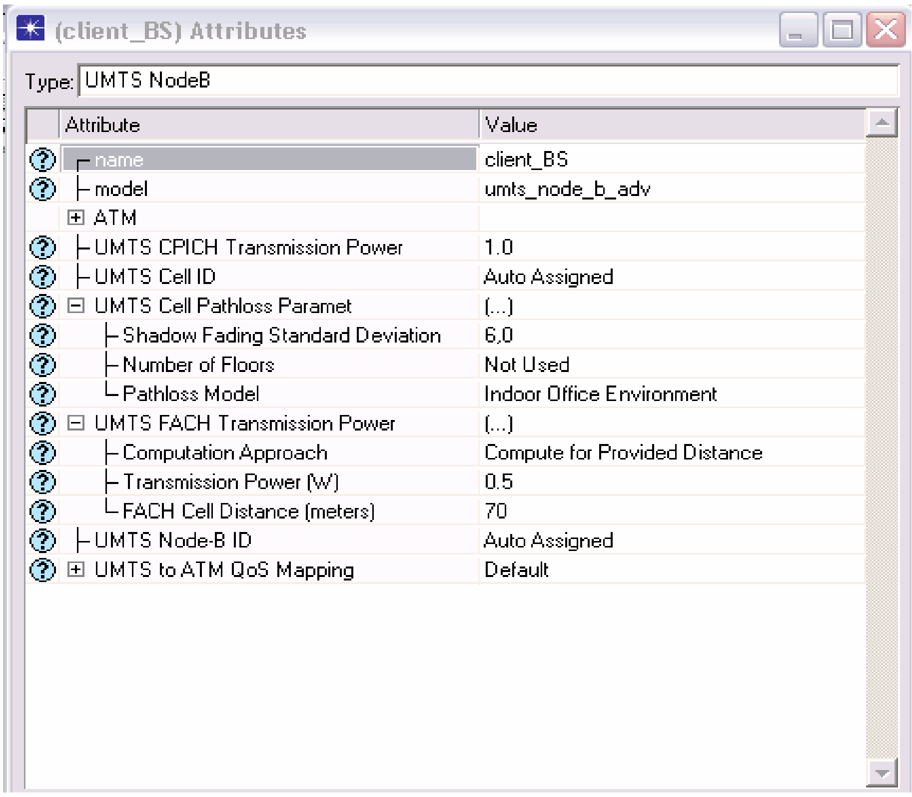
If we use the traditional UE counting algorithm instead of our proposed algorithm, according to the simulation results an appropriate UE threshold should be 10 users. If end users are moving to the edge of the cell, the loss of power consumption will be extremely high (59,5%) since the threshold for the average distance of 90m is 3-4 users.

## 5.5 Indoor

The indoor office is an indoor environment (both base stations and pedestrian users are located indoors), characterized by very high user density and null or very low user mobility. The table below describes the scenario parameters in more detail.

| ***Parameter*** | ***Value*** |
|---|---|
| Path loss | Indoor –Office |
| Shadow Fading Standard Deviation | 10dB |
| Traffic sent | Streaming video |
| Cell radius | 70m |
| Number of server UEs | 10 |
| Number of client UEs | 10 |
| Average distance | Increasing from 50m to 90m |
| Sectorization | No |
| Cell layout | Hexagonal |
| Transport Channels | DCH and FACH |
| FACH transmitted power | 0.0000182 W |
| Max Node-B transmitted power | 20W |

**Table 10 –Parameters for Indoor**



Type: UMTS NodeB

| Attribute | Value |
|---|---|
| name | client_BS |
| model | umts_node_b_adv |
| ATM | |
| UMTS CPICH Transmission Power | 1.0 |
| UMTS Cell ID | Auto Assigned |
| UMTS Cell Pathloss Paramet | (...) |
| Shadow Fading Standard Deviation | 6.0 |
| Number of Floors | Not Used |
| Pathloss Model | Indoor Office Environment |
| UMTS FACH Transmission Power | (...) |
| Computation Approach | Compute for Provided Distance |
| Transmission Power (W) | 0.5 |
| FACH Cell Distance (meters) | 70 |
| UMTS Node-B ID | Auto Assigned |
| UMTS to ATM QoS Mapping | Default |

***Figure 41:Node B Indoor Parameters***

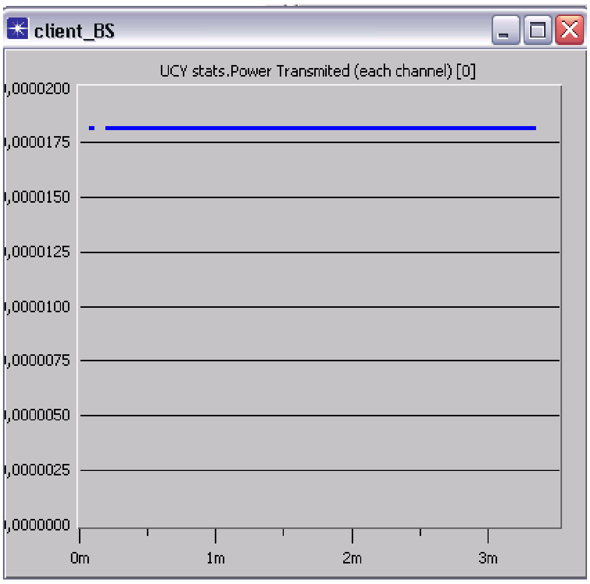


***Figure 42: Indoor FACH Transmitted Power***

Following the steps of our previous scenarios we aim to prove the high sensitivity of the average distance of the UEs with the total transmitted power in the case of DCH channel. For the indoor scenario we have 10 users moving from 40 to 70 m from the base station. The total power transmitted versus the average distance is shown below.

Its obvious that the power is extremely high at the edge of the cell, while the power remains at very low levels near the base station.

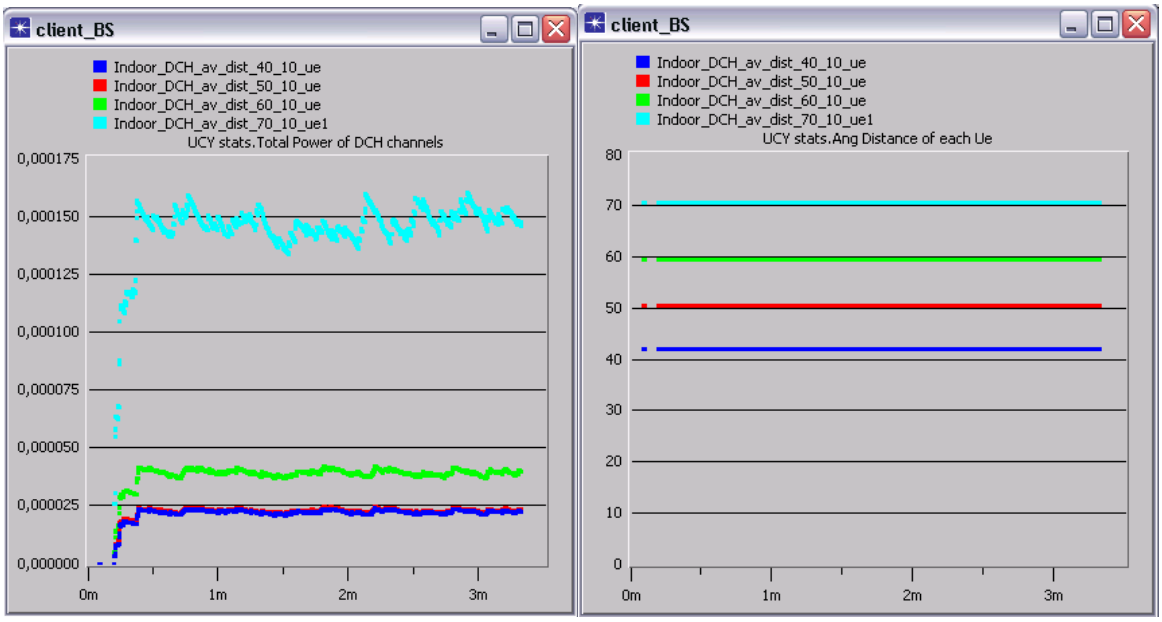


***Figure 43:DCH Power for Indoor  Vs Average Distance of UEs***

In the next sub scenarios we aim to prove the power gain of the proposed algorithm in the Indoor environment. We first identify appropriate thresholds for an average distance of 50m and then for 60m, and compare the results. In the first sub scenario users are allocated 50m from the base station and the number of users is increasing from 6 to 10 in order to identify the power thresholds.

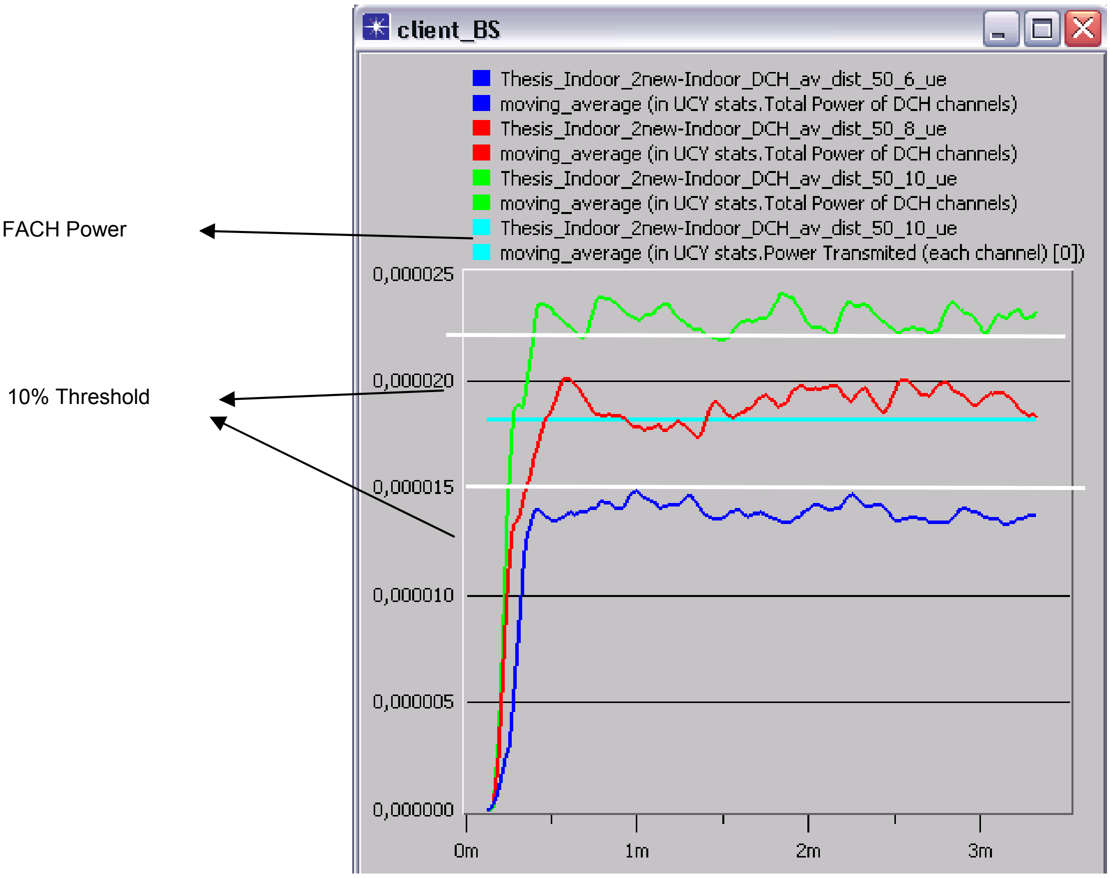


*Figure 44: Moving Average Power for Indoor vs number of client UEs at 50m average distance*

At 50 m when the number of users is 10 we can see that the average power for the DCH channel some times crosses the line of the 10% threshold. This means that if we are in p2p and the number of users suddenly increases to 10 a switch to p2m is necessary. Additionally if we are in p2m and the number of users reduces to 6 a switch to p2p is necessary. In this sub scenario we accomplished a 10% gain of power consumption when we move from one state to another and we have a solid user threshold for avoiding the ping pong effects (4 users).

In the second sub scenario users are allocated 60m from the base station and the number of users is increased from 3 to 7. In this case, a switch from p2p to p2m is necessary when the number of users increases to 7 and a switch from p2m to p2p is necessary when the number of users decreases to 4. Because of the high dependency of the power to the average distance, the UE thresholds for this sub scenario were reduced. Apart from that, we still have an acceptable number of users between the two thresholds which helps us to avoid the ping pong effect.

Applying the UE counting method to these particular sub scenarios the results would be completely different. According to the simulation results, the UE threshold for the UE counting algorithm is 8, since the total power of the DCH channel crosses the line of the FACH channel at the 50m average distance (Figure 44). This means that we must make a switch from p2p to p2m and visa versa when the number of users is 8. According to simulation results shown in Figure 45 this will cost as a significant amount of power (40%) when we switch from p2m to p2p .

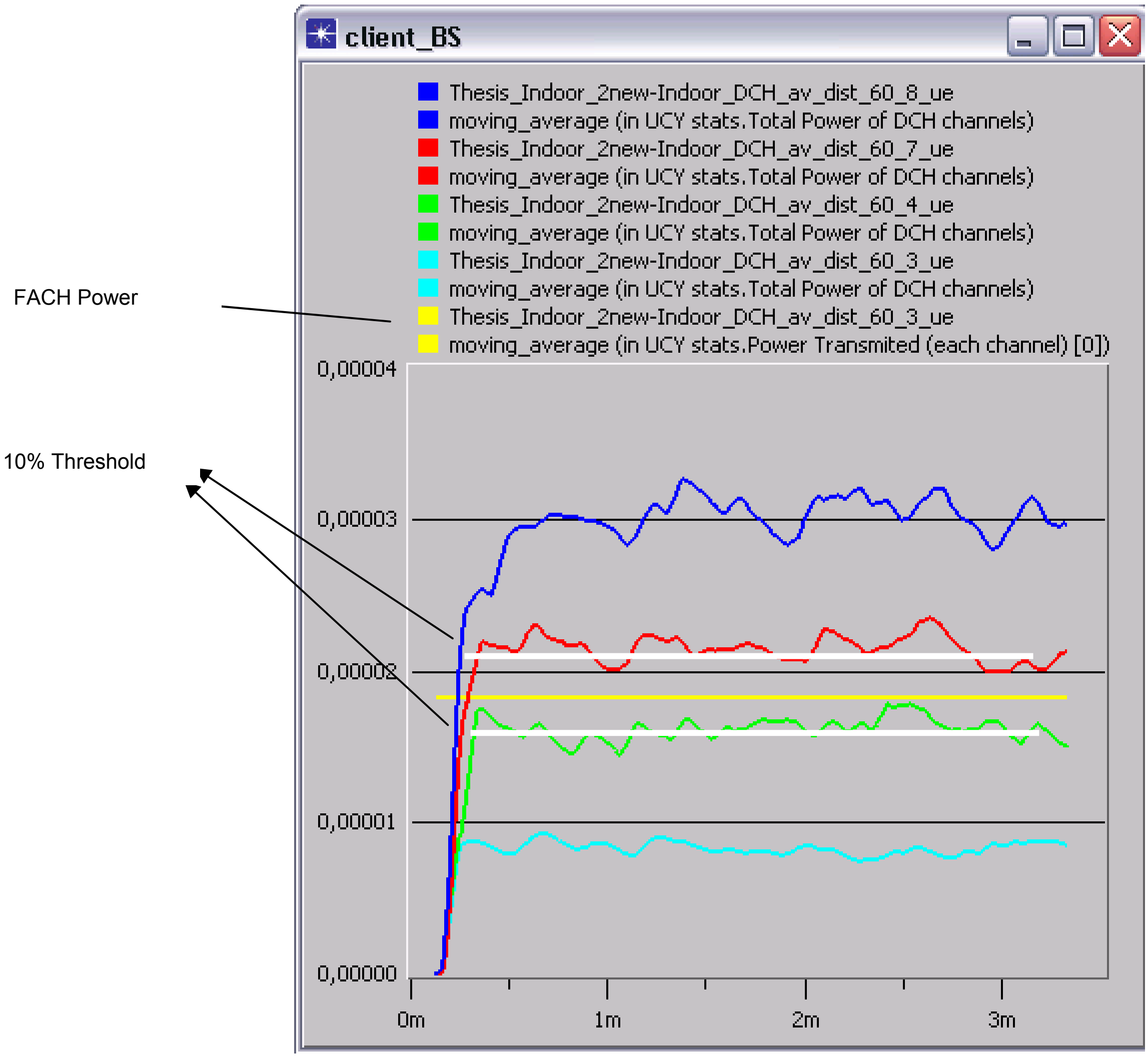


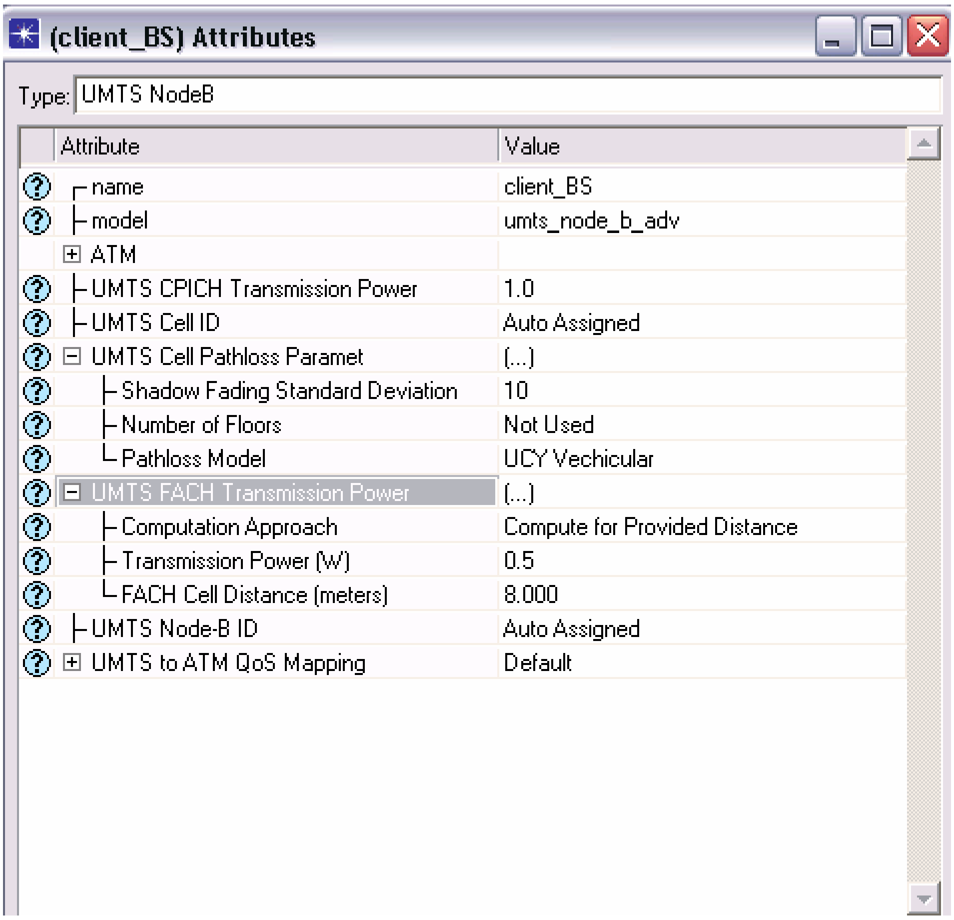
*Figure 45: Moving Average Power Indoor vs number of client UEs at 60m average distance*

## 5.6 Rural

Rural areas are characterised by high vegetation and low building densities. The population density is therefore low, mainly residential and from the primary sector. Commerce is almost inexistent. Primary roads are typically inserted in these rural areas and are characterized by relatively high-speed users.

| ***Parameter*** | ***Value*** |
|---|---|
| Path loss | Ucy-vechicular |
| Shadow Fading Standard Deviation | 10 dB |
| Traffic sent | Streaming video |
| Cell radius | 8km |
| Number of server UEs | 10 |
| Number of client UEs | 10 |
| Average distance | Increasing from 2Km to 7Km |
| Sectorization | No |
| Cell layout | Hexagonal |
| Transport Channels | DCH and FACH |
| FACH transmitted power | 6.3 W |
| Max Node-B transmitted power | 20W |

**Table 11 – Parameters for Rural**



Type: UMTS NodeB

| Attribute | Value |
|---|---|
| name | client_BS |
| model | umts_node_b_adv |
| ATM | |
| UMTS CPICH Transmission Power | 1.0 |
| UMTS Cell ID | Auto Assigned |
| UMTS Cell Pathloss Paramet | (...) |
| Shadow Fading Standard Deviation | 10 |
| Number of Floors | Not Used |
| Pathloss Model | UCY Vechicular |
| UMTS FACH Transmission Power | (...) |
| Computation Approach | Compute for Provided Distance |
| Transmission Power (W) | 0.5 |
| FACH Cell Distance (meters) | 8.000 |
| UMTS Node-B ID | Auto Assigned |
| UMTS to ATM QoS Mapping | Default |

***Figure 46:Node B Parameters for Rural***

For rural scenario we apply to Node-B the parameters above (Figure 46). For the FACH channel the power needed was 6.3 W (Figure 47). As we expected FACH power was constant, independent of the number of users and the distance between the Node B and the end users.

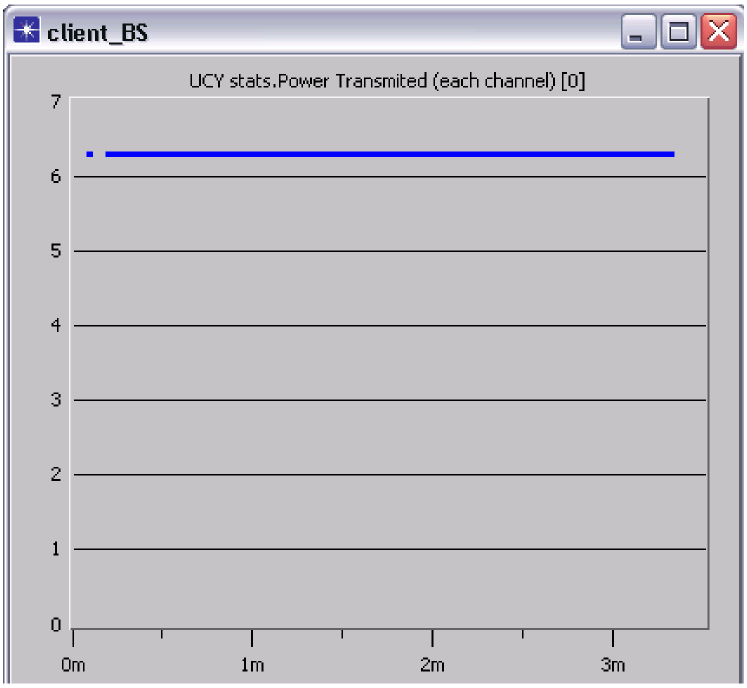


*Figure 47: FACH transmitted power for Rural*

In order to observe the effect of the average end user distance from the Node-B, in the next sub scenario we increased the average distance of the UEs (from 2Km to 7Km) keeping the number of users constant (10 users). The results (Figure 48) once again demonstrate that the average power of the DCH channel is highly depended on the distance of the UEs from the Node-B. As can be seen when 10 users are within 2Km from the Node-B the power transmitted is about 0.1 W. For 4Km (close to the middle of the cell) the power becomes 1W. When the average distance becomes 6Km and 7Km (closer to the edge of the cell) the power becomes 5 W and 8W respectively. This huge increase of the transmitted power supports our assertion for the dependency of the two parameters on power.

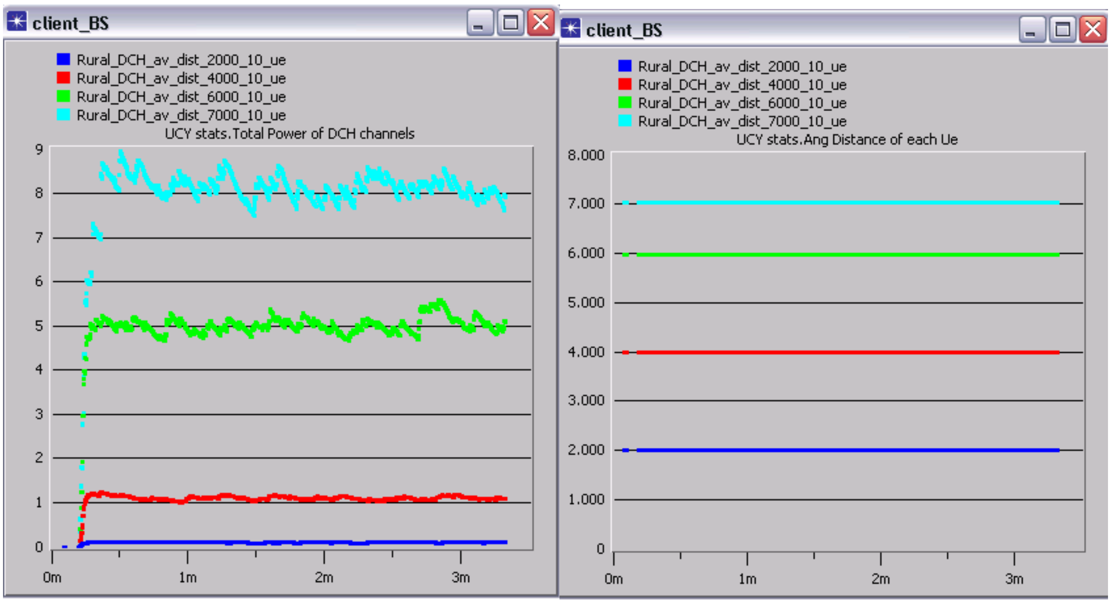


***Figure 48:DCH Power for Rural Vs Average Distance of UEs***

In the next sub scenario the number of users is also increased in order to show the effect in our results. First we have our UEs within 6Km from the base station while the number of users increased from 10 to 12. The results are shown below.

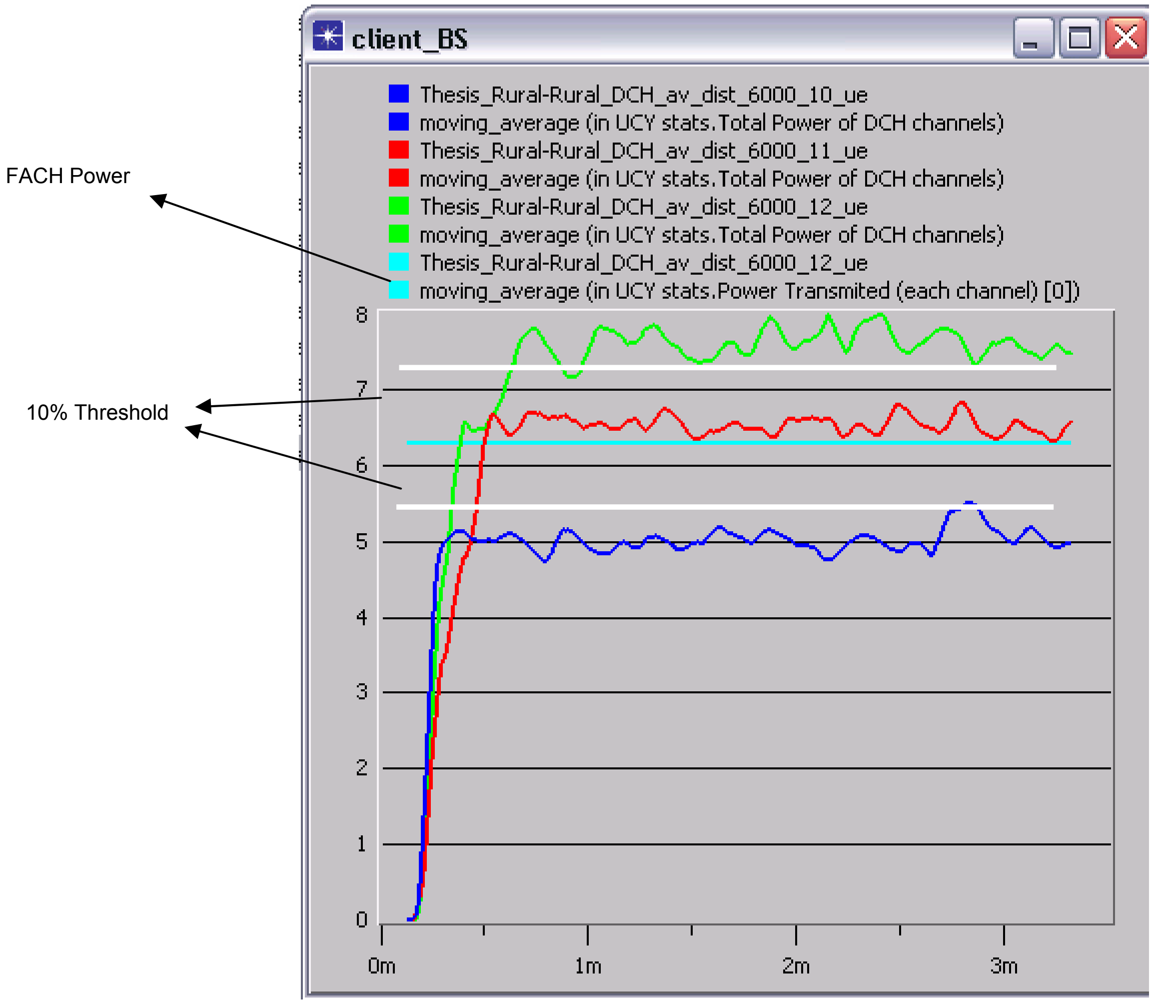


*Figure 49: Moving Average Power Rural vs number of client UEs at 6000m average distance*

At 6Km when the number of users is 10 the total transmitted power is just below the 10% limit for the switch from p2m to p2p. This means that if we are in p2m and the number of users decreases to 10 we need to switch to p2p according to our proposed algorithm. We can see that for 12 users the average power exceeds the 10% threshold. In other words if the number of users increase to 12 a switch from p2p to p2m has to be made. In this sub scenario we manage to reduce to/BY 10% the average transmitted power to each switch and to establish an acceptable UE difference to avoid the ping pong effect.

Next we increase the average distance of the UE to 7Km. As a result the number of users needed was reduced to 7 up to 9. The results are shown below.

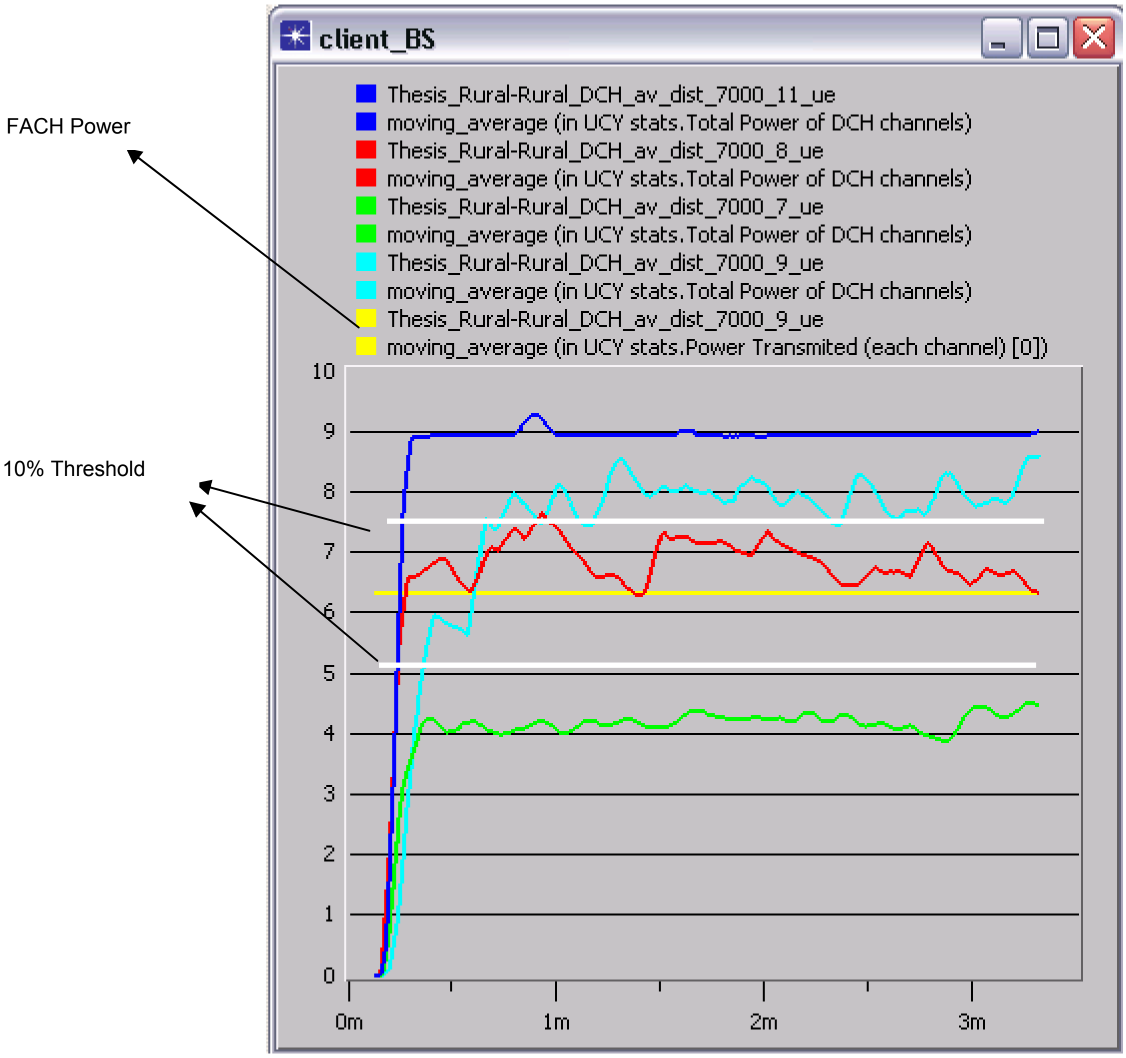


*Figure 50: Moving Average Power for Rural vs number of client UEs at 7000m average distance*

For 7Km average distance the thresholds for the switch are crossed when the number of UEs increases to 7 and 9 respectively. So for this sub scenario the switch from p2m to p2p is necessary when the number of users reduces to 7 with approximately 34% power gain, and respectively the switch from p2p to p2m is necessary when the number of users increases to 9 with power gain approximately 20%. From the results we can observe that they are similar (in a linear way) with the previous sub scenario while the switch thresholds were reduced by 3 UEs in both ways. Furthermore in this sub scenario we had more than 10% gain for each switch and an acceptable UE number between the switch for the ping pong effect.

Finally we compare the two algorithms for this sub scenario. If we follow the UE counting algorithm according to the produced results an acceptable UE threshold could be

11 UEs, if we assume that end users are located at an average distance of 6Km from the Node–B. If the average distance of the UEs increases to the edge of the cell (7 Km) the UE counting algorithm would cost waist of power (30%) since the switch would be made up to 11 users. In addition to that, looking at figure 50 we can observe that the power for 11 users has reached the upper limit of maximum power transmition of the Node B. This means that the Node B will not be able to serve any other Ue due to lack of power This leads us to the conclusion that for this sub scenario also the power counting algorithm perform better rather than the UE counting algorithm.

## 5.7 Concluding remarks for the evaluation

Finally we summarise all the results in order to give a more general idea for the performance of the proposed algorithm. In the next table all the necessary values for the performance evaluation are shown.

| **Scenario** | **FACH (W)** | **Cell ratius(m)** | **Distance(m)** | **ptp->ptm** | **ptm->ptp** | **UE threshold** | **Distance(m)** | **ptp->ptm** | **ptm->ptp** | **Power Gain** |
|---|---|---|---|---|---|---|---|---|---|---|
| **Urban** | 0.36 | 600 | 400 | 14 | 11 | 12 | 450 | 10 | 8 | 55% |
| **SubUrban** | 0.034 | 2000 | 1500 | 11 | 10 | 10 | 1700 | 8 | 7 | 32% |
| **Dense Urban** | 1.5 E-4 | 90 | 70 | 11 | 10 | 10 | 90 | 4 | 3 | 59% |
| **Indoor** | 1.82 E-5 | 70 | 50 | 10 | 6 | 8 | 60 | 7 | 4 | 40% |
| **Rural** | 6.3 | 8000 | 6000 | 12 | 10 | 11 | 7000 | 9 | 7 | 30% |

As we can see in the first scenario (Urban) when the average distance from Node-B was 400m ,switch thresholds from one state to the other were 14 (for ptp to ptm ) and 11 (for ptm to ptp). A proposed UE counting threshold for this scenario was 12 users. By increasing the average distance to 450m, switch thresholds were 10 and 8.If we use UE counting threshold instead of power threshold the loss of power was going to be 55% .

Moving to the SubUrban scenario we had similar results. For 1500m average distance switch thresholds were 11 and 10 (ptp->ptm,ptm->ptp) and for 1700m were 8 and 7 (ptp->ptm,ptm->ptp).In this case the mechanism for the ping pong effect (number of UEs between the switches) wasn't so efficient because we had only one user between them. A proposed UE counting threshold was 10.The power gain of power counting algorithm compared to UE counting algorithm was in this case 32%.

For the Dense Urban scenario we investigate switching thresholds for average distance 70 and 90 metres. The proposed thresholds were 11,10(ptp->ptm,ptm->ptp) for 70m and 4 ,3(ptp->ptm,ptm->ptp) for 90m accordingly. UE counting threshold for this scenario was 10 Ues. Comparing the two algorithms we proved that Ue counting is causing 59% waste of power which is the highest percentage of all scenarios investigated. Although we had very good performance regarding power gain in this scenario, ping pong effect still remains since the number of UEs is the minimum between the switches

For the Indoor environment we investigate the performance of our algorithm for average distance 50 and 60m.The proposed thresholds were 10,6 (ptp->ptm,ptm->ptp) and 7,4 (ptp->ptm,ptm->ptp). The corresponding UE threshold was 8 Ues. In this scenario we manage to establish an acceptable difference between the switches and to eliminate the ping pong effect.Comparing the two algorithms we proved that power counting had 40% power gain .

Finally for the Rural scenario results were taken for average distance 6km and 7km.Proposed thresholds were 12,10 (ptp->ptm,ptm->ptp) and 9,7 (ptp->ptm,ptm->ptp) accordingly. Ue threshold for this scenario was 8 Ues .For this scenario the power gain when using power counting algorithm instead of using Ue counting algorithm was 30% .Furthermore we observe that if we use Ue counting algorithm with average distance 7km, Node-b reach the maximum power transmition which might block other Ues to participate in the multicast session.

The results above can help us to conclude about the performance of our proposed algorithm. In all of the above scenarios our algorithm had at least 10% gain in each switch...Furthermore in most of the scenarios (except Dense Urban and Rural) we achieve to have a reasonable UE offset between the switches in order to avoid ping pong effects. This can make our algorithm to perform better without changing state continuously .

Looking at the comparison of UE counting algorithm and Power counting algorithm we can observe that in all scenarios Power counting had a significant power gain compared to Ue counting from 30-59%. This can lead us to the conclusion that Power counting algorithm is more effective than Ue counting due to the adaptation ability that our algorithm has according to the average distance from the Node B.In addition to that UE counting algorithm doesn't have any mechanism to avoid ping pong effects which make the performance even worst.

## 6. Conclusion

In this thesis we investigate the delivery of MBMS content using power controlled switching between ptp and ptm. Our goal is to minimize the total power for delivering MBMS content. Currently, the traditional technique of UE counting uses only the number of UEs participating in a multicast session to determine when to switch from ptp to ptm and vice versa. With our simulative evaluation we demonstrate that the total transmitted power is a more important factor, as it is sensitive to distance and number of UEs, as expected in CDMA environments. In our proposed algorithm we define a power threshold to determine when to switch to another channel, as it includes all the factors that affect power transmission.

We have demonstrated the trade-off between the number of users and the average distance from the Node B. We also identified possible power thresholds for switching from the DCH to FACH and vice versa so as to compare with the UE counting approach. These thresholds correspond to specific number of users according to the average distance that they are located. From the results obtained we show that our proposed algorithm is more efficient than UE counting because in each scenario we determine the best possible threshold, according to the power consumed and the average distance of the UEs from Node B and in each scenario our algorithm had better performance in terms of power consumption. Furthermore our algorithm handles the ping pong effects. In most of the scenarios an acceptable number of UEs was between the thresholds of the switching in order to avoid the unnecessary ping pong effects. Note however, as stated in the thesis, determination of the switching threshold remains an open issue, as many factors affect its value. Finally we demonstrate that the signalling overhead for switching from one channel to another is not effecting network performance, since the background singalling traffic send and received in order to establish and release the new channels is minimal (in the order of 100s of bits per second). On the contrary, when we decide to switch to another channel, network performance improves as we have at least 10% gain (sometimes even higher) in terms of downlink power, which means that Node B service capacity is increased.

Future research work includes setting and investigation of sensitivity of several parameters, like:

- Setting of a dynamic threshold value
- Mobility, and how it effects the performance of our algorithm
- If switching from one channel to another affects QoS
- Include handover scenarios in order to examine the behaviour of the proposed algorithm.
- Investigate sensitivity to the update interval (instead of 5 sec) or a dynamic interval for our algorithm need to be investigated.

## LIST OF PAPERS AND REPORTS PRODUCED AS A RESULT OF THE THESIS

[1] Power Control for Efficient Multicasting in IP-based 3G and beyond mobile networks ,Neophytos Vlotomas, Josephine Antoniou, George Hadjipollas, Vasos Vassiliou, Andreas Pitsillides

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