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Technical Report

Universal Mobile Telecommunications System (UMTS); UMTS Terrestrial Radio Access (UTRA); Concept evaluation (UMTS 30.06 version 3.0.0)

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Contents

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Foreword

This Technical Report (TR) has been produced by ETSI Special Mobile Group (SMG) of the European Telecommunications Standards Institute (ETSI). This Report has been elaborated by SMG2 "Radio aspects", as part of the evaluation of the Universal Mobile Telecommunications System UMTS Terrestrial Radio Access (UTRA) concepts. SMG2 have not be able to conclude that any single one of these concept provides a better solution than the other concepts.

This Technical Report was prepared during the UTRA evaluation work of SMG2 as a possible basis for the UTRA standard. It is published with the understanding that the full details of the contents have not necessarily been reviewed by, or agreed by, ETSI SMG or SMG2.

NOTE: SMG 2 is responsible for the physical layer of the radio interface and the study of all radio engineering aspects of GSM, DCS 1800 and UMTS,

1 Scope

This document describes the detailed evaluation work towards the definition of the Universal Mobile Telecommunications System UMTS Terrestrial Radio Access (UTRA) within SMG2.

2 References

The documentation for the four concepts compiled in this report may also be found in the following ETSI SMG documentation:

For the α-concept:

- Tdoc SMG 903/97: "System Description Summary";
- Tdoc SMG 904/97: "Evaluation Summary";
- Tdoc SMG 905/97: "Evaluation Report".

For the β-concept:

- Tdoc SMG 894/97: "System Description Summary";
- Tdoc SMG 895/97: "Evaluation Summary";
- Tdoc SMG 896/97: "Evaluation Report".

For the γ-concept

- Tdoc SMG 900/97: "System Description Summary";
- Tdoc SMG 901/97: "Evaluation Summary";
- Tdoc SMG 902/97: "Evaluation Report".

For the δ-concept:

- Tdoc SMG 897/97: "System Description Summary";
- Tdoc SMG 898/97: "Evaluation Summary";
- Tdoc SMG 899/97: "Evaluation Report".

3 Summary of the UTRA definition procedure in SMG2

SMG2's detailed work towards the definition of the UMTS Terrestrial Radio Access (UTRA) within SMG2 was initiated by a workshop on radio access technologies held December 1996. Since then SMG2 have dealt with UMTS Terrestrial Radio Access at several meetings amongst these 4 SMG2 plenaries, 4 ad-hoc meetings dedicated to UMTS, a joint SMG2-ARIB workshop, a question and answer session and numerous concept group meetings.

In the first step of the process the procedure and time schedule for the UTRA definition was elaborated by SMG2 and agreed by SMG at SMG#21. Hereafter, the requirements impacting the UMTS Terrestrial Radio Access was collected and the high level requirements for the UMTS Terrestrial Radio Access documented and approved by SMG#22. The high level requirements were further detailed in UMTS 21.01.

At the same time UMTS 30.03 describing evaluation criteria for the UTRA definition procedure was elaborated. UMTS 21.01 and UMTS 30.03 were approved by SMG#22. In parallel with the work on these reference documents, SMG2 were collecting technical proposals for radio access technologies for the UMTS Terrestrial Radio Access.

These proposals grouped into the following five concepts:

α -concept based on wideband CDMA (WCDMA)

β -concept based on OFDMA

γ -concept based on wideband TDMA (WB-TDMA)

δ -concept based on TDMA with spreading (WB TDMA/CDMA)

ε -concept based on ODMA (Opportunity Driven Multiple Access)

This grouping was presented to SMG#22 for approval. Hereafter, SMG2 formed five concept groups to assist in evaluation of the different building blocks suggested. Through the period since SMG#22 detailed evaluation of the proposals have been performed and the different original proposals combined into one single proposal for UMTS Terrestrial Radio Access per concept group. Originally the intention was then to merge the concepts into one single concept for the UMTS Terrestrial Radio Access. Unfortunately, SMG2 have failed in doing so.

This leaves a situation where the concepts have been refined and their performance been evaluated in detail. Results of link level and system level results have been discussed within SMG2. Further the SMG2 have checked the different concept against the high level requirements. In general it can be said that the concepts can be claimed to fulfil the high level requirements. However, it should be noted that the area of private and residential operation and the use of unpaired spectrum are not areas on which the concept groups have placed the highest attention. Therefore the issue of UMTS deployment of private and residential operation will require further studies in SMG2 to ensure that the requirements in this area are properly met. The issue of how UMTS can be implemented to enable an operator to make the most effective use of the unpaired spectrum, has not been fully addressed and will require further studies in SMG2.

In particular it may be necessary to consider modification of any adopted UMTS Terrestrial Radio Access concept to improve these aspects of performance.

Regarding the results of the evaluation and refinement work performed, SMG2 has informed SMG about the following findings and conclusions regarding the epsilon concept (ODMA - Opportunity Driven Multiple Access):

- Investigation of relay systems has been carried out within the SMG2 considering the technology called Opportunity Driven Multiple Access – ODMA. The protocols used in ODMA are very similar to those of a packet radio system currently being trialed. System level simulations were carried out in accordance with UMTS 30.03 which showed that wide area high data rate coverage was possible in all environments using a subscriber relay system and that there was potential for increased capacity when used in a cellular hybrid.
- Feasibility studies were conducted to determine the practicality of supporting relaying using the basic WCDMA and WB TDMA/CDMA designs. The conclusion was that both the WCDMA and the WB TDMA/CDMA designs were sufficiently flexible to support relaying with negligible increase to the mobile station complexity or cost. These technologies can therefore offer the flexibility of simple relaying but also provide a suitable platform for advanced relay protocols such as ODMA.
- For the above reasons it was decided that relaying/ODMA should be presented as an enhancement to both WCDMA and WB TDMA/CDMA rather than as a standalone technology. As a result documentation from the studies of epsilon concept is included as a part of the evaluation reports on the alpha and delta concepts.

Regarding the four other concepts (α, β, γ, δ) SMG2 has not been able to obtain any further merging. Moreover, when the uncertainty on simulations and the differences in the assumptions made in order to evaluate that performance of the concepts are considered SMG2 has not be able to conclude that any single one of these concept provides a better solution than the other concepts.

Therefore SMG2 requested SMG to decide on the basis of which of the concepts α, β, γ, or δ SMG2 shall continue the work on the UMTS Terrestrial Radio Access. In order to assist SMG in making the decision SMG2 has prepared the following documentation for each of the concepts:

- A summary of system description for the concept
- A summary of the concept evaluation for the concept
- An evaluation report for the concept

It should be noted that SMG2 does not recommend SMG to make a direct comparison of the performance results for concept based directly on the values contained in the evaluation documentation. This due to the different nature of the concepts, which has lead to differences in the assumptions for the performance evaluation, which lead to differences in the results. Especially regarding guard bands SMG2 would like to highlight, that it is difficult to perform a direct comparison of Minimum Coupling Loss (MCL) based guard band analysis, as, e.g., the likelihood for different scenarios might be different for the different concepts.

SMG2 has not been able to reach a consensus on how the results of the evaluation should be compared, and is therefore unlikely to be able to reach a consensus on the technology for UMTS Terrestrial Radio Access in the foreseeable future. SMG2 therefore recommended to SMG that the best way forward for the elaboration of the UMTS radio interface would be for SMG to make a decision on one concept that should be used by SMG2 in the refinement phase.

It is the understanding of SMG2 that by deciding to base the UMTS Terrestrial Radio Access on a given concept, SMG approves the summary of the system description for that concept. This means that the further refinement of the selected concept is done with reference hereto. Meaning that changes in order to improve the concept shall be justified relative to the concept described in the summary system description.

Annex A:

Concept Group Alpha α - Wideband Direct-Sequence CDMA

This report contained in this annex was prepared during the evaluation work of SMG2 as a possible basis for the UTRA standard. It is published on the understanding that the full details of the contents have not necessarily been reviewed by, or agreed by, ETSI SMG or SMG2.

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Agenda item 4.1: UTRA

Concept Group Alpha - Wideband Direct-Sequence CDMA: System Description Summary

Concept Group Alpha - Wideband Direct-Sequence CDMA

System Description Summary

Introduction

Within the Alpha concept group in SMG2, a UTRA proposal based on wideband direct-sequence CDMA has been developed. The WCDMA concept is described in the Alpha group's evaluation document (Tdoc SMG2 359/97), that contains a system description section. This document presents a summary of the WCDMA system description.

The WCDMA system includes:

- Wideband CDMA carrier to offer a high degree of frequency diversity and high bit-rates
- Flexible physical layer for implementation of UMTS services, with support for large range of varying bit-rates with high granularity
- Built in support for co-existence and efficient handovers with GSM
- Feasible implementation from day one of UMTS, with possibility for performance enhancement using more demanding features like adaptive antennas and multi-user detection in the future

Key technical characteristics of the basic system

Table 1 below summarises the key technical characteristics of the WCDMA radio-interface.

Multiple-access scheme	DS-CDMA
Duplex scheme	FDD / TDD
Chip rate	4.096 Mcps (expandable to 8.192 Mcps and 16.384 Mcps)
Carrier spacing (4.096 Mcps)	Flexible in the range 4.4-5.2 MHz (200 kHz carrier raster)
Frame length	10 ms
Inter-base station synchronisation	FDD mode: No accurate synchronisation needed TDD mode: Synchronisation needed
Multi-rate/variable-rate scheme	Variable-spreading factor and multi-code
Channel coding scheme	Convolutional coding (rate 1/2-1/3) Optional outer Reed-Solomon coding (rate 4/5)
Packet access	Dual mode (common and dedicated channel)

Table 1. WCDMA key technical characteristics.

Performance enhancing features

There exist a number of ways to enhance the performance of the WCDMA system. In general in CDMA, it is very easy to get immediate quality, coverage and capacity gains directly from link improvements. This is due to the single-cell reuse and the fact that power is the only shared resource. If one user's link is improved the transmit power can be lowered on that link, and all users in the system will benefit from this since they are sharing the same power resource.

Listed below are some performance enhancing features that can be applied to the WCDMA system:

- **Downlink antenna diversity.** Antenna diversity in the mobile station is not required in the concept. However, since antenna diversity gives a gain of around 3 dB in performance it can be employed in the terminal for better quality and system capacity.
- **Transmitter diversity.** Orthogonal transmit diversity, where the data stream is split into several streams and sent through different antennas, can be used in the downlink to get quality and capacity gains. This is a good way to get diversity gains in the downlink without increasing the mobile station complexity.
- **Receiver structures.** WCDMA is designed to work without requiring receivers for joint detection of multiple user signals. However, the potential capacity gains of such receivers in a WCDMA system have been recognised and taken into account in the design of the concept. In the uplink the possibility to use only short codes facilitates introduction of more advanced receiver structures with reasonable complexity.
- **Adaptive antennas.** Adaptive antennas are recognised as a way to greatly enhance capacity and coverage of the system. Solutions employing adaptive antennas are already supported in the WCDMA concept through the use of connection-dedicated pilot bits on both uplink and downlink. Moreover, adaptive antenna issues have been included in the design of the downlink common physical channels.
- **Support for relaying and ODMA.** A feasibility study conducted by the Alpha and Epsilon concept groups concluded that WCDMA can support relaying and the ODMA protocol with negligible increase in mobile complexity or cost. ODMA is an intelligent relaying protocol that sits upon the WCDMA radio sub-system. The protocol breaks difficult radio paths into a sequence of shorter hops which enables lower transmit powers or higher data rates to be used. It is the goal of the protocol to chose the least cost route through the relaying system when the relays are moving and the radio paths are dynamically changing. Simulations have shown that relaying has the potential to improve coverage and flexibility and may also increase capacity by lowering transmission powers and associated inter-cell interference.

System description

Physical channel structure, spreading and modulation

There exist two basic physical channels in WCDMA: the dedicated physical data channel and the dedicated physical control channel. The data channel is used to carry dedicated data generated at layer 2 and above, i.e. the dedicated logical channels. The control channel carries control information generated at layer 1. The control information consists of known pilot bits to support channel estimation for coherent detection, transmit power-control commands, and optional (variable-length) rate information. The rate information informs the receiver about the instantaneous rate of the different services and how services are multiplexed on the dedicated physical data channels.

The frame length on the physical channels is 10 ms, and each frame is divided into 16 slots of 0.625 ms each, corresponding to one power-control period. In the downlink the dedicated physical control and data channels are time-multiplexed within the slots, with one power-control command per slot. In the uplink control and data are code-multiplexed and transmitted in parallel.

In both uplink and downlink, the dedicated physical control and data channels are spread to the chip-rate using orthogonal variable rate spreading factor codes. These channelization codes have varying spreading factors to carry varying bit-rate services, i.e the channelization codes are of different lengths to match different user bit rates, with spreading factors from 4 up to 256. Using different channelization codes, several data and control channels of different rates can be spread to the chip-rate and still be orthogonal after spreading. Hence, multi-code transmission can be employed for the highest bit-rates, typically above 384 kbps, and several services of different rates can be transmitted in parallel with maintained orthogonality.

Spreading with the channelization codes is followed by scrambling. In the downlink the scrambling code is base-station specific 10 ms segment of a Gold code of length 2^{18}-1. The number of available scrambling codes is as high as 512, making code planning trivial. In the uplink, the primary scrambling code is a complex code, built from extended VL-Kasami sequences of length 256. This short code facilitates the introduction of advanced receiver structures, such as multi-user detection. For cells without such receivers, a long secondary scrambling code is used for improved cross-correlation properties and interference averaging. The secondary scrambling code is a 10 ms segment from a Gold code of length 2^{41}-1.

In uplink and downlink QPSK modulation is used, with root-raised cosine pulse-shaping filters (roll-off 0.22 in the frequency domain).

Channel coding and service multiplexing

WCDMA offers three basic service classes with respect to forward error correction coding: standard services with convolutional coding only (BER $\approx 10^{-3}$), high-quality services with additional outer Reed-Solomon coding (BER $\approx 10^{-6}$), and services with service-specific coding where WCDMA layer 1 does not apply any pre-specified channel coding. The latter class can be used to enable other coding schemes such as e.g. turbo-coding. Rate 1/2 or 1/3 convolutional codes are used, with block interleaving over one or several frames depending on delay requirements. The additional Reed-Solomon code employed is of rate 4/5, and is followed by symbol-wise inter-frame block interleaving.

Multiple services belonging to the same connection are, in normal cases, time multiplexed. Time multiplexing takes place both after possible outer coding and inner coding. After service multiplexing and channel coding, the multi-service data stream is mapped to one or several dedicated physical data channels. A second alternative for service multiplexing is to treat parallel services completely separate with separate channel coding/interleaving and map them to separate physical data channels in a multi-code fashion. With this alternative scheme, the power and consequently the quality of each service can be more independently controlled.

After channel coding and service multiplexing, the total bit rate is almost arbitrary. Rate matching is used to match the coded bit-rate to the limited set of possible bit-rates of a dedicated physical data channel. In the uplink puncturing and repetition is employed to match the rate, while in the downlink puncturing and repetition for the highest rate is used together with discontinuous transmission for the lower rates.

Using the above mentioned coding, interleaving and rate matching techniques the WCDMA concept has shown that rates of at least 2 Mbps can be achieved using a 4.096 Mcps carrier. Also, low bit-rates as well as high bit-rates can be supported efficiently, with high bit-rate granularity.

Radio resource functions

A fast and efficient random access procedure has been defined. The random access is based on slotted Aloha transmission of a random access burst. The burst contains a preamble part, where a base station specific preamble code is used to transmit a preamble sequence randomly picked by the mobile station. The preamble sequence is detected in the receiver using a matched filter, and tells the receiver what scrambling code has been used for the data part of the burst. Using this scheme, the base station may receive up to 80 random-access attempts within one 10 ms frame using only one matched filter for the preamble code.

The WCDMA system operates with a frequency re-use of one. Soft handover enables this, and gives capacity and coverage gains compared to hard handover. Seamless inter-frequency handover is needed for operation in hierarchical cell structures and handover to other systems e.g. GSM.

A key requirement for the support of seamless inter-frequency handover is the possibility for the mobile station to carry out cell search on a carrier frequency different from the current one, without affecting the ordinary data flow. For a mobile station with receiver diversity, there is a possibility for one of the receiver branches to temporarily be reallocated from diversity reception and instead carry out reception on a different carrier. A single-receiver mobile station uses slotted downlink transmission to do inter-frequency measurements. In the slotted mode, the information normally transmitted during a certain time, e.g. a 10 ms frame, is transmitted in less than that time, leaving an idle time that the mobile can use for measurements on other frequencies.

The FDD mode assumes asynchronous base stations. To enable asynchronous operation a fast cell search scheme has been defined. In the cell search procedure the mobile station acquires two synchronisation codes broadcasted by the base station, from which the mobile can determine the scrambling code and frame synchronisation of the base station.

Packet access

Due to the varying characteristics of packet data traffic in terms of packet size and packet intensity, a dual-mode packet-transmission scheme is used for WCDMA. With this scheme, packet transmission can either take place on a common fixed-rate channel or on a dedicated channel, with an adaptive choice of method based on the packet traffic characteristics. Small infrequent packets are typically transmitted on the common channel, while larger more frequent packets are transmitted on a dedicated channel.

Summary

In the development of the WCDMA concept a prerequisite has been to fulfil the UMTS requirements described in ETR-0401. To summarise, the following key features are included in the WCDMA concept for flexible and efficient support of UMTS service needs:

- Support for high data-rate transmission with 384 kbps wide-area coverage and 2 Mbps local area coverage. This can be achieved in a bandwidth of 5 MHz, including guardbands.
- High service flexibility, i.e. good support of multiple bearers and variable bit rates. This is achieved using a physical channel structure that allows multiple bearers on the same physical channel and supports changed user bit-rate on a frame-by-frame basis with very high granularity.
- High capacity and coverage in the basic system without the need for multi-user/joint-detection receivers, dynamic radio-resource-management algorithms and link adaptation, frequency planning etc. However, for future performance enhancements, features like multi-user detection, adaptive antennas, ODMA etc. are supported within the concept.
- Fast and efficient packet access using a dual mode access scheme (common or dedicated channel transmission) with adaptive mode selection based on packet traffic characteristics, together with an efficient random-access mechanism.
- Flexible system deployment with asynchronous base station operation in FDD mode, and spectrum-efficient deployment of hierarchical cell structures.
- Support for inter-frequency handover for operation with hierarchical cell structures, and inter-system handover with second generation systems like GSM.

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Concept Group Alpha
Wideband Direct-Sequence CDMA:
Evaluation Summary

Title: Summary of the Concept Evaluation for the Alpha Concept

Source: SMG 2

Introduction

This document contains a short description on how the high level requirements that are relevant for the UMTS Terrestrial Radio Access (UTRA) concept are met by the WCDMA concept as being defined within concept group Alpha in SMG 2.

The high level requirements are defined in UMTS 21.02 version 3.0.0 [1], but are also part of TR 101 111 (UMTS 21.01 version 3.0.1) [2]. The latter report has been used to derive the boxes with the requirements as shown below.

The documents that has been issued to SMG 2 from the alpha group has been used in order to make this summary on how the requirements are fulfilled [1-10]. The detailed concept is described in the evaluation report [9] with a summary in [10] and the concept will not be described in detail here. To get a better and deeper understanding of the concept and its fulfilment of the requirements the reader is referred to the referenced documents.

The ODMA (Opportunity Driven Multiple Access) can be used with the Alpha concept WCDMA radio technology as described in the evaluation report [9]. That report also contains a section describing the fulfilment of the high level requirements of WCDMA with the enhancement of ODMA for the routing and access control.

It is shown that the Alpha concept will provide all characteristics in order to support the multitude if services and provide flexible coverage/capacity trade-offs also for future proof evolution.

Fulfilment of the High Level Requirements

Bearer Capabilities

Maximum User Bit Rates

The UTRA should support a range of maximum user bit rates that depend upon a users current environment as follows:
Rural Outdoor: at least 144 kbit/s (goal to achieve 384 kbit/s), maximum speed: 500 km/h
Suburban Outdoor: at least 384 kbps (goal to achieve 512 kbit/s), maximum speed: 120 km/h
Indoor/Low range outdoor: at least 2Mbps, maximum speed: 10 km/h
It is desirable that the definition of UTRA should allow evolution to higher bit rates.

The transmission blocks have been defined to support up to 2048 kbps user data on one Radio Frequency (RF) Carrier having a transmission rate of 4.096 Mchips/second after spreading. There are error protection schemes defined for both transparent and non-transparent services for the whole range of user data bit rates.

- For Rural outdoor 384 kbps has been evaluated by using the Vehicular test environment as it is defined in UMTS 30.03. Up to 500 km/h is supported as shown in the SMG2 Q&A workshop [11].

- For Suburban Outdoor 384 kbps is supported for the required vehicle speed.
- For Indoor and low range outdoor environment 2048 kbps is supported.

The concept supports 8.196 and 16.392 Mcps, i.e. bit rates up to 4 and 8 Mbps respectively can be supported without large modifications.

Flexibility

Negotiation of bearer service attributes (bearer type, bit rate, delay, BER, up/down link symmetry, protection including none or unequal protection), *parallel bearer services (service mix), real-time / non-real-time communication modes, adaptation of bearer service bit rate* *Circuit switched and packet oriented bearers* *Supports scheduling (and pre-emption) of bearers (including control bearers) according to priority* *Adaptivity of link to quality, traffic and network load, and radio conditions (in order to optimise the link in different environments).* *Wide range of bit rates should be supported with sufficient granularity* *Variable bit rate real time capabilities should be provided.* *Bearer services appropriate for speech shall be provided.*

It is possible to provide bit rates from 100 bps up to 2 048 kbps with a granularity of 100 bps. The detailed bearer service is negotiated according to bearer type, bit rate(s), delay, BER etc. and during a call the transmitted bit rate can be changed on a 10 ms basis for efficient spectrum usage, e.g. utilising the variable rate nature of speech. The negotiated bearer characteristics can be different in the uplink and the downlink. Both circuit and packet oriented bearers are supported simultaneously to one user. Priority schemes are supported between e.g. circuit-oriented, like speech, and packet transmissions. This can be done easily since there are no need to time share a certain physical resource like a time slot. All users share the same frequency simultaneously and a packet user can instantly be placed on short hold if a higher priority user urgently needs the resource. In WCDMA the resource is total transmitted power. The more power the more resource a user takes.
The TDD mode can be used if asymmetry exists between the needed uplink and downlink traffic capacity to be able to achieve high flexibility. The FDD mode can also be used for the case that more downlink traffic capacity than uplink traffic capacity is needed.

Handover

Provide seamless (to user) handover between cells of one operator. *The UTRA should not prevent seamless HO between different operators or access networks.* *Efficient handover between UMTS and 2nd generation systems, e.g. GSM, should be possible.*

For the same operator or also between operators or access networks two types of handover are provided. Macro diversity is used for handover between cells using the same frequency (intra-RF HO) and will be the one used most often. It provides for a very good mechanism for seamless handover since no data is lost due to the handover execution. The quality to be provided to a user is then similar to wire-line connection since the loss of data due to the handover does not need to be considered. For inter-frequency handover, which occurs when the used RF-carrier can no longer be used or when a handover between HCS-layers should be performed, a hard handover scheme is used. This HO can be controlled by either the mobiles itself, e.g. if the MS quickly looses the served link in case of very fast changing propagation characteristics, or by the network as in GSM. The handover decision is supported by measurements by using slotted mode transmission for single receiver mobile stations.

Handover between UMTS and GSM depends on the type of multi-mode mobile station implementation. If dual receiver chains are used then the requirement is fulfilled easily. If the UMTS wideband receiver is used for the GSM reception, measurement slots to get knowledge of possible neighbouring GSM base stations. The handover is then performed as a normal hard handover.

Operational Requirements

Compatibility with services provided by present Core Transport Networks

ATM bearer services *GSM services* *IP (Internet Protocol) based services* *ISDN services*

The design of the WCDMA concept has also included the interoperability with GSM radio access, see the handover section above, and naturally the services in GSM are supported also in the case of handover.

The provisioning of other types of services (networks) are possible since the available bit rates in WCDMA are in the range from 0.1 kbps up to 2 048 kbps in 0.1 kbps steps. There are both transparent and non-transparent transmission modes and several different types of services could be simultaneously used by the same user, i.e. multimedia is supported. The required flexibility in service provisioning like variable bit rate and multimedia services are easily provided, taking into account sharing of the radio resources with other users, since no allocations/re-allocations of physical resources are needed when the bit rate changes. It is only needed to adjust the spreading factors and power levels.

The ISDN basic rate access, (2B+D) 144 kbps, has been shown to be supported for wide area coverage. Other ISDN services up to 2048 kbps are also supported with local area coverage.

Radio Access Network Planning

If radio resource planning is required automatic planning shall be supported

In the existing systems, like GSM, they has been defined for basically a single type of quality criteria enabling the radio resource planning to deal with only one C/I requirement that was designed for speech. UMTS will need to support a multitude of different bearer services. A bearer service is characterised by bit rate, delay and bit error rate and for different services different settings will be used. This will create another dimension in the radio network planning to handle this to be able to offer the users the required coverage for the different services.

In WCDMA the common radio resource to be used by all users is power since a frequency re-use of one is used for all bearer services. There is no need to plan codes or code phase since the number of codes are sufficiently large and no inter-base synchronisation is needed. It is needed to plan the number of base stations needed for the level of traffic that is expected including the service mix. This can be done by an automatic planning tool with input parameters: expected services, radio propagation, mobile speeds, quality requirements etc.

Public Network Operators

It shall be possible to guarantee pre-determined levels of quality-of-service to public UMTS network operators in the presence of other authorised UMTS users.

This is done by allocating to each operator exclusive rights spectrum rights and ensure suitable guardbands between the operators.

Private and Residential Operators

The radio access scheme should be suitable for low cost applications where range, mobility and user speed may be limited. Multiple unsynchronised systems should be able to successfully coexist in the same environment. It should be possible to install basestations without co-ordination. Frequency planning should not be needed.

The mechanisms WCDMA can utilise to handle uncoordinated systems are by:

- Frequency avoidance techniques, e.g. not make an access on frequency that is to disturbed.

- Power control is used to be able to minimise interference but still be able react on increased received interference
- Multi-user detection and interference cancellation techniques can be applied to mitigate interference from e.g. a single dominant interferer as is the most probably case in such operating environment. This will also give a low cost implementation since only one interferer needs to be taken care of.

Spectrum sharing with a so called low tier TDD/WCDMA-system, i.e. low output power mobiles, and FDD/WCDMA-system has also been shown to work in certain environments with limited impact on efficiency.

Efficient Spectrum Usage

Spectrum Efficiency

High spectrum efficiency for typical mixtures of different bearer services.
Spectrum efficiency at least as good as GSM for low bit rate speech.

The WCDMA system has been designed to efficiently handle a mixture of services, both for a single user and within cells for all users, without requiring any pre-planned allocation of services to frequencies or codes. All services share the same resource, which is the power.

It has been shown that the performance for speech is between 78-189 kbps/MHz/cell. The result depends on the radio propagation case and vehicle speed. The performance figures are higher than for GSM.

For a 384 kbps@BER=10^{-6} connection oriented service for vehicular 120 km/s the simulated performance is between 85-250 kbps/MHz/cell depending on whether antenna diversity or not is used in the downlink.

For a packet service in pedestrian environment and with traffic characteristics of 384 kbps then the performance is 470 to 565 kbps/MHz/cell, uplink and downlink respectively. For indoor packet services with 2048 kbps the performance is between 230 - 500 kbps/MHz/cell depending on whether or not downlink antenna diversity is used.

Variable Asymmetry of Total Band Usage

Variable division of radio resource between uplink and down link resources from a common pool (NB: This division could be in either frequency, time, or code domains)

This is primarily supported by the TDD-mode. It makes it possible to use a portion of the spectrum asymmetrically between the uplink and downlink. In case that FDD only is allowed, it is possible to pair different uplink and downlink portions by using a variable duplex distance. This means that a fixed duplex distance is not needed which enables a little more flexibility in term of asymmetric operation and to have an efficient use of the spectrum. However, it is not possible in this case to switch from a downlink allocation to an uplink allocation due to the FDD operation.
The FDD mode can also be used for the case of that more downlink traffic capacity than uplink traffic capacity is needed. The mechanism to use is the trade off between transmitted power and bit rate needed and the distance MS-to-BS for the uplink. The lower bit rate needed gives a larger coverage in the uplink since this link is power limited due to the MS while the downlink is not so much output power limited.

Spectrum utilisation

Allow multiple operators to use the band allocated to UMTS without co-ordination[1].
It should be possible to operate the UTRA in any suitable frequency band that becomes available such as first & second generation system's bands.
-
[1]NOTE: The feasability of spectrum sharing requires further study

Spectrum sharing, without any co-ordination, in the same geographical area and still guarantee a level of quality of service to the users is impossible in any system, see footnote 1. See also the answers to the Private and Residential Operators Requirement for answers related to shared spectrum between operators.

If neighbouring operators operates UMTS then the carrier spacing is 5 MHz yielding a 600 kHz total guardband. For co-sited operation no guardband is needed so the total guardband needed lies between 0 to 600 KHz.

Spectrum refarming is possible. The following figures are for uncoordinated operation between the neighbouring system and WCDMA. For coordinated operation with co-sited GSM and UMTS, the figures shown can be less. If the band is a GSM band 5.2 MHz needs to be cleared if the neighbours are GSM on one side and UMTS on the other band-edge. This results in a carrier spacing of 3 MHz between the first 200 KHz GSM carrier and the WCDMA carrier. If GSM is on both sides 5.6 MHz needs to be cleared.
A 200 kHz frequency grid is assumed for the definition of WCDMA frequency carriers to support refarming.

Coverage / Capacity

The system should be flexible to support a variety of initial coverage/capacity configurations and facilitate coverage/capacity evolution
Flexible use of various cell types and relations between cells (e.g. indoor cells, hierarchical cells) within a geographical area without undue waste of radio resources.
Ability to support cost effective coverage in rural areas

The basic property of WCDMA is to have the trade-off between capacity and coverage. The less capacity that are needed the larger the cell can be. Since no frequency re-planning is needed, new cells can be inserted easily to facilitate capacity expansion. In case of asymmetric data traffic and when the major type of traffic in an area are more downlink than uplink it is possible to extend the coverage compared with a symmetric case since the uplink is limited by the mobile power and the interference is less. Note that it is the total sum of traffic that matters so certain individuals can have another asymmetry.

Different types of cells can be handled in the same geographical environment in a limited bandwidth. The basic spectrum building block is 4.4 MHz, without guardband considerations, to handle traffic up to 2 Mbps. A case where there are indoor cells, micro cells and macro cells overlapping each other 14.4 MHz of spectrum is requiered including necessary guardbands. If one neighbour is an GSM operator the spectrum needed becomes 14.7 MHz. A 15 MHz bandwidth is sufficient to have a three different overlapping cell layers in one geographical region. Sharing of a carrier can be done if the cells have a sufficiently propagation isolation.

Complexity/Cost

Mobile terminal Viability

Handportable and PCMCIA card sized UMTS terminals should be viable in terms of size, weight, operating time, range, effective radiated power and cost.

The WCDMA terminals and its required complexity is well understood, based on both the analytical calculations and also on the implemented test equipment. The calculated complexity for the base band shows that it could be implemented in the technology of today.

The peak power requirement is very close to the average power and thus this can be taken into account in dimensioning the power amplifier. Since continuous transmission is used for all types of services a duplexer is needed but it is already today used in many GSM terminals.

Network Complexity and Cost

The development and equipment cost should be kept at a reasonable level, taking into account the cost of cell sites, the associated network connections , signalling load and traffic overhead (e.g. due to handovers).

The WCDMA system are intended to be used in all environments. The link budgets have shown that it is possible to re-use GSM sites planned for 13 kbps speech service and still provide at least the 144 kbps circuit oriented service considering that the GSM sites are planned for approximately the same frequency band. Low and medium rate services can thus be provided by re-using the GSM-1800 sites.

Since the radio transmission resources are in a common pool, it is possible to share those in a site using sectored antennas. It is also possible to use as many sectors as needed in order to increase capacity. This is possible due to the frequency re-use of one. There is also no advanced adaptation mechanisms needed if the environment changes thus limiting the signalling needed and reconfiguration of the higher layers.

If WCDMA will be a world-wide standard, it is expected that the cost of base stations and associated equipment will benefit from a larger market. Interoperability between operators not only in Europe will also be much simpler since the core network will be based on GSM.

Mobile Station types

It should be possible to provide a variety of Mobile Station types of varying complexity, cost and capabilities in order to satisfy the needs of different types of users.

It will be possible to support a variety of mobile station types in terms of bit rate capabilities but also performance. In terms of performance, a low end data/speech terminal could be developed without antenna diversity while in more advanced terminals two antennas and receiver chains could be implemented for diversity reception.

It is also possible to have the same type of basic functionality in the lower layers of the MS, since all are using the same type of RF channel, but having different service capabilities in the higher layers. For instance, not everybody need a video encoder/decoder which influences the cost. A small number of mobile station types are needed. As an example there could be single or multi-code terminals and they could have antenna diversity or not.

All those types do no need any special considerations or replanning of the radio resources and base station sites. The performance gain from any advanced receiver techniques can be readily used for increasing the capacity.

Requirements from Bodies Outside SMG

Alignment with IMT-2000

UTRA shall meet at least the technical requirements for submission as a candidate technology for IMT 2000 (FPLMTS).

As shown in the alpha group documents issued to SMG2, in particular the evaluation report [9], the proposed WCDMA technology fulfils all the UTRA requirements. The UTRA requirements [2] do include the IMT-2000 requirements, or even exceed in some, so the IMT-2000 requirements are also fulfilled.

Minimum Bandwidth Allocation

It should be possible to deploy and operate a network in a limited bandwidth

The lowest bandwidth carrier rate is 4.096 MChips/s. This will provide at least 384 kbps in a vehicular environment and 2 Mbps in the indoor case. The minimum bandwidth required including guardbands is 5 MHz. For refarming issues, the case when one GSM operator is neighbour at one side of the band then it is required to have a 5.2 MHz band allocated for the WCDMA. If there are GSM operators at either side then 5.6 MHz is needed, including guardbands, i.e. 3 MHz of carrier spacing between the WCDMA carrier and the GSM carrier.

In case of co-ordinated case, as when it is the same operator of GSM and WCDMA, co-ordinated use of GSM and WCDMA the needed carrier spacing can be further relaxed.

Electro-Magnetic Compatibility (EMC)

The peak and average power and envelope variations have to be such that the degree of interference caused to other equipment is not higher than in today's systems.

Compared with GSM and similar TDMA-based systems the WCDMA technology improves the peak to average power ratio and envelope variations due to its continuos transmission properties and fast power control.

RF Radiation Effects

UMTS shall be operative at RF emission power levels which are in line with the recommendations related to electromagnetic radiation.

See the question above. The required E_b/N_0 requirements for the services are improved due to the fact that there is a continuos transmission yielding low envelope variations, peak-to average ratio is low and it uses fast power control. This will result in good link budgets minimising the RF emission power levels within the limits specified by the authorities. As a conclusion WCDMA will have smaller RF radiation effects and at least as good electro magnetic compatibility as GSM whilst offering higher bit rates.

Security

The UMTS radio interface should be able to accommodate at least the same level of protection as the GSM radio interface does.

From a ciphering point of view, all radio interface technologies offer the same level of protection as good as of GSM. Considering the WCDMA concept from a physical layer perspective, the only way that someone can detect a user’s uplink signal and read the ciphered data is by using a matched filter since the data is spread. To do this, one must know the spreading code which is selected from a pool with 1 million codes and then also synchronise to the correct phase of the uplink transmission.

WCDMA offers therefore a much higher level of security than what is offered by ciphering alone which is what the GSM radio interface and similar technologies rely upon.

Coexistence with Other Systems

The UMTS Terrestrial Radio Access should be capable to co-exist with other systems within the same or neighbouring band depending on systems and regulations

Depending on what system it has to coexist with a separate analysis has to be made but it is unlikely that the requirement cannot be fulfilled. For GSM an analysis of the required guardbands have been made and it is 5.2 MHz if there is one GSM operator on one edge of the band while there is an UMTS operator on the other side of the band. If there is GSM operators on either side then 5.6 MHz is needed to operate one WCDMA carrier including the necessary guardbands. The figures are for uncoordinated use. In case of any co-ordination the figures can be relaxed.

Multimode Terminal Capability

It should be possible to implement dual mode UMTS/GSM terminals cost effectively.

The basic assumption here is that UMTS will not provide wide-area coverage from the beginning but instead work together with a GSM-900/1800 network and hence it is also needed to perform handover between the radio access schemes. To measure the GSM carriers in WCDMA-mode a slotted mode has been defined.

Separate RF filters are needed for dual mode operation. If dual receiver chains are used then the requirement is fulfilled easily. If the UMTS wideband receiver is used also for the GSM reception the WCDMA concept allows for measurement slots to get knowledge of possible neighbouring GSM base stations. The handover is then performed as a normal hard handover .

References

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[4] Alpha Concept Group, "Compliance WCDMA with Operational Requirements (ref. Agenda item 9.2)," Tdoc SMG 2 UMTS 157/97, November 17-21, 1997, Helsinki, Finland
[5] Alpha Concept Group, "Spectrum Usage of WCDMA," Tdoc SMG 2 UMTS 138/97, November 17-21, 1997, Helsinki, Finland
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[9] Alpha Concept Group, "Evaluation Report for the Alpha Concept," Tdoc SMG 2 359/97, December 1-5, 1997, Cork, Ireland
[10] Alpha Concept Group, "Summary of System Description for the Alpha Concept," Tdoc SMG 2 361/97, December 1-5, 1997, Cork, Ireland
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ETSI SMG
Meeting no 24
Madrid, Spain
15 - 19 December 1997

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Concept Group Alpha - Wideband Direct-Sequence CDMA (WCDMA)

EVALUATION DOCUMENT (3.0)

Part 1: System Description Performance Evaluation

In the procedure to define the UMTS Terrestrial Radio Access (UTRA), the wideband DS-CDMA concept group (Alpha) will develop and evaluate a multiple access concept based on direct sequence code division. This group was formed around the DS-CDMA proposals from ACTS FRAMES Consortium (FMA2), Fujitsu, NEC and Panasonic. The main radio transmission technology (RTT) and parameters of the common concept from the Alpha group along with performance results are presented in this document.

This document was prepared during the evaluation work of SMG2 as a possible basis for the UTRA standard. It is provided to SMG on the understanding that the full details of the contents have not necessarily been reviewed by, or agreed by, SMG2.

Part 2:

Introduction

Answers to the Annex1 in ETR0402

Link budget calculation

Complexity and dual mode GSM/UMTS terminal analysis

Part 3:

Detailed simulation results and parameters

Part 4:

WCDMA/ODMA description

Glossary of abbreviations used in the document:

ARQ	Automatic repeat request
BCCH	Broadcast Control Channel
BER	Bit error rate
BLER	Block error rate
BS	Base Station
CCPCH	Common Control Physical Channel
DL	Downlink (forward link)
DCCH	Dedicated Control Channel
DPCCH	Dedicated Physical Control Channel
DPDCH	Dedicated Physical Data Channel
DS-CDMA	Direct-Sequence Code Division Multiple Access
DTCH	Dedicated Traffic Channel
FACH	Forward Access Channel
FCH	Frame control header
FDD	Frequency Division Duplex
FER	Frame error rate
Mcps	Mega Chip Per Second
MS	Mobile Station
ODMA	Opportunity Driven Multiple Access
OVSF (codes)	Orthogonal Variable Spreading Factor (codes)
PCH	Paging Channel
PG	Processing gain
PRACH	Physical Random Access Channel
PUF	Power Up Function
RACH	Random Access Channel
SCH	Synchronization Channel
SF	Spreading factor
SIR	Signal-to-interference ratio
TDD	Time Division Duplex
UL	Uplink (reverse link)
VA	Voice activity
WCDMA	Wideband CDMA

1. INTRODUCTION

SMG has agreed on a process of selecting the UTRA concept before the end of 1997. According to this process WCDMA concept group presents an updated version of the Evaluation Document to the SMG2 UMTS Ad Hoc meeting, November 17-21, 1997. The Evaluation Document from each concept group should include of a description of the concept group's concept and simulation results using the models from ETR0402 and the services from Tdoc260/97 from SMG2#22. In this report the Wideband DS-CDMA (WCDMA) concept group (the Alpha concept group) presents its UTRA concept and its performance results.

The first inputs to the Alpha group (the concept group was then not officially started) were given at SMG2#21, March 3-7, 1997. The inputs were primarily from ACTS FRAMES[1] project (FMA2), Fujitsu, NEC, and Panasonic.These main inputs were based on concepts developed during several years and partly verified in test systems.

At the SMG2#22 meeting, May 12-16, 1997, five concept groups were created and officially approved at an SMG meeting thereafter. The Alpha Concept group is one of these groups. After that, the Alpha group has had the following meetings:

- In London, June 25, 1997, where a few basic assumptions of the WCDMA concept were agreed.
- In Rennes (an afternoon meeting at the SMG2 UMTS ad hoc, August 5-8, 1997), where more inputs to the Alpha concept group were given.
- In Stockholm September 15-16, 1997.
- In London, November 3-4, 1997

At all these meeting a number of companies have contributed with inputs to the Alpha concept development discussion. With all inputs and different proposals for the WCDMA concept, the Alpha group has gone through a merging process to one common WCDMA concept. This merging process was finalized at the Stockholm meeting where all participants agreed on one common WCDMA concept in the Alpha group. The Stockholm meeting had participants from 26 companies.

Having so many companies involved in the Alpha group has created a working technical discussion with feedback on the proposed solutions from companies with experience from several multiple-access techniques. Thus the merging process towards a common concept has resulted in the thoroughly reviewed concept accepted by all participants of the concept group.

In the development of the WCDMA concept presented in this report a prerequisite has been to fulfil the UMTS requirements described in ETR0401. To summarise, the following key features are included in the Alpha group's WCDMA concept for flexible and efficient support of UMTS service needs:

- Support for high data-rate transmission (384 kpbs with wide-area coverage and 2 Mbps with local area coverage). This can be achieved in a bandwidth of 5 MHz.
- High service flexibility, i.e., good support of multiple bearers and variable bit rates. This is achieved with a DPCCH/DPDCH channel structure which allows multiple bearers on the same physical channel and which supports the user bit-rate to be changed on a frame-by-frame basis (10 ms) with a granularity as low as 100 bps.
- Good capacity and coverage in the basic system without the need for complex methods (complicated multi-user/joint-detection receivers, sophisticated dynamic radio-resource-management algorithms, complex link adaptation, frequency planning, etc.). However, in order to preserve future proofness, features like multi-user detection, adaptive antennas etc. are supported within the concept to be used for future performance enhancements.
- Efficient power control. This reduces the emitted interference (increased capacity) and reduces the transmission power (increased battery life time).

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[1] ACTS FRAMES project consortium consists of several European industrial partners including CSEM/Pro Telecom, Ericsson, France Telecom, Nokia, Siemens and of several university partners. The project is partially funded by the European Comission.

- Efficient utilisation of the achievable frequency diversity with wideband signal.
- Efficient packet access with a very fast control channel for packet-access signalling and packet acknowledgements.
- Spectrum-efficient support of HCS.
- No periodicity in the envelope of the uplink transmitted signal avoids problems with audible interference.

The concept presented in this report has many similarities with the Wideband CDMA system which is currently being standardised in the Japanese standardisation body ARIB. This gives good possibilities for a standard not only for UMTS in Europe, but also for a global IMT2000 standard in ITU. In terms of system deployment this means cost efficiencies due to the economics of scale in the equipment manufacturing. It also facilitates roaming on a global basis.

The following is an outline of this document:

Part 1 begins with the Alpha concept description in Chapter 2 "System Description".

The performance evaluation of the Alpha concept is described in Chapter 3. Chapter 3.1 describes how the FDD simulations have been implemented and interpreted from ETR0402. In Chapter 3.2 all FDD simulations results are presented and in Chapter 3.3 the FDD simulation results are summarised.

Finally, in Chapter 4, conclusions are presented.

The report also consists of Part 2, Part 3 and Part 4. Part 2 contains the first version of the Alpha group's answers to Annex 1 of ETR0402. Part 3 contains the detailed simulation results and parameters used in the simulations as well as link budget calculations and dual mode GSM UMTS terminal issues. Part 4 contains the WCDMA/ODMA description.

This is the final version of the Alpha Group evaluation report, additional items may be provided if needed then later as an annex, but this document forms the basis for the UMTS standardisation if WCDMA is selected as the UMTS Terrestrial Radio Access (UTRA) concept as recommended by the Alpha group.

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2. SYSTEM DESCRIPTION

2.1 WCDMA key features

Listed below are the key service- and operational features of the WCDMA radio-interface:

- Support for high-data-rate transmission (384 kbps with wide-area coverage, 2 Mbps with local coverage).
- High service flexibility with support of multiple parallel variable-rate services on each connection.
- Efficient packet access.
- Built-in support for future capacity/coverage-enhancing technologies, such as adaptive antennas, advanced receiver structures, and transmitter diversity.
- Support of inter-frequency handover for operation with hierarchical cell structures and handover to other systems, including handover to GSM.
- Both FDD and TDD operation.

2.2 WCDMA key technical characteristics

Table 1 summarises the key technical characteristics of the WCDMA radio-interface.

Multiple-Access scheme	DS-CDMA
Duplex scheme	FDD / TDD
Chip rate	4.096 Mcps (expandable to 8.192 Mcps and 16.384 Mcps)
Carrier spacing (4.096 Mcps)	Flexible in the range 4.4-5.2 MHz (200 kHz carrier raster)
Frame length	10 ms
Inter-BS synchronization	FDD mode: No accurate synchronization needed TDD mode: Synchronization needed
Multi-rate/Variable-rate scheme	Variable-spreading factor + Multi-code
Channel coding scheme	Convolutional coding (rate 1/2-1/3) Optional outer RS coding (rate 4/5)
Packet access	Dual mode (common and dedicated channel)

Table 1 WCDMA key technical characteristics

2.3 WCDMA Logical-Channel Structure

The WCDMA logical-channel structure basically follows the ITU recommendation ITU-R M.1035. The following logical-channel types are defined for WCDMA:

- Common Control Channels
    - Broadcast Control Channel (BCCH)
    - Forward-Access Channel (FACH)
    - Paging Channel (PCH)
    - Random-Access Channel (RACH)
- Dedicated Channels
    - Dedicated Control Channel (DCCH)
    - Dedicated Traffic Channel (DTCH)

These logical-channel types are described in more detail below.

2.3.1 Common Control Channels

2.3.1.1 BCCH - Broadcast Control Channel (DL)

The Broadcast Control Channel (BCCH) is a downlink point-to-multipoint channel that is used to broadcast system- and cell-specific information. The BCCH is mapped to the Primary Common Control Physical Channel (Primary CCPCH), see Section 2.4.2.1. The BCCH is always transmitted over the entire cell.

2.3.1.2 FACH - Forward Access Channel (DL)

The Forward Access Channel (FACH) is a downlink channel that is used to carry control information to a mobile station when the system knows the location cell of the mobile station. The FACH may also carry short user packets. The FACH is, together with the PCH, mapped to the Secondary Common Control Physical Channel (Secondary CCPCH), see Section 2.4.2.1. The FACH may be transmitted over only a part of the cell by using lobe-forming antennas.

2.3.1.3 PCH - Paging Channel (DL)

The Paging Channel (PCH) is a downlink channel that is used to carry control information to a mobile station when the system does not know the location cell of the mobile station. The PCH is, together with the FACH, mapped to the Secondary CCPCH. The PCH is always transmitted over the entire cell.

2.3.1.4 RACH - Random Access Channel (UL)

The Random Access Channel (RACH) is an uplink channel that is used to carry control information from a mobile station. The RACH may also carry short user packets. The RACH is mapped to the Physical Random Access Channel (PRACH), see Section 2.4.2.2. The RACH is always received from the entire cell.

2.3.2 Dedicated Channels

2.3.2.1 DCCH - Dedicated Control Channel (DL and UL)

The Dedicated Control Channel (DCCH) is a bidirectional channel that is used to carry control information between the network and a mobile station. The DCCH serves the same function as the two logical channels Stand-Alone Dedicated Control Channel (SDCCH) and Associated Control Channel (ACCH) defined within ITU-R M.1035. In WCDMA there is thus no distinction between dedicated control channels that are linked to a traffic channel and those that are not. The DCCH is, possibly together with one or several DTCHs, mapped to a Dedicated Physical Data Channel (DPDCH), see Section 2.4.1.1 and 2.4.1.2.

2.3.2.2 DTCH - Dedicated Traffic Channel (DL and/or UL)

The Dedicated Traffic Channel (DTCH) is a bidirectional or unidirectional channel that is used to carry user information between the network and a mobile station. A DTCH is, together with a DCCH and possibly other DTCHs, mapped to a Dedicated Physical Data Channel (DPDCH).

2.3.3 Summary of logical-to-physical channel mapping

Figure 1 summarises the mapping of logical channels to physical channels. The physical channels are described in detail in Section 2.4.

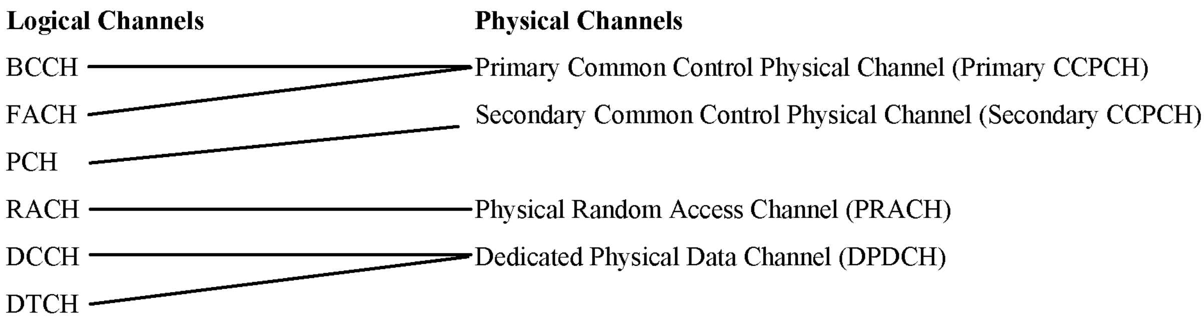


Figure 1 Logical-channel to physical-channel mapping

2.4 WCDMA Physical-Channel Structure

2.4.1 Dedicated physical channels

There are two types of dedicated physical channels, the Dedicated Physical Data Channel (DPDCH) and the Dedicated Physical Control Channel (DPCCH).

The DPDCH is used to carry dedicated data generated at layer 2 and above, i.e. the dedicated logical channels of Section 2.3.2.

The DPCCH is used to carry control information generated at layer 1. The control information consists of known pilot bits to support channel estimation for coherent detection, transmit power-control (TPC) commands, and (variable-length) rate information (RI). The rate information informs the receiver about the instantaneous rate of the different services multiplexed on the dedicated physical data channels.

2.4.1.1 Downlink dedicated physical channels

For the downlink, the DPDCH and the DPCCH are time multiplexed within each radio frame and transmitted with QPSK modulation.

2.4.1.1.1 Frame structure

Figure 2 shows the principle frame structure of the downlink DPDCH/DPCCH. Each frame of length 10 ms is split into 16 slots, each of length T_{slot} = 0.625 ms, corresponding to one power-control period. Within each slot, the DPDCH and the DPCCH are time multiplexed. The slots of Figure 2 correspond to the power-control periods, see Section 2.6.3

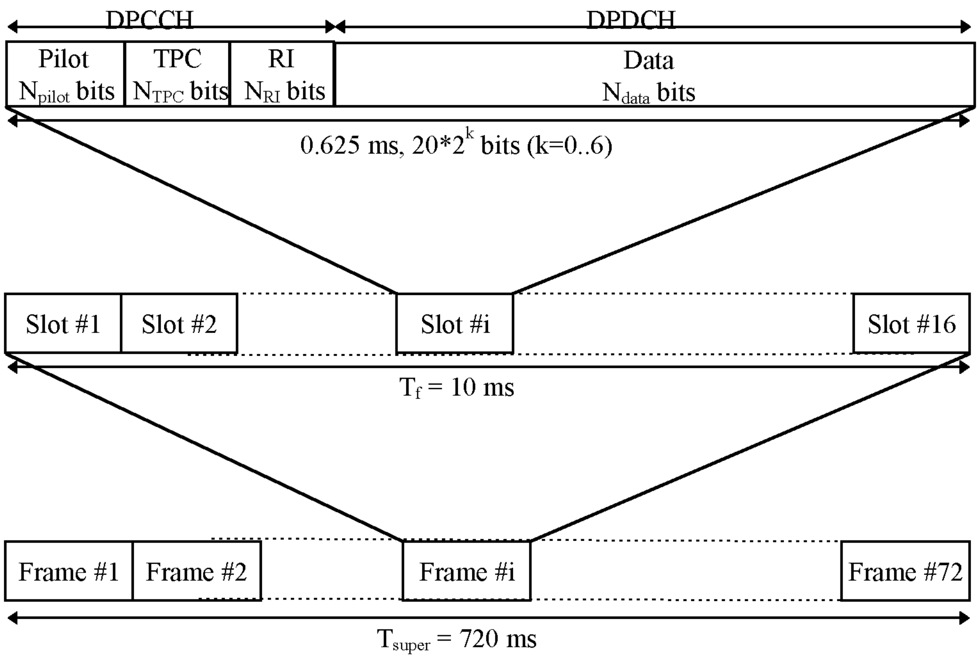


Figure 2 Frame structure for downlink dedicated physical channels.

The parameter k in Figure 2 determines the total number of bits per DPDCH/DPCCH slot. It is related to the spreading factor SF of the physical channel as SF = $256/2^k$. The spreading factor may thus range from 256 down to 4.

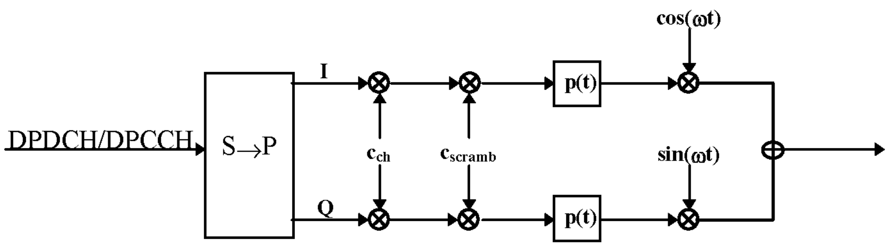
The exact number of bits of the different fields in Figure 2 (N_{pilot}, N_{TPC}, N_{RI}, and N_{data}) is yet to be determined and is also expected to vary for different spreading factors and service combinations.

Note that connection-dedicated pilot bits are transmitted also for the downlink in order to support the use of downlink adaptive antennas. With downlink adaptive antennas, an omni-directional pilot channel will, in general, not propagate over the same radio channel as a dedicated physical channel transmitted in a narrow lobe.

72 consecutive downlink frames constitute one WCDMA super frame of length 720 ms.

2.4.1.1.2 Spreading and modulation

Figure 3 illustrates the spreading and modulation for the DPDCH/DPCCH. Data modulation is QPSK where each pair of two bits are serial-to-parallel converted and mapped to the I and Q branch respectively. The I and Q branch are then spread to the chip rate with the same channelization code c_{ch} and subsequently scrambled by the same cell specific scrambling code c_{scramb}.



c_{ch}: channelization code
c_{scramb}: scrambling code
p(t): pulse-shaping filter (root raised cosine, roll-off 0.22)

Figure 3 Spreading/modulation for downlink dedicated physical channels

For multi-code transmission, each additional DPDCH/DPCCH should also be spread/modulated according to Figure 3. Each additional DPDCH/DPCCH should be assigned its own channelization code.

The channelization codes of Figure 3 are Orthogonal Variable Spreading Factor (OVSF) codes that preserve the orthogonality between downlink channels of different rates and spreading factors. The OVSF codes can be defined using the code tree of Figure 4.

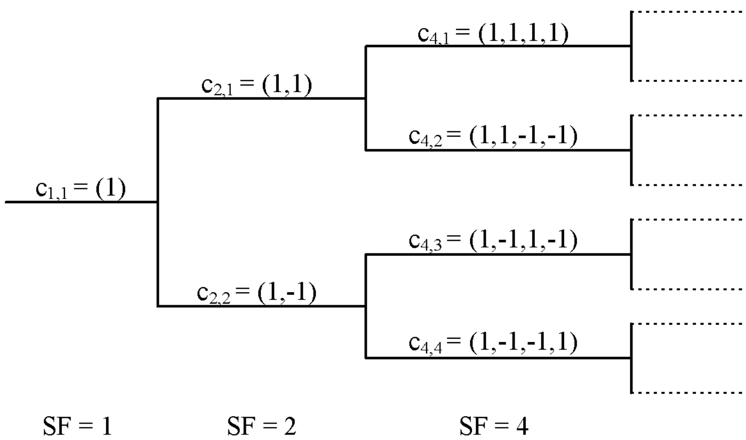


Figure 4 Code-tree for generation of Orthogonal Variable Spreading Factor (OVSF) codes

Each level in the code tree defines channelization codes of length SF, corresponding to a spreading factor of SF in Figure 3. All codes within the code tree cannot be used simultaneously within one cell. A code can be used in a cell if and only if no other code on the path from the specific code to the root of the tree or in the sub-tree below the specific code is used in the same cell. This means that the number of available channelization codes is not fixed but depends on the rate and spreading factor of each physical channel.

The downlink scrambling code c_{scramb} is a 40960 chips (10 ms) segment of a length 2^{18}-1 Gold code repeated in each frame. The total number of available scrambling codes is 512, divided into 16 code groups with 32 codes in each group. The grouping of the downlink codes is done in order to facilitate a fast cell search, see Section 2.6.4.

The pulse-shaping filters are root raised cosine (RRC) with roll-off α=0.22 in the frequency domain.

2.4.1.2 Uplink dedicated physical channels

For the uplink, the DPDCH and the DPCCH are IQ/code multiplexed within each radio frame and transmitted with dual-channel QPSK modulation. Each additional DPDCHs is code multiplexed on either the I- or the Q-branch with this first channel pair.

2.4.1.2.1 Frame structure

Figure 5 shows the principle frame structure of the uplink dedicated physical channels. Each frame of length 10 ms is split into 16 slots, each of length T_{slot} = 0.625 ms, corresponding to one power-control period. Within each slot, the DPDCH and the DPCCH are transmitted in parallel.

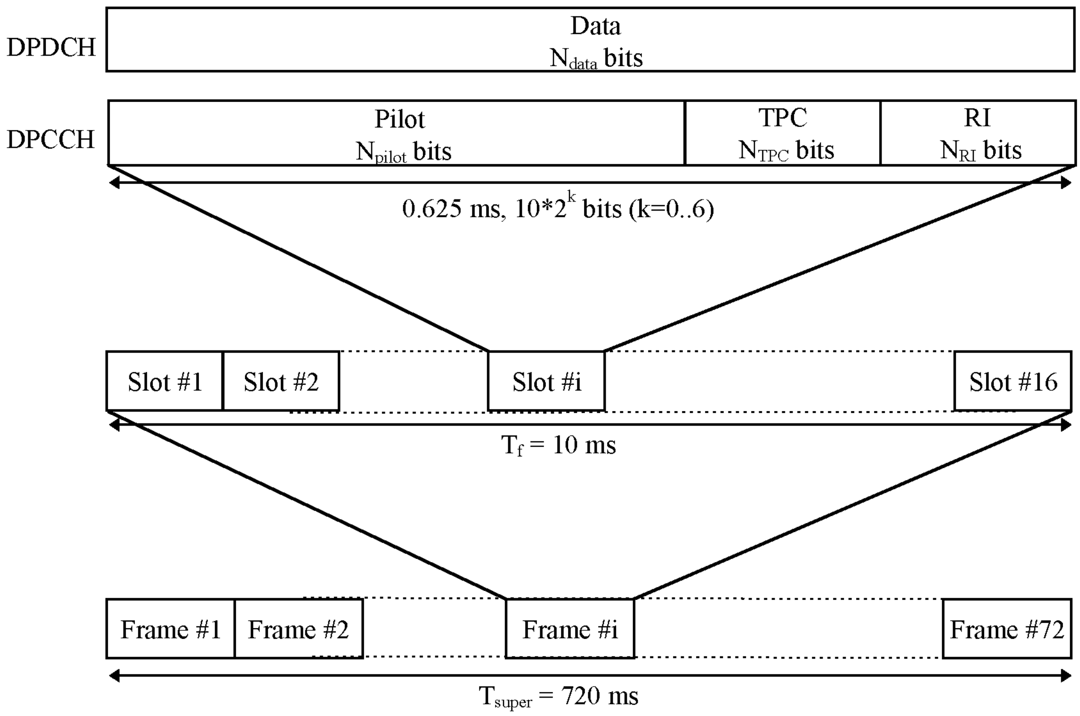


Figure 5 Frame structure for uplink dedicated physical channels

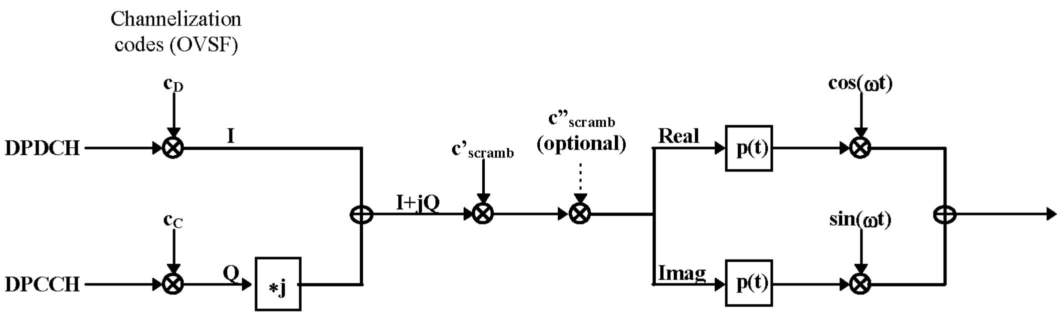
The parameter k in Figure 5 determines the number of bits per DPDCH or DPCCH slot. It is related to the spreading factor SF of the physical channel as SF = $256/2^k$. The spreading factor may thus range from 256 down to 4. Note that the DPDCH and DPCCH may be of different rates, i.e. have different spreading factors and thus different values of k.

As for the downlink, the exact number of bits of the different fields in Figure 5 (N_{pilot}, N_{TPC}, N_{RI}, and N_{data}) is yet to be determined and is once again expected to vary for different spreading factors and service combinations.

72 consecutive uplink frames constitute one WCDMA super frame of length 720 ms.

2.4.1.2.2 Spreading and modulation

Figure 6 illustrates the spreading and modulation for the uplink dedicated physical channels. Data modulation is dual-channel QPSK, where the DPDCH and DPCCH are mapped to the I and Q branch respectively. The I and Q branch are then spread to the chip rate with two different channelization codes c_D/c_C and subsequently complex scrambled by a mobile-station specific primary scrambling code c'_{scramb}. The scrambled signal may then optionally be further scrambled by a secondary scrambling code c''_{scramb}.



c_D,c_C: channelization codes
c'_{scramb}: primary scrambling code
c''_{scramb}: secondary scrambling code (optional)
p(t): pulse-shaping filter (root raised cosine, roll-off 0.22)

Figure 6 Spreading/modulation for uplink dedicated physical channels

For multi-code transmission, each additional DPDCH may be transmitted on either the I or the Q branch. For each branch, each additional DPDCH should be assigned its own channelization code. DPDCHs on different branches may share a common channelization code.

The channelization codes of Figure 6 are the same type of OVSF codes as for the downlink, see Figure 4. For the uplink, the restrictions on the allocation of channelization codes given in 2.4.1.1 are only valid within one mobile station.

The primary scrambling code is a complex code $c'_{scramb} = c_I + jc_Q$, where c_I and c_Q are two different codes from the extended Very Large Kasami set of length 256.

The secondary scrambling code is a 40960 chips (10 ms) segment of a length 2^{41}-1 Gold code.

The pulse-shaping filters are root-raised cosine (RRC) with roll-off α=0.22 in the frequency domain.

2.4.2 Common physical channels

2.4.2.1 Primary and Secondary Common Control Physical Channel (CCPCH)

The Primary and Secondary Common Control Physical Channels are fixed rate downlink physical channels used to carry the BCCH and FACH/PCH respectively.

Figure 7 shows the principle frame structure of the CCPCH. The frame structure differs from the downlink dedicated physical channel in that no TPC commands or rate information is transmitted. The only layer 1 control information is the pilot bits needed for coherent detection.

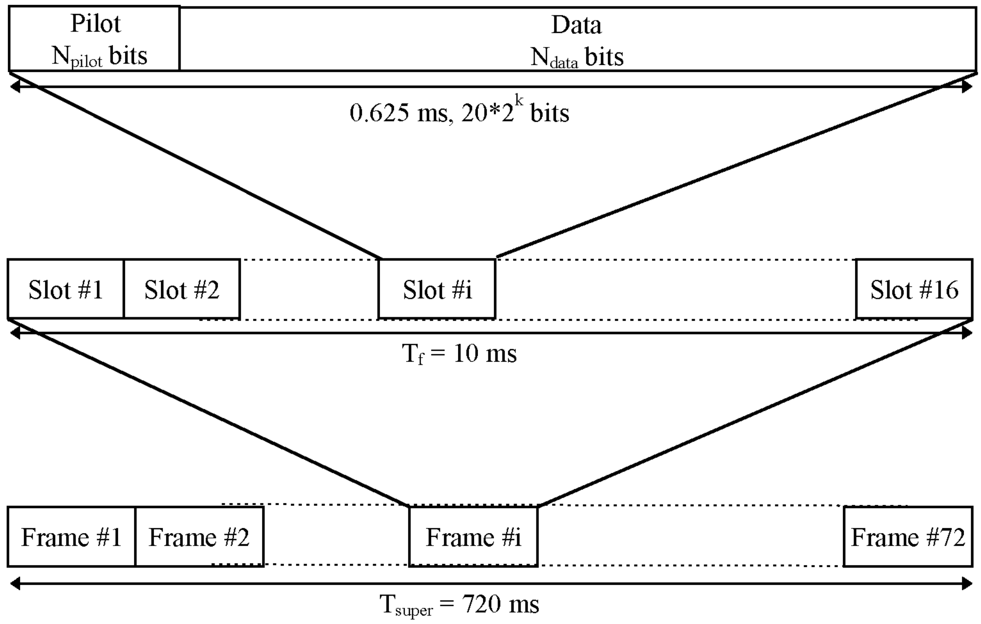


Figure 7 Frame structure for downlink Common Control Physical Channels

The CCPCH is modulated and spread in the same way as the Downlink Dedicated Physical Channels, see Figure 3.

In the case of the Secondary CCPCH, the FACH and PCH are time multiplexed on a frame-by-frame basis within the super-frame structure. The set of frames allocated to FACH and PCH respectively is broadcasted on the BCCH.

The main difference between a CCPCH and a downlink dedicated physical channel is that a CCPCH is not power controlled and is of constant rate. The main difference between the Primary and Secondary CCPCH is that the Primary CCPCH has a fixed predefined rate (32 kbps) while the Secondary CCPCH has a constant rate that may be different for different cells, depending on the capacity needed for FACH and PCH. 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 FACH frames).

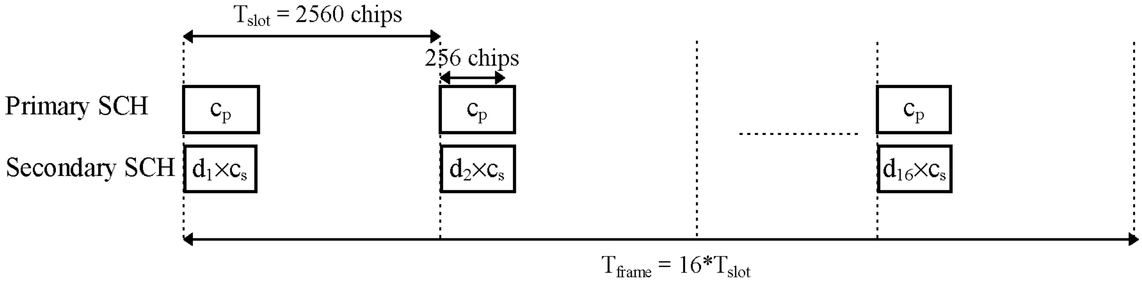
2.4.2.2 Physical Random Access Channel

The Physical Random Access Channel is described in Section 2.6.1.

2.4.2.3 Synchronisation Channel

The Synchronisation Channel (SCH) is a downlink signal used for cell search, see Section 2.6.4.

The SCH consists of two sub channels, the Primary and Secondary SCH. Figure 8 illustrates the structure of the SCH:



c_p: Primary Synchronization Code
c_s: Secondary Synchronization Code (one of 16 codes)
$d_1, d_2, ..., d_{16}$: Secondary SCH modulation

Figure 8 Structure of Synchronisation Channel (SCH)

The Primary SCH consists of an *unmodulated* orthogonal Gold code of length 256 chips, the Primary Synchronisation Code, transmitted once every slot. The Primary Synchronisation Code is the same for every base station in the system and is transmitted time-aligned with the slot boundary as illustrated in Figure 8.

The Secondary SCH consists of one *modulated* Orthogonal Gold code of length 256 chips, the Secondary Synchronisation Code, transmitted in parallel with the Primary Synchronization channel. The Secondary Synchronisation Code is chosen from a set of 16 different codes $\{c_1,c_2,...,c_{16}\}$ depending on to which of the 16 different code groups (see Section 2.4.1.1.2) the base station downlink scrambling code c_{scramb} belongs.

The Secondary SCH is modulated with a binary sequence d_1, d_2, ..., d_{16} of length 16 bits which is repeated for each frame. The modulation sequence, which is the same for all base stations, has good cyclic autocorrelation properties.

The multiplexing of the SCH with the other downlink physical channels (DPDCH/DPCCH and CCPCH) is illustrated in Figure 9. The figure illustrates how the SCH is only transmitted intermittently (one codeword per slot) and also that the SCH is multiplexed *after* long code scrambling of the DPDCH/DPCCH and CCPCH. Consequently, the SCH is *non-orthogonal* to the other downlink physical channels.

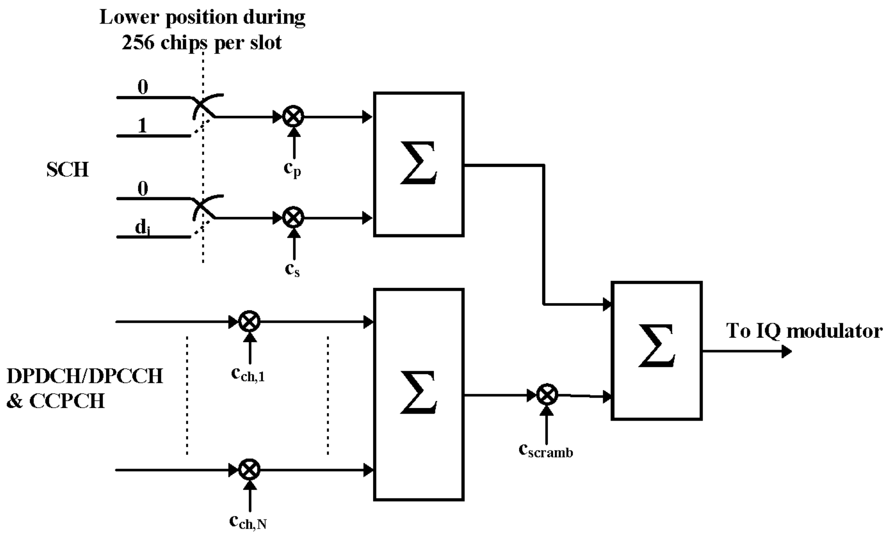


Figure 9 Multiplexing of SCH

The use of the SCH for cell search is described in detail in Section 2.6.4.

2.5 Channel Coding and Service Multiplexing

2.5.1 Channel coding/interleaving for user services

As shown in Figure 10, WCDMA offers three basic service classes with respect to forward-error-correction (FEC) coding:

- Standard-services with convolutional coding only
- High-quality services with additional outer Reed-Solomon coding
- Services with service-specific coding, i.e. services for which the WCDMA layer 1 does not apply any pre-specified channel coding.

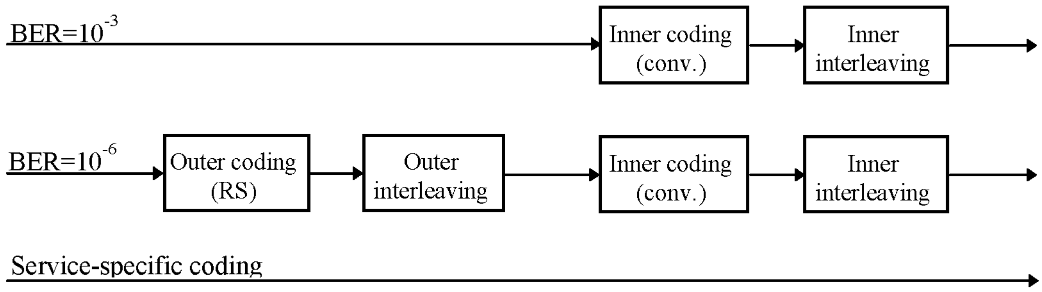


Figure 10 Basic FEC coding for WCDMA

2.5.1.1 Inner coding/interleaving

The inner convolutional coding is of rate 1/3 except for the highest rates where a rate 1/2 code is used. The code polynomials are given in octal form in Table 2.

Rate	Constraint length	Generator polynomial 1	Generator polynomial 2	Generator polynomial 3	Free distance
1/3	9	557	663	711	18
1/2	9	561	753	N/A	12

Table 2 Parameters for convolutional coding. Generator polynomials in octal form.

After convolutional coding, block interleaving is applied. For low-delay services, intra-frame interleaving over one 10 ms frame is applied. For services that allow for more delay, inter-frame interleaving over up to 15 frames (150 ms) is possible.

2.5.1.2 Outer coding/interleaving

The current assumption for the outer RS coding is a rate 4/5 code over the 2^8-ary symbol alphabet.

After outer RS coding, symbol-wise inter-frame block interleaving is applied.

2.5.2 Service multiplexing

Multiple services belonging to the same connection are, in normal cases, time multiplexed. Time multiplexing may take place either before or after the inner or outer coding as illustrated in Figure 11.

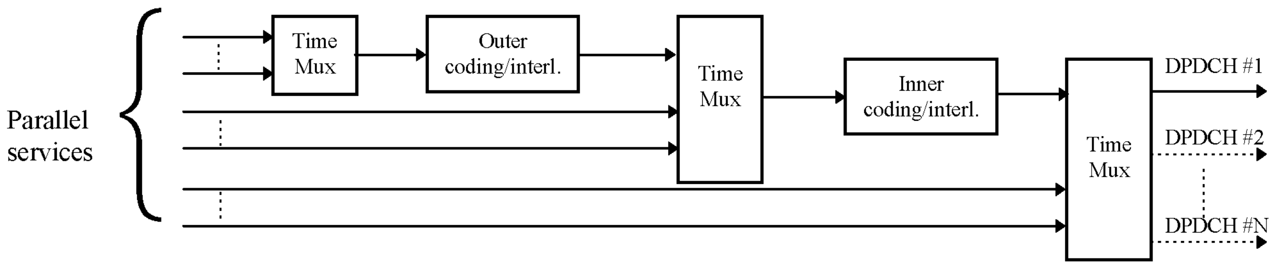


Figure 11 Service multiplexing of WCDMA

After service multiplexing and channel coding, the multi-service data stream is mapped to one or, if the total rate exceeds the upper limit for single-code transmission, several DPDCHs.

A second alternative for service multiplexing is to treat parallel services completely separate with separate channel coding/interleaving and mapping to separate DPDCHs in a multi-code fashion, see Figure 12. With this alternative scheme, the power and consequently the quality of each service can be separately and independently controlled. The disadvantage is the need for multi-code transmission which will have an impact on mobile-station complexity.

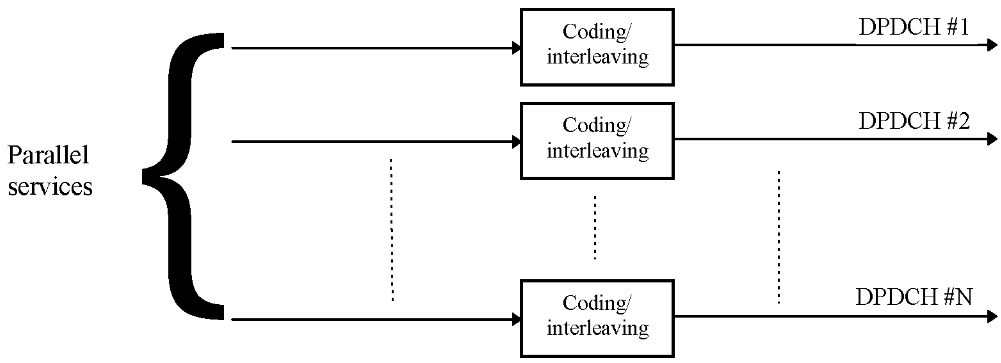


Figure 12 Alternative service multiplexing

2.5.3 Rate matching

After channel coding and service multiplexing, the total bit rate is almost arbitrary. The rate matching matches this rate to the limited set of possible bit rates of a Dedicated Physical Data Channel. The rate matching is somewhat different for uplink and downlink. The rule of unequal repetition for rate maching is given in part II of this document.

2.5.3.1 Uplink

For the uplink, rate matching to the closest uplink DPDCH bit rate is always based on unequal repetition (a subset of the bits repeated) or code puncturing. In general, code puncturing is chosen for bit rates less than ≈20% above the closest lower DPDCH bit rate. For all other cases, unequal repetition is done to the closest higher DPDCH bit rate. The repetition/puncturing patterns follow a regular predefined rule, i.e. only the amount of repetition/puncturing needs to be agreed on. The correct repetition/puncturing pattern can then be directly derived at both the transmitter and receiver side.

2.5.3.2 Downlink

For the downlink, rate matching to the closest DPDCH bit rate, using either unequal repetition or code puncturing, is only done for the highest rate (after channel coding and service multiplexing) of a variable-rate connection and for fixed-rate connections. For lower rates of a variable-rate connection, the same repetition/puncturing pattern as for the highest rate is used and the remaining rate matching is based on discontinuous transmission where only a part of each slot is used for transmission. This approach is used in order to simplify the implementation of blind rate detection in the mobile station.

2.5.4 Channel coding/interleaving for control channels

2.5.4.1 Dedicated Control Channel

The dedicated control channel (DCCH) uses the same rate 1/3 convolutional coding as the traffic channels. Intra-frame block interleaving is carried out after channel coding. Mapping to the Dedicated Physical Data Channel is done in exactly the same way as for dedicated traffic channels.

2.5.4.2 Downlink Common Control Channels

The downlink common control channels (BCCH, FACH, and PCH) use the same rate 1/3 convolutional coding as the traffic channels. Intra-frame block interleaving is carried out after channel coding before mapping to the Primary and Secondary Common Control Physical Channels.

In the case of the Secondary CCPCH, the FACH and PCH are time multiplexed on a frame-by-frame basis within the super-frame structure. The set of frames allocated to FACH and PCH respectively is broadcasted on the BCCH.

2.5.5 Example mapping for the test services

This section exemplifies the general channel coding and service multiplexing for some of the services used in the performance evaluation For simplicity, only the uplink mapping is shown.

2.5.5.1 8 kbps bearer

This bearer is used for the 8 kbps speech service. In this case, a 8 kbps speech frame appended with a 8 bits CRC is channel coded and mapped to a 32 kbps DPDCH according to Figure 13. Unequal repetition is used to match the 28.8 kbps data rate after channel coding to the closest DPDCH rate.

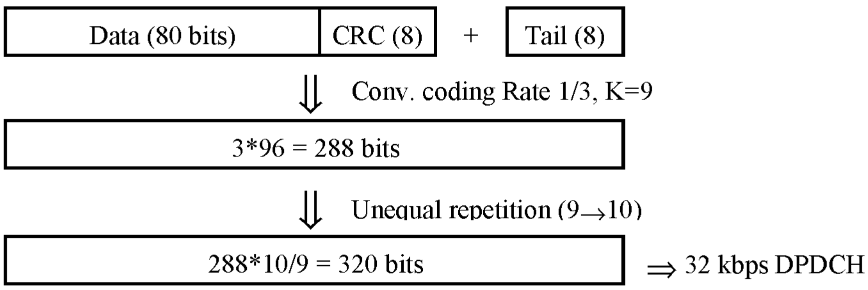


Figure 13 Channel coding and service mapping for an 8 kbps bearer (8 kbps speech service)

2.5.5.2 144 kbps bearer

This bearer is used for the 144 kbps LCD service. In this case, a 144 kbps data frame is RS coded, convolutional coded frame, and mapped to a 512 kbps DPDCH according to Figure 14. Code puncturing is used to match the 542.4 kbps data rate after channel coding to the closest DPDCH rate.

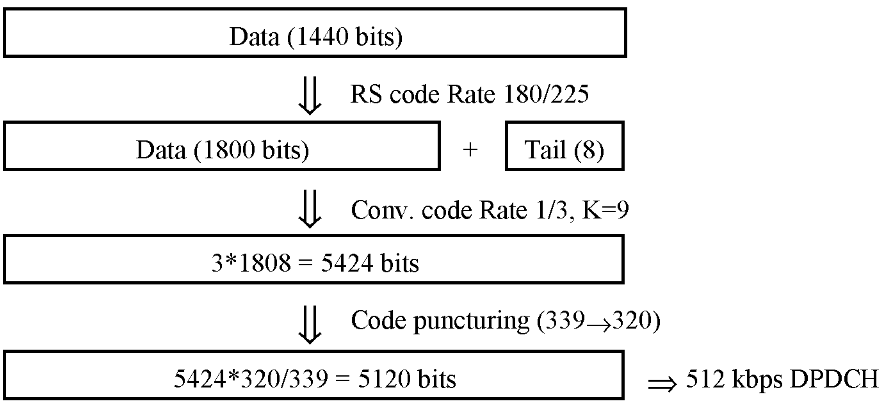


Figure 14 Channel coding and service mapping for a 144 kbps bearer (144 kbps LCD service)

2.5.5.3 384 kbps bearer

This bearer is used for the 384 kbps LCD service. In this case, a 384 kbps data frame is RS coded, convolutional coded frame, and mapped to a 1024 kbps DPDCH according to Figure 15. Unequal repetition is used to match the 964.8 kbps data rate after channel coding to the closest DPDCH rate.

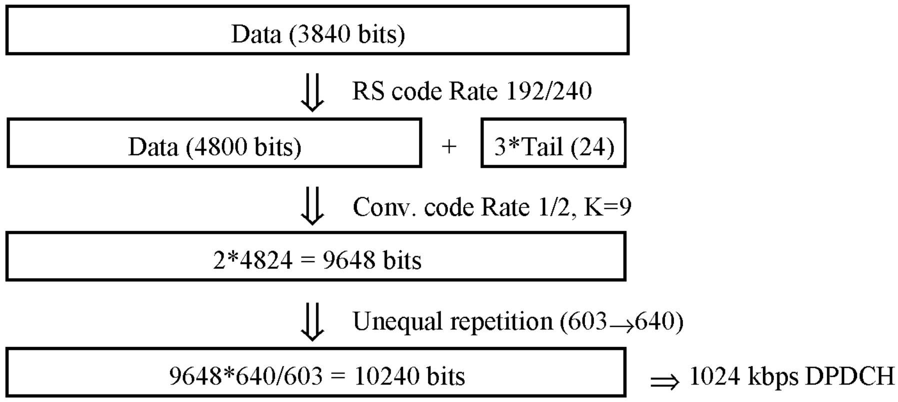


Figure 15 Channel coding and service mapping for a 384 kbps bearer (384 kbps LCD service)

2.5.5.4 480 kbps bearer

This bearer is used for the 384 kbps UDD service. In this case, 16 parallel blocks of 300 bits each are appended with a 12 bits header (CRC and Sequence Number). Each block is convolutionally encoded and mapped to a 1024 kbps DPDCH according to Figure 16. No rate matching is needed.

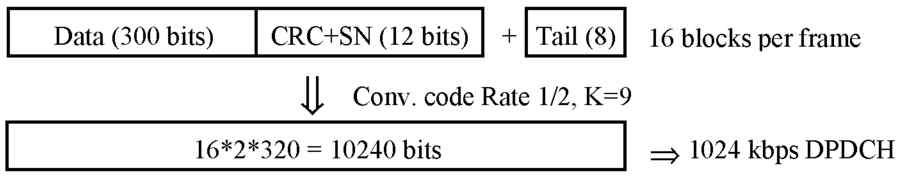


Figure 16 Channel coding and service mapping for a 480 kbps bearer (384 kbps UDD service)

2.5.5.5 2.4 Mbps bearer

This bearer is used for the 2.048 Mbps UDD service. In this case, 80 parallel blocks of 300 bits each are appended with a 12 bits header (CRC and Sequence Number). Each block is convolutionally encoded and mapped to a 5 parallel 1024 kbps DPDCHs according to Figure 17. No rate matching is needed.

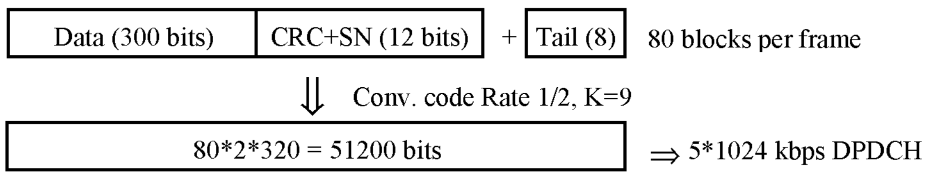


Figure 17 Channel coding and service mapping for a 2.4 Mbps bearer (2.048 Mbps UDD)

2.6 Radio Resource Functions

2.6.1 Random Access

2.6.1.1 Random-Access burst structure

The structure of the Random-Access burst is shown in Figure 18. The Random-Access burst consists of two parts, a preamble part of length 16*256 chips (1 ms) and a data part of variable length.

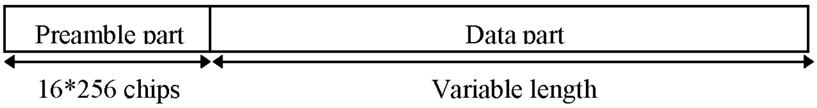
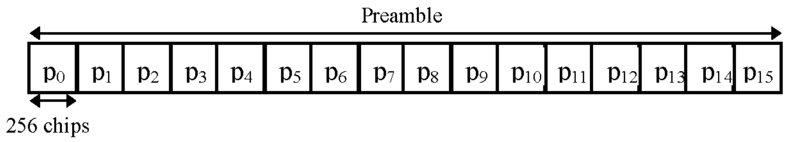


Figure 18 Structure of the Random-Access burst

2.6.1.1.1 Preamble part

Figure 19 shows the structure of the preamble part of the Random-Access burst.



$p_0, p_1, ..., p_{15}$: Preamble sequence

Figure 19 Structure of Random-Access burst preamble part

The preamble consists of 16 symbols (the preamble sequence) spread by an Orthogonal Gold code (the preamble code) of length 256 chips.

The preamble sequence is randomly chosen from a set of 16 orthogonal code words of length 16. All 16 preamble sequences are available in each cell.

Neighbouring base stations use different preamble codes and information about what preamble code(s) are available in each cell is broadcasted on the BCCH.

2.6.1.1.2 Data part

Figure 20 shows the structure of the data part of the Random-Access burst. It consists of the following fields (the values in brackets are preliminary values):

- Mobile station identification (MS ID) [16 bits]. The MS ID is chosen at random by the mobile station at the time of each Random-Access attempt.
- Required Service [3 bits]. This field informs the base station what type of service is required (short packet transmission, dedicated-channel set-up, etc.)
- An optional user packet. The possibility to append uplink user packets directly to the Random-Access request is described in Section 2.7.1.
- A CRC to detect errors in the data part of the Random-Access burst [8 bits].

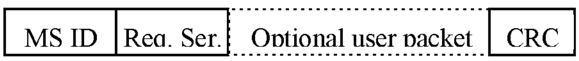


Figure 20 Structure of Random-Access burst data part

The spreading and modulation of the data part of the Random-Access burst is basically the same as for the uplink dedicated physical channels, see Figure 6. The scrambling code for the data part is chosen based on the base-station-specific preamble code, the randomly chosen preamble sequence, and the randomly chosen Random-Access time-offset, see 2.6.1.2. This guarantees that two simultaneous Random-Access attempts that use different preamble codes and/or different preamble sequences will not collide during the data part of the Random-Access bursts.

2.6.1.2 Random-Access procedure

Before making a Random-Access attempt, the mobile station should do the following

- Acquire chip and frame synchronisation to the target base station according to 2.6.4
- Acquire information about what Random-Access (preamble) codes are available in the cell from the BCCH
- Estimate the uplink path-loss from measurements of the received BS power and use this path-loss estimate, together with the uplink receieved interference level and received SIR target, to decide the transmit power of the Random-Access burst. The uplink interference level as well as the required received SIR are broadcasted on the BCCH.

The mobile station then transmits the Random-Access burst with a n*2 ms time-offset (n=0..4) relative to the received frame boundary, see Figure 21. The value of n, i.e. the time-offset, is chosen at random at each Random-Access attempt.

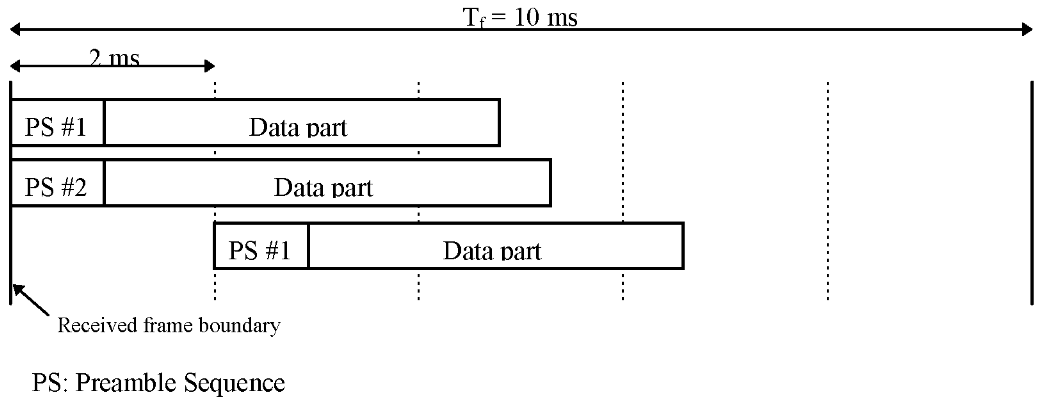


Figure 21 Possible transmission timing for parallel Random-Access attempts

A typical implementation of the base-station random-access receiver for a given preamble code and preamble sequence is illustrated in Figure 22. The received signal is fed to a matched filter, matched to the preamble code. The output of the matched filter is then correlated with the preamble sequence. The output of the preamble correlator will have peaks corresponding to the timing of any received Random-Access burst using the specific pramble code and preamble sequence. The estimated timing can then be used in a ordinary RAKE combiner for the reception of the data part of the Random-Access burst.

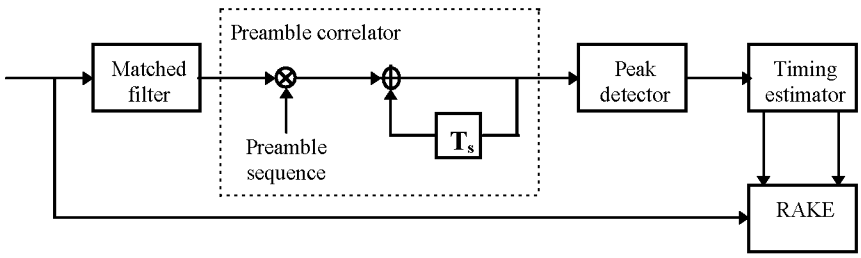


Figure 22 Base-station Random-Access receiver.

With this scheme, a base station may receive up to 80 (16 preamble sequences and 5 time-offsets) Random-Access attempts within one 10 ms frame using only one (preamble) matched filter.

Upon reception of the Random-Access burst, the base station responds with an Access Grant message on the FACH. In case the Random Access request is for a dedicated channel (circuit-switched or packet) and the request is granted, the Access Grant message includes a pointer to the dedicated physical channel(s) to use. As soon as the mobile station has moved to the dedicated channel, closed-loop power control is activated.

2.6.2 Code allocation

2.6.2.1 Downlink

2.6.2.1.1 Channelization codes

The channelization code for the BCCH is a predefined code which is the same for all cells within the system.

The channelization code(s) used for the Secondary Common Control Physical Channel is broadcasted on the BCCH.

The channelization codes for the downlink dedicated physical channels are decided by the network. The mobile station is informed about what downlink channelization codes to receive in the downlink Access Grant message that is the base-station response to an uplink Random Access request. The set of channelization codes may be changed during the duration of a connection, typically as a result of a change of service or an inter-cell handover. A change of downlink channelization codes is negotiated over the DCCH.

2.6.2.1.2 Scrambling code

The downlink scrambling code is assigned to the cell (sector) at the initial deployment. The mobile station learns about the downlink scrambling code during the cell search process, see Section 2.6.4.

2.6.2.2 Uplink

2.6.2.2.1 Channelization codes

Each connection is allocated at least one uplink channelization code, to be used for the Dedicated Physical Control Channel. In most cases, at least one additional uplink channelization code is allocated for a Dedicated Physical Data Channel. Further uplink channelization codes may be allocated if more than one DPDCH are required.

As different mobile stations use different uplink scrambling codes, the uplink channelization codes may be allocated with no co-ordination between different connections. The uplink channelization codes are therefore always allocated in a predetermined order. The mobile-station and network only need to agree on the number of uplink channelization codes. The exact codes to be used are then implicitly given.

2.6.2.2.2 Primary scrambling code

The uplink primary scrambling code is decided by the network. The mobile station is informed about what primary scrambling code to use in the downlink Access Grant message that is the base-station response to an uplink Random Access Request.

The primary scrambling code may, in rare cases, be changed during the duration of a connection. A change of uplink primary scrambling code is negotiated over the DCCH.

2.6.2.2.3 Secondary (optional) scrambling code

The secondary uplink scrambling code is an optional code, typically used in cells without multiuser detection in the base station The mobile station is informed if a secondary scrambling code should be used in the Access Grant Message following a Random-Access request and in the handover message.

What secondary scrambling code to use is directly given by the primary scrambling code. No explicit allocation of the secondary scrambling code is thus needed.

2.6.3 Power control

2.6.3.1 Uplink power control

2.6.3.1.1 Closed loop power control

The uplink closed loop power control adjusts the mobile station transmit power in order to keep the received uplink Signal-to-Interference Ratio (SIR) at a given SIR target.

The base station should estimate the received DPCCH power after RAKE combining of the connection to be power control. Simultaneously, the base station should estimate the total uplink received interference in the current frequency band. The base station then generates TPC commands according to the following rule:

$SIR_{est} > SIR_{target,UL} \rightarrow$ TPC command = “down”
$SIR_{est} < SIR_{target,UL} \rightarrow$ TPC command = “up”

Upon the reception of a TPC command, the mobile station should adjust the transmit power of both the DPCCH and the DPDCH in the given direction with a step of Δ_{TPC} dB. The step size Δ_{TPC} is a parameter that may differ between different cells.

In case of soft handover, the mobile station should adjust the power with the largest step in the “down” direction ordered by the TPC commands received from each base station in the active set.

2.6.3.1.2 Outer loop (SIR target adjustment)

The outer loop adjusts the SIR target used by the closed-loop power control. The SIR target is independently adjusted for each connection based on the estimated quality of the connection. In addition, the power offset between the uplink DPDCH and DPCCH may be adjusted. How the quality estimate is derived differs for different service combinations. Typically a combination of estimated bit-error rate and frame-error rate is used.

2.6.3.1.3 Open-loop power control

Open-loop power control is used to adjust the transmit power of the physical Random-Access channel. Before the transmission of a Random-Access frame, the mobile station should measure the received power of the downlink Primary Common Control Physical Channel over a sufficiently long time to remove any effect of the non-reciprocal multi-path fading. From the power estimate and knowledge of the Primary CCPCH transmit power (broadcasted on the BCCH) the downlink path-loss including shadow fading can be found. From this path loss estimate and knowledge of the uplink interference level and the required received SIR, the transmit power of the physical Random-Access channel can be determined. The uplink interference level as well as the required received SIR are broadcasted on the BCCH.

2.6.3.2 Downlink power control

2.6.3.2.1 Closed loop power control

The downlink closed loop power control adjusts the base station transmit power in order to keep the received downlink SIR at a given SIR target

The mobile station should estimate the received DPCCH power after RAKE combining of the connection to be power control. Simultaneously, the mobile station should estimate the total downlink received interference in the current frequency band. The mobile station then generates TPC commands according to the following rule:

$SIR_{est} > SIR_{target,DL} \rightarrow$ TPC command = “down”
$SIR_{est} < SIR_{target,DL} \rightarrow$ TPC command = “up”

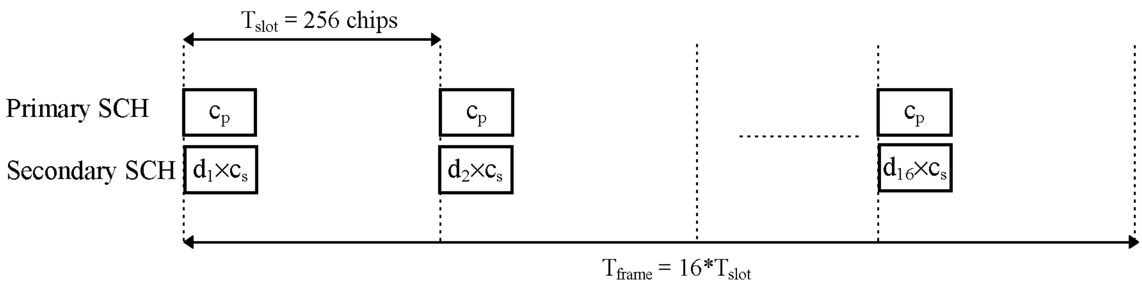
Upon the reception of a TPC command, the base station should adjust the transmit power in the given direction with a step of Δ_{TPC} dB. The step size Δ_{TPC} is a parameter that may differ between different cells.

2.6.3.2.2 Outer loop (SIR target adjustment)

The outer loop adjusts the SIR target used by the closed-loop power control. The SIR target is independently adjusted for each connection based on the estimated quality of the connection. In addition, the power offset between the downlink DPDCH and DPCCH may be adjusted. How the quality estimate is derived differs for different service combinations. Typically a combination of estimated bit-error rate and frame-error rate is used.

2.6.4 Initial cell search

During the initial cell search, the mobile station searches for the base station to which it has the lowest path loss. It then determines the downlink scrambling code and frame synchronisation of that base station. The initial cell search uses the synchronization channel (SCH) described in Section 2.4.2.3, the structure of which is repeated in Figure 23 below.



c_p: Primary Synchronization Code
c_s: Secondary Synchronization Code (one of 16 codes)
$d_1, d_2, ..., d_{16}$: Secondary SCH modulation

Figure 23 Structure of synchronization channel (SCH)

This initial cell search is carried out in three steps:

2.6.4.1 Step 1: Slot synchronisation

During the first step of the initial cell search procedure the mobile station uses the primary SCH to acquire slot synchronisation to the strongest base station. This is done with a single matched filter (or any similar device) matched to the primary synchronisation code c_p which is common to all base stations. The output of the matched filter will have peaks for each ray of each base station within range of the mobile station, see Figure 24. Detecting the position of the strongest peak gives the timing of the strongest base station modulo the slot length. For better reliability, the matched-filter output should be non-coherently accumulated over a number of slots.

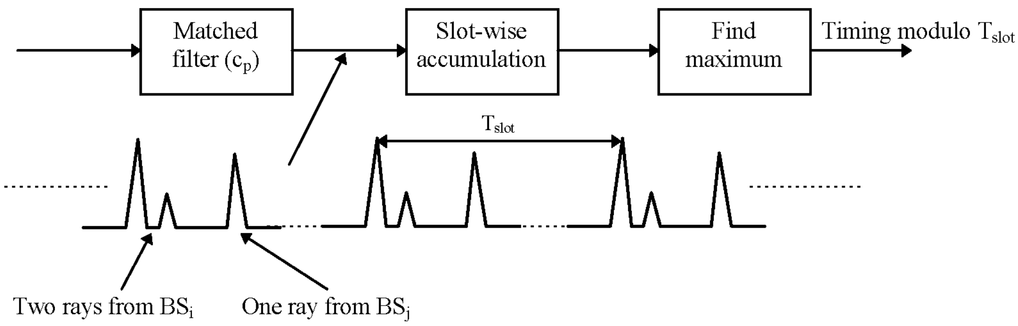


Figure 24 Matched-filter search for primary synchronization code to slot synchronization (timing modulo the slot length)

2.6.4.2 Step 2: Frame synchronisation and code-group identification

During the second step of the initial cell search procedure, the mobile station uses the secondary SCH to find frame synchronisation and identify the code group of the base station found in the first step. This is done by correlating the received signal at the positions of the Secondary Synchronisation Code with all possible (16) Secondary Synchronisation Codes. Note that the position of the Secondary Synchronisation Code is known after the first step, due to the known time offset between the Primary and the Secondary Synchronisation Codes. Furthermore, the unmodulated primary SCH can be used as a phase reference in the demodulation of the modulated SCH.

The correlation with the 16 different Secondary Synchronization Codes gives 16 different demodulated sequences. To achieve frame synchronization, the 16 demodulated sequences should be correlated with the 16 different cyclic shifts of the Secondary SCH modulation sequence $\{d_1, d_2, ..., d_{16}\}$, giving a total of 256 different correlation values. By identifying the code/shift pair that gives the maximum correlation value, the code group as well as the frame synchronization is determined.

2.6.4.3 Step 3: Scrambling-code identification

During the third and last step of the initial cell-search procedure, the mobile station determines the exact scrambling code used by the found base station. The scrambling code is identified through symbol-by-symbol correlation over the Primary CCPCH with all scrambling codes within the code group identified in the second step. Note that, from step 2, the frame boundary and consequently the start of the scrambling code is known. Correlation must be carried out symbol-wise, due to the unknow modulation of the primary CCPCH.

After the scrambling code has been identified, the Primary CCPCH can be detected, super-frame synchronisation can be acquired and the system- and cell specific BCCH information can be read.

2.6.5 Handover

2.6.5.1 Intra-frequency handover

2.6.5.1.1 Soft handover

When in active mode, the mobile station continuously searches for new base stations on the current carrier frequency. This cell search is carried out in basically the same way as the initial cell search described in Section 2.6.4. The main difference compared to the initial cell search is that an active mobile station has received a priority list from the network. This priority list describes in which order the downlink scrambling codes should be searched for and does thus significantly reduce the time and effort needed for the scrambling-code search (step 3) described in Section 2.6.4.3. Also the second step may be reduced if the priority list does only include scrambling codes belonging to a subset of the total set of code groups. The priority list is continuously updated to reflect the changing neighbourhood of a moving mobile station.

During the search, the mobile station monitors the received signal level broadcasted from neighbouring base stations, compares them to a set of thresholds, and reports them accordingly back to the base station. Based on this information the network orders the mobile station to add or remove base station links from its *active set*. The *active set* is defined as the set of base station from which the same user information is sent, simultaneously demodulated and coherently combined, i.e. the set of mobile terminals involved in the soft handover.

An example algorithm for reporting signal level and optimising the active set can be found in Tdoc SMG2 UMTS A16/97.

From the cell-search procedure, the mobile station knows the frame offset of the CCPCH of potential soft-handover candidates relative to that of the source base station(s) (the base stations currently within the active set). When a soft handover is to take place, this offset together with the frame offset between the DPDCH/DPCCH and the Primary CCPCH of the source base station, is used to calculate the required frame offset between the DPDCH/DPCCH and the Primary CCPCH of the destination base station (the base station to be added to the active set). This offset is chosen so that the frame offset between the DPDCH/DPCCH of the source and destination base stations at the mobile-station receiver is minimised. Note that the offset between the DPDCH/DPCCH and Primary CCPCH can only be adjusted in steps of one DPDCH/DPCCH symbol in order to preserve downlink orthogonality.

2.6.5.1.2 Softer handover

Softer handover is the special case of a soft handover between sectors/cells belonging to the same base station site. Conceptually, a softer handover is initiated and executed in the same way as an ordinary soft handover. The main differences are on the implementation level within the network. For softer handover, it is e.g. more feasible to do uplink maximum-ratio combining instead of selection combining as the combining is done on the BTS level rather than on the BSC level.

2.6.5.2 Inter-frequency handover

In WCDMA the vast majority of handovers are within one carrier frequency, i.e. intra-frequency handover. Inter-frequency handover may typically occur in the following situations:

- Handover between cells to which different number of carriers have been allocated, e.g. due to different capacity requirements (hot-spot scenarios).
- Handover between cells of different overlapping orthogonal cell layers using different carrier frequencies
- Handover between different operators/systems using different carrier frequencies including handover to GSM.

A key requirement for the support of seamless inter-frequency handover is the possibility for the mobile station to carry out cell search on a carrier frequency different from the current one, without affecting the ordinary data flow. WCDMA supports inter-frequency cell search in two different ways, a dual-receiver approach and a slotted-downlink-transmission approach.

2.6.5.2.1 Dual-receiver

For a mobile station with receiver diversity, there is a possibility for one of the receiver branches to temporarily be reallocated from diversity reception and instead carry out reception on a different carrier.

2.6.5.2.2 Slotted downlink transmission

With slotted downlink transmission, it is possible for a single-receiver mobile station to carry out measurements on other frequencies without affecting the ordinary data flow. The principle of slotted downlink transmission is illustrated in Figure 25. When in slotted mode, the information normally transmitted during a 10 ms frame is compressed in time, either by code puncturing or by reducing the spreading factor by a factor of 2. In this way, a time period of up to 5 ms is created during which the mobile-station receiver is idle and can be used for interfrequency measurements. Note that the idle slot is created without any loss of data as the number of information bits per frame is kept constant, while the processin gain is reduced by either reducing the spreading factor or increasing the coding rate. As illustrated in Figure 25, the instantaneous transmit power is increased in the slotted frame in order to keep the quality (BER, FER, etc.) unaffected by the reduced processing gain.

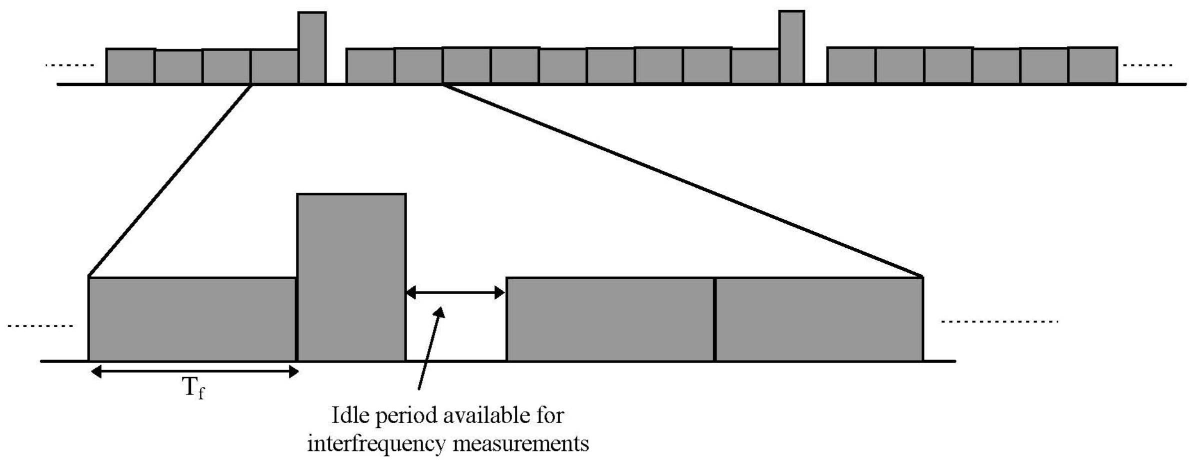


Figure 25 Downlink slotted transmission

When in slotted mode, slotted frames should occur periodically, as illustrated in Figure 25. The rate of slotted frames is variable and depends on the environment and the measurement requirements. It is estimated that a rate of slotted frames of 10 Hz, i.e. having a slotted frame every 10o ms is more than sufficient for e.g. the HCS environment.

For services that allows for a larger delay, e.g. data services with interleaving over several frames, multiple frames can be compressed together in order to create a short measurement slot. This is useful e.g. for high-rate services where a reduction of the processing gain of e.g. a factor of two may be difficult. As an example, for a 2 Mbps service, with interleaving of 5 frames (50 ms), a 5 ms idle slot can be created by reducing the processing gain with only 10% during 5 frames, see Figure 26.

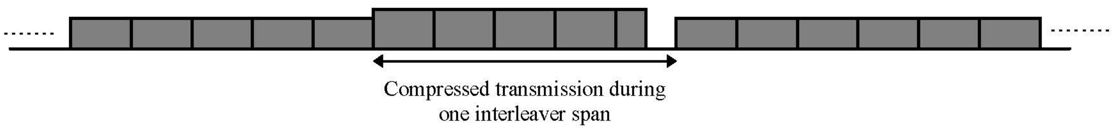


Figure 26 Multi-frame compressed mode for long-delay services

2.6.5.2.3 Measurements from GSM with slotted mode

The WCDMA concept has shown that although the frame length is different from GSM frame length, the dual mode terminal can be implemented also with a single receiver chain similar to other UTRA solutions. The more important aspect than the frame length is the higher level frame structure which must be able to facilitate measurements from GSM system. The WCDMA multiframe structure of 120 ms is identical to GSM and thus similar measurements and GSM carrier decode procedures can be provided as in GSM. The principle is indicated in Figure 27, which shows the identical measurement time as for GSM. For the power measurements additional blank slots can be used during which it is estimated that 9 200 kHz GSM carriers could be measured for their power level when using a GSM like RF parts resulting to similar measurement performance as with GSM.

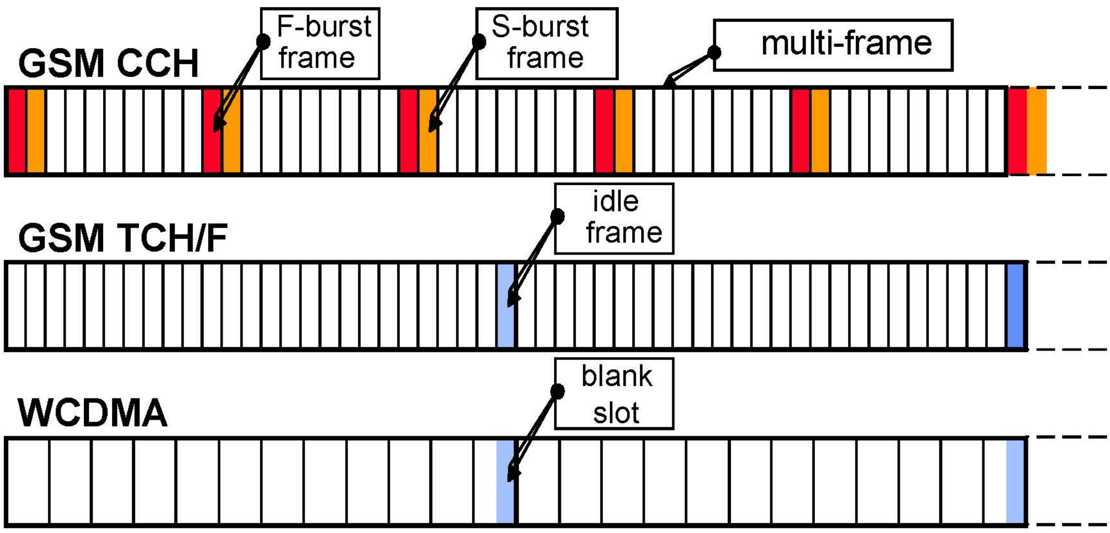


Figure 27. GSM measurement timing from WCDMA operation mode.

2.7 WCDMA Packet Access

Due to the varying characteristics of packet data traffic in terms of packet size and packet intensity, a dual-mode packet-transmission scheme is used for WCDMA. With this scheme, packet transmission can either take place on a common fixed-rate channel or on a dedicated channel.

2.7.1 Common-channel packet transmission

In this mode, an uplink packet is appended directly to a Random-Access burst. Common-channel packet transmission is typically used for short infrequent packets, where the link maintenance needed for a dedicated channel would lead to unacceptable overhead. Also the delay associated with a transfer to a dedicated channel is avoided. Note that, for common-channel packet transmission, only open-loop power control is in operation. Common-channel packet transmission should therefore be limited to short packets that only use a limited amount of capacity.

Figure 28 illustrates packet transmission on a common channel.

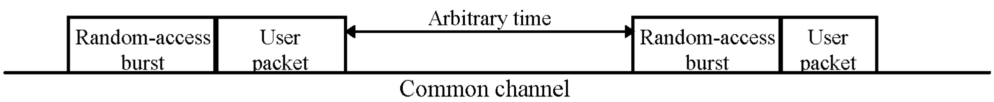


Figure 28 Packet transmission on common channel

2.7.2 Dedicated-channel packet transmission

In this mode, an initial Random-Access request is used to set up a dedicated channel for the packet transmission. On this dedicated channel, closed-loop power control is in operation. The dedicated channel can either be set up for the transmission of a single packet or for the transmission of a sequence of packets (multi-packet transmission).

2.7.2.1 Single-packet transmission

Single-packet transmission is typically used for the transmission of large infrequent packets. For single-packet transmission on a dedicated channel, the initial Random-Access request includes the amount of data to be transmitted. The network may respond to the access request in two different ways:

- With a short acknowledgement. A scheduling message is then sent to the mobile station at the time when the actual packet transmission can start. The scheduling message includes the transfer format, e.g. the bit rate, to be used for the packet transmission.
- With an immediate scheduling message, that either allows for immediate packet transmission, or that indicates at what time in the (near) future the mobile station may start its transmission.

Figure 29 illustrates single-packet transmission on a dedicated channel.

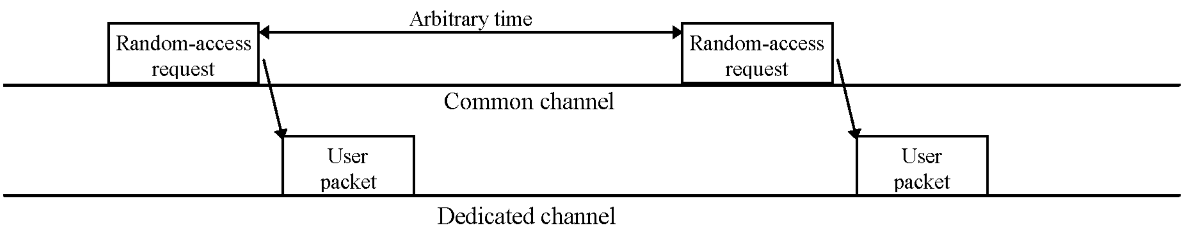


Figure 29 Single-packet transmission on dedicated channel

2.7.2.2 Multi-packet transmission

For multi-packet transmission on a dedicated channel an initial Random-Access request is used to set up a dedicated packet channel. On this channel, short packets may be transmitted without any scheduling, similar to the common-channel packet transmission. Larger packets may require that an access request is first sent by the mobile station on the dedicated channel. The network responds to this request in the same way as for the single-packet case

- With a short acknowledgement. A scheduling message is then sent to the mobile station at the time when the actual packet transmission can start. The scheduling message includes the transfer format, e.g. the bit rate, to be used for the packet transmission.
- With an immediate scheduling message, that either allows for immediate packet transmission, or that indicates at what time in the (near) future the mobile station may start its transmission.

Figure 30 illustrates multi-packet transmission on a dedicated channel. The link maintenance consists of power-control commands and pilot symbols needed to preserve power control and synchronization of the dedicated physical channel.

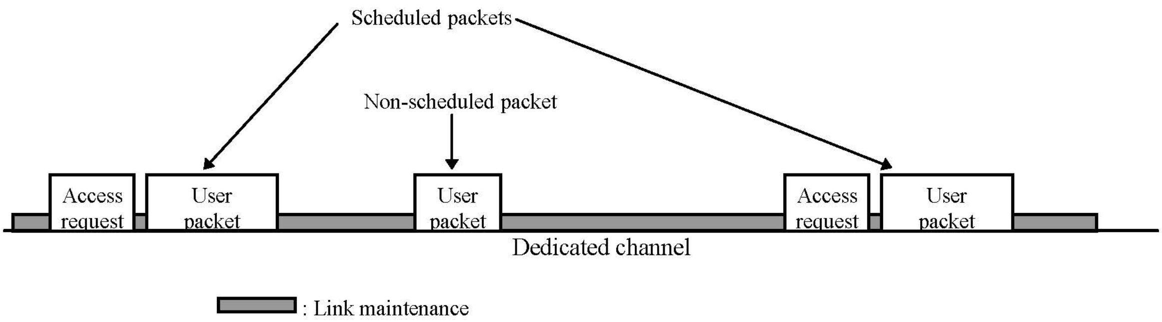


Figure 30 Multi-packet transmission on dedicated channel

2.7.3 Layer 2 overview

Figure 31 illustrates the general structure of layer 2. Main sublayers on layer 2 are logical link control (LLC) and medium access control (MAC). The software instances (LLCi) within LLC execute a selective retransmission protocol. The main responsibility of MAC is the multiplexing of different logical channels to the physical layer. MAC should provide very flexible means to combine different variable-rate real-time and non-real-time services with different QoS requirements to the same physical channel. Taking into account the random access procedure being able to process several simultaneous random access attempts, the transmissions are only limited by the soft capacity of the WCDMA system and thus the kind of request and allocation procedures that are executed in TDMA-based systems for each slot reservation are not needed. This is advantageous especially in the uplink with transmission coming from several mobiles to one base station as in the downlink the base station naturally has control of all the data sent as well as reources available for it. As indicated earlier for the very high bit rate packets, access request can be also used if desired.

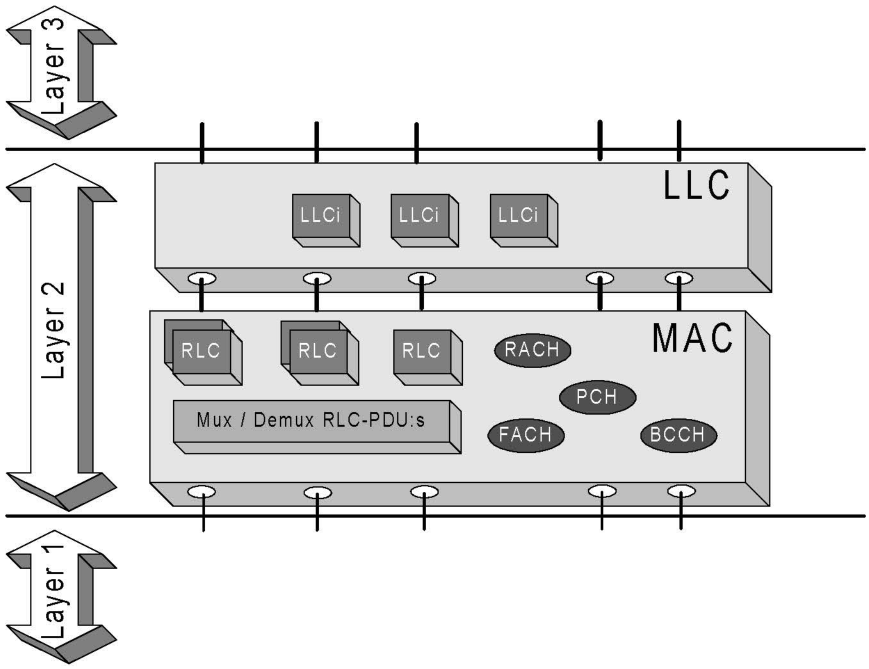


Figure 31. Layer 2 with connections to layer 1 and layer 3 control plane

A generic description of envisaged layer 2 functions is given in the following sections. One document on the subject has been distributed by Lucent Technologies during the Alpha meeting on 3-4.11.1997 (Data Link Control (DLC) Proposal for UMTS, Tdoc SMG2 UMTS A44 / 97) and these issues will be then defined further in the coming UMTS specification work.

2.7.3.1 Logical Link Control (LLC)

LLC sets up a logical link over the radio interface. Connection control facilities take care of connection establishment and release. User data transfer for non-real-time data is provided with error correction by selective retransmission including sequence control. Flow control functionality takes care of limiting the amount of data that can be sent without acknowledgements.

The retransmission features of LLC are seldom used and they are mainly intended to recover from errors relating to e.g. handovers.

2.7.3.2 Medium Access Control (MAC)

The main responsibility of the MAC sublayer is to manage the access to physical layer functions. In addition to allocating resources to user services and control channels, MAC controls the frame data rate signalling for different bearers.

A multiplexing / demultiplexing unit within MAC can mix services with equal QoS requirements on layer 2. Where different coding schemes are required, the data streams are transferred separately to the physical layer, which then provides coding, repetition and puncturing as requested by MAC.

MAC provides separate functionality and procedures for control channels including RACH, FACH, PCH and BCCH.

2.7.3.3 Radio Link Control (RLC)

The radio link control units within MAC are responsible for fulfilling QoS requirements over the radio interface. For non-real-time bearers RLC provides low-level selective retransmission ARQ functionality with CRC-based error detection.

2.7.4 Packet data handover

In the current simulation results the handover for packet data has been assumed to be hard handover, where connection unlike with LCD services is enabled only to a single base station. This results for the mobiles at the cell egde to not necessary be optimal in terms of interference to the other cells in the system. In the Alpha group technical discussion in the London the method was proposed where the control channel (PCCH) would be in soft handover and packet data would be still routed via a single base station causing no network overhead. The data channel (PDCH) would thus be using thus hard handover.

This kind of operation would facilitate fast rerouting of the packet data as the synchronisation would exist to the most likely base stations for handover as they would be in the active set instead of the candidate set, similar to the LCD soft handover case. Clearly with this solution for the packet data the gains from diversity combining could not be achieved, but faster handover improves the performance otherwise although not offering diversity towards fading channel as such. The method will be studied in further phase of the standardisation work to fully see all the impacts to system operation and achievable improvements to packet data performance.

2.8 Support of positioning functionality

The wideband nature of the WCDMA facilitates the high resolution in position location as the resolution achievable is directly proportional to the channel symbol rate, in this case chip rate. The duration of one chip corresponds to approximately 73 meters in propagation distance and if the delay estimation operates on the accuracy of samples/chip then the achievable maximum accuracy is approximately 18 meters with the 4.096 Mchips/s chip rate. Naturally there are then other inaccuracies that will cause degradation to the positioning but 18 meters can be considered as kind of lower bound on the positioning performance. With higher sampling rate or chip rate the bound is then naturally even lower.

With the WCDMA concept the position location has been discussed in two input documents in the Alpha meetings. The one example solution to use is the proposed power up function (PUF) which in the need for a MS to be heard by several base stations will increase the transmission power over short interval. Other aspects of the position mechanism are how the issue of actual measurement is done and whether that is based on loop around time or on Time Difference Of Arrival (TDOA) or other measures.

The exact solution will not be decided until the standardisation phase during 1998 and to what extent it need to be specified needs to determined as well, but the presented alternatives in the Alpha group work show that the positioning can be provided with the WCDMA system concept.

2.9 Support of TDD

2.9.1 TDD operation

In this section the TDD part of the WCDMA concept is described. In the TDD mode, both forward and reverse link use the same frequency band, see Figure 32. The intention has been to keep the TDD mode as similar to the FDD mode as possible, in order to facilitate easy implementation of dual mode FDD/TDD phones as well as to facilitate reuse of IC's in single mode TDD phones. The control channel multiplexing and uplink and downlink spreading codes is therefore the same in TDD mode as in FDD mode.

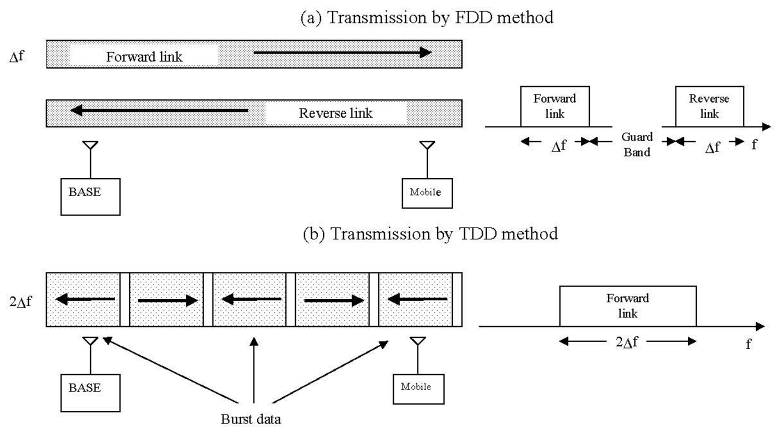


Figure 32 Principle for FDD and TDD operation

The TDD mode shares all key features of WCDMA, such as a high degree of service flexibility. There are two main reasons for the introduction of a TDD mode. The two reasons reflect two different target markets.

2.9.1.1 Cellular public

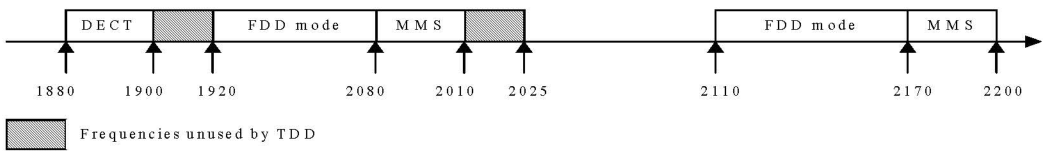


Figure 33 shows the spectrum allocated for UMTS in Europe, and shows two frequency bands which can not be utilised by a FDD system and for which a TDD mode is needed.

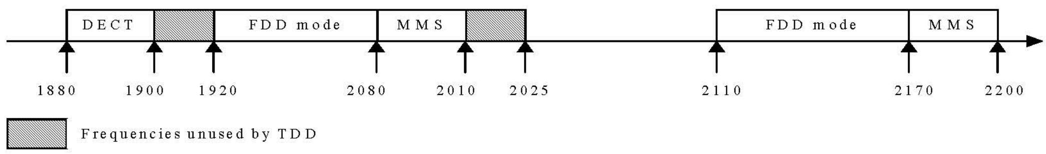


Figure 33 Spectrum allocation for UMTS

Figure 34 illustrates the fragmented nature of frequency allocations around the world and the potential for a TDD solution to utilise these and also second generation spectrum re-farming opportunities. There are obvious candidates even today in the 2010-2025 MHz band, the DECT and PHS allocations, the TDD WLL allocation in China and possibly in the 2110 to 2165MHz allocation in the US.

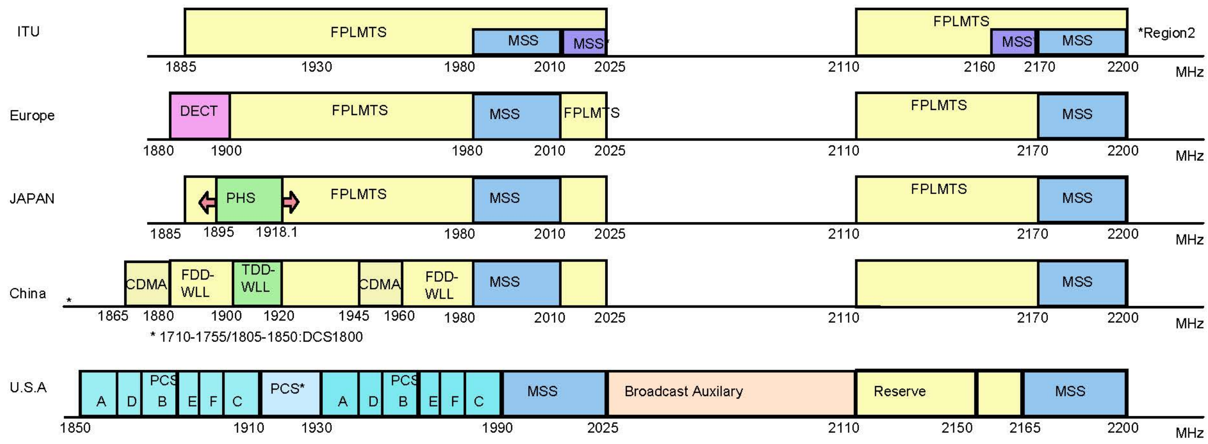


Figure 34 Frequency allocation around the world

2.9.1.2 Unlicensed private

Today most lower-power, small area cellular systems use TDD. In Europe DECT and in Japan PHS are both based on TDD-TDMA. It is reasonable to allow UMTS to address the need of these market segments. TDD allows several simplifications of the RF circuitry, as no duplexer is required. In addition as TDD use the same frequency band in both the uplink and downlink the fading patterns are highly correlated. This in turn facilitates several techniques to be used for mitigating multipath fading, such as open loop power control and transmit and receive antenna diversity, see 2.9.3.

2.9.2 Frame structures

The TDD mode is based on the same general frame structure as the FDD mode, i.e. a 10 ms frame split into 16 slots of 0.625ms each, compare Section 2.4.1. In TDD each slot can be used either for uplink or downlink. However two main modes are currently anticipated.

- Each slot of 0.625ms is used alternating for Rx and Tx, see Figure 35. This mode will allow the open loop power control to work up to a mobile-station speed of 120 km/h. This mode is intended for suburban outdoor environments as stipulated by 04.02.

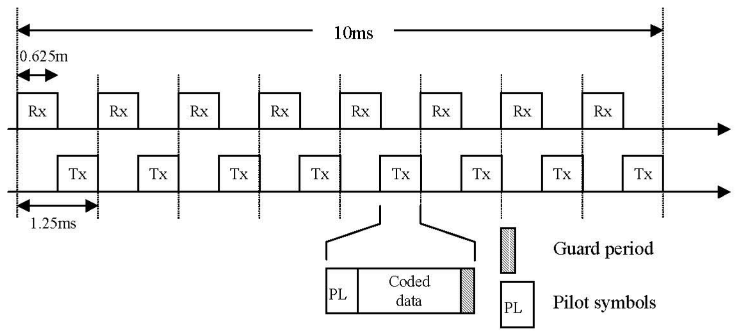


Figure 35 Suggested Rx/Tx cycle for cellular public applications

- Each frame of 10ms consists of one transmit block and one receive block, see Figure 36. The size of the receive block is a multiple of 0.625ms. This facilitates asymmetric services, with the maximum asymmetry being of the order of 15 to 1 (9.375 ms to 0.625ms). In this configuration speeds up to 10km/h can be accommodated with open loop power control. This mode is intended for indoor and low-speed outdoor use.

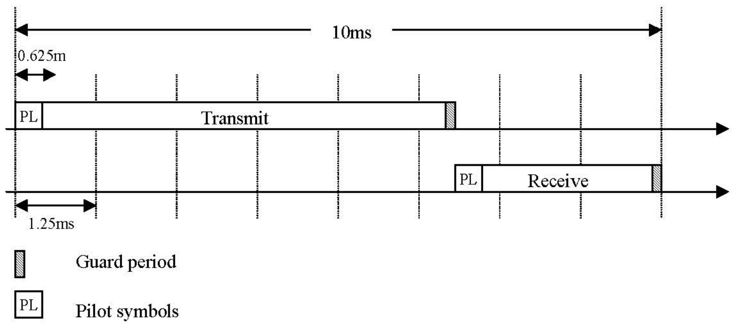


Figure 36 Suggested Rx/Tx cycle for unlicenced private use.

2.9.3 TDD advantages

Due to the high correlation of the channel in the forward and reverse directions, TDD offers several ways to improve system performance and simplify terminal equipment.

- **Open loop power control**. Fast uplink open loop power control may be implemented in the mobile. In the downlink only slow power control is applied. At the mobile the received level can be compared with the expected level and the fading state of the channel can be estimated. As the channel is assumed to be reciprocal the state of the channel for the next mobile transmit burst can be estimated, and the transmit power level set accordingly.
- **Base station transmit antenna selection**. In indoor environments path diversity gain can not be expected to be large (i.e. flat fading). Antenna diversity must therefore be used both in the mobile and the base station. Due to the high correlation of the forward and reverse path the mobile antenna diversity can be moved to the base station. This in turn reduces the interference and therefore improves the capacity of the system.
- **Pre-RAKE combining diversity.** For outdoor use frequency selective fading can be expected. To take advantage of the path diversity the mobile must implement several RAKE fingers, which in turn will increase the cost of the unit. In a TDD system the RAKE combining can be carried out in the base station also for the downlink.
- **Adaptive Antennas**. Channel estimation of the uplink facilitates not only the use of uplink reception techniques but also efficient implementation of adaptive antenna techniques for the downlink.

2.10 Performance enhancing features

In this section, a number of performance enhancing features, currently not seen as parts of the WCDMA concept are described. It can be assumed that during the refinement phase, most of these features will be included in the concept.

2.10.1 Support of adaptive antennas

Adaptive antennas are recognised as a way to enhance capacity and coverage of the system. As mentioned in Section 2.4.1, solutions employing adaptive antennas are already supported in the WCDMA concept through the use of connection-dedicated pilot bits on both uplink and downlink.

2.10.2 Support of advanced receiver structures

WCDMA is designed to work without requiring complex joint detection of multiple user signals. However, the potential capacity gains of such receivers in a WCDMA system have been recognised and taken into account in the design of the concept. In the uplink the possibility to use only short codes (no secondary scrambling code) facilitates more advanced receiver structures with reasonable complexity.

2.10.3 Support of transmitter diversity

Transmitter diversity in the downlink provides a means to achieve similar performance gains as for mobile-station receiver diversity without the complexity of a second mobile-station receiver. For the WCDMA concept, transmitter diversity is possible for both the FDD and the TDD mode.

2.10.3.1 Transmitter diversity for FDD mode

A typical transmit diversity technique such as delay transmit diversity has two main drawbacks - self-interference at locations with good SINR and requirement for additional Rake fingers in the mobile receiver.

However, in WCDMA, orthogonal transmit diversity (OTD) offers significant advantages in the downlink performance, while being free from the above problems.

The implementation of OTD is as follows. Coded bits are split into two data streams and transmitted via two separate antennas. Different orthogonal channelization codes are used per antenna for spreading. This maintains the orthogonality between the two output streams, and hence self-interference is eliminated in flat fading. Note that by splitting the coded data into two separate data streams, the effective number of channelization codes per user is the same as the case without OTD.

The above structure is highly flexible:

- It may be easily extended to more antennas (4, 8, etc.)

OTD may be an optional feature that can be turned on only if needed. In addition, it is possible to support a mixture of mobiles with and without OTD capability.

The additional required processing at the mobile station is small. Figure 37 illustrates Rake finger processing with OTD. It is important to note that the Pilot signal is also split and transmitted on both antennas which allows coherent detection of the signals received from both antenna. The data is processed using a Rake finger with parallel processing capability. Both transmitted signal streams are received simultaneously at the same delay (for a given multipath ray), hence no additional buffering and skewing of data is necessary. This significantly reduces the hardware complexity/cost associated with OTD implementation.

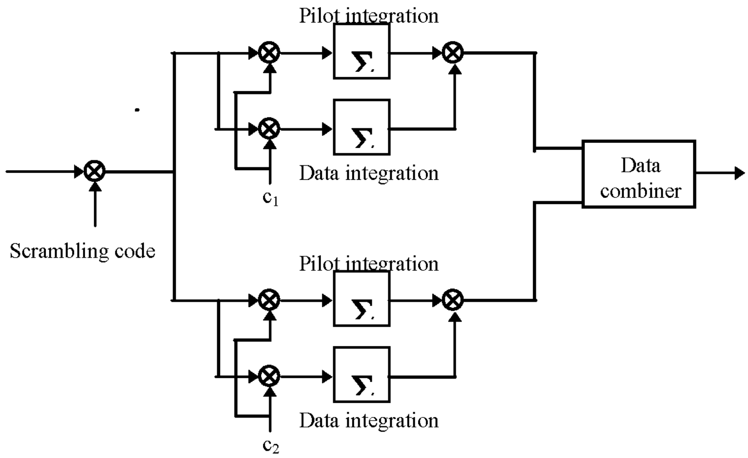


Figure 37 Rake finger processing with OTD

In the base station transmitter, the baseband processing (i.e. data splitting and separate spreaders) required for OTD already exists with multicode transmission in the downlink. From the OTD viewpoint, it is advantageous to employ multicode transmission for all data rates, and it is also recommended to match the number of codes assigned to the user with the number of transmit antennas.

Simulation results indicate that at high speeds, the improvement due to OTD over the system with no diversity is 2.5 dB and about 3 dB over delay transmit diversity. At slow speeds OTD is only slightly better than delay transmit diversity, but the improvement relative to the system with no diversity is as much as 7 dB. Furthermore at slow speeds OTD reduces the required power variance of the downlink fast forward power control.

2.10.3.2 Transmitter diversity for TDD mode

As discussed in, for TDD transmission there is full channel-reciprocity between uplink and downlink, due to the use of a common uplink/downlink carrier frequency. From uplink measurements, the base station may then decide the best antenna to use for the downlink transmissions and thus avoid downlink fades.

2.10.4 Optimised uplink pilot power

With the current uplink scheme, the uplink pilot power is constant for all rates within a variable-rate connection. By including additional variable-strength pilot-bits on the I branch, the uplink pilot power could be optimised for each rate within the rate set of a variable-rate connection.

3. PERFORMANCE EVALUATION

As a part of the work in the ETSI/SMG2 concept group Alpha, Wideband DS-CDMA, a performance evaluation of the WCDMA concept has been carried out by means of simulation for the FDD mode. Results exist also for the TDD mode, but not for the prioritised test cases.

The SMG document UMTS 30.03 ("30.03") [2] describes how this evaluation is to be made. It lists a large number of environments and services to be tested. In Tdoc SMG2 260/97 [3] a subset of all these test cases are listed as prioritised. In addition to this, at SMG2#23 some additional test cases were identified, see Tdoc SMG2 329/97 [4]. Simulation results obtained so far are for the test cases described in these two documents. The prioritised simulations from Tdoc SMG2 260/97 and Tdoc SMG2 329/97 are shown in Table 3.

Environment	Service mixture	Propagation model	Cell type	Link level	System level
Outdoor to indoor and pedestrian 3 km/h	UDD 384	Outdoor to indoor and pedestrian A	Micro	X	X
	Speech			X	X
	LCD 144			X	
	UDD 2048			X	
Indoor office 3 km/h	UDD 2048	Indoor office A	Pico	X	X
	Speech			X	
	LCD 384			X	
	50% speech + 50% UDD 384				X
	LCD 2048			(X)	(X)
Vehicular 120 km/h	UDD 144	Vehicular A	Macro	X	
	Speech			X	X
	LCD 384			X	X
	50 % speech + 50 % UDD 384			(X)	(X)
Vehicular 120 km/h	Speech	Vehicular B	Macro	(X)	
Vehicular 250 km/h	Speech	Vehicular B	Macro	(X)	

Table 3. Required simulations according to Tdoc SMG2 260/97 and Tdoc SMG2 329/97. Optional results in brackets.

This document contains the WCDMA simulation results for the services in Table 3. Compared to the results presented in the draft 1.0 version of the Evaluation document [7], a number of improvements have been made, both on link-level and system-level. Also, results are presented for those services where results were missing in the previous version of this document.

3.1 Implementation of WCDMA/FDD simulations

For the moment the most comprehensive WCDMA simulation results come from the original FRAMES FMA2 proposal. In this section, the FMA2 simulation results are reported. However, the WCDMA concept differs in some areas compared to the FMA2 concept. The largest difference is that the WCDMA concept uses time multiplexed control information in the downlink while FMA2 uses code/IQ multiplexing in both links. Hence, the simulation chain does not agree fully with the current WCDMA group concept. However, this difference between time and IQ/code multiplexing has been evaluated, and is being further evaluated, and there is evidence that there is no major performance difference between the two techniques. It can even be argued that the current WCDMA concept should have slightly better downlink performance compared to the original FMA2 downlink. The downlink performance figures presented here should then be slightly pessimistic.

Also, simulations performed by NEC agree well with the results obtained with the FMA2 simulation chain. The NEC simulations were done with time multiplexing in both uplink and downlink, and are described in [5].

3.1.1 Link-Level Simulations

3.1.1.1 Simulation Model

The WCDMA system description is the basis for the simulation model. However, the downlink simulations use the original FMA2 downlink, described in [1]. Once again one should note that the performance is basically the same.

In the simulations sampling was made at chip level, i.e. with no oversampling and no pulse-shaping filters. Comparative simulations showed negligible performance differences between the filtered and non-filtered case.

Fast power control is included in all simulations. Instead of sending the uplink power control commands on the downlink and vice versa, power control commands are passed through a binary symmetric channel with error probability of 1 %. Simulations have verified that the 1 % error probability agrees well with real errors on transmitted power control commands. Link-level simulations assume unlimited dynamic range for the fast power control, and the delay in the power control loop is one slot. The power amplifier is not modelled, i.e. an ideal amplifier is assumed.

The uplink simulations assume receiver antenna diversity with zero correlation between the antennas, while the downlink assumes one receiver antenna only. Ordinary RAKE reception is used in all simulations. Channel estimation is done through simple averaging of pilot symbols from two consecutive slots.

A fixed searcher is used in the receiver, i.e. the receiver knows the delay of all rays and picks up the energy of some rays using a fixed set of fingers in the RAKE. In the section on channel models the rays picked up by the RAKE are shown.

All interference is modelled as additive white Gaussian noise.

3.1.1.2 Searcher Performance

This chapter shows the results on the practical serarcher in WCDMA derived from the testbed results presented in Tdoc SMG2 UMTS A41/97, [6]. The searcher used in the evaluation consisted of the following steps:

- Correlation between the received signal and the spreading code is calculated at each pilot symbol position with the specified timing resolution.
- Complex correlation values at the step 1 are summed up over the time length-1 (vector integration time) after removing pilot modulation for SINR improvement.
- Squared value of the summation obtained at the step 2 is summed up over the time length-2 (power integration time) for noise and interference smoothing.
- Path timings are selected in descending order from the timings with large squared value given at the step 3.

The number of path timings to be selected was equal to the number of fingers of the RAKE receiver at maximum. At step 4, the power level of a path candidate was compared with the noise and interference floor level as well as the level of the first selected path timing (the maximum power) so that path to be selected efficiently contributes to the path diversity effect at the RAKE receiver. The guard time is also introduced between the path timing already chosen and a path candidate for path separation. In order to utilize path diversity effect due to multipaths coming at very close timing, the performance with the guard time of less than 1 chip duration often outperforms over the one with 1 chip guard time.

The BER performance with the adaptive searcher was compared to the one with fixed searcher, which knows the optimum setting of RAKE fingers in advance. Test were done both with and wihtout power control and the test environment was set to Vehicular B with Doppler frequencies ranging from 5 Hz to 240 Hz. Two antenna branches were used, and one searcher was provided per one antenna branch. Path timings with the four largest powers were set to RAKE receiver fingers out of 8 path timing candidates, each 4 of which were detected by the searcher for each antenna. As a service, LCD 32kbps was used for evaluation.

From the results it can be concluded that the **performance degradation due to using the practical searcher is very little, 0.2-0.3 dB at most, if the proper parameter setting is used.**

In higher speed environment, though instantaneous power level of each channel path fluctuates due to Rayleigh fading more rapidly, the power level can be averaged for shorter obeservation time at searcher. Therefore, for UMTS link-level simulation, **the fixed searcher based on average power level gives a link performance very similar to the one with non-fixed searcher in high speed environment**, though it may not enjoy instantaneous path-selection diversity effect which only gives a small fraction of dB at most.

In practical environment, path timings (channel profile) vary according to the change of radio propagation. The higher the speed becomes, the more rapid change occurs in channel profile. This factor has not been considered in the UTRA link-level simulation based on 04.02. It is partly because the practical modeling of channel profile change is very difficult. But the main reason, we believe, is that properly designed searcher can track this channel change without significant performance degradation, which is explained below.

A good measure of this channel change is the de-correlation length of the long-term fading, at which the auto-correlation of shadowing becomes 0.5. A typical de-correlation length for vehicular environment is 20 m[2], which takes 288 ms when travelling at 250 km/h. With 80 ms path search time, the auto-correlation of shadowing based on the calculation in [2] is 0.82 at 250 km/h and 0.68 at 500 km/h. The studies for different seracher times have shown that degradation is at most 1 dB at BER of 10^{-3} with path search time of 20 ms, in the case of which the auto-correlation of shadowing is 0.95 at 250 km/h and 0.82 at 500 km/h. Therefore, the channel profile change is not so great even in high-speed vehicular environment. Thus a properly designed searcher tracks channel changes in practical situations without causing significant degradation in performance.

Thus it can be concluded that no significant performance degradation is caused by the implemented searcher. Also, the discussion indicates that path timing change is not so rapid to make searcher output obsolete at practical vehicle speeds. The studies done conclude that properly designed searcher gives no significant degradation to link-level performance in WCDMA and also that simulation results in the Alpha group evaluation document can be used for the performance comparison with other groups' results, if other groups also take the proper assumption into account.

3.1.1.3 Channel Models

The channel models given in 30.03 cannot be used right away, since the time resolution of the simulation model is one sample. For the simulations the following modelling of the 30.03 channel models was used:

Each ray is split into two rays, one to the sample to the left and one to the sample to the right. The power of these new rays is such that the sum is equal to the original power, and the power of each of the new rays is inversely proportional to the distance to the original ray. Finally, the power of all rays on one sample are added up and normalised. This yields a model with a number of independently Rayleigh fading rays on the sampling instants.

In the Vehicular B channel the delay spread is very large, so moving the rays to the nearest sampling instant have only marginal impact on the look of the impulse response. Hence, for this channel the rays have been moved instead of interpolated to sampling instants.

In the simulations the sampling time is equal to the chip time, resulting in the channel models in Figure 38 that were used in simulations.

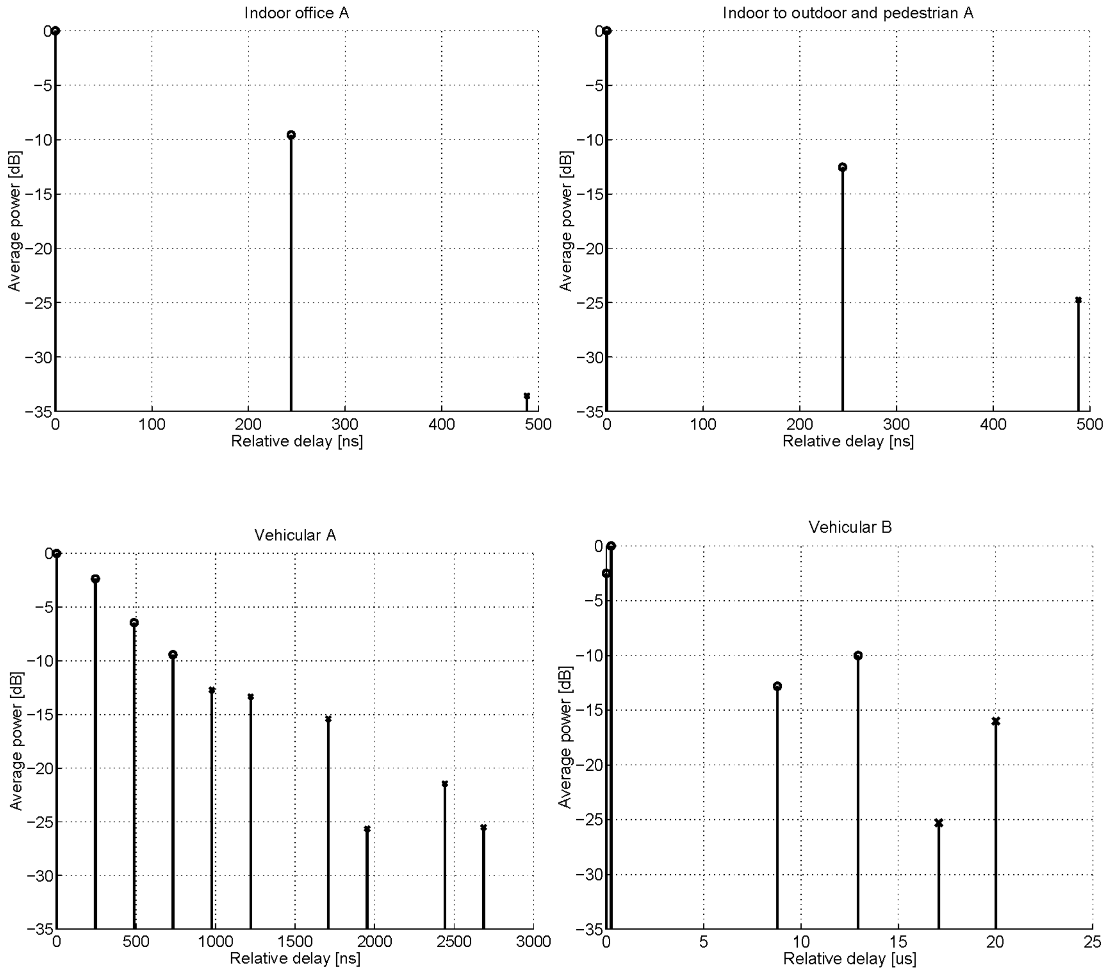


Figure 38. Modified channel models used in the simulations.

The rays picked up by the RAKE receiver are marked with "o" in the figure, while other rays are marked "x". No special link simulations were made for soft handover situations. In a soft handover the result from two single connection RAKEs are combined. For the Vehicular case this would mean 8 RAKE fingers. However, the number of RAKE fingers can be lowered in soft handover without affecting the performance, so 4 - 6 fingers should suffice.

Simulations have been made for mobile station speeds of 3, 120 and 250 km/h, corresponding to Doppler frequencies of 5.6, 213 and 444 Hz respectively for the uplink.

3.1.2 System-Level Simulations

3.1.2.1 Simulation Environment

The simulation environments are described in 30.03. Implementation assumptions are described below.

The Outdoor to indoor and pedestrian deployment environment is a Manhattan-like environment with the block size of 200 m and low speed (3 km/h) users. The environment consists of 72 base stations and are located as described in 30.03. The base stations are using omni-directional antennas and are deployed 10 m above ground, which is below the roof tops. The radio propagation going above roof tops is also included in the system simulation model. The street width is 30 m and it is assumed that the pedestrians are moving in the middle of the street.

The Indoor office environment characterises a three floors office building where users are moving (3 km/h) between an office room to the corridor or vice versa. The base stations (60 base stations all using omni-directional antennas) are deployed in every second office room.

The Vehicular environment is a classic macro environment with site-to-site distance of 6 km. Tri-sectored sites are used, i.e. each site is serving three sectors (cells). The speed of the mobile stations is

120 km/h. Wrap around is used in order to make an infinite cell plan, i.e. there are no border effects in the simulations.

3.1.2.2 Downlink Orthogonality

The downlink will not be perfectly orthogonal due to multipath propagation. The downlink orthogonality factor, i.e. the fraction of the total output power that will be experienced as intra-cell interference, has been calculated for the different environments and is presented in Table 4. An orthogonality factor of zero corresponds to a perfectly orthogonal downlink, while a factor of one is a completely non-orthogonal downlink. As seen in the table below, 40% of the power transmitted from the own cell will act as intra-cell interference in the Vehicular environment.

Propagation model	Orthogonality factor
Indoor office A	0.10
Outdoor to indoor and pedestrian A	0.06
Vehicular A	0.40

Table 4. Orthogonality factor for the environments' different propagation models.

The orthogonality factor has been derived in the following way:

Two simulations were made, one with white Gaussian noise and one with intra-cell interference. The BER was then plotted as a function of E_b/N_o and E_b/I_o respectively. These curves may differ significantly, where the E_b/I_o curve is to the left of the E_b/N_o curve. A difference of 10 dB means that a given E_b/I_o gives the same BER as $E_b/N_o = E_b/I_o + 10$. Consequently, a certain I_o in the system simulations is equivalent to having 10 dB less N_o in the link-level simulations. Hence, one can say that the orthogonality removes 90% of the interference, or we have an orthogonality factor of 10% (10% of the interference remains).

3.1.2.3 Soft / Softer Data Combining

For the Indoor office and the Outdoor to indoor and pedestrian environment soft handover is used between base stations. This means that the uplink C/I (or SIR = PG×C/I) is calculated as selection diversity and the downlink as maximum ratio combining (a sum of the received C/I from each base station). For the Vehicular environment softer handover is used, i.e. the mobile is connected to several sectors belonging to the same site, which will affect the calculation of the uplink C/I. Therefore the uplink C/I for all sectors belonging to one site is calculated as maximum ratio combining. Soft handover in the Vehicular environment is treated as regular selection diversity.

The softer handover data combining (maximum ratio combining) is performed on layer 1 in the WCDMA concept. Softer handover is used only in the Vehicular environment. In the uplink and downlink the SIR during *softer* handover is modelled as:

$$SIR_{combined} = \sum_{sectors} SIR_{sector}$$

The combined downlink (maximum ratio combining) SIR during *soft* handover is modelled as:

$$SIR_{DL,combined} = \sum_{sectors} SIR_{sectors}$$

The combined uplink (selection diversity) SIR during *soft* handover is modelled as:

$$SIR_{UL,combined} = \max_{sectors}(SIR_{sector})$$

3.1.2.4 Increase in TX Power due to Power Control

One effect of the fast power control is that the transmitted power from each mobile will vary with time, and this can cause an increase in background interference power.

For the speech service the average transmitter power increase is used when calculating the interference to other cells (the power increase will not affect the own cell). A good model of the power increase is perfect tracking of the fast fading. This assumption is valid only for the 3 km/h cases (Indoor office and Outdoor to indoor and pedestrian). The power increase in the Vehicular environment is negligible since the power control cannot track the fading, and is therefore not included in the system simulations.

For the UDD simulations fast fading values from the link-level simulations are used in the system-level simulator to adjust the output power of the transmitters for each frame. This means that for each frame a new fading value will be used when calculating the gain matrix (including path loss, shadow fading and fast fading).

3.1.2.5 Radio Resource Management

Fast SIR based power control is assumed in both uplink and downlink, and the power of the transmitters are balanced to meet the averaged SIR during one frame.

The downlink power control may introduce a "near-far" problem if a user near the base station is interfered by the power transmitted to a user at the cell border, due to a non-orthogonal downlink. This problem is avoided by having a limited dynamic range in the downlink. A 20 dB dynamic range per bearer (traffic channel) is assumed in the simulations.

Soft/softer handover is used for the circuit-switched services. The soft/softer handover algorithm simply connects the strongest, based on pathloss (excluding fast fading), base stations within the handover window. The soft/softer handover window threshold is set to 3 dB and the algorithm is executed every 0.5 second and the maximum active set size is two. No significant performance improvement is expected by having an active set size of three or more in these environments. Measurement errors are not included. No soft handover is currently used in the packet simulations; the user simply connects to the strongest base station.

For the UDD service dedicated channel packet transmission is used. No random access / forward access signalling is included in the results.

We assume that a RLC block can be re-transmitted in the next frame, i.e. that the ACK/NACK channel is error free and infinitely fast. A packet data user is queued if no resources are available. If there is a choice between queuing two users, the latest arrived user is queued.

3.1.2.6 Performance Measures

Circuit-Switched Services

Two circuit-switched services, speech and LCD 384, have been evaluated by means of dynamic system simulations. The performance measure of the speech (8 kbps, 50% voice activity) and LCD 384 services is that 98% of the users are *satisfied.* A user is satisfied if all three of the following constraints are fulfilled:

1. The user does not get blocked when arriving to the system.
2. The user has sufficiently good quality more than 95% of the session time. The quality threshold is defined as BER =10^{-3} (speech) or BER = 10^{-6} (LCD).
3. The user does not get dropped. A speech user is dropped if BER > 10^{-3} during 5 s and a LCD 384 user is dropped if BER > 10^{-6} during 26 s.

Packet Services

Two different packet data services have been evaluated: UDD 384 and UDD 2048.

The performance measure of the packet services is that 98% of the users are *satisfied.* A user is satisfied if all three of the following constraints are fulfilled:

1. The user does not get blocked.
2. The user does not get dropped.

The *active session throughput* shall not be below 38.4 kbps (UDD 384) or 204.8 kbps (UDD 2048).

The time waiting on ACK/NACK (i.e. when the transmitter buffer is empty) is not included when calculating the active session throughput. If the data packet that shall be transmitted has less bits than can be transmitted in a frame, dummy bits (or rather dummy blocks) are added. These dummy bits are not included when calculating the session throughput, however they will increase the interference in the system. A data packet will be divided into data blocks of 320 bits (300 information bits). Several blocks are then put into a frame, e.g. 8 blocks per frame for the UDD 384 service. For a detailed description, see section 3.2.1.3.

3.2 Results

3.2.1 Link-Level Simulations

The E_b/N_o values presented here are the actual E_b/N_o values needed in the receiver to achieve the corresponding BER, FER and BLER. The E_b/N_o values include all overhead, i.e. the DPCCH (Dedicated Physical Control Channel: pilot bits, power control bits, FCH) and overhead on the DPDCHs (Dedicated Physical Data Channels) such as CRCs, block numbers and tail bits for the convolutional code. In other words, the E_b value contains all energy needed to transmit one information bit. Energy from common broadcast channels are not included in the link-level results.

The user bit stream is coded using convolutional codes and possibly also a Reed-Solomon code. After coding of the DPDCH rate matching is applied, using puncturing or repetition. On the DPCCH rate matching is always performed using repetition. The rate matching used for the different services are given below, e.g. 9/10 rate matching means "9 bits in, 10 bits out" or repetition of every 9:th bit.

All plots with link-level results are found in Part 3, together with tables specifying the parameters used for the simulations.

3.2.1.1 Speech Service

The speech-service simulations assume a hypothetical 8 kbps speech codec with a user BER requirement of 10^{-3}. The simulations have been carried out with interleaving over one frame only (10 ms) and two frames (20 ms), both of which should satisfy the UMTS requirements of a one-way delay of at most 20 ms. Larger inter-frame interleaving can be applied if more delay is allowed. This would improve performance, especially for medium-speed mobile terminals. A convolutional code of rate 1/3 with constraint length 9 was used for both uplink and downlink. Since the variable rate speech service only has two different bit rates, 0 and 8 kbps, blind rate detection is easily done. Hence, simulations have been made both with and without explicit rate information (FCH, Frame Control Header).

In the simulations the FCH was restricted to two values of the 64 possible. This yields an FCH word error rate of around 10^{-4} for all environments, which means that the rate detection will have virtually no impact on link quality.

The simulation results are shown in Table 5 below.

Environment & mobile speed	E_b/N_0 @ BER = 10^{-3} [dB] (Diversity / No diversity)			
	10 ms interl. With FCH	10 ms interl. No FCH	20 ms interl. With FCH	20 ms interl No FCH
Indoor office A, 3 km/h	4.2 / 7.4	- / 7.1	3.7 / -	3.1 / 6.4
Outdoor to indoor and pedestrian A, 3 km/h	4.5 / 8.0	- / 7.5	4.1 / -	3.3 / 6.7
Vehicular A, 120 km/h	6.5 / 9.0	- / 8.8	6.1 / 8.0	5.0 / 7.6
Vehicular B, 120 km/h				4.9 / 7.7
Vehicular B, 250 km/h	7.0 / -		6.4 / -	6.0 / 8.2

Table 5. Link-level results, speech 8 kbps service.

3.2.1.2 LCD Services

In order to reach the BER=10^{-6} requirement for LCD services, outer Reed-Solomon coding of rate 4/5 is used together with an inner convolutional code and interleaving over 120 ms. The inner convolutional coding is made over one frame or part of a frame.

LCD 144, 384 and 2048 have been simulated in different environments. The LCD 144 uses an inner convolutional code of rate 1/3, while the LCD 384 and 2048 services use a rate of 1/2.

Results are found in Table 6 below. The values without antenna diversity have been estimated from the simulated case with antenna diversity. Based on the speech and UDD simulations, a difference of 3 dB is assumed for the Indoor office and Outdoor to indoor and pedestrian environments, while a difference of 2.5 dB is assumed for the Vehicular environment.

Service	Environment & mobile speed	E_b/N_0 @ BER = 10^{-6} [dB] (Diversity / No diversity)
LCD 144	Outdoor to indoor and pedestrian A, 3 km/h	1.3 / 4.3
LCD 384	Indoor office A, 3 km/h	2.1 / 5.1
	Vehicular A, 120 km/h	3.1 / 5.6
LCD 2048	Indoor office A, 3 km/h	3.0 / 6.0

Table 6. Link-level results, LCD services.

3.2.1.3 UDD Services

For the UDD services, packets to be transmitted are divided into blocks of 320 bits each, which constitutes the retransmittable unit. The user data rates that have been simulated are 240 kbps, 480 kbps, and 2.4 Mbps. These rates are then used in the system-level simulations to get an active session throughput of at least 10 % of the packet bit rate. The 320 bit blocks includes data, CRC, block number, and encoder tail.

Rate 1/2 convolutional coding with constraint length 9 is used, and on top of that an ARQ protocol. However, the effects of ARQ are included in the system-level simulations. The aim of the link-level simulations is to find the required E_b/N_o to achieve certain BLERs. Interleaving is made over one or two frames (10-20 ms).

The performance of the FCH is very good for these services. Since the power of the DPCCH can be relatively high and still not affect the overhead too much, the FCH error rate is much less than 10^{-4} for the target BLER when there are 8 different FCH words to distinguish between.

Results are found in Table 7 below.

Service	Environment & mobile speed	Link-level bit rate [kbps]	E_b/N_0 @ BLER = 10% [dB] (Diversity / No diversity)
UDD 144	Vehicular A, 120 km/h	240	1.9 / 4.2
UDD 384	Indoor office A, 3 km/h	240	0.2 [1] / 2.8
	Outdoor to indoor and pedestrian A, 3 km/h	240	0.2 / 3.2 [2]
UDD 2048	Indoor office A, 3 km/h	480	0.2 / 2.8
		2400	0.7 / 3.3 [3]
	Outdoor to indoor and pedestrian A, 3 km/h	480	0.2 / 3.2
		2400	0.6 / 3.6 [3]

Table 7. Link-level results, UDD services.

Note 1: The simulation without antenna diversity shows that equal E_b/N_0 performance can be obtained for 240 and 480 kbps bearers. The 240 kbps figure with antenna diversity is thus assumed to be the same as the corresponding 480 kbps figure.

Note 2: The simulation with antenna diversity shows that equal E_b/N_0 performance can be obtained for 240 and 480 kbps bearers. The 240 kbps figure without antenna diversity is thus assumed to be the same as the corresponding 480 kbps figure.

Note 3: Estimated value without antenna diversity based on E_b/N_0 difference between 480 and 2400 kbps with antenna diversity.

3.2.2 System-Level Simulations

Dynamic system simulations have been performed for three different services in three different environments described in 30.03. In these simulations all base stations are assumed to be equipped with *one* 4.096 Mcps WCDMA carrier using 5 MHz carrier spacing (assuming 3 carriers within 15 MHz). It is likely that the concept will perform better if a larger bandwidth is used for higher data rates due to a better truncing efficiency. Therefore all results of higher data rate services shall be regarded as pessimistic results. Also, the simulations of the UDD services have only used a *fixed* bit-rate radio bearer, which will also decrease the performance of the UDD services.

The system simulation parameters are listed more in detail in Part 3.

3.2.2.1 Circuit-Switched Services

Two circuit-switched services, speech and LCD 384, have been evaluated by means of dynamic system simulations. The performance measure of the speech (8 kbps, 50% voice activity) and LCD 384 services is that 98% of the users are *satisfied*. No admission control has been used, therefore no users are blocked. Also, the simulation results show that cell capacity in all cases is limited by the requirement that a satisfied user must have sufficiently good quality more than 95% of the session time and not by the dropping criteria. This mean that we have no blocking nor dropping in these simulation results, hence the offered load (Erlang capacity) is same as the served load.

The WCDMA concept uses fast power control also in downlink. This means that slow moving users can compensate for the fast channel fading, hence no substantial diversity gain from connecting more base stations (i.e. increase the maximum number of active set) is seen. Connecting more base stations will only increase the required capacity of base station to base station controller transmission. High speed users do not require good tracking of the fast channel fading due to the gain from coding and interleaving.

The system simulation parameters are listed in Part 3. In Table 8 speech results are found for 20 ms interleaving. LCD results are presented in Table 9.

The speech service is evaluated using 50% voice activity. However, the DPCCH is transmitted with constant bit-rate independent of the speech user information rate (8 kbps or 0 kbps information bit-rate). Therefore, the spectrum efficiency will increase more than 30% if a voice activity of 100% is used, due to the decreased DPCCH (relative) overhead.

A C/I based soft handover algorithm has been studied in the Outdoor to indoor and pedestrian environment, in order to show the improvements that can be achieved by such an algorithm. The basic strategy behind the C/I based algorithm is that the MSs connect to the BS/BSs that requires the lowest amount of output power. Since the handover decision is network evaluated in this case, the MSs still measure the pathlosses to different BSs and report them to the network. In the new scheme, the interference received at the different BSs is also added to the handover decision. Thus, no signaling of interference levels is required over the air interface. The increase in uplink spectrum efficiency (from 127 to 189 kbps/MHz/cell) is due to the load sharing, i.e. the downlink will be the limited link in that case. Another way to achieve a similar load sharing effect is to have a large active set and a large handover margin. The evident disadvantage of that approach is the increased number of mobiles in soft handover.

Service	Environment	E_b/N_o @ BER = 10^{-3} [dB] (UL / DL)	Cell capacity [Erlang/carrier/cell] (UL / DL)	Spectrum efficiency [kbps/MHz/cell] (UL / DL)
Speech (8 kbps, 50% VA)	Outdoor to indoor and pedestrian A	3.3 / 6.7	159 / 204 237 / -	127 / 163 189 / - (C/I based HO)
	Vehicular A	5.0 / 7.6	123 / 98	98 / 78

Table 8. Spectrum efficiency of the speech service: 8 kbps, 50% voice activity, 20 ms interleaving.

Service	Environment	Eb/No @ BER = 10^{-6} [dB] (UL / DL)	Cell capacity [Erlang/carrier/cell] (UL / DL)	Spectrum efficiency [kbps/MHz/cell] (UL / DL)
LCD 384	Vehicular A	3.1 / 5.6	1.8 / 1.1 5.3 / 3.2 (30 dBm MS, 8 Mcps)	138 / 85 204 / 123 (30 dBm MS, 8 Mcps)
		3.1 / 3.1 (ant div)	1.8 / 2.8 2.3 / 2.8 (30 dBm MS) 5.3 / 6.6 (30 dBm MS, 8 Mcps)	138 / 211 175 / 211 (30 dBm MS) 204 / 250 (30 dBm MS, 8 Mcps)

Table 9. Spectrum efficiency of the LCD services.

It is likely that the LCD 384 applications will be executed on a laptop, therefore antenna diversity in the downlink is assumed in some of the results. It can be seen from the LCD 384 results that noise has a large impact on the uplink capacity. To overcome this a mobile transmitted power of 30 dBm was also tested. Also, an 8 Mcps (with 30 dBm MS) carrier was tested to see the effect of increased truncing efficiency.

3.2.2.2 Packet Services

Two different packet data services have been evaluated: UDD 384 and UDD 2048. The performance measure of the packet services is that 98% of the users are *satisfied.*

New results are provided due to the new UDD performance definition, i.e. the 10% active session throughput requirement, see "CR's on UMTS 30.03 A001 and A002", Tdoc SMG 97-771. The results are found in Table 10 below.

The current implementation of the UDD 2048 service use fixed bearers; i.e. one or more codes of 480 kbps user bit-rate each. A real system will of course have a higher granularity of the bearers, but for simplicity only 5 different bearers have been tested in the system level simulations. The UDD 2048 (Indoor office A) performance has improved compared to the "100%" results due to better truncing efficiency. The spectrum efficiency is in the uplink 300 kbps/MHz/cell and downlink 244 kbps/MHz/cell. With downlink antenna diversity the downlink spectrum efficiency is 510 kbps/MHz/cell. The system simulation parameters and pdf of the active session throughput for different bearer choices are found in Part 3.

Also the UDD 384 service (Outdoor to indoor and pedestrian A) results have been improved. The spectrum efficiency is in the uplink 470 kbps/MHz/cell and in the downlink 565 kbps/MHz/cell. With antenna diversity the downlink will be code limited (i.e. 672 kbps/MHz/cell) and the coding may therefore be reduced in order to increase the spectrum efficiency above 672 kbps/MHz/cell.

Service	Environment	E_b/N_o @ BLER = 10% [dB] (UL/DL)	Spectrum efficiency [kbps/MHz/cell] (UL / DL)
UDD 2048	Indoor office A	0.2 / 2.8 0.2 / 0.2 (DL ant div)	300 / 230 300 / 500 (DL ant div)
UDD 384	Outdoor to indoor and pedestrian A	0.2 / 3.2	470 / 565

Table 10. Spectrum efficiency of the UDD services.

3.2.2.3 Mixed Services

The UDD 384 is using a 240 kbps bearer and therefore we define the average number of packet user as the average session bit-rate divided with 240 kbps. The offered load is controlled so the number of packet and speech users is the same. The number of speech users is defined as the number of simultaneously transmitting (8 kbps) users.

The spectum efficiency is calculated as:

Spectrum efficiency = Cell capacity × (240 + 8) / 5 [kbps/MHz/cell]

The results are found in Table 11 below.

Service	Environment	Cell capacity [Erlang/carrier/cell] (UL / DL)	Unsatisfied Speech Users [%] (UL / DL)	Unsatisfied UDD Users [%] (UL / DL)	Spectrum efficiency [kbps/MHz/cell] (UL / DL)
Speech + UDD 384	Indoor office A	6.3 / 4.2	2% / 2%	1% / 0.1%	315 / 207
		6.3 / 9.3 (DL ant div)	2% / 2%	1% / 0.2%	315 / 460 (DL ant div)

Table 11. Spectrum efficiency of the mixed service case.

3.3 Summary of Simulation Results

Table 12 summarises the results from the WCDMA/FDD link and system simulations.

Service	Environment & speed	E_b/N_o [dB] (UL / DL)	Cell capacity [Erlang/carrier/cell] (UL / DL)	Spectrum efficiency [kbps/MHz/cell] (UL / DL)	Notes
Speech 8 kbps 50% VA	Indoor office A, 3 km/h	3.1 / 6.4			
	Outdoor to indoor and pedestrian A, 3 km/h	3.3 / 6.7	159 / 204 237 / -	127 / 163 189 / -	C/I based handover
	Vehicular A, 120 km/h	5.0 / 7.6	123 / 98	98 / 78	
	Vehicular B, 120 km/h	4.9 / 7.7			
	Vehicular B, 250 km/h	6.0 / 8.2			
LCD 144	Outdoor to indoor and pedestrian A, 3 km/h	1.3 / 4.3			
LCD 384	Indoor office A, 3 km/h	2.1 / 5.6			
	Vehicular A, 120 km/h	3.1 / 5.6 3.1 / 3.1	1.8 / 1.1 5.3 / 3.2 1.8 / 2.8 5.3 / 6.6	138 / 85 204 / 123 138 / 211 204 / 250	30 dBm MS, 8 Mcps DL antenna diversity DL antenna diversity, 30 dBm MS, 8 Mcps
LCD 2048	Indoor office A, 3 km/h	3.0 / 6.0			
UDD 144	Vehicular A, 120 km/h	1.9 / 4.2			
UDD 384	Indoor office A, 3 km/h	0.2 / 2.8			
	Outdoor to indoor and pedestrian A, 3 km/h	0.2 / 3.2		470 / 565	
UDD 2048	Indoor office A, 3 km/h	0.2 / 2.8 0.2 / 0.2		300 / 230 300 / 500	DL antenna diversity
	Outdoor to indoor and pedestrian A, 3 km/h	0.2 / 3.2			
Mixed speech + UDD 384	Indoor office A, 3 km/h		6.3 / 4.2 6.3 / 9.3	315 / 207 315 / 460	UDD DL antenna div.

Table 12. Summary of WCDMA/FDD simulation results.

References

[1] “FMA - FRAMES Multiple Access, A Harmonized Concept for UMTS/IMT-2000: FMA2 - Wideband CDMA,” ITU Workshop on Radio Transmission Technologies for IMT-2000, Toronto, Canada, September 10-11 1997.

[2] UMTS 30.03, version 3.0.0, ETSI Technical Report, 1997-05.

[3] Tdoc SMG2 260/97, “Common Workplan of SMG2 UTRA Concept Groups”.

[4] Tdoc SMG2 329/97, “Next simulation test cases”.

[5] Tdoc SMG2 UMTS A39/97, “Simulation Results”.

[6] Tdoc SMG2 UMTS A41/97, “Link-level Performance with Adaptive Searcher”.

[7] Tdoc SMG2 270/97, “Concept Group Alpha - Wideband Direct Sequence CDMA: Evaluation Document, draft 1.0”.

4. CONCLUSIONS

This document has presented the wideband DS-CDMA concept proposed as UMTS Terrestrial Radio Access (UTRA) radio interface by the ETSI SMG2 Alpha (WCDMA) concept group. The proposed concept has been studied in a wide range of environments and has been shown to fulfil all the UTRA requirements. It can thus be recommended to be chosen as the UTRA air interface. The concept has several advantageous features including :

- Flexible multirate and service multiplexing concept for varying UMTS service needs.
- The wide range of UMTS services up to 2 Mbps supported with the concept.
- Support for two types of packet transmission for efficient packet access support.
- Future proofness taken into account into system design to enable later performance enhancements when even more capacity is needed after initial deployment.
- Flexible system deployment with asynchronous operation and efficient support for hierarchical cell structures.
- Competitive implementation complexity with the studied RAKE receiver solution compared to other UTRA options with no exponential elements in the complexity as a function of data rate.
- Competitive performance in terms of capacity and coverage compared to other UTRA concepts, especailly the range with high bit rate applications shows generally several dBs of difference to competing solutions.
- Transmission concept which avoids audible interference problems and results in low power transmission with the aid of an efficient power-control scheme and utilisation of frequency diversity due to the wideband signal.

The studied aspects include also the dual-mode terminal implementation with GSM, which is taken into account when defining concept details to allow smooth migration between second generation systems and third generation wideband CDMA with UMTS service capability. Furthermore, as wideband CDMA solutions are currently being adopted for other regions as well, the concept offers very good opportunities for global roaming and improved cost efficiency due to larger volumes of the terminal and network equipment. The existing validators from several vendors for WCDMA equipment will also provide a faster development path towards UMTS roll-out.

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Concept Group Alpha - Wideband Direct-Sequence CDMA (WCDMA)

EVALUATION DOCUMENT (3.0)

Part 2: Annex 1 Answers Link Budget Calculation Complexity and dual mode GSM/UMTS terminal complexity analysis Rate Matching Principle

In the procedure to define the UMTS Terrestrial Radio Access (UTRA), the wideband DS-CDMA concept group (Alpha) will develop and evaluate a multiple access concept based on direct sequence code division. This group was formed around the DS-CDMA proposals from FRAMES Mode 2, Fujitsu, NEC and Panasonic. The main radio transmission technology (RTT) and parameters of the common concept from the Alpha group along with performance results are presented in this document

This document was prepared during the evaluation work of SMG2 as a possible basis for the UTRA standard. It is provided to SMG on the understanding that the full details of the contents have not necessarily been reviewed by, or agreed by, SMG2.

1 Introduction

In the evaluation process of the different concepts the questions in Annex 1 of ETR 0402 have to be answered. The Alpha group's set of answers to the Annex 1 questions is found in Chapter 2. Chapter 3 provides link budgets according to the link budget template given in ETR 0402. In Chapter 4 a complexity evaluation is presented and finally in Chapter 5 the principle for rate matching is shown.

2 Answers to Annex1 on ETR 0402

	A1.1	Test environment support
ti	A1.1.1	In what test environments will the SRTT operate? **Answer:** Indoor office (I), Outdoor to indoor and pedestrian (P), Vehicular (V), and Mixed-cell pedestrian/vehicular (M)
td	A1.1.2	If the SRTT supports more than one test environment, what test environment does this technology description template address? **Answer:** The template addresses all four test environments.
	A1.1.3	Does the SRTT include any feature in support of FWA application ? Provide detail about impact of those features on the technical parameters provided in this template, stating whether the technical parameters provided apply for mobile as well as for FWA applications. **Answer:** The concept can be applied to FWA applications. No special features are needed for FWA operation.
	A1.2	Technical parameters Note : Parameters for both forward link and reverse link should be described separately, if necessary.
ti	A1.2.1	What is the minimum frequency band required to deploy the system (MHz)? **Answer:** FDD mode 2×5 MHz, TDD mode 5 MHz.
it	A1.2.2	What is the duplex method: TDD or FDD? **Answer:** Both FDD and TDD modes are specified.
ti	A1.2.2.1	What is the minimum up/down frequency separation for FDD? **Answer:** 80 MHz in the UMTS band.
ti	A1.2.2.2	What is requirement of transmit/receive isolation? Does the proposal require a duplexer in either the mobile or base station. **Answer:** FDD mode: Duplexer needed. Transmit/receive isolation 80 dB. TDD mode: No duplexer needed.
ti	A1.2.3	Does the SRTT allow asymmetric transmission to use the available spectrum? Characterize. **Answer:** The possibility for a large range of uplink/downlink asymmetry on the connection level follows from the possibility of independent setting of uplink and downlink bearer-service characteristics (rate, delay, bit-error-rate etc.). The possibility for uplink/downlink asymmetry on the cell-level is due to the use of one-cell reuse, where downlink and uplink resources can independently of each other be moved between neighbouring cells. Asymmetry on a total-system level can be achived with the proposed TDD mode where the total available time can be asymmetrically allocated to the uplink/downlink. For the FDD mode, total-system asymmetry is possible if and only if more bandwidth is allocated to downlink than uplink or vice versa. ~~The SRTT allows for asymmetry in terms of different bit rates, bit error rates, delay, etc. between the uplink and downlink of a two-way connection. In TDD the spectrum can be divided assymetrically in time between uplink and downli~~

ti	A1.2.4	What is the RF channel spacing (kHz)? In addition, does the SRTT use interleaved frequency allocation? Note: Interleaved frequency allocation; allocating the 2nd adjacent channel instead of adjacent channel at neighboring cluster cell is so called "interleaved frequency allocation". If a proponent is going to employ this allocation type, proponent should be stated at A1.2.4 and fill A1.2.15 of protection ratio for both of adjacent and 2nd adjacent channel. **Answer:** The SRTT uses an RF channel raster of 200 kHz. A fixed RF channel spacing is not defined but depends on the deployment scenario, e.g. if adjacent downlink carriers are of the same power or of significantly different power such as is e.g. the case for Hierarchical Cell Structures (HCS). The recommended RF channel spacing is 4.2-5 MHz for the 4.096 Mcps chip rate, 8.4-10 MHz for 8.192 Mcps, and 16.8-20 MHz for 16.384 Mcps. The SRTT does not use interleaved frequency allocation.
ti	A1.2.5	What is the bandwidth per duplex RF channel (MHz) measured at the 3 dB down points? It is given by (bandwidth per RF channel) x (1 for TDD and 2 for FDD). Please provide detail. **Answer:** FDD mode: 8.192 MHz (16.384 / 32.768 MHz) TDD mode: 4.096 MHz (8.192 / 16.384 MHz)
ti	A1.2.5.1	Does the proposal offer multiple or variable RF channel bandwidth capability? If so, are multiple bandwidths or variable bandwidths provided for the purposes of compensating the transmission medium for impairments but intended to be feature transparent to the end user? **Answer:** The basic chip rate of the SRTT is 4.096 Mcps corresponding to a channel bandwidth of ≈5MHz. Additional chip rates 8.192 Mcps and 16.384 Mcps, corresponding to bandwidths of ≈10MHz and ≈20MHz respectively, are also supported by the specification. Although services up to 2 Mbps are supported by the basic chip-rate (4.096 Mcps), high-rate services (> 500 kbps) are more efficiently supported by the higher chip-rates. The different bandwidths are not used to compensate for transmission medium impairments. The different bandwidths are transparent to the end user.
ti	A1.2.6	What is the RF channel bit rate (kbps)? **Answer:** RF channel bit rate: Variable (0 kbps, 16 kbps, 32 kbps, 64 kbps, 128 kbps, 256 kbps, 512 kbps, 1024 kbps) RF channel chip rate: 4.096 Mcps (8.192 Mcps, 16.384 Mcps)

ti	A1.2.7	Frame Structure : Describe the frame structure to give sufficient information such as; - frame length - the number of time slots per frame - guard time or the number of guard bits - user information bit rate for each time slot - channel bit rate (after channel coding) - channel symbol rate (after modulation) - associated control channel (ACCH) bit rate - power control bit rate. Note 1: Channel coding may include FEC, CRC, ACCH, power control bits and guard bits. Provide detail. Note 2: Describe the frame structure for forward link and reverse link, respectively. Note 3: Describe the frame structure for each user information rate **Answer:** Frame length: 10 ms Number of time slots per frame: 16 (time slot = power-control period). Guard time FDD-mode: None, TDD mode: 31.25 µs. User information bit rate for each time slot: Variable Channel bit rate (after channel coding and rate matching): UL: $16*2^k$ kbps per IQ/branch (16/32/64/128/256/512/1024 kbps) DL: $32*2^k$ kbps (32/64/128/256/512/1024/2048 kbps) Channel symbol rate (after modulation): $16*2^k$ ksps (16/32/64/128/256/512/1024 ksps) Associated control channel bit rate: 0 and 16 kbps [preliminary assumption, still under study] Power-control rate: 1.6 kHz (possibility for variable rate in the range 500 Hz - 2 kHz) See also W-CDMA Evaluation Document, System Description part.
ti	A1.2.8	Does the SRTT use frequency hopping? If so characterize and explain particularly the impact (e.g. improvements) on system performance. **Answer:** The SRTT does not use frequency hopping.
td	A1.2.8.1	What is the hopping rate? **Answer:** N/A
td	A1.2.8.2	What is the number of the hopping frequency sets? **Answer:** N/A
ti	A1.2.8.3	Are base stations synchronized or non-synchronized? **Answer:** FDD mode - No accurate inter-base station synchronization is needed. To simplify the handover procedure, an inter-base station synchronization accuracy on the order of 10 ms is preferred. Such synchronization can be achieved through the ordinary network, i.e. no external equipment such as GPS is needed for inter-base station synchronization. TDD mode - Inter-base station synchronization is needed in the order of ±3µs. As the TDD mode is mainly considered for small-cell environments with low mobility, in order to reduce the guard-time requirements, the possibility to achieve the inter-base-station synchronization in an autonomuous way, without the need for external systems, is currently being considered.

ti	A1.2.9	Does the SRTT use spreading scheme? **Answer:** Yes, the SRTT is based on Direct-Sequence CDMA
td	A1.2.9.1	What is the chip rate (Mchip/s): Rate at input to modulator. **Answer:** 4.096 / 8.192 / 16.384 Mcps
td	A1.2.9.2	What is the processing gain: 10 log (Chip rate / Information rate). **Answer:** The processing gain depends on the specific service. The processing gain (chip-rate/information-rate) is variable in the range 3-46 dB for 4.096 Mcps.
td	A1.2.9.3	Explain the uplink and downlink code structures and provide the details about the types (e.g. PN code, Walsh code) and purposes (e.g. spreading, identification, etc.) of the codes. **Answer:** Channelization codes (UL & DL): Orthogonal Variable Spreading Factor codes. Spreading factor: 4-256 (4.096 Mcps) Primary scrambling code (UL): Short complex MS-specific code of length 256 chips based on extended Very-Large Kasami set. Secondary scrambling code (UL):Optional MS-specific code of length 10 ms (40960 chips). Segment of long Gold code. Scrambling code (DL): BS-specific code of length 10 ms (40960 chips). Segment of long Gold code. Short Orthogonal Gold codes used on Physical Random-Access channel and synchronization channel. See also W-CDMA Evaluation Document, System Description part.
ti	A1.2.10	Which access technology does the proposal use: TDMA, FDMA, CDMA , hybrid, or a new technology? In the case of CDMA which type of CDMA is used: Frequency Hopping (FH) or Direct Sequence (DS) or hybrid? Characterize. **Answer:** Single-carrier Wideband Direct-Sequence CDMA.
ti	A1.2.11	What is the baseband modulation technique? If both the data modulation and spreading modulation are required, please describe detail. What is the peak to average power ratio after baseband filtering (dB)? **Answer:** Data modulation: Dual-channel QPSK (UL), QPSK (DL) Spreading modulation: QPSK (UL), BPSK (DL). Root raised cosine pulse shaping, roll-off factor 0.22. Maximum peak-to-average ratio: ≤4.8 dB.

ti	A1.2.12	What are the channel coding (error handling) rate and form for both the forward and reverse links? e.g. - Does the SRTT adopt FEC (Forward Error Correction) or other schemes? **Answer:** Convolutional inner code (rate 1/3 or rate 1/2, constraint length K=9) for BER=10^{-3} services. Optional outer Reed-Solomon code (rate 4/5) for BER=10^{-6} circuit-switched services. Possibility for service-specific coding. Unequal repetition and/or puncturing for rate matching. - Does the SRTT adopt unequal error protection? Please provide details. **Answer:** Unequal error protection is possible with code puncturing/repetition or with service-specific coding.. - Does the SRTT adopt soft decision decoding or hard decision decoding? Please provide details. **Answer:** The decoding scheme of the SRTT is an implementation issue and is not covered by the SRTT description. There is nothing in the SRTT that prevents the use of either soft or hard decision decoding. The Rake receiver used in the simulations is well suited to provide soft decisions with maximal ratio combining. - Does the SRTT adopt iterative decoding (e.g. turbo codes)? Please provide details. **Answer:** Turbo codes is not an inherent part of the SRTT, but can be included as service-specific coding- Other schemes.
ti	A1.2.13	What is the bit interleaving scheme? Provide detailed description for both up link and down link. **Answer:** Inner interleaving: Block interleaving with variable block size (10-150 ms) Outer interleaving: Block interleaving with variable block size (10-150 ms)
ti	A1.2.14	Describe the taken approach for the receivers (MS and BS) to cope with multipath propagation effects (e.g. via equalizer, RAKE receiver, etc.). **Answer:** The processing gain of DS-CDMA supresses interference due to multipath propagation A RAKE receiver (or more advanced multi-user detectors) combines multiple paths and gives diversity gains.
ti	A1.2.14.1	Describe the robustness to intersymbol interference and the specific delay spread profiles that are best or worst for the proposal. **Answer:** WCDMA can handle time-dispersion up to 62.5 µs. This limit is due to the length of the uplink scrmabling codes (256 chips). Within that range, the *size* of the delay spread does not, in itself, have any impact on the performance. On the other hand, the *shape* of the delay spread may have an impact on the performance. With multi-path reception (multiple received rays), the performance is improved for the following reasons: • Improved frequency diversity. This is especially the case for high mobile-station speeds where the fast power control does not compensate for the fast fading. • Reduced excess transmit power. This is especially the case for low mobile-station speeds where the fast power control creates excess transmit power when it compensates for the fast fading For a very large number of non-neglegible rays, there may be a performance degradation due to non-captured signal-energy (insufficent number of RAKE fingers). By increasing the number of RAKE fingers, this performance degradation can be removed. A good relation between performance and delay spread is impossible to give, as the performance does not directly depend on the size of the delay spread but on the size of the delay spread, see above.

ti	A1.2.14.2	Can rapidly changing delay spread profiles be accommodated? Please describe. **Answer:** Variations in path amplitudes/phases up to at least 500 Hz can be tracked with the pilot-bit-assisted coherent detection. Long term variations in the path profile, e.g. the occurance of new paths can be tracked on a frame-by-frame basis (10 ms). The environment specific pilot conficurations allow to make pilot configuration accoring to environment conditions without having the same overhead in all environments where propagation conditions are less severe.
ti	A1.2.15	What is the Adjacent channel protection ratio? In order to maintain robustness to adjacent channel interference, the SRTT should have some receiver characteristics that can withstand higher power adjacent channel interference. Specify the maximum allowed relative level of adjacent RF channel power in dBc. Please provide detail how this figure is assumed. **Answer:** 45 dB.
	A1.2.16	Power classes
ti	A1.2.16.1	Mobile terminal emitted power: What is the radiated antenna power measured at the antenna? For terrestrial component, please give (in dBm). For satellite component, the mobile terminal emitted power should be given in EIRP (dBm). **Answer:** 24 dBm (Nominal value, not limited by SRTT)
ti	A1.2.16.1.1	What is the maximum peak power transmitted while in active or busy state? **Answer:** 30 dBm (Nominal value, not limited SRTT)
ti	A1.2.16.1.2	What is the time average power transmitted while in active or busy state? Provide detailed explanation used to calculate this time average power. **Answer:** 100%, continuous transmission for DPCCH, for DPDCH on need basis 0-100%.
ti	A1.2.16.2	Base station transmit power per RF carrier for terrestrial component
ti	A1.2.16.2.1	What is the maximum peak transmitted power per RF carrier radiated from antenna? **Answer:** Not limited by the SRTT
ti	A1.2.16.2.2	What is the average transmitted power per RF carrier radiated from antenna? **Answer:** Not limited by the SRTT, nominal value 24 dBm per code channel.
ti	A1.2.17	What is the maximum number of voice channels available per RF channel that can be supported at one base station with 1 RF channel (TDD systems) or 1 duplex RF channel pair (FDD systems), while still meeting G.726 performance requirements? **Answer:** Depends on the environment and conditions but the SRTT allows the following number of data channels per carrier for 4.096 Mchips/s: 256 with FDD, 128 with TDD.

ti	A1.2.18	Variable bit rate capabilities: Describe the ways the proposal is able to handle variable base band transmission rates. For example, does the SRTT use: -adaptive source and channel coding as a function of RF signal quality **Answer:** Source coding is not part of the SRTT. Adaptive source coding as a function of RF quality is possible. Adaptive channel coding as a function of RF signal quality is not needed due to power control and CDMA multirate scheme and spreading. -variable data rate as a function of user application **Answer:** The user rate can vary on a 10 ms basis with a granularity of 100 bps -variable voice/data channel utilization as a function of traffic mix requirements? **Answer:** The SRTT allows for variable voice/data channel utilization as a function of traffic mix requirements. -Characterize how the bit rate modification is performed. In addition, what are the advantages of your system proposal associated with variable bit rate capabilities? **Answer:** Different channel bit rates are possible by changing the spreading factor in factors of 2 from 256 down to 4. For the highest rates, multi-code transmission, i.e. transmission on several parallel code channels, is used. An arbitrary user bit rate after channel coding is matched to the closest possible channel bit rate by code puncturing/repetition. For variable-rate transmission, the rate can vary on a 10 ms basis. Explicit rate information, to simplify decoding, may be transmitted on a parallel control channel. Multiple variable services can be time multiplexed on one variable-rate physical channel or code multiplexed on different variable-rate physical channels. The advantages with this approach is that the bit rate can be varied on a frame-by-frame basis without any explicit resource allocation and negotiation. It also for the independent quality control of each service on a multi-service connection.

td	A1.2.18.1	What are the user information bit rates in each variable bit rate mode? **Answer:** The user bit rate can be varied from 0-2048 kbps with a granularity of 100 bps. For a given connection, a sub-set of these rates are chosen at call set-up. During the call, the rate can be varied between the rates within the sub-set on a frame-by-frame basis. The sub-set of rates can also be changed during a call, e.g. due to the addition/removal of services..
ti	A1.2.20	Data services: Are there particular aspects of the proposed technologies which are applicable for the provision of circuit-switched, packet-switched or other data services like asymmetric data services? For each service class (A, B, C and D) a description of SRTT services should be provided, at least in terms of bit rate, delay and BER/FER. Note 1: See [draft new] Recommendation [FPLMTS.TMLG] for the definition of - “circuit transfer mode” - “packet transfer mode” - “connectionless service” and for the aid of understanding “circuit switched” and “packet switched” data services Note 2: See ITU-T Recommendation I.362 for details about the service classes A, B, C and D **Answer:** All service classes can be supported with the proposed SRTT.
ti	A1.2.20.1	For delay constrained, connection oriented. (Class A)
ti	A1.2.20.2	For delay constrained, connection oriented, variable bit rate (Class B)
ti	A1.2.20.3	For delay unconstrained, connection oriented. (Class C)

ti	A1.2.20.4	For delay unconstrained, connectionless. (Class D)
ti	A1.2.21	Simultaneous voice/data services: Is the proposal capable of providing multiple user services simultaneously with appropriate channel capacity assignment? **Answer:** Up to 16 parallel services can be provided with some limitations on the variable-rate properties of the different services. The different services can have independent bit rate, bit-error rate, delay, etc., and can have different transfer modes (packet/circuit-switched).
		Note : The followings describe the different techniques that are inherent or improve to a great extent the technology described above to be presented: Description for both BS and MS are required in attributes from A2..22 through A1.2.23.2.
ti	A1.2.22	Power control characteristics: Is power control scheme included in the proposal? Characterize the impact (e.g. improvements) of supported power control schemes on system performance. **Answer:** The SRTT uses fast closed-loop C/I based power control + slow quality-based power control on both uplink and downlink. Open loop power control is used for random access. The use of fast power control significantly improves the link-performance (BER as a function of E_b/N_0) especially in the case slow-moving mobile stations. For fast moving mobile stations (>100 km/h), there is no performance improvement due to fast power control.
td	A1.2.22.1	What is the power control step size in dB? **Answer:** UL: Variable in the range 0.25-1.5 dB DL: Variable in the range 0.25-1.5 dB
td	A1.2.22.2	What are the number of power control cycles per second? **Answer:** UL: 1.6 kHz (possibility for variable rate in the range 500 Hz - 2 kHz) DL: 1.6 kHz (possibility for variable rate in the range 500 Hz - 2 kHz)
td	A1.2.22.3	What is the power control dynamic range in dB? **Answer:** UL: 80 dB DL: 30 dB
td	A1.2.22.4	What is the minimum transmit power level with power control? **Answer:** -50 dBm at MS with highest power class
td	A1.2.22.5	What is the residual power variation after power control when SRTT is operating? Please provide details about the circumstances (e.g. in terms of system characteristics, environment, deployment, MS-speed, etc.) under which this residual power variation appears and which impact it has on the system performance. **Answer:** The residual power variation depends on the channel conditions, (Doppler spread and frequency selectivity). TBD
ti	A1.2.23	Diversity combining in mobile station and base station: Are diversity combining schemes incorporated in the design of the SRTT? **Answer:** Yes

td	A1.2.23.1	Describe the diversity techniques applied in the mobile station and at the base station, including micro diversity and macro diversity, characterizing the type of diversity used, for example: - time diversity : repetition, RAKE-receiver, etc., - space diversity : multiple sectors, multiple satellite, etc., - frequency diversity : FH, wideband transmission, etc., - code diversity : multiple PN codes, multiple FH code, etc., - other scheme. Characterize the diversity combining algorithm, for example, switch diversity, maximal ratio combining, equal gain combining. Additionally, provide supporting values for the number of receivers (or demodulators) per cell per mobile user. State the dB of performance improvement introduced by the use of diversity. **Answer:** Time diversity: Channel coding and interleaving in both uplink and downlink. Multipath diversity: RAKE receiver with maximum ratio combining in both BS and MS. Space diversity: Antenna diversity with maximum ratio combining in BS and optionally in MS. Possibility for orthogonal transmit diversity in the BS. Macro diversity: Soft (inter-site) handover with maximum ratio combining in downlink, selection combining in uplink. Softer (inter-sector) handover with maximum ratio combining in both uplink and downlink. Frequency diversity: Wideband carrier. For the mobile station: what is the minimum number of RF receivers (or demodulators) per mobile unit and what is the minimum number of antennas per mobile unit required for the purpose of diversity reception? These numbers should be consistent to that assumed in the link budget template in Annex 2 and that assumed in the calculation of the "capacity" defined at A1.3.1.5. **Answer:** Minimum one receiver/antenna (no downlink receiver diversity required by SRTT or used in the simulations).
td	A1.2.23.2	What is the degree of improvement expected in dB? Please also indicate the assumed condition such as BER and FER. **Answer:** For receiver antenna diversity the diversity gain is 2.5 - 3.5 dB in required E_b/N_o for BER=10^{-3}. If power control is disabled the gain is much higher for the low speed cases. On top of the gain in reduced required E_b/N_o there is a gain in decreased transmitted power. This gain can be up to 2.5 dB, depending on the environment. Orthogonal transmit diversity can also be employed, especially in the downlink. A gain similar to the gain with receiver antenna diversity is expected. All other diversity methods are inherent parts of the W-CDMA concept and therefore it is difficult to specify an explicit diversity gain figure in dB.

ti	A1.2.24	Handover/Automatic Radio Link Transfer (ALT) : Do the radio transmission technologies support handover? Characterize the type of handover strategy (or strategies) which may be supported, e.g. mobile station assisted handover. Give explanations on potential advantages, e.g. possible choice of handover algorithms. Provide evidence whenever possible. **Answer** The SRTT supports automatic handover. The handover scheme is based on a mobile assisted soft handover mechanism. The mobile station (MS) monitors the pilot signal levels received from neighboring base stations and reports to the network pilots crossing or above a given set of dynamic thresholds. Based on this information the network orders the MS to add or remove pilots from its *Active Set*. The *Active Set* is defined as the set of base station for which user signal is simultaneously demodulated and coherently combined. The same user information modulated by the appropriate base station code is sent from multiple base stations. Coherent combining of the different signals from different sectorized antennas, from different base stations, or from the same antenna but on different multiple path components is performed in the MS by the usage of Rake receivers. The signal transmitted by a mobile station is processed by base stations with which the mobile station is in soft handover. The received signal from different sectors of a base station (cell) can be combined in the base station, and the received signal from different base stations (cells) can be combined at the base station controller. Soft handover results in increased coverage range on the uplink. This soft handover mechanism results in seamless handover without any disruption of service. The spatial diversity obtained reduces the frame error rate in the handover regions and allows for improved performance in difficult radio environment.
td	A1.2.24.1	What is the break duration (sec) when a handover is executed? In this evaluation, a detailed description of the impact of the handover on the service performance should also be given. Explain how the estimate derived. **Answer:** Soft handover: No break duration (make before break) Hard handover: TBD
td	A1.2.24.2	For the proposed SRTT, can handover cope with rapid decrease in signal strength (e.g. street corner effect)? Give a detailed description of - the way the handover detected, initiated and executed, - how long each of this action lasts (minimum/maximum time in msec), - the timeout periods for these actions. **Answer:** The MS continuously searches for signal from new and existing BS. It also maintains two thresholds (e.g. pilot Ec/Io) based on current combined quality of the down link soft handover legs to add newly detected BS or to drop existing BS from its soft handover 'active' set. The need to add or drop is sent in a message to the system which determines whether to execute the addition and deletion. The time it takes to perform the above actions depends on the searcher and infrastructure speed. When compared to the initial cell access the procedure is much faster as only the base stations indicated in the neighbour set need to be searched and thus the search time is greatly reduced and thus dependent on the size of the base station set to be searched. There is no time out period when soft or softer handover is performed.
ti	A1.2.25	Characterize how does the proposed SRTT react to the system deployment in terms of the evolution of coverage and capacity (e.g. necessity to add new cells and/or new carriers): - in terms of frequency planning - in terms of the evolution of adaptive antenna technology using mobile identity codes (e.g. sufficient number of channel sounding codes in a TDMA type of system) - other relevant aspects **Answer:** No frequency planning needed. No limitation in number of codes, current set considered offers unique code for 512 different base stations on each frequency.

ti	A1.2.26	Sharing frequency band capabilities: To what degree is the proposal able to deal with spectrum sharing among UMTS systems as well as with all other systems: - spectrum sharing between operators **Answer:** Spectrum sharing possible through frequency division. - spectrum sharing between terrestrial and satellite UMTS systems **Answer:** Spectrum sharing possible through frequency division. - spectrum sharing between UMTS and non-UMTS systems **Answer:** Spectrum sharing possible through frequency division. - spectrum sharing between private and public UMTS operators **Answer:** Spectrum sharing possible through frequency division. - other sharing schemes **Answer:** For uncoordinated systems, frequency sharing is possible through code division within one frequence band with some limitations

ti	A1.2.27	Dynamic channel allocation: Characterize the DCA schemes which may be supported and characterize their impact on system performance (e.g. in terms of adaptability to varying interference conditions, adaptability to varying traffic conditions, capability to avoid frequency planning, impact on the reuse distance, etc.) **Answer:** DCA not needed
ti	A1.2.28	Mixed cell architecture: How well do the technologies accommodate mixed cell architectures (pico, micro and macrocells)? Does the proposal provide pico, micro and macro cell user service in a single licensed spectrum assignment, with handoff as required between them? (terrestrial component only) Note: Cell definitions are as follows: pico - cell hex radius (r) < 100 m micro - 100 m < (r) < 1000 m macro - (r) > 1000 m **Answer:** The SRTT can provide pico, micro, and macro cells in one common frequency band or in separate frequency bands. In the later case, a total of 2*15 MHz spectrum assignment is needed. In either case, seamless handover is possible between the cell layers.
ti	A1.2.29	Describe any battery saver / intermittent reception capability **Answer:** During circuit switched operation the transmitter is continuosly on. With packet traffic, depending on the packet-access mode, the reciever and transmitter can be used only periodically, i.e. being swiched off until data is available for transmission or the base station indicates the mobile station that is to be received. In the latter case, the polling is done according to A1.2.29.1
td	A1.2.29.1	Ability of the mobile station to conserve standby battery power: Please provide details about how the proposal conserve standby battery power. **Answer:** The mobile station uses slotted reception when it is not on a dedicated traffic channel. Most of the circuits are turned off during the slots in a cycle that not assigned to that mobile station. They are powered-on only in time to receive the assigned slot for any possible pages or messages.
td	A1.2.30	Signaling transmission scheme: If the proposed system will use radio transmission technologies for signaling transmission different from those for user data transmission, describe details of signaling transmission scheme over the radio interface between terminals and base (satellite) stations. **Answer:** The signalling scheme for the SRTT is basically the same as for user data. User data and signalling is time multiplexed on layer 1.

td	A1.2.30.1	Describe the different signaling transfer schemes which may be supported, e.g. in connection with a call, outside a call. Does the SRTT support new techniques? Characterize. Does the SRTT support signalling enhancements for the delivery of multimedia services? Characterize. **Answer:** The SRTT does not limit the use of any advanced techniques. The physical layer provides means for transmission rate signalling which can be used also to indicate which services are active and thus introduction of an associated control channel with service negotiation is supported by the SRTT.
ti	A1.2.31	Does the SRTT support a Bandwidth on Demand (BOD) capability? Bandwidth on Demand refers specifically to the ability of an end-user to request multi-bearer services. Typically this is given as the capacity in the form of bits per second of throughput. Multi bearer services can be implemented by using such technologies as multi carrier, multi time slot or multi codes. If so, characterize these capabilities. Note: BOD does not refer to the self-adaptive feature of the radio channel to cope with changes in the transmission quality (see A1.2.5.1). **Answer:** Bandwidth on demand is supported with a granularity of 100 bps in the range 100 bps to 2.048 Mbps channel rate. The bandwidth-on-demand possibility is implemented by multiplexing the multi-bearer traffic on a single L1 traffic stream to be carried by the variable rate DPDCH resource, which is for low and medium rates a variable spreading factor single code channel and for higher rates a combination of variable spreading factor and multi-code transmission.
ti	A1.2.32	Does the SRTT support channel aggregation capability to achieve higher user bit rates? **Answer:** Channel aggregation to achieve higher rates is normally not needed with the proposed SRTT, due to the variable-bit-rate properties of each physical channel (0-1024 kbps). Channel aggregation (multi-code transmission) is supported and used for the highest user rates (up to 2 Mbps).
	A1.3	Expected Performances
	A1.3.1	for terrestrial test environment only
ti	A1.3.1.1	What is the achievable BER floor level (for voice)? Note: BER floor level under BER measuring condition defined in Annex 2 using the data rates indicated in section 1 of Annex 2. **Answer:** Below BER = 10^{-3}
ti	A1.3.1.2	What is the achievable BER floor level (for data)? Note: BER floor level under BER measuring condition defined in Annex 2 using the data rates indicated in section 1 of Annex 2. **Answer:** Below BER = 10^{-6}

ti	A1.3.1.3	What is the maximum tolerable delay spread (in nsec) to maintain the voice and data service quality requirements? Note: The BER is an error floor level measured with the Doppler shift given in the BER measuring conditions of ANNEX 2. **Answer:** Receiver-implementation dependent. The SRTT concept allows for a maximum time dispersion of 62.5 µs, see also A1.2.14.1.

ti	A1.3.1.4	What is the maximum tolerable doppler shift (in Hz) to maintain the voice and data service quality requirements? Note: The BER is an error floor level measured with the delay spread given in the BER measuring conditions of ANNEX 2. **Answer:** More than 500 Hz.
ti	A1.3.1.5	Capacity : The capacity of the radio transmission technology has to be evaluated assuming the deployment models described in ANNEX 2 and technical parameters from A1.2.22 through A1.2.23.2.
ti	A1.3.1.5.1	What is the voice traffic capacity per cell (not per sector): Provide the total traffic that can be supported by a single cell in Erlangs/MHz/cell in a total available assigned non-contiguous bandwidth of 30 MHz (15 MHz forward/15 MHz reverse) for FDD mode or contiguous bandwidth of 30 MHz for TDD mode. Provide capacities considering the model for the test environment in ANNEX 2. The procedure to obtain this value in described in ANNEX 2. The capacity supported by not a standalone cell but a single cell within contiguous service area should be obtained here. **Answer:** See Simulation Results.
ti	A1.3.1.5.2	What is the information capacity per cell (not per sector): Provide the total number of user-channel information bits which can be supported by a single cell in Mbps/MHz/cell in a total available assigned non-contiguous bandwidth of 30 MHz (15 MHz forward / 15 MHz reverse) for FDD mode or contiguous bandwidth of 30 MHz for TDD mode. Provide capacities considering the model for the test environment in ANNEX 2. The procedure to obtain this value in described in ANNEX 2. The capacity supported by not a standalone cell but a single cell within contiguous service area should be obtained here. **Answer:** See Simulation Results.
ti	A1.3.1.6	Does the SRTT support sectorization? If yes, provide for each sectorization scheme and the total number of user-channel information bits which can be supported by a single site in Mbps/MHz (and the number of sectors) in a total available assigned non-contiguous bandwidth of 30 MHz (15 MHz forward/15 MHz reverse) in FDD mode or contiguous bandwidth of 30 MHz in TDD mode. **Answer:** See Simulation Results.
ti	A1.3.1.7	Coverage efficiency: The coverage efficiency of the radio transmission technology has to be evaluated assuming the deployment models described in ANNEX 2.
ti	A1.3.1.7.1	What is the base site coverage efficiency in km^2/site for the lowest traffic loading in the voice only deployment model? Lowest traffic loading means the lowest penetration case described in ANNEX 2. **Answer:** See Link Budget Template.
ti	A1.3.1.7.2	What is the base site coverage efficiency in km^2/site for the lowest traffic loading in the data only deployment model? Lowest traffic loading means the lowest penetration case described in ANNEX 2. **Answer:** See Link Budget Template.

ti	A1.3.3	Maximum user bit rate (for data): Specify the maximum user bit rate (kbps) available in the deployment models described in ANNEX 2. **Answer:** At least 2048 kbps for 4.096 Mcps. Higher chip rates (with 8.192 or 16.384 Mcps) give better efficiency.

ti	A1.3.4	What is the maximum range in meters between a user terminal and a base station (prior to hand-off, relay, etc.) under nominal traffic loading and link impairments as defined in Annex 2? **Answer:** See Link Budget Template.
ti	A1.3.5	Describe the capability for the use of repeaters **Answer:** Repeaters can be used.
ti	A1.3.6	Antenna Systems : Fully describe the antenna systems that can be used and/or have to be used; characterize their impacts on systems performance, (terrestrial only) e.g.: - Does the SRTT have the capability for the use of remote antennas: Describe whether and how remote antenna systems can be used to extend coverage to low traffic density areas. **Answer:** Remote antennas can be used. - Does the SRTT have the capability for the use of distributed antennas: Describe whether and how distributed antenna designs are used, and in which UMTS test environments. **Answer:** Distributed antennas can be used. - Does the SRTT have the capability for the use of smart antennas (e.g. switched beam, adaptive, etc.): Describe how smart antennas can be used and what is their impact on system performance. **Answer:** Adaptive antennas are supported through the use of connection dedicated pilot bits in both uplink and downlink. - Other antenna systems.
	A1.3.7	Delay (for voice)
ti	A1.3.7.1	What is the radio transmission processing delay due to the overall process of channel coding, bit interleaving, framing, etc., not including source coding? This is given as transmitter delay from the input of the channel coder to the antenna plus the receiver delay from the antenna to the output of the channel decoder. Provide this information for each service being provided. In addition, a detailed description of how this parameter was calculated is required for both the up-link and the down-link. **Answer:** Service specific delay (depends on interleaving/channel-coding setting). Minimum delay: 12 ms for 10 ms interleaving, 2 ms for if non-interleaved mode is applied. Processing time of 2 ms included.
ti	A1.3.7.2	What is the total estimated round trip delay in msec to include both the processing delay, propagation delay (terrestrial only) and vocoder delay? Give the estimated delay associated with each of the key attributes described in Figure 1 of Annex 3 that make up the total delay provided. **Answer:** 25 ms for 10 ms interleaving, not including vocoder delay.
ti	A1.3.9	Description on the ability to sustain quality under certain extreme conditions.

ti	A1.3.9.1	System overload (terrestrial only) : Characterize system behavior and performance in such conditions for each test services in Annex 2, including potential impact on adjacent cells. Describe the effect on system performance in terms of blocking grade of service for the cases that the load on a particular cell is 125%, 150%, 175%, and 200% of full load. Also describe the effect of blocking on the immediate adjacent cells. Voice service is to be considered here. Full load means a traffic loading which results in 1% call blocking with the BER of 10^{-3} maintained. **Answer:** Overload causes graceful degradation of system performance. The techniques commonly referred to as ‘cell breathing’ can also be applied. *I.e.,* when the loading of a cell in a system is overloaded, the up link interference is high and the effective range of MS is reduced due to power constraints. If the downlink power is reduced accordingly, then the MS on the border will be naturally handed over to the neighbouring cells, effectively reducing the coverage of the overloaded cell and decreasing its load without impacting the link performance.
ti	A1.3.9.2	Hardware failures: Characterize system behavior and performance in such conditions. Provide detailed explanation on any calculation. **Answer:** Implementation dependent.
ti	A1.3.9.3	Interference immunity: Characterize system immunity or protection mechanisms against interference. What is the interference detection method? What is the interference avoidance method? **Answer:** Interference is supressed by the processing gain. Multi-user detection and/or interference cancellation can be used but is not required.
ti	A1.3.10	Characterize the adaptability of the proposed SRTT to different and/or time varying conditions (e.g. propagation, traffic, etc.) that are not considered in the above attributes of the section A1.3. **Answer:** Adaptive transmit power is used.
	A1.4	Technology Design Constraints
ti	A1.4.1	Frequency stability : Provide transmission frequency stability (not oscillator stability) requirements of the carrier (include long term - 1 year - frequency stability requirements in ppm).
ti	A1.4.1.1	For Base station transmission (terrestrial component only) **Answer:** 0.02 ppm
ti	A1.4.1.2	For Mobile station transmission **Answer:** 3 ppm (unlocked), 0.1 ppm (locked)

ti	A1.4.2	Out of band and spurious emissions: Specify the expected levels of base or satellite and mobile transmitter emissions outside the operating channel, as a function of frequency offset. **Answer:** Multicode case (K=4, 512 kbps) frequency offset (MHz) 0 2.5 5 7.5 10 OBO=6dB 0 -30 -37 -50 -58 OBO=9dB 0 -36 -44 -56 -65 OBO=12dB 0 -37 -47 -61 -70 Single code case (K=1, 128 kbps) frequency offset (MHz) 0 2.5 5 7.5 10 OBO=6dB 0 -38 -43 -54 -60 OBO=9dB 0 -39 -44 -60 -66 OBO=12dB 0 -40 -46 -65 -70 All results for a W-CDMA signal of bandwidth 5 MHz (4.096 Mcps with 0.22 Roll-off factor) for an example mobile amplifier.
ti	A1.4.3	Synchronisation requirements: Describe SRTT's timing requirements , e.g. - Is base station-to-base station or satellite LES-to-LES synchronisation required? Provide precise information, the type of synchronisation, i.e., synchronisation of carrier frequency, bit clock, spreading code or frame, and their accuracy. **Answer:** FDD - not required, TDD - synchronisation within ±3μs required. - Is base station-to-network synchronisation required? (terrestrial only) **Answer:** Yes - State short-term frequency and timing accuracy of base station (or LES) transmit signal. **Answer:** Not specified - State source of external system reference and the accuracy required, if used at base station (orLES)(for example: derived from wireline network, or GPS receiver). **Answer:** FDD - not required, TDD - GPS receiver (example). - State free run accuracy of mobile station frequency and timing reference clock. **Answer:** 3 ppm - State base-to-base bit time alignment requirement over a 24 hour period, in microseconds. **Answer:** 10 ms when softhandover between base stations is supported - For private systems: can multiple unsynchronized systems coexist in the same environment? **Answer:** For TDD synchronisation is a requirement for the same environment
ti	A1.4.4	Timing jitter : For base (or LES) and mobile station give: - the maximum jitter on the transmit signal, - the maximum jitter tolerated on the received signal. Timing jitter is defined as RMS value of the time variance normalized by symbol duration. **Answer:** TBD

ti	A1.4.5	Frequency synthesizer : What is the required step size, switched speed and frequency range of the frequency synthesizer of mobile stations? **Answer:** Step size 200 kHz, switched speed TBD, frequency range 140 MHz for UMTS band.
td	A1.4.6.1	Describe the special requirements on the fixed networks for the handover procedure. Provide handover procedure to be employed in proposed SRTT in detail. **Answer:** No special requirements.

ti	A1.4.8	Characterize any radio resource control capabilities that exist for the provision of roaming between a private (e.g., closed user group) and a public UMTS operating environment. **Answer:** TBD
ti	A1.4.9	Describe the estimated fixed signaling overhead (e.g., broadcast control channel, power control messaging). Express this information as a percentage of the spectrum which is used for fixed signaling. Provide detailed explanation on your calculations. **Answer:** In downlink, system and cell specific information are broadcasted in broadcast control channel. Reference (pilot) symbols for coherent detection, power control commands, and rate information are provided in dedicated physical control channel (DPCCH). In uplink, DPCCH uses fixed 16 kbps Q-branch channel, while DPDCH uses variable rate I-branch channel. In downlink, DPCCH is time multiplexed with DPDCH, and its rate can be variable depending on the DPDCH rate. The signalling overhead of DPCCH in dedicated physical channel is ranging from 2.8% up to 25% in downlink, while 5.9% - 33% in uplink. See system description for more details.
ti	A1.4.10	Characterize the linear and broadband transmitter requirements for base and mobile station. (terrestrial only) **Answer:** SRTT requires linear amplifier. At the mobile AB class amplifier can be used. High Power Amplifier are required to be linear in a 5/10/20 MHz band. At OBO = 6dB, IM3 was 38dB and IM5 = 54 dB for the HPA amplifier in section A1.4.2.
ti	A1.4.11	Are linear receivers required? Characterize the linearity requirements for the receivers for base and mobile station. (terrestrial only) **Answer:** Base station: Linear reciever required Mobile station: Linearity requirements depend on the terminal capabilities.
ti	A1.4.12	Specify the required dynamic range of receiver. (terrestrial only) **Answer:** 80 dB for Automatic Gain Control, for AD-converter 4-6 bits sufficient for MS

ti	A1.4.13	What are the signal processing estimates for both the handportable and the base station? - MOPS (Mega Operation Per Second) value of parts processed by DSP - gate counts excluding DSP - ROM size requiements for DSP and gate counts in kByte - RAM size requirements for DSP and gate counts in kByte Note 1: At a minimum the evaluation should review the signal processing estimates (MOPS, memory requirements, gate counts) required for demodulation, equalization, channel coding, error correction, diversity processing (including RAKE receivers), adaptive antenna array processing, modulation, A-D and D-A converters and multiplexing as well as some IF and baseband filtering. For new technologies, there may be additional or alternative requirements (such as FFTs etc.). Note 2 : The signal processing estimates should be declared with the estimated condition such as assumed services, user bit rate and etc. **Answer:** Service Uplink (BS) Downlink (MS) 8 kbits/s 5 5 144 kbits/s 9 9 384 kbits/s 24 21 2048 kbits/s 86 83 Answer given in million real multiplications with DSP with correlators included in the values via method described in section 4 in this document. There the power consumption estimates are given as well. The convolutional encoding/decoding is not included in the figures as it is the same recardless of the multiple access for the same data rate(s).
ti	A1.4.15	Characterize the frequency planning requirements: - Frequency reuse pattern: given the required C/I and the proposed technologies, specify the frequency cell reuse pattern (e.g. 3-cell, 7-cell, etc.) and, for terrestrial systems, the sectorization schemes assumed; **Answer:** 1-cell reuse, 3 sectorization is used, thus not limited to only 3 sectors as having larger number of sectors is straingforward in the desing and does not require additional frequency considerations. - Characterize the frequency management between different cell layers; **Answer:** Frequency-separated cell layers - Does the SRTT use interleaved frequency allocation? **Answer:** Mainly No (1-cell reuse), but the adjacent carrier can be partly overlapping as the carrier spacing is restricted to the 200 kHz raster and thus on that raster carrier spacing from 4 to 5 MHz could be used. - Are there any frequency channels with particular planning requirements? **Answer:** No - Can the SRTT support self planning techniques? **Answer:** No frequency planning is needed with the proposed SRTT (1-cell reuse) - All other relevant requirements Note: Interleaved frequency allocation is to allocate the 2nd adjacent channel instead of adjacent channel at neighboring cluster cell.

ti	A1.4.16	Describe the capability of the proposed SRTT to facilitate the evolution of existing radio transmission technologies used in mobile telecommunication systems migrate toward this SRTT. Provide detail any impact and constraint on evolution. **Answer:** The detailed parameters of the SRTT have been chosen with the easy implementation of dual-mode UMTS/GSM.
ti	A1.4.16.1	Does the SRTT support backwards compatibility into GSM/DCS in terms of easy dual mode terminal implementation, spectrum co-existence and handover between UMTS and GSM/DCS? **Answer:** The detailed parameters of the SRTT, e.g. the the clock frequencies and carrier raster has been chosen to facilitate the easy implementation of dual-mode UMTS/GSM/DCS terminals. Handover between UMTS and GSM/DCS can be supported.

ti	A1.4.17	Are there any special requirements for base site implementation? Are there any features which simplify implementation of base sites? (terrestrial only) **Answer:** The base station configuration can be modular thus the number of user supported can be increased modularly if desired, similar to introducing new TX/RX units to a GSM base station with the difference being that RF hardware is not effected an only single R/TX per base station is required.
ti	A1.5	Information required for terrestrial link budget template: Proponents should fulfill the link budget template given in Table 1.3 of Annex 2 and answer the following questions.
ti	A1.5.1	What is the base station noise figure (dB)? **Answer:** See Link Budget Template.
ti	A1.5.2	What is the mobile station noise figure (dB)? **Answer:** See Link Budget Template.
ti	A1.5.3	What is the base station antenna gain (dBi)? **Answer:** See Link Budget Template.
ti	A1.5.4	What is the mobile station antenna gain (dBi)? **Answer:** See Link Budget Template.
ti	A1.5.5	What is the cable, connector and combiner losses (dB)? **Answer:** See Link Budget Template.
ti	A1.5.5	What are the number of traffic channels per RF carrier? **Answer:** Variable (depends on the rate of each traffic channel).
ti	A1.5.6	What is the SRTT operating point (BER/FER) for the required E_b/N_0 in the link budget template? **Answer:** For speech and LCD BER = 10^{-3}, for UDD BLER = 10%

ti	A1.5.7	What is the ratio of intra-sector interference to sum of intra-sector interference and inter-sector interference within a cell (dB)? **Answer:** Depends on the environment.
ti	A1.5.8	What is the ratio of in-cell interference to total interference (dB)? **Answer:** Depends on the environment
ti	A1.5.9	What is the occupied bandwidth (99%) (Hz)? **Answer:** 5 MHz
ti	A1.5.10	What is the information rate (dBHz)? **Answer:** Service dependent.

3 Link Budget Calculation

In the following pages a link budget is presented for the simulated test cases. The link budgets follows the link budget template in Annex 2 in ETR 0402, and also presents some range calculations using concept optimized parameters.

3.1 Basic Assumptions

Since it is the average transmitter power per traffic channel that is specified in ETR 0402, power control is included in the link-level simulations to find the coverage. However, this means that the transmitted power can be increased due to the power control, and this is compensated for in the row "Power control TX power increase". Also, the highest mobile TX power used is 24 dBm, which gives some margin to 30 dBm. This means that building an amplifier that can cope with the power peaks should be feasible.
The TX power increase is dependent on the environment and service. For speech and LCD soft handoff is assumed, while UDD uses no soft handoff. The values used are presented in Table 1.

Environment	Speech & LCD Uplink [dB]	Speech & LCD Downlink [dB]	UDD Uplink [dB]	UDD Downlink [dB]
Indoor office	0	2	2	4
Outdoor to indoor and pedestrian	0	2	2	4.5
Vehicular	0	0	0	0

Table 1. TX power increase in different environments.

The handoff gain and log-normal fade margin were calculated for 95% area coverage with a shadowing correlation of 50%. Values can be found in Table 2.

Environment	σ [dB]	α	Log-normal fade margin [dB]	Handoff gain (soft handoff) [dB]	Handoff gain (hard handoff) [dB]
Indoor office	12	3.0	15.4	6.1	5.9
Outdoor to indoor and pedestrian	10	4.0	11.3	5.0	4.7
Vehicular	10	3.76	11.3	5.0	4.7

Table 2. Log-normal fade margins and handoff gains.

Please note that the total TX EIRP is not computed. Also, the coverage analysis is done for an unloaded system. This means that the RX interference density is zero (set to -1000 dBm/Hz in the tables).

All link-budgets presented assume no antenna diversity in the downlink. If antenna diversity is assumed the maximum path loss in the downlink will increase by around 3 dB.

3.2 Concept Optimized Parameters

An alternative link budget is presented below the link budget according to ETR 0402, in which the antenna gains and TX powers are modified to more reasonable values.

The specified three sector antenna in the Vehicular environment has a gain of only 13 dBi, which is rather low. A more reasonable value of 17 dBi has been used. The mobile antenna gain is specified as 0 dBi for all services and environments. It is expected that a mobile station handling the high bit rates will not be used next to the ear. This is taken into account by increasing the gain to 2 dBi.
The average TX powers specified in ETR 0402 are quite low, especially for high bit rate services. Higher values are proposed (DL/UL): Indoor office A 13/10 dBm, Outdoor to indoor and pedestrian A 23/20, Vehicular A 30/24 dBm.

3.3 Link Budget Templates

		Downlink	Uplink	Downlink	Uplink	Downlink	Uplink
Test environment		Indoor	Indoor	Pedestr.	Pedestr.	Vehicular	Vehicular
Multipath channel class		A	A	A	A	A	A
Test service		Speech	Speech	Speech	Speech	Speech	Speech
Note		20 ms int	20 ms int	20 ms int	20 ms int	20 ms int	20 ms int
Bit rate	bit/s	8000	8000	8000	8000	8000	8000
Average TX power per traffic ch.	dBm	10	4	20	14	30	24
Maximum TX power per traffic ch.	dBm	10	4	20	14	30	24
Maximum total TX power	dBm	10	4	20	14	30	24
Cable, conn. and combiner losses	dB	2	0	2	0	2	0
TX antenna gain	dBi	2	0	10	0	13	0
TX EIRP per traffic channel	dBm	10	4	28	14	41	24
Total TX EIRP	dBm	10	4	28	14	41	24
RX antenna gain	dBi	0	2	0	10	0	13
Cable and connector losses	dB	0	2	0	2	0	2
Receiver noise figure	dB	5	5	5	5	5	5
Thermal noise density	dBm/Hz	-174	-174	-174	-174	-174	-174
RX interference density	dBm/Hz	-1000	-1000	-1000	-1000	-1000	-1000
Total effect. noise + interf. density	dBm/Hz	-169	-169	-169	-169	-169	-169
Information rate	dBHz	39.0	39.0	39.0	39.0	39.0	39.0
Required Eb/(No+Io)	dB	6.4	3.1	6.7	3.3	7.6	5.0
RX sensitivity	dB	-123.6	-126.9	-123.3	-126.7	-122.4	-125.0
Power control TX power increase	dB	2.0	0.0	2.0	0.0	0.0	0.0
Handoff gain	dB	6.1	6.1	5.0	5.0	5.0	5.0
Explicit diversity gain	dB	0	0	0	0	0	0
Other gain	dB	0	0	0	0	0	0
Log-normal fade margin	dB	15.4	15.4	11.3	11.3	11.3	11.3
Maximum path loss	dB	122.3	121.6	143.0	142.4	157.1	153.7
Maximum range	m	695.5	659.1	747.3	721.9	5894.6	4786.6
Coverage efficiency	km^2/site	1.5	1.4	1.8	1.6	22.6	14.9
Concept optimized parameters							
Maximum TX power per traffic ch.	dBm	13	10	23	20	30	24
TX antenna gain	dBi	2	0	10	0	17	0
RX antenna gain	dBi	0	2	0	10	0	17
Maximum path loss	dB	125.3	127.6	146.0	148.4	161.1	157.7
Maximum range	m	875.6	1044.6	888.1	1019.7	7530.7	6115.2
Coverage efficiency	km^2/site	2.4	3.4	2.5	3.3	36.8	24.3

		Downlink	Uplink	Downlink	Uplink
Test environment		Vehicular	Vehicular	Vehicular	Vehicular
Multipath channel class		B	B	B	B
Mobile speed		120 km/h	120 km/h	250 km/h	250 km/h
Test service		Speech	Speech	Speech	Speech
Note		20 ms int	20 ms int	20 ms int	20 ms int
Bit rate	bit/s	8000	8000	8000	8000
Average TX power per traffic ch.	dBm	30	24	30	24
Maximum TX power per traffic ch.	dBm	30	24	30	24
Maximum total TX power	dBm	30	24	30	24
Cable, conn. and combiner losses	dB	2	0	2	0
TX antenna gain	dBi	13	0	13	0
TX EIRP per traffic channel	dBm	41	24	41	24
Total TX EIRP	dBm	41	24	41	24
RX antenna gain	dBi	0	13	0	13
Cable and connector losses	dB	0	2	0	2
Receiver noise figure	dB	5	5	5	5
Thermal noise density	dBm/Hz	-174	-174	-174	-174
RX interference density	dBm/Hz	-1000	-1000	-1000	-1000
Total effect. noise + interf. density	dBm/Hz	-169	-169	-169	-169
Information rate	dBHz	39.0	39.0	39.0	39.0
Required Eb/(No+Io)	dB	7.7	4.9	8.2	6.0
RX sensitivity	dB	-122.3	-125.1	-121.8	-124.0
Power control TX power increase	dB	0.0	0.0	0.0	0.0
Handoff gain	dB	5.0	5.0	5.0	5.0
Explicit diversity gain	dB	0	0	0	0
Other gain	dB	0	0	0	0
Log-normal fade margin	dB	11.3	11.3	11.3	11.3
Maximum path loss	dB	157.0	153.8	156.5	152.7
Maximum range	m	5858.6	4816.0	5681.9	4502.3
Coverage efficiency	km^2/site	22.3	15.1	21.0	13.2
Concept optimized parameters					
Maximum TX power per traffic ch.	dBm	30	24	30	24
TX antenna gain	dBi	17	0	17	0
RX antenna gain	dBi	0	17	0	17
Maximum path loss	dB	161.0	157.8	160.5	156.7
Maximum range	m	7484.8	6152.8	7259.1	5752.0
Coverage efficiency	km^2/site	36.4	24.6	34.2	21.5

		Downlink	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink	Uplink
Test environment		Indoor	Indoor	Indoor	Indoor	Pedestr.	Pedestr.	Vehicular	Vehicular
Multipath channel class		A	A	A	A	A	A	A	A
Test service		LCD 384	LCD 384	LCD 2048	LCD 2048	LCD 144	LCD 144	LCD 384	LCD 384
Note									
Bit rate	bit/s	384000	384000	2048000	2048000	144000	144000	384000	384000
Average TX power per traffic ch.	dBm	10	4	10	4	20	14	30	24
Maximum TX power per traffic ch.	dBm	10	4	10	4	20	14	30	24
Maximum total TX power	dBm	10	4	10	4	20	14	30	24
Cable, conn. and combiner losses	dB	2	0	2	0	2	0	2	0
TX antenna gain	dBi	2	0	2	0	10	0	13	0
TX EIRP per traffic channel	dBm	10	4	10	4	28	14	41	24
Total TX EIRP	dBm	10	4	10	4	28	14	41	24
RX antenna gain	dBi	0	2	0	2	0	10	0	13
Cable and connector losses	dB	0	2	0	2	0	2	0	2
Receiver noise figure	dB	5	5	5	5	5	5	5	5
Thermal noise density	dBm/Hz	-174	-174	-174	-174	-174	-174	-174	-174
RX interference density	dBm/Hz	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000
Total effect. noise + interf. density	dBm/Hz	-169	-169	-169	-169	-169	-169	-169	-169
Information rate	dBHz	55.8	55.8	63.1	63.1	51.6	51.6	55.8	55.8
Required Eb/(No+Io)	dB	5.1	2.1	6.0	3.0	4.3	1.3	5.6	3.1
RX sensitivity	dB	-108.1	-111.1	-99.9	-102.9	-113.1	-116.1	-107.6	-110.1
Power control TX power increase	dB	2.0	0.0	2.0	0.0	2.0	0.0	0.0	0.0
Handoff gain	dB	6.1	6.1	6.1	6.1	5.0	5.0	5.0	5.0
Explicit diversity gain	dB	0	0	0	0	0	0	0	0
Other gain	dB	0	0	0	0	0	0	0	0
Log-normal fade margin	dB	15.4	15.4	15.4	15.4	11.3	11.3	11.3	11.3
Maximum path loss	dB	106.8	105.8	98.6	97.6	132.8	131.8	142.3	138.8
Maximum range	m	211.5	195.8	113.0	104.6	416.5	393.2	2379.6	1920.5
Coverage efficiency	km^2/site	0.1	0.1	0.0	0.0	0.5	0.5	3.7	2.4

(continued)

(concluded)

		Downlink	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink	Uplink
Test environment		Indoor	Indoor	Indoor	Indoor	Pedestr	Pedestr	Vehicular	Vehicular
Multipath channel class		A	A	A	A	A	A	A	A
Test service		LCD 384	LCD 384	LCD 2048	LCD 2048	LCD 144	LCD 144	LCD 384	LCD 384
Note									
Concept optimized parameters									
Maximum TX power per traffic ch.	dBm	13	10	13	10	23	20	30	24
TX antenna gain	dBi	2	2	2	2	10	2	17	2
RX antenna gain	dBi	2	2	2	2	2	10	2	17
Maximum path loss	dB	111.8	113.8	103.6	105.6	137.8	139.8	148.3	144.8
Maximum range	m	310.4	361.9	165.8	193.3	555.5	623.2	3436.2	2773.3
Coverage efficiency	km^2/site	0.3	0.4	0.1	0.1	1.0	1.2	7.7	5.0

		Downlink	Uplink	Downlink	Uplink
Test environment		Indoor	Indoor	Indoor	Indoor
Multipath channel class		A	A	A	A
Test service		UDD 384	UDD 384	UDD 2048	UDD 2048
Note					
Bit rate	bit/s	240000	240000	480000	480000
Average TX power per traffic ch.	dBm	10	4	10	4
Maximum TX power per traffic ch.	dBm	10	4	10	4
Maximum total TX power	dBm	10	4	10	4
Cable, conn. and combiner losses	dB	2	0	2	0
TX antenna gain	dBi	2	0	2	0
TX EIRP per traffic channel	dBm	10	4	10	4
Total TX EIRP	dBm	10	4	10	4
RX antenna gain	dBi	0	2	0	2
Cable and connector losses	dB	0	2	0	2
Receiver noise figure	dB	5	5	5	5
Thermal noise density	dBm/Hz	-174	-174	-174	-174
RX interference density	dBm/Hz	-1000	-1000	-1000	-1000
Total effect. noise + interf. density	dBm/Hz	-169	-169	-169	-169
Information rate	dBHz	53.8	53.8	56.8	56.8
Required Eb/(No+Io)	dB	2.8	0.2	2.8	0.2
RX sensitivity	dB	-112.4	-115.0	-109.4	-112.0
Power control TX power increase	dB	4.0	2.0	4.0	2.0
Handoff gain	dB	5.9	5.9	5.9	5.9
Explicit diversity gain	dB	0	0	0	0
Other gain	dB	0	0	0	0
Log-normal fade margin	dB	15.4	15.4	15.4	15.4
Maximum path loss	dB	108.9	107.5	105.9	104.5
Maximum range	m	249.2	223.8	197.8	177.7
Coverage efficiency	km^2/site	0.20	0.16	0.12	0.10
Concept optimized parameters					
Maximum TX power per traffic ch.	dBm	13	10	13	10
TX antenna gain	dBi	2	2	2	2
RX antenna gain	dBi	2	2	2	2
Maximum path loss	dB	113.9	115.5	110.9	112.5
Maximum range	m	365.8	413.6	290.3	328.3
Coverage efficiency	km^2/site	0.42	0.54	0.26	0.34

		Downlink	Uplink	Downlink	Uplink	Downlink	Uplink
Test environment		Pedestr.	Pedestr.	Pedestr.	Pedestr.	Vehicular	Vehicular
Multipath channel class		A	A	A	A	A	A
Test service		UDD 384	UDD 384	UDD 2048	UDD 2048	UDD 144	UDD 144
Note							
Bit rate	bit/s	240000	240000	480000	480000	240000	240000
Average TX power per traffic ch.	dBm	20	14	20	14	30	24
Maximum TX power per traffic ch.	dBm	20	14	20	14	30	24
Maximum total TX power	dBm	20	14	20	14	30	24
Cable, conn. and combiner losses	dB	2	0	2	0	2	0
TX antenna gain	dBi	10	0	10	0	13	0
TX EIRP per traffic channel	dBm	28	14	28	14	41	24
Total TX EIRP	dBm	28	14	28	14	41	24
RX antenna gain	dBi	0	10	0	10	0	13
Cable and connector losses	dB	0	2	0	2	0	2
Receiver noise figure	dB	5	5	5	5	5	5
Thermal noise density	dBm/Hz	-174	-174	-174	-174	-174	-174
RX interference density	dBm/Hz	-1000	-1000	-1000	-1000	-1000	-1000
Total effect. noise + interf. density	dBm/Hz	-169	-169	-169	-169	-169	-169
Information rate	dBHz	53.8	53.8	56.8	56.8	53.8	53.8
Required Eb/(No+Io)	dB	3.2	0.2	3.2	0.2	4.2	1.9
RX sensitivity	dB	-112.0	-115.0	-109.0	-112.0	-111.0	-113.3
Power control TX power increase	dB	4.5	2.0	4.5	2.0	0.0	0.0
Handoff gain	dB	4.7	4.7	4.7	4.7	4.7	4.7
Explicit diversity gain	dB	0	0	0	0	0	0
Other gain	dB	0	0	0	0	0	0
Log-normal fade margin	dB	11.3	11.3	11.3	11.3	11.3	11.3
Maximum path loss	dB	128.9	128.4	125.9	125.4	145.4	141.7
Maximum range	m	332.4	323.0	279.5	271.6	2884.4	2299.6
Coverage efficiency	km^2/site	0.35	0.33	0.25	0.23	5.40	3.43
Concept optimized parameters							
Maximum TX power per traffic ch.	dBm	23	20	23	20	30	24
TX antenna gain	dBi	10	2	10	2	17	2
RX antenna gain	dBi	2	10	2	10	2	17
Maximum path loss	dB	133.9	136.4	130.9	133.4	151.4	147.7
Maximum range	m	443.3	511.9	372.8	430.5	4165.1	3320.6
Coverage efficiency	km^2/site	0.62	0.82	0.44	0.58	11.27	7.16

4 Complexity and dual mode GSM/UMTS terminal complexity analysis

This contains analysis of the terminal and base station receiver implementation complexity and of GSM/UMTS dual mode terminal implementation. In the next sections, first the implementation complexity criteria and methodology are presented. Then, detailed transceiver configurations for each service option are presented.

4.1 Implementation complexity criteria

In the complexity analysis following criteria were used:

- baseband complexity
- RF complexity
- modularity

In baseband complexity analysis the main emphasis was in the computational complexity of the receiver algorithm since it is the most complex baseband part of the receiver. In the RF complexity analysis power amplifier linearity, A/D and D/A converter requirements and the number of filters and mixers were considered. The modularity analysis concentrated to study the increase of complexity as a function of the bit rate increase.

Complexity of discrete RF component was considered more significant than complexity of baseband due to faster development of baseband technology like decrease of ASIC power consumption and increase of ASIC integration density. Also with W-CDMA one should note that the performance critical parts can be done with ASIC and do not need to be done with software thus more efficient implementation in terms of power consumption compared to implementing the similar functions with general purpose DSP. An example purpose of this is the correlators, which require only one bit multiplications and are therefore very well suited for ASIC implementation with low gate count per multiplier.

4.2 GSM/UMTS dual mode terminal implementation[1]

Starting point was the assumption that in the beginning UMTS will not provide wide area coverage. Therefore, service coverage has to be ensured by use of dual mode terminal with existing second generation systems. Since GSM will be the major 2nd generation digital technology world-wide at the time of UMTS deployment, only GSM/UMTS dual mode terminal implementation was investigated. There are four different scenarios that can be considered

- GSM and UMTS are separate systems and mode of operation will be selected when the mobile is switched on or a call initiated. It is not possible to change the mode during a call.
- handover from UMTS to GSM during a call is possible
- handover from UMTS to GSM and vice versa is possible
- handover only from GSM to UMTS possible but this is not considered as interesting option and is not investigated further.

In the first option additional complexity from the hardware point of view comes mainly from the GSM receiver implementation, i.e. receiver has to be able to filter out the 200 kHz signal and to demodulate it with the MLSE receiver. Frequency hopping has to be also possible. However, in this mode power consumption of the original scheme is not increased that much since GSM and UMTS do not operate at the same time.

[1] Also triple mode GSM/DCS/UMTS terminal implementations are possible. However, since addition of the DCS mode into a UMTS terminal after GSM mode has been introduced would mean same extra complexity for all modes it is not included into analysis.

In the second option complexity increase depends on the desired level of handover. First alternative is to make a “blind” handover when the UMTS terminal does not need to measure the GSM BCCH channel. Second possibility is to have more seamless handover which means that the UMTS terminal has to have capabilities to measure GSM BCCH frequency during the UMTS call. This option is studied in here without the use of slotted mode for interfrequency UMTS or GSM measurements.

In the third option in addition to changes of second option GSM standard needs to be modified to include interworking with UMTS i.e. the new GSM terminals have to have capabilities to make handover from GSM to UMTS. Depending on the desired level of compatibility dual mode terminal can measure UMTS BCCH in the GSM mode or they can make a blind handover into UMTS carrier. In this scenario a change into GSM specification would be required so that new GSM terminal could measure the UMTS BCCH, which most likely differs from the GSM BCCH.

In the following the first and the second option are analyzed further since they are the most relevant ones.

In all scenarios for dual mode GSM/UMTS another duplexer and another RF filter are required for dual mode operation. (Which should be a valid statement for all UMTS schemes)

4.3 Study Methodology

The receiver complexity was analyzed by detailed break down of receiver structures. In baseband complexity analysis the main emphasis was in the computational complexity of the receiver algorithm. The complexity of each block in the baseband was analyzed separately by determining the number of real multiplications or instructions needed to perform the operation. The total number of instructions needed was calculated from this break down analysis. The power consumption and complexity were determined by the needed computational power. The support for GSM option in baseband was studied according to the baseband break down analysis.

As part of functions, at least correlators, will be done with ASIC, to achieve a single complexity figure in MIPS, methology for “normalised” MIPS calculations from the ASIC implementable parts is presented. The reason why correlators are very suitable for handware implementation is the 1 bit multiplication which is sufficient to be used in the correlators with the proposed Wideband CDMA concept from the alpha group.

The complexity analysis of RF parts was based on the following criteria: requirements of power amplifier linearity, requirements of A/D converter and the number of synthesisers, mixers and IF filters needed. The complexities of these criteria in each scheme were assessed.

4.3.1 General transceiver configuration

General transceiver configuration can be seen in Figure 4.1. The approach is a traditional CDMA transceiver where in the uplink the narrowband signal is spread, pulse shaped, and digital-analog converted for the direct up-sampling. On the receiver side harmonic downsampling is utilised after which the signal is converted to digital format. Dynamic range is decreased compared to TDMA systems due to spreading procedure. Fast power control also relaxes the dynamic range because of lower fading marginal. Still some non-linearities are likely to be accepted which are overcome by the robust nature of the DS-SS signal.

4.3.1.1 Transmitter

The transmitter structure does not need to buffer the outgoing data. Decrease can be mainly seen in the amount of required memory, while the high chip rate pulse shaping requires extra effort from the digital filters (could be perhaps done in an analog way). Depending on the chip rate, and oversampling ratio the DAC cost / power consumption is increased.

Interestingly the complexity is constant with respect to the data rate. This is because the effect of decreasing the spreading ratio can only be seen as increased PA power level while the digital signal dynamics stays the same. Still the memory requirements for the data path are low (no timeslot buffering).

4.3.1.2 Receiver

The receiver is a typical Rake type CDMA receiver utilising coherent reception in both channel impulse response estimation, and code tracking procedures. Basically each code channel to be despread needs two real correlators per path in case of BPSK channel and four in case of QPSK channels. Delay estimation is committed inside the possible channel delay spread, and sampling rate parameters are to be defined for this action. On the RF side lower dynamic range for the ADC is allowed due to spread spectrum nature of the signal. Generally, some 4-6 bits/chip is enough. 6 bits has been assumed in the analysis based on the following comment:

4.3.1.3 The ADC wordlength

Is likely to be affected by the following items:

a) higher chip rate than in IS-95 and therefore higher sampling rate.

b) different BER requirements for different services and hence different spectrum densities before spreading. In other words, the difference in power levels between users can be larger than the difference in data rates even if we completely ignore fades, inaccuracies of power control, etc.

c) linearity of ADC

Consider 8 kbps speech transmission, and a 4 bit ADC in the downlink (or uplink) receiver. For a 5 MHz bandwidth, the simulation results from FRAMES indicate that the system is capable of supporting about 100 users per carrier per cell. Assume that total power of interfering signals from the other cells adds 40% to the composite power at the receiver input. Also assume ideal power control, and therefore no level variations around the nominal level at the ADC input, which is of course more than optimistic.

In the receiver, the AGC puts the composite signal, ie. its standard deviation, at 6 dB (ie. 1bit) below the max quantization level. 8 kbps signal is approx[10*log(100)+10*log 1.4]=21.4 dB below the composite, which corresponds to approx 3.5 bits, and therefore 4.5 bits below the peak quantization level and 0.5 bit below the lowest quantization level. This is not an impossible mode of operation in presence of thermal noise and noise-like interference. Quantization noise is not likely to be an issue - we are only interested in its power within the bandwidth, which equals data rate, and it will worst affect 2 Mbps signals, the actual impact depending on the oversampling ratio . However, as pointed out above, we may hit a problem with ADC linearity.

The dynamic range will be obviously bigger (by 10*log4=6 dB, ie 1 bit) in a 20 Mhz bandwidth. It can be concluded that minimum 5 or 6 bits of wordlengh will be required for the ADC, and an additional increase will be necessary to allow for imperfect power control.

4.3.1.4 Transmit/receiver filtering

One aspect to remember is the required filtering for the receive and transmit filters. With purely DSP based solutions effort is naturally needed due high symbol rates. In the current concept the roll-off is specified to be 0.22. This is kind of roll-off value that makes in possible to make the filtering with analog components, at least partly, thus greatly reducing power consumption and not contributing to the MIPS figures. More thighter roll-off requires to fully digital implementation.This is inherently different from the solutions like in IS-95 where it is obvious that analog components can not be used due different requirements in the filter transition band.

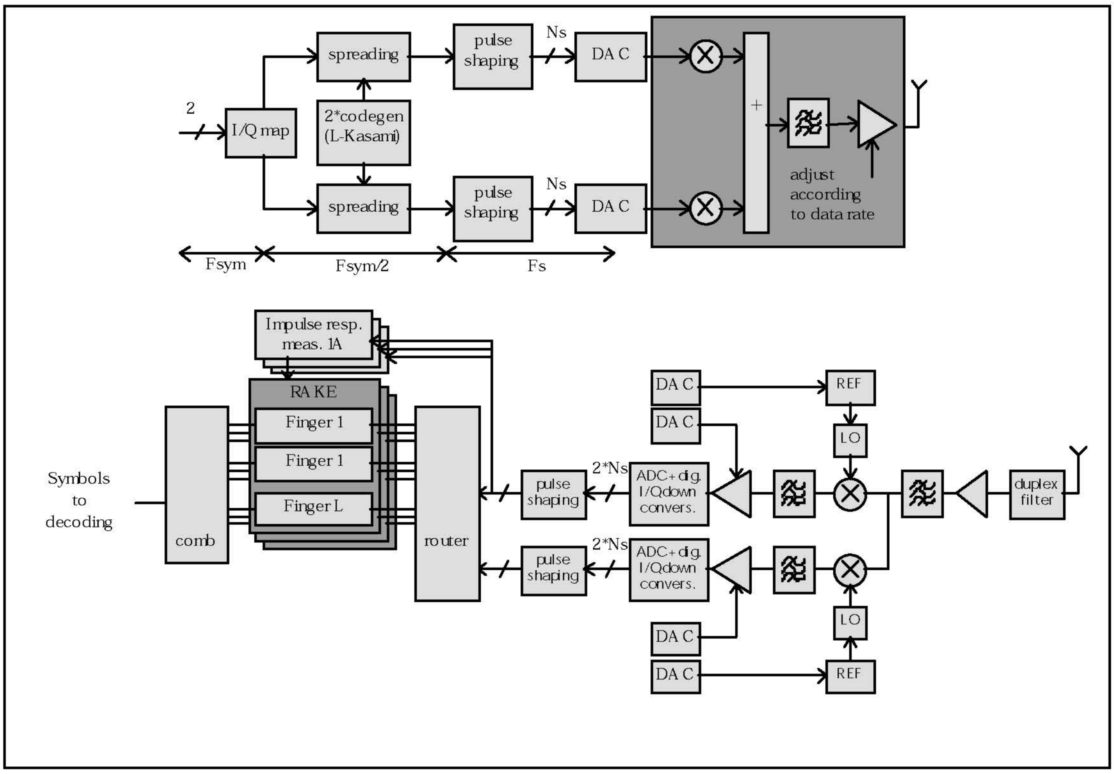

Figure 4.1. WCDMA General transceiver block diagram with dual receiver functionality.

In Table 4.1 are shown the formulas and parameters for calculating the baseband complexity of the W-CDMA mobile receiver. One sample per chip is assumed. In the calculations DLL (delay locked loop) is assumed to be incoherent. For the ones familiar with the analysis for FRAMES FMA2 do note that pilot symbols are now in the data stream and thus no separate correlators are needed for channel estimation from the pilot channel in the downlink direction. In the uplink as well the pilots symbols are in the data stream and thus no extra hardware is needed for the transmission at the mobile or for the reception at the base station.

Table 4.1. Formulas for calculating the baseband complexity of W-CDMA mobile receiver

Operation	Number of real multiplications needed	Parameter values
Correlators + code tracking	Fchip*2*Nchannel*L/15.0, Fchip=chip rate Nchannel=number of code channels L=number of Rake fingers The division by 15.0 is to take into account the low word length requirement of the correlator. The following reasoning has been used: • 16-bit MAC = 16*16+32+32=320 primitive operations • multiply by 1 bit and add to 6-bit number=6*1+6+10=22 ref. units The word length factor=320/22≈15	Fchip=4.096 Mchip/s Nchannel: Downlink/Uplink 8 kbit/s: 2/1+1 144 kbit/s: 2/1+1 384 kbit/s: 2/1+1 2048 kbit/s: 4/8+1 (**BPSK** channels) L=4 For uplink the constant rate PCCH icluded with 16 kbits/s and spreading ratio 256. 1*QPSK = 2*BPSK channels
Delay estimation	2*Lsearch*Rirsampling*Nchannel Lsearch=search window of delay taps in chips Rirsampling=rate of estimating impulse response Nchannel=Number of channels to follow for delay estimation	Lsearch=100 corresponding to delay spread of 20 µs Rirsampling=100 Hz Nchannel=2

		(can be 1 as well depending on the implementation)
Rake combining	4*Rsymbol*L*Nchannel, Rsymbol=symbol rate L=number of Rake fingers Nchannel=number of **QPSK** code channels, see correlator section and note 2 BPKS = 1 QPSK 16 kbits/s BPSK PCCH in the uplink	Rsymbol=Downlink/Uplink (kbits/s per channell) 8 kbit/s: 32/16+16 (PCCH) 144 kbit/s: 512/256+16 384 kbit/s: 1024/512+16 2048 kbit/s: 1024/512+16

Notes: In the analysis 4.096 Mcps/s assumed for all services, however the use of 8.192 Mcps/s or higher chip rate is not expected to changes the results significantly as for using the higher chip rate for higher rate services will naturally increase the parameter Fchip but the parameter Nchannel will be reduced respectively if the spreading ratio is kept constant and then the number of parallel code channels is reduced.

4.3.1.5 Transceiver RF architecture candidates analysis

The wideband nature of the system suggests that the receiver should filter out as much adjacent channel interference as possible on the analog side. This would make it possible to use lower sampling frequencies for the ADC.

Aspects that should be taken into account on the TX side are:

- Faster power control needed than in non-DS-SS approaches (assumed not to affect very much the total cost/power consumption)

Aspects that should be taken into account on the RX side are:

- Lower dynamic range than in slotted transmision due to spreading (hard limiting possible in case of DS-SS without affecting the performance too much)
- Expected to be more robust against non-linearities (compression etc.)
- Two IF sections are needed for inter-frequency handover for higher bit rates terminal when slotted mode is not used

4.3.2 Service classes

All the specified services can be supported using a single carrier. The following summarises the modes for the specified service classes. Note that some services are defined slightly different from the simulated ones, but regardless of the small differences the complexity estimates are valid with reasonable accuracy.

4.3.2.1 Downlink services

8 kbits/s, for rate 1/3 rate coding 24 kbits/s which in the analysis corresponds to a QPSK transmission with spreading ratio of 256 providing 32 kbits/s with well enough room to include all the overhead due pilot symbols and power control commands.

144 kbits/s, for rate 1/3 coding 432 kbits/s, resulting to a single QPSK channel with spreading ratio 16 having gross data rate of 512 kbits/s. Alternatively 1/2 rate coding with 288 kbits/s could use spreading ratio 32 with some puncturing.

384 kbits/s, for rate 1/2 coding with 768 kbits/s single QPSK channel with spreading ratio 8 and gross bit rate 1024 kbits/s. Alternatively 1/3 rate coding will fit to the same spreading ratio with approximately 12% of puncturing.

2048 kbits/s, for rate 1/2 coding four QPSK channels are needed with spreading ratio of 8 resulting to 4096 kbits/s gross data rate. Alhtough this is calculated for 4.096 Mchips/s one should note that the complexity is the same for the 8.192 Mchips/s and also for higher bit rates as the number of channels decreases as the chip rate increases and the number of calculations is about the same.

In the downlink the pilot overhead is now time multiplexed in the data stream taking 2 out of 16 symbols in a 0.625 ms slot with spreading ratio 256. For higher rates the overhead percentage reduces naturally respectively.

4.3.2.2 Uplink services

The difference between uplink and downlink multiplexing results to somewhat different service implementations

8 kbits/s, 1/2 rate coding resulting to 16 kbits/s on a single code channel with spreading ratio 256.
144 kbits/s, 1/2 rate coding resulting to 288 kbits/s on a single code channel with spreading ratio 16 with slight puncturing
384 kbits/s, 1/2 rate coding resulting to 768 kbits/s on two code channels with spreading ratio 8. Note that simulated slightly differently with a single code channel with spreading ratio 4.
2048 kbits/s, 1/2 rate coding resulting to 2048 kbits/s provided with spreading ratio 4 and four paraller code channels. (BPSK channels, two per branch with the effecttive total processing gain around 2). The complexity will be calculated for the case with processing gain of 8 and eight paraller channels and this result is valid for the higher chip rates as well, see the calculation principles for more details.

In the uplink the overhead due pilot symbos, power control and rate information is in the 16 kbits/s fixed rate control channel.This is included and should be noted in any comparison to other access schemes based on these figures if similar signalling is not included.

4.3.3 Support for GSM option

In order to implement a dual-receiver the following aspects need to be taken into account:
Baseband section:

- Transmission buffer more on the TX side
- MLSE block on the RX side

RF section:

- On the TX side possibly a more expensive PA in case of low-end UMTS terminal
- RX side with 200kHz IF filter + higher dynamic range ADC (maybe another ADC with low Fs)
- Second duplexer, and RX RF filter

  Since the signal is continuous WCDMA needs dual receiver for GSM monitoring. If there is already the dual receiver due to interfrequency handover there is no additional changes.

This analysis is valid when no slotted mode is used, with the slotted mode the situation is similar than with the TDMA based concepts. The slotted mode is expected to be interesting alternative for low cost terminals, but for the high capability UMTS terminals the relative part of the GSM radio modem part is expected to that low that the way how dual mode feature for GSM is intoduced does not make a real difference to the and cost of an UMTS terminal product.

4.3.4 Baseband power consumption

A complexity comparison of baseband parts for different (circuit switched) services is calculated in the table below and given as "normalised" real multiplications per second/10^6 for DSP implementation with the correaltor complexity derived from ASIC implementation.

Table 4.2. Baseband complexity of the receivers (at BS average per user). [real multiplications per second/10^6]

kbit/s	Uplink (BS RAKE-receiver)	Downlink (MS RAKE-receiver)
8	5	5
144	9	9
384	24	21
2048	86	83

Notes on software / hardware implementation

The baseband complexity is calculated in real multiplications per second which does not reflect the different word length requirements of different receiver algorithms. If hardware implementation is used, those schemes that have low word length requirements are more favourable as is exatcly the case with W-CDMA.

Power consumption estimate in [mW]

In the Table 4.3 a rough estimate of baseband power consumption is made with the assumption that power consumption per MIPS = 1.0 mW which is a fairly conservative estimate after 5 or 10 years. It should be noted that the complexity figures in previous tables don't include all the baseband processing e.g. source and channel coding and decoding and they are therefore optimistic. The values for coding/decoding is not dependent on the multiple access scheme and therefore not presented here. It has been assumed in the table below that 1 real multiplication requires 3 instructions on a signal processing device.

Table 4.3. Baseband power consumption (at BS average per user)

Baseband power consumption	8 kbit/s	144 kbit/s	384 kbit/s	2000 kbit/s
Uplink (BS)	20 mW	40 mW	90 mW	320 mW
Downlink (MS)	20 mW	40 mW	75 mW	300 mW

4.3.5 RF power consumption and cost

The RF power consumption is mainly determined by the power consumption of power amplifier, A/D converter, D/A converter and synthesisers.

In Table 4.4 an estimate of RF power consumption is shown. The used assumptions for calculating the power consumption of the power amplifier are shown in Table 4.4,

Table 4.4. Assumptions in calculating power amplifier power consumption

Maximum average output power	100 mW
Power amplifier efficiency	40 %
Power consumption at maximum output power	250 mW
Power consumption at minimum output power. It is here assumed that the minimum power consumption is 6 dB below the maximum power consumption.	250 mW/6 dB=63 mW

The power amplifier power consumption is assumed to be only 6 dB below the maximum power consumption even if output power is 30 - 80 dB below the maximum output power. This is because the efficiency of the power amplifier decreases as the output power decreases. Therefore, the power amplifier takes power even if the transmission power in small cells is very low. On the other hand, two or more amplifiers can be used to improve the efficiency at low output powers.

The power consumption of the A/D converter in the receiver and the D/A converter in the transmitter depends on the sampling frequency, on the word length requirements, and on the proportional time the converter is on/off during the operation. Factors affecting the word length requirements are e.g. the number of modulation levels or/and parallel codes, the performance of automatic gain control in fading channel and the required SIR. An approximate formula for calculation of ADC and DAC power consumption = sampling frequency / 1e8 *2^bits [mW]. Here it is assumed that the ADC and DAC power consumption together is 50 mW or less. For more exact values to be compared with other UMTS schemes, the word length requirements should be taken into account.

The power consumption of the synthesisers depends on the number of synthesisers needed. It is assumed that the power consumption of the synthesisers is 50 mW. This estimate is based on the power consumption of the current mobile terminals.

Table 4.5. Estimated total RF power consumption

	Power amplifier	**ADC + DAC**	**Synthesisers**	**Total**
At maximum output power	250 mW	50 mW	50 mW	350 mW
At minimum output power	63 mW	50 mW	50 mW	163 mW

4.3.6 Baseband vs. RF power consumption

The baseband power consumption should be compared to the power consumption of RF parts to find out which one is dominating in transmission mode. According to Table 4.5 the power consumption of RF parts at maximum output power is 500 mW or less. Therefore the baseband power consumption of Table 4.3 is significant compared to RF parts. For comparison, the power consumption of current GSM phones in talk mode at 250 mW average transmission power is typically 1500 mW including baseband, RF and all the other functions.

4.4 GSM/UMTS Dual mode terminal implementation

In the following table changes needed for the UMTS/GSM dual mode terminal are listed.

Table 4.6. The needed changes for UMTS terminals for dual mode UMTS/GSM operation

Change	Changes/additions due to GSM support (not simultaneous with UMTS)	Changes due to handover from UMTS to GSM	Notes
Impact	- GSM/DCS duplexer, and RF filter - 200kHz IF filter + higher dynamic range ADC - more transmission buffer on the TX side - MLSE block - possibly a more expensive PA in case of low-end UMTS terminal	None (If dual receiver for interfrequency handover utilised) Second receiver if only slotted mode used for W-CDMA inter-frequency measurements	As GSM measurement during connection MLSE block extra regardless of DSP or ASIC implementation.

5 Rate Matching Principle

In the WCDMA concept an essential part of the flexibility is the used rate matching principle which allows basically any arbitrary information bit rate after channel encoding to be matched to the channel symbol rate in an efficient way. This section presents the simple rules for repetition/puncturing which are then known by both the receiver and transmitter and the needed operation for decoding can be interpreted based on the explicit rate information on the control channel.

The generic repetition and puncturing rule is as defined by the following algorithm:

Let's denote:

$S_N = \{N_1, N_2, \ldots, N_L\}$ = ordered set (in ascending order from left to right) of allowed number of bits per frame

N_C = number of bits per frame after TCH and ACCH multiplexing

$S_0 = \{d_1, d_2, \ldots, d_{N_C}\}$ = set of N_C data bits

P = maximum amount of puncturing allowed (tentatively 0.2, for further study)

The rate matching rule is as follows.

find N_i and N_{i+1} so that $N_i \le N_C < N_{i+1}$

j = 0

$$z = \left\lfloor \frac{N_{i+1}}{N_C} \right\rfloor$$

$$if(z > 1 \& N_C \neq N_i)$$

repeat every bit from set S_j z times

$$N_C = N_C z$$

$$if(\frac{N_C - N_i}{N_C} < P)$$

$x = N_C$

$y = N_C$-N_i

$$S_j = \{d_1, d_2, \ldots, d_{N_C}\}$$

do while $y > 1$

$$z = \left\lceil \frac{x}{y} \right\rceil$$

$$k = \left\lfloor \frac{x}{z} \right\rfloor$$

$x = x$-k

$y = y\text{-}k$

puncture every zth bit from set S_j

form new set S_{j+1} from not punctured bits of set S_j

$j = j+1$

end do

if y == 1

puncture last bit from set S_j

else

$x = N_C$

$y = N_{i+1}\text{-}N_C$

$$S_j = \{d_1, d_2, \ldots, d_{N_C}\}$$

do while $y > 1$

$$z = \left\lceil \frac{x}{y} \right\rceil$$

$$k = \left\lfloor \frac{x}{z} \right\rfloor$$

$x = x\text{-}k$

$y = y\text{-}k$

repeat every zth bit from set S_j

form new set S_{j+1} from not repeated bits of set S_j

$j = j+1$

end do

if y == 1

repeat first bit from set S_j

end if

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Concept Group Alpha - Wideband Direct-Sequence CDMA (WCDMA)

EVALUATION DOCUMENT (3.0)

Part 3: Detailed simulation results and parameters

In the procedure to define the UMTS Terrestrial Radio Access (UTRA), the wideband DS-CDMA concept group (Alpha) will develop and evaluate a multiple access concept based on direct sequence code division. This group was formed around the DS-CDMA proposals from FRAMES Mode 2, Fujitsu, NEC and Panasonic. The main radio transmission technology (RTT) and parameters of the common concept from the Alpha group along with performance results are presented in this document.

This document was prepared during the evaluation work of SMG2 as a possible basis for the UTRA standard. It is provided to SMG on the understanding that the full details of the contents have not necessarily been reviewed by, or agreed by, SMG2.

1. INTRODUCTION

This is the Part 3 of the Alpha (Wideband DS-CDMA) concept group evaluation document and presents detailed parameters and simulation result curves of the W-CDMA concept. This is a separate file for purely editorial reasons. This document contains two sections: link-level simulations and system-level simulations for the FDD mode.

In the sections with link-level simulations both detailed parameters used in each simulation and also curves with simulation results are presented. In system-level sections the detailed simulation parameters are presented. Also, some additional figures related to the sytem simulations are shown here.

2. LINK-LEVEL SIMULATIONS

In this section link-level simulation parameters for the different test cases are listed for the FDD mode, together with plots with simulation results. Note that the first row of each column in the parameter tables lists the number of the figure where the simulation result can be found.

2.1 Speech

Some improvements have been done to get better results than the previously presented values in Evaluation Document Draft 1.0. These improvements are due to:

- For 20 ms interleaving, both the coding and interleaving is now performed over 20 ms which implies less overhead for CRC and convolutional coding tail.
- Blind rate detection can be easily implemented since only two information bit-rates (0 and 8 kbps) are used and therefore the FCH bits can be used as pilot symbols.
- For the Vehicular environment, a smaller power control step is used (now 0.25 dB, before 0.5 dB).

2.1.1 Indoor Office A, 3 km/h

Figure number	1	1	1	2	2	2
Plot symbol	*	O	+	*	O	+
Service	Speech	Speech	Speech	Speech	Speech	Speech
Link-level bit rate	8 kbps	8 kbps	8 kbps	8 kbps	8 kbps	8 kbps
Channel type	Indoor A	Indoor A	Indoor A	Indoor A	Indoor A	Indoor A
Mobile speed	3 km/h	3 km/h	3 km/h	3 km/h	3 km/h	3 km/h
Antenna diversity	Yes	Yes	Yes	No	No	No
Chip rate [Mcps]	4.096	4.096	4.096	4.096	4.096	4.096
DPDCH						
Code allocation	1 × SF 128	1 × SF 128	1 × SF 128	1 × SF 128	1 × SF 128	1 × SF 128
Info / CRC / tail bits per frame	80 / 8 / 8	80 / 8 / 8	80 / 4 / 4	80 / 8 / 8	80 / 8 / 8	80 / 4 / 4
Convolutional code rate	1/3	1/3	1/3	1/3	1/3	1/3
Rate matching	9 / 10	9 / 10	33 / 40	9 / 10	9 / 10	33 / 40
Interleaver	10 ms	20 ms	20 ms	10 ms	10 ms	20 ms
DPCCH						
Code allocation	1 × SF 256	1 × SF 256	1 × SF 256	1 × SF 256	1 × SF 256	1 × SF 256
PC frequency [Hz]	800	800	800	800	800	800
PC step [dB]	1	1	1	1	1	1
Slots per frame	8	8	8	8	8	8
Pilot / PC / FCH bits per slot	12 / 4 / 4	12 / 4 / 4	16 / 4 / 0	12 / 4 / 4	16 / 4 / 0	16 / 4 / 0
Valid FCH words	2	2	-	2	-	-
DPCCH - DPDCH power [dB]	-3	-3	-3	-3	-3	-3

Table 1. Parameters for speech Indoor A simulations.

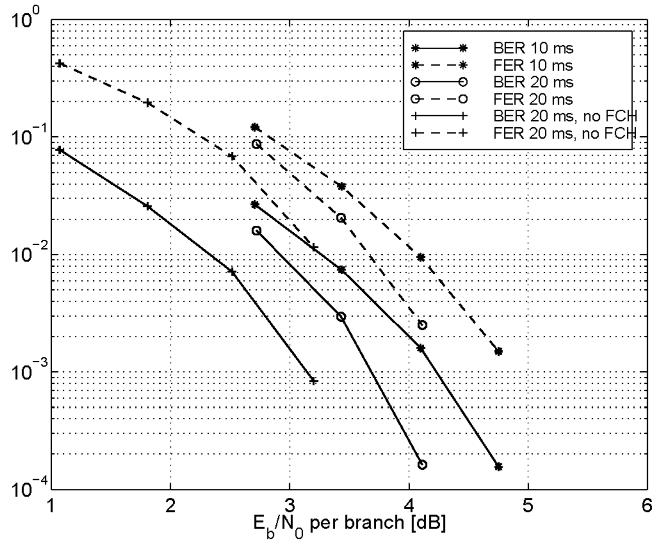


Figure 1. Speech, Indoor office A, with antenna diversity.

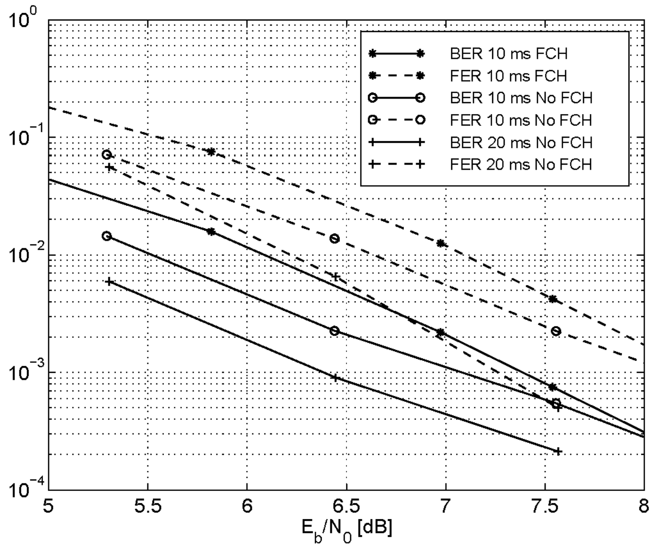


Figure 2. Speech, Indoor office A, without antenna diversity.

2.1.2 Outdoor to Indoor and Pedestrian A, 3 km/h

Figure number	3	3	3	4	4	4
Plot symbol	*	O	+	*	O	+
Service	Speech	Speech	Speech	Speech	Speech	Speech
Link-level bit rate	8 kbps	8 kbps	8 kbps	8 kbps	8 kbps	8 kbps
Channel type	Out. to In. A	Out. to In. A	Out. to In. A	Out. to In. A	Out. to In. A	Out. to In. A
Mobile speed	3 km/h	3 km/h	3 km/h	3 km/h	3 km/h	3 km/h
Antenna diversity	Yes	Yes	Yes	No	No	No
Chip rate [Mcps]	4.096	4.096	4.096	4.096	4.096	4.096
DPDCH						
Code allocation	1 × SF 128	1 × SF 128	1 × SF 128	1 × SF 128	1 × SF 128	1 × SF 128
Info / CRC / tail bits per frame	80 / 8 / 8	80 / 8 / 8	80 / 4 / 4	80 / 8 / 8	80 / 8 / 8	80 / 4 / 4
Convolutional code rate	1/3	1/3	1/3	1/3	1/3	1/3
Rate matching	9 / 10	9 / 10	33 / 40	9 / 10	9 / 10	33 / 40
Interleaver	10 ms	20 ms	20 ms	10 ms	10 ms	20 ms
DPCCH						
Code allocation	1 × SF 256	1 × SF 256	1 × SF 256	1 × SF 256	1 × SF 256	1 × SF 256
PC frequency [Hz]	800	800	800	800	800	800
PC step [dB]	1	1	1	1	1	1
Slots per frame	8	8	8	8	8	8
Pilot / PC / FCH bits per slot	12/ 4 / 4	12 / 4 / 4	16 / 4 / 0	12 / 4 / 4	16 / 4 / 0	16 / 4 / 0
Valid FCH words	2	2	0	2	-	-
DPCCH - DPDCH power [dB]	-3	-3	-3	-3	-3	-3

Table 2. Parameters for speech Outdoor to Indoor A simulations.

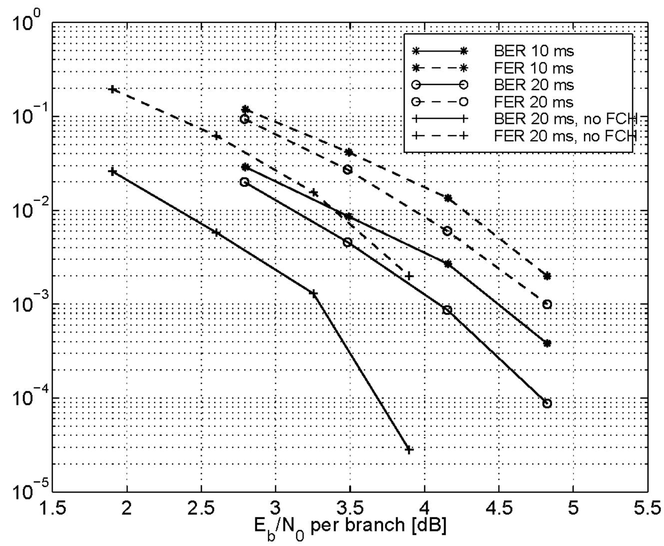


Figure 3. Speech, Outdoor to indoor and pedestrian A, with antenna diversity.

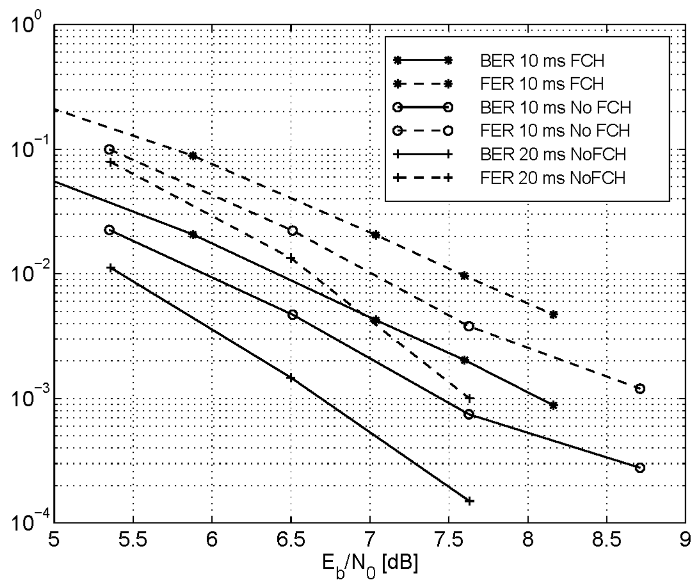


Figure 4. Speech, Outdoor to indoor and pedestrian A, without antenna diversity.

2.1.3 Vehicular A, 120 km/h

Figure number	5	5	5
Plot symbol	*	O	+
Service	Speech	Speech	Speech
Link-level bit rate	8 kbps	8 kbps	8 kbps
Channel type	Vehicular A	Vehicular A	Vehicular A
Mobile speed	120 km/h	120 km/h	120 km/h
Antenna diversity	Yes	Yes	Yes
Chip rate [Mcps]	4.096	4.096	4.096
DPDCH			
Code allocation	1 × SF 128	1 × SF 128	1 × SF 128
Info / CRC / tail bits per frame	80 / 8 / 8	80 / 8 / 8	80 / 4 / 4
Convolutional code rate	1/3	1/3	1/3
Rate matching	9 / 10	9 / 10	33 / 40
Interleaver	10 ms	20 ms	20 ms
DPCCH			
Code allocation	1 × SF 256	1 × SF 256	1 × SF 256
PC frequency [Hz]	1600	1600	1600
PC step [dB]	0.5	0.5	0.25
Slots per frame	16	16	16
Pilot / PC / FCH bits per slot	6/ 2 / 2	6/ 2 / 2	8 / 2 / 0
Valid FCH words	2	2	0
DPCCH - DPDCH power [dB]	-3	-3	-3

Table 3. Parameters for speech Vehicular A 120 km/h with antenna diversity simulations.

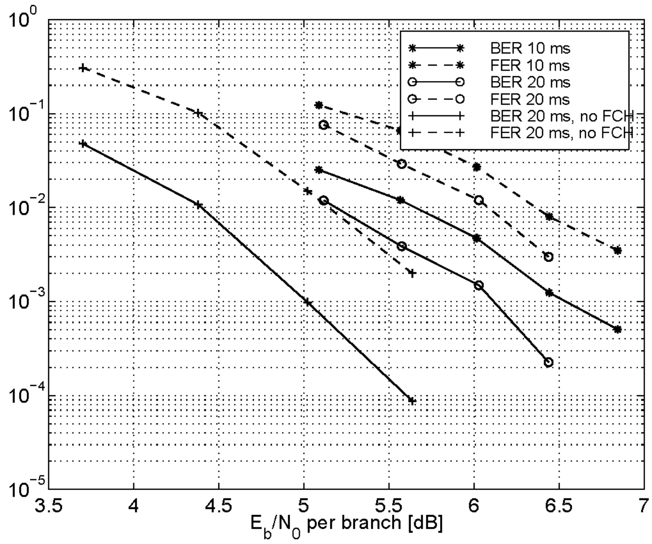


Figure 5. Speech, Vehicular A 120km/h, with antenna diversity.

Figure number	6	6	6	6
Plot symbol	*	O	+	□
Service	Speech	Speech	Speech	Speech
Link-level bit rate	8 kbps	8 kbps	8 kbps	8 kbps
Channel type	Vehicular A	Vehicular A	Vehicular A	Vehicular A
Mobile speed	120 km/h	120 km/h	120 km/h	120 km/h
Antenna diversity	No	No	No	No
Chip rate [Mcps]	4.096	4.096	4.096	4.096
DPDCH				
Code allocation	1 × SF 128	1 × SF 128	1 × SF 128	1 × SF 128
Info / CRC / tail bits per frame	80 / 8 / 8	80 / 8 / 8	80 / 4 / 4	80 / 4 / 4
Convolutional code rate	1/3	1/3	1/3	1/3
Rate matching	9 / 10	9 / 10	33 / 40	33 / 40
Interleaver	10 ms	10 ms	20 ms	20 ms
DPCCH				
Code allocation	1 × SF 256	1 × SF 256	1 × SF 256	1 × SF 256
PC frequency [Hz]	1600	1600	1600	1600
PC step [dB]	0.25	0.5	0.25	0.25
Slots per frame	16	16	16	16
Pilot / PC / FCH bits per slot	7/ 1 / 2	8/ 2 / 0	7/ 1 / 2	8/ 2 / 0
Valid FCH words	2	-	2	-
Dynamic range [dB]	-10:+10	-10:+10	-10:+10	-10:+10
DPCCH - DPDCH power [dB]	-3	-3	-3	-3

Table 4. Parameters for speech Vehicular A 120 km/h simulation without antenna diversity.

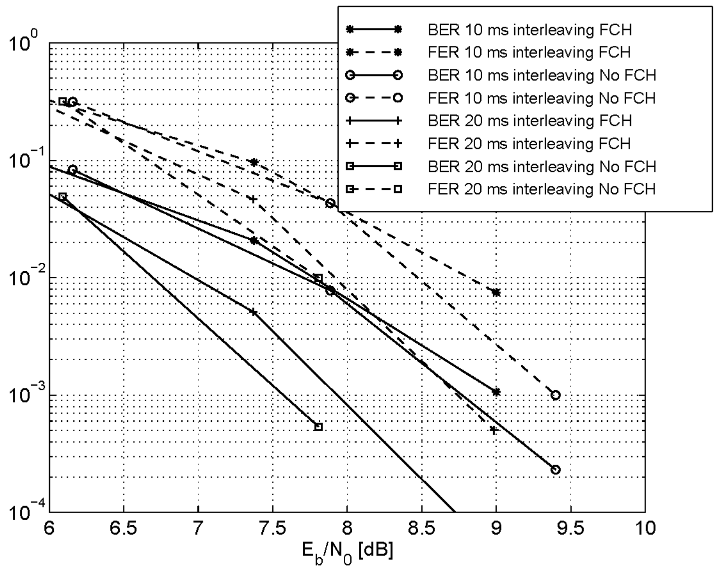


Figure 6. Speech, Vehicular A 120 km/h, without antenna diversity.

2.1.4 Vehicular B, 120 km/h

Figure number	7	8
Plot symbol	*	*
Service	Speech	Speech
Link-level bit rate	8 kbps	8 kbps
Channel type	Vehicular B	Vehicular B
Mobile speed	120 km/h	120 km/h
Antenna diversity	Yes	No
Chip rate [Mcps]	4.096	4.096
DPDCH		
Code allocation	1 × SF 128	1 × SF 128
Info / CRC / tail bits per frame	80 / 4 / 4	80 / 4 / 4
Convolutional code rate	1/3	1/3
Rate matching	33 / 40	33 / 40
Interleaver	20 ms	20 ms
DPCCH		
Code allocation	1 × SF 256	1 × SF 256
PC frequency [Hz]	1600	1600
PC step [dB]	0.25	0.25
Slots per frame	16	16
Pilot / PC / FCH bits per slot	8 / 2 / 0	8 / 2 / 0
Valid FCH words	-	-
DPCCH - DPDCH power [dB]	-3	-3

Table 5. Parameters for speech Vehicular B 120 km/h simulations.

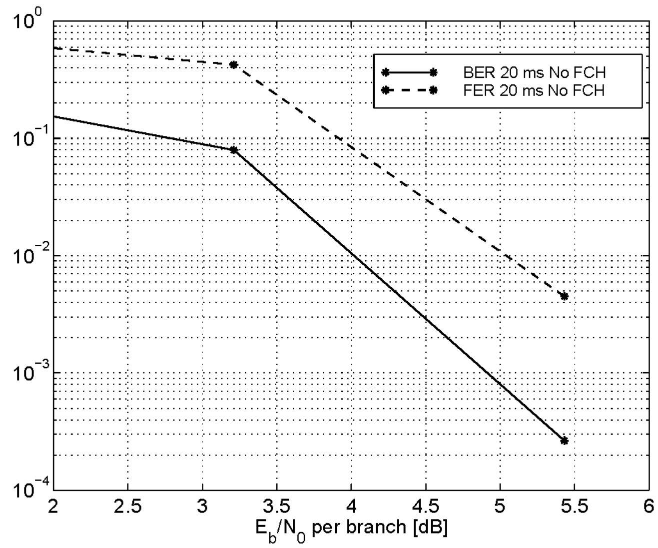


Figure 7. Speech, Vehicular B 120 km/h, with antenna diversity.

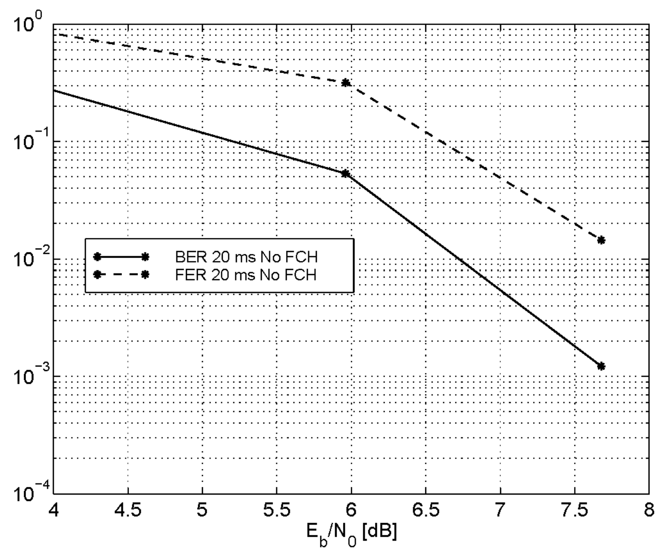


Figure 8. Speech, Vehicular B 120 km/h, without antenna diversity.

2.1.5 Vehicular B 250 km/h

Figure number	9	9	9	10
Plot symbol	*	O	+	*
Service	Speech	Speech	Speech	Speech
Link-level bit rate	8 kbps	8 kbps	8 kbps	8 kbps
Channel type	Vehicular B	Vehicular B	Vehicular B	Vehicular B
Mobile speed	250 km/h	250 km/h	250 km/h	250 km/h
Antenna diversity	Yes	Yes	Yes	No
Chip rate [Mcps]	4.096	4.096	4.096	4.096
DPDCH				
Code allocation	1 × SF 128	1 × SF 128	1 × SF 128	1 × SF 128
Info / CRC / tail bits per frame	80 / 8 / 8	80 / 4 / 4	80 / 4 / 4	80 / 4 / 4
Convolutional code rate	1/3	1/3	1/3	1/3
Rate matching	9 / 10	33 / 40	33 / 40	33 / 40
Interleaver	10 ms	20 ms	20 ms	20 ms
DPCCH				
Code allocation	1 × SF 256	1 × SF 256	1 × SF 256	1 × SF 256
PC frequency [Hz]	3200	3200	3200	3200
PC step [dB]	0.25	0.25	0.25	0.25
Slots per frame	32	32	32	32
Pilot / PC / FCH bits per slot	3 / 1 / 1	3 / 1 / 1	4 / 1 / 0	4 / 1 / 0
Valid FCH words	2	2	-	-
DPCCH - DPDCH power [dB]	-3	-3	-3	-3

Table 6. Parameters for speech Vehicular B 250 km/h simulations.

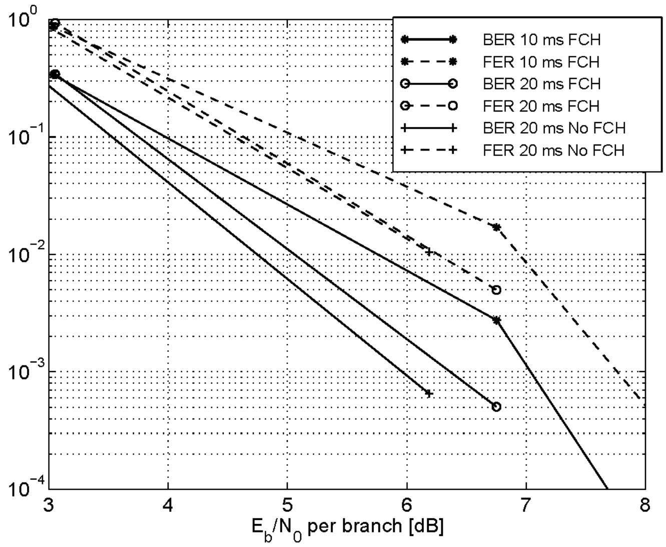


Figure 9. Speech, Vehicular B 250 km/h, with antenna diversity.

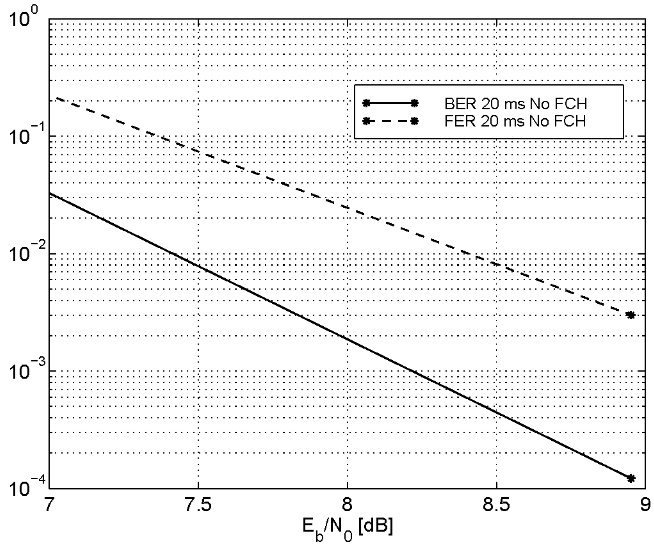


Figure 10. Speech, Vehicular B 250 km/h, without antenna diversity.

2.2 LCD

Figure number	11	11	11	12	12
Plot symbol	o	*	□	*	+
Service	LCD 144	LCD 384	LCD 384	LCD	LCD
Link-level bit rate	144 kbps	384 kbps	384 kbps	384 kbps	2048 kbps
Channel type	Out. to In. A	Indoor A	Vehicular A	Indoor A	Indoor A
Mobile speed	3 km/h	3 km/h	120 km/h	3 km/h	3 km/h
Antenna diversity	Yes	Yes	Yes	Yes	Yes
Chip rate [Mcps]	4.096	4.096	4.096	4.096	4.096
DPDCH					
Code allocation	1 × SF 8	1 × SF 4	1 × SF 4	1 × SF 4	5 × SF 4
Info / tail bits per frame	1440 / 8	3840 / 3 × 8	3840 / 3 × 8	3840 / 3 × 8	1440 / 8
Reed-Solomon code rate	180/225	192/240	192/240	192/240	192/240
Convolutional code rate	1/3	1/2	1/2	1/2	1/2
Rate matching	339/320	603/640	603/640	603/640	201 / 200
Inner interleaver [bits]	128 × 480	256 × 480	128 × 960	256 × 480	300 x 256
Outer interleaver [bytes]	225 × 12	80 × 90	240 × 30	80 × 90	240 x 160
DPCCH					
Code allocation	1 × SF 256	1 × SF 256	1 × SF 256	1 × SF 256	1 × SF 256
PC frequency [Hz]	800	800	1600	800	800
PC step [dB]	1	1	1	1	1
Slots per frame	8	8	16	8	8
Pilot / PC / FCH bits per slot	12 / 4 / 4	12 / 4 / 4	6 / 2 / 2	12 / 4 / 4	12 / 4 / 4
Valid FCH words	16	16	4	16	2
DPCCH - DPDCH power [dB]	-10§	-10	-10	-10	-10

Table 7. Parameters for LCD simulations.

Due to the fact that the simulation time to achieve a BER of 10^{-6} is so long, no results with RS coding are available at the moment for the LCD 2048 service. Using the results from the LCD 384 simulations, the performance can be estimated. Comparing with the results from the LCD 384 service in the Indoor office environment, a BER without RS coding of $6*10^{-4}$ yields a BER with RS coding of 10^{-6}. For the LCD 2048 service, a BER without RS coding of $6*10^{-3}$ is reached at approximately 2 dB, and by adding 1 dB for overhead due to the RS coding the E_b/N_0 for a RS coded BER of 10^{-6} is estimated to 3 dB.

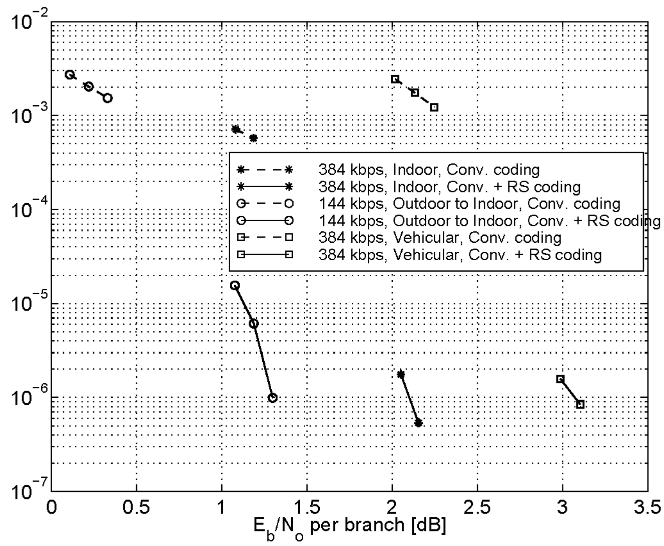


Figure 11. LCD 144 and LCD 384, with antenna diversity.

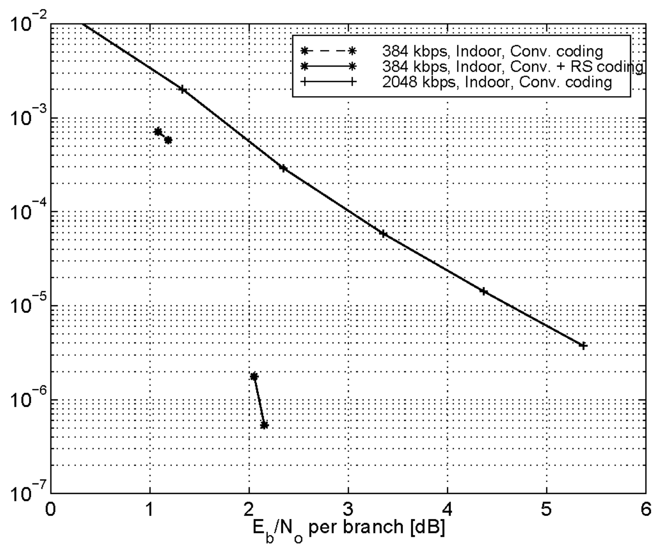


Figure 12. LCD 2048, with antenna diversity.

2.3 UDD

2.3.1 UDD 144

Figure number	13	14
Plot symbol	□	□
Service	UDD 144	UDD 144
Link-level bit rate	240 kbps	240 kbps
Channel type	Vehicular A	Vehicular A
Mobile speed	120 km/h	120 km/h
Antenna diversity	Yes	No
Chip rate [Mcps]	4.096	4.096
DPDCH		
Code allocation	1 × SF 8	1 × SF 8
Blocks per frame	8	8
Info / CRC +block nr/ tail bits per frame	300 / 12 / 8	300 / 12 / 8
Convolutional code rate	1/2	1/2
Rate matching	None	None
Interleaver	20 ms	20 ms
DPCCH		
Code allocation	1 × SF 256	1 × SF 256
PC frequency [Hz]	1600	1600
PC step [dB]	1	1
Slots per frame	16	16
Pilot / PC / FCH bits per slot	6 / 2 / 2	6 / 2 / 2
Valid FCH words	8	8
DPCCH - DPDCH power [dB]	-8	-10

Table 8. Parameters for UDD 144 Vehicular A 120 km/h simulations.

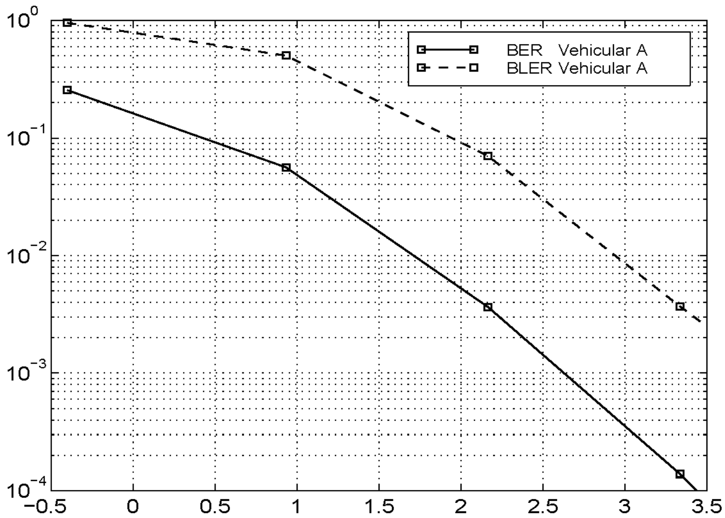


Figure 13. UDD 144, with antenna diversity.

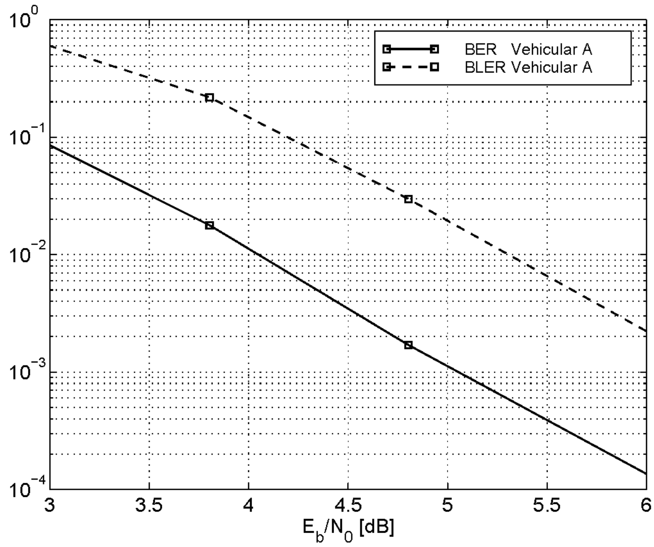


Figure 14. UDD 144, without antenna diversity.

2.3.2 UDD 384

Figure number	15	16
Plot symbol	o	*
Service	UDD 384	UDD 384
Link-level bit rate	240 kbps	240 kbps
Channel type	Out. to In. A	Indoor A
Mobile speed	3 km/h	3 km/h
Antenna diversity	Yes	No
Chip rate [Mcps]	4.096	4.096
DPDCH		
Code allocation	1 × SF 8	1 × SF 8
Blocks per frame	8	8
Info / CRC +block nr/ tail bits per frame	300 / 12 / 8	300 / 12 / 8
Convolutional code rate	1/2	1/2
Rate matching	None	None
Interleaver	10 ms	10 ms
DPCCH		
Code allocation	1 × SF 256	1 × SF 256
PC frequency [Hz]	800	800
PC step [dB]	0.5	0.5
Slots per frame	8	8
Pilot / PC / FCH bits per slot	14 / 2 / 4	14 / 2 / 4
Valid FCH words	8	8
DPCCH - DPDCH power [dB]	-10	-10

Table 9. Parameters for UDD 384 simulations.

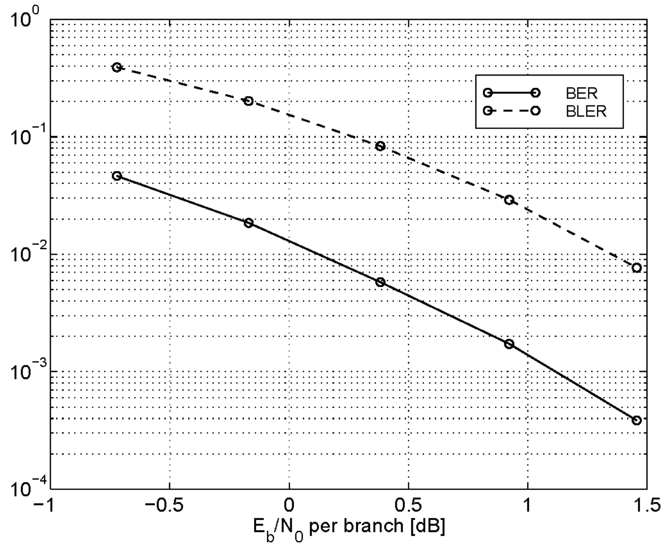


Figure 15. UDD 384, information bit rate 240 kbps, Outdoor to indoor and pedestrian A, with antenna diversity.

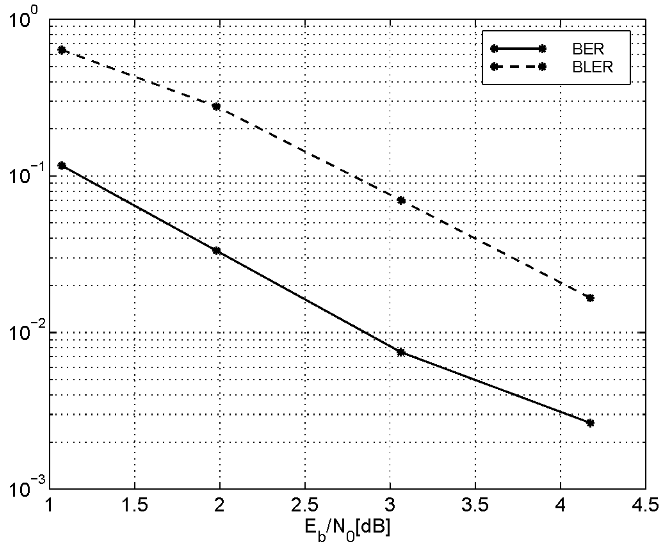


Figure 16. UDD 384, information bit rate 240 kbps, Indoor office A, without antenna diversity.

2.3.3 UDD 2048

Figure number	17	17	18	18	19	19
Plot symbol	*	o	*	o	*	o
Service	UDD 2048	UDD 2048	UDD 2048	UDD 2048	UDD 2048	UDD 2048
Link-level bit rate	480 kbps	480 kbps	480 kbps	480 kbps	2.4 Mbps	2.4 Mbps
Channel type	Indoor A	Out. to In. A	Indoor A	Out. to In. A	Indoor A	Out. to In. A
Mobile speed	3 km/h	3 km/h	3 km/h	3 km/h	3 km/h	3 km/h
Antenna diversity	Yes	Yes	No	No	Yes	Yes
Chip rate [Mcps]	4.096	4.096	4.096	4.096	4.096	4.096
DPDCH						
Code allocation	1 × SF 4	1 × SF 4	1 × SF 4	1 × SF 4	5 × SF 4	5 × SF 4
Blocks per frame	16	16	16	16	80	80
Info / CRC +block nr/ tail bits per frame	300 / 12 / 8	300 / 12 / 8	300 / 12 / 8	300 / 12 / 8	300 / 12 / 8	300 / 12 / 8
Convolutional code rate	1/2	1/2	1/2	1/2	1/2	1/2
Rate matching	None	None	None	None	None	None
Interleaver	10 ms	10 ms	10 ms	10 ms	10 ms	10 ms
DPCCH						
Code allocation	1 × SF 256	1 × SF 256	1 × SF 256	1 × SF 256	1 × SF 256	1 × SF 256
PC frequency [Hz]	800	800	800	800	800	800
PC step [dB]	1	1	1	1	1	1
Slots per frame	8	8	8	8	8	8
Pilot / PC / FCH bits per slot	12 / 4 / 4	12 / 4 / 4	12 / 4 / 4	12 / 4 / 4	12 / 4 / 4	12 / 4 / 4
Valid FCH words	8	8	8	8	8	8
DPCCH - DPDCH power [dB]	-10	-10	-10	-10	-12	-12

Table 10. Parameters for UDD 2048 simulations.

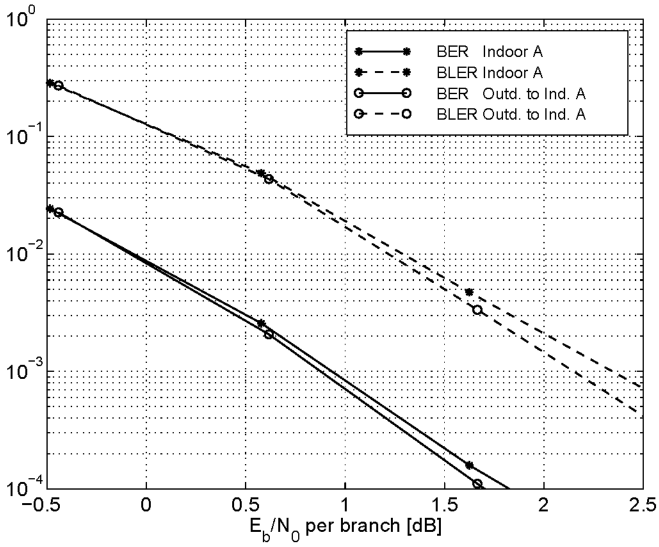


Figure 17. UDD 2048, information bit rate of 480 kbps, with antenna diversity.

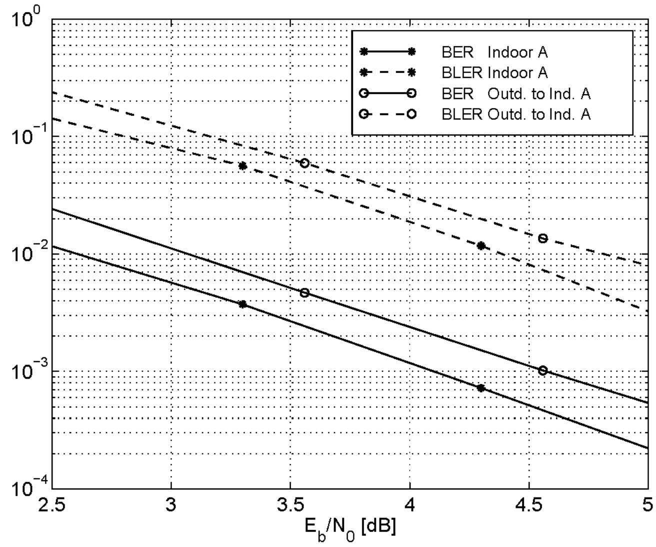


Figure 18. UDD 2048, information bit rate of 480 kbps, without antenna diversity.

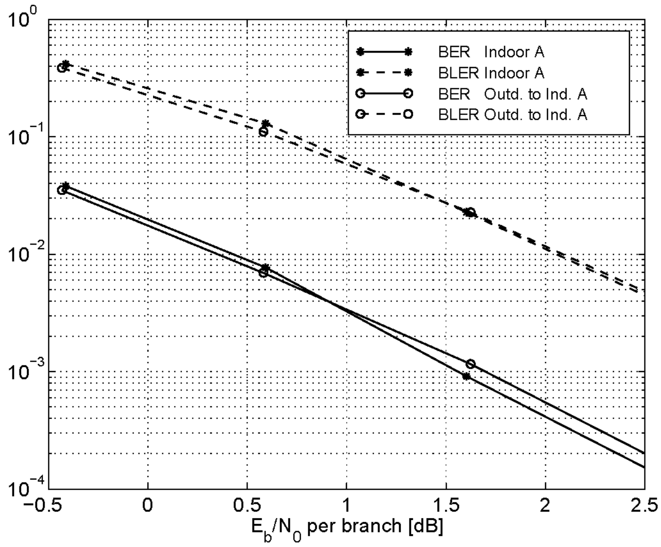


Figure 19. Link-level results for UDD 2048 with information bit rate of 2.4 Mbps with antenna diversity.

3. SYSTEM-LEVEL SIMULATIONS

This section describes the system simulation parameters used for the speech, LCD and UDD services, for the FDD mode.

3.1 Speech

Table 11. Parameters for FDD speech system simulations.

Service	Speech	Speech
Link-level bit rate	8 kbps	8 kbps
Channel type	Outdoor to indoor and pedestrian A	Vehicular A
Mobile speed	3 km/h	120 km/h
Antenna diversity (UL / DL)	Yes / No	Yes / No
Downlink orthogonality factor	0.06	0.40
Chip rate	4.096 Mcps	4.096 Mcps
Processing gain	27.1 dB	27.1 dB
Link-level assumptions		
UL E_b/N_o @ BER=10^{-3}	3.3 dB	5.0 dB
DL E_b/N_o @ BER=10^{-3}	6.7 dB	7.6 dB
DPDCH code allocation	1 × SF 128	1 × SF 128
DPCCH code allocation	1 × SF 256	1 × SF 256
Interleaver	20 ms	20 ms
Power settings		
UL TCH max power	14 dBm	24 dBm
UL PC dynamic range	80 dB	80 dB
DL TCH max power	20 dBm	30 dBm
DL PC dynamic range	20 dB	20 dB
DL broadcast channels power	26 dBm	37 dBm
UL noise power (F= 5 dB)	-102 dBm	-102 dBm
DL noise power (F= 5 dB)	-102 dBm	-102 dBm
HO algorithm settings		
Soft HO window	3 dB	3 dB
Softer HO window	N/A	3 dB
AS update rate	0.5 s	0.5 s
AS max size	2	2

3.2 LCD

Table 12. Parameters for FDD LCD system simulations.

Service	LCD 384
Link-level bit rate	384 kbps
Channel type	Vehicular A
Mobile speed	120 km/h
Antenna diversity (UL / DL)	Yes / No (Yes)
Downlink orthogonality factor	0.40
Chip rate	4.096 Mcps
Processing gain	10.3 dB
Link-level assumptions	
UL E_b/N_o @ BER=10^{-6}	3.1 dB
DL E_b/N_o @ BER=10^{-6}	5.6 dB (3.1 dB)
DPDCH code allocation	1 × SF 4
DPCCH code allocation	1 × SF 256
Interleaver	120 ms
Power settings	
UL TCH max power	24 dBm or 30 dBm
UL PC dynamic range	80 dB
DL TCH max power	30 dBm
DL PC dynamic range	20 dB
DL broadcast channels power	20 dBm
UL noise power (F= 5 dB)	-102 dBm
DL noise power (F= 5 dB)	-102 dBm
HO algorithm settings	
Soft HO window	3 dB
Softer HO window	3 dB
AS update rate	0.5 s
AS max size	2

3.3 UDD

Table 13. Parameters for FDD UDD system simulations.

Service	UDD 384	UDD 2048
Link-level bit rate	240 kbps	480-2880 kbps (1,2,3,4 & 6 codes)
Channel type	Outdoor to indoor and pedestrian A	Indoor A
Mobile speed	3 km/h	3 km/h
Antenna diversity (UL / DL)	Yes / No	Yes / No (Yes)
Downlink orthogonality	0.06	0.10
Chip rate	4.096 Mcps	4.096 Mcps
Processing gain	9.3 dB	9.3 dB
Link-level assumptions		
UL E_b/N_o @ BLER=10%	0.2 dB	0.2 dB: 1 code
DL E_b/N_o @ BLER=10%	3.2 dB	2.8 dB (0.2 dB): 1 code
DPDCH code allocation	1 × SF 8	1,2,3,4 & 6 x SF 4
DPCCH code allocation	1 × SF 256	1 × SF 256
Interleaver	10 ms	10 ms
Power settings		
UL TCH max power	14 dBm	4 dBm
UL PC dynamic range	80 dB	80 dB
DL TCH max power	20 dBm	10 dBm
DL PC dynamic range	20 dB	20 dB
DL broadcast channels power	13 dBm	-3 dBm
UL noise power (F= 5 dB)	-102 dBm	-102 dBm
DL noise power (F= 5 dB)	-102 dBm	-102 dBm
HO algorithm settings		
Soft HO window	N/A	N/A
Softer HO window	N/A	N/A
AS update rate	0.5 s	0.5 s
AS max size	1	1

3.4 PDFs of Active Session Bit-rate

The figures below show the UL session mean bit-rate for the UDD services (at 98% satisfied users), i.e. UDD 2048 in the Indoor office A environment and UDD 384 in the Outdoor to indoor and pedestrian A environment. The minimum required active session throughput is 204.8 kbps for the UDD 2048 service and 38.4 kbps for the UDD 384 service. Note for the UDD 2048 five separate simulations have been performed using different radio bearers (480, 960, 1440, 1920 and 2880 kbps bearers). The PDFs of the DL session mean bit-rate look very similar to the UL PDFs and therefore not shown here.

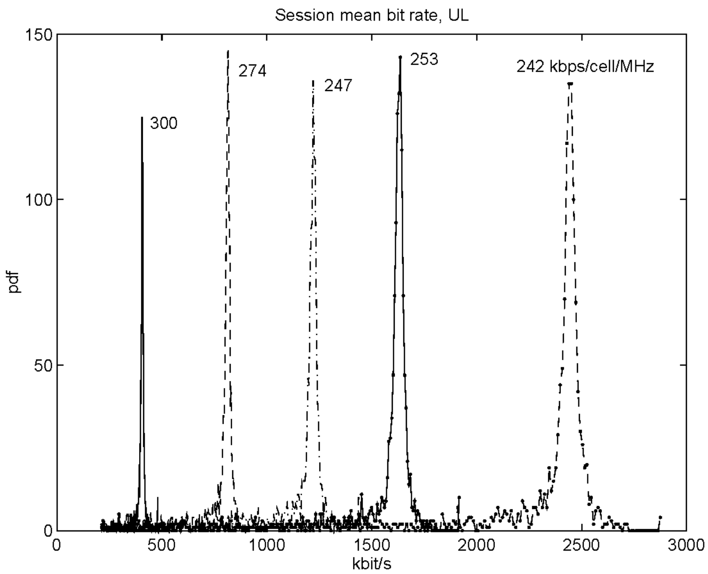


Figure 20. Pdf of uplink session mean bit rate for the UDD 2048 service in the Indoor A environment for 1, 2, 3,4 and 6 codes. The maximum information bit-rate for one code is 480 kbps. The maximum spectrum efficiency in the uplink is when a single 480 kbps bearer is used (one code), but the other bearers (multicode) show also very good performance.

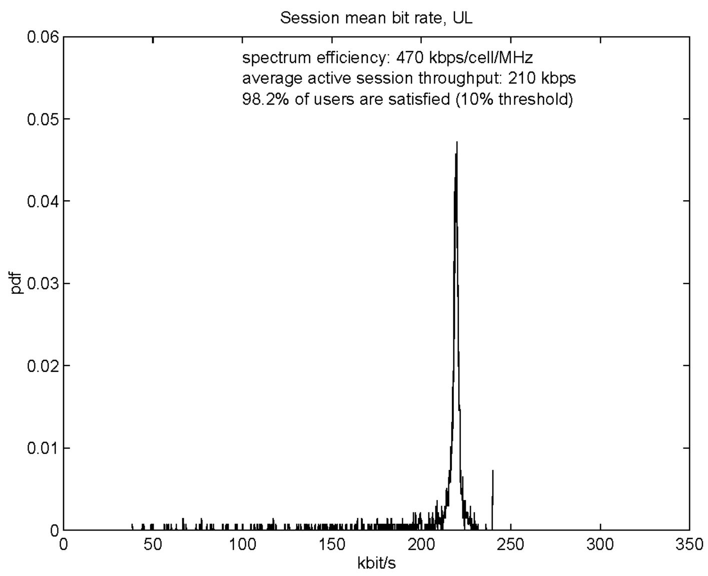
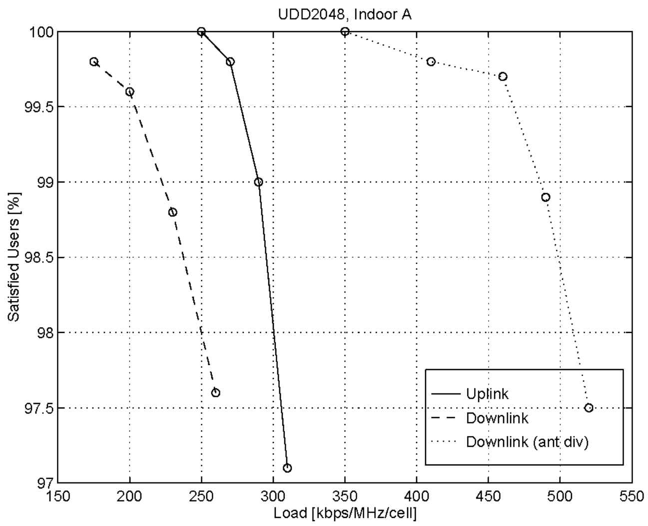
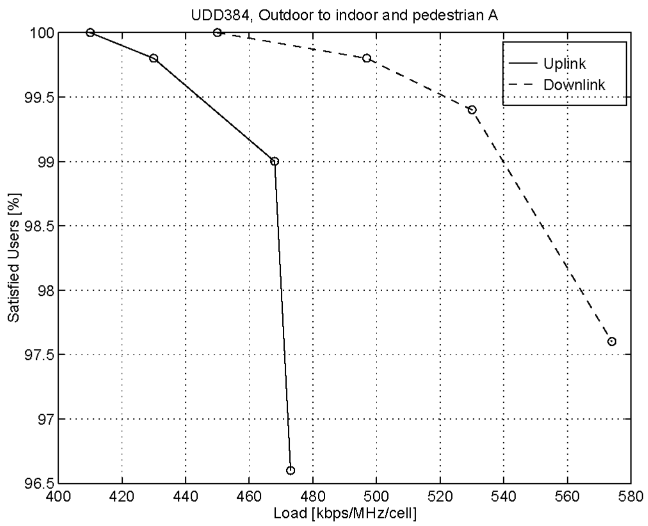


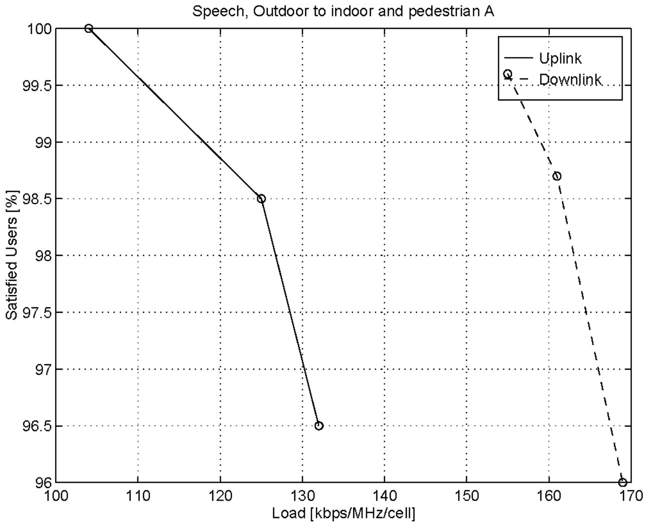
Figure 21. Pdf of uplink session mean bit-rate for UDD 384 service in the Outdoor to indoor and pedestrian A environment. The maximum information bit-rate for the bearer is 240 kbps. The spectrum efficiency in the uplink is 470 kbps/MHz/cell.

3.5 Satisfied Users versus Load

At the SMG2 Q&A Workshop curves that show "Satisfied users versus Load" were requested. Three examples are shown below: UDD 2048 (Indoor office A), UDD 384 (Outdoor to indoor and pedestrian A) and speech (Outdoor to indoor and pedestrian A). The requirement of this kind of curves was removed (due to long simulation time) by the change request: CSEM/Pro Telecom, Ericsson, France Telecom, Nokia, Siemens AG, "Change Request on UMTS 30.03 A001 and A002," Tdoc SMG 97-771, Budapest, 13-17 October, 1997.

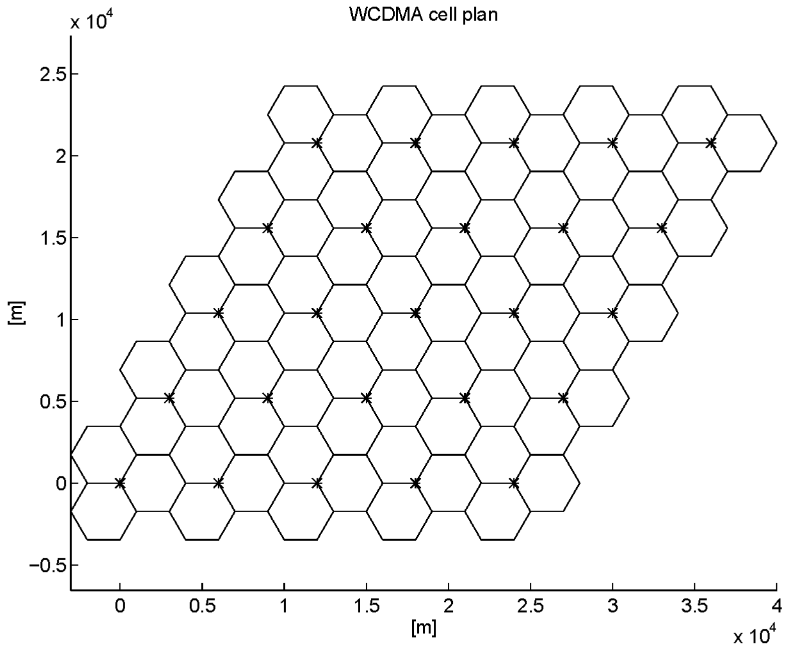


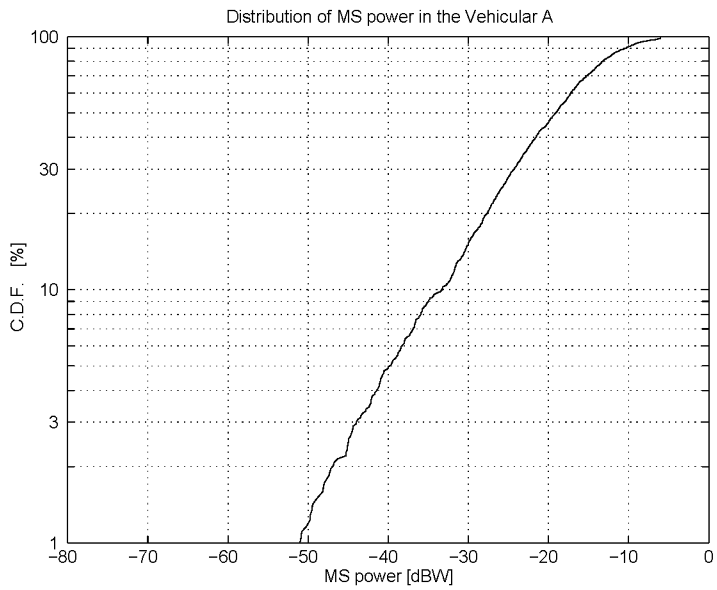



Speech, Outdoor to indoor and pedestrian A
Satisfied Users [%]
Load [kbps/MHz/cell]
Uplink
Downlink
100
99.5
99
98.5
98
97.5
97
96.5
96
100
110
120
130
140
150
160
170

3.6 Some Notes on the Vehicular Environment

The figures below show the cell plan (2 km cell radius or 6 km site-to-site distance) used and the MS power distribution in the Vehicular A environment. Wrap around is used and therefore statistics are collected from all cells (75 in the figure below). As seen in the figure showing the CDF of MS power, 99% of the MS are within 47 dB range, so an UL dynamic range of 80 dB will not effect the system capacity.





ETSI SMG
Meeting no 24
Madrid, Spain
15 - 19 December 1997

Tdoc SMG 905/97

Source: SMG2

Concept Group Alpha - Wideband Direct-Sequence CDMA (WCDMA)

EVALUATION DOCUMENT (3.0)

Part 4: WCDMA/ODMA description

This document was prepared during the evaluation work of SMG2 as a possible basis for the UTRA standard. It is provided to SMG on the understanding that the full details of the contents have not necessarily been reviewed by, or agreed by, SMG2.

1. INTRODUCTION

WCDMA satisfies the high level requirements for the UTRA and particular consideration has been given to the future evolution of the system in terms of performance and flexibility. Many advanced features have already been incorporated into the core design but WCDMA is also a suitable platform for the support of relaying.

Relaying is a widely used technique for radio packet data transmission both in commercial and military systems but it has so far not been widely used in Cellular systems. Relaying has the potential to improve coverage and flexibility but may also increase capacity by lowering transmission powers and associated intercell interference.

Within the ETSI SMG2 process for UTRA evaluation, investigation of relay systems was carried out within the Epsilon Concept Group by considering a technology called Opportunity Driven Multiple Access - ODMA. The protocols used in ODMA are very similar to those of a packet radio system currently being trialed in South Africa. System level simulations were carried out in accordance with UMTS 04.02 which showed that very wide area coverage was possible in all environments using a subscriber relay system and that there was potential for increased capacity when used in a cellular hybrid. Findings from the Epsilon evaluation work are recorded in this text.

A feasibility study was jointly conducted by the Alpha and Epsilon concept groups to determine the practicality of supporting relaying using the basic WCDMA design. The outcome of the study is included in this text and the basic conclusion was that the WCDMA design was sufficiently flexible to support relaying with negligible increase to the MS complexity or cost. WCDMA can therefore offer the flexibility of simple relaying but also provide a suitable platform for advanced relay protocols such as ODMA.

1.1 Terminology

The definition of terms listed below may help when reading the following text.

Mobile or MS	An ODMA terminal.
Seed	Roughly described as a deliberately placed Mobile that never moves and is always powered on.
Gateway or BTS	A fixed ODMA Node with interfaces to “the network” — the equivalent of a GSM base station.
Node	A Mobile, Seed or Gateway/BTS
Relay Node	A Mobile or Seed involved in relaying information between two other Nodes.

2. RELAYS

Relays add flexibility to a communication system. The figure below illustrates a range of options from simple one hop relays to ODMA which is an intelligent adaptive multi-hop system supporting full mobility of callers and relays.

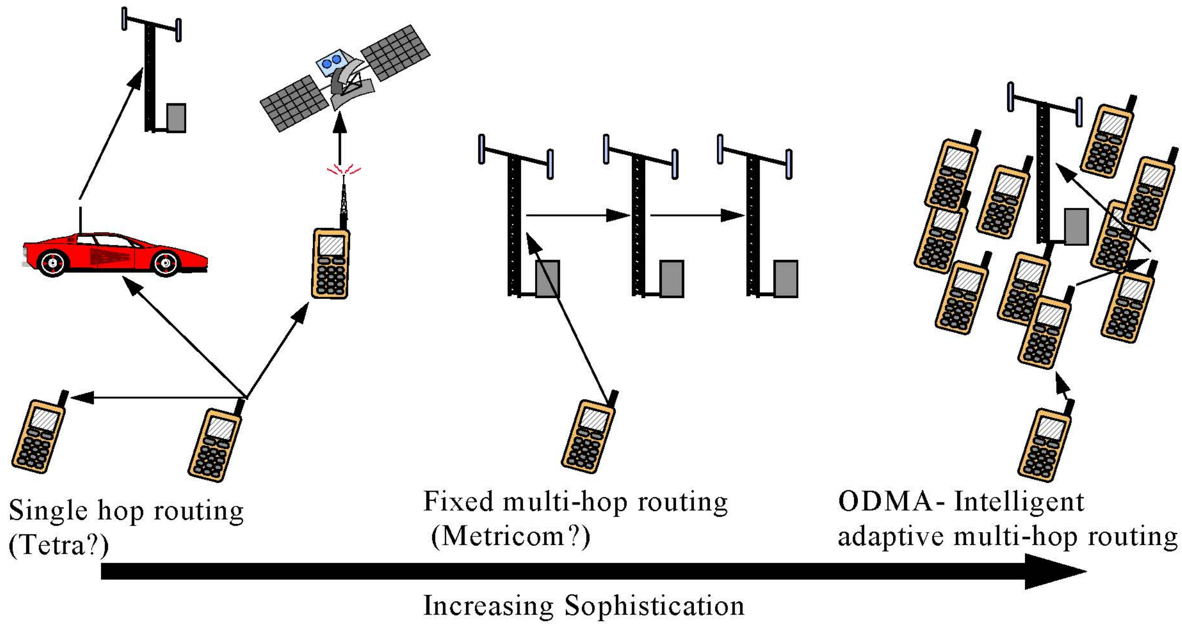


Figure 1 Relaying Options

All the options shown above are possible providing that from the outset the UTRA can support the direct transfer of information from one MS to another. Potential benefits of relaying include;

- Extension of high data rate coverage (144-384kbps)
- Reduction of TX power
- Overcoming dead-spots
- Relaying to satellite system
- Relaying to a vehicle
- Directly linking terminals (private and uncoordinated systems, home BTS etc.)

The above list is by no means exhaustive and the real motivation for relaying will only become apparent as the UTRA standard develops, however there appears sufficient justification to support relaying within WCDMA given the following pre-conditions;

- Relaying must not degrade the QoS of a UMTS cell
- Relaying must not add significant cost or complexity to a UMTS terminal
- Relaying can be enabled or disabled by an operator

2.1 WCDMA + ODMA Scenario

Figure 1 shows a WCDMA cell using an ODMA enhancement. Relaying is used to route packet data services to and from mobiles close to the WCDMA BTS - using a separate unpaired spectrum band. The relay nodes in range of the BTS will toggle between ODMA and WCDMA modes. Relaying extends the range of the high rate data services and can be used to provide coverage in dead spots.

The final hop to the BTS uses the WCDMA slotted mode. In this way relaying can bring concentrated traffic near to the WCDMA BTS which can then work in a spectrally efficient manner over a short range.

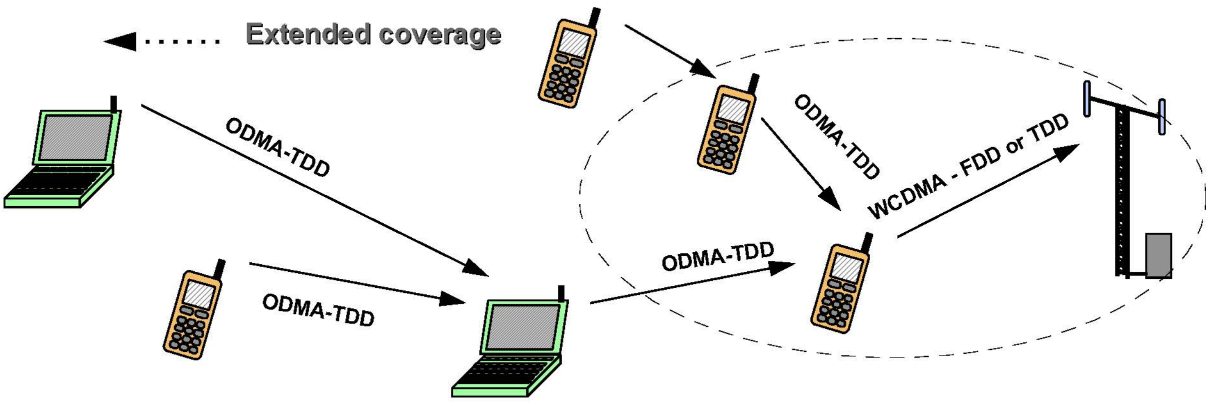


Figure 1 Scenario for WCDMA with ODMA enhancement

3. AN OVERVIEW OF ODMA

The Principle:

Opportunity Driven Multiple Access is a mechanism for maximising the potential for effective communication. This is achieved by distributing intelligence within communicating nodes and providing multiple communication paths between them. The intelligent nodes measure and evaluate their communications options and adapt to exploit the optimum opportunity.

The Practice:

ODMA is an intelligent protocol that sits upon a radio sub-system that supports relaying. The protocol breaks difficult radio paths into a sequence of shorter hops which enables lower transmit powers or higher data rates to be used. It is the goal of the protocol to chose the least cost route through the relaying system when the relays are moving and the radio paths are dynamically changing.

3.1 Multi-hop Transmissions

The transmission of information over a radio channel is subject to some fundamental rules e.g. it becomes more difficult the higher the data rate and the longer the distance. Difficulty maps to a requirement for higher transmitted powers which cause practical problems for mobile equipment and have an associated interference effect which limits the number of possible simultaneous transmissions (capacity). As high data rates are encouraged in UMTS that only leaves the distance aspect to consider.

Relaying is one of the enhancements WCDMA may use to offset the difficulties of high data rate transmission over significant distances.

3.2 Relaying v Direct Transmission

It is not difficult to identify a potential benefit from relaying rather than using direct transmission. Consider the vehicular simulation scenario of UMTS 04.02. The path loss is given by

$$\text{Loss (dB)} = 127 + 37.6\text{LOG}(D)$$

[where D is in km]

Figure 2 below shows the benefits of breaking a long path into a number of shorter hops . It plots effective pathloss for a 1km transmission against the number of relay hops (0 = direct). (Effective pathloss is the loss between hops multiplied by the number of hops)

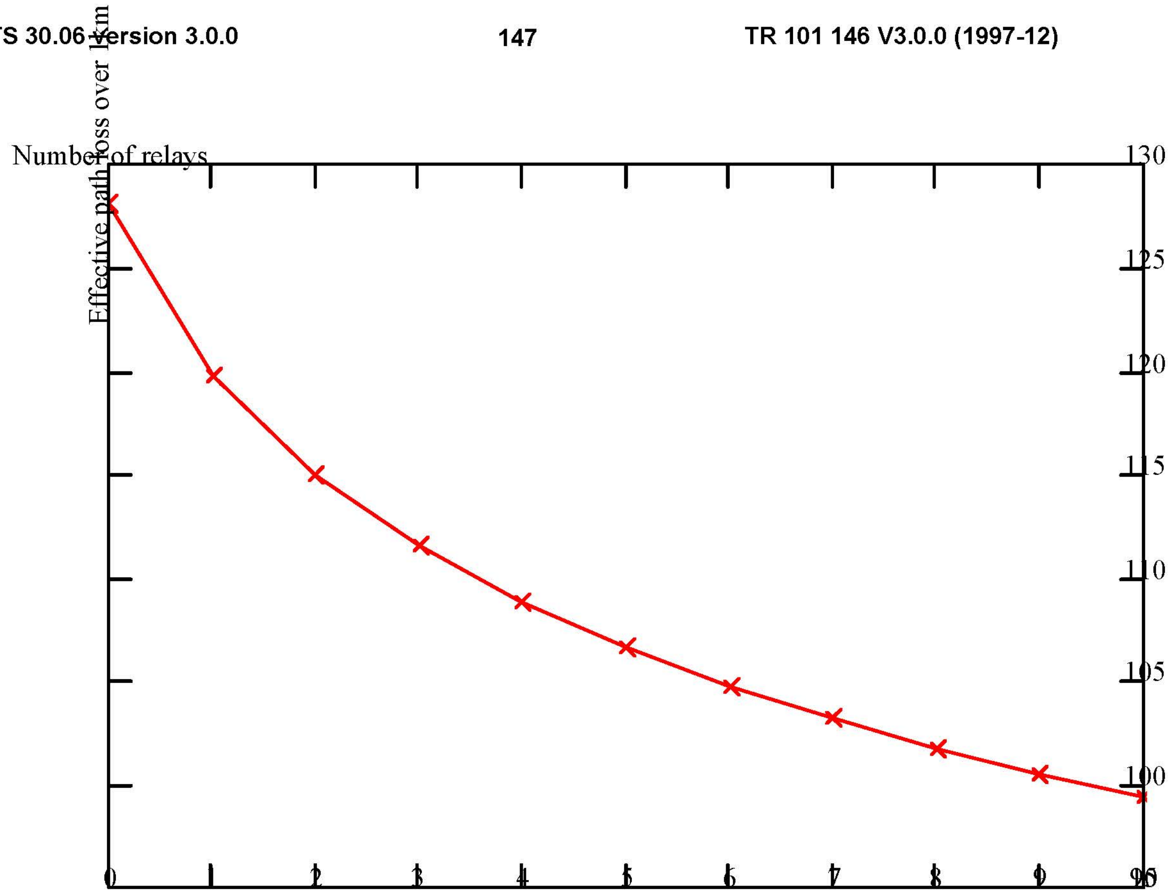


Figure 2 Effective Pathloss v Number of Relays

The graph shows benefits in the range of 10-30dB and that just 2 intermediate relays give a +12dB benefit.

3.3 Relaying to Avoid Shadowing

Radio channels are more complicated than the previous example suggest and show considerable temporal variation of shadow(slow) fading. This fading makes it hard to predefine an optimum route as the shortest paths may be heavily attenuated. However an intelligent relay can make the best local choice of route.

Consider the situation shown in Figure 3 - it is possible to use a number of paths to reach the BTS but the least cost route is to relay around the buildings. To put this into perspective @ 2GHz it is possible to experience 30dB fluctuations around “Manhattan“ street corners. Combine this with fast fading variations and burst noise/interference then the ability to identify least cost routing becomes even more desirable.

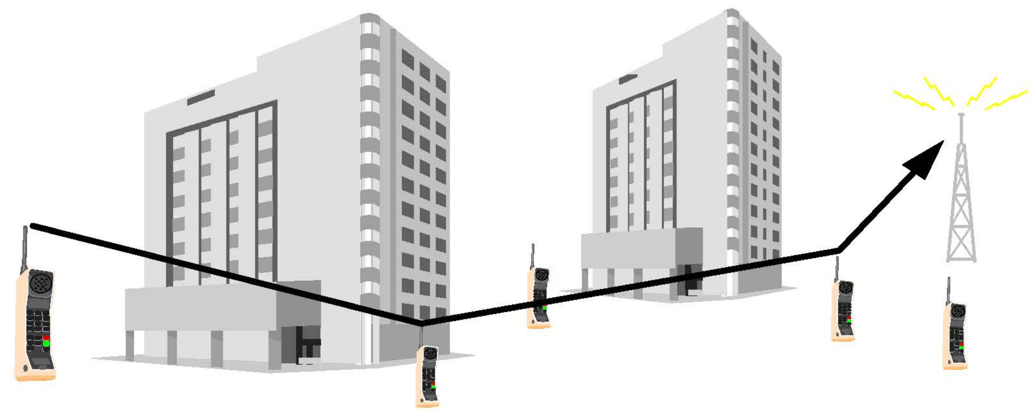


Figure 3 Relaying to Avoid Shadowing

Even if the complexities of real scenarios are ignored and the simple log normal variation model of UMTS 04.02 is used then a gain can be extracted by being allowed to chose the best of several routes.

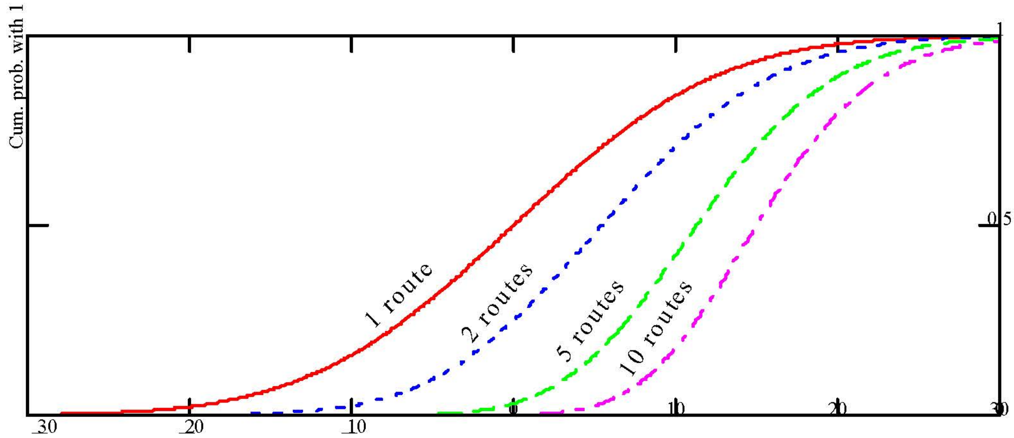


Figure 4 Benefits of Path Selection - Space Diversity

Figure 4 shows the probability of signal loss for a single path but also for the cases where you can chose the best from a number of paths e.g. @ a probability of 0.5 there is a 10dB benefit in being able to chose 1 from 10 paths.

3.4 Radio Resource Re-use

To relay information requires the use of radio resources such as codes. In a conventional structure resources are used once per cell however in ODMA the resources can be used many times within the basic cell area. This is because transmissions are lower power and so interference has only localised effect.

Figure 5 shows just 2 resources being re-used several times along a relay route and elsewhere in the cell - if the transmission circles of a single resource do not overlap interference is avoided.

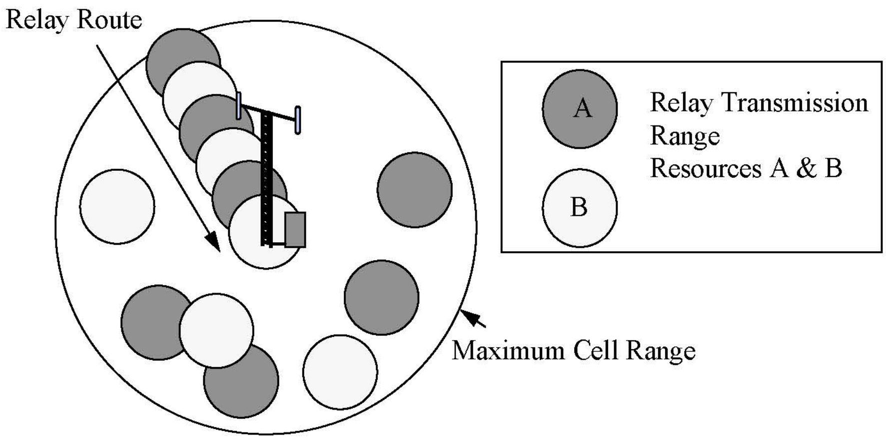


Figure 5 Re-using Resources Within a Cell Area

3.5 Potential For Capacity Gain

The potential for reducing TX power and extending the range of high data rate coverage is an obvious consideration for a relaying solution however it may be less clear that there is potential for increasing capacity. Figure 6 shows a scenario with 3 cells - normally they would be planned to avoid gaps between coverage areas. The resulting overlap will create intercell interference which ultimately reduces capacity.

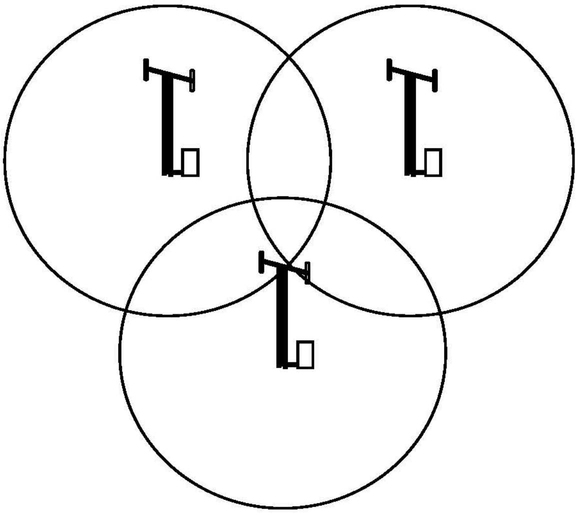


Figure 6 Normal Overlapping Cell Coverage

If the cell areas are restricted so that they do not overlap they become more spectrally efficient (spot coverage) but coverage is poor. Relaying would then be used to fill in the coverage gaps. (This would also be a useful technique at country borders).

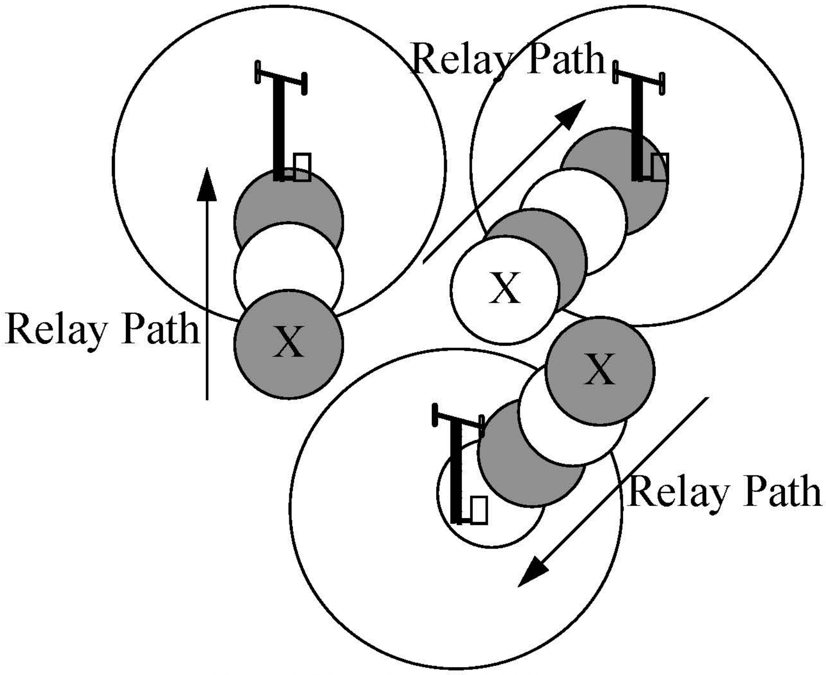


Figure 7 Discontinuous Cell Coverage

The above example does not imply that only a single relay stream can be brought to the vicinity of a BTS. For example there could be multiple ODMA nodes or "data buckets" distributed around the BTS each collecting and distributing significant amounts of traffic (as shown in

Figure 8). In this case it is the final hop to the BTS that becomes critical and so the high efficiency of WCDMA is of great benefit especially if relaying has reduced the level of intercell interference.

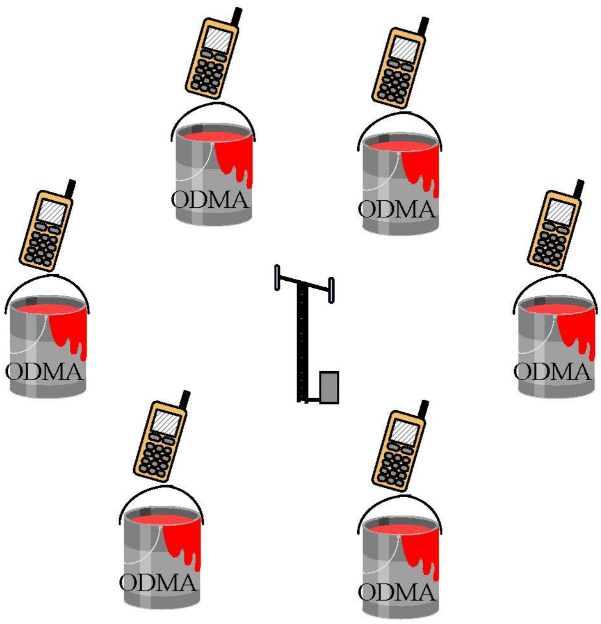


Figure 8 Cluster of ODMA Nodes around WCDMA BTS

4. OVERVIEW OF THE ODMA PROTOCOL

ODMA supports packet data transfer between an origin and destination via a network of intermediate relay nodes (fixed or mobile). The technology is characterised by a TDD mode which enables each node to receive other node's transmissions and build a connectivity table at each node. This table is subsequently used to route packets across a network in a dynamic manner without incurring a significant routing overhead.

The ODMA logical channel map in Figure 9 comprises two main types of channel:

- The first type of channel is the *calling channel (CCH),* used to transfer system overhead information and limited amounts of data, where each CCH is distinguished by different modem rates and RF carriers to minimise interference.
- The second type of channel is the *data channel (DCH),* used to transfer larger volumes of data and each DCH is associated with a specific CCH.

Note, Figure 9 is an illustration only. In practice, the logical channel structure may comprise several CCHs, each with up to *N* associated data channels.

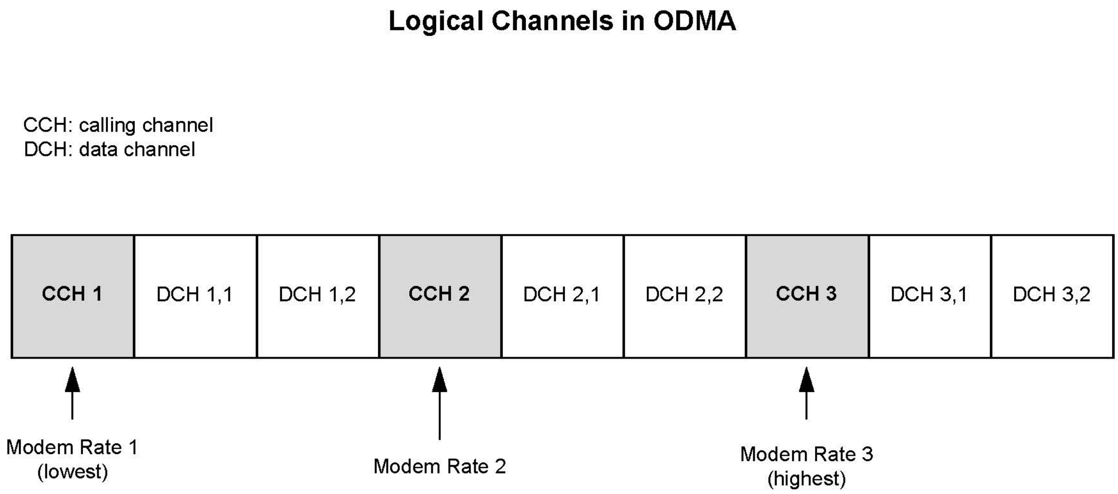


Figure 9. Logical Channels in ODMA.

This document summarises the key protocol features of ODMA which permit calls to be made via several intermediate relay nodes using the logical channel structure in Figure 9. Section 2 discusses the concept of probing on the CCH, a mechanism used by ODMA nodes to detect neighbours which may be used as relays during a call. In addition to supporting the probing function, the CCH may also be used to transfer limited amounts of data and in Section 3, methods of transferring data on the CCH and DCH is described in some detail. Finally, Section 4 details the innovative routing concept which is used to establish network-wide connectivity.

4.1 Idle Mode Functions

4.1.1 Probing for Neighbours

Probing is a mechanism used to indicate mobile activity in the ODMA network. When a mobile station, MS_{new}, is switched on for the first time it has no information about its surroundings. In this case the mobile will camp on one of the predefined system calling CCHs in idle mode which are used by all mobile stations to receive and broadcast system overhead information and data. With no system information stored in memory, MS_{new} will begin a probing session, where the mobile initially camps on a CCH and periodically *broadcasts* a probe packet. The broadcast probe includes the current neighbour list for MS_{new}, which will initially be empty. If a mobile station, MS_a, receives the broadcast packet it will register MS_{new} as a neighbour and send an *addressed* probe in response. The response probe is transmitted at random to avoid contention with other mobiles and typically one response is sent for every *n* broadcast probes received from a particular MS.

The next time MS_{new} transmits a broadcast probe the neighbour list will have one new entry, MS_a, and an associated quality indicator (a weighted factor based on the received signal strength of the response probe). It is through this basic mechanism that each mobile builds a neighbour list.

4.1.2 Calling Channel Adaptation

The probe-response mechanism enables each MS to build a neighbour list which should contain at least 5 mobiles. In the initial state when an MS is first switched on and the neighbour list is empty, the MS will transmit probes on the CCH which has the highest modem data rate and at the minimum transmit power in order to minimise interference with other mobiles.

Each time a mobile receives a response to a broadcast probe, the responding mobile is included as a neighbour. If the required number of neighbours is not met within time, T_{adapt}, the MS will increase its transmit power by x dB and reset T_{adapt}. The MS will continue to increase the broadcast probe transmit power until it achieves the required number of neighbours. If the maximum transmit power is reached before this condition is satisfied, the MS will switch to a lower rate CCH, defined as the Previous CCH and will stay at the maximum transmit power. The CCH data rate will continue to decrease, each time reseting T_{adapt}, until the MS achieves the required number of neighbours.

Conversely, if the number of mobiles in the neighbour list exceeds the required number, the CCH rate is incremented to the Next CCH. The CCH rate will continue to increase until the required number of neighbours is within acceptable bounds. If the MS reaches the highest CCH and the number of neighbours is still excessive the MS will start to drop the transmit power. Each time the CCH state is changed (i.e. the CCH or broadcast probe transmit power), T_{adapt} is reset.

4.1.3 Neighbours on Adjacent Calling Channels

The CCH adaption algorithm dictates that as the number of neighbours increases in a local area, mobiles will begin to move to higher rate CCHs. This CCH migration implies that distant or widely separated mobiles will have fewer neighbours and will camp on lower rate CCHs, resulting in non-contiguous connectivity. To overcome this problem, the MS in idle mode periodically cycles through all the CCHs and listens for broadcast probes. If a broadcast probe is received, the MS will send an addressed response so that the appropriate neighbour lists can be updated.

Two timers are used to govern the checking process. The first timer is, *Check_timer_1*, which is initiated when a mobile arrives on a new CCH and is proportional to the CCH data rate. When *Check_timer_1* expires for the first time, the Check Channel status will be null and the MS will set the *Check Channel* to the highest rate CCH. On starting the checking process a second timer, *Check_timer_2* (much less than *Check_timer_1*), is initiated and when this timer expires the MS sets the Check Channel status to the next lowest CCH and returns to the Current CCH, reseting *Check_timer_1*. When Check_timer_1 expires for the second time, the Check Channel status is no longer null and the MS continues the check cycle until *Check_timer_2* expires, at which point the Check Channel status is updated and the MS returns to the Current CCH, reseting *Check_timer_1*. This cycle repeats, skipping the Current CCH, until the Previous CCH is reached and the MS automatically returns to the Current CCH.

Since *Check_timer_2* is also proportional to the Current CCH modem rate, it takes a relatively short time to check the higher rate channels. However as the as the cycle progresses the MS will spend longer on each channel, which is why the checking terminates when the Check Channel reaches the Previous CCH.

The checking cycle is illustrated in Figure 10

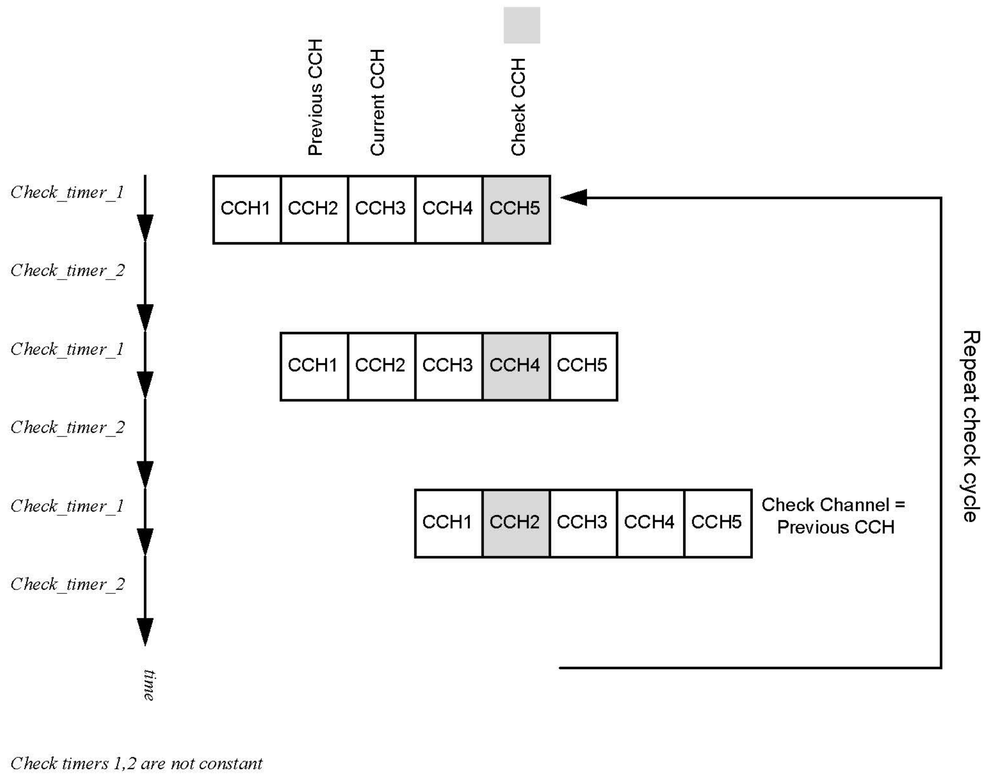


Figure 10. Check channel cycle.

4.2 Transmitting Data

Data may be transmitted on either the CCH or on a dedicated DCH, depending on the volume of data to be sent.

4.2.1 Transmitting Data on the CCH

In addition to responding to broadcast probes, addressed probes may also be used to transmit small amounts of data on the CCH. When an MS has data to send it may transmit an addressed probe packet on the CCH at an interval proportional to the CCH modem rate, R_{CCH}, and is defined by *Probe_timer_1*. This interval also defines the broadcast probe interval, *Probe_timer_2*, which is typically five times longer than *Probe_timer_1*. When an addressed node receives a probe packet with an acceptable error it transmits an acknowledgement immediately in an addressed response packet, in accordance with the ODMA Layer 2 radio link protocol (RLP).

Every time an MS transmits an addressed probe containing data on the CCH, it may be received, but not acknowledged, by third party neighbour mobiles, and provides an implicit indication of activity. In this instance broadcast probes are not necessary and *Probe_timer_2* is reset after every addressed probe transmission. Only when an MS has no data to send is it necessary to transmit a broadcast probe every *Probe_timer_2* seconds to register its active status with its neighbours.

In order to avoid overlapping packet transmissions the length of the packet may not exceed the probe timer interval, *Probe_timer_1*. The relationship between the different probe timers is illustrated in Figure 11.

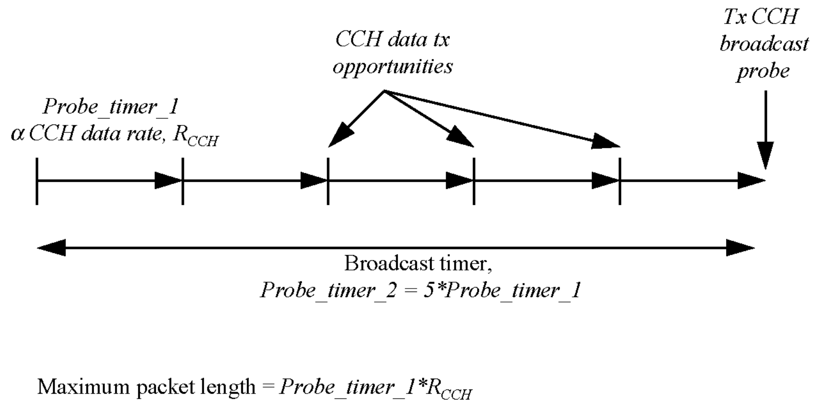


Figure 11. CCH Timer Relationships.

4.2.2 Transmitting Data on a DCH

Clearly, if all mobiles were to transmit a lot of data on the CCH, the channel would be become heavily congested and the throughput would decrease. Each CCH therefore has an associated set of DCHs which are used to transfer larger volumes of data between ODMA nodes. In this case either the first addressed data probe sent on the CCH or the corresponding response packet may indicate a DCH in the header field on which subsequent packets will be transmitted. Data exchanges will continue on the data channel until:

- no more data needs to be transmitted, or,
- the data channel timer, T_{data}, expires.

In a lengthy data transfer session the MS will still need to maintain the current status of its neighbours. The data channel timer, T_{data}, ensures that the MS will periodically revert back to the CCH and continue data exchanges on the CCH. At this stage a new DCH may be requested and the cycle repeats until the session is completed.

4.3 Routing and Connectivity

Sections 2 and 3 have described the core mechanisms which enable ODMA nodes (mobiles or fixed units) to derive neighbour list information and relay data. This section will explain how packets are routed and connectivity between two remote nodes is achieved. The ODMA packet structure, described below in Figure 13, is designed to enable nodes to listen to neighbour broadcasts or data transmissions and derive the required connectivity information.

The packet header contains physical layer characteristics, such as transmit powers local modem noise levels and the packet payload encapsulates either data segments, in the case of data packet, or neighbour list information, in the case of a broadcast probe.

Two levels of connectivity may be considered in ODMA:

- *local connectivity*, which enables a node to select an appropriate Receiving ID for a single relay hop and,
- *end-to-end connectivity*, which enables a node to determine the final Destination ID field for a data segment in a call session.

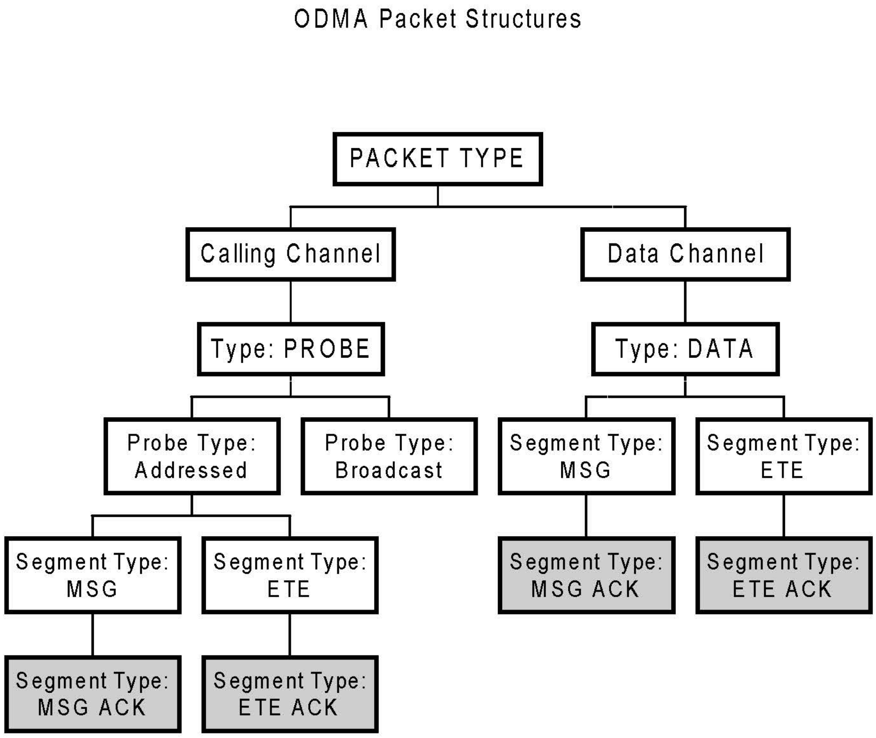


Figure 12 ODMA Packet Structures

Packet Header Information

Sending ID	The ID of the transmitting MS
Receiving ID	The ID of the receiving MS
Transmit power	The mobile transmit power
Local path loss	The path loss between the transmitting MS and addressed MS (addressed probes only)
Background RSSI	The noise level at the current modem
Background RSSI + 1	The noise level at the next highest rate modem
Background RSSI -1	The noise level at the next lowest rate modem
Requested Rx/Tx channel	Required RF channel when transmitting MS wants to move to a dedicated TCH.

Data Segment Header Information

Segment type	i.e. MSG, MSG ACK, ETE, ETE ACK
Origin ID	The originating MS
Destination ID	The destination MS
TOC	Time of segment creation
TTD	Time to die
Time Elapsed	Relative segment life-time in the network
Message number	The message number, segment type and Origin ID uniquely define a message segment in the system.

Figure 13. Packet Header Structures in ODMA.

4.3.1 Local Connectivity

Each packet comprises a header section and a payload section. In the case of a broadcast probe transmitted on a CCH, the payload comprises a neighbour list and receive quality indicator. On receiving a broadcast probe with a populated neighbour list a node can derive connectivity up to two hops away. For example, MS_0 in Figure 14 receives broadcast probes from mobiles in tier 1, whose neighbours also reside in tier 2. The tier two nodes are not classed as neighbours, since they cannot be received directly, but may be included in the MS_0 routing table.

The probing mechanism therefore enables an MS to populate the Sending ID and Receiving ID fields in the packet header to relay data over a single hop and define the end-to-end (ETE) connectivity if the Destination ID is in the routing table.

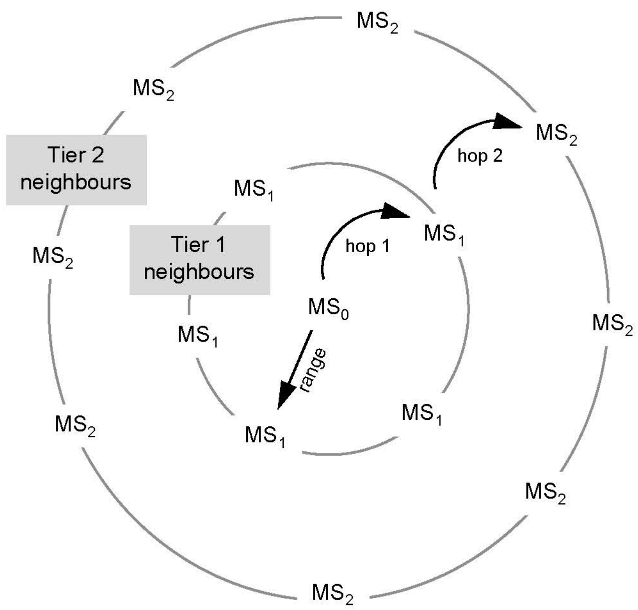


Figure 14. Localised connectivity through probing.

4.3.2 Connectivity Metrics

Within a local connectivity area, defined by the current neighbour list information, a mobile could select one of several relays which may be used to route a packet towards a final destination. Clearly, a choice needs to be made to determine which mobile would represent the best connection for a single hop. Whenever an MS receives a packet from a neighbour, the header provides sufficient information to perform a basic link budget assessment, which determines the transmit power required to reach a mobile with a sufficient S/N.

Connectivity beyond a local area is derived from layer 2 segment header information. The Origin ID and Destination ID fields provide new entries in the routing table and an ETE segment indicates connectivity with a final destination. The Time-of-creation (TOC) and Time Elapsed fields show the relative time at which a segment was created and how long it has been in the network. The Time Elapsed field is incremented at each relay node and compared with the TOC to determine the delay. Using these fields a node can monitor a packet being transmitted between two other nodes and derive the packet delay. If a segment does not reach its destination within a specified time, defined by the TTD, it is deleted from the transmission queue.

In summary the minimum transmit power (for a required S/N) and network delay are the two main parameters which indicate connectivity quality in the ODMA routing algorithm.

4.3.3 End-to-End Connectivity

In a non-cellular environment, if a mobile wants to initiate an ODMA call with a node which is not listed in the routing table, the MS creates a Destination ID and sends a *router message*, which is a very small, high priority message, routed towards nodes with good connectivity and away from the origin, flooding the immediate local area within the network. The router message will only flood to mobiles within a limited region restricted by a Time To Die field in the router message.

N.B. [In a WCDMA cellular environment all traffic is to or from a Gateway/BTS, the majority of mobiles will always know a route to the Gateway/BTS and since the Gateway/BTS can page them directly without relaying it can request them to initiate a relaying call and so does not have to find a route to the mobile. Once the gateway has received a message from the mobile via relays in response to a page it can then send data back down the same route to the mobile. Therefore router messages may not be required or used very rarely with flooding only over small localised areas.]

If the Destination ID receives the router message it responds via the same route with an ETE acknowledgement which also has a high priority. If the router message does not reach the Destination ID within a given time, specified by the time to die TTD field, another router message is sent, this time via two well connected nodes.

The ETE is sent on a chain of CCHs to acknowledge connectivity and is also received by third party mobiles using the same CCHs but not involved in the call directly. On receiving an ETE, mobiles are able to update their routing tables to include nodes which lie outside their local connectivity area.

Consider the example in Figure 15. ODMA could be considered as a set of overlapping local connectivity areas, A, B, C, D, containing mobiles A={1,2,3}, B={3, 4, 5, 6}, C={6, 7, 8, 9} and D={9,10}, where mobiles within the same area can receive each others transmissions. If MS_1 wants to communicate with MS_{10}, it needs to send a router message across the network and the corresponding ETE is sent on a reciprocal path. On the outbound and return paths, the router and ETE messages are also received by MS_4 and MS_8, allowing MS_1 and MS_{10} to be entered into each mobile's routing table. When a subsequent outbound packet reaches MS_3 for the second time, MS_3 will assess the connectivity between its neighbours and may conclude (from the neighbour list information) that MS_4 provides a better connection to MS_6, which has been noted to have connectivity to MS_{10}. This mechanism implies that within each local area call connectivity changes dynamically depending on the link budget and network delay.

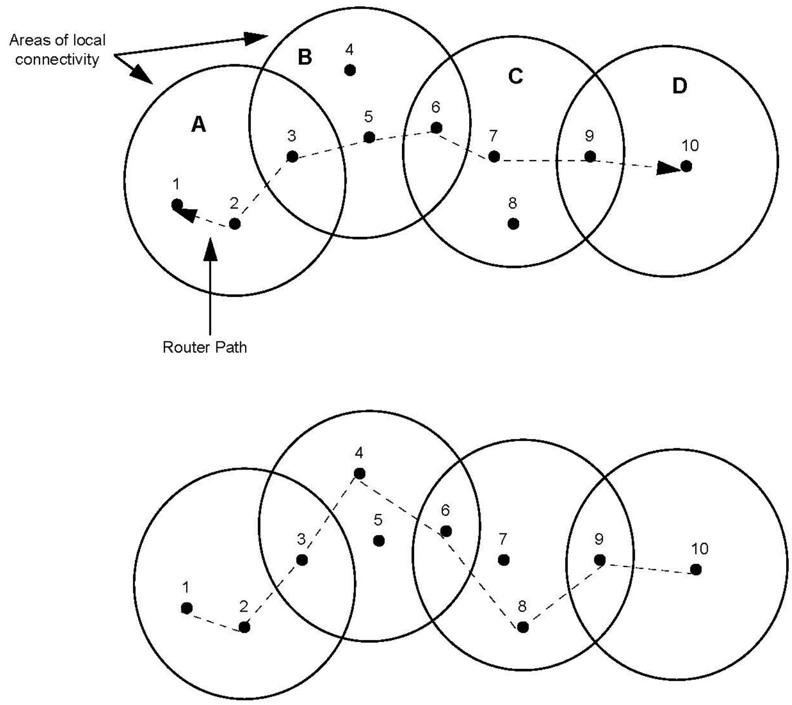


Figure 15. ETE connectivity in ODMA.

When the originating mobile receives the ETE, connectivity is established and the data transfer can proceed according to the Layer 2 protocol, illustrated in Figure 16.

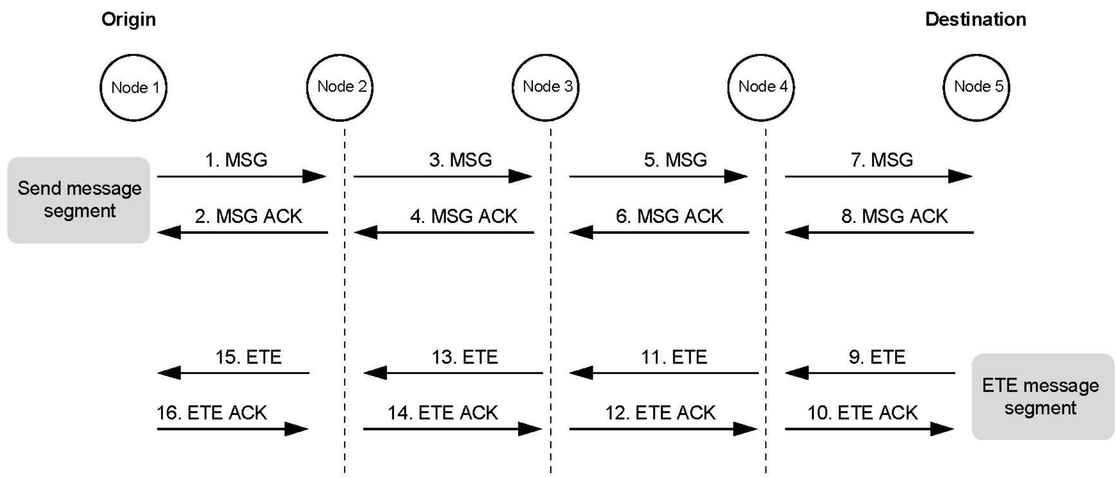


Figure 16. ODMA Layer 2 RLP.

5. SIMULATIONS

Within the Epsilon concept group simulations were performed on the ODMA technology. For this purpose a system simulator tool was created such that the environments, traffic and mobility models of UMTS 04.02 could be supported. The simulated ODMA nodes were software kernels taken from a prototype packet radio system in South Africa which is based on the ODMA technology. Simulations using this tool should therefore be close to reality as the simulated nodes are themselves deciding on the best relay paths, the power levels, overall routing etc. A disadvantage of this approach is that simulations have taken a long time to run and the number of simulated nodes has been limited. As a consequence it has been necessary to concentrate on a small subset of simulation tests relevant to ODMA data relaying i.e. LCD 384kbps. The LCD model was used as it was considered a better measure of performance than UDD which was more open to different interpretations.

A representative link level was used during the simulations but this was not WCDMA. However it is expected that future results using WCDMA would achieve much better results.

Most of the simulations concentrated on extended coverage scenarios using subscriber relay but some initial work was carried out on capacity for a combined ODMA/cellular solution where traffic is concentrated at a number of nodes close to the BTS.

Where subscriber relay is assumed only 1% of the mobiles believed to be within a coverage area are assumed available as relays. (User density estimate based on figures in early versions of UMTS 04.02).

The very wide area coverage simulations were not to prove that such areas should be covered by a single BTS but rather to show the flexibility of systems that support relaying.

5.1 Indoor office (x60) LCD 384kbps Coverage

Figure 17 shows a distribution of packet delays for communications within a 60 office indoor environment using a single BTS and subscriber relay. It can be seen that in general delays are within the 300ms LCD bearer limit and that the mobile TX power during a call is very low (115uW)

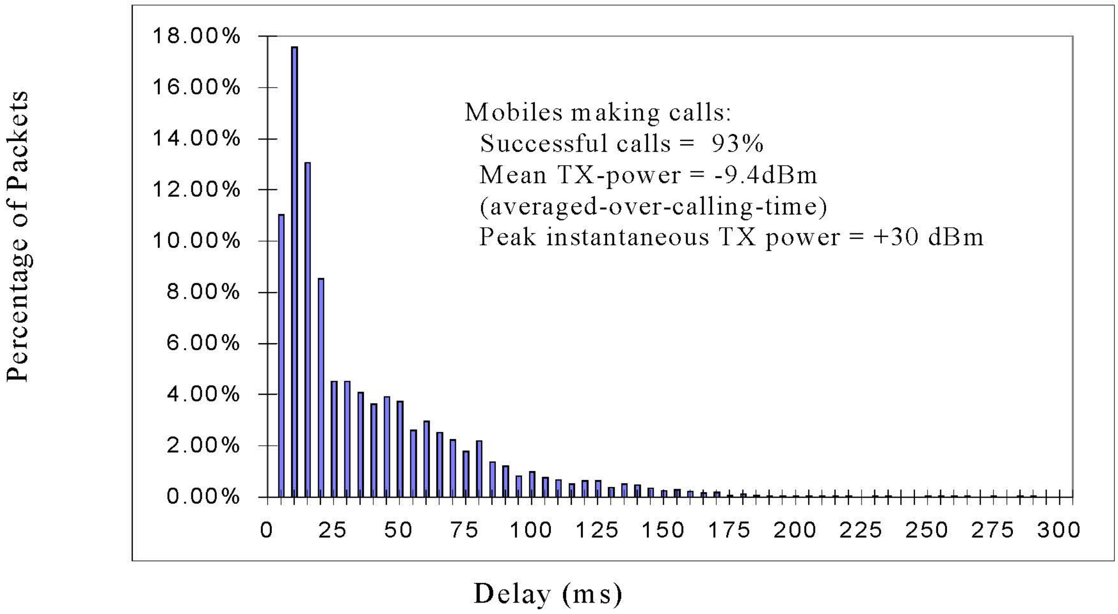


Figure 17 Packet Delay Distribution for Indoor Office (x60) LCD 384kbps Coverage

5.2 Manhattan 10x10 Blocks LCD 384kbps Coverage

Figure 18 shows distribution of packet delays for LCD 384kbps over a 10x10 block of Manhattan. There is more of a delay variation with respect to Indoor attributable to the more difficult environment e.g. corner effects and building loss. The power during a call is also greater (49mW) which suggests fewer or more difficult radio paths.

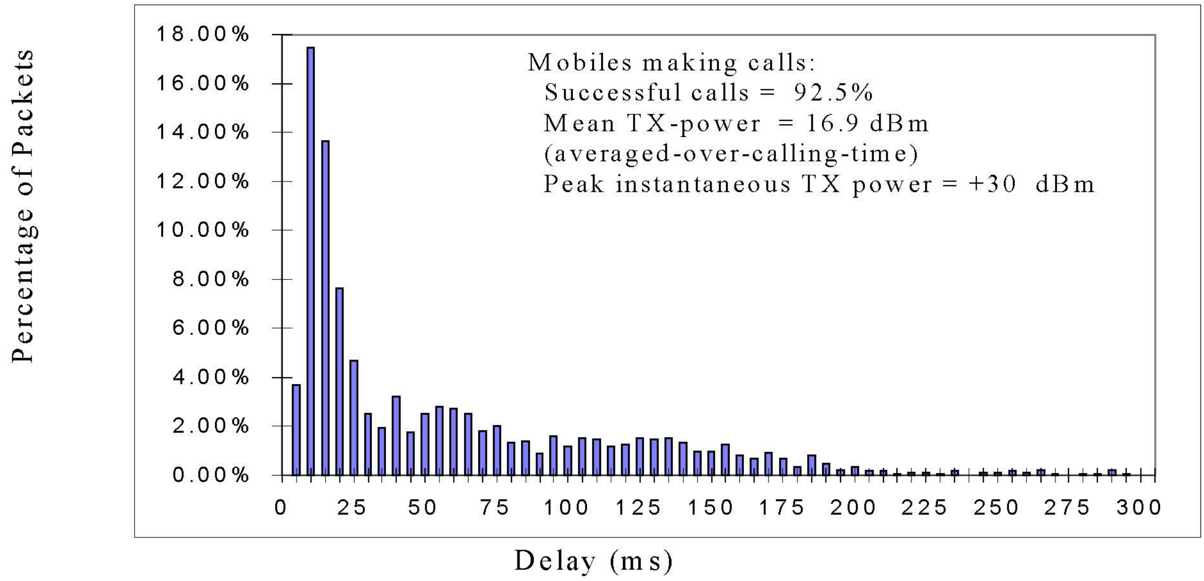


Figure 18 Packet Delay Distribution for Manhattan (10x10) LCD 384kbps Coverage

5.3 Vehicular - 6km x 6km LCD 384kbps Coverage

Figure 19 shows distribution of packet delays for LCD 384kbps over a 6km x 6km vehicular coverage area. There is less delay variation with respect to Manhattan attributable to having less relay hops with a corresponding increased TX power (323mW).

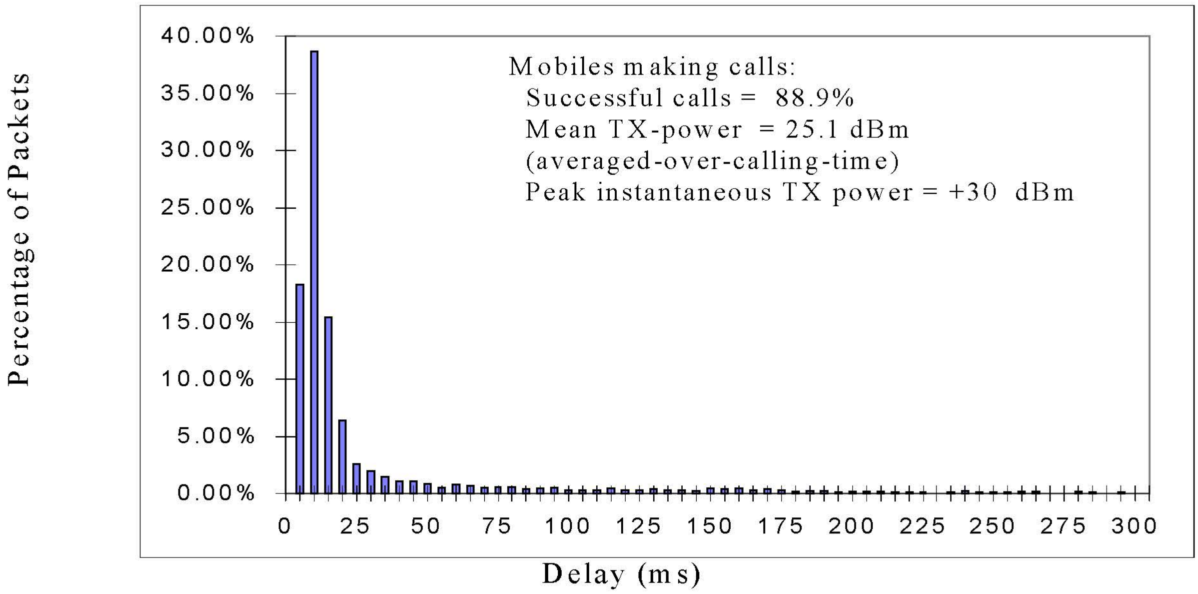


Figure 19 Packet Delay Distribution for Vehicular 6km x 6km LCD 384kbps Coverage

5.4 Manhattan 3x3 Blocks LCD 384kbps Capacity

Figure 20 shows distribution of packet delays for LCD 384kbps over a 3x3 block of Manhattan using 8 WCDMA/ODMA nodes close to the BTS to concentrate traffic. For the spectrum utilised the efficiency of this group of 8 is 860kbps/MHz. This is an interesting initial result which can be improved but the link between the interface between the ODMA layer and the WCDMA cell requires more detailed investigation which has not been possible within the given timescales.