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Contents

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Satellite Earth Stations and Systems (SES).

Introduction

One of the major novelties of third-generation (3G) wireless networks is the introduction of new high-speed data-based multimedia services on top of the conventional voice and low-rate messaging applications. Mobile Internet, i.e. efficient provision of Internet-based applications to mobile and nomadic users is considered the key to the 3G wireless networks success.

The present document assumes that the Core Network to be used by S-UMTS systems will re-use the terrestrial Core Network, including the same terrestrial Iu interface. The present document concentrates therefore on the air interface aspects, describing the likely differences between satellite systems and their terrestrial counterparts.

It also lists preliminary solutions to some of the open issues identified in the present document. Some of these solutions have been incorporated into the S-UMTS-A air interface [11] to [14].

1 Scope

The present document summarizes the packet mode operation defined within 3GPP's Release 1999 of the terrestrial UMTS UTRAN FDD-mode at air interface level (layers 1 and 2). Additionally, it also describes some of the enhancements in Releases 4 and 5 of 3GPP in order to provide a high-speed Downlink Access.

The present document analyses the impact on the satellite component of UMTS/IMT2000 and defines solutions adapted to the satellite component.

2 References

For the purposes of this Technical Report (TR) the following references apply:

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[2] ETSI TS 125 211: "Universal Mobile Telecommunications System (UMTS); Physical channels and mapping of transport channels onto physical channels (FDD) (3G TS 25.211 version 3.3.0 Release 1999)".

[3] ETSI TS 125 212: "Universal Mobile Telecommunications System (UMTS); Multiplexing and channel coding (FDD) (3G TS 25.212 version 3.3.0 Release 1999)".

[4] ETSI TS 125 213: "Universal Mobile Telecommunications System (UMTS); Spreading and modulation (FDD) (3G TS 25.213 version 3.3.0 Release 1999)".

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[12] ETSI TS 101 851-2: "Satellite Component of UMTS/IMT2000; A-family; Part 2: Multiplexing and channel coding (S-UMTS-A 25.212)".

[13] ETSI TS 101 851-3: "Satellite Component of UMTS/IMT2000; A-family; Part 3: Spreading and modulation (S-UMTS-A 25.213)".

[14] ETSI TS 101 851-4: "Satellite Component of UMTS/IMT2000; A-family; Part 4: Physical layer procedures (S-UMTS-A 25.214)".

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[17] ETSI TS 125 321: "Universal Mobile Telecommunications System (UMTS); MAC protocol specification (3G TS 25.321 version 3.3.0 Release 1999)".

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the following term and definition applies:

propagation delay: propagation time from the ground to satellite, and back to the ground (single hop)

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

2G	Second Generation
3G	Third Generation
3GPP	Third Generation Partnership Project
3GPP2	Third Generation Partnership Project 2
AI	Acquisition Indicator
AICH	Acquisition Indicator CHannel
ANSI	American National Standards Institute
AP	Access Preamble
AP-AICH	Access Preamble-Acquisition Indicator CHannel
ARQ	Automatic Repeat reQuest
ASC	Access Service Class
BCH	Broadcast CHannel
BS	Base Station
CCPCH	Common Control Physical CHannel
CD	Collision Detection
CD-AICH	Collision Detection-Acquisition Indicator CHannel
CD-P	Collision Detection Preamble
CDMA	Code Division Multiple Access
CPCH	Common Packet CHannel
CSMA-CD	Carrier Sensing Multiple Access with Collision Detection
DCH	Dedicated CHannel
DL	Downlink
DPCCH	Dedicated Physical Control CHannel
DPDCH	Dedicated Physical Data CHannel
DSCH	Downlink Shared CHannel
FACH	Forward Access CHannel
FAUSCH	FAst Uplink Signalling CHannel
FDD	Frequency Division Duplex
FER	Frame Error Rate
F-PCH	Forward Paging CHannel
GEO	GEO-stationary orbit
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communications
HDR	High Data Rate downlink
IP	Internet Protocol
LEE	Land Earth Station
LEO	Low Earth Orbit
MAC	Medium Access Control
MEO	Medium Earth Orbit
OVSF	Orthogonal Variable Spreading Factor
PAPR	Peak-to-average Ratio
PC-P	Power Control Preamble
PCH	Paging CHannel

PCPCH	Physical Common Packet CHannel
PDSCH	Physical Downlink Shared CHannel
PICH	Paging Indicator CHannel
PLICF	Physical Layer Independent Convergence Function
PLMN	Public Land Mobile Network
PPP	Point-to-Point Protocol
PRACH	Physical Random Access CHannel
QoS	Quality of Service
RACH	Random Access CHannel
RAN WG1	Radio Access Network Working Group 1
R-ACH	Reverse Access CHannel
R-CCCH	Reverse Common Control CHannel
RLP	Radio Link Protocol
RNC	Radio Network Controller
RNTI	Radio Network Temporary Identifier
RRC	Radio Resource Control
S-CCPCH	Secondary Common Control Physical CHannel
SDB	Short Data Burst
S-UMTS	Satellite Universal Mobile Telecommunications System
SFN	Super-Frame Number
SW-CDMA	Satellite Wide-band - Code Division Multiple Access
TDD	Time Division Duplex
TDMA	Time Division Multiple Access
TFCI	Transport Frame Combination Indicator
TFCS	Transport Frame Combination Set
TPCI	Transmission Power Control Indicator
T-UMTS	Terrestrial UMTS
UE	User Equipment
UL	UpLink
UMTS	Universal Mobile Telecommunications System
USCH	Uplink Shared CHannel
UTRA	UMTS Terrestrial Radio Access
UTRAN	UMTS Terrestrial Radio Access Network
QPSK	Quaternary Phase Shift Keying
W-CDMA	Wideband CDMA
WWW	World Wide Web

4 Packet Data Transmission in Third Generation Mobile Systems

4.1 Third Generation Systems

Due to the explosive growth of the Internet and the increasing demand for all sorts of IP based services (voice and data, multimedia), fast and efficient handling of packet data in third generation wireless networks now becomes an important issue.

The market expects 3G mobile radio networks to provide Quality of Service (QoS) and transmission speed of similar order than fixed wire access networks. However, these expectations can hardly be met, since the available spectrum and transmit power resources in terrestrial and especially in satellite mobile radio networks are very limited. Nevertheless, future 3G wireless systems are obliged to deliver packet-oriented services to users in an efficient manner, exploiting the scarce physical resources as best as possible.

One of the key objectives behind 3G mobile systems is then to achieve a significantly higher transmission speed capability as compared to 2G systems (e.g. GSM, GPRS, IS-95). This enhancement includes both circuit- and packet-switched networks, and should support multimedia services.

The activities leading to the definition of these 3G mobile systems take place mainly in two parallel projects, 3GPP and 3GPP2. They define radio transmission technologies for the integration with Core Networks based on GSM/GPRS and ANSI-41 (IS-95) respectively, with the appropriate provisions to ensure interoperability among the different technologies.

In a first phase, from the start of the work to the present, the effort has been mainly on the radio interface optimization with respect to 2G. It has meant basically a new radio interface based in CDMA technology, optimizing the resource management for wireless transmission of multimedia services, including thus packet data. However this radio transmission can still be described as circuit oriented, in the sense that there is a quasi-permanent allocation of logical resources (user identifier) in the idle transmission periods, although trying to minimize as much as possible the use of the scarce radio resources. The provision of mobile services over IP directly to the users is not tackled yet in current proposals.

An enhancement envisaged to the present 3G architectures turns around the so-called All-IP network. As this refers basically to a change to an All-IP Core Network, the present document will not study it in further details, the study of the Core Network being beyond the scope of the present document.

4.2 Packet data radio transmission

Packet data services typically exhibit highly bursty traffic patterns with relatively long periods of inactivity, demanding fast traffic channel allocation and de-allocation and high peak rate transmission during activity periods (e.g. for fast Internet access). This is in contrast to the classical circuit mode based voice and data services permitting a relatively slow connection set-up and release using a dedicated channel and continuous transmission at a constant data rate [1].

The solution adopted within 3GPP for an efficient use of the available capacity in a wideband CDMA system requires allocation of dedicated traffic and control channels at least on a temporary basis, rather than just connectionless packet switching. The use of dedicated control signalling channels allows for accurate adaptation of individual radio links to the varying propagation conditions. In the uplink, the allocation of dedicated channels guarantees transmission without the risk of collisions.

These channels are dynamically allocated on demand. If there is a high amount of data, dedicated traffic channels may be allocated. At the end of the activity period the radio resources are then released.

However, releasing dedicated channels and re-establishing them when new packet data arrives introduces latency and signalling overhead due to the re-negotiation process that has to take place between the network (BS) and the UE. 3G radio interface protocols therefore need to be highly sophisticated and flexible trading service quality with spectrum efficiency to meet the requirements of a future service profiles with its large variety of characteristics and requirements.

A different approach is pursued in HDR, where the operational mode is closer to TDM, in the sense that users are scheduled in different time slots, and CDM is used mainly to improve the frequency reuse. This, together with the absence of closed loop power control, allows for a simpler transmission scheme. In this case, the adaptation to radio channel characteristics is performed through rate adaptation, reducing the bit rate to users with worse channels.

In the following clauses, the various packet data transmission schemes as foreseen in two mainstream 3G radio interface candidate standards (3GPP FDD W-CDMA and cdma2000) are briefly described.

4.3 Packet Data Transmission in 3GPP "FDD W-CDMA" (IMT-DS)

Unless otherwise stated, the following description of packet data transmission refers to the 3GPP UTRA FFD mode Technical Specifications Release 1999 [2] to [5].

4.3.1 Transmission in connected mode

After power-on the UE enters the idle mode, where it searches, evaluates and selects a cell of its preferred network. A UE synchronized to the Broadcast Common Control CHannel (BCCH) is said to be "camped on a cell". The UE will then normally register its presence by means of a non-access stratum registration procedure. A Radio Network Temporary Identity (RNTI) which is unique within a Public Land Mobile Network (PLMN) is assigned to the UE to be used on common transport channels.

Being in idle mode, a hand portable UE normally "camps" in a discontinuous reception mode (DRX) in order to reduce its power consumption. When DRX is used, an UE needs only to monitor the Paging Indicator on the Page Indicator Channel (PICH) in one paging occasion per DRX cycle. The PICH is a physical channel (Layer 1 signalling) always associated with a Secondary-Common Control Physical CHannel (S-CCPCH) to which the Paging transport Channel (PCH) is mapped. The PICH actually allows support of power-efficient sleep (idle) mode procedures. To page an UE, the RNTI is actually broadcast using the PCH.

A UE stays in idle mode until an RRC connection is established, after which it enters into connected mode. the set-up of an RRC connection could be either network initiated or UE initiated depending of the origin of a service request.

Several states are defined in the connected mode with different level of activity to efficiently support packet data services of different traffic characteristics and QoS requirements. In addition, the concept of shared channels is employed to utilize statistical multiplexing to better exploit the available physical resources (spectrum, infrastructure hardware, power).

The basic way of operation of the Medium Access Control (MAC) in connected mode can be described as follows: The MAC transitions between the active state and a non-active state. By definition, dedicated physical channels are assigned to users only in the active state. These channels are torn down if the MAC transitions to a non-active state. If there is a burst of packet data in the buffer large enough to justify dedicated physical channels, then dedicated physical channels are set-up. In the downlink, there is the possibility to additionally use a special high capacity channel being shared by several users.

If no new data enters the packet buffer before the inactivity timer expires, the dedicated physical channels are ceased and MAC enters a non-active state. In this state and in the downlink, common transport channels can be used to transfer small or medium size data bursts not justifying assignment of dedicated channels. In the uplink, this is the random access channel or a special common packet channel. The choice of type of transport channel will depend on the packet size. The use of these uplink physical channels requires special provisions for collision detect and contention resolution.

These various methods used in the downlink and in the uplink for packet data transmission are briefly described in the following clauses. A more detailed description of the various physical channels is contained in annex A.

4.3.2 Packet data transmission in downlink direction

4.3.2.1 Downlink Shared CHannel (DSCH)

The 3GPP FDD mode standard foresees a special transport channel denoted Downlink Shared CHannel (DSCH) to support efficient and rapid packet data transfer on the downlink. The concept bases on the idea to allocate a high rate downlink channel that can be entirely used for sending high amount of data in a short time to a single user, rather than to allocate multiple low rate channels to multiple users for a long time. The main advantages of DSCH over a Dedicated CHannel (DCH) are:

- higher peak transfer rate to a single user;
- lower overall delay;
- fast access to physical resources;
- more efficient use of available resources (OVSF codes, power) thanks to statistical multiplexing;
- fast adaptation to varying channel conditions;
- no reliance on imperfect packet call admission control.

The DSCH is always accompanied by at least one (usually a two way) DCH per packet connection. The DSCH control channel shall carry control information such as resource allocation messages and L1 signalling (TPCI) to the UE for operating the DSCH when not associated with a DCH. Under certain conditions, the use of the DSCH control channels permits to send large bursts of data without a dedicated physical channel assignment. Thus, it can only be used in an active state of the connected mode. If high amount of data occurs exceeding the DCH capacity, the MAC layer may decide (based on priority) to use the high capacity DSCH for rapid delivery of packet data.

The DSCH is carried by the Physical Downlink Shared CHannel (PDSCH) and the associated DCH by the Dedicated Physical Channel. The frame structure of the associated DPCH is time aligned to the PDSCH frame structure. The concept of the DSCH assumes a UE receiver capable to process multiple code channels in parallel.

If the PDSCH is used for data transfer, then the main purpose of the DPCH is to exchange control information. This control information may be higher layer control information transmitted on the Dedicated Physical Data Channel (DPDCH) and/or Layer 1 signalling conveyed by the Dedicated Physical Control CHannel (DPCCH).

The PDSCH spreading factor may vary in the range from 256 to 4 on a frame-to-frame basis. The downlink DPCH indicates presence of traffic data to be decoded on a corresponding PDSCH frame as well as the PDSCH transport format (TFCI). Presence of data can be indicated either by the DPDCH (higher layer control) or by the DPCCH in the TFCI field. A two way DPCCH can also be used for fast transmit power control and rate adaptation purposes of the downlink PDSCH and the DPCH in both directions.

In 3GPP it has been proposed to use a minimum spreading factor of 8 for the PDSCH. For higher throughput, the DSCH may be mapped on multiple PDSCHs.

4.3.2.2 Forward Access Channel (FACH)

To deliver small and medium size packets to users in the non-active state, when there are no dedicated channels assigned, the MAC may decide to use the Forward Access Channel (FACH). This is a downlink transport channel that is also used for dedicated and common control purposes. The FACH is conveyed by the Secondary Common Control Physical CHannel (S-CCPCH). The S-CCPCH can support variable spreading factor in the range from 256 down to 4 and allows slow power control.

In the non-active state, occurrence of a packet on the FACH may be signalled in advance using the Page Indicator Channel (PICH). A UE will periodically listen on the PICH until it is alerted by the occurrence of its code sequence. This procedure avoids continuous decoding of the FACH and is therefore more economic.

4.3.3 Packet data transmission in uplink direction

The 3GPP UTRA FDD standard defines four different packet data transmission schemes for the uplink to be used in connected mode. The first two schemes use a common transport (random access) channel, whereas the last two approaches use a dedicated channel to transfer the user data.

At the end of this clause the concept of the Fast Uplink Signalling CHannel (FAUSCH) is also briefly described.

4.3.3.1 Slotted ALOHA using RACH

For the transfer of short data bursts (typically in the order of a few hundred bits) in the uplink, the Random Access transport CHannel (RACH) can be used by UEs. A frequent use of the RACH for the purpose of short packet data transfer would increase the risk of collisions. The 3GPP standard therefore defines a slotted ALOHA scheme with fast acquisition indication. Collisions are resolved in the MAC.

The RACH is mapped to the Physical Random Access CHannel (PRACH). A random access transmission consists of at least one preamble of length 4 096 chips followed by one (or optionally two) 10 ms long radio frame(s) containing the message part.

For the purpose of transmission of random access preambles, the time period of two radio frames (20 ms) is divided into 15 time slots each having a duration of 1,33 ms (= 5 120 chips). A User Equipement (UE), synchronized to the network, can start random access transmission at the beginning of any of these time offsets, denoted access slots.

The preamble part of the random access burst consists of 256 repetitions of a bi-polar signature of length 16 additionally scrambled by the long bi-polar scrambling sequence. The resulting scrambled sequence is transmitted using a π/2-QPSK spreading modulation to reduce the peak-to-average ratio. There are a total of 16 different signatures taken from the set of orthogonal Walsh-Hadamard-Codes. Thus, in theory, 16 UEs may simultaneously start preamble transmissions in the same access slots without risk of collision.

Multiple preamble transmission (access probe sequence) may be used by successively increasing the terminal power starting with an open loop power setting until the UTRAN (BS) responds on the Aquisition Indication Channel (AICH). In addition, access slots for preamble retransmissions are randomly selected from a set of available access slots to avoid persisting collisions of different random access transmissions started in the same access slot.

The AICH is also organized in time slots, denoted AICH access slots. There are 15 AICH access slots in 2 radio frames each of length 1,33 ms. The UTRAN responds on a successful preamble detection earliest 1,5 access slots (2 ms) later using a bit sequence corresponding to the signature of the PRACH preamble.

Between the beginning of the last preamble and the beginning of the message part there exists an idle period of predefined length (3 or 4 access slots). The 10 ms message part is split into 15 slots, each of length 2 560 chips. Each slot consists of a data part, carrying Layer 2 information and a control part carrying Layer 1 signalling information. Data part and control part of the PRACH are transmitted in parallel, in quadrature (I/Q) as well as code-multiplexed. Each control slot contains 8 pilot bits and 2 TFCI channel bits. The spreading factor of the control part is 256. A data slot contains 10 x 2^k bits, where k = 0, 1, 2, 3. This corresponds to a spreading factor of 256, 128, 64 and 32. The random access frame contains a protocol header of about 20 bit length including 16 bits for User Identification (UId). In case of highest spreading factor (lowest data rate) layer 2 data overhead is about 13 %. It is also possible to transmit a double radio frame long message part (20 ms).

The maximum bearer information rate provided by the RACH during its transmission period may be in the order of 40 kbit/s. The large amount of overhead per radio frame (or double radio frame) mainly due to the preamble part as well as the high collision risk indicates that it is not wise to transmit large amount of packet data via the RACH. Closed loop power control is also not possible. However, if packet frequency is low and packets are small, then the slotted ALOHA method using the RACH is adequate since it does not require signalling overhead for dedicated channel assignment.

4.3.3.2 Multiple Access with Collision Detection (MA-CD) using the Common Packet CHannel (CPCH)

To send larger packets without the need of a dedicated physical channel assignment, the 3GPP candidate standard provides an extra Common Packet CHannel (CPCH). For the purpose of the CPCH, the 3GPP candidate standard defines a two step contention based mechanism with multiple access preamble and a collision detection preamble transmission. The UTRAN (Node B) performs collision detection, fast acquisition and collision indication on the AICH. The access slot structure is identical to that of the RACH method.

The preamble of the Physical CPCH (PCPCH) consists of three parts:

- at least one access preamble of length 4 096 chips (as per PRACH);
- one collision detection preamble of length 4 096 chips;
- a power control preamble.

Between these three PCPCH preamble parts, there are idle periods of predefined lengths. Multiple access preamble transmission may be used by continuously increasing the UE power until the UTRAN (Node B) responses on the AICH. Upon reception of the Access Preamble AICH (AP-AICH), the contention resolution phase starts. The UE randomly selects a Collision Detection (CD) signature from the signature set as well as an access slot to transmit the CD preamble. Upon positive acknowledgement on the AICH (CD-AICH message), the UE starts power control preamble transmission a specified time after the CD preamble.

The power control preamble is immediately followed by N radio frames containing the message part. Each radio frame is divided into 15 slots, each consisting of a data part, carrying Layer 2 information and a control part that carries Layer 1 signalling information. The data and control parts are transmitted in parallel in quadrature (I/Q) as well as code-multiplexed. Each control slot contains 8 pilot bits and 2 TFCI bits. The spreading factor of the control part is 256. The data part contains 150 x 2^k bits, where k = 0...6.

The use of the PCPCH in the uplink requires assignment of an associated DPCCH on the downlink, mainly for power control purposes.

The main advantage compared to the first method (RACH) is the smaller overhead since the preamble sequence and Layer 2 header need to be sent only once in a composition of multiple radio frames. Moreover, better contention resolution and fast power control is possible on the PCPCH. However, there is still a certain risk of collision.

4.3.3.3 Single large packet using the Dedicated CHannel (DCH)

If the UE has to send a single large packet, the following mode may be applied: The UE first sends a request for a dedicated channel using the RACH. This RACH message contains also the size of the packet intended to be transmitted. If there is channel resource, the UTRAN (Node B) sends a channel assignment together with a transport format combination set and transmission start time of transmission to the UE via the FACH. The UE selects then a transport format combination from the offered set and starts transmission of the packet on the DCH. The DCH will be ceased immediately after the transmission of the packet.

Single packet transmission on DCH permits fast power control and rate adaptation.

4.3.3.4 Multiple-packet transmission using the Dedicated CHannel (DCH)

An initial random access procedure is applied to set up the DCH in the same way as described above. After the transmission of the first packet the dedicated channel will be maintained for a certain time by solely transmitting the DPCCH (MAC remains in the active state). If new packets arrive before the inactivity timer is elapsed, the UE either immediately starts transmission of these packets (in case of relatively short packets) or it requests further capacity via the DCH (in case there is large amount of data waiting in the packet buffer).

During the idling intervals between packets in the active state, link maintenance is performed by solely transmitting the DPCCH ensuring that the channel remains efficient in terms of power control, synchronization etc. for succeeding packet transmissions. Idling intervals can only have an integer number of frames. Rate adaptation is used for frames that are partially filled with data. If inactivity timer elapses before the arrival of new data in the packet buffer, the DPCCH is torn down and MAC enters the non-active state.

4.3.3.5 The Concept of the Fast Uplink Signalling CHannel (FAUSCH)

The concept of the FAUSCH is not part of the Release 1999 of the 3GPP UTRA Technical Specification. However, it is mentioned here as it provides insight into the different alternatives studied at 3GPP for the provision of shared channels, and as such, could be used for a satellite environment.

The Fast Uplink Signalling Channel is an alternative to the use of the RACH either for conveying a short packet or for the purpose of a dedicated physical channel set-up.

The proposal of the FAUSCH was motivated by the recognition that:

- the RACH has an inherent risk of collision;
- the overhead associated with the use of the RACH is significant, when only a small data burst is to be transmitted.

The FAUSCH concept offers a collision free signalling channel with low overhead most suitable for the transmission of small or medium sized packets (up to a few hundred bits). The FAUSCH can give significant advantages in performance, leading to higher system capacity. The fact that the FAUSCH is collision free gives improved reliability and reduced transmission delay, particularly with high system loading.

UEs requesting dedicated resources for packet data transmission on the uplink may transmit a short cell-specific code sequence (signature) at an assigned time offset relative to the BCH frame boundary on the downlink. This is in contrast to the RACH where at least one preamble and one radio frame containing the Uid have to be transmitted. Detection of a FAUSCH transmission by the Node B at a particular time offset with a particular signature permits unambiguous user identification. Upon detection of the FAUSCH transmission, the uplink resource is granted by the UTRAN on the FACH, and the packet transmission starts using the DCH.

The FAUSCH is an uplink dedicated control transport channel carried by the Physical FAUSCH (PFAUSCH). The PFAUSCH is based on the transmission of signatures of length 16 of the set of signatures used for the PRACH preamble in access slots assigned by the UTRAN to each UE. The PFAUSCH code sequences are identically composed to those used for the PRACH preambles.

Access slots are additionally subdivided into 20 subslots, denoted *fast access slots* (length 256 chips). Theoretically, there exist $15 \times 20 = 300$ time offsets at which a UE may be assigned to start a PFAUSCH transmission. To avoid the possibility of collisions, no two UEs are allowed to transmit with the same signature within the same fast access slot.

To avoid possible confusion of transmissions from different UEs using the same signature, the separation between allocations of fast access slots must be sufficient to account for largest round trip delay and multi-path excess delay, which may occur in a cell. Therefore, the allocation of fast access slots may be limited by the UTRAN.

A *fast access identifier*, comprising a unique combination of signature, access slot, and fast access slot number, may be assigned to the UE by the UTRAN when entering connected mode, but the assignment may be updated with appropriate signalling.

4.3.4 High speed downlink packet access

The transmission modes listed above have a maximum transmission speed of about 2 Mbit/s in the downlink. For Release 4 of the radio interface specifications new transmission modes have been studied which allow for a significantly higher throughput in the cell. These modes are not part yet of the specifications, pending detailed implementation complexity studies, but can however provide appropriate hints in order to optimize the satellite access.

The basic idea behind these high-speed techniques is the fullest possible exploitation of the channel to each user. It is well known that wireless channel suffers from fading, and that the link to each user depends in addition to their position in the cell. Traditional power control mechanisms, as applied to voice circuits, try to compensate these effects, by increasing the transmitted power for users in a fade and/or away from the cell centre. Somehow, efficient high-speed techniques follow the opposite approach. The specific speed per user is not expected to be a constant, but rather dependent on their instantaneous channel characteristics, including the position. It means, for instance, that users located close to the transmitting station will have a higher data rate than users in the periphery. Another possibility is that users are served with higher order modulations/higher rate codes during constructive fades, when the available signal-to-noise ratio is better, so that a higher data rate can be supported.

The basic technique in some sense follows the way shown by power control, that is, that transmission has to adapt to the specific channel conditions. But on the other hand, it performs the adaptations in the opposite way to that used with power control. Instead of equalizing the different user channels, so that all of them are set in foot of equality, their very differences are exploited in order to increase the total cell throughput. The total efficiency goes up by providing a higher data rate to "good" users. Some of these ideas can already be found in the downlink packet access for IS-95, HDR and are described in [6].

In particular, the work performed within 3GPP focuses on the following items [7]:

- adaptive modulation and coding. The principle behind it is to change the modulation and coding format in accordance with variations in the channel conditions, subject to system restrictions;

- hybrid ARQ. In this case, the measurement on the channel conditions is used for the re-transmission decisions, either in the transmitter or in the receiver. For instance, the re-transmitted packet can be a copy of the original one, but with more redundancy, decoded accordingly at the receiver, or only additional redundancy can be transmitted;.

- fast Cell Selection. The UE indicates which is the best cell which should serve it in the downlink, through uplink signalling. Of all the possible active cells, only one transmits at any time, potentially decreasing interference and increasing system capacity. This implies that soft hand-over use for packet access can have negative effects on the total capacity, as opposed to circuit-like transmission;

- multiple Input Multiple Output Antenna Processing. This processing uses several antennas both at the transmitter and the receiver, increasing the total throughput by code re-use among the different channels/antennas.

4.4 Packet Data Transmission in 3GPP2 "cdma2000" (IMT-MC)

4.4.1 Introduction

The 3G North American Standard TIA IS-2000.2, "cdma2000" [8], [9] provides several enhancements (compared to TIA/EIA-95-B) to handle packet data more efficiently in terms of capacity, data rates, inter-arrival time, UE battery autonomy, etc.

- A 5 ms framing (instead of 20 ms) for the Dedicated Control Channel (DCCH) permitting faster signalling.
- The use of common control channels in forward and reverse link for short packet data bursts.
- Packet data service handling by a special MAC layer function using a 4-state approach (Active State, Control Hold State, Suspended State, Dormant State) permitting fast activation and de-activation of traffic channels, QoS control, and UE battery saving (TIA/EIA-95-B uses a 2-state approach only).
- Supplemental code channel (SCH) to support variable rate transmission, assigned by the base station using the SCH assignment message (SCAM) on the downlink or requested by the UE through the SCH request message (SCRM) on the uplink.
- Channel quality feedback from UE to BS based on forward-link pilot receive quality measurements.
- Blind data rate detection in the mobile receiver (if supported) avoiding transmission of SCAM, saving radio resources.
- Single SCH with variable spreading factor (instead of multiple code channel as in TIA/EIA-95-B) and a minimum spreading factor 2 resulting in a peak data rate of 307,2 kbit/s in 1,2 MHz (614,4 kbit/s in 5 MHz option).
- Discontinuous DCCH transmission in Control Hold State to save UE battery.
- Slotted monitoring mode in Suspended and Dormant State.

4.4.2 Large data burst transmission

The cdma2000 terrestrial radio interface tries to reduce the latency and overhead, due to re-establishing the dedicated channels after a period of inactivity, by permitting the UE and the BS to save a set of state information after the initialization phase. This is controlled by a special MAC layer function, called Packet Data Radio MAC Physical Layer Independent Convergence Function (Packet PLICF), an instance individual for each registered packet data service. The Packet PLICF may change between 4 different states.

Upon request from a call origination with the packet data service option (if there is large amount of packet data to send) a packet data service-level registration will be established. A service negotiation will take place for channel resource assignment in both forward and reverse link handled by the MAC sublayer.

When no data transfer occurs for a predefined short period of inactivity (T_{active}), the traffic channels (*dtch*) are released, but the dedicated MAC channel control (*dmch_control*) remains allocated. This is called the Control Hold State. When no traffic occurs before the Hold Time (T_{hold}) expires, the forward and the *reverse dmch_control* are released. This state is called the Suspended State, in which the UE monitors the forward common MAC suspended channel control (*f-cmsch_control*) only. Being in the suspended state for a certain time, the UE is put into a slotted *f-cmsch_control* monitoring mode to save battery. If there is still no new traffic data arriving, the MAC protocol enters into the dormant state. The UE now monitors the forward common MAC dormant channel (*f-cmdch_control*) in a slotted mode.

During Control Hold, Suspended State, and Dormant State, the packet data service registration remains valid. The dormant state is left when new traffic arrives before the registration expires. Upon arrival of new traffic, the *dtch* are set-up rapidly based on the existing packet data registration. (The so-called Point-to-Point Protocol (PPP) state is remembered, but the Radio Link Protocol (RLP) must be re-initialized.)

For delay sensitive applications, fast access to a dedicated traffic channel is needed to satisfy QoS delay requirements. It may be necessary to provide the ability to transition from a power saving slotted mode of operation to the Active State very quickly. Since fast activation is possible from the Control Hold State, the "cdma2000" also defines an extra slotted mode substate in the Control Hold Sate. In this Slotted Substate, the pilot and power control channels are periodically enabled and disabled to provide a limited degree of power control while reducing UE power consumption.

Transmission at a basic fundamental code channel (FCH) data rate may be permitted immediately after packet data link establishment. Afterwards, a UE may request a supplemental channel for high rate data burst transmission via the SCRM. A SCH is granted based on demand, system load, and interference. This is called burst-level admission control. The network sends a SCAM to the UE indicating SCH assignment, the data burst length, and action time. Upon reception of the SCAM, the UE starts high-rate burst transmission using the FCH and SCH.

4.4.3 Short data burst transmission

Infrequent and Short Data Bursts (SDBs) generally associated with the packet data service are normally transmitted on a Common Channel such as the Forward Paging Channel (F-PCH), Forward/Reverse Common Control Channel (F/R-CCCH), the Reverse Access Channel (R-ACH). Sending an SDB on these common channels is identical to sending signalling information. This is to further reduce the overhead associated with channel assignment, becoming even more important when data bursts are small. SDB transmission may be used during the dormant state.

On the reverse link, the SDB transmission consists of a preamble followed by a message consistent with the slot structure and modulation parameters of the R-ACH or R-CCH. SDBs are acknowledged by the information receiving side via the F-PCH or F-CCH in case of reverse SDB transmission and via the R-ACH or R-CCCH in case of forward SDB transmission.

The R-ACH allows to transmit data at 9,6 kbit/s (optional 4,8 kbit/s) with a 20 ms frame size, while the R-CCH offers to transmit at a maximum of 38,4 kbit/s and with three different frame sizes (5, 10 and 20 ms).

The R-ACH and R-CCH are multiple-access channels as UEs transmit without explicit authorization by the network (BS). A slotted ALOHA type of mechanism is used for both reverse link common control channels.

The RACH or R-CCH message may be preceded by a sequence of preambles with increasing transmit power (access probe sequence). The first probe of a sequence is transmitted at a power level based on open loop power control. Transmit power is then successively increased until an acknowledgement is received from the network.

In addition a random time period is selected between consecutive preambles to avoid persisting collision, in case there are many UEs starting their access transmissions in the same access slot.

4.5 Comparison with Second Generation Systems

4.5.1 Introduction

In order to guarantee compatibility with second-generation systems, and to ease the deployment, the new packet-oriented features have been created mainly as enhancement of already existing second-generation voice capabilities. This new set of features can be grouped into two major lines, namely at the physical layer (Layer 1) and at the MAC sub-layer (Layer 2) [9].

At the physical layer, shared packet data channels are introduced. Their main advantages are:

1) They allow for higher peak data rates, compared to fixed-rate circuits, as the data rate assignment can be done on a frame-by-frame basis, allowing for a faster reaction to changes in the channel. This increased flexibility leads to a better sharing of resources.

2) A shared channel allows for efficient access to a large data pipe, which means that high priority packets can be served first, improving the overall QoS. With DCH, high priority packets may have to wait for the release of a DCH, if there is no one free.

For the downlink, a shared channel provides an efficient method of sharing access to the limited number of downlink codes.

Additionally, at Layer 1, low rate control channels, specifically 7,5 kbit/s in the downlink and 15 kbit/s in the uplink, are extensively used. They carry the necessary information for channel measurements, fast power control and indicate the changes in frame-to-frame transmission characteristics (coding, data rates, etc.).

At the MAC sub-layer, the main aim is to allow fast acquisition and release of resources, both at the beginning of a transmission and during the inactivity periods. To do so, a new mobile dormant state (with no data transfer) is created, during which the use of the air interface is reduced. Procedures are then designed for fast re-activation from this dormant state to active data transfer. This line is elaborated with some detail in the cdma2000 proposal.

4.5.2 Shared channels

In the 3GPP terrestrial system the proposed common channels are [2] to [5]:

1) Downlink Shared Channel (DSCH).

2) Uplink Common Packet Channel (CPCH), for FDD mode.

3) Uplink Shared Channel (USCH), for TDD mode.

The DSCH is proposed as an efficient means of sharing code and power resources in the downlink. Scheduling of data packets is done at MAC level in the UTRAN. Its operation is similar to a multi-code transmission, in the sense that several channels (codes) are transmitted in parallel, with the difference that the control channel is not shared between the different users. Within 3GPP RAN WG1, it was shown that a shared downlink control channel is less efficient in power terms than several control DCH, one for each UE, as it would need one order of magnitude more power to control the DSCH, so there is one control channel for each transmission. For each active UE, there is an associated dedicated control channel in the uplink, used to carry power control commands.

The CPCH is a contention-based acquisition, contention-free transmission channel. The UE acquires the channel through a Slotted ALOHA procedure, similarly to the RACH access. This is followed by a collision detection part, whose aim is to prevent simultaneous access to the same channel (code) by more than one user. The overall procedure resembles a CSMA-CD multiple access channel method, with the first access preambles playing the role of carrier sensing, and with a second part of collision detection. Once the eventual collision has been solved, and the channel is available for the user, the packet transmission starts immediately afterwards, for a number of 10 ms frames, up to a maximum of N (operator dependent). A simultaneous dedicated downlink channel is used for power control purposes.

The USCH allows sharing of the power resources by the users, with a granularity in the assignment and re-assignment of power to the users every frame (10 ms). A common downlink control is used, broadcast continuously to carry the uplink power control bits. It requires a sharp synchronization between the UEs in the uplink, so it is more appropriate for the TDD mode in the terrestrial system.

In addition to these shared channels, a basic packet transmission through a circuit is also possible. This calls for the establishment of connections, the so-called Dedicated Channels, both in down- and uplink. The resource assignment operations can be made either at level 3 (RRC) or at level 2 (MAC). Whereas originally the use of level 3 was considered, as for voice circuits, the advantages of MAC-controlled scheduling becomes evident as soon as we take into account the involved delays, which are significantly lower for MAC operation (tens of ms, compared to hundreds of ms). Scheduling performed at level MAC allows for much faster set-up and release of circuits, as well as adaptation to changes in the environment, or for that purpose in the used data rate.

If DCH are used to support packet data services, they are established at each activity period with a given TFCS chosen by the RRC in the RNC, which corresponds to a given maximum transmission bit rate. The TFCS may then be further controlled through RRC procedures in order to adapt the transmission bit rate to the network load conditions.

4.5.3 MAC enhancements

In IS-95 Revision B a packet data service is proposed. During a packet data call, if there is no data transfer during a period long enough for the inactivity timer to expire, the air interfaces resources are released. This is the transition between active and dormant states. When new data arrive, the air interface resources must be re-initialized, but the data registration is already established. This means that the Point-to-Point Protocol (PPP) state is remembered, but the Radio Link Protocol (RLP) is to be re-initialized.

In cdma2000, two additional MAC states are defined for fast access and set-ups with efficient air interface usage. The control/hold state includes an assigned control DCH with possible discontinuous transmission in this control DCH; this channel allows for quick access to the traffic channels and faster activation. In suspended state, no air interface channels are assigned, but the RLP state is remembered to avoid delays during re-initialization.

In annex C a procedure to set up a connection for rapid data transfer is explained, as found in the current 3GPP specifications. It explains the signalling in the common channels (RACH and FACH) and the timing relations between these common channels and the dedicated transport channels (DSCH and DCH). Annex C describes the procedures suggested in the current 3GPP specifications in order to allow for rapid data transfer. They are based in a fast switching between active and hold states, as explained above. However, their direct applicability to satellite systems need prior careful considerations about the slotted character of the RACH/FACH access procedure (not directly applicable in S-UMTS), and the larger delays involved in the transmission, which are likely to change the values of the different timing parameters. All the values subsequently cited are directly extracted from the T-UMTS standard, are should be taken only as indicative figures for T-UMTS.

5 Packet and Circuit Modes of Operation

5.1 Introduction

In this clause, the capacity ratio of the over-the-air packet-transfer mode over circuit-transfer mode is derived. The main factors that determine the capacity ratio and which transfer mode should be selected are:

- Radio protocol efficiency in packet transfer mode.
- Duty cycle of the packet traffic source.
- Mean packet length and bit rate.
- Channel set-up time, release time, and inactivity timer in circuit transfer mode.

The trunking efficiency, that is, the loss in capacity due to the finite number of resources, which will cause the loss of some calls, has not been condidered. For not very low capacity systems, in the order of at least tens of circuits, this factor can be taken as about 0,5. For small capacities, 1 to 10, the efficiency would be further reduced, down to 0,05.

5.2 Numerical analysis

More concretely, the following parameters impact the capacity ratio:

- call set-up time, the end-to-end call set-up time. However, portion of this time that corresponds to the traffic channel idle time is the time of interest in this analysis;
- call release time, the time it takes to release the Radio Link channel after the release message is generated in either end;
- inactivity timer, the time it takes to release the channel if the link is inactive in that time period;
- average message length (L);
- bit Rate (f_b);
- radio Channel efficiency (γ);
- radio Common Access Protocol efficiency (φ);
- duty Cycle (α).

We start with the calculation of the average call duration time in circuit mode transmission. For L kbytes of data operating at f_b kbit/s, this time is:

$$T_{average\text{-}call\text{-}duration} = T_{inactivity} + T_{Set\text{-}up} + T_{release} + 8\,L/(\alpha\,\gamma\,f_b)$$

Of this time, the real over-the-air time is $T_{over\text{-}the\text{-}air} = 8\,L/(\gamma\,f_b)$, so we can define a circuit mode inefficiency factor due to radio channel inactivity:

$$F_{circuit\text{-}mode\ (channel\ inactivity\ inefficiency)} = T_{Over\text{-}the\text{-}air}/T_{average\text{-}call\text{-}duration}$$

An additional factor due to the trunking inefficiency $F_{circuit\text{-}mode\ (trunking\ inefficiency)}$ (of value about 0,5) needs to be included to estimate the global circuit mode inefficiency factor.

If the resource is shared between the users, then the only source of inefficiency is the shared access protocol inefficiency factor ($F_{protocol\ inefficiency}$). Then the packet mode inefficiency factor is:

$$F_{packet\text{-}mode} = \gamma\,F_{protocol\text{-}inefficiency}$$

It is now straightforward to calculate now the efficiency ratio for circuit and packet mode:

$$R = \gamma\,F_{protocol\ inefficiency}/(F_{circuit\text{-}mode\ (channel\ inactivity\ inefficiency)}\,F_{circuit\text{-}mode\ (trunking\ inefficiency)})$$

In particular, we have evaluated this equation for the following bit rates: 64 kbit/s, 144 kbit/s and 384 kbit/s. The following other parameters apply:

- duty cycle is 100 %;
- packet length = Variable;
- channel inactivity time = $T_{inactivity} + T_{set\text{-}up} + T_{release}$ = {50 ms, 500 ms, 1 s};
- $F_{protocol\ inefficiency} = 7$.

Figure 1 shows the result of the analysis for 64 kbit/s, 144 kbit/s and 384 kbit/s. The main conclusion of this analysis is that two major factors impact the capacity ratio: channel inactivity time and packet length. Additionally trunking inefficiency would become an issue for higher data rates (up to 2 048 Mbit/s). The impact of duty cycle is neglected in these plots. As the traffic load increases on RACH, the channel set-up time increases and the use of circuit switching becomes less efficient for packet data services. Even if the channel inactivity time was not an issue, the trunking inefficiency of 5 MHz system for high data rate services could cause a floor for capacity ratio between the packet and circuit transfer modes.

This simple model allows us to:

- assess the efficiency of RACH-like channels for short packet transmission;
- study the influence of channel hold-up time, which includes the propagation delay, and thus the effect of the different constellation possibilities (LEO, MEO, GEO);
- verify that for low data rates the loss in capacity is smaller than for higher data rates.

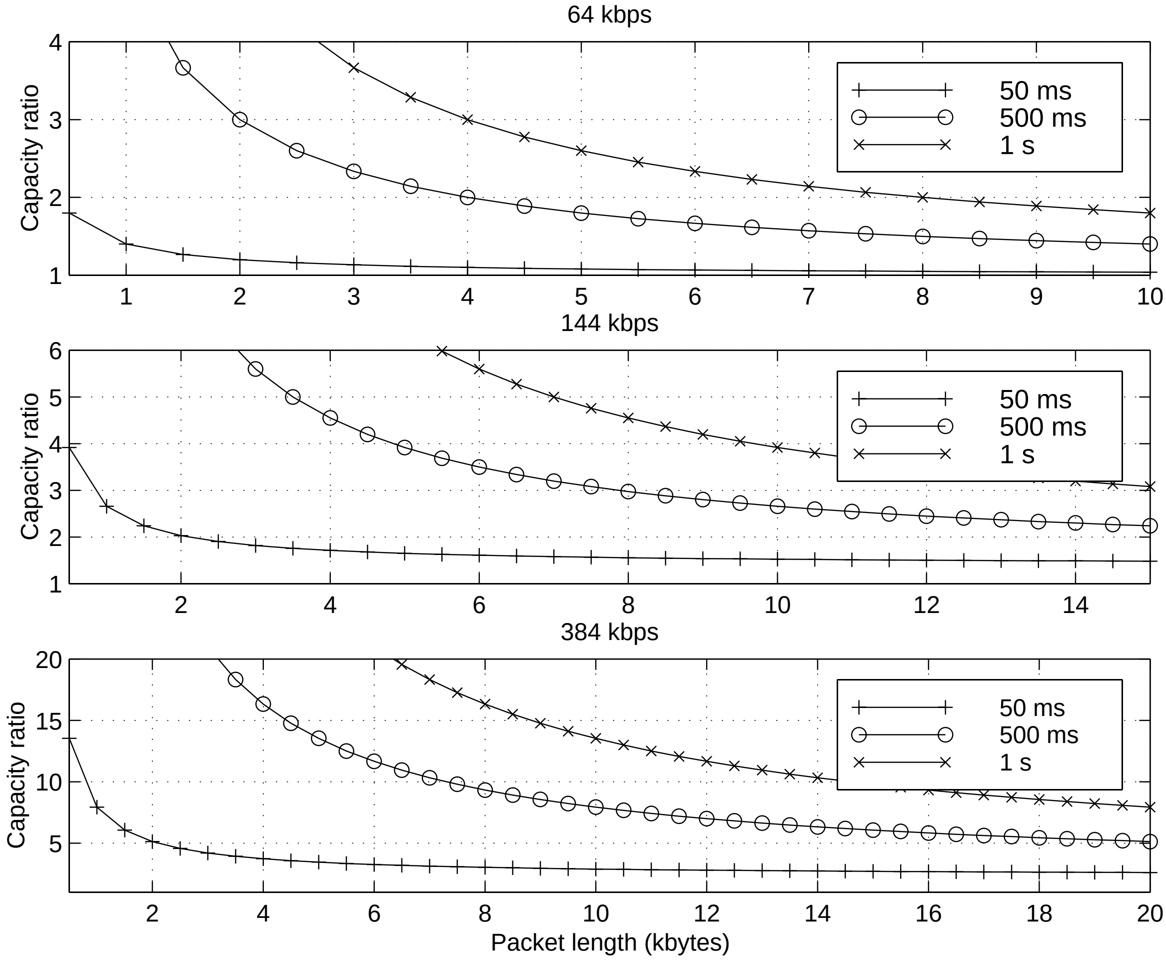

Figure 1: Capacity ratio versus Packet length

5.3 Conclusions

The conclusions we have reached can be summarized as:

1) When the sum of set-up time, release time and channel inactivity time is equal or higher than the over-the-air message transfer time, packet transfer mode is more efficient.

2) When the sum of set-up time, release time and channel inactivity timer is less than the over-the-air message transfer time, and the duty cycle is 100 %, circuit mode transfer is more efficient.

3) When the sum of set-up time, release time and channel inactivity timer is less than the over-the-air message transfer time, and the duty cycle is 100 %, circuit mode transfer is more efficient.

These results can be used as a guideline for the switch between MAC states indicated in clause 4.3, describing the different transmission states, depending on the packet length. They provide a rule of thumb on the cases in which it is more convenient to set up a permanent channel connection, and the cases where a pure packet-like access uses resources more efficiently.

6 Applicability of UMTS Terrestrial Techniques to a Satellite-based Environment

The present clause analyses the applicability on the satellite component of UMTS/IMT2000 of the packet mode operation defined within 3GPP's Release 1999 of the terrestrial UMTS UTRAN FDD-mode at air interface level (layers 1 and 2), as described in clause 4.

6.1 General overview of packet data transmission over satellite

The methods currently considered in terrestrial FDD mode W-CDMA candidate standards to enhance efficiency of packet-oriented data transmission may be briefly summarized as follows:

- introduction of a shared channel (fat pipe) with MAC scheduling in the forward link;
- quick allocation, adaptation and de-allocation of traffic channels using lean control procedures introducing minimum signalling overhead and delay;
- introduction of a multi-state MAC function in connected mode (active, control hold, and dormant state);
- use of common channels (PRACH, CPCH) with contention-based access control mechanism in the return-link.

As already mentioned in clause 4, a fast access to large amount of physical resources (fat pipes), when required, is a key issue for efficient handling of packet data with short inter-arrival times and high peak transfer rates to single users.

Moreover, the efficient use of an FDD mode W-CDMA technology requires smart scheduling and multiplexing of packet data burst transmissions to make best use of statistical multiplexing and to keep composite interference uniformly distributed as ever possible. Low fluctuation of the sum interference level (intra-cell as well as inter-cell) is of vital importance in a W-CDMA system especially with respect to real-time services requiring high QoS or to conventional constant rate connection-oriented voice and data services. Nevertheless, future 3G W-CDMA systems will have to cope with a generally more bursty interference environment.

A relevant aspect, when considering packet data transmission over satellites, is the propagation delay. Typical values for propagation delay are in the order of 50 ms for a LEO satellite, rising to about 250 ms in case a GEO satellite is used. A large round trip delay affects two-way control.

The increased delay of feedback information such as needed for transmit power control and data rate control (transport format indication) makes it more difficult for a satellite system to adapt to rapidly changing propagation conditions and traffic needs. As experienced in terrestrial systems, in scenarios dominated by packet-mode traffic transmitted at high peak rates, interference is expected to be highly bursty (abruptly changing) demanding fast and accurate power control. The use of a high capacity shared forward-link channel (fat pipe) implies a relatively small number of users that are simultaneously served, thus, individual power control errors will have strong impact on system capacity and stability (less averaging effect). Possible solutions include the use of higher link margins and the use of adaptive data rates.

On the other hand, a satellite system is able to support high data rates more uniformly across the coverage area. This is in contrast to terrestrial cellular networks, where only the users located near the base station provide high link margins and therefore have the potential to transmit at extremely high data rates with limited terminal power.

The mobile satellite channel model presented in [10] describes the channel basically as a two-state one, depending on the link availability. Due to blockage (buildings, trees), the effective channel switches between an "on" state, with Rician fading and log-normal shadowing, and an "off" state, in which no signal is present. These considerations are also to be taken into account in the scheduling algorithm, and in the power and data rate control.

Furthermore, a large round trip delay may lead to large data transfer delays if retransmission schemes (ARQ) are employed. The application of ARQ is quite usual for packet-oriented services. In real-time services (e.g. VoIP), such delays may lead to unacceptably low QoS. This effect could somewhat be limited by using some flavour of Hybrid ARQ, as used for High Speed Downlink Access (see clause 4.3.4). Another possibility is avoiding ARQ altogether, by using a better channel protection.

In a satellite environment, the delay spread between users is larger than in a terrestrial mobile one. Within a beam, and taking into account the relatively small beam dimensions, this might be not a serious problem; but from a global system point of view, there will be huge differences in delay between different users, depending on their position, and this difference will change with the satellite motion. For discontinuous packet transmission, this causes a larger range of uncertainty in the expected time of arrival of packets.

The overall system synchronization is a more complex problem for a satellite system compared to a terrestrial one, and especially for a LEO constellation. When added to the previous point on delay spread, it makes the use of slotted access protocols, such as Slotted ALOHA, more difficult. Slotted ALOHA is preferred for the channel efficiency, as non-slotted access schemes are less efficient than slotted methods.

The power ramp-up procedures envisaged for RACH are less efficient for the satellite system due to the longer feedback delay. This means that power is more likely to be wasted and that one-shot acquisition procedures should be employed, in which no feed-back is used, and acquisition is expected with the initial transmitting power.

The large round trip delay considerably increases time to set-up and release dedicated physical channels. It seems that longer inactivity periods (in which control channels are solely transmitted) must be therefore chosen in satellite systems. This can lead to lower efficiency, decreasing battery life in UEs.

For S-UMTS systems, handheld terminals are expected to have a lower achievable data rate than vehicular or fixed terminals. This is due to the terminal power limitation. Although, typical Internet usage does not need a fast return-link, the return-link peak data rate may become an issue in some future applications. In contrast to terrestrial networks, mobile satellite systems are compelled to operate with low link margins at any point in a coverage area.

6.2 Applicability of terrestrial packet transmission techniques to a satellite network

In clause 5 it was shown that the inefficiencies of circuit-mode transmission with respect to packet-mode are not large for the proposed data rates, so that a first basic mode of operation based on the use of dedicated channels would be not as inefficient as in a terrestrial case. This mode can thus be directly used with satellite systems. If however, concerns on low efficiency should remain, a discontinuous transmission scheme could be adopted. In this case, the timing description in Annex C should be adapted to the satellite system, mainly in order to cope with two problems, namely the overall synchronization and the involved delays.

In the downlink, the packet mode suggested for terrestrial systems, that is, the DSCH, is probably directly applicable to satellite-based networks. It is very close to a multi-code mode, with several control channels. Its functionality is very similar to that of the DCH, so no particular problems, different from those in normal DCH transmission, are expected. A possible enhancement, parallel to that one taking place in the terrestrial systems, is to drop altogether the power control closed loop, and use instead the channel and traffic measurements in order to schedule the various users.

One point of concern is the larger delays involved in satellite transmission, which could render acquisition and re-acquisition costly. Similarly, the associated control channels might be too costly for modest peak rates, in terms of consumed resources (power and codes).

Similarly, the FACH can be directly mapped from terrestrial systems.

The major differences appear in the uplink packet mode. Both pure ALOHA RACH and CPCH need careful thinking before application to satellite. A simple change is moving from ALOHA to Slotted ALOHA, thus relaxing the synchronization requirements. Again, the main problems seen are in the slotted characteristics, in the larger cell size (which leads to a higher spread in propagation delays) and in the larger propagation delays.

First of all, the acquisition procedure is radically different for satellite. The longer feedback delay probably make ARQ scheme less efficient, so the acquisition is to be guaranteed purely by means of power, with the consequent less optimal resource assignation.

In RACH and CPCH access is done by means of a slotted structure, which helps synchronizing the down- and the uplink. The downlink carries acquisition indicators in the Acquisition Indication Channel (AICH), and there is a one-to-one correspondence between the downlink slots and their corresponding uplink slots. Due to the larger cell size, this correspondence is expected to be more difficult, or at least require some extra signalling. Additionally, there would possibly be a larger delay between any uplink slot and its corresponding downlink one. The overall procedure is very much TDMA-like, and this is difficult to replicate with a LEO satellite constellation.

7 Packet Data Transmission in S-UMTS-A

The packet mode described in this clause is based on the work done for Release 1 of S-UMTS-A. Further studies are on-going and the present document is expected to be updated in order to reflect the outputs of this work.

7.1 High level description

The current release of S-UMTS-A specifications [11] to [14] has been created as a modification to present terrestrial standards, taking into account the particular satellite environment, and notably the points raised in clause 6. The proposed S-UMTS-A procedures are then very close to the terrestrial mode, at least for the downlink. Specifically, the main adaptation has been done in the downlink transmission, with the uplink schemes still open for future developments.

Packet data transmission in the downlink is carried mainly through the Downlink Shared Channel (DSCH), a common channel intended to share downlink code and power resources by the different UE. No major changes are expected, as the downlink satellite environment is not very different from the terrestrial one, apart from a larger propagation and feed-back delays, and the different data rates envisaged. As in T-UMTS, two control channels, one up- and one downlink, are set; each pair controlling a downlink transmission. The resource management is done centrally in the URAN, in a frame-by-frame basis, to take into account possible channel changes. This channel variations include fading, shadowing and blockages.

The deviations from T-UMTS do not stem from general differences, but more exactly from the procedures in acquisition and transmission. As these mechanisms have not been specified yet in the available 3GPP documents (they concern implementation issues), it is in these concrete procedures that we expect the most significant differences, but, as stated before, mainly in the detailed implementation level.

For small packets, transmission in the FACH and the RACH is also possible, as it is done in terrestrial UMTS.

And additionally a transmission by means of a circuit (dedicated channel) is a possibility, particularly for the low data-rate case, where the inefficiency of circuit transmission as compared to packet is small.

Concerning the uplink, the current state is much less mature. The direct use of terrestrial (RACH, CPCH) channels does not appear feasible, as hinted in clause 6. Anyhow, at least a RACH model has been included, which basically uses the terrestrial skeleton, with some differences in MAC level (no Slotted ALOHA, no Acquisition Indicator channel, different timings) and at physical level (acquisition). In order to ease acquisition, the power ramp-up procedure in T-UMTS is replaced by a one-shot acquisition period. Only one preamble is to be sent, at a power defined by the open loop power estimate, which will allow for immediate acquisition. Its duration is correspondingly longer than in T-UMTS, and is provisionally set at about 10 ms.

At present time, lacking an equivalent to CPCH, the only envisaged transmission scheme for packet data is the establishment of a permanent circuit (DCH) in the uplink.

Concerning the MAC and RLC procedures, the same protocol specification, as defined by 3GPP, is to be applied in S-UMTS-A. This means that the exact protocol is operator and system dependent, with only the general framework specified. There are some open activities on the development of general guidelines on how to schedule different users, and to share the radio and logical resources between them. They follow the general approach of deriving from 3GPP, by maximizing the commonalities.

7.2 Packet data transmission in forward-link direction

7.2.1 Downlink Shared CHannel (DSCH)

The allocation of the DSCH resource needs one-way control only and can be entirely managed by the gateway. It therefore appears that the concept of a shared forward-link channel with high capacity (fat pipe) can be adopted for S-UMTS.

Low spreading factor codes, requiring less complex UE receivers, may be used for the DSCH in satellite channels since propagation delay spread typically is smaller than in terrestrial channels.

Concerning the high-capacity DSCH, there are two alternative streams of thought. On the one hand, it is believed that the use of a high-capacity DSCH needs accurate power control as well as a good link budget avoiding excessive power (mainly in high system loading conditions). This is to maintain inter-beam/satellite interference levels as low as possible. This may lead to the solution that users with fast or strong fading/shadowing should not be served via the DSCH. The DSCH will be subject to those users without fading as it is normally the case for non-shadowed fixed or quasi-stationary operation with satellites at higher elevation angles. But on the other hand, especially by taking into account the experience from terrestrial wireless networks, power control is sometimes dropped altogether, and the very differences in channel conditions and data traffic among the users are exploited, serving only the users with better likelihood of using up the channel capacity. This is expected to be introduced in future releases of the specifications.

The high peak power needed for a high capacity DSCH should not impose any particular problems, since on-board power resources are shared. Actually, it is irrelevant whether beam/satellite power is allocated to a high number or a small number of simultaneous forward-link channels. This is in contrast to the return-link where maximum data rates are limited by the peak power available in a UE.

7.2.2 Forward Access CHannel (FACH)

The principle of using the FACH for transmission of short data bursts, when there is no available dedicated channel, can be also retained for S-UMTS. The FACH allows slow power control, which may be provided in a satellite system with large round trip delay.

UEs in non-active connected-mode are alerted by the PICH to listen on the FACH in order to save battery.

7.3 Packet data transmission in return-link direction

7.3.1 Short packet transmission using slotted ALOHA, RACH and CPCH

The adoption of the 3GPP slotted ALOHA random access scheme with 15 access slots per two radio frames for the S-UMTS is not directly applicable. Nevertheless, a slotted structure may help to easily determine the round trip delay in the gateway. A reasonable approach for S-UMTS could be the definition of one access slot per radio frame. This would allow to unambiguously determine the round trip delay in a LEO satellite system with a high number of spot beams (> 30).

Concerning the preamble preceding the PRACH burst, it is felt that a longer preamble sequence period would be needed than the length 16 codes as specified in 3GPP to reduce collision probability.

Multiple preamble transmission (access probing) by successively increasing UE power as well as fast access and collision detection indication on the forward-link are certainly not feasible in a satellite system. All these methods require immediate response by the network, which cannot be provided when there is a large propagation delay.

Since random access transmission via the RACH is based on open loop power control, sufficient power margin has to be taken into account for reliable reception. Moreover, satellite path diversity will be difficult to exploit for short data burst transmissions. This in turn increases the potential of causing interference. Since there is also no collision detection indication, the RACH and especially the Common Packet Channel (CPCH) have to be used with caution.

7.3.2 Packet transmission using the Dedicated CHannel (DCH)

The use of dedicated physical channels with control hold mode during inactivity periods seems to be a reasonable solution for packet data transmission in S-UMTS. In the forward-link, rapid packet delivery can be supported by additionally assigning resources on a high capacity DSCH. In this case the dedicated physical channel is mainly used for control purposes (Layer 1 and 2).

A Layer 3 connection is established at the beginning of a packet session. During a session the connection may be in at least three different states:

- an active state in which packet data is transferred;
- a non-active control hold state in which DPCCH are solely allocated for link maintenance (power control, synchronization tracking);
- a non-active suspended or dormant state in which control data (DPCCH) is transmitted in an intermittent mode (slotted control mode permitting at least a low grade link maintenance by saving energy) or complete transmission silence, respectively. (The slotted control mode will need highly sophisticated synchronization tracking techniques in the LES).

The connection enters the non-active suspended or dormant state after the inactivity timer is elapsed.

Figure 2 shows an example (possibility) how to transmit a large data burst via a dedicated channel in connected mode in the Return-Link (RL). It is further assumed that the UE location is covered by spot beams of two different satellites, thus permitting the exploitation of macro path diversity. The depicted procedure is described in the following steps:

1) The UE requests a dedicated physical channel allocation by transmitting a random access burst to the satellite best received. The random access burst is preceded by a preamble. The data part of the random access burst contains the UId, the resource request, and a measurement report indicating forward-link (FL) reception quality also for the co-coverage satellite.
2) Upon successful reception of the random access burst, the gateway responds via the FACH with a dedicated channel assignment, indicating start time of RL transmission, support of a co-coverage satellite and the dedicated FL channel allocation there-on.
3) The gateway commands two dedicated channel receivers on each satellite which are waiting for the arrival of a preamble indicating start of the RL traffic data.
4) The gateway immediately sets-up a dedicated control channel on the FL of both satellites to send power control commands to the UE.
5) The UE starts traffic data transmission with a preceding preamble to enable more reliable synchronization acquisition at both receivers.
6) After successful reception of preambles, the gateway demodulates traffic and control data on each receiver and combines symbols according maximal ratio combining principles.
7) After a certain time, the gateway may decide to increase RL data rate and a Traffic Format Change (TFC-C) is sent to the UE using a FACH. Upon reception, the UE increases transmission speed as well as power. This is also indicated in the TFCI field of the RL-DPCCH.
8) Having successfully received a number of packets, the gateway sends a Layer 3 ACKnowledgement (ACK).
9) The UE stops transmission, since its packet buffer is empty.
10) The gateway sends a selective REPeat ReQuest (REP-RQ) as well as a TFC-C indicating a lower rate, since some data was found to be corrupted.
11) The UE repeats the requested data frames and enters the control hold state waiting for new packet data or for expiry of the inactivity timer.
12) After having successfully received the retransmitted data, the gateway enters in the control-hold mode and stays in this state until the inactivity timer expires.
13) After the inactivity timer has expired, the connection enters the dormant state.

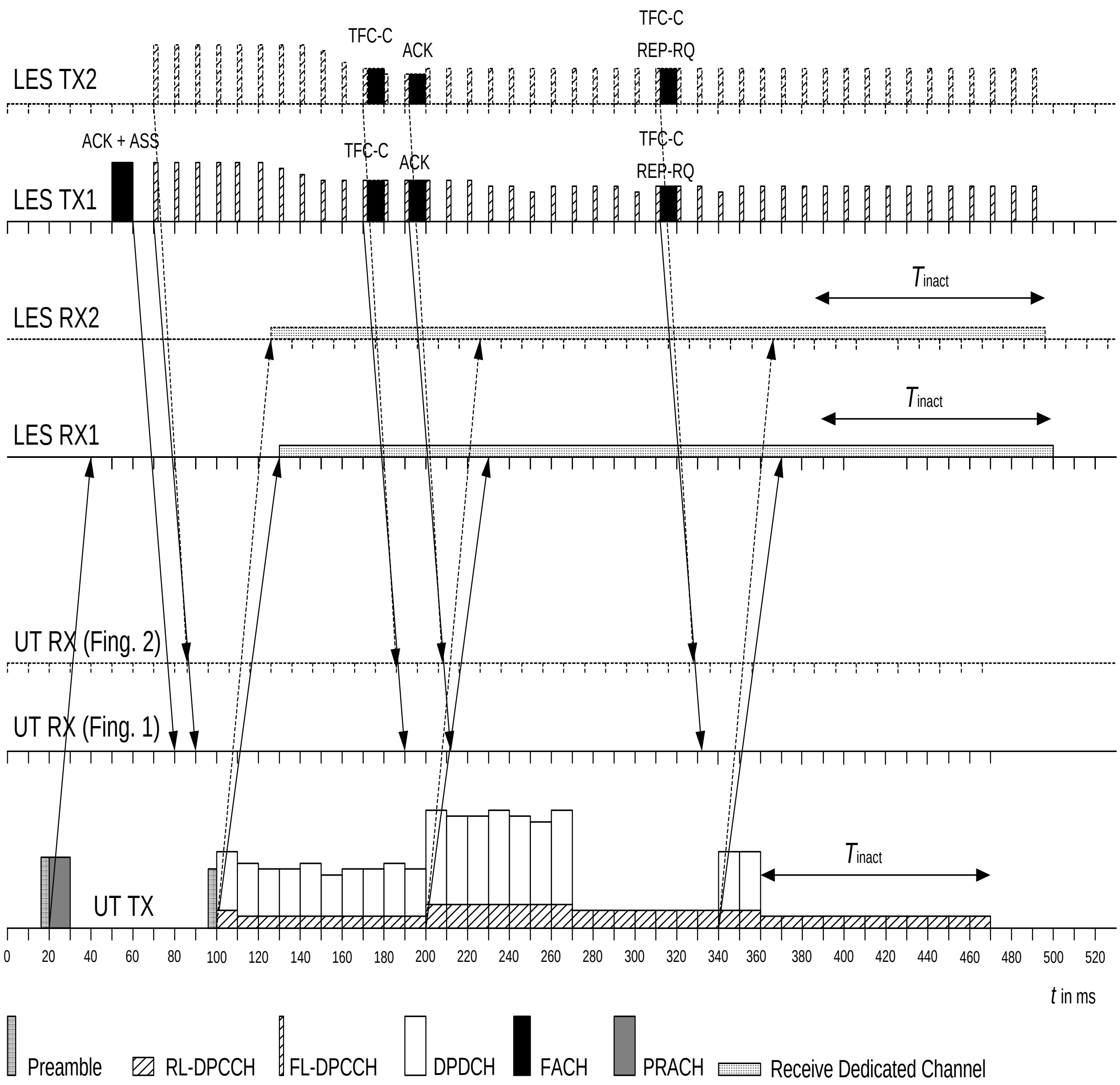

Figure 2: Data transmission in the return link between the UE (UT) and Gateways (LES)

8 Open Issues for Future Studies

This clause summarizes the main areas in the field of packet data transmission for mobile satellite systems identified during the study. It is intended to be a guideline for future research activities, which would set some of the open questions. Additionally, this list should also be helpful to system developers as it identifies a few key points needing still further clarification.

The major open issues identified so far concern the physical radio transmission aspects and link level performance, (MAC/RLC protocol optimization). Important aspects about the Core Network (e.g. all-IP core network) are beyond the scope of the present document, however important they are for the general topic of data transmission. These points are listed here below:

1) Detailed assessment of the proposed packet mode (with temporary resource release during idle periods), extending the model in clause 5 to burst-like traffic.

2) Quantitative study of the overall effect of uplink delay spread between different users/paths/channels. This impacts the system dimensioning and the user performance.

3) Efficiency improvement of (permanent) control channels for low data-rate packet transmission. Estimation of the gain/loss in code and/or power due to the quasi-continuous transmission of a dedicated control channel for transmission. This might eventually lead to the dropping of these channels, if it can be shown that the system can work with negligible losses without them. In order to study this point, an accurate mobile satellite channel model is necessary.

4) Downlink shared channel timing parameters (for fast re-acquisition after an idle state) optimization, and in general, methods for quick channel acquisition. This assumes a burst-like mode of operation, for instance, if in point 3 it is decided that no continuous control channels are transmitted.

5) Study of the channel impairments effect, and of possible ways to exploit them in a similar way to that done for HDR [6] or High Speed DL Packet Access [7]. This might lead, for instance, to abandon the power control mechanism altogether, and assign the different users a data rate proportional to the channel quality. A clear example is not to transmit to users known to be in blockage, and divert those resources to other users. However simple it might seem, the effect of channel measurement errors needs to be measured.

6) RACH mode is quite different in T-UMTS and S-UMTS-A, both at MAC level and at physical level, mainly in the acquisition procedure. A detailed performance assessment should be done. However preliminary results mentioned in clause 5 seem to indicate that this loss is not significant.

7) Study efficient ways of using Slotted ALOHA, particularly for a GEO environment.

8) In uplink transmission mode, an alternative to CPCH may be needed, and the RACH implementation needs some refinement. The final user is likely to need a large enough (e.g. higher than 16 kbit/s) data rate in the uplink.

9) Hand-over procedures are missing, and generally speaking, the impact of mobility (including satellite mobility) is still to be done. This has also a big impact on the core network integration, and both aspects should rather be studied together.

10) Single-hop procedures should be studied. This has impacts both on the air interface and on the core network integration.

11) Methods to cope with satellite path diversity, both for acquisition and, if possible, to combine packets. Or alternatively, if shown a better alternative, quantify the improvement in total throughput by having a single signal transmission, similar to Fast Cell Selection in 3GPP.

12) A guideline in the RLC/MAC protocol parameter fine-tuning should be provided. Some indications on how to schedule the different users depending on the total traffic and the user channel conditions are important. This point is closely related to most of the others mentioned above, and gives them a general name.

Annex A: Physical Channels used for Data transmission (3GPP - FDD W-CDMA)

A.1 Forward Access CHannel (FACH)

The Forward Access CHannel (FACH) is a downlink transport channel [2]. The FACH is transmitted over the entire cell or over only a part of the cell using beam-forming antennas. The FACH uses slow power control.

The FACH is carried at the physical level by the Secondary CCPCH (Common Control Physical Channel). Its structure is very similar to that of the dedicated channels, with the exception that no inner-loop power control is performed. The Secondary CCPCH can support variable rate with the help of the TFCI field included. The spreading factor values range from 256 down to 4.

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.

The same coding possibilities than for dedicated channels apply (convolutional, turbo or no coding at all).

Spreading and modulation of the S-CCPCH is done in identical way to the dedicated channel.

A.2 Downlink Shared CHannel (DSCH)

The Downlink Shared CHannel (DSCH) is a downlink transport channel. The Physical Downlink Shared CHannel (PDSCH) carries it at the physical layer. It is used for the simultaneous downlink transmission to several UE, as an efficient means of sharing code and power resources.

The set-up procedure is presented in annex C, as it is presented in the current version of the 3GPP documents. As it is now, the resource is released during the idle state.

The DSCH is associated with a DCH, making the PDSCH transmission a special case of multi-code transmission. The PDSCH and DPCH do not have necessarily the same spreading factors and, additionally, the spreading factor of the PDSCH may vary from frame to frame. For PDSCH the allowed spreading factors may vary from 256 to 4. For each active transmission, the relevant Layer 1 control information is transmitted on the DPCCH part of the associated DPCH, as the PDSCH does not contain physical layer information.

Two possibilities exist to indicate the UE that there is data to be decoded on the DSCH, namely either the use of the TFCI field or through higher layer signalling. If the spreading factor and other physical layer parameters can vary on a frame-by-frame basis, the TFCI shall be used to inform the UE what are the instantaneous parameters of PDSCH including the channelization code from the PDSCH OVSF code tree.

A DSCH may be mapped to multiple parallel PDSCHs as well, as negotiated at higher layer prior to starting data transmission. In such a case the parallel PDSCHs shall be operated with frame synchronization between each other.

Data can be encoded with the same possibilities than for dedicated channels (convolutional, turbo or no coding at all).

Spreading and modulation of the PDSCH is done in identical way to the dedicated channel.

A.3 Random Access CHannel (RACH)

A.3.1 General description

The Random Access CHannel (RACH) is an uplink (common) transport channel. The RACH is always received from the entire cell. The RACH is characterized by a limited size data field, a collision risk (which is solved at MAC level) and by the use of open loop power control.

There is one transport RACH, which is mapped onto one Physical Random Access Channel (PRACH). It can be used for the transmission of short packets.

A.3.2 RACH transmission

The random-access transmission is based on a Slotted ALOHA approach with fast acquisition indication, sent in the downlink Acquisition Indication CHannel (AICH).

The UE can start the transmission at a number of well-defined time-offsets, denoted *access slots.* There are 15 access slots per two frames and they are spaced 5 120 chips apart. Figure A.1 shows the access slot numbers and their spacing to each other. The higher layers determine which access slots are available in the current cell.

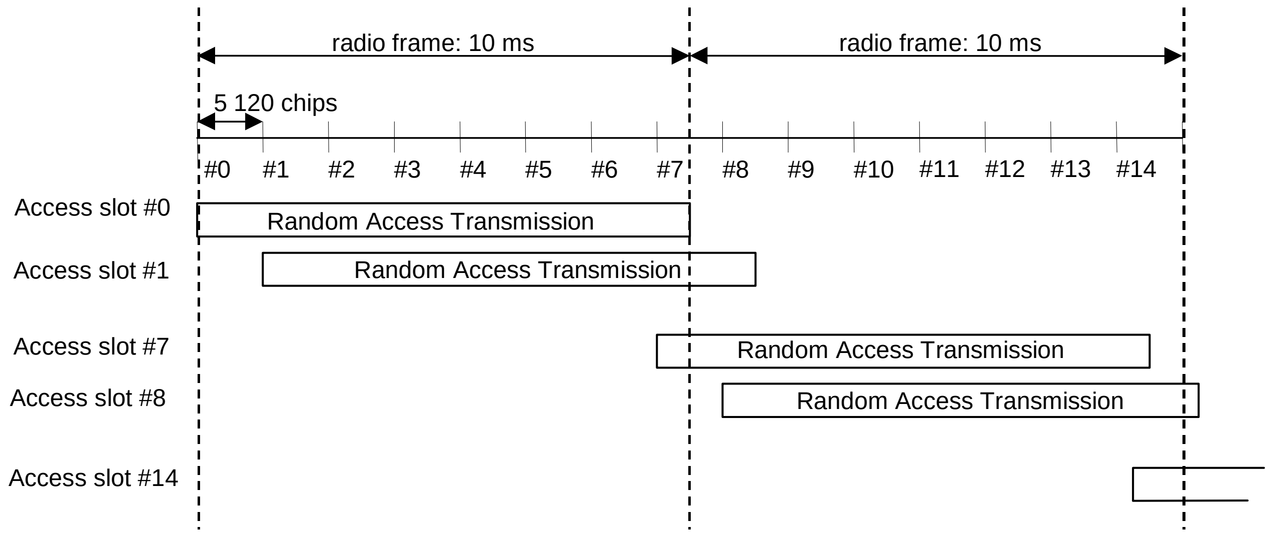

Figure A.1: RACH access slot numbers and spacing

The structure of the random-access transmission is shown in figure A.2. The random-access transmission consists of one or several *preambles* of length 4 096 chips and a *message* of length 10 ms or 20 ms. The UE indicates the length of the message part to the network by using specific signatures and/or access slots. The assignment of signatures and/or access slots to message lengths is performed by higher layers.

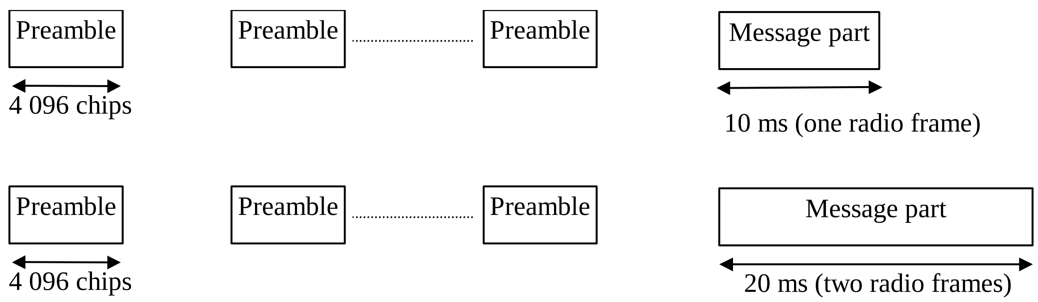

Figure A.2: Structure of the random-access transmission

The preamble part of the random-access burst consists of 256 repetitions of a signature, as described in figure A.2.

Figure A.3 shows the structure of the random-access message-part radio frame. The 10 ms message-part radio frame is split in 15 slots, each of length T_{slot} = 2 560 chips. Each slot consists of two parts, a data part that carries Layer 2 information and a control part that carries Layer 1 control information. The data and control parts are transmitted in parallel. A 20 ms long message part consists of two consecutive message part radio frames.

The data part consists of 10 x 2^k bits, where k = 0, 1, 2, 3. This corresponds to a spreading factor of 256, 128, 64 and 32 respectively for the message data part.

The data part is encoded with a (9, 1/2) convolutional code.

The control part consists of 8 known pilot bits to support channel estimation for coherent detection and 2 TFCI bits. This corresponds to a spreading factor of 256 for the message control part. The total number of TFCI bits in the random-access message is 15 x 2 = 30. The TFCI value corresponds to a certain transport format of the current Random-access message.

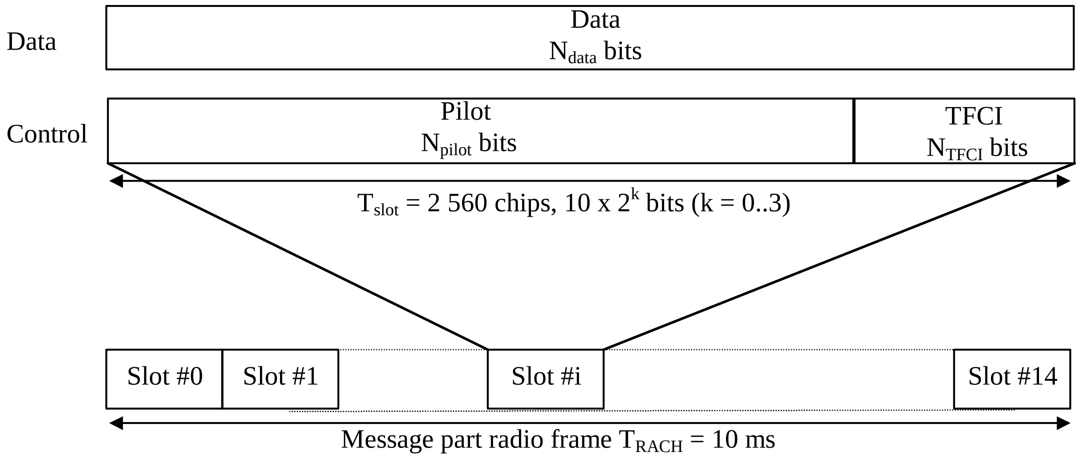

Figure A.3: Structure of the random-access message-part radio frame

A.3.3 PRACH/AICH timing relation

The Acquisition Indicator CHannel (AICH) is a physical channel used to carry Acquisition Indicators (AI). The Acquisition Indicator AI_s corresponds to signature number *s* on the PRACH.

The AICH is divided into 15 consecutive downlink access slots; each access slot is of length 5 120 chips. These downlink access slots are time aligned with the P-CCPCH.

The uplink PRACH is divided into uplink access slots, each access slot is of length 5 120 chips. Uplink access slot number *n* is transmitted from the UE τ_{p-a} chips prior to the reception of downlink access slot number *n*, *n* = 0, 1, 14.

Transmission of downlink acquisition indicators may only start at the beginning of a downlink access slot. Similarly, transmission of uplink RACH preambles and RACH message parts may only start at the beginning of an uplink access slot.

The PRACH/AICH timing relation is shown in figure A.4.

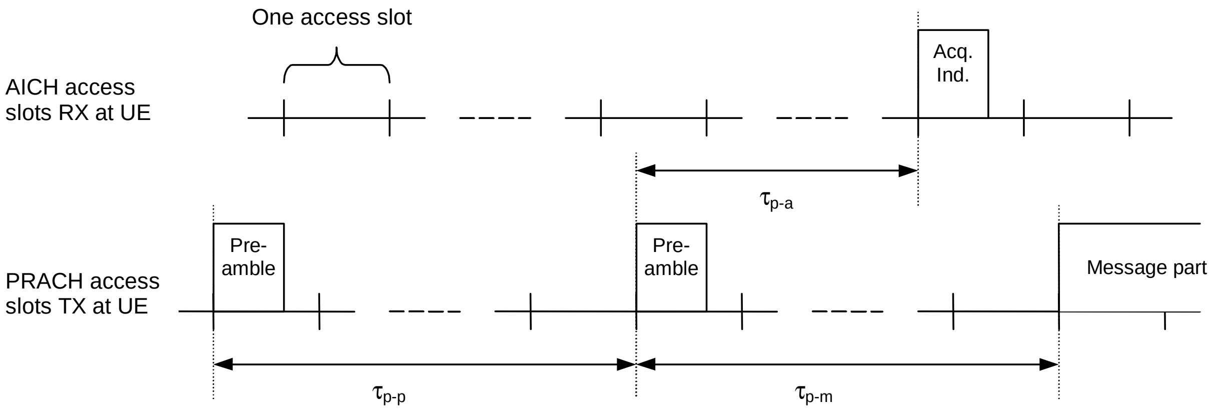

Figure A.4: Timing relation between PRACH and AICH as seen at the UE

The preamble-to-preamble distance $\tau_{p\text{-}p}$ shall be larger than or equal to the minimum preamble-to-preamble distance $\tau_{p\text{-}p,min}$, i.e. $\tau_{p\text{-}p} \geq \tau_{p\text{-}p,min}$.

In addition to $\tau_{p\text{-}p,min}$, the preamble-to-AI distance $\tau_{p\text{-}a}$ and preamble-to-message distance $\tau_{p\text{-}a}$ are defined as follows:

- When AICH_Transmission_Timing is set to 0, then:

$$\tau_{p\text{-}p,min} = 15\,360 \text{ chips (3 access slots)}$$

$$\tau_{p\text{-}a} = 7\,680 \text{ chips}$$

$$\tau_{p\text{-}m} = 15\,360 \text{ chips (3 access slots)}$$

- When AICH_Transmission_Timing is set to 1, then

$$\tau_{p\text{-}p,min} = 20\,480 \text{ chips (4 access slots)}$$

$$\tau_{p\text{-}a} = 12\,800 \text{ chips}$$

$$\tau_{p\text{-}m} = 20\,480 \text{ chips (4 access slots)}$$

A.3.4 PRACH spreading and modulation

A.3.4.1 PRACH Preamble part

The random access preamble code $C_{pre,w}$ is a complex valued sequence. It is built from a preamble scrambling code $S_{r\text{-}pre,n}$ and a preamble signature $C_{sig,s}$ as follows:

$$C_{pre,n,s}(k) = S_{r\text{-}pre,n}(k) \times C_{sig,s}(k) \times e^{j\left(\frac{\pi}{4}+\frac{\pi}{2}k\right)}, \quad k = 0, 1, 2, 3, \ldots, 4\,095,$$

Where k = 0 corresponds to the chip transmitted first in time.

The scrambling code $S_{r\text{-}pre,n}$ for the PRACH preamble part is constructed from the long scrambling sequences.

The preamble signature corresponding to a signature s consists of 256 repetitions of a length 16 signature $P_s(n)$, n = 0…15. This is defined as follows:

$$C_{sig,s}(i) = P_s(i \text{ modulo } 16), \; i = 0, 1, \ldots, 4\,095.$$

The signature $P_s(n)$ is from the set of 16 Hadamard codes of length 16.

The complex stream is QPSK modulated. In order to reduce the peak-to-average ratio (PAPR), the preamble sequence includes the term $e^{j(\frac{\pi}{4}+\frac{\pi}{2}k)}$. This is equivalent to the HPSK modulation used for the data part, and the auto-correlation properties of the preamble do not change after this operation.

A.3.4.2 PRACH message part

Figure A.5 illustrates the principle of the spreading and scrambling of the PRACH message part, consisting of data and control parts. The binary control and data parts to be spread are represented by real-valued sequences, i.e. the binary value "0" is mapped to the real value +1, while the binary value "1" is mapped to the real value -1. The control part is spread to the chip rate by the channelization code c_c, while the data part is spread to the chip rate by the channelization code c_d.

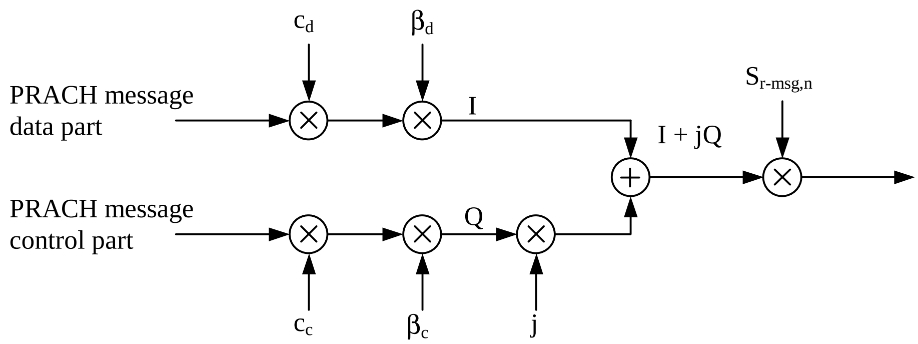

Figure A.5: Spreading of PRACH message part

After channelization, the real-valued spread signals are weighted by gain factors, β_c for the control part and β_d for the data part, which set the relative power between the data and control parts. After the weighting, the stream of real-valued chips on the I- and Q-branches are treated as a complex-valued stream of chips. This complex-valued signal is then scrambled by the complex-valued scrambling code $S_{r\text{-}msg,n.}$ The 10 ms scrambling code is applied aligned with the 10 ms message part radio frames, i.e., the first scrambling chip corresponds to the beginning of a message part radio frame.

The channelization codes of figure A.5 are Orthogonal Variable Spreading Factor (OVSF) codes that preserve the orthogonality between a user's different physical channels. The preamble signature s, $1 \le s \le 16$, points to one of the 16 nodes in the code-tree that corresponds to channelization codes of length 16. The sub-tree below the specified node is used for spreading of the message part. The control part is spread with the channelization code of spreading factor 256 in the lowest branch of the sub-tree, i.e. $c_c = C_{ch,256,m}$ where m = 16(s - 1) + 15. The data part uses any of the channelization codes from spreading factor 32 to 256 in the upper-most branch of the sub-tree. To be exact, the data part is spread by channelization code $c_d = C_{ch,SF,m}$ and SF is the spreading factor used for the data part and $m = SF \times (s - 1)/16$.

The PRACH message part is scrambled with a long scrambling code. The scrambling code used for the PRACH message part is 10 ms long, cell-specific and has a one-to-one correspondence to the scrambling code used for the preamble part.

The *n*-th PRACH message part scrambling code, denoted $S_{r\text{-}msg,n,}$ is based on the long scrambling sequence and is defined as

$$S_{r\text{-}msg,n}(i) = C_{long,n}(i + 4\,096),\ i = 0, 1, \ldots, 38\,399$$

where the lowest index corresponds to the chip transmitted first in time and $C_{long,n}$ is defined in clause A.3.2.2.

A.3.5 PRACH Power control

The message part of the uplink PRACH channel employs the gain factors β_c and β_d to control the control/data part relative power, in a similar way to the uplink dedicated physical channels. This is a function of the data bit rate of the transport channel, the coding rate and the rate matching parameters.

No inner loop power control is performed, the power being set through the initial open loop.

A.3.6 Physical random access procedure

A.3.6.1 Initialization

The physical random access procedure described in this clause is initiated upon request of a PHY-Data-REQ primitive from the MAC sublayer (see TS 125 321 [17]).

Before the physical random-access procedure can be initiated, Layer 1 receives the following information from the higher layers (RRC):

- the preamble scrambling code;
- the message length in time, either 10 ms or 20 ms;
- the AICH_Transmission_Timing parameter [0 or 1, depending on whether it is a large cell or not];
- the available signatures and RACH sub-channel groups for each Access Service Class (ASC), where a sub-channel group is defined as a group of some of the sub-channels defined in clause A.6.1.1;
- the power-ramping factor Power_Ramp_Step [integer > 0];
- the parameter Preamble_Retrans_Max [integer > 0];
- the initial preamble power Preamble_Initial_Power;
- the set of Transport Format parameters. This includes the power offset ΔP_{p-m} between the preamble and the message part for each Transport Format.

Note that the above parameters may be updated from higher layers before each physical random access procedure is initiated.

At each initiation of the physical random access procedure, Layer 1 shall receive the following information from the higher layers (MAC):

- the Transport Format to be used for the PRACH message part;
- the ASC (Access Service Class) of the PRACH transmission;
- the data to be transmitted (Transport Block Set).

A.3.6.2 Physical procedure

The physical random-access procedure shall be performed as follows:

1) Randomly select the RACH sub-channel group from the available ones for the given ASC. The random function shall be such that each of the allowed selections is chosen with equal probability.

2) Derive the available access slots in the next two frames, defined by SFN and SFN + 1 in the selected RACH sub-channel group with the help of SFN and table A.1. Randomly select one uplink access slot from the available access slots in the next frame, defined by SFN, if there is one available. If there is no access slot available in the next frame, defined by SFN then, randomly select one access slot from the available access slots in the following frame, defined by SFN + 1. The random function shall be such that each of the allowed selections is chosen with equal probability.

3) Randomly select a signature from the available signatures for the given ASC. The random function shall be such that each of the allowed selections is chosen with equal probability.

4) Set the Preamble Retransmission Counter to Preamble_Retrans_Max.

5) Set the preamble transmission power to Preamble_Initial_Power.

6) Transmit a preamble using the selected uplink access slot, signature, and preamble transmission power.

7) If no positive or negative acquisition indicator corresponding to the selected signature is detected in the downlink access slot corresponding to the selected uplink access slot:

   7.1) Select a new uplink access slot as next available access slot, i.e. next access slot in the sub-channel group used, as selected in 1

   7.2) Randomly selects a new signature from the available signatures within the given ASC. The random function shall be such that each of the allowed selections is chosen with equal probability.

   7.3) Increase the preamble transmission power by ΔP_0 = Power_Ramp_Step [dB].

   7.4) Decrease the Preamble Retransmission Counter by one.

   7.5) If the Preamble Retransmission Counter > 0 then repeat from step 6. Otherwise pass L1 status ("No ack on AICH") to the higher layers (MAC) and exit the physical random access procedure.

8) If a negative acquisition indicator corresponding to the selected signature is detected in the downlink access slot corresponding to the selected uplink access slot, pass L1 status ("Nack on AICH received") to the higher layers (MAC) and exit the physical random access procedure.

9) Transmit the random access message three or four uplink access slots after the uplink access slot of the last transmitted preamble depending on the AICH transmission timing parameter. Transmission power of the random access message is modified from that of the last transmitted preamble with the specified offset $\Delta P_{p-m.}$

10) Pass L1 status "RACH message transmitted" to the higher layers and exit the physical random access procedure.

A.3.6.3 RACH sub-channels

A RACH sub-channel defines a sub-set of the total set of access slots. There are a total of 12 RACH sub-channels. RACH sub-channel #i (i = 0, …,11) consists of the following access slots:

- access slot #i transmitted in parallel to P-CCPCH frames for which SFN mod 8 = 0 or SFN mod 8 = 1;
- every 12^{th} access slot relative to this access slot.

The access slots of different RACH sub-channels are also illustrated in table A.1.

Table A.1: Available access slots for different RACH sub-channels

	Sub-channel Number											
SFN modulo 8	0	1	2	3	4	5	6	7	8	9	10	11
0	0	1	2	3	4	5	6	7				
1	12	13	14						8	9	10	11
2				0	1	2	3	4	5	6	7	
3	9	10	11	12	13	14						8
4	6	7					0	1	2	3	4	5
5			8	9	10	11	12	13	14			
6	3	4	5	6	7					0	1	2
7						8	9	10	11	12	13	14

A.4 Common Packet CHannel (CPCH)

A.4.1 General Description

The Common Packet CHannel (CPCH) is an uplink (common) transport channel. The CPCH is a contention based random access channel used for transmission of burst-like data traffic.

CPCH is associated with a dedicated channel on the downlink which provides power control for the uplink CPCH. The Physical Common Packet CHannel (PCPCH) is used to carry the CPCH.

Each active packet user can be considered to hold a CPCH, so that there will be several different CPCH active at the same instant. The total number will be limited by the availability of system resources (number of slots and codes).

A.4.2 CPCH transmission

The CPCH transmission is based on CSMA-CD approach with fast acquisition indication. The UE can start transmission at a number of well-defined time-offsets, relative to the frame boundary of the received BCH of the current cell. The access slot timing and structure is identical to RACH. The structure of the CPCH random access transmission is shown in figure A.6. The CPCH random access transmission consists of one or several Access Preambles [A-P] of length 4 096 chips, one Collision Detection Preamble (CD-P) of length 4 096 chips, a DPCCH Power Control Preamble (PC-P) which is either 0 slots or 8 slots in length, and a message of variable length N x 10 ms.

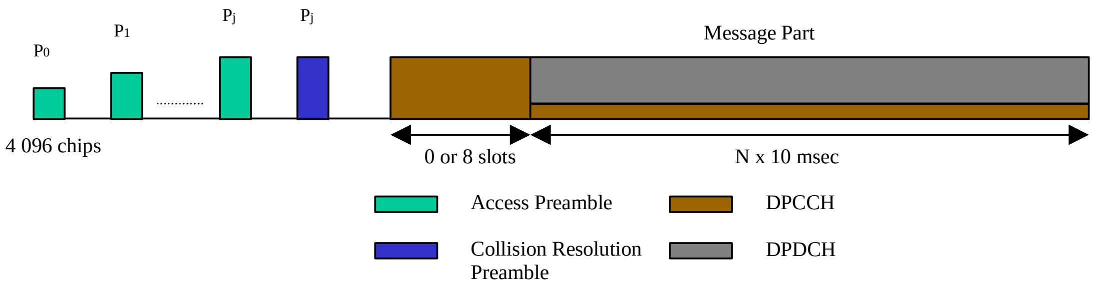

Figure A.6: Structure of the CPCH random-access transmission

The CPCH access preamble and the CPCH collision detection preamble parts are similar to the RACH preamble part. The number of sequences used could be less than the ones used in the RACH preamble. For the access preamble part, the scrambling code could be a different code segment of the Gold code used for the scrambling code in the RACH preambles, or could be the same code if the signature set is shared. The scrambling code for the collision detection preamble part is a different code segment of the Gold code used to form the scrambling code of the RACH and CPCH preambles.

Figure A.7 shows the structure of the CPCH message part. Each message consists of up to $N_{\_Max\_frames}$ 10 ms frames. $N_{\_Max\_frames}$ is a higher layer parameter. Each 10 ms frame is split into 15 slots, each of length T_{slot} = 2 560 chips. Each slot consists of two parts, a data part that carries higher layer information and a control part that carries Layer 1 control information. The data and control parts are transmitted in parallel.

The data part consists of 10 x 2^k bits, where k = 0, 1, 2, 3, 4, 5, 6 corresponding to spreading factors of 256, 128, 64, 32, 16, 8, 4 respectively. Note that various rates might be mapped to different signature sequences.

The spreading factor for the UL-DPCCH (message control part) is 256.

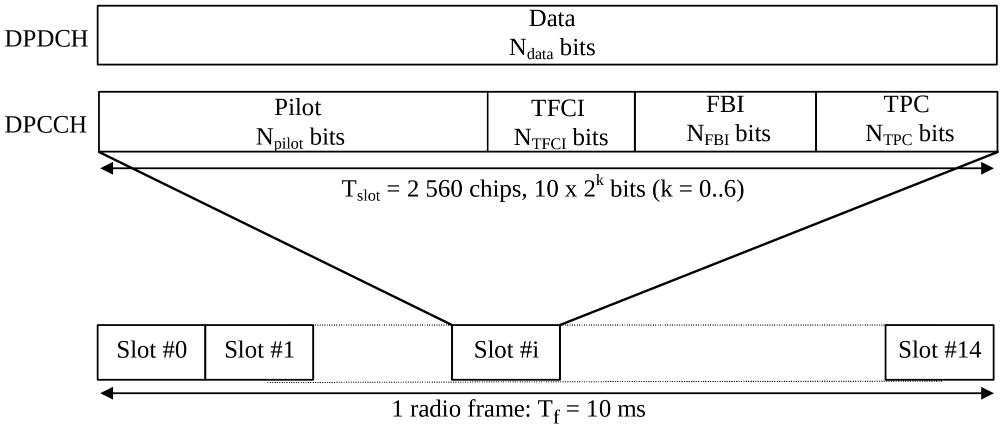

Figure A.7: Frame structure for uplink DPDCH/DPCCH

The spreading factor for the UL-DPCCH (message control part) is 256. The spreading factor for the DL-DPCCH (message control part) is 512. The channel symbol rate is 7,5 ksymbol/s.

A.4.3 PCPCH/AICH timing relation

Transmission of random access bursts on the PCPCH is aligned with access slot times. The timing of the access slots is derived from the received Primary CCPCH timing. The transmit timing of access slot n starts n $\times$ 20/15 ms after the frame boundary of the received Primary CCPCH, where n = 0, 1, …, 14. In addition, transmission of access preambles in PCPCH is limited to the allocated access slot sub-channel group, which is assigned by higher layer signalling to each CPCH set. Twelve access slot sub-channels are defined and PCPCH may be allocated all sub-channel slots or any subset of the twelve sub-channel slots. The access slot sub-channel identification is identical to that for the RACH.

Everything in the clause on PRACH/AICH timing applies to this clause as well. The timing relationship between preambles, AICH, and the message is the same as PRACH/AICH. Note that the collision resolution preambles follow the access preambles in PCPCH/AICH. However, the timing relationship between the CD-Preamble and the CD-AICH is identical to RACH Preamble and AICH. The timing relationship between CD-AICH and the Power Control Preamble in CPCH is identical to AICH to message in RACH. The T_{cpch} timing parameter is identical to the PRACH/AICH transmission timing parameter. When T_{cpch} is set to zero or one, the following PCPCH/AICH timing values apply.

Note that a1 corresponds to AP-AICH and a2 corresponds to CD-AICH.

$\tau_{p\text{-}p}$ = Time to next available access slot, between Access Preambles.

Minimum time = 15 360 chips + 5 120 chips x Tcpch

Maximum time = 5 120 chips x 12 = 61 440 chips

Actual time is time to next slot (which meets minimum time criterion) in allocated access slot subchannel group.

$\tau_{p\text{-}a1}$ = Time between Access Preamble and AP-AICH has two alternative values: 7 680 chips or 12 800 chips, depending on T_{cpch}.

$\tau_{a1\text{-}cdp}$ = Time between receipt of AP-AICH and transmission of the CD Preamble has one value: 7 680 chips.

$\tau_{p\text{-}cdp}$ = Time between the last AP and CD Preamble. is either 3 or 4 access slots, depending on T_{cpch}.

$\tau_{cdp\text{-}a2}$ = Time between the CD Preamble and the CD-AICH has two alternative values: 7 680 chips or 12 800 chips, depending on T_{cpch}.

$\tau_{cdp\text{-}pcp}$ = Time between CD Preamble and the start of the Power Control Preamble is either 3 or 4 access slots, depending on T_{cpch}.

Figure A.8 illustrates the PCPCH/AICH timing relationship when T_{cpch} is set to 0 and all access slot sub-channels are available for PCPCH.

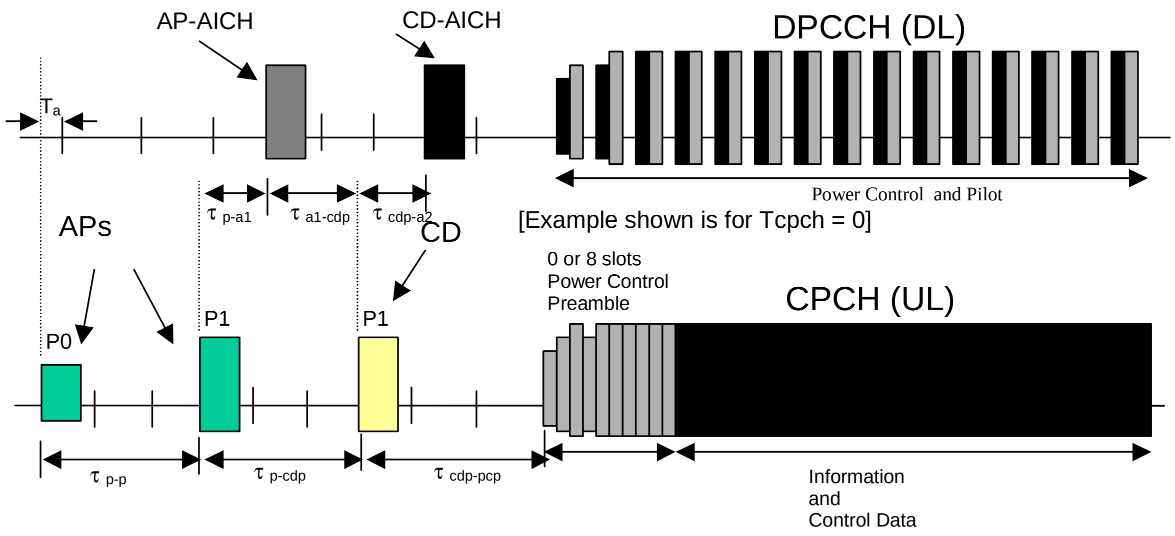

Figure A.8: Timing of PCPCH and AICH transmission as seen by the UE, with Tcpch = 0

A.4.4 PCPCH spreading and modulation

A.4.4.1 PCPCH preamble part

Similar to PRACH access preamble codes, the PCPCH access preamble codes $C_{c\text{-}acc,n,s}$ are complex valued sequences. The PCPCH access preamble codes are built from the preamble scrambling codes $S_{c\text{-}acc,n}$ and a preamble signature $C_{sig,s}$ as follows:

$$C_{c\text{-}acc,n,s}(k) = S_{c\text{-}acc,n}(k) \times C_{sig,s}(k) \times e^{j\left(\frac{\pi}{4}+\frac{\pi}{2}k\right)}, \; k = 0, 1, 2, 3, \ldots, 4\,095.$$

The access preamble scrambling code generation is done in a way similar to that of PRACH

The n:th PCPCH access preamble scrambling code is defined as:

$$S_{c\text{-}acc,n}(i) = c_{long,1,n}(i), \; i = 0, 1, \ldots, 4\,095,$$

where $c_{long,1,n}$ is the n-th long scrambling sequence.

In the case when the access resources are shared between the PRACH and PCPCH, the scrambling codes used in the PRACH preamble are used for the PCPCH preamble as well.

The access preamble part of the CPCH-access burst carries one of the sixteen different orthogonal complex signatures identical to the ones used by the preamble part of the random-access burst.

Similar to PRACH access preamble codes, the PCPCH CD preamble codes $C_{c\text{-}cd,n,s}$ are complex valued sequences. The PCPCH CD preamble codes are built from the preamble scrambling codes Sc-cd,n and a preamble signature $C_{sig,s}$ as follows:

$$C_{c\text{-}cd,n,s}(k) = S_{c\text{-}cd,n}(k) \times C_{sig,s}(k) \times e^{j\left(\frac{\pi}{4}+\frac{\pi}{2}k\right)}, \; k = 0, 1, 2, 3, \ldots, 4\,095.$$

The scrambling code for the PCPCH CD preamble is derived from the same scrambling code used in the CPCH access preamble.

The *n*:th PCPCH CD access preamble scrambling code is defined as:

$$S_{c\text{-}cd,n}(i) = c_{long,1,n}(i + 4\,096),\ i = 0, 1, \ldots, 4\,095,$$

where $c_{long,1,n}$ is the *n*-th long scrambling sequence.

In the case when the access resources are shared between the RACH and CPCH, the scrambling codes used in the RACH preamble will be used for the CPCH CD preamble as well.

The CD-preamble part of the CPCH-access burst carries one of sixteen different orthogonal complex signatures identical to the ones used by the preamble part of the random-access burst.

A.4.4.2 PCPCH message part

Figure A.9 illustrates the principle of the spreading of the PCPCH message part, consisting of data and control parts. The binary control and data parts to be spread are represented by real-valued sequences, i.e. the binary value "0" is mapped to the real value +1, while the binary value "1" is mapped to the real value -1. The control part is spread to the chip rate by the channelization code c_c, while the data part is spread to the chip rate by the channelization code c_d.

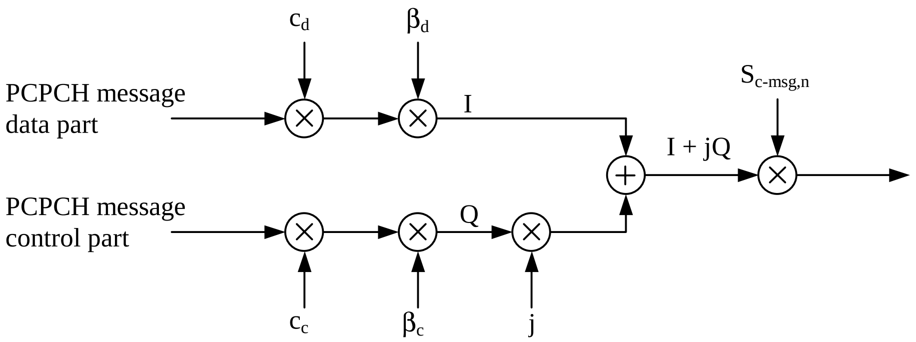

Figure A.9: Spreading of PCPCH message part

After channelization, the real-valued spread signals are weighted by gain factors, β_c for the control part and β_d for the data part. At every instant in time, at least one of the values β_c and β_d has the amplitude 1,0.

After the weighting, the stream of real-valued chips on the I- and Q-branches are treated as a complex-valued stream of chips. This complex-valued signal is then scrambled by the complex-valued scrambling code $S_{c\text{-}msg,n}$. The 10 ms scrambling code is applied aligned with the 10 ms message part radio frames, i.e. the first scrambling chip corresponds to the beginning of a message part radio frame.

A.4.4.3 Code allocation for PCPCH message part

The channelization codes of figure A.9 are Orthogonal Variable Spreading Factors (OVSF) codes which preserve the orthogonality between a user's different physical channels. The signature in the preamble specifies one of the 16 nodes in the code-tree that corresponds to channelization codes of length 16. The sub-tree below the specified node is used for spreading of the message part. The control part is always spread with a channelization code of spreading factor 256. The code is chosen from the lowest branch of the sub-tree. The data part may use channelization codes from spreading factor 4 to 256. A UE is allowed to increase its spreading factor during the message transmission by choosing any channelization code from the uppermost branch of the sub-tree code. For channelization codes with spreading factors less that 16, the node is located on the same sub-tree as the channelization code of the access preamble.

A.4.4.4 Channelization code for PCPCH power control preamble

The channelization code for the PCPCH power control preamble is the same as that used for the control part of the message part.

A.4.4.5 PCPCH message part scrambling code

The set of scrambling codes used for the PCPCH message part are 10 ms long, cell-specific and have a one-to-one correspondence to the signature sequences and the access sub-channels used by the access preamble part. Either long or short scrambling codes can be used to scramble the CPCH message part.

The *n*-th PCPCH message part scrambling code, denoted $S_{c\text{-}msg,n}$ is based on the scrambling sequence and is defined as:

In the case when the long scrambling codes are used,

$$S_{r\text{-}msg,n}(i) = C_{long,n}(i + 8\,192),\ i = 0, 1, \ldots, 38\,399,$$

where the lowest index corresponds to the chip transmitted first in time.

In the case when the access resources are shared between the RACH and CPCH, then $S_{c\text{-}msg,n}$ is defined as

$$S_{r\text{-}msg,n}(i) = C_{long,n}(i + 4\,096),\ i = 0, 1, \ldots, 38\,399,$$

where the lowest index corresponds to the chip transmitted first in time.

In the case the short scrambling codes are used,

$$S_{r\text{-}msg,n}(i) = C_{short,n}(i),\ i = 0, 1, \ldots, 38\,399$$

A.4.4.6 PCPCH power control preamble scrambling code

The scrambling code for the PCPCH power control preamble is the same as for the PCPCH message part. The phase of the scrambling code shall be such that the end of the code is aligned with the frame boundary at the end of the power control preamble.

A.4.5 CPCH Access Procedures

For each CPCH physical channel in a CPCH set allocated to a cell the following physical layer parameters are included in the System Information message:

- UL Access Preamble (AP) scrambling code;
- UL Access Preamble signature set;
- The Access preamble slot sub-channels group;
- AP- AICH preamble channelization code;
- UL Collision Detection (CD) preamble scrambling code;
- CD Preamble signature set;
- CD preamble slot sub-channels group;
- CD-AICH preamble channelization code;
- CPCH UL scrambling code;
- CPCH UL channelization code (variable, data rate dependant);
- DPCCH DL channelization code (512-chip long).

NOTE 1: There may be some overlap between the AP signature set and CD signature set if they correspond to the same scrambling code.

The following are access, collision detection/resolution and CPCH data transmission parameters.

Power ramp-up, Access and Timing parameters (Physical layer parameters):

1) N_AP_retrans_max = Maximum Number of allowed consecutive access attempts (retransmitted preambles) if there is no AICH response. This is a CPCH parameter and is equivalent to Preamble_Retrans_Max in RACH.

2) $P_{RACH} = P_{CPCH}$ = Initial open loop power level for the first CPCH access preamble sent by the UE.

   [RACH/CPCH parameter]

3) ΔP_0 = Power step size for each successive CPCH access preamble.

   [RACH/CPCH parameter]

4) ΔP_1 = Power step size for each successive RACH/CPCH access preamble in case of negative AICH. A timer is set upon receipt of a negative AICH. This timer is used to determine the period after receipt of a negative AICH when ΔP_1 is used in place of $\Delta P_{0.}$

   [RACH/CPCH parameter]

5) T_{cpch} = CPCH transmission timing parameter: This parameter is identical to PRACH/AICH transmission timing parameter.

   [RACH/CPCH parameter]

6) $L_{pc\text{-}preamble}$ = Length of power control preamble (0 or 8 slots)

   [CPCH parameter]

The CPCH access procedure in the physical layer is:

1) The UE MAC function selects a CPCH transport channel from the channels available in the assigned CPCH set. The CPCH channel selection includes a dynamic persistence algorithm (similar to RACH) for the selected CPCH channel.

2) The UE MAC function builds a transport block set for the next TTI using transport formats which are assigned to the logical channel with data to transmit. The UE MAC function sends this transport block set to the UE PHY function for CPCH access and uplink transmission on the selected CPCH transport channel.

3) The UE sets the preamble transmit power to the value PCPCH_ which is supplied by the MAC layer for initial power level for this CPCH access attempt.

4) The UE sets the AP Retransmission Counter to N_AP_Retrans_Max (value TBD).

5) The UE randomly selects a CPCH-AP signature from the signature set for this selected CPCH channel. The random function is TBD.

6) The UE Derives the available CPCH-AP access slots in the next two frames, defined by SFN and SFN + 1 in the AP access slot sub-channel group with the help of SFN and table A.1 in clause A.3.6.3. The UE randomly selects one access slot from the available access slots in the next frame, defined by SFN, if there is one available. If there is no access slot available in the next frame, defined by SFN then, randomly selects one access slot from the available access slots in the following frame, defined by SFN + 1. Random function is TBD

7) The UE transmits the AP using the MAC supplied uplink access slot, signature, and initial preamble transmission power.

8) If the UE does not detect the positive or negative acquisition indicator corresponding to the selected signature in the downlink access slot corresponding to the selected uplink access slot, the UE:

   a) Selects the next uplink access slot from among the access slots in the CPCH-AP sub-channel group, as selected in clause 4.1. There must be a minimum distance of three or four access slots from the uplink access slot in which the last preamble was transmitted depending on the CPCH/AICH transmission timing parameter.

NOTE 2: Use of random function here to select access slot is FFS for RACH and CPCH.

b) Increases the preamble transmission power with the specified offset ΔP. Power offset ΔP_0 s is used unless the negative AICH timer is running, in which case ΔP_1 is used instead.

c) Decrease the Preamble Retransmission Counter by one.

d) If the Preamble Retransmission Counter < 0, the UE aborts the access attempt and sends a failure message to the MAC layer.

9) If the UE detects the AP-AICH_nak (negative acquisition indicator) corresponding to the selected signature in the downlink access slot corresponding to the selected uplink access slot, the UE aborts the access attempt and sends a failure message to the MAC layer. The UE sets the negative AICH timer to indicate use of ΔP_1 use as the preamble power offset until timer expiry.

10) Upon reception of AP-AICH, the access segment ends and the contention resolution segment begins. In this segment, the UE randomly selects a CD signature from the signature set and also select one-CD access slot sub-channel from the CD sub-channel group supported in the cell and transmits a CD Preamble, then waits for a CD-AICH from the Node B.

11) If the UE does not receive a CD-AICH in the designated slot, the UE aborts the access attempt and sends a failure message to the MAC layer.

12) If the UE receives a CD-AICH in the designated slot with a signature that does not match the signature used in the CD Preamble, the UE aborts the access attempt and sends a failure message to the MAC layer.

13) If the UE receives a CD-AICH with a matching signature, the UE transmits the power control preamble $\tau_{cd\text{-}p\text{-}pc\text{-}p}$ ms later as measured from initiation of the CD Preamble. The transmission of the message portion of the burst starts immediately after the power control preamble.

14) During CPCH Packet Data transmission, the UE and UTRAN perform inner-loop power control on both the CPCH UL and the DPCCH DL.

15) If the UE detects loss of DPCCH DL during transmission of the power control preamble or the packet data, the UE halts CPCH UL transmission, aborts the access attempt and sends a failure message to the MAC layer.

16) If the UE completes the transmission of the packet data, the UE sends a success message to the MAC layer.

To end, a small remark concerning this CPCH procedure is needed, as it seems that it is still an open subject within 3GPP, so it should not be taken as a final and definitive description.

Annex B: Model for packet mode traffic

B.1 Real time services

For all real time test services, calls should be generated according to a Poisson process assuming an average call duration of 120 seconds for speech and circuit switched data services.

For speech, the traffic model should be an on-off model, with activity and silent periods being generated by an exponential distribution. Mean value for active and silence periods are equal to 3 seconds and independent on the up and downlink and both are exponentially distributed.

For circuit switched data services, the traffic model should be a constant bit rate model, with 100 % of activity.

B.2 Non-real time services

Figure B.1 depicts a typical WWW browsing session, which consists of a sequence of packet calls. We only consider the packets from a source, which may be at either end of the link but not simultaneously. The user initiates a packet call when requesting an information entity. During a packet call several packets may be generated, which means that the packet call constitutes of a bursty sequence of packets, see [15] and [16]. It is very important to take this phenomenon into account in the traffic model. The burstiness during the packet call is a characteristic feature of packet transmission in the fixed network.

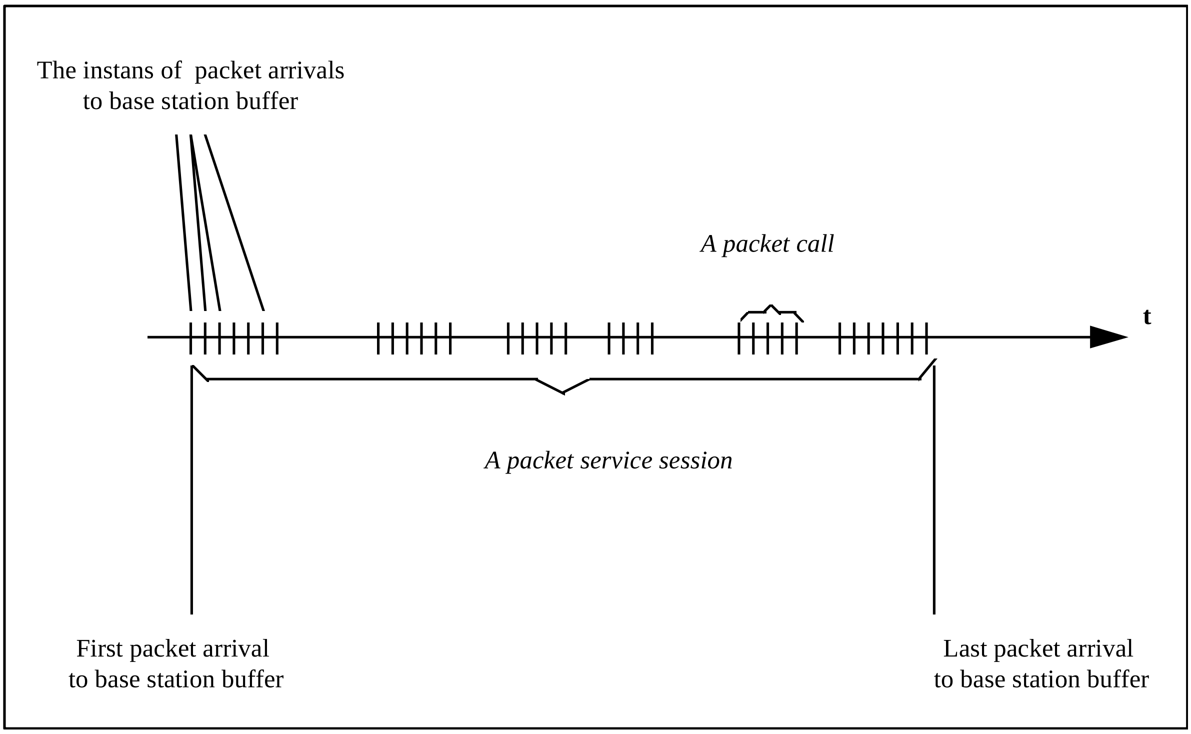

Figure B.1: Typical characteristic of a packet service session

A packet service session contains one or several packet calls depending on the application. For example in a WWW browsing session a packet call corresponds the downloading of a WWW document. After the document is entirely arrived to the terminal, the user is consuming certain amount of time for studying the information. This time interval is called reading time. It is also possible that the session contains only one packet call. In fact this is the case for a file transfer (FTP). Hence, the following must be modelled in order to catch the typical behaviour described in figure B.1:

- session arrival process;
- number of packet calls per session, $N_{pc;}$
- reading time between packet calls, $D_{pc;}$
- number of datagrams within a packet call**,** N_d;
- inter arrival time between datagrams (within a packet call) $D_{d;}$
- size of a datagram**,** S_d.

Note that the session length is modelled implicitly by the number of events during the session.

Next it will be described how these six different events are modelled. The geometrical distribution is used (discrete representation of the exponential distribution), since the simulations are using discrete time scale.

Session arrival process: How do session arrive to the system. The arrival of session set-ups to the network is modelled as a Poisson process. For each service there is a separate process. It is important to note that this process for each service only generates the time instants when service calls begin and it has *nothing to do with call termination*.

The number of packet call requests per session, N_{pc}: This is a geometrically distributed random variable with a mean $\mu_{N\text{pc}}$ [packet calls], i.e.

$$N_{pc} \in Geom\,(\mu_{Npc})$$

The reading time between two consecutive packet call requests in a session, D_{pc}: This is a geometrically distributed random variable with a mean $\mu_{D\text{pc}}$ [model time steps], i.e.

$$D_{pc} \in Geom\,(\mu_{Dpc})$$

Note that the reading time starts when the last packet of the packet call is completely received by the user. The reading time ends when the user makes a request for the next packet call.

The number of packets in a packet call, N_d: The traffic model should be able to catch the various characteristic features possible in the future UMTS traffic. For this reason different statistical distributions can be used to generate the number of packets. For example $\mathbf{N}_d$ can be geometrically distributed random variable with a mean $\mu_{N\text{d}}$ [packet], i.e.

$$N_d \in Geom\,(\mu_{Nd})$$

It must be possible to select the statistical distributions that describes best the traffic case under study should be selected. An extreme case would be that the packet call contains a single large packet.

The time interval between two consecutive packets inside a packet call, D_d: This is a geometrically distributed random variable with a mean $\mu_{D\text{d}}$ [model time steps], i.e.

$$D_d \in Geom\,(\mu_{Dd})$$

Naturally, if there are only one packet in a packet call, this is not needed.

Packet size, $\mathbf{S_d}$: The traffic model can use such packet size distribution that suits best for the traffic case under study. Pareto distribution with cut-off is used.

The normal Pareto distribution (without cut-off) is defined by:

$$\begin{cases} f_x(x) = \dfrac{\alpha \cdot k^{\alpha}}{x^{\alpha+1}}, x \geq k \\ F_x(x) = 1 - \left(\dfrac{k}{x}\right)^{\alpha}, x \geq k \\ \mu = \dfrac{k\alpha}{\alpha - 1}, \alpha > 1 \\ \sigma^2 = \dfrac{k^2 \cdot \alpha}{(\alpha-2)\cdot(\alpha-1)^2}, \alpha > 2 \end{cases}$$

PacketSize is defined with the following formula:

PacketSize = min(P, m)

where P is normal Pareto distributed random variable (α = 1,1, k = 81,5 bytes) and m is maximum allowed packet size, m = 66 666 bytes. The pdf of the PacketSize becomes:

$$f_n(x) = \begin{cases} \dfrac{\alpha \cdot k^{\alpha}}{x^{\alpha+1}}, k \leq x < m \\ \beta, x = m \end{cases}$$

where β is the probability that x>m. It can easily be calculated as:

$$\beta = \int_m^{\infty} f_x(x)dx = \left(\frac{k}{m}\right)^{\alpha}, \alpha > 1$$

Then it can be calculated as:

$$\mu_n = \int_{-\infty}^{\infty} x\, f_n(x)dx = \int_k^{m-} x \frac{\alpha k^{\alpha}}{x^{\alpha+1}} dx + m\left(\frac{k}{m}\right)^{\alpha} = \ldots calculating \ldots = \frac{\alpha k - m\left(\frac{k}{m}\right)^{\alpha}}{\alpha - 1}$$

with the parameters above the average size is:

$$\mu_n = 480 \ \ bytes$$

Table B.1 gives the default mean values for the distributions of typical www service. According to the values for α and k in the Pareto distribution, the average packet size μ is 480 bytes. Average requested file-size is μ_{Nd} x μ = 25 x 480 bytes ≈ 12 kBytes. The inter-arrival time is adjusted in order to get different average bit rates at the source level.

Table B.1: Characteristics of connectionless information types

Packet based information types	Average number of packet calls within a session	Average reading time between packet calls [s]	Average amount of packets within a packet call [s]	Average inter-arrival time between packets [s]	Parameters for packet size distribution
WWW surfing UDD 8 kbit/s	5	412	25	0,5	k = 81,5 α = 1,1
WWW surfing UDD 32 kbit/s	5	412	25	0,125	k = 81,5 α = 1,1
WWW surfing UDD 64 kbit/s	5	412	25	0,062 5	k = 81,5 α = 1,1
WWW surfing UDD 144 kbit/s	5	412	25	0,027 7	k = 81,5 α = 1,1
WWW surfing UDD 384 kbit/s	5	412	25	0,010 4	k = 81,5 α = 1,1
WWW surfing UDD 2 048 kbit/s	5	412	25	0,001 95	k = 81,5 α = 1,1

Annex C: Example procedure for rapid data transfer

This annex provides an overview of some typical procedures created for data transfer in UMTS, paying particular attention to the performance values achievable with them. They are meant to give a general picture of what can be done, and more importantly, how it is to be done, emphasizing the synchronization aspects.

C.1 On rapid packet data transfer

It is obvious that assigning a DCH to all UE in an active packet session would waste a significant amount of system capacity. Instead, a DCH should only be assigned for the duration of the packet call. However, packet calls are not long and last only a few seconds or less. Therefore, there will be frequent transitions from the RACH/FACH mode to the DCH/DCH + DSCH mode. Therefore, it is critical that the transition between these states be swift. The DCH may be established and ready to transfer data within 10 ms following a FACH message assigning the downlink OVSF code.

C.2 Procedure description

Synchronization of the DCH may be expedited so that data transmission may commence in slightly over 10 ms following the FACH burst assigning the DCH. Figure C.1 shows a timing diagram of RACH/FACH to DCH/DCH + DSCH state transition. The parameter T_A specifies the RACH/FACH response time. The parameters T_B, T_C and T_D are referenced relative to the FACH frame. T_B specifies the time period when the downlink DPCCH is started. The parameter T_C specifies the period at which the UE will start the uplink DPCCH. Finally, T_D specifies the period that the DCH will be stable and the first frame of data may arrive. The parameters T_B, T_C, and T_D have the following relationship:

$$T_B < T_C << T_D$$

$$T_D = T_B + N \text{ x } T_{slot}$$

where *N* is a positive integer. The parameters T_B, T_C, and T_D may be negotiated with each individual UE or broadcast by the system so that the transition from RACH/FACH to DCH/DCH + DSCH sub-state is optimized.

This technique for rapidly synchronizing a DCH may be applied to the transfer of uplink packets. Figure C.2 shows that the same parameters T_B, T_C, and T_D applied to an uplink packet data transfer. The UE, upon detecting data in its queue, transmits a RACH with measurement report. After the UTRAN assigns resource via the FACH message, the UE may begin transmitting the data on the DPDCH after the period T_D.

Finally, this technique may be extended to resume a DCH/DCH + DSCH connection that has been dropped for a short period. The procedure would be identical to the one shown in figure C.1, however, the first RACH may be omitted since the searcher data will not have grown stale and DPCCH may be safely acquired by the UTRAN. Figure C.3 shows the case where the DCH has been discontinued based on an inactivity timer. The UTRAN, upon detecting data in the queue, may resume the DCH operation provided the period T_E has not elapsed.

C.2.1 Rapid initialization of DCH for packet data transfer using DSCH

The DSCH provides a method for scheduling of downlink packets by sharing a low SF (high data rate) OVSF code between multiple packet data users. The scheduling of DSCH may be done on a frame-by-frame basis. Figure C.1 shows the timing diagram of RACH/FACH to DCH/DCH + DSCH state transition, as described in clause C.2 above.

In case of transmission of data generated at the network using DSCH, the operation of the reverse link power control loop, the acquisition searcher and the channel estimator need to be primed. As such, the transmission of reverse link DPCCH starts Ns slots (Ns: 1 slots to 16 slots) prior to the scheduled downlink packet data transmission using DSCH. The DPCCH is transmitted with an additional negative power offset (0 to P_{offset} dB) from the computed open loop estimate. The initial power control step size for transmitting the DPCCH can be set at a higher value (typically: 2 dB) so that the power control loop converges faster if the UE is in a deep fade. On the receipt of the first down power control command at the UE during the uplink DPCCH transmission phase, the step size reverts back to the normal power control (PC) step size (typically: 1 dB). The step size always goes back to its nominal setting at the beginning of the DSCH transmission.

C.2.2 Rapid initialization of DCH for uplink packet data transfer

The idea of fat-pipe scheduling and rapidly synchronizing a DCH can also be applied for transfer of uplink data packets. This facilitates short leases on the radio resource, typically on a frame-by-frame basis. Figure C.2 shows the same parameters T_B, T_C, and T_D applied to an uplink packet data transfer. The UE, upon detecting data in its queue, transmits a RACH with measurement report. After the UTRAN assigns resources via the FACH message, the downlink DPCCH is started after a time period T_B. The UE then begins transmission of the uplink DPCCH at time period T_C. T_C is measured relative to the FACH transmit timing. Finally, the UE begins transmitting the data on the DPDCH after the period $T_{D,}$ which typically is set to T_C + 10 msec. The procedure to start the uplink DPCCH transmission will be similar to that in clause C.2.1.

C.2.3 Resumption of DCH for downlink or uplink packet data transfer

Since packet data transmission is discontinuous, there is no need to Re-RACH if the discontinuity between packets does not exceed a pre-set time threshold. This can reduce the delay significantly for uplink/downlink packet data transfer. As such, this technique can be extended to resume a DCH/DCH + DSCH connection that has been dropped for a short period, since the channel estimator and search parameters did not change significantly within the inactivity period. This is applicable for packet data transfer using DSCH or uplink DPDCH or bi-directional data transfer using DSCH/Uplink DPDCH. Figure C.3 shows the case where the DCH has been discontinued based on an inactivity timer T_E. The UTRAN, upon detecting data in the queue, may resume the DCH operation provided the period T_E has not elapsed. Typically T_E is set to 1 000 ms.

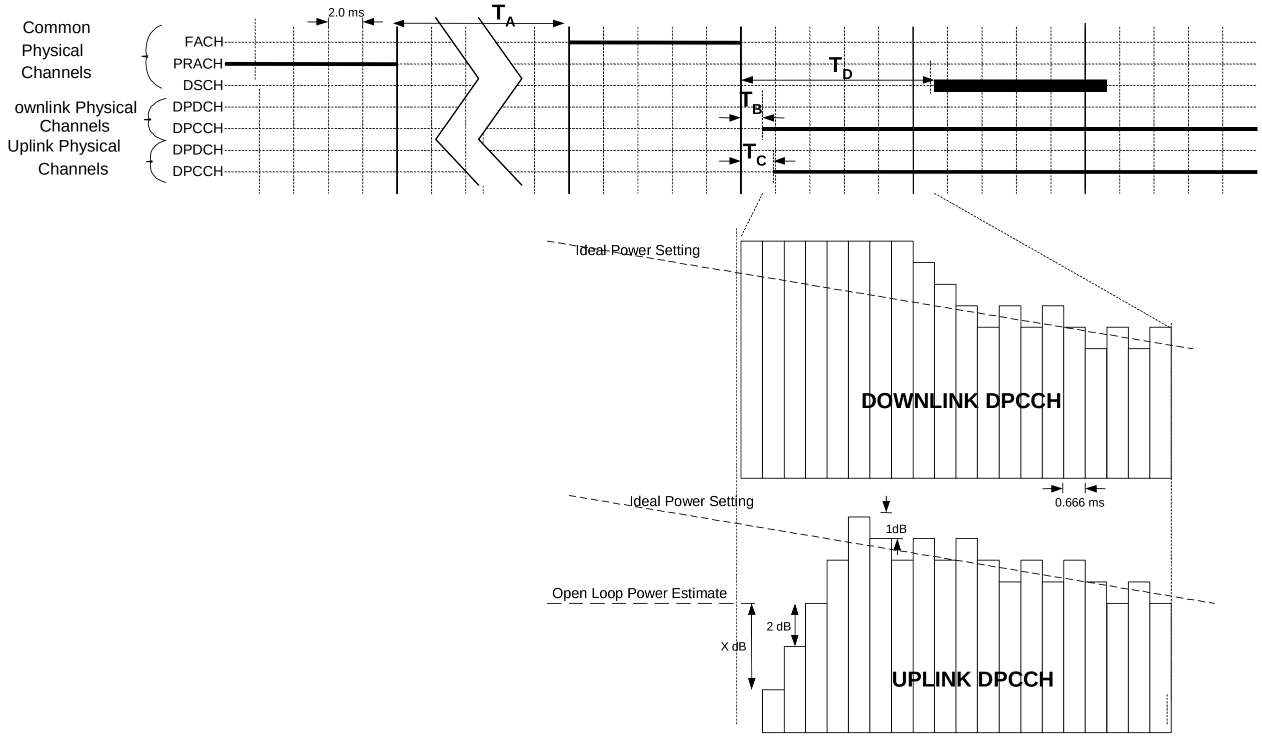

Figure C.1: Rapid initialization of DCH for packet data transfer over the DSCH

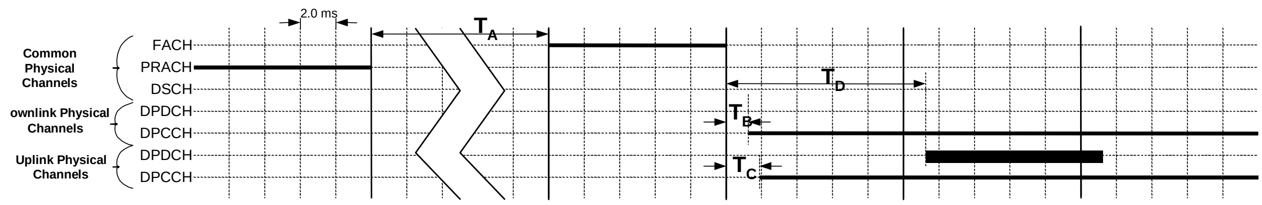

Figure C.2: Rapid initialization of the DCH for transfer of uplink packet data

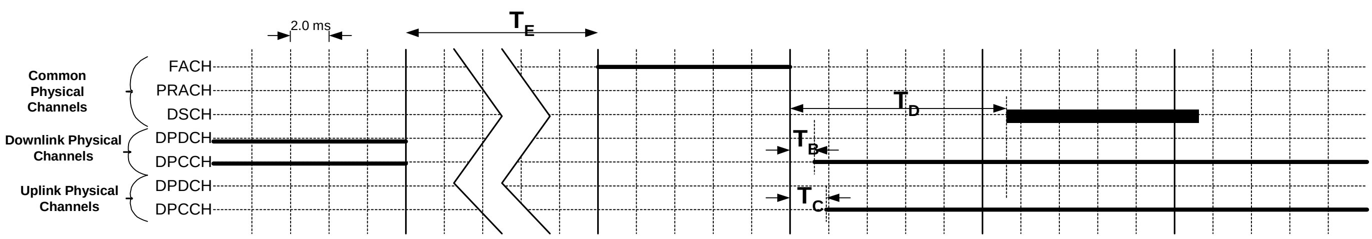

Figure C.3: Resumption of the DCH for transmission of downlink packet data.

C.3 Mean time to transmit a packet

The mean time to transmit a packet can be defined as the expected time that a sender needs for the successful completion of a packet transmission, from the moment of the first transmission, to the final acknowledgement reception. It takes into account, in our approach, the acquisition performances of the destination receiver (a packet can be missed, for instance), the propagation delays, the time-out timer before packet retransmission and the FER value. At a first moment, the effects of false alarm in the receiver are not taken into account, what is equivalent to assuming infinite resources; otherwise, false alarms could lead to occupation of a demodulator, thus increasing the probability of missed detection due to lack of an available receiver. Let us also assume that the time needed for the physical transmission of the packet is negligible. This makes the calculation independent of the bit rate, and simplifies the equations.
It is easy to see that a simple equation of this delay τ can be derived:

$$\tau = P_d\left(\left(1 - FER\right)\Delta_{ack} + FER(\Delta_{time-out} + \tau)\right) + (1 - P_d)(\Delta_{time-out} + \tau)$$

from where the delay is found to be:

$$\tau = \frac{P_d\left(1 - FER\right)\Delta_{ack} + P_d FER \Delta_{time-out} + (1 - P_d)\Delta_{time-out}}{P_d\left(1 - FER\right)}$$

Furthermore, assuming that the time-out time is roughly the same as the acknowledgement delay, and in turn, equal to the maximum round-trip time, the equation can be further simplified to:

$$\tau \approx \frac{\Delta_{round-trip}}{P_d\left(1 - FER\right)}$$

And again, for typical values of missed detection (1 out of 10 packets), and FER (0.1), the expected time to transmit a packet is about 1,25 times the round-trip time. The increase in delay due to retransmissions is thus kept within acceptable values.

History

Document history		
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