The Physical Layer of UTRA TDD

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Abstract – The third generation mobile radio system UTRA that has been specified in the Third Generation Partnership Project (3GPP) consists of an FDD and a TDD mode. This paper presents the physical layer of the UTRA TDD mode, which is based on TD-CDMA. Important system features are explained in detail. The physical layer is responsible for the transmission of transport blocks over the air interface. This includes forward error correction, multiplexing of different transport channels on the same physical resources, rate matching, modulation, spreading and RF processing.

1. Introduction

Third generation mobile radio systems will provide low up to high data rate services with a maximum data rate of 2 Mbps (Mega-bits-per-second). Multimedia applications use several services such as voice, audio/video, graphics, data, internet access and e-mail in parallel. These services, both packet and circuit switched, have to be supported by the radio interface and the network subsystem. For instance, for certain data services and for internet access, the transmission from the base station to the mobiles (downlink) will require more capacity than the transmission from the mobiles to the base station (uplink). It is expected that the demand for such asymmetric traffic will increase significantly in the future [1][2].

In January 1998, the European standardization body for third generation mobile radio systems, the ETSI SMG (European Telecommunications Standards Institute - Special Mobile Group), has agreed on a radio access scheme for third generation mobile radio systems, called Universal Mobile Telecommunications System (UMTS) [3]. The UMTS Terrestrial Radio Access (UTRA) consists of two modes, a frequency division duplex (FDD) mode [4][5], where the uplink and the downlink are transmitted on different frequencies, and a time division duplex (TDD) mode, where the uplink and the downlink are transmitted on the same carrier frequency, multiplexed in time [6]. The agreement recommends the use of WCDMA (Wideband Code Division Multiple Access) for UTRA FDD and TD-CDMA (Time Division – Code Division Multiple Access) for UTRA TDD. TD-CDMA is based on a combination of TDMA (Time Division Multiple Access) and CDMA, whereas WCDMA is a pure CDMA-based system as depicted in Figure 1. The UMTS Terrestrial Radio Access (UTRA) can be used for operation within a minimum spectrum of 2 x 5 MHz for UTRA FDD and 5 MHz for UTRA TDD. Paired and unpaired frequency bands have been identified in the region of 2 GHz to be used for third generation mobile radio systems. Both modes of UTRA have been harmonized with respect to the basic system parameters such as carrier spacing, chip rate and frame length [7]. Thereby, FDD/TDD dual mode operation is facilitated, which provides a basis for the development of low cost terminals. Also, the interworking of UTRA with GSM is ensured.

In UTRA, the different service needs are supported in a spectrum efficient way by a combination of FDD and TDD. The FDD mode is intended for applications in public macro and micro cell environments with data rates of up to 384 kbps and high mobility. The TDD mode, on the other hand, is advantageous for public micro and pico cell environments, for licensed and unlicensed cordless and wireless local loop applications. It facilitates an efficient use of the unpaired spectrum and supports data rates of up to 2 Mbps. Therefore, the TDD mode is particularly well suited for environments with high traffic density (e.g., city centers, business areas, airports, shopping malls, fairs) and indoor coverage, where the applications require high data rates and tend to create highly asymmetric traffic (e.g., internet access).

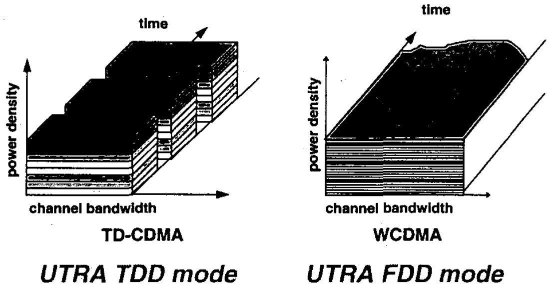

Figure 1 The UMTS Terrestrial Radio Access (UTRA): UTRA TDD uses TD-CDMA (left) and UTRA FDD uses WCDMA (right)

In parallel to the European activities [8][9], extensive work on third generation mobile radio has been performed in Japan [10][11]. The Japanese standardization body ARIB (Association of Radio Industry and Business) decided for WCDMA, where the Japanese and European proposal for FDD were practically aligned. Very similar concepts have also been developed by the North-American T1 standardisation body.

In order to work towards a truly global third generation mobile radio standard, the Third Generation Partnership Project (3GPP, http://www.3gpp.org/) was formed in December 1998. 3GPP consists of members of the standardization bodies in Europe (ETSI), the US (T1), Japan (ARIB), Korea (TTA - Telecommunications Technologies Association), and China (CWTS – China Wireless Telecommunication Standard). 3GPP merged the already well harmonised proposals by the regional standardisation bodies and now works on one common third generation mobile radio standard still called UTRA, with its two modes, which is based on the evolved GSM core network. The Third Generation Partnership Project 2 (3GPP2, http://www.3gpp2.org/), on the other hand, works towards a third generation mobile radio standard, which is based on an IS-95 evolution and was originally called cdma2000.

In June 1999, major international operators in the Operator Harmonization Group (OHG) have proposed a harmonized G3G (Global Third Generation) concept, which has been accepted by 3GPP and 3GPP2 [7]. The harmonized G3G concept is a single standard with the following three modes of operation:

- CDMA direct spread (CDMA – DS), based on UTRA FDD as specified by 3GPP,
- CDMA multi carrier (CDMA – MC), based on cdma2000 using FDD as specified by 3GPP2,
- TDD (CDMA TDD), based on UTRA TDD as specified by 3GPP.

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In cooperation with the manufacturers community, the Operator Harmonization Group (OHG) achieved this harmonized concept for the CDMA based proposals by aligning radio parameters as far as possible and by a combined protocol stack. This simplifies the implementation of multimode terminals and enables the connection either to an evolved GSM MAP and an evolved ANSI-41 core network. The recommendations of the OHG have been taken into account in the first release of the standard, the release 1999 of the 3GPP specifications, which have been available at the end of 1999 [12].

The specifications elaborated by 3GPP and 3GPP2 are, among others, part of the ITU (International Telecommunication Union) recommendations for International Mobile Telecommunications 2000 (IMT-2000). Furthermore, China has presented to ITU a TD-SCDMA proposal based on a synchronous TD-CDMA scheme for TDD applications including mobility and wireless local loop applications. In the ITU recommendations, for CDMA TDD two TDD subsections (UTRA TDD and TD-SCDMA) share the same higher layer (Layers 2 and Layer 3) but actually with different physical layer specifications. The chip rates are 3.84 Mchip/s for UTRA TDD and 1.28 Mchip/s for TD-SCDMA. The goal is to enable the full integration of the low chip rate TDD option and its specific characteristics into the release 2000 specifications of 3GPP. The higher layers of the UTRA TDD mode are presented in a companion paper [13].

2. Basic System Parameters

UTRA TDD is based on a combined time and code division multiple access scheme (TD-CDMA) that is well suited for TDD operation due to its inherent time division component. Moreover, the intracell interference can be eliminated by joint detection (JD) [14][15], which can be implemented with a reasonable computational complexity due to the additional separation in the time domain [16]. Other basic system parameters such as chip rate, bandwidth, modulation are the same as in UTRA FDD mode. This enables the development of low cost terminals supporting FDD/TDD dual mode operation. Table 1 compares the basic system parameters for UTRA TDD and FDD.

TABLE 1 UTRA FDD/TDD BASIC SYSTEM PARAMETERS

Duplex Scheme	FDD	TDD
Multiple Access Scheme	WCDMA	TD-CDMA
Chip Rate	3.84 Mchip/s	
Modulation	QPSK	
Bandwidth	5 MHz	
Pulse Shaping	Root Raised Cosine, r=0.22	
Frame Length	10 ms	
Number of time slots per frame	15	

UTRA TDD also comprises a low chip rate option (1.28 Mchip/s) in order to facilitate the implementation of future system extensions such as adaptive antennas for beamforming [20], uplink synchronisation and baton handover. This low chip rate option will be elaborated as part of release 2000 in 3GPP.

3. Frame Structure

The choice of the data burst size is a trade-off between two conflicting requirements. On the one hand large, bursts lead to trunking effects and low granularity, i.e., this leads to the transmission of too much redundant data if not enough data are available to fill the available resources. On the other hand, small bursts involve too much overhead for physical layer control data that require a minimum length. For instance, the length of the training sequences may not fall below a particular length to allow larger delay spreads and an appropriate performance of the channel estimation. As a good compromise, each frame of length 10 ms is divided into 15 time slots, each of which may be allocated to either the uplink or the downlink as depicted in Figure 2.

With such a flexibility, the TDD mode can be adapted to different environments and deployment scenarios, e.g., mobile internet applications will contribute to a significant asymmetry in favor of the downlink. UTRA TDD can cope with such asymmetric traffic distributions in a very flexible fashion by using different switching point configurations.

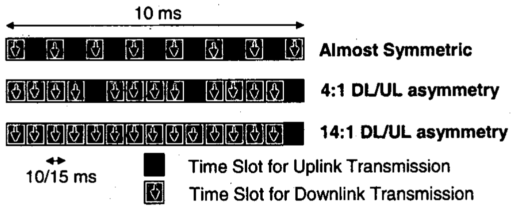

Figure 2 Frame Structure of UTRA TDD mode and exemplary switching point configurations

4. Synchronisation Channel and Initial Cell Search

Two downlink time slots are used for the transmission of the physical synchronisation channel PSCH in UTRA TDD. Note that other physical downlink channels may be transmitted in the same time slots in parallel. The use of two time slots with a 7 slot space is necessary for monitoring purposes to enable a proper intersystem handover from GSM or UTRA FDD to UTRA TDD.

To facilitate cell planning, up to 128 cells in a TDD system can be distinguished, each of which has a unique cell specific scrambling code and two corresponding basic midamble codes used for the construction of long and short training sequences [17]. The 128 cells are grouped into 32 code groups. The PSCH is designed in such a way that the terminal can acquire frame synchronisation and cell parameters, i.e., scrambling codes and basic midamble codes, within a single three-step procedure.

In a first step, synchronisation is achieved by a fixed primary synchronisation code C_P with a length of 256 chips. This sequence is constructed as a so-called generalised hierarchical Golay sequence and is chosen to have good aperiodic auto correlation properties [18]. The special construction allows for an efficient implementation of the correlator in the terminal.

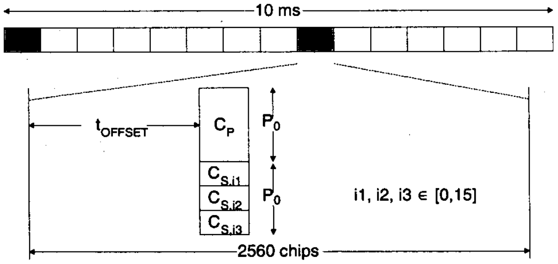

Figure 3 Structure of the Physical Synchronisation Channel PSCH

In a second step, once the C_P is found, the terminal can start detecting three modulated secondary codes $C_{S,i1}$, $C_{S,i2}$, $C_{S,i3}$, i1, i2, i3 = 0,..,15, that are transmitted at the same time and with the same overall power P_0 as the C_P as illustrated in Figure 3. A sequence of four modulated secondary codes allows the discrimination of the 32 code groups. The modulation also carries the information about the beginning of the interleaving interval, which is necessary for later decoding of the broadcast channel. Moreover, the modulated codes C_S allow to distinguish between the two PSCH time slots. This information is needed in case of intersystem handover from GSM or UTRA FDD to UTRA TDD, if only one of both slots can be monitored.

In the last step of the initial cell search procedure, the terminal determines one out of four cells within the code group by correlating with the four different basic midamble codes that belong to the code group that was identified in step two.

In order to maximise system capacity, it is favorable that all cells are synchronised within a TDD system. In this case, a capture effect may occur if synchronisation sequences from different cells are transmitted at the same time. At the receiver only the strongest cells can be heard. Therefore, cells within different code groups transmit their synchronisation sequences with a particular time offset t_{OFFSET} with respect to the slot boundary as shown in Figure 3. After step two of the cell search procedure, the time offset and, therefore, also the slot boundaries are known. Frame synchronisation is achieved after reading the broadcast channel which includes the number of the first PSCH time slot.

The construction of all synchronisation sequences is done in the same way as for UTRA FDD. This facilitates inter-mode handover between UTRA FDD and TDD and allows for an efficient hardware reuse in the terminals.

5. Physical Channel Structure

In addition to the PSCH, the physical layer of UTRA TDD provides a number of different physical channels that carry the transport channels from the MAC sub layer. All physical channels, except the synchronisation channel, are based on the time slot structures, spreading operations and training sequences described below.

5.1 Time Slot Structure

Each time slot is divided into two data fields, one midamble field and one guard period field, see Figure 4 The data fields contain the data bits from the transport channels after multiplexing, interleaving, coding, and spreading. Within the midamble field training sequences are transmitted. The guard period GP is used to cope with timing inaccuracies, power ramping, delay spread and, if no timing advance mechanism is used, also with the propagation delay.

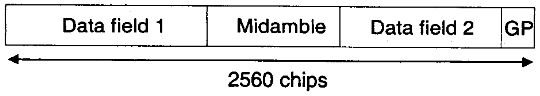

Figure 4 Time Slot Structure of Physical Channels

Three different burst types may be used for data transmission. These burst types differ in the length of each field, as listed in table 2.

TABLE 2 BURST TYPES, LENGTH OF FIELDS IN CHIPS

Burst type	Data 1	Data 2	Midamble	Guard Period
Burst Type 1	976	976	512	96
Burst Type 2	1104	1104	256	96
Burst Type 3	976	880	512	192

Burst type 1 provides less space for data transmission but a longer midamble field. This allows for a better performance and an increased number of channel estimations compared with burst type 2.

The larger guard period of burst type 3 is used for the physical random access channel (PRACH) only. It is necessary to cope with the missing timing information in the terminal during the initial access. The asymmetric data fields of burst type 3 allow for a mixture with traffic of burst type 1 within one time slot. A mixture of all different burst types is possible within one cell in order to allow a greater flexibility with respect to channel allocation and spectrum efficiency.

5.2 Spreading of Data

The number N_{bits} of data bits that may be transmitted in the data fields of the bursts depends on the overall length N_{data} [chips] of both data fields and the spreading factor SF

$$N_{bits} = 2 \times N_{data} / SF, \qquad SF=1, 2, 4, 8, \text{ or } 16.$$

$N_{symbol}=N_{bits}/2$ complex data symbols are generated from a pair of two subsequent, interleaved and encoded data bits by mapping the bits on the I- or Q-branch, respectively. The complex data symbols are at first spread with a complex channelisation code which is generated by chip wise complex rotation (multiplying with j^n) of a real orthogonal variable spreading factor (OVSF) code, see Figure 5. The OVSF codes are defined with the same tree structure as in the UTRA FDD mode. However, in UTRA TDD a maximum SF of 16 is used, which enables the introduction of JD in the receiver, since JD algorithms with moderate complexity can cope with a limited number of codes only [15].

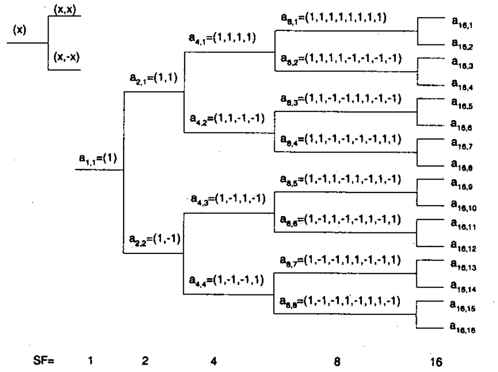

Figure 5 OVSF code tree in UTRA TDD

After channelisation, the spread data are scrambled with a cell specific scrambling code of length 16 to reduce intercell interference. The scrambling codes are optimized with respect to an efficient use of the wideband spectrum. The principle overall spreading operation is shown in Figure 6.

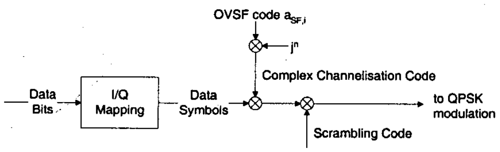

Figure 6 Channelisation and Scrambling

5.2.1 Spreading for Downlink Physical Channels

To facilitate the implementation of low cost terminals, downlink physical channels only use the maximum spreading factor 16. To support higher data rates, multiple different channelisation codes may be used in parallel. This is called the multicode operation.

In particular scenarios with low intercell interference, operation with a single channelisation code with spreading factor 1 is also possible for the downlink physical channels for high data rates.

5.2.2 Spreading for Uplink Physical Channels

For the uplink physical channels, transmission with a single code and different spreading factors in the range of 16 down to

1 is better suited, because this leads to a smaller peak-to-average transmission power ratio and, by this, to lower battery consumption. Moreover, it enables the implementation of more efficient power amplifiers in the terminal. For higher granularity, each terminal is allowed to apply multicode operation with a maximum of two different channelisation codes in parallel.

5.3 Training Sequences

On the downlink the channel is in general the same for all users, whereas on the uplink different user-specific channel impulse responses have to be estimated. In order to reduce the complexity of the channel estimation, the training sequences (midambles) in UTRA TDD are based on a particular construction algorithm to allow a joint channel estimation by one single cyclic correlator [17]. The midambles of different users that are active in the same time slot are time-shifted versions of one single periodic basic code [17] as depicted in Figure 7. Different cells use different periodic basic codes. The different channel impulse response estimates are obtained sequentially in time at the output of this correlator and can be separated by simple windowing with a window function of length *W*. Therefore, the maximum length of the channel impulse response is given by the length *W* that it is equal to the time shift between two midambles.

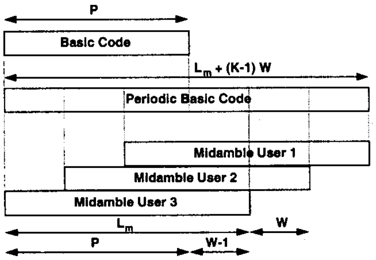

Figure 7 UTRA TDD midamble structure (In this example, up to K=3 different channels can be estimated)

The number of channel impulse responses that can be estimated at the same time depends on the length of the period of the basic code *P* and on the channel estimation window length *W*. Due to the longer midamble field length L_m and, by this, a longer period *P*, burst type 1 provides more possible channel estimates than burst type 2, see Table 3. Here, T_c denotes the chip duration.

TABLE 3 BASIC CODE PERIOD, MAX. NUMBER OF CHANNEL ESTIMATES K, AND MAX. LENGTH OF CHANNEL IMPULSE RESPONSE T_{IR} FOR BURST TYPES 1 AND 2

Burst Type	*P*	*W*	*K*	$T_{IR} = W\,T_C$ [μs]
Burst type 1	456	57	8	13.9
Burst type 2	192	64	3	15.6

The use of 8 additional intermediate shifts for burst type 1 allows for up to K=16 channel estimates per time slot on the uplink with a reduced channel impulse response length of up to 7 μs. This option can be used if in a particular scenario, e.g., in pico cells, no large delay spread is to be expected. Burst type 1 is suited for the uplink in case that more than three users share one time slot. Burst type 2 can be used for the downlink and, if the bursts within a time slot are allocated to less than four users, also for the uplink.

If transmit diversity techniques or adaptive antennas for beamforming are used on the downlink, user-specific midamble sequences as used on the uplink is also applied on the downlink instead of using the same midamble for all downlink connections [20]. This enables user-specific space-selective beamforming techniques on the downlink to provide a significant capacity increase through interference reduction.

6. Dedicated Physical Channels DPCH

The dedicated physical channels DPCH are used on the uplink and the downlink to carry the data bits from the dedicated transport channels DCH. User dedicated data and user dedicated control information is transmitted via the DCH.

6.1 TFCI transmission

UTRA is designed to support a very flexible transmission of variable data rates and different services. This is handled by the transport format concept, explained in section 7. In order to allow a proper decoding, de-interleaving and de-multiplexing in the physical layer, the transport format combination is signalled as a physical layer parameter, the so-called transport format combination indicator TFCI. For simpler services such as fixed rate speech, no TFCI is necessary.

In UTRA TDD the TFCI is optionally transmitted within the data fields of the burst, see Figure 8. The number of coded TFCI bits depends on the number of possible transport format combinations and reduces the number of user data bits. The location of the TFCI adjacent to the midamble allows for the best possible transmission of this important parameter, since interference from the midamble can be cancelled and channel estimation is most reliable for the bits adjacent to the midamble.

6.2 TPC transmission

UTRA TDD facilitates the use of closed loop power control for the downlink DPCH. Transmit-power-control (TPC) commands are sent on the uplink as a physical layer signaling parameter to allow the adjustment of the transmission power at the base station. The first two bits of the data field 2 are optionally used as a TPC command, see Figure 8.

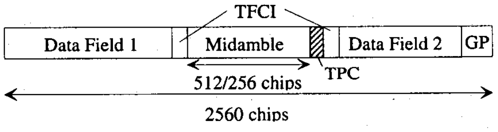

Figure 8 Transmission of TFCI and TPC within the data fields of the burst

7. Common Physical Channels

7.1 Primary CCPCH

The primary common control physical channel P-CCPCH is used on the downlink to carry the data bits of the broadcast transport channel BCH. A fixed multiplexing, coding, and interleaving scheme is used for the BCH so that no TFCI is necessary. The P-CCPCH is transmitted with a fixed power, the value of which is broadcasted, thus providing a reference for measurements in the terminal. Moreover, the P-CCPCH is transmitted always in the first PSCH time slot within a frame, see section 4, and uses a pre-defined channelisation code and midamble. This allows immediate decoding of the broadcast information, once synchronisation is achieved as explained in section 4.

7.2 Secondary CCPCH

The secondary common control physical channel is used for the transmission of downlink common control information, i.e., messages from the paging transport channel PCH and the forward access transport channel FACH. Multiplexing of PCH and FACH and different transport formats on the same physical channels are allowed by the use of the TFCI which is transmitted in the same way as for the DPCH.

7.3 PICH

The page indicator channel PICH provides an efficient discontinuous reception mechanism DRX in idle mode, i.e., when the terminal is waiting for paging messages. In a configurable number of frames, the PICH replaces the S-CCPCH carrying an associated PCH. The PICH contains only physical layer information, the so-called page indicators PI. Dependent on the burst type and the number of bits used for one PI, the PICH provides a number of N_{PI} PI per frame, where N_{PI} is in the range between 17 and 69, see example in Figure 9. The two symbols adjacent to the midamble are left unused if they cannot be used for the transmission of a full length PI. The number of PI can be increased by increasing the number of S-CCPCH frames that are replaced by the PICH.

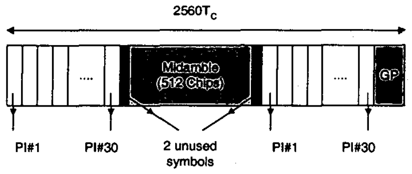

Figure 9 Example of Transmission of Page Indicators PI in the PICH for Burst Type 1 and a PI length of 4 data symbols

Each PI is associated with a group of terminals that has to detect its own PI, when waiting for paging messages. Only if the PI indicates the presence of a paging message, the terminal will start decoding the PCH. A large number of PI avoids unnecessary decoding of paging messages that are sent to different terminals, thus reducing power consumption.

7.4 PRACH

To acquire access to the network, the terminal randomly transmits messages in one or more time slots that are used for the physical random access channel PRACH. Collisions may occur if two or more mobiles transmit at the same time instant and with the same code, i.e., transmit their RACH message in the same collision group.

The random access leads to time-divided collision groups. The usage of up to 16 orthogonal spreading codes per time slot increases the amount of collision groups and throughput. For the PRACH, only SF 8 and 16 are allowed to ensure the reception of RACH messages also in cells with larger radius.

8. Channel Coding and Service Multiplexing

The multiplexing and coding functions, although located within the UTRA physical layer, serve as an interface to the MAC- and RRC-layer and are controlled by those layers. Regarding the basic functionality, there is no difference between TDD and FDD, which guarantees an optimum interoperability of these modes.

Compared to well-known 2G systems such as GSM, one of the new features of UTRA is the possibility to transmit all radio bearers in a uniform and very flexible manner. Therefore, a wide range of services defined just by their quality of service (QoS) can be transmitted. Within the physical layer, bearers carrying higher layer signaling and those for data transmission are handled identically, which easily allows the incorporation of new features in the future. Additionally, several bearers can be transmitted simultaneously, e.g., speech and internet browsing. UTRA provides a toolbox that allows a very flexible variation of transmission parameters for any service.

Each bearer relates to one Transport Channel (TrCH) with a specific Transmission Time Interval (TTI), which defines the delivery period of one or several Transport Blocks (TrBk) from MAC to the physical layer. However, since unlike in GSM all bits of one TrCH are always transmitted with the same quality, services like AMR[1] speech can be split into several TrCH with individual QoS, to achieve unequal error protection.

To indicate the chosen transport format (TF) of each TrCH to the receiver, an indicator concept is used in UTRA: The TFCI, built in the physical layer, can be interpreted as a pointer to a table containing all allowed TF combinations (TFC). A TFCI is always transmitted on the uplink and the downlink if at least two different TFC are possible. Depending on the TFCI length (in the range of 1 up to 10 bits), a repetition option and two block coding schemes are available for TFCI encoding. They ensure a high detection reliability.

Since the TFC table will be updated during the establishment of a radio link and additionally at any modification of the current TFC, the receiving side can always unequivocally interpret the TFCI value. Thus, with a known TFC, all algorithms used during the encoding of the data on the transmitting side can be reversed.

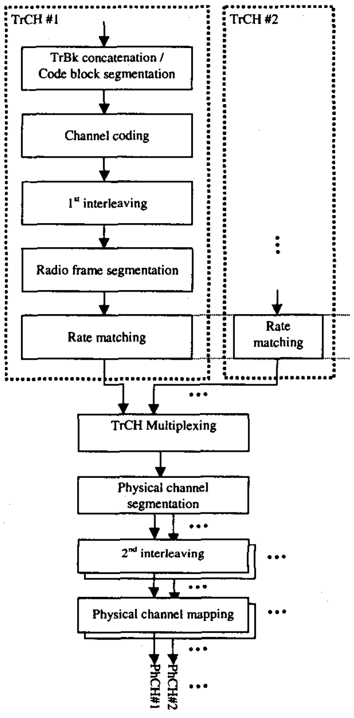

Figure 10 UTRAN multiplexing and coding chain

Figure 10 depicts the multiplexing and coding chain used for UTRA TDD in more detail. For each TrCH the following steps are performed. After CRC attachment to each TrBk separately, these blocks are concatenated and afterwards again segmented to achieve an optimum coding block size dependent on the respective coding scheme. Four different coding schemes are available:

- Rate $^1/_3$ convolutional coding,
- Rate $^1/_2$ convolutional coding,
- Rate $^1/_3$ turbo codes,
- No coding.

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[1] The Adaptive Multi-Rate speech codec was chosen for UTRA and supports 8 different source coding rates as well as silent indicator description (SID) frames with discontinuous transmission (DTX).

By applying these schemes, bit error rates in the range from 10^{-3} down to 10^{-6} can be realized depending on the individual service requirements.

After encoding, a first interleaving step is applied to each TrCH independently which distributes the bits over the whole TTI of that TrCH. Then, by means of radio frame segmentation, the data is distributed equally to all frames of the respective TTI. The next step is the application of a rate matching algorithm [19], which by means of repeating or puncturing certain bits, fulfils three tasks simultaneously, both, for uplink and downlink:

1. In case of transmitting multiple TrCH within one Coded Composite Transport Channel (CCTrCH) it guarantees that each TrCH exhibits the required BER as closely as possible.
2. Depending on the amount of data to be transmitted the number of actually used physical channels is minimised , in each frame.
3. Independent of the number of bits to be transmitted in each frame, all used physical channels are completely filled with data.

Task 1 is an essential prerequisite for the transmission of a multiplexed signal in the time domain. To cope with the constraint of a constant transmission power of this signal, balancing the bit energy must be performed by using a linear rate matching scheme for each TrCH. Task 2 enables a very efficient use of the physical resources by switching off the transmission of certain codes on a frame by frame basis when not needed for the instantaneous data rate. Furthermore, due to a possible reduction of the midamble power, also the interference is reduced, resulting in an increased spectral capacity. Task 3 is required to guarantee a constant burst length on the air interface which simplifies the design of the RF module and reduces the effort of the base band processing.

Although information of all other TrCH is already evaluated during the determination of the individual rate matching parameters, the multiplexing of all data bits is performed in the next step by writing the data bits of all TrCH sequentially into one stream. This data stream, called CCTrCH, is segmented into single portions to be mapped separately onto physical channels. Due to the flexible multiplexing scheme, the borders between two adjacent TrCHs within the CCTrCH do, in general, not coincide with the borders of the physical codes.

For the 2nd interleaving, two options are available. It either interleaves the bits of all TrCHs of the respective CCTrCH or only those bits to be transmitted within one timeslot. The last option becomes relevant if the interference of the respective cell strongly varies dependent on the timeslot. In that case the use of self-contained timeslots is beneficial for packet transmission with a low coding rate utilising a HARQ scheme, since it allows the error-free reception of certain packets although packets in other timeslots may be corrupted. As indicated in Figure 10 by means of the multiple boxes, the 2nd interleaving as well as the following mapping onto the physical channels can be applied separately to certain parts of each CCTrCH. Hereby, the time- and code diversity is maximised for all TrCHs needed for shared channel operation.

9. Conclusions

The third generation mobile radio system UTRA extends the services of second generation systems by wide area coverage of high data rate transmission and efficient packet access. Furthermore, it opens new opportunities for wireless high data rate and multi media services. UTRA, which has been specified in the Third Generation Partnership Project (3GPP), consists of an FDD and a TDD mode. The combination of FDD and TDD allows to support the different services in a spectrum efficient way. The physical layer of the UTRA TDD mode has been presented in this paper.

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