

OVERVIEW OF PHYSICAL LAYER FOR 3G LOW CHIP RATE TDD SYSTEMS

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This paper reviews the 3GPP standard based on TD-SCDMA technology (termed UMTS Terrestrial Radio Access Low Chip Rate Time-Division Duplex - UTRA LCR-TDD). We first present a brief overview of the system followed by more detailed descriptions of the physical layer of UTRA LCR-TDD. We then discuss the various features of UTRA LCR-TDD and explain the rationale of the selection of these features by focusing on the unique features of UTRA LCR-TDD rather than offering lengthy discussions on every single feature common among different systems. Finally, some success factors for 3G are also mentioned for positioning our research and development activities in a correct direction.

1. INTRODUCTION

In 1998, the International Telecommunications Union (ITU) called for proposals for the next-generation mobile wireless communications system, termed International Mobile Telecommunications 2000 or IMT2000. The proposals had to meet specific criteria and were subdivided into satellite-based and terrestrial systems, the latter of which is the focus of our paper.

For terrestrial systems, several candidates based upon code-division multiple access (CDMA) and time-division multiple access (TDMA) technology were proposed, and these proposals were put forward from standardization bodies worldwide [1].

ETSI	European Telecommunications Standards Institute
ARIB	Japanese Association of Radio Industry and Business
CWTS	China Wireless Telecommunication Standards Group
TIA	North American Telecommunications Industry Association
TTA	Korean Telecommunications Technology Association

The main candidates proposed within ETSI were as follows:

W-CDMA	Wideband CDMA
MC-CDMA	Multi-carrier CDMA
TD-CDMA	Time-division CDMA
W-TDMA	Wideband TDMA

A relay principle termed opportunity-driven multiple access (ODMA) was also considered and was eventually merged into the TD-CDMA proposal [2].

ETSI SMG and ARIB then chose W-CDMA for paired spectrum application (applying frequency division duplex, FDD). Additionally, ETSI also selected TD-CDMA for unpaired spectrum application (applying time division duplex, TDD). Therefore, W-CDMA was also referred to as UTRA FDD (UMTS Terrestrial Radio Access FDD), and TD-CDMA as UTRA TDD. Both W-CDMA and TD-CDMA are considered to be the evolution paths of Global System for Mobile Communications (GSM) and the North American TDMA standards.

ETSI and ARIB later handed over the responsibility of standardization for W-CDMA and TD-CDMA to the Third-Generation Partnership Project 3GPP [3] in 1999, with ETSI, ARIB and other major standardization bodies serving as organizational partners of 3GPP.

A 2nd organization called 3GPP2 [4] came into existence, mainly driven by North American and Korean telecommunications industries. It was principally created for handling the standardization effort of cdma2000 that is based upon multi-carrier CDMA (MC-CDMA) and single-carrier CDMA technology. cdma2000 is considered to be the evolution path of cdmaOne.

In view of its late entrance into the W-CDMA and MC-CDMA development, China's CWTS proposed another standard based on time-division synchronous CDMA (TD-SCDMA). This was to ensure that the Chinese industry could at least be on par with its peers overseas if not lead in the development of 3G based on this standard. The TD-SCDMA standard was accepted by ITU as the UTRA low chip rate TDD (UTRA LCR-TDD) option of 3GPP that is envisaged to co-exist with UTRA FDD (W-CDMA) and UTRA high chip rate TDD (UTRA HCR-TDD) systems. The main characteristic of UTRA LCR-TDD is that it utilizes a

frequency spectrum of 1.6 MHz compared to that of 5 MHz for UTRA FDD and UTRA HCR-TDD. This can prove useful when some operators fail to obtain a full 5 MHz spectrum portion for operating UTRA FDD or UTRA HCR-TDD systems. The chip rate for UTRA LCR-TDD is only 1.28 Mcps, whereas the chip rate for UTRA HCR-TDD is 3.84 Mcps. Despite its lower chip rate, UTRA LCR-TDD still promises to fulfill the 3G data rate guideline set out by IMT2000 of 384 kbps for vehicular and 2 Mbps for indoor and pedestrian environments. This is possible since LCR-TDD employs an 8-Phase Shift Keying (8-PSK) modulation in addition to Quadrature Phase Shift Keying (QPSK) modulation for the higher data rate services. As opposed to UTRA FDD, both UTRA TDD modes promise a more efficient spectrum usage by their asymmetric channel allocation. As opposed to UTRA FDD and, less so, to UTRA HCR-TDD, the better possibility to implement advanced joint detection receivers and beam forming antennas promises improved performance as well. Therefore, up to a certain degree, we can expect capacity and service enhancement from UTRA LCR-TDD. Nevertheless, the degree of this improvement must still be proved in practice.

In this paper, we present the UTRA LCR-TDD system specified by 3GPP. Section 2 provides an overview of the UTRA LCR-TDD system. Section 3 provides a description of the physical layer. Section 4 outlines some success factors for general 3G deployments. Finally, Section 5 concludes this paper. Throughout this paper, text comparisons are made between the UTRA LCR-TDD, UTRA HCR-TDD and UTRA FDD systems.

2. SYSTEM OVERVIEW

2.1. System Architecture

In 3GPP, one of the objectives is to provide a common system architecture for different modes of the system so as to lower down the cost of building and maintaining these systems in addition to providing opportunities for multimode support. Therefore, the system architecture for UTRA LCR-TDD is similar to UTRA FDD and UTRA HCR-TDD, as shown

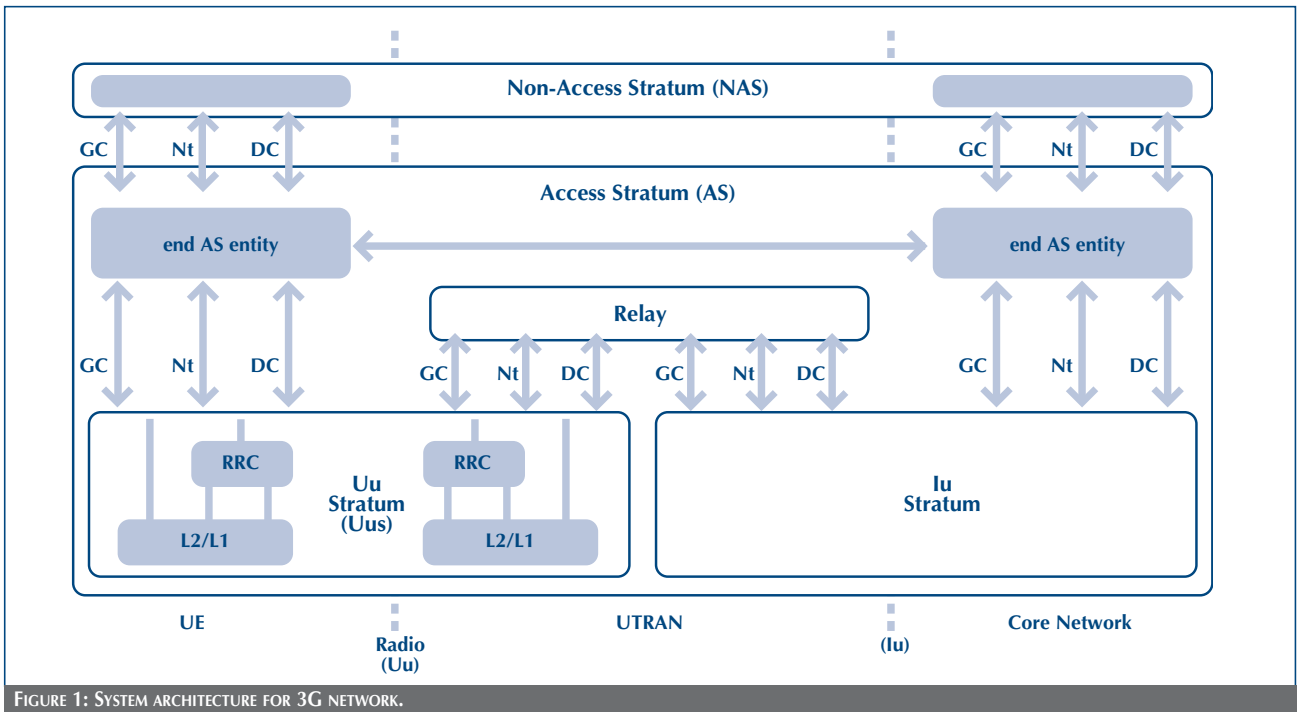


FIGURE 1: SYSTEM ARCHITECTURE FOR 3G NETWORK.

in Fig. 1 [5]. The network architecture includes three main components: Core Network (CN), UMTS Terrestrial Radio Access Network (UTRAN) and User Equipment (UE).

The CN is an evolution from the existing GSM standard and will eventually evolve to an All-Internet Protocol (All-IP) network. The UTRAN is an almost all new portion for 3GPP, as depicted in Fig. 1. It consists of several Radio Network Subsystems (RNS), where each RNS is composed of a Radio Network Controller (RNC) and several base stations termed Node-B's. The UE is the acronym for mobile stations in 3G that combines the mobile terminal and UMTS Security Identity Module (USIM) for providing various kinds of services.

2.2. Protocol

Similar to the system architecture, the protocol stack for UTRA LCR-TDD also has the same partition of layers as other 3G systems. In other words, the same protocol stack controls different modes of system that may exist in the same UTRAN or UE.

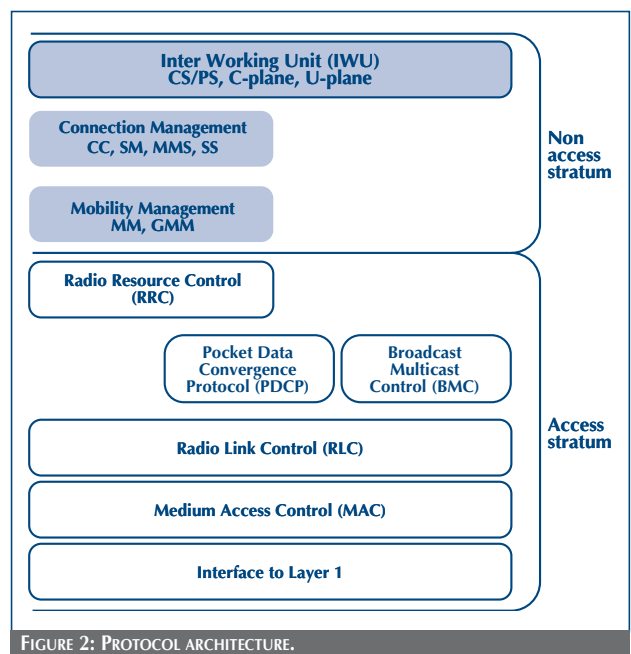


FIGURE 2: PROTOCOL ARCHITECTURE.

Basically, the 3G protocol stack is Radio-Resource Control (RRC) centric, divided into two main entities, namely the access stratum

(AS) and the non-access stratum (NAS) as shown in Fig. 2. The AS manages tasks related to radio calls such as radio resource control, radio link control, and the quality of service of the channel. In contrast, the NAS handles tasks that are independent of the radio link, such as call control, mobility management, supplementary services and messaging services.

2.3. Migration Path

Since the number of 2G subscribers is large, with some countries achieving more than 90% of the population penetration rate, a proper migration path needs to be identified so as to introduce as little service disruption as possible when migrating from 2G to 3G systems. The TD-SCDMA technology promises a smooth migration path from GSM to 3G and beyond as mentioned in [6]. The migration path is essentially divided into three phases.

Phase 1 utilizes the existing GSM/GPRS infrastructure by setting up a Node-B that uses the 3G spectrum. The Node-B is connected to the Mobile Switching Center (MSC) of the existing GSM network via an enhanced Base Station Controller (BSC). This configuration will result in short term availability of 3G services without the need to install a completely new core network.

In phase 2, the core network can be gradually upgraded and the Node-Bs can be connected to the core network via standardized interfaces. This setup allows continued use of the existing handsets and is transparent to the end users. Thus, risks related to technical migration can be minimized and the investment is significantly less than other 3G technologies.

Finally, phase 3 involves further network evolution to All-IP based networks. The base stations remain unchanged and the existing handsets remain operational. This leads to a fully UTRA LCR-TDD 3G-compliant system.

The incremental upgrade for mixed GSM / TD-SCDMA to a full UTRA LCR-TDD system provides an attractive alternative for

network operators who wish to employ 3G services with the lowest initial investment. It is also worthwhile to note that the end users are normally neutral about which 3G standard network operators use. Their main concerns are rather the services and contents that can be provided by these operators.

3. UTRA LCR-TDD PHYSICAL LAYER

This section is the main focus of the paper and details the main features outlined in the UTRA LCR-TDD specifications [7]-[12].

3.1. System Parameters

In contrast to UTRA FDD or W-CDMA, where there is only one multiple-access scheme, i.e., CDMA, UTRA LCR-TDD or TD-SCDMA is based on TDMA with a flexible CDMA component. Therefore, it is considered as a hybrid multiple-access system. For duplex operation, UTRA LCR-TDD utilizes the same frequency band for both uplink and downlink transmission in a TDD structure, i.e., the uplink and the downlink are separated in time, as opposed to UTRA FDD, where these links are separated in frequency. By using the same frequency band, channel reciprocity characteristics exist in UTRA LCR-TDD, which is useful especially for channel estimation. The multiple user access for each link is achieved by generating multiple timeslots (applying TDMA) and by employing CDMA in these timeslots.

The carrier spacing for UTRA LCR-TDD is specified at 1.6 MHz, less than 1/3 of that of UTRA FDD and UTRA HCR-TDD, which is 5 MHz. Considering that UTRA FDD requires two separate frequency bands for uplink and downlink transmissions, UTRA LCR-TDD spectrum usage is only 1/6 compared to that of UTRA FDD¹. The adoption of lower spectrum utilization indirectly implies a great saving in cost. This is because the total price paid for the approximately 100 worldwide 3G spectrum licenses is about \$ 112 billion to date, which represents a large portion of the initial investment cost for

¹ - This simple comparison is only a hint to show the spectrum efficiency of ULTRA LCR-TDD. A more thorough analysis of radio frequency engineering is necessary to really compare the system.

the network operators. With the lower carrier spacing, the chip rate of 1.28 Mcps for UTRA LCR-TDD is three times lower than that of UTRA FDD and UTRA HCR-TDD. However, the maximum data rate supported for UTRA LCR-TDD is still 2 Mbps, the same as UTRA FDD and UTRA HCR-TDD. This is possible since a spreading factor (SF) of 1 is possible in UTRA LCR-TDD and a higher order modulation scheme of 8-PSK may be adopted. However, it should be noted that the consequence of having the same data rate in a much smaller bandwidth is a reduction in the quality of the radio link. Therefore, higher power (resulting in higher signal-to-noise ratio) is necessary for achieving the purpose.

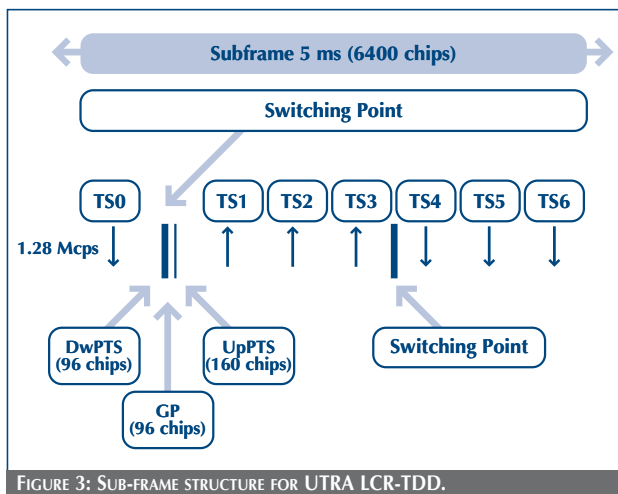


FIGURE 3: SUB-FRAME STRUCTURE FOR UTRA LCR-TDD.

3.2. Frame Structure

The UTRA LCR-TDD frame structure is different from that of UTRA HCR-TDD. One 10 ms frame is divided into two identical sub-frames, each lasting for 5 ms, with each 5 ms sub-frame composed of seven time slots for conveying data and uplink/downlink synchronization pilot slots, as indicated in Fig. 3.

The Downlink Pilot Time Slot (DwPTS) is used for downlink synchronization, and the Uplink Pilot Time Slot (UpPTS) is used for synchronizing the reception of the mobiles signals at the base station. The guard period (GP) of 96 chips (equal to

75 μ s) between DwPTS and UpPTS determines the maximum cell size of an UTRA LCR-TDD cell, which is thus

$$\frac{75\mu}{2} \cdot 3 \times 10^8 = 11.25 \text{ km.}$$

The timeslots are denoted as TS0 to TS6. TS0 is always assigned for the downlink direction and conveys control messages such as Broadcast Channel (BCH). TS1 is always allocated for the uplink direction.

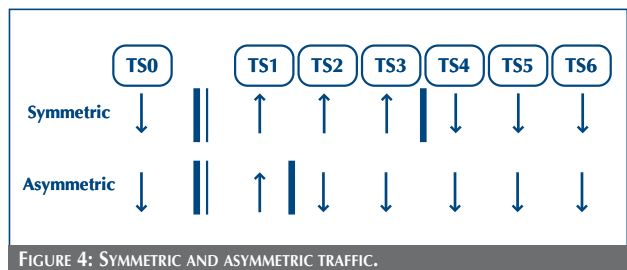


FIGURE 4: SYMMETRIC AND ASYMMETRIC TRAFFIC.

The point where a transition from uplink to downlink and vice versa occurs is termed a switching point. Within one 5 ms sub-frame, only two switching points are allowed. The first switching point is at the GP between the DwPTS and the UpPTS. The second switching point can occur anywhere between the end of TS1 and the end of TS6, as indicated in Fig. 4. It is this second switching point that determines the traffic nature of this particular sub-frame, i.e., symmetric or asymmetric.

3.3. Synchronization

We can divide the synchronization procedure for UTRA LCR-TDD into downlink cell search and uplink synchronization.

The cell-search procedure is used to determine the timing and codes contained in the downlink transmission. Document [11] provides a typical 4-step scenario for cell search. In step 1, the UE acquires the timing of the DwPTS by correlating with the SYNC-DL code transmitted in the DwPTS. It also identifies which SYNC-DL sequence is used by the Node-B out of the 32

possible sequences. In step 2, since a SYNC-DL is mapped to four basic midamble codes (there are 128 basic midamble codes in total), it is easy to identify which basic midamble code is used at the Node-B by correlating the basic midamble codes residing in the Primary Common Control Physical Channel (P-CCPCH) in TS0. As a basic midamble code is associated with a scrambling code, this step also provides us with the scrambling code used by the Node-B. In step 3, the correct timing of the BCH, which is mapped to the P-CCPCH, needs to be identified since the BCH is not transmitted in every sub-frame. This can be achieved by examining the QPSK phase modulation of the DwPTS [10]. By knowing the QPSK phase modulation, the position for the Master Information Block (MIB) of the multi-frame BCH can be identified. In the last step, the UE has to decode and read the information from the BCH channel.

The uplink synchronization is performed during the random-access procedure and begins after obtaining downlink synchronization. In order to reduce interference to traffic channels resulting from the unsynchronized uplink, the first transmission from the UE at the uplink direction has to be in the UpPTS. The timing used for the UpPTS transmission is estimated from the received power level of the DwPTS and / or P-CCPCH. The Node-B then detects the SYNC-UL transmitted

in the UpPTS and issues timing advance commands to the UE for adjusting its new transmission time in a resolution of 1/8 chips. During normal timeslots, the Node-B can also signal the UE to properly adjust its transmission timing by using Synchronization Shift (SS) commands. The main purpose for uplink synchronization is to reduce the uplink interference and, at the same time, facilitate possible multi-user detection in the Node-B.

3.4. Physical-Channel Structure

A typical UTRA LCR-TDD physical channel can be described using the time-slot structure, physical channel spreading, midamble and guard period.

3.4.1. TIME SLOT STRUCTURE

Fig. 5 depicts the timeslot structure used within UTRA LCR-TDD. There is only one burst format, and this consists of two fields of data symbols, a fixed-length 144 chip midamble, and control fields for (i) Synchronization Shift (SS), (ii) Transmit Power Control (TPC), and (iii) Transport Format Indicator (TFCI). The timeslot is delimited by a 16-chip guard period (GP).

The purpose of TFCI is to convey transport format information to the receiver, which is used by the channel decoder to recover transport channels. The TPC is used for the purpose of power

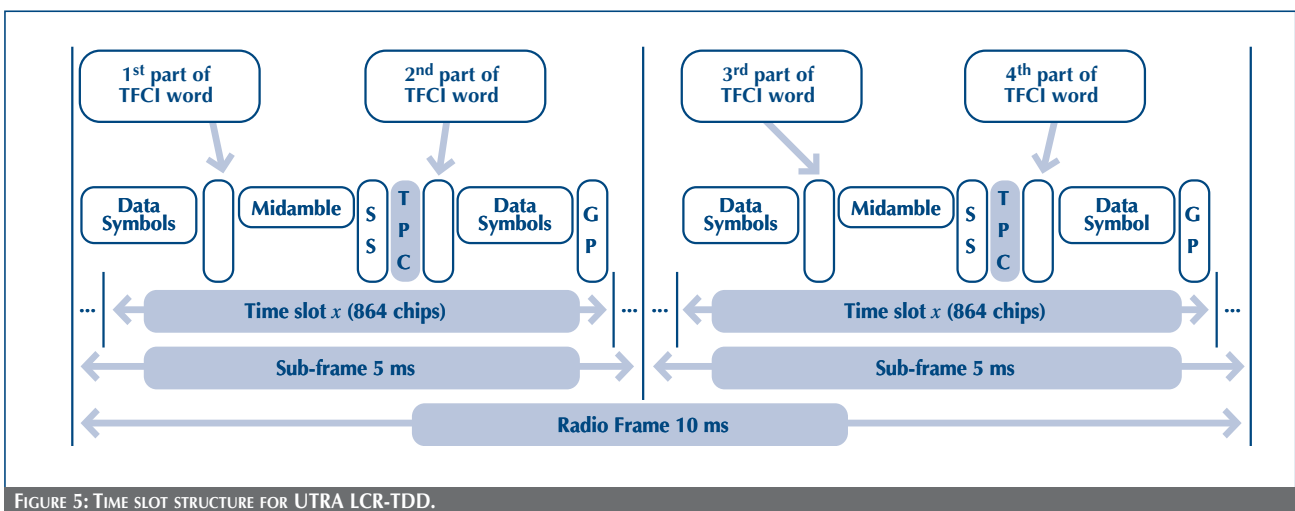


FIGURE 5: TIME SLOT STRUCTURE FOR UTRA LCR-TDD.

control, and as the TPC is transmitted every sub-frame (5 ms), the maximum frequency for closed-loop transmit power control is 200 Hz. The SS field adjusts timing advance between the UE and UTRAN. The last part of the burst structure is the GP, used to allow for power ramping and received signal delay spread.

Each data field consists of a maximum of 352 chips, which is mostly used for conveying data. The control fields can occupy the inner section of the data field. The TFCI information is transmitted every 10 ms and is distributed into four segments in the two 5 ms sub-frames. Each segment appears on either side of the midamble as indicated in Fig. 5. The same timeslot in the two 5 ms sub-frames carries the same TFCI codeword. The TFCI information occupies some of the area allocated to the data field, and the UE is able to know this allocation based upon information conveyed from higher layers.

3.4.2. PHYSICAL CHANNEL SPREADING

In Section 3.1, we mentioned that UTRA LCR-TDD consists of both TDMA and CDMA components. For CDMA, the information bits are spread to a wider bandwidth before transmission. Spreading involves two operations: (i) channelization and (ii) scrambling.

Channelization is by means of spreading the information data with Orthogonal Variable Spreading Factor (OVSF) codes. The OVSF codes used by UTRA LCR-TDD are exactly the same as those used by UTRA FDD and UTRA HCR-TDD. The spreading factor allowed in UTRA LCR-TDD is the same as that in UTRA HCR-TDD, i.e., 1 to 16. However, for the downlink, only spreading factors 1 or 16 are allowed in order to facilitate the implementation of low cost UE.

After channelization, the spread data is scrambled using scrambling codes of length 16. These scrambling codes are not the same as those employed in UTRA FDD but are the same as those in UTRA HCR-TDD. A smaller scrambling code length for both uplink and downlink ensures easier adoption of Joint-Detection (JD) receiver with moderate complexity.

The purpose of the channelization process is for extracting information symbols that are symbol-time synchronized, while the purpose of scrambling is the suppression of the possible noise resulting from interfering signals, which might not be time synchronized.

3.4.3. MIDAMBLE SEQUENCE

An UTRA LCR-TDD system consists of 128 basic midamble codes, as mentioned in Section 3.3. The length for each basic midamble code is 128, while the length for the midamble field in the timeslot structure presented in Section 3.4.1 is 144 chips. Although the lengths differ, it is extended to 144 chips by repeating the basic midamble codes from the beginning [8]. The actual midamble sequence transmitted from the midamble field in the TS structure also depends on the user number and the total number of users allocated the same basic midamble sequence [8]. Each user's midamble sequence has a unique shift from the sequence, constructed from the basic midamble plus repetition. The purpose of using the same midamble source sequence is for reducing the complexity of JD receiver since a single cyclic correlator is sufficient for joint channel estimation [14].

3.5. Physical Channels

There are two types of physical channels for UTRA LCR-TDD: (i) dedicated physical channels and (ii) common physical channels. There is only one type of dedicated physical channel, which exists in both uplink and downlink, namely the Dedicated Physical Channel (DPCH). DPCH is used to carry a transport channel, termed the Dedicated Channel (DCH), from the higher-layer after going through channel coding.

There are eight different types of common physical channels, namely P-CCPCH, Secondary Common Control Physical Channel (S-CCPCH), Fast Physical Access Channel (FPACH), Physical Random Access Channel (PRACH), Synchronization Channel (DwPCH and UpPCH), Physical Uplink Shared Channel (PUSCH), Physical Downlink Shared Channel

(PDSCH) and Page Indicator Channel (PICH). In general, there are two types of common physical channels. One type is used to carry channel-coded transport channels such as P-CCPCH, S-CCPCH, PRACH, PUSCH and PDSCH. The other type does not go through any channel coding process such as PICH, FPACH, DwPCH and UpPCH.

Except for FPACH, DwPCH and UpPCH, the physical channels are similar and have the same terminology as that used for UTRA HCR-TDD.

It is worthwhile to note that the DwPCH is transmitted in every sub-frame while the UpPCH is transmitted only when necessary, i.e., during uplink synchronization. The DwPCH transmits at a constant power level, which is signaled by the higher layers. The knowledge of the power level can be used for estimating the propagation loss and setting the transmission time advance of UpPCH.

3.6. Coding and Multiplexing

The channel coding and multiplexing scheme for UTRA LCR-TDD is similar to that of UTRA FDD and UTRA HCR-TDD systems. Data streams from the Medium Access Control (MAC) layer and higher layers are encoded to offer transport services over the radio transmission link.

Data packets are presented for channel coding in a timing interval termed the Transmission Time Interval (TTI), with four intervals of 10, 20, 40 and 80 ms possible, as is the case for UTRA FDD and UTRA HCR-TDD. For UTRA LCR-TDD, there is an additional TTI of 5 ms for the RACH, which is possible due to the 5 ms sub-frame.

TYPE OF TRCH	CODING SCHEME	CODING RATE
BCH	Convolutional coding	1/3
PCH		1/3, 1/2
RACH		1/2
DCH, DSCH, FACH, USCH	Turbo coding	1/3, 1/2
	No coding	1/3

TABLE 1: CHANNEL CODING SCHEME AND CODING RATE.

Table 1 illustrates the channel coding schemes and coding rates for various transport channels in UTRA LCR-TDD [9]. These schemes are similar to that of UTRA FDD and UTRA HCR-TDD, except for the BCH and PCH, which use 1/3 rate codes as there are a sufficient number of bits available because of the way these two channels are allocated to the physical channel.

After the coding scheme, when a long sequence of the same data symbol is transmitted, it can give rise to a large direct current (DC) value in the spectrum of the transmitted signal [15]. Therefore, a special operation called bit scrambling is introduced for both UTRA LCR-TDD and UTRA HCR-TDD. The idea is to scramble the coded information source bits with a known pseudo-random sequence so as to reduce the DC content in the transmitted spectrum. This operation does not exist in UTRA FDD since UTRA FDD adopts much longer scrambling code sequences that ensure a whitened spectrum without a DC component.

Both UTRA LCR-TDD and UTRA HCR-TDD support two different 2nd interleaving schemes, i.e., (i) frame interleaving and (ii) timeslot interleaving. The second option is useful when the interference of the respective cell strongly varies, depending on the timeslot. This is different from UTRA FDD, where only the frame interleaving applies.

In UTRA LCR-TDD, the 10 ms frame is sub-divided into two 5 ms sub-frames. As a result, sub-frame segmentation is required where the bit streams in the coded data are mapped equally over the two 5 ms sub frames. This operation does not exist in UTRA FDD and UTRA HCR-TDD.

Since UTRA LCR-TDD also supports 8-PSK modulation, the coding for TFCI is more involved. TFCI coding for 8-PSK is further divided into two categories, namely coding of long TFCI lengths (6 to 10 TFCI bits) and short TFCI lengths (TFCI less than 6 bits). The mapping of TFCI code word is also different since it is spread over two sub-frames, as seen in Fig. 5.

4. SUCCESS FACTORS

In order to have wide acceptance of 3G systems, i.e., UTRA FDD, UTRA HCR-TDD, UTRA LCR-TDD or cdma2000, various factors have to be considered. In this section, we look into some of the important factors that decide the fate of 3G, i.e., low power, multimode and killer applications. These factors may affect the research areas for 3G and its supplementary.

For subscribers to accept 3G services, the UE has to last for a certain period of time before the battery goes flat. The news that the first generation of Freedom of Multimedia Access (FOMA) 3G phones in Japan last only about half an hour has impeded users from subscribing to a 3G network. Therefore, low power designs such as proper system partitioning, system on a chip (SoC), or a CMOS power amplifier are important to ensure the success of 3G networks. Another important and related area of research will be in battery technology although advances in this technology are slow compared to levels of integration of silicon chips.

Today, the 2G networks have a large number of subscribers and worldwide coverage. As companies begin to deploy the 3G networks, the coverage area will be limited due to the cost of setting up new and expensive 3G infrastructure. For instance, NTT DoCoMo started their commercial 3G services in the Tokyo area only in the initial phase of 3G deployment. Unfortunately, this limited coverage has hindered new subscribers from taking up the new services. Therefore, in order for subscribers to accept the new services, a method of retaining the current services while gradually deploying 3G services transparently to the end subscribers should be adopted. This explains the importance of multimode UEs. In the early phase of 3G deployment, UEs that support GPRS and one or more 3G systems will emerge as the preferred choice. Therefore, integrating multimode systems efficiently in a single and tiny UE represents a big challenge for the 3G designers all over the world.

Although the previous two factors are very important in ensuring successful 3G services, an even more important factor will be the development of a “killer application” for 3G. In the 1980s, a personal computer (PC) boom evolved, largely due to the development of a killer application that people now still use, but maybe unaware of its importance to PC utilization, i.e., spreadsheet applications. Later in the 1990s, another PC boom emerged as a result of the wide adoption of Internet services. These services became so important that people termed the 1990s the Internet Era. Similarly for 3G, in order to have a successful 3G acceptance, 3G-specific killer applications will play a very important role.

5. CONCLUSION

In summary, we have provided a general description of UTRA LCR-TDD systems, including their system architecture, protocol, physical layer and migration paths. The physical layer was described in more detail and the rationales behind the decision of the parameters/procedure/features were given.

In general, UTRA LCR-TDD was designed to be suitable for beam-forming/smart antennas and joint detection receivers. However, factors that decide the success of 3G deployment should lie on low-power design, multimode support, and 3G killer applications.

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REFERENCES

- [1] RAST9(00)13 “HARMONIZED STANDARDS FOR THE IMT-2000 FAMILY”, Aug. 2000.

- [2] H. Holma and A. Toskala, “**WCDMA FOR UMTS**”, New York: Wiley, 2000.
- [3] Third-Generation Partnership Project:
<http://www.3gpp.org>.
- [4] Third-Generation Partnership Project 2:
<http://www.3gpp2.org>.
- [5] 3GPP TS25.301 v4.2.0, “**RADIO INTERFERENCE PROTOCOL ARCHITECTURE (RELEASE 4)**”, Dec. 2001.
- [6] TD-SCDMA Forum, <http://www.tdscdma-forum.org>.
- [7] 3GPP TS25.201 v4.2.0, “**PHYSICAL LAYER - GENERAL DESCRIPTION (RELEASE 4)**”, March 2002.
- [8] 3GPP TS25.221 v4.4.0,
“**PHYSICAL CHANNELS AND MAPPING OF TRANSPORT CHANNELS ONTO PHYSICAL CHANNELS (TDD) (RELEASE 4)**”, March 2002.
- [9] 3GPP TS25.222 v4.3.0,
“**MULTIPLEXING AND CHANNEL CODING (TDD) (RELEASE 4)**”, March 2002.
- [10] 3GPP TS25.223 v4.4.0, “**SPREADING AND MODULATION (TDD) (RELEASE 4)**”, March 2002.
- [11] 3GPP TS25.224 v4.4.0, “**PHYSICAL LAYER PROCEDURES (TDD) (RELEASE 4)**”, March 2002.
- [12] 3GPP TS25.225 v4.3.0, “**Physical Layer - Measurements (TDD) (RELEASE 4)**”, March 2002.
- [13] 3GPP TR25.928 v4.0.1,
“**1.28 Mcps FUNCTIONALITY FOR UTRA TDD PHYSICAL LAYER (RELEASE 4)**”, March 2001.
- [14] M. Haardt, A. Klein, R. Koehn, S. Oestreich, M. Purat, V. Sommer and T. Ulrich,
“**THE TD-CDMA BASED UTRA TDD MODE**”,
IEEE J. Sel. Areas Commun.,
pp. 1375-1385, vol. 18, no. 8, Aug. 2000.
- [15] TDoc R1-00-1340,
“**TRANSMISSION OF LONG SEQUENCES WITH SAME DATA**”,
Siemens AG, 3GPP TSG RAN WG1#17 meeting,
Stockholm, Sweden, 24-27 Nov. 2000

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