S-38.220
Licentiate Course on Signal Processing in Communications,
FALL - 97

Wideband CDMA in Europe and Elsewhere

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Date: 23.10.1997

ABSTRACT

The scope of this paper is to give an overview of wideband CDMA (W-CDMA) standard proposals. This paper concentrates on the European W-CDMA which is proposed within ETSI SMG2, where UMTS Terrristrial Radio Access (UTRA) technology is vurrently being selected. The main features of the air interface of ETSI SMG2 W-CDMA concept group proposal are described. The main differences to the two other W-CDMA proposals, one from Japan and other from US, are covered.

1. INTRODUCTION

In After the successful second generation cellular systems aimed mainly for the provision of speech services, the third generation systems with enhanced service capabilities are being standardised. The major candidate for world-wide systems on all continents is Wideband CDMA (W-CDMA). It is being considered in the standardisation or preparatory bodies in all regions [1], with the main W-CDMA proposals being:

ETSI (Europe)WCDMA, being one of the candidates for UMTS in ETSI SMG2
ARIB (Japan) WCDMA, being selected to making the standard
TTA (Korea), where two WCDMA proposals are proposed
Wideband cdmaOne, an IS-95 based proposal in US, [2].

This paper and its main chapter 4 will concentrate on the European W-CDMA, but the differences between different W-CDMA proposals will be briefly covered as other schemes are considered in chapter 5. On the presented information one should note that none of the system is not yet a standard, so changes are likely to occur until the final specification. Moreover in some markets, like US there are more than just one proposal for the W-CDMA as well thus unlike in Europe or Japan the single W-CDMA proposal is still missing. In US also other proposals are presented for the evolution of different PCS standards into the IMT-2000 era.

2. MAIN DIFFERENCES FROM THE 2ND GENERATION CDMA

There are several issues generally in the third generation proposals different from the IS-95 based solutions. The factors affecting the performance are the use of wider bandwidth, which allows to achieve higher degree of multipath diversity and thus less power fluctuations in the received signal level, and coherent detection on both directions.

The selected coding etc. solutions are different as the 2nd generation systems where optimised for speech type of traffic while with third generation systems efficient support of high speed data, both circuit and packet type, is expected.

The wider bandwidth systems in general allow also better statistical multiplexing effect as the number of users increases, especially with lower data rates. Also the interference averaging works well as inherent part of the air interface with W-CDMA.

There was also attempt to get W-CDMA system accepted in US for the US PCS but the standard was not adopted by any operator. The system was based around 32 kbits/s ADPCM speech coding but during the time of PCS system selection the implementation issues with W-CDMA for speech service dominating market caused the system not to gain acceptance among manufacturers and operators. The system was proposed by Oki America and InterDigital.

Although the second generation CDMA systems, like IS-95, have a lot of differences to the third generation proposals, the existing test and operational systems have shown that the basic CDMA features like fast power control and reuse order of 1 are functional and work in real conditions. Additionally the second generation systems have created implementation know-how of the required receiver solutions, such as Rake receiver. This kind of know-how is expected to make the equipment development faster as the basic fundamentals are known by the designers.

3. ETSI SMG2 UMTS TECHNOLOGY SELECTION

In the Europe, the selection process for UMTS or more exactly UMTS Terrestrial Radio Access (UTRA) is going on at the moment. There exist five different concept groups of which four are actual air interface proposals and one is more like a packet protocol to be applied on top of air interface solutions. The actual air interface concept groups in the ETSI SMG2 are:

- W-CDMA
- OFDM
- TDMA/CDMA
- W-TDMA

And the proposed packet relaying protocol in the ODMA (Opportunity Driven Multiple Access) concept group. In this paper only Wideband CDMA concept groups technical contents will be covered in more detail.

The ETSI SMG2 Wideband CDMA concept group was formed around the following four proposals:

- **FRAMES FMA Mode 2 (FMA2)**
  By ACTS FRAMES project (Nokia, Ericcson, Siemens, France Telecom/CNET, CSEM and several universities. (Only ETSI members mentioned)
- **Wideband Code Division Multiple Access (W-CDMA)**
  By Fujitsu
- **Wideband Direct Sequence (DS) CDMA**
  By NEC
- **DS-CDMA Utilising FDD and TDD**
  By Panasonic (Matsushita)

Based on the proposals made to the concept group, the consensus was achieved on a single W-CDMA concept to be proposed by the concept group to be selected as UMTS air interface. The main features of the air interface proposal from the ETSI W-CDMA concept group are described in the following chapters.

4. ETSI SMG2 W-CDMA

As within ETSI the most successful standard is the GSM, having also biggest market share in the world among the digital standards, it is natural that one of the most import features is the co-existence with existing GSM system. This means that the handover to and from GSM along with providing the full GSM service set will be very important. Also clearly from the backbone network side, the GSM based network solutions will be the building platform for the third generation cellular systems in ETSI.

Table 1. ETSI SMG2 W-CDMA proposal main parameters

Multiple Access	Single carrier wideband DS-CDMA
Duplex scheme	FDD/TDD
Carrier spacing	4.2-5 MHz (200 kHz raster)
Basic Chip Rate	4.096
Frame length	10 ms
Inter BS Synchronisation	FDD Asynch, TDD Synch.
Spreading codes	Short+long (long code optional in the uplink)
Coherent Detection	Both directions with pilot symbols
Multirate/variable rate concept	Variable spreading factor and multicode
Transmission Rate Detection	Explicit rate information on control channel
Channel coding	Convolutional coding 1/2 or 1/3 rate, RS-code outer code (optional)
Data/Control multiplexing	Code multiplex/Time multiplex (Uplink/Downlink)

4.1 Physical Channel Structure

One of the characteristic features for the ETSI W-CDMA is the physical channel structure which is designed with the UMTS varying service requirements in mind. In ETSI W-CDMA there are two types of physical channels defined:

- Dedicated Physical Control Channel (DPCCH) for carrying layer 1 control information like power control, pilot symbols and rate detection information.
- Dedicated Physical Data Channel (DPDCH) for carrying user data.

One or more DPDCHs carry the user data. For medium and low bit rates only single DPDCH (code) is used together with a single DPCCH channel with fixed spreading ratio. For high bit rates multiple DPDCHs can be used with multicode principle.

The uplink and downlink have different multiplexing principles. The uplink principle where for single data channel case the control and data channel form a QPSK signal from two BPSK channels is indicated in Figure 1 for the uplink and resulting modulation principle in Figure 2. As the two channels can have a different power level due to different data rates, the complex valued scrambling code is applied on the top of the signal to achieve similar envelope to QPSK regardless of the power differences between the channels.

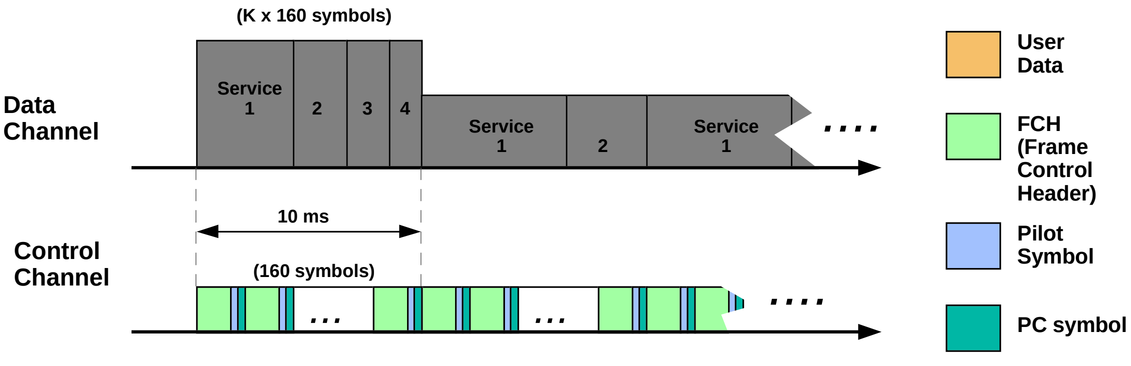

Figure 1. Uplink control and data channel usage.

The control channel in Figure 1 has always fixed parameters, like the spreading ratio of 256, which allows the control channel to change to spreading ratio of the data channel. As the control channel parameters are always known there is also no risk of error propagation as could be the case when spreading ratio of the both channel would be changed.

As the principle in Figure 1 is used in the uplink, it allows also a pulsing free implementation of DTX, where during silent periods both with speech and data connections, only the control channel is transmitted thus resulting to lower total transmission power, maintaining synchronisation and power control and avoiding undesirable effects with power pulsing caused if the transmitter was gating on and off.

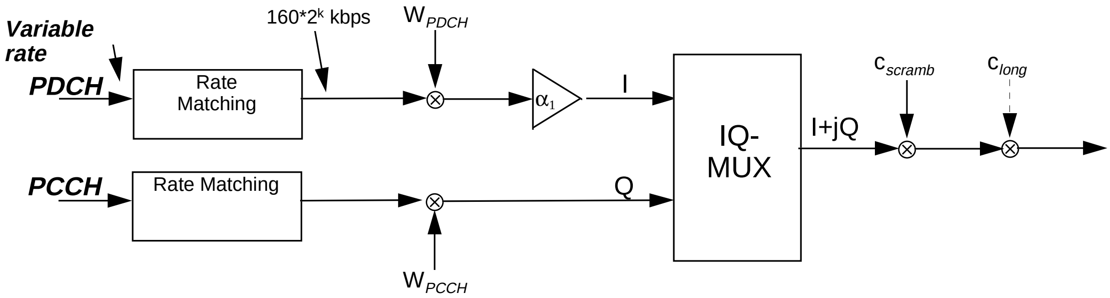

Figure 2. Uplink modulation with separate PDCH and PCCH.

The different code channels in the case of multicode transmission are separated by orthogonal codes from the code three in Figure 3 which allows the channel with different spreading factor to remain orthogonal. Ideal orthogonality is naturally maintained in a single path channel only, but also the orthogonal codes give a substantial gain also in severe multipath environment. The codes are picked from the three so that the codes on the underlying branch are not used. In the uplink the code three is user specific since the users are additionally separated with a short 256 chip scrambling code with the long 10 ms (40960 chip) scrambling code being optional if additional interference averaging is required.

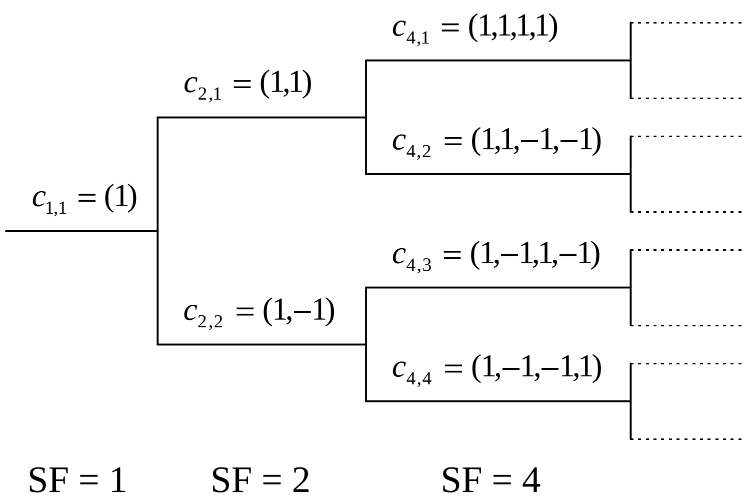

Figure 3. Orthogonal code three used for channelisation.

In the downlink the code three is base station specific and the base station has base station specific scrambling code used for separating the different base stations and also sectors within the same base station. The multiplexing of the control and data channel is done with time multiplexing with the multiplexing period of 0.625 ms resulting to the 16 “slots” in each 10 ms frame. The resulting rate for fast power control is 1.6 kHz although different rates can be applied quite easily if desired. In the downlink the base station transmission is anyway continuos and thus DTX can be done with gating the transmission on and off periodically as the control channel are always active anyway. Also the audible interference problems from the base station are not considered that critical but do not occur there either due relative constant envelope.

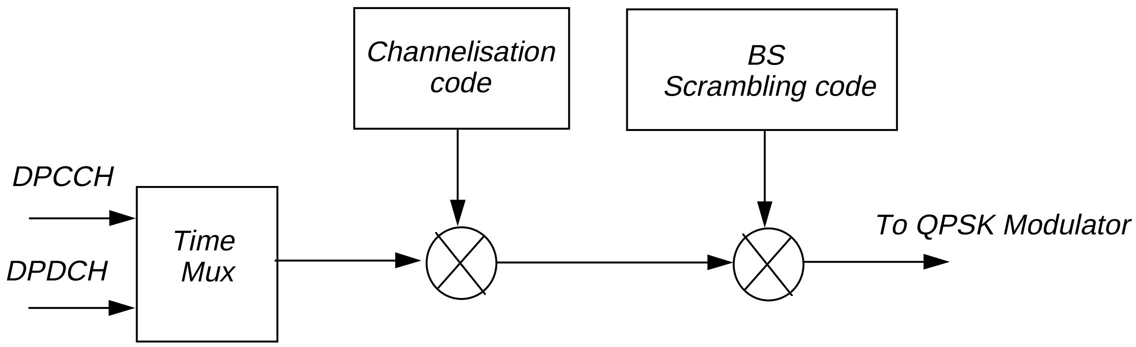

Figure 4. Downlink PCCH and PDCH multiplexing.

The spreading ratios used for the basic chip rate (4.096 Mchips/s) are starting from 256 with the lowest spreading ration currently considered being 8. Thus in the uplink the symbol rate for the data channel is 16 kbits/s of uncoded data. The default symbol rate for the control channel is the same. In the downlink the QPSK type time multiplexed channel has the channel bit rate of 32 kbits/s including both user and control data.

4.2 Service multiplexing

For the efficient mobile terminal functionality in the both reception and the transmission direction, the use of parallel code channels should be avoided as long as possible. In the uplink the complexity of spreading the additional code channels is not considered a problem, but the power amplifier can be run more efficiently when only a single DPDCH is used. In the downlink direction the number of RAKE fingers is for each channel in the order of 4, thus adding additional channels quickly increases the required number of correlators in the terminal. This is also an issue related to power consumption in the terminal, although the required accuracy for RAKE receiver processing in terms of number of bits in AD conversion and correlators is rather low. The needed number of bits has been studied and reported to be in the order 5 to 6 bits per correlation sum in the integrate and dump circuitry as studied for example in [6].

The service multiplexing principle being the working assumption is according to the figure 5, where the different service classes can be multiplexed to the same physical transmission resource. The two step coding mechanism allows to mix service with different quality requirements as separate inner and outer coding is used. Also service specific coding can be provided without physical layer coding. The data rate is eventually matched to the physical channel symbol rate with unequal repetition. Alternatively puncturing can be used as well.

If the services are considered to have that much different quality requirements the parallel code channel approach can be used with the earlier mentioned drawbacks.

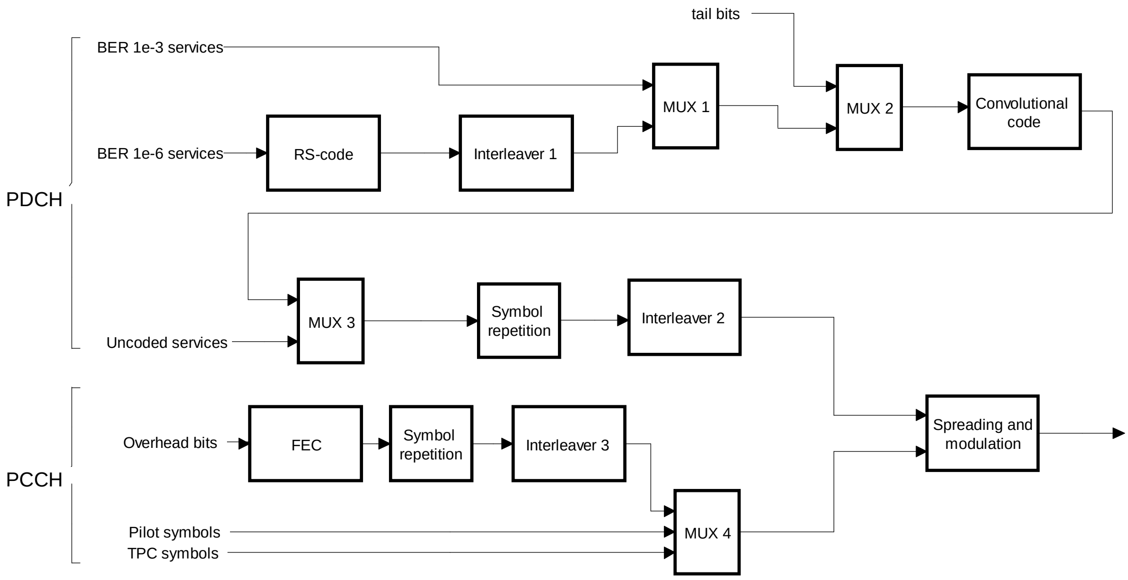

Figure 5. Multiplexing of different service classes.

4.3 Channel coding

The currently selected codes used are relative traditional convolutional codes although constraint lenght 9 is used. For part of the data services in ETSI evaluations also the outer Reed-Solomon coding is implemented. The packet services have combined FEC (convolutional coding) and ARQ.

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

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

The detailed channel coding procedures are expected to be further discussed when deriving the actual standard.

4.4 Random Access

One of the important features of the third generation cellular system is the provision of efficient random access as several services are expected not to be circuit switched type with continuos traffic. The solution in the ETSI W-CDMA is currently based on slotted ALOHA type approach. The mobile first after having done the code acquisition measures the signal level from the downlink signal of the base station and estimates the needed transmission power for the random access burst. Additionally the mobile must take into account the possible correction terms as there might be unbalance between uplink and downlink due to antenna diversity etc. receiver structures. This correction term is a base station specific parameter and transmitted on common control channels.

The random access message can be followed by a short packet directly without the need for setting up the user dedicated channels. This can be naturally done for only relative short packets. For longer and/or more frequent packet connection dedicated channels are set up as the power control etc. functionalities must be maintained. [4].

The format of the random access message is presented in figure 6. The burst is started with a preamble with also allows several random access messages to be processed at the same time. The spreading code for the random access part is common but the modulation patterns for the preambles are orthogonal and thus different patterns allow simultaneous random access. Typical CSMA/CS collisions behaviour as for example with the Ethernet solutions, where collisions always means that packets do not get through, is avoided and thus throughput remains high without typical slotted ALOHA bell shape curve. This has been studied analytically also in [3].

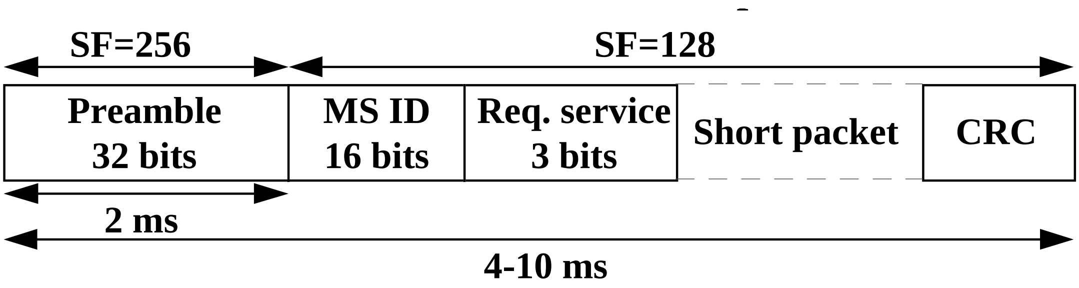

Figure 6. Random access message with optional packet, SF indicates spreading factor.

4.5 Packet Access

As discussed earlier, the efficient packet access considered very important for the UMTS air interface tehcnology. This is supported in many ways. In connection with random access message it was possible to transmit short packet (SMS etc.) directly wihtout setting up a connection. For the larger packets there exits two operation modes:

- Single packet transmission mode
- Multi packet transmission mode

With the single packet tranmission mode the terminals require permission to transmit a packet on a common channel and they are indicated when they are alloweed to do so. The other option is to set up a dedicated connection with continuos link maintenance for sending several packets. This mode of operation is indicated in Figure 7. Depending the size of the packets and the peak rate of the transmission either scheduled or non scheduled transmission can be used. If the desired peak rate of the packets is very high, in the order of 1 Mbis/s or so, the interference situation must be coordinated somehow. For small rate transmission ratker common load control is needed and interference averaging can take care of the interfence situation.

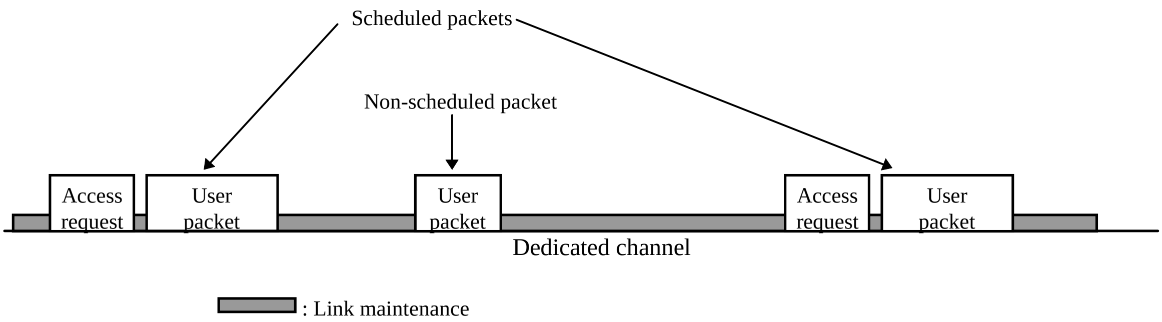

Figure 7. Multipacket transmission mode

4.6 Power control

The ETSI W-CDMA uses fast power control for both directions. The uplink has additionally open loop power control to deal with corner effects etc. sudden changes in the pathloss. The mobile measures the received downlink power and if the received power level suddenly increases more than the threshold, the mobile will reduce its transmission power.

For both direction additional so called outer control loop is operated which monitors the received signal quality and based on that adjust the required C/I target for the fast power control operation.

Table 3. Power control parameters

Uplink power control	Fast closed loop and open loop
Dynamic range	80 dB
Downlink power control	Fast closed loop
Dynamic range	15 dB

The power control frequency can be adjusted by having power control commands less often than in every slot, thus typical frequencies to be used are expected to be 800 Hz and 1.6 kHz. With TDD no closed loop power control is used as discussed later.

4.7 Handovers

With ETSI W-CDMA three types of handovers are expected to be supported in the system desing:

- Soft handover
- Softer handover
- Inter-frequency handover (hard handover)
- Handover from GSM to W-CDMA and vice versa

The soft handover means handover when the mobile is connected to several base stations simultaneously while softer handover means that mobile is being connected to several sectors at the same cell simultaneously. The inter-frequency handover is handover between different frequencies due to Hierarchical Cell Structures (HCS) or additional carriers for hot spot coverage etc.

The soft and softer handover go more straightforward as then the used frequency remains the same. For inter-frequency handover some kind additional arrangements are needed to provide the mobile with measurement capability. In ETSI W-CDMA concept group two solutions exist. The solution intended for the simpler terminals is the so called slotted mode where there is a break organised in the downlink transmission from the base station. During this break (1 frame or less) the mobile goes to measure the other frequencies when indicated of their existence by the base station. This kind of procedure is similar to GSM where the base station informs on the BCCH what are the neighbouring base stations to follow for possible handover. The second approach is that terminals with dual receiver (with antenna diversity) have a second receiver branch which they can allocate for measurements when needed. This solutions is naturally the most costly one in terms of added complexity.

Additionally handovers from GSM/DCS will be supported naturally supported as especially during the initial deployment the coverage will be poorer compared to the coverage of the existing GSM/DCS networks. Providing the GSM/DCS service set is not going to be problem with W-CDMA as the air interface allows basically any data rate between zero rate and 2 Mbits/s to be provided. Measurements from the GSM/DCS can be arranged either by a dual receiver or then having breaks in the downlink transmission in the order of 5 ms or so during which the W-CDMA mobile goes out to measure the GSM/DCS carrier frequencies.

4.8 Support of TDD

In the ETSI W-CDMA concept also TDD (Time Division Duplex) mode is included. The main differences to FDD mode is the use of open loop power control and division of the uplink/downlink transmission on slot by slot (0.625 ms) basis. The TDD mode can rely on the open loop power control as the uplink and downlink paht losses have high correlation since they use the same frequency. Thus the correct transmission power can be adjusted more accurately than with FDD mode where there is the duplex separation between uplink and downlink.

For several TDD cells to co-exist the TDD network needs to be synchronised, otherwise mobiles trying to receive at the same frequency will be easily blocked by the near far effect from other mobiles transmitting near-by at the same time and frequency allocation.

The TDD mode is more limited in the performance as a function of mobile speed, otherwise the power control estimate will change too much during the transmission period due fast Doppler. Terminal speeds up to at least 120 km/h can be supported according to the simulations in the ETSI W-CDMA concept group. Rather than suddenly deteriorating the single link performance the effect of speed is more visible in the system capacity as the power control error deviation starts to increase.

The TDD mode has two configurations where the slots can be either changing transmission direction by every slot (0.625 ms) or the other and is that inside the 10 ms frame there is only one direction change. The latter approach allows asymmetric resource allocation between uplink and downlink while the former approach tolerates higher mobiles speeds.

5. MAIN DIFFERENCES BETWEEN DIFFERENT W-CDMA PROPOSALS

Between several different W-CDMA air interface proposals they are few fundamental parameters which have a lot of impact in the system design. The use of either synchronous or asynchronous network has not so much impact in the operation of individual cells, unless users are expected to be time controlled as well, but rather on the way spreading codes are allocated and handovers designed. Also if one transmission direction is multicarrier transmission as being an option with wideband cdmaOne, then differences occur. Also as the proposals have as a common feature coherent detection in both direction, the means of providing the needed phase reference varies.

In ARIB W-CDMA the reference symbols are provided as inserted in the data stream, although similar solution as with ETSI SMG2 W-CDMA where separate control channel is used is also being considered in ARIB. In the Wideband cdmaOne the pilot is provided as the separate pilot channel on both directions.

Other smaller parameter differences included the slightly different chip rates with 3.6864 Mchips/s in US and 4.096 Mchips/s elsewhere, also in Korea. The selection in the proposal in the US is due to the backwards compatibility reason with IS-95 as is the case with the 20 ms frame lenght. Table 4 summarises the key technical characteristics and parameters of the different W-CDMA radio-interface proposals.

Table 4. W-CDMA key technical characteristics

Proposal	ARIB	Wideband cdmaOne	ETSI SMG2
Multiple-Access scheme	DS-CDMA	DS-CDMA	DS-CDMA
Duplex scheme	FDD / TDD	FDD	FDD / TDD
Chip rate	4.096 Mcps	3.6864	4.096 Mcps
Carrier spacing (4.096 Mcps)	5 MHz	5 MHz	Flexible in the range 4.4-5.2 MHz (200 kHz carrier raster)
Frame length	10 ms	20 ms	10 ms
Inter-BS synchronization	Asynch.	Synch.	Asynch.
Multi-rate/Variable-rate scheme	Variable-spreading factor + Multi-code	Variable-spreading factor + Multi-code	Variable-spreading factor + Multi-code
Pilot multiplexing	Time multipled	Separate pilot channel	Time/code multiplexed on separate control channel in the uplink Time multiplexed on the downlink
Channel coding scheme	1/2 or 1/3 convolutional coding, optional RS coding	1/4, !/3 or 1/2 convolutional coding	Convolutional coding (rate 1/2-1/3) Optional outer RS coding (rate 4/5)

Korean proposals are not included in this comparison. In Korea currently two W-CDMA proposals exist for IMT-2000, with the other being based on synchronous network and the other being based on asynchronous network. For more details see [1].

6. CONCLUSIONS

The wideband CDMA is currently actively being present in all regions in the standardisation forums. Based on this alone it seems to be so that achieving a world phone, if ever possible, will be achievable with W-CDMA alone. What will be the commonality of the different air interface proposals when the standards are finalised remains to be seen. The ITU has also the time schedule for submission of the candidate Radio Transmission Technologies during summer 1998, by which each region should have it clear which proposal(s) shall be presented to ITU.

In ETSI the wideband CDMA is also strong candidate for UMTS radio access technology and decisions in ETSI are expected during the end of 1997 in order to have sufficient time to prepare the ETSI radio access input towards ITU. As it seems likely that ETSI will go also for W-CDMA, then W-CDMA contributions to ITU are expected from all regions.

As the different regions have their own requirements for their W-CDMA system depending on the existing second generation systems, like PDC, GSM, D-AMPS, IS-95, the requirements from the backwards compatibility point of view can still leave some issue in the air interface that will remain region specific and cannot be agreed even if desired in ITU level.

7. REFERENCES

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