WCDMA – The Third Generation Radio Access

Mikael Gudmundson
Ericsson Research
mikael.gudmundson@era.ericsson.se

Abstract - Work on WCDMA as a concept for 3rd generation mobile communication (IMT-2000) started almost a decade ago in research projects sponsored by the European Community. The work continued with standardization activities of WCDMA in a number of standardization bodies, i.e., ETSI, ARIB, TTA and in T1P1. This year the standardization work has been transferred into one joint standardization project, 3GPP (3rd Generation Partnership Project) with members from all these standardization bodies. During the last year manufacturers and operators have also together succeeded in harmonizing all proposed cdma-based 3rd generation concepts into one standard with three different modes. The Direct-Sequence mode is based on WCDMA specified by 3GPP (UTRA/FDD), the Multi-Carrier mode is based on cdma2000 Multi-Carrier specified by 3GPP2, and the TDD mode is based on the TDD mode specified by 3GPP (UTRA TDD). In the paper we give a brief description of the WCDMA radio interface.

I. INTRODUCTION

The growth of mobile communications is well known. The prediction is that by year 2001, there will be more than 600 million subscribers worldwide in the cellular systems. Today the dominating standard is GSM and this will continue to be the case for a number of years. GSM started as a pan-European initiative with the first commercial systems deployed 1991. Today GSM has a footprint that covers most of the world.

At the same time as we can observe the tremendous growth of the mobile systems, there is a similar growth of internet usage, see Fig. 1.

The combination of mobile and internet growth has the possibility to create the real driving force for the third generation systems.

The standardization of third generation mobile communication systems is now rapidly progressing in all major regions of the world. These systems, that go under the ITU name of IMT-2000 and within ETSI as UMTS (Universal Mobile Telecommunications System) will extend the services provided by current second generation systems (GSM, PDC, IS-136, and IS-95) with high-rate data capabilities. The main application for these high-rate data services will be wireless packet transfer, e.g. for wireless access to the internet. However, UMTS will also support high-rate circuit-switched services such as video.

Wideband CDMA (WCDMA) has been chosen as basic radio-access technology for UMTS/IMT-2000 in all major areas of the world.

Compared to second generation narrowband CDMA, the WCDMA radio interface offers significant improvements, in addition to the support of higher-rate services. These includes: improved coverage and capacity due to a higher bandwidth and coherent uplink detection; support of inter-frequency handover necessary for high-capacity Hierarchical Cell Structures (HCS); support for capacity-improving technologies such as adaptive antennas and multi-user detection; and a fast and efficient packet-access protocol.

UTRA (Universal Terrestrial Radio Access) includes both a Frequency-Division Duplex (FDD) mode and a Time-Division Duplex (TDD) mode. The FDD mode is based on pure WCDMA while the TDD mode includes an additional TDMA. This paper focuses on the pure WCDMA-based FDD mode (UTRA/FDD).

The paper is outlined as follows: We begin in Section II by defining the spectrum allocation situation in different parts of the world. Section III gives a short background to the research and standardization activities behind WCDMA. Section IV summarizes the harmonization activities of WCDMA and other related cdma standards. Section V gives an overview of the existing WCDMA standard. The paper in is concluded with Section VI. Finally, in Section VII a reference list is given.

II. SPECTRUM ALLOCATION

In ITU, a spectrum identification for IMT-2000 services has been made on parts of the 2 GHz band. According to that recommendation, Europe will allocate the paired bands 1920-1980 MHz and 2110-2170 MHz for FDD operation and the unpaired bands 1900-1920 MHz and 2010-2025 MHz for TDD operation. In Japan, there will be an identical allocation, for the FDD part,

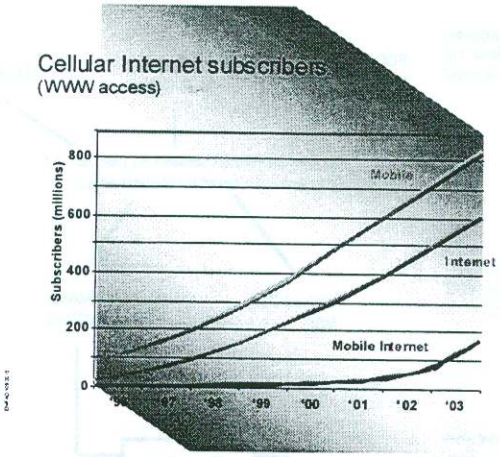

Figure 1. Growth of mobile and internet subscribers

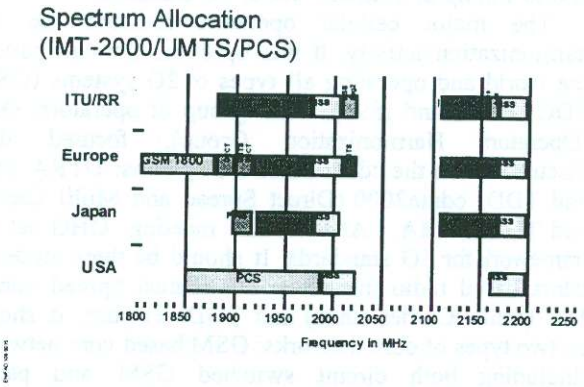

Figure 2. Spectrum allocation

while no allocation is made for TDD operation. In US the spectrum allocation is different. Parts of the 2 GHz frequency band is already allocated to PCS. Hence, it is not possible with a common worldwide frequency allocation for IMT-2000, see Fig. 2.

Although a spectrum has been set aside for IMT-2000 services in parts of the world, it does not mean that similar services cannot be provided in existing bands. For instance EDGE (which is a migration path for both GSM and D-AMPS in existing spectrum) and MC (Multi Carrier) cdma2000 (which is a migration path for IS-95 in existing spectrum) both supports the majority of the IMT-2000 services. The main difference is that for the new spectrum, a standard can be designed without strong backward compatibility requirements which allows for an air-interface more optimized for 3G services.

III. BACKGROUND TO WCDMA

Extensive European research on WCDMA has been carried out for almost a decade. In the RACE/CODIT project [1] (1992-1995), a WCDMA concept fulfilling the third generation requirements was first developed. The CODIT concept was also the basis for hardware testbeds used to evaluate and verify the performance of the WCDMA technology. One example is the Ericsson Wideband Test Bed (WBTB) [2].

The WCDMA technology was then further refined into the FMA2 (FRAMES Multiple Access 2) concept developed within the FRAMES project [3,4,5,6,7].

In March 1997, the FMA2 concept was submitted to ETSI as a candidate technology for UTRA. Within ETSI, the FMA2 proposal was first merged with other WCDMA proposals into the ETSI Alpha concept.

Finally, in January 1998, the WCDMA-based Alpha concept was, by a consensus decision, chosen by ETSI as the main technology for UTRA FDD.

The work on further enhancements and refinements of UTRA continued within ETSI during 1998, with the target to have a complete description of the radio interface ready at the end of 1998. Since early 1999 the WCDMA standardization has continued within 3GPP (3rd Generation Partnership Project). 3GPP is a joint project between ETSI (Europe), ARIB & TTC (Japan), T1 (USA) and TTA (Korea) with the task to specify a third generation system with the UTRA radio access network connected to a GSM based core network. The target for 3GPP is to have a complete specification ready by the end of 1999.

IV. HARMONIZATION OF 3G STANDRARDS

The UTRA radio-interface has also been submitted to ITU as a candidate radio-interface for IMT-2000. In parallel to the WCDMA activities in Europe, there has also been extensive work on third generation WCDMA in Japan, Korea and in North America. Standardization bodies in these countries also submitted their variants of WCDMA to ITU as candidates for IMT-2000. Before the submission of the ITU candidates it was strong cooperation and coordination between the WCDMA proponents, therefore all four variants of WCDMA was more or less identical. Now, with the 3GPP project it exists only one WCDMA standard.

ITU also got another cdma proposal, i.e., cdma2000. cdma2000 was proposed by a standardization body in the North America (TIA/TR45.5) and as an alternative proposal from Korea. Note that cdma2000 really contains two modes, one direct spread mode with a 5 MHz single-carrier in uplink and downlink and one Multi Carrier mode with three IS-95 carriers in a multi-carrier format in the downlink. Furthermore, TIA also proposed UWC-136 (EDGE and a wideband TDMA mode).

In total ITU received three families of FDD proposals: WCDMA, cdma2000 and UWC-136.

ITU also received three TDD proposals, UTRA/TDD (Europe), TD-SCDMA (China) and DECT (Europe). The UTRA/TDD mode is harmonized with the UTRA/FDD (WCDMA) mode.

After the submissions of IMT-2000 candidates to ITU the general understanding in the industry was that it was too many 3G systems. Therefore there has been

intense activities to harmonize the IMT-2000 candidates and to end up in a smaller set of 3G standards.

The major cellular operators initiated the last harmonization activity. It was operators from all parts of the world and operating all types of 2G systems (GSM, PDC, IS136 and IS95). This group of operators, OHG (Operators Harmonization Group), focused their discussions on the cdma based 3G systems: UTRA FDD and TDD, cdma2000 (Direct Spread and Multi Carrier) and TD-SCDMA. At their first meeting, OHG set the framework for 3G standards. It should be three modes of cdma based radio interfaces: DS (Direct Spread cdma), MC (Multi Carrier cdma) and TDD. Further, it should be two types of core networks: GSM based core networks (including both circuit switched GSM and packet switched GPRS) and ANSI-41 based core networks (including both circuit and packet switched networks). All Radio Access Network modes should be able to connect to both types of core networks, see Fig. 3.

The OHG also invited major manufactures to their meetings during the spring of 1999. Finally, in May 1999 the OHG and the invited manufactures concluded the harmonization discussion at a meeting in Toronto, Canada.

The agreement in the industry of cdma based 3G systems is as follows: The cdma DS mode should be based on WCDMA (specified by 3GPP). The agreement also said that 3GPP should do some minor modifications of the existing specifications. This is described later in the paper. Further, the WCDMA standard should include hooks to make it possible to connect WCDMA with ANSI-41 based networks.

The MC mode should be based on the cdma2000 MC (Multi Carrier) mode (specified by 3GPP2). The cdma2000 MC specifications should include hooks to make it possible to connect cdma2000 MC with GSM based networks.

The TDD mode should be based on the UTRA TDD mode. Now work is going on to harmonize the UTRA TDD mode with the Chinese TD-SCDMA system. Again, the TDD specifications should allow for connections to both GSM and ANSI-41 based networks.

In conclusion, the harmonization activities has resulted in one cdma 3G standard with three modes, i.e., a DS mode based on WCDMA, a MC mode based on cdma2000 and a TDD mode based on UTRA TDD. Currently the standardization projects 3GPP and 3GPP2 are working on the last details of the different 3G cdma modes. As already mentioned, the first complete specifications will be ready by the end of 1999.

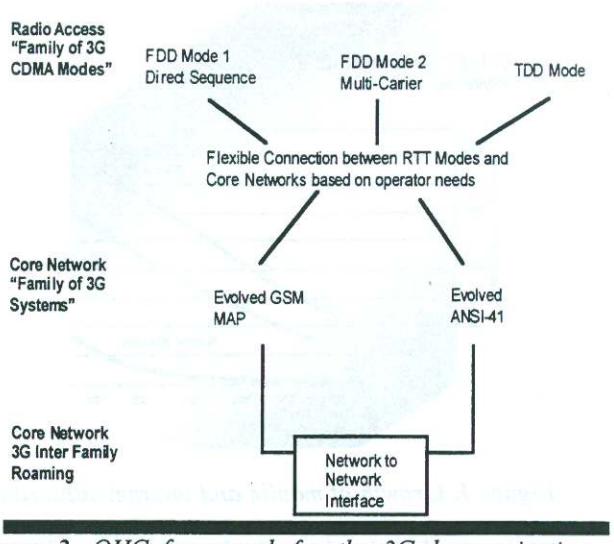

Figure 3. *OHG framework for the 3G harmonization activity.*

V. WCDMA DESCRIPTION

Focusing on the radio parts of WCDMA, a number of interfaces and functional splits have to be standardized. In Fig. 4, a block-diagram of UTRAN (Universal Terrestrial Radio Access Network) is shown.

Comparing with GSM architecture, UTRAN corresponds to the BSS (Base Station Subsystem). The Iu-interface between UTRAN and the core network correspond to the A-interface in GSM (Gb interface in GPRS). The Iub-interface corresponds to the A´´-interface. A new interface is the Iur-interface between the RNC's to support the soft handover functionality. Last, but not least, is the air-interface between the basestation and the terminal (Node B and UE in Fig. 4).

A radio interface based on wideband direct sequence CDMA gives the opportunity to design a system with properties fulfilling the third generation requirements. The key properties that are emphasized in WCDMA are:

- Improved performance over second generation systems including
  - improved capacity
  - improved coverage
- High degree of service flexibility including
  - support of a wide range of services with maximum bit rates above 2 Mbps and the possibility for multiple services on one connection
  - a fast and efficient packet-access scheme

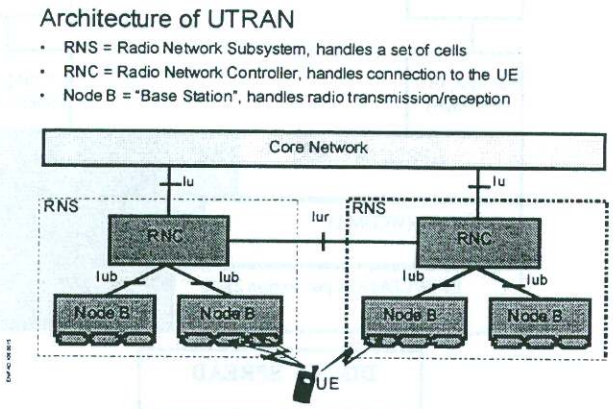

Figure 4. UMTS Terrestrial Radio Access Network

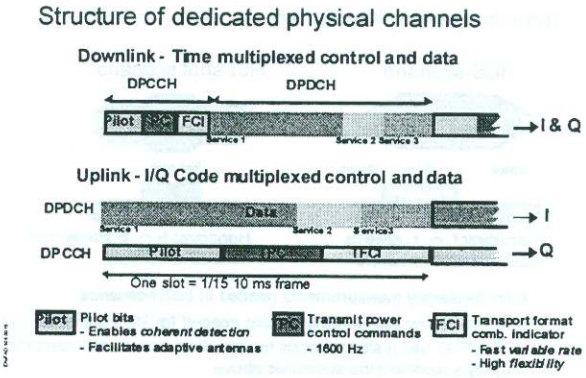

Figure 5. Structure of WCDMA physical layer

- High degree of operator flexibility including
  - support of asynchronous inter-base-station operation leading to easier deployment in many environments
  - efficient support of different deployment scenarios including Hierarchical Cell Structure (HCS) and hot-spot scenarios
  - support of evolutionary technologies such as adaptive antenna arrays and multi-user detection

As noted above, the WCDMA standard should contain the necessary hooks for future performance enhancements, such as the introduction of smart antenna solutions. The way to support that is to have user unique pilot information, see Fig. 5.

This is necessary to facilitate channel estimation in the terminal, since each connection will have a different antenna pattern, which in turn is a part of the channel.

Other important details on the physical layer is the TPC (Transmit Power Control commands) and TFCI (Transport Format Combination Indicator). Note that TPC is included in both uplink and downlink, although only necessary for the downlink. Note that, in contrast to 2nd generation narrow-band CDMA systems, WCDMA uses fast power control also in downlink. The reason to have TPC also in the uplink is to improve performance. TFCI makes it possible to have fast variable rate supported, i.e. to provide high flexibility.

Another important requirement that must be fulfilled is the support of HCS (Hierarchical Cell Structures) in Fig. 6.

In an HCS scenario the two cell layers are operating at two different frequencies. In 2nd generation narrow-band CDMA there is continuous transmission and reception, i.e. there is no time for inter-frequency measurements. That means that there is no measurement support for handover decisions. To overcome this problem a feature called compressed mode has been introduced. The idea is to temporarily compress the date and thereby create idle time for the receiver. During the idle time, the receiver can be used to carry out inter-frequency measurements

A. Additions / modifications to WCDMA

The WCDMA specifications in 3GPP prior to the OHG agreement specified a cdma system with a chiprate of 4.096 Mcps, time multiplex pilot information for all physical channels, see Fig. 5. In the OHG agreement it was concluded that the DS mode (WCDMA) should have a chiprate of 3.84 Mcps. The motivation for this change was to allow for easier implementation of DS & MC dual mode terminals. It has been stated that if the chiprate of the two modes differ by less than 5 % it will be easier to use the same RF chain in both modes. Due to backward compatibility constraints, the MC chip rate was looked to 3.6864 Mcps.

OHG also agreed that the DS mode should have a common code multiplexed pilot. For cells with no "smart" antennas or with no sophisticated transmit diversity schemes it was argued that a common pilot might provide better performance, compared to only using dedicated pilots. These modifications (chiprate and common pilot) are now incorporated into the latest versions of 3GPP specifications.

As mentioned earlier it should be possible to connect the WCDMA radio interface to an ANSI-41 network. In the OHG agreement Fig. 7 is used to describe how this will be done.

For a connection of WCDMA (including the radio protocols up to Layer 3 RR) to a GSM network or to an ANSI-41 network, the radio protocols defined in 3GPP should be used. However, 3GPP has until now only been working on a WCDMA to a GSM core network connection. Therefore some modifications/additions of the WCDMA radio protocols may be needed. This is to guarantee that all services and functionality in an ANSI-41 can be used together with the WCDMA radio interface. Further, the CC (Call Control) and MM (Mobility Management) are taken from GSM when

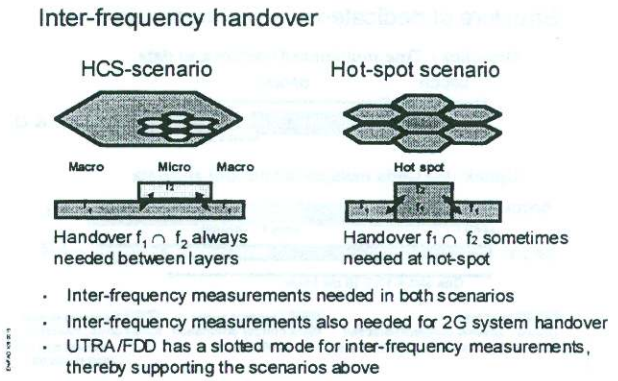

Figure 6. *Support of HCS (Inter-frequency handover)*

connecting to a GSM network and taken from IS634 when connecting to an ANSI-41 network.

In Fig. 7 the words "Hooks" and "Extensions" are used for the Modifications and Additions respectively. The hooks (modifications), if any needed, of the WCDMA protocols needs to be incorporated into the 1999 years Release of WCDMA specifications, whereas the Extensions (Additions) can be done in later releases.

The work of defining the hooks and extensions are now ongoing in 3GPP.

VI. CONCLUSIONS

After almost a decade of research and standardization activities in Europe and in other parts of the world we have reach consensus for a global CMDA-based 3rd generation standard. In Europe the work started in EU sponsored research programs such as CODIT and FRAMES, then continued with standardization activities in ETSI SMG2. During the years Europe has cooperated with other regions to make sure that we would get one large cdma standard, WCDMA. In May 1999 we also reached a global consensus for WCDMA as the global standard for Direct Sequence CDMA. This standard has support from all regions and standardization bodies in the world.

In parallel to WCDMA it will be two other cdma standards, cdma2000 MC and TDD.

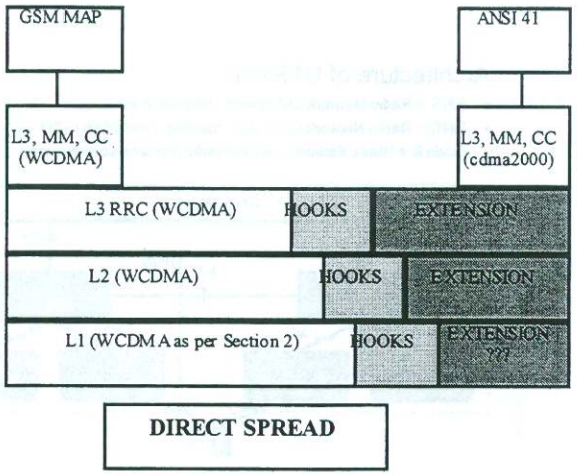

Figure 7. *Connection of WCDMA to both GSM and ANSI-41 networks.*

VII. REFERENCES

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