SIEMENS

White Paper

TD-SCDMA: the Solution for TDD bands

CONTENTS

1. Executive Summary

Introduction

- Global 3GPP standard
- Covers all Radio Deployment Scenarios
- Voice and Data Services

Jointly developed by Siemens and the China Academy of telecommunications Technology (CATT), TD-SCDMA is an innovative mobile radio standard for the physical layer of a 3G air interface. It has been adopted by **ITU** and by **3GPP** as part of UMTS release 4, becoming in this way a global standard, **which covers all radio deployment scenarios**: from **rural** to **dense urban areas**, from pico to micro and macrocells, from **pedestrian** to **high mobility**.
TD-SCDMA is equally adept at handling both **symmetric** and **asymmetric** traffic, making it perfectly suited for **mobile Internet access** and **multimedia applications**.
TD-SCDMA, which stands for Time Division Synchronous Code Division Multiple Access, combines an advanced **TDMA/TDD** system with an adaptive **CDMA** component operating in a synchronous mode.

3G Service and Functionality

- Data Rate up to 2 Mb/s
- Flexible Uplink – Downlink
- Large Coverage: up to 40 Km
- High Mobility: at least 120 Km/h
- Optimum Spectrum Efficiency

TD-SCDMA offers several unique characteristics for **3G** services. In particular its TDD nature allows TD-SCDMA to master **asymmetric services** more efficiently than other 3G standards.
Up- and downlink resources are flexibly assigned according to traffic needs, and flexible data rate ranging from 1.2 Kbit/s to **2Mbit/s** are provided.
This is especially helpful in an environment with increasing data traffic (mobile data), which tends to be **asymmetric**, often requiring little uplink throughput, but significant bandwidth for downloading information (**mobile Internet**).
Many radio technology, such as GSM, EDGE, W-CDMA or cdma2000, require separate bands for uplink and downlink (paired FDD spectrum). In this case with **asymmetric loads**, such as Internet access, portions of the spectrum are occupied but not used for data transfer. These idle resources cannot be utilized for any other service, leading to an inefficient use of the spectrum.
On the contrary, TD-SCDMA adapts the uplink/downlink ratio according to the data load within a single unpaired frequency, thus utilizing the spectrum more efficiently.
Highly effective technologies like **smart antennas**, **joint detection** and **dynamic channel allocation** are integral features of the TD-SCDMA radio standard. They contribute to minimize **intra-cell interference** (typical of every CDMA technology) and **inter-cell interference** leading to a considerable improvement of the **spectrum efficiency**. This is especially helpful in **high-populated areas**, which are capacity driven and require an efficient use of the available spectrum.

TD-SCDMA can also cover large areas (up to 40 Km) and supports high mobility. It is therefore well suited to provide mobile services to subscribers driving on motorways or travelling on high-speed trains.

Reduced Capital Spending

- LOW INVESTMENT COSTS
- CAPEX AND OPEX SAVINGS

A remarkable benefit coming from minimizing intra-cell interference and inter-cell interference is the sensible reduction of the so-called ***cell breathing* effect**. In CDMA systems like W-CDMA and cdma2000, due to intra-cell interference cell area is reduced when data rates or numbers of user grow. As a result, when traffic increases, new sites have to be introduced in order to guarantee an adequate coverage. On the other hand, in TD-SCDMA systems the traffic load can be increased without reducing coverage: the cell-breathing effect is not an issue anymore. This has a huge impact on the infrastructure costs, which are considerably reduced, and on network planning, which is sensibly simplified.

The ability to handle asymmetric traffic better than other 3G standards, together with the high spectrum efficiency and the elimination of the *cell-breathing effect* give TD-SCDMA a considerable competitive advantage in terms of **lower investments costs** and **CAPEX savings**.

In order to mitigate the effect of interference and improve the coverage at the cell's edge, 3G systems like W-CDMA and cdma2000 have to use the so-called *soft handover* when an ongoing call needs to be transferred from one cell to another as a user moves the through the coverage area.
During soft handover, however, the user's terminal has concurrent traffic connections with more than one base station. To handle this increased traffic more channel units and leased lines are required, resulting in higher operating costs.

Thanks to joint detection, smart antennas and an accurate terminal synchronization TD-SCDMA does not need to rely on soft handover. On the contrary, TD-SCDMA uses **conventional handover** (similarly to GSM) which leads to a sensible reduction of the cost of leased lines compared with W-CDMA and cdma 2000, thus **savings in OPEX**.

Smooth Migration from 2G to 3G

- TECHNICAL RISKS REDUCED
- PAST INVESTMENTS SECURED

TD-SCDMA offers a smooth and seamless way of introducing 3G mobile networks and services.
A GSM operator with large portions of TDD bands available (unpaired TDD bands), can efficiently and cost effectively introduce a **complete TD-SCDMA Radio Access Network (RAN)** while using the existing GSM core network, including its signaling and protocols and at the same time introducing 3G services. In this case, the total migration costs are sensibly reduced compared with W-CDMA. The total investment risk is reduced and at the same time investment in already purchased GSM infrastructure is secured. Inter-system handover between TD-SCDMA and GSM/GPRS assures seamless interworking between the two radio systems.

An operator with FDD and TDD spectrum can opt to deploy **TD-SCDMA as a complement to W-CDMA networks**. In this case TD-SCDMA and W-CDMA share the same core network, including the UTRAN signaling and protocol stacks. The W-CDMA network can thus take advantage of TD-SCDMA's performance in dense urban areas, where traffic and service demands require a higher flexibility in the allocation of resources. Inter-mode handover between TD-SCDMA and W-CDMA guarantees service continuity between the two UMTS standard.

TD-SCDMA Market Perspective

- CHINESE MARKET MOMENTUM
- OPTIMAL USE OF LICENSED TDD BANDS

Since October 2001 CATT and Siemens are successfully running Field Trials in Beijing. Customer trials will be possible starting from the second quarter of 2002 depending on the award of trials licences by the Chinese Ministry.
It's expected that the first TD-SCDMA commercial network will be deployed in China in 2003; at that time dual mode GSM/GPRS/TD-SCDMA terminal will be available.

In China the prospects of the TD-SCDMA technology are very attractive.
With 140 million mobile subscribers in December 2001, China became the largest mobile phone market in the world, although mobile market penetration is only 7%.
China can easily provide the scale for his home grown 3G technology, since by 2007 there will be more than 400 million mobile subscribers in China.
Moreover, the unique Chinese demographic distribution is characterized by large urban areas with high population density, which can benefit best from the high spectral efficiency provided by TD-SCDMA.
The development of its own mobile standard, especially one that has distinct technological advantages with respect to other standards, is a great source of national pride not to mention the large savings in royalty fees. The mass deployment in the world's largest market will assure significant economies of scale and make the standard attractive to other countries.

The early introduction of TD-SCDMA in China encourages the early development of TDD products and services worldwide. Current estimates indicate that TDD will be introduced in Europe in 2004-2005; by that time operators will be able to take advantage of a mature, market-proven technology.

All operators holding TDD spectrum can benefit from the additional voice traffic capacity as well as data services optimized for asymmetric connections such as mobile Internet.

Terminals

- GSM CHIPSET BASED
- COST EFFECTIVE
- LOW POWER CONSUMING

The first commercial TD SCDMA handsets will be dual mode GSM/TD-SCDMA; it will be based on the GSM chipset with an additional ASIC TD-SCDMA specific. It means that cost-effective terminals will already be available for the launch of TD-SCDMA in China. Joint Detection and beam steering Smart Antennas keep the Terminals' Power Consumption low, which leads to a long lasting battery lifetime. TD-SCDMA co-processing platform will be then integrated in the GSM/WCDMA chipset, resulting in a triple mode handset. Various international handset players are committed to bring TD-SCDMA terminals into the market. This will facilitate the availability of TD-SCDMA capable handsets for the global market.

2. TD-SCDMA - a 3G Radio Access Technology

2.1. What is TD-SCDMA ?

Jointly developed by Siemens and the China Academy of Telecommunications Technology (CATT), TD–SCDMA (Time Division Synchronous Code Division Multiple Access) is one of the five IMT-2000 standards accepted by the ITU.

In March 2001 the standard was also adopted by the Third Generation Partnering Project (3GPP), as part of UMTS Release 4. In this way it became a truly global standard, **which covers all radio deployment scenarios**: from **rural** to **dense urban areas**, from **pedestrian** to **high mobility**.

Designed as an advanced TDMA/TDD system with an adaptive CDMA component operating in synchronous mode, TD-SCDMA masters both **symmetric circuit switched services** (such as speech or video) as well as **asymmetric packet switched services** (such as mobile Internet access).

The main benefits of TD-SCDMA are that it can be implemented less expensively than comparable 3G systems since it is much more spectrum efficient and is compatible with GSM network elements, allowing 3G services without installation of completely new infrastructure. The key benefits are:

- **Services optimally suited for asymmetric 3G applications (mobile Internet).** Real-time applications like voice and multimedia require minimum delay during transmission and generate symmetric traffic. For non real-time applications like e-mail or Internet access, timing constraints are less strict and the generated traffic is asymmetric. For all those radio technologies which require separate bands for uplink and downlink (such as GSM, EDGE, W-CDMA or cdma2000) portions of the spectrum are occupied but not used when an asymmetric data load is applied. These idle resources cannot be utilized for any other service, leading to an inefficient use of the spectrum. On the contrary, TD-SCDMA adapts the uplink/downlink ratio according to the data load within a single unpaired frequency thus utilizing the spectrum more efficiently, and provides data rates ranging from 1.2 kbps to **2Mbps**. This is especially helpful in an environment with increasing data traffic (mobile data), which tends to be **asymmetric**, often requiring little uplink throughput, but significant bandwidth for downloading information (**mobile Internet**).
- **Outstanding Spectrum Efficiency increases capacity**: TD-SCDMA utilizes the available spectrum more efficiently than other 3G standards like W-CDMA or cdma2000, since it employs only one band for both uplink and downlink traffic (TDD unpaired band) instead of two separate bands for uplink and downlink (FDD paired bands). Moreover, highly effective technologies like *smart antennas*, *joint detection* and *dynamic channel allocation* - which are integral features of the TD-SCDMA radio standard - contribute to minimize intra-cell interference (typical of every CDMA technology) and inter-cell interference leading to an **outstanding spectrum efficiency** (3-5 times GSM). This is especially helpful in **densely**

populated urban areas, which are capacity driven and require an efficient use of the available spectrum.

- **Smooth migration to 3G**: TD-SCDMA allows an easy migration path: GSM/GPRS/TD-SCDMA. 3G services are introduced adding TD-SCDMA radio subsystems to existing stable and established GSM infrastructures. The total migration costs from 2G to 3G decrease considerably, compared to W-CDMA and cdma2000. The total investment risk is reduced and at the same time investment in already purchased GSM infrastructure is secured.
- **Increased flexibility**: TD-SCDMA's carrier bandwidth of **1.6 MHz** provides high flexibility in spectrum usage and network design.
- **Low power emission**: Beam Steering Smart Antennas direct power to active mobile terminals only. The high directivity and sensibility of smart antenna together with the fact that terminals transmit power only during active timeslots contributes to keep the terminal's power consumption low, which leads to more cost effective handsets.
  In addition, since the transmitted power is directed only to active users, the radio illuminated area is strongly reduced.
- **Reduced Investment Costs**. In CDMA systems like W-CDMA and cdma2000, due to intra-cell interference cell area is reduced when data rates or numbers of user grow (*cell breathing effect*). As a result, when traffic increases, new sites have to be introduced in order to guarantee an adequate coverage. On the other hand, in TD-SCDMA systems the traffic load can be increased without reducing coverage: the cell-breathing effect is not an issue anymore. This leads to a considerable reduction of infrastructure costs.
- **Costs of Leased Lines reduced.** Thanks to joint detection, smart antennas and an accurate terminal synchronization TD-SCDMA does not need to rely on *soft handover*. On the contrary, TD-SCDMA uses *conventional handover* (similarly to GSM) which leads to a sensible reduction of the cost of leased lines compared with W-CDMA and cdma2000.
- **Simple Network planning:** Network Planning is sensibly simplified since TD-SCDMA is not affected by *cell breathing* and *soft handovers*.

TD-SCDMA enjoys considerable backing in China. Field Trials started in October 2001 in Beijing and the first commercial networks will be deployed in China in 2003.

2.2. TD-SCDMA is an Universal Standard for 3G

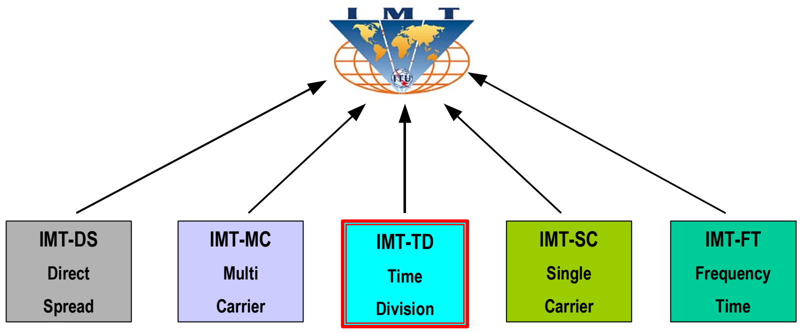
IMT- 2000

The international 3G standards are accepted by the **ITU** (International Telecommunication Union) under the name of **International Mobile Telecommunication – 2000** (**IMT-2000**). A comprehensive set of **terrestrial radio interface specifications** for IMT-2000 was approved in November 1999. These included (Figure 1.1):

- IMT-DS (Direct Spread) **W-CDMA**
- IMT-MC (Multi Carrier): **CDMA2000**
- IMT-SC (Single Carrier): **UWC**
- IMT-FT (Frequency Time) **DECT**
- IMT-TD (Time Division) **CDMA TDD**
    - **TD-CDMA** (Time Division-Code Division Multiple Access)
    - **TD-SCDMA** (Time Division- Synchronous Code Division Multiple Access)

Being acknowledged as one mode of the interface IMT-TD, **TD-SCDMA** air interface became in this way an international standard in 1999.

Fig. 2.2.1. IMT-2000 Radio Interface Standard



UMTS/3GPP

In Europe, the 3G standard has been initially developed by **ETSI** (European Telecommunication Standard Institute) under the designation of UMTS (Universal Mobile Telecommunications System).

The radio access interface of the **UMTS** (UTRA) comprises two standards for operation in the **FDD** and **TDD** modes. Both interfaces have been accepted by **ITU** and are designated **IMT-DS** and **IMT-TD** respectively.

The UMTS standard is being currently defined by Third Generation Partnership Project (**3GPP**): a joint venture of industry organizations and of several Standards Developing Organizations (SDOs) from Europe (ETSI), US (T1), Japan (ARIB), Korea (TTA), and China (CWTS).

3GPP is introducing UMTS in phases and annual releases.

Release '99

The first release (**Rel'99**), issued in December 1999, defined the following two standards:

- UTRA FDD
- UTRA TDD

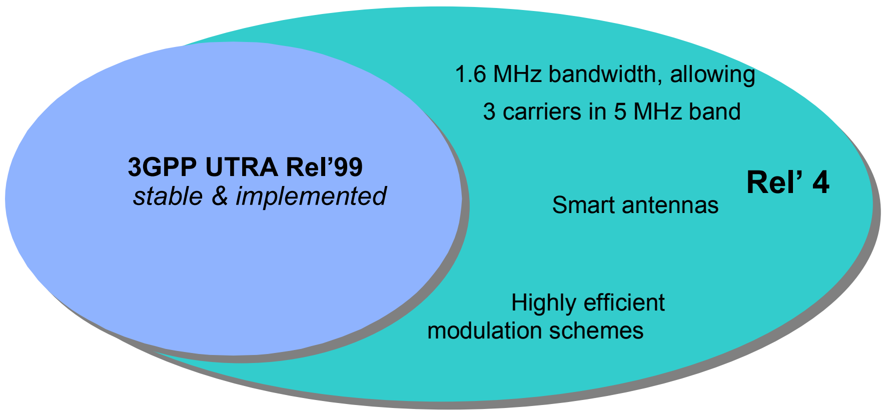
These two standards were complementary: UTRA-FDD to be employed in Micro and Macro Cells, UTRA TDD to cover micro, pico cells and indoor.
In order to offer seamless services everywhere and every time, the two modes of the UTRA standard should be deployed together in a common network.

Release '4

In the second release of the UTRA standard (called **Release 4**, March 2001), 3GPP agreed upon the worldwide harmonization and extension of the TDD performance spectrum. Additional features of **TD-SCDMA** radio technology were also included in the specification for this UMTS Standard (Figure 2.2.2).

According to Release 4, **TD-SCDMA** radio interface is integrated in 3GPP as the 1.28 Mcps option of the UTRA TDD, also called **TDD**$_{LCR}$ (TDD Low Chip Rate).

Fig. 2.2.2. TD-SCDMA Air Interface is part of UMTS Release 4



The current status of the UMTS terrestrial radio access standard include the following modes:

- **UTRA FDD** (W-CDMA)
- **UTRA TDD**$_{HCR}$ (3.84 Mcps, 5 MHz bandwidth, TD-CDMA air interface)
- **UTRA TDD**$_{LCR}$ (1.28 Mcps, 1.6 MHz bandwidth, **TD-SCDMA** air interface)

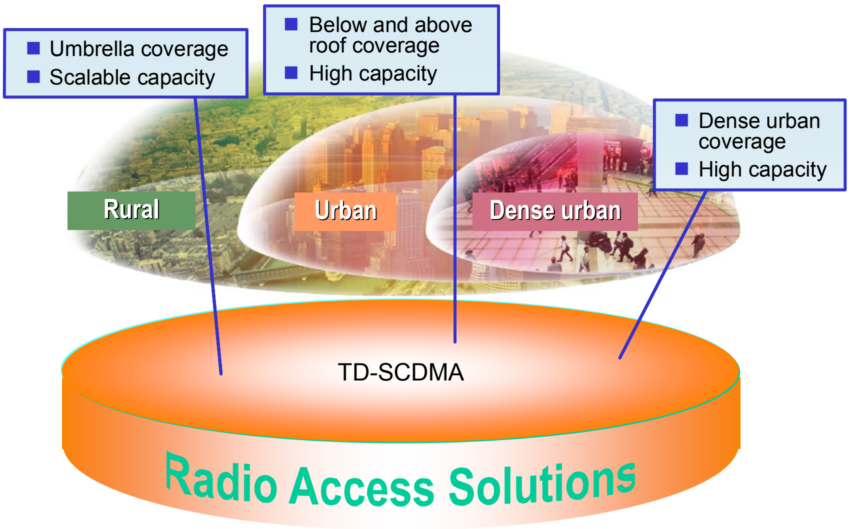
UTRA-FDD targets public areas where high mobility in micro and macro cells together with symmetric services are required. Based on the classic DS-CDMA principle this technology uses paired frequency bands with a radio carrier bandwidth of 5 MHz.

UTRA TDD$_{HCR}$ is best suited for low mobility micro/pico public areas outdoor and indoor.

TDD_{LCR}

UTRA TDD_{LCR} (TD-SCDMA), on the contrary, covers all application scenarios. This technology is designed to address all sizes of deployment environements – from rural to densely populated urban areas and indoor applications, from stationary to high mobility.

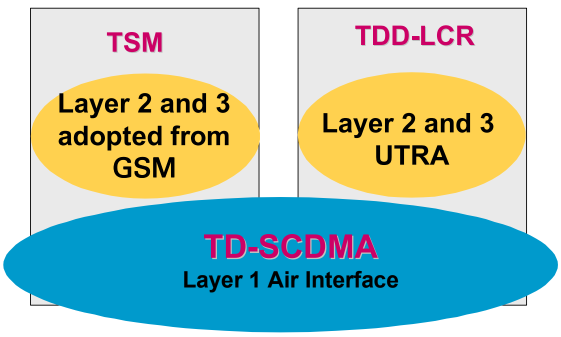
Fig. 2.2.3. Offers a Complete Solution – Macro, Micro and Pico Coverage, Pedestrian and High Mobility



TSM

TDD_{LCR} uses the UTRA core network and the TD-SCDMA air interface. It is also possible, however, to introduce a TD-SCDMA Radio Access Channel while using the GSM core network, including the signaling and protocols (Fig 2.2.4). This TD-SCDMA deployment, called **TSM** (TD-SCDMA System for Mobile Communication), offers a smooth and seamless way of introducing 3G mobile networks and services while keeping a GSM infrastructure. Both TD-SCDMA deployments – **TSM** and **TDD_{LCR}** – offer the same performances in terms of data rate, spectrum efficiency, coverage, mobility and reliability and basically can be introduced by all operators having TDD unpaired bands awarded.

Figure 2.2.4. TD-SCDMA Protocols



2.3. The TD-SCDMA Market Opportunity

China

In **China** the prospects of the TD-SCDMA technology are very attractive.

With 140 million mobile subscribers in December 2001, China became the largest mobile phone market in the world, although mobile market penetration is only 7%.

China can easily provide the scale for a home grown 3G technology: by 2007 there will be 400 million mobile subscribers in China

Moreover, the unique Chinese demographic distribution is characterized by large urban areas with high population density, which can benefit best from the high spectral efficiency provided by TD-SCDMA.

If we compare urban distribution of Chinese provinces such as Shandong, Guangsong or Anhui with countries having an equivalent total population (like France, Germany or Italy) we realize that the population density in the Chinese provinces is remarkably higher (Figure 2.3.1).

Fig. 2.3.1. Population density - comparison of provinces

Selected Chinese *provinces*	Total population* (millions)	Population density (people / km2)	*Countries* of comparable population size	Total population** (millions)	Population density (people / km2)
Shandong	86,2	**562**	**Mexico**	84,5	**43**
Guangdong / Hainan	72,6	343	**Germany**	79,4	222
Jiangsu	68,0	663	-	-	-
Hunan	62,5	**306**	**Iran**	58,9	**36**
Anhui	58,7	420	**Italy**	57,0	189
Hubei	55,9	301	**France**	56,7	103
Liaoning	39,8	273	**Spain**	39,3	78
Shanxi	29,6	**189**	**Canada**	27,8	**3**
Inner Mongolia	22,0	19	**Australia**	16,9	2
Tianjin	8,9	787	**Sweden**	8,6	19
Ningxia	4,9	95	**Finland**	5,0	15

* in 1993
** in 1990

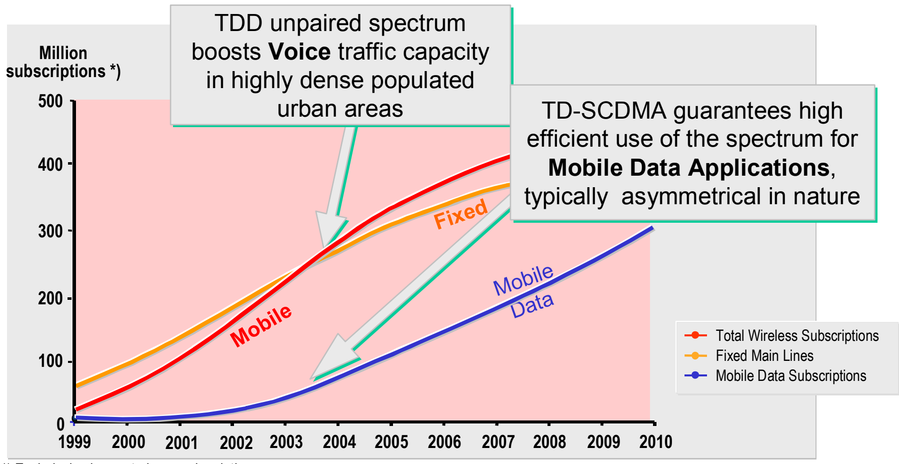
Source: IIASA 1999

These high-populated areas are capacity-driven and require an efficient use of the available spectrum. They can benefit best from the high spectral efficiency provided by the TD-SCDMA standard.

In China TD-SCDMA will be deployed in commercial networks in 2003. The mass deployment in the world's largest market will assure significant economies of scale.

The development of its own mobile standard, especially one that has distinct technological advantages with respect to other standards, is a great source of national pride not to mention the large savings in royalty fees.

Fig. 2.3.2. TD-SCDMA meets China's Voice & Data Requirement



*) Each device is counted as a subscription
Source: Siemens ICM N Marketing

Asia-Pacific

The widespread deployment of TD-SCDMA in China will make the standard very attractive to other **Asia-Pacific** countries, some of which are already contributing to its development.

TDD spectrum has been already assigned in Australia (4 operators out of 6 have 5 MHz unpaired spectrum), Hong Kong (4 operators out of 4 have 5 MHz unpaired spectrum), Singapore (3 operators out of 3 have 5 MHz unpaired spectrum) and Taiwan (4 operators out of 5 have 5 MHz unpaired spectrum).

Also in these regions operators have to cope with large urban areas with high traffic demand per subscriber. TD-SCDMA will allow these operators to handle high data rate and give them high flexibility in supporting asymmetric traffic requirements.

TD-SCDMA high spectrum efficiency will also help Asian-Pacific operators to boost basic services in these high dense populated areas where GSM network are reaching their capacity limits.

Europe

In **Europe** TD-SCDMA, being the solution for the UMTS TDD unpaired band, will be deployed jointly with W-CDMA sharing the same core network.

Most of 3G Licenses already assigned and awarded to European operators consist of a combination of FDD for paired and TDD for unpaired spectrum.

Given the fact that in Europe licenses were defined and awarded when UTRA TDD technology was considered a technology only for hot spots and high data rate traffic (status Release 99), the predominant role in the spectrum assignment has been played by UTRA FDD paired bands.

For these reasons, in Europe 3G deployment will start with W-CDMA networks. However, since most European operators already have TDD bands assigned and awarded, they will adopt TD-SCDMA as a capacity enhancement for high data rate asymmetric traffic once need arises.

At that time, driven by the deployment in China, TD-SCDMA will be already a mature technology, with the ubiquity and economies of scale to effectively serve a mass market in Europe.

TD-SCDMA, being a UMTS technology, will share with W-CDMA the same core network. Moreover, seamless handover between the two UMTS technologies and GSM/GPRS will guarantee easy mobility between bands and standards

North America

In **North America**, for all operators that are now deploying GSM-GPRS, the evolutionary path is clear: GSM-GPRS-EDGE.

Many operators are interested to deploy full UMTS networks although separate 3G spectrum suitable for UMTS has still to be allocated. Until such spectrum is allocated and cleared, GSM operators are hindered from advancing beyond GPRS and EDGE to W-CDMA. TD-SCDMA technology does not need paired spectrum (like W-CDMA and cdma2000) and has a carrier granularity of 1.6 MHz (versus 5MHz of W-CDMA). Consequently, it would be much easier for the FCC to identify and allocate spectrum for TD-SCDMA than for other 3G technologies.

Rest of the World

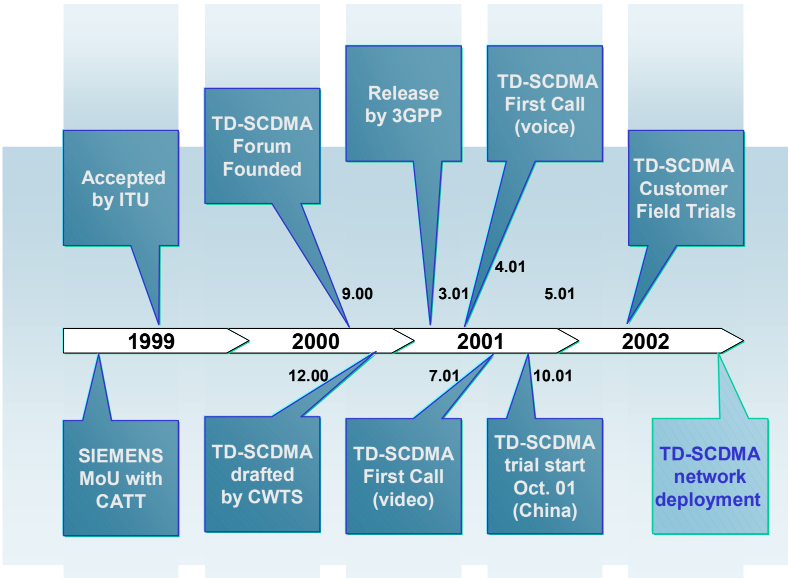
Due to its unique way of cost effectively migrating GSM networks to 3G networks, TD-SCDMA has the potential of being deployed also in other countries throughout the world. This is especially true for countries which have newer GSM networks, which are not willing or capable of making the huge investments necessary with other 3G technologies, or which have geographically large networks, making simultaneous and transparent operation of 2G and 3G networks a basic requirement, or which are at the limit if their capacity and urgently need new frequency bands in order to guarantee service to their customers.

2.4 Industry Commitment to TD-SCDMA

Siemens has committed a considerable amount of resources for the development of TD-SCDMA. Development is undertaken in a number of locations in China, Germany, Italy, Austria and UK. Currently, more than 400 high-motivated engineers in Europe and Asia are developing TD-SCDMA technology.

TD-SCDMA hardware development has been completed while software development is at an advanced integration and testing phase.

Fig. 2.4.1. TD-SCDMA Technology Progress



Field Trial

Since October 2001 engineering teams from CATT and Siemens are working on the Master Field Trial. Their major task is to deploy the technology in the field, thereby proving the functionality of TD-SCDMA, test the compliance with **CWTS** (China Wireless Telecommunications Standard group) specifications and conformity to the **RITT** (Research Institute of Telecommunications Simulation Network) system test (MTNet, the Digital Mobile Telecommunication Network) and demonstrate advanced 3G applications.

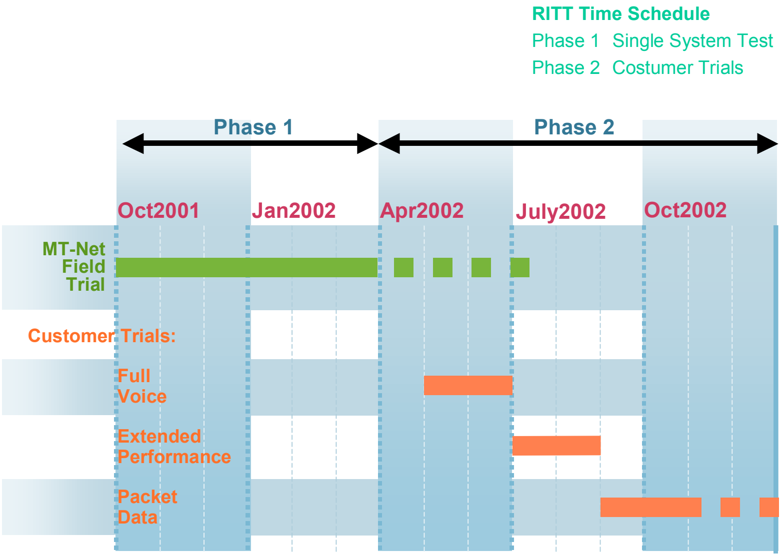
CATT and Siemens jointly perform all TD-SCDMA trials.

For the general introduction of 3G technologies in China, 3G TEG (a commission formed by regulators, operators and domestic manufacturers) defined a schedule divided in two main phases:

1) The **first phase** consists of a single system test with RITT (MTNet). The Master Field Trial will focus on interface and protocol tests and it will be run in **Beijing** jointly by CATT and Siemens. The TD-SCDMA NodeBs used in the Master Field Trials have been deployed in macro-cell environments.

2) The **second phase** consists of customer field trials, which will take place in **several locations in China** depending on the operators requirements. Throughout 2002 a minimum of four customer trials will be deployed.

Fig. 2.4.2. Phases of the TD-SCDMA China Field Trial



Important steps reached during the field trials

During the field trials, Siemens and CATT engineers have reached an important milestone. They have taken an important step forward by installing a TD-SCDMA terminal in a vehicle and using it to make successful video calls, with the participation of representatives from the Chinese government and network operators.

Besides stationary applications, it was shown that calls can also be made by mobile users on terminals installed in vehicles traveling at high speeds, without detriment to high data transfer rates. It was possible to make calls even at speed of up to **125 km/h** without any noticeable loss in quality.

It was also shown that for TD-SCDMA distance is not an issue: the vehicle traveled up to **21 kilometers** from the base station (Node B). Video data was successfully transmitted without interruption by completely loading one time slot and using all available 16 codes. This furthermore proves the robustness of the TD-SCDMA air interface.

The results of these tests confirm that TD-SCDMA, achieves the performance requirements necessary for the deployment of complete 3G networks, and the capability to achieve macro coverage in high mobility scenarios.

TD-SCDMA Forum

In order to make TD-SCDMA accepted worldwide, Siemens, CATT and the TD-SCDMA Forum (which include the major foreign and domestic equipment providers as well as the two mobile operators China Mobile and China Unicom) have been promoting it to the most important players of the wireless industry.

Several equipment providers and operators have already stated their commitment or interest to TD-SCDMA standard:

- **Alcatel** has already started system engineering work on TD-SCDMA technology in the Shanghai R&D facility. The goal is the commercialization of TD-SCDMA infrastructure integrated in W-CDMA and GSM products by E03.
- **Fujitsu**, together with **South China University of Technology** will develop TD-SCDMA mobile networks in China.
- **RTX Telecom** (Scandinavian wireless platform developer) has been developing TD-SCDMA terminal platforms since August 2000. The first commercial integrated GSM/GPRS/TD-SCDMA platform will be launched in 2003.
- **Nokia, Texas Instruments, China Academy of Telecommunication Technology (CATT), LG Electronics, China PTIC Information and Industry Corporation** and other 12 foreign and Chinese firms formed a company in China called COMMIT Inc. to develop TD-SCDMA standard wireless handsets.
- **Philips Semiconductors**, **CATT/Datang Telecom** and **China Eastern Communication Wireless Research Center** (**CEC Wireless**) jointly established a joint venture for the development of TD-SCDMA user terminals, chipsets and software.
- **Synopsys, Inc**., the technology leader for complex IC designs, announced the availability of the TD-SCDMA Design Conformance Lab, the result of a collaborative effort between Synopsys Professional Services and the China Academy for Telecommunications Technology (CATT). The Design Conformance Lab offers a set of integrated modules that provide wireless developers with a design reference, standards conformance verification, and test management and automation.
- In **Taiwan**, the **Ministry of Economic Affairs** (**MOEA**) together with the **Industrial Technology Research Institute** (**ITRI**), is working with China since 2000 to research and develop TD-SCDMA for 3G mobile networks.

3. Key Features of TD-SCDMA

3.1. 3G Services and Functionality

Future applications are based on "Bearer Services". Real-time applications like voice, video conferencing or other multimedia applications require minimum delay during the transmission and generate symmetric traffic. This type of communication is nowadays carried via circuit switching systems. For non real-time applications like e-mail, Internet and Intranet access timing constraints are less strict. In addition, the generated traffic is asymmetric. This type of communication is relayed via packet switched systems. Future pattern of use will show a mix of real-time and non real-time services at the same time and same user terminal. Based on the TDD principle, with adaptive switching point between uplink and downlink, TD-SCDMA is equally adept at handling both symmetric and asymmetric traffic.

Wireless Multi Media requires high data rates. With data rates of up to **2 Mbit/s** TD-SCDMA offers sufficient data throughput to handle the traffic for **Multi Media** and **Internet** applications.

With their inherent flexibility in asymmetry traffic and data rate TD-SCDMA-based systems offer 3G services in a very efficient way.

TD-SCDMA covers all application scenarios

Although it is optimally suited for **Mobile Internet** and **Multi Media applications**, **TD-SCDMA covers all application scenarios**: **voice** and **data** services, **packet** and **circuit** switched transmissions for **symmetric** and **asymmetric** traffic, **pico**, **micro** and **macro coverage** for **pedestrian** and **high mobility** users.

3.2. Outstanding Spectrum Efficiency

Frequency bands for 3G systems are rare and expensive. In the advent of a forthcoming increase of data traffic each operator will optimize his spectrum policy in order to cope with this rising demand. Radio technologies such as GSM and UTRA-FDD require two separate bands for uplink and downlink with a design-specific separation between the bands. TDD-based technologies use a common band for uplink and downlink.

As already described, **data applications often show asymmetric traffic characteristics.** Internet applications in particular lead to significantly different data volumes in uplink and downlink. Adaptive allocation of radio resources to uplink and downlink is one key to optimized spectrum efficiency which is achieved by the TDD operation of TD-SCDMA.

Radio interference needs to be minimized. Cellular mobile radio systems are basically limited by intercell and intracell interference. Minimization of radio interference is the second key to highest spectrum efficiency.

All basic technologies and principles of TD-SCDMA interact to optimize spectrum utilization.

An intelligent combination of **Joint Detection**, **Smart Antennas**, **Terminal Synchronization** and **Dynamic Channel Allocation** eliminates intracell interference and strongly reduces intercell interference leading to a considerable improvement of the spectrum efficiency.

This is especially helpful in **densely populated urban areas**, which are capacity driven and require an efficient use of the available spectrum.

Simulations

Siemens internal simulations have been performed in order to determine TD-SCDMA's spectrum efficiency.

Spectrum efficiency is given in kbits/s/MHz/cell, indicating the number of bits that can be transferred while keeping almost all users (98%) satisfied.

The results show that **TD-SCDMA spectrum efficiency for voice traffic is 3-5 times higher than GSM** (Figure 3.2.1), allowing higher traffic with even fewer base stations per unit area.

Fig. 3.2.1. Spectrum Efficiency for TD-SCDMA - Simulation Results

Scenario (macro, reuse factor 1)	Spectrum efficiency
Speech, **60** km/h, **city** (vehicular A)	**140** kbit/s/MHz/cell
Speech, **120**km/h, **city** (vehicular A)	**120** kbit/s/MHz/cell
Speech, **120** km/h, **rural** (OTIA)	**110** kbit/s/MHz/cell
Packet data 64 kbit/s, **60** km/h **rural** (OTI)	UL: **311** kbit/s/MHz/cell DL: **327** kbit/s/MHz/cell
Packet data 64 kbit/s, **60** km/h, **city** (vehicular A)	UL: **304** kbit/s/MHz/cell DL: **325** kbit/s/MHz/cell
Packet data 64 kbit/s, **120** km/h, **rural** (OTI A)	UL: **295** kbit/s/MHz/cell DL: **310** kbit/s/MHz/cell
Packet data 144 kbit/s, **60** km/h, **city** (vehicular A)	UL: **282** kbit/s/MHz/cell DL: **304** kbit/s/MHz/cell

3.3. Support of all Radio Network Scenarios

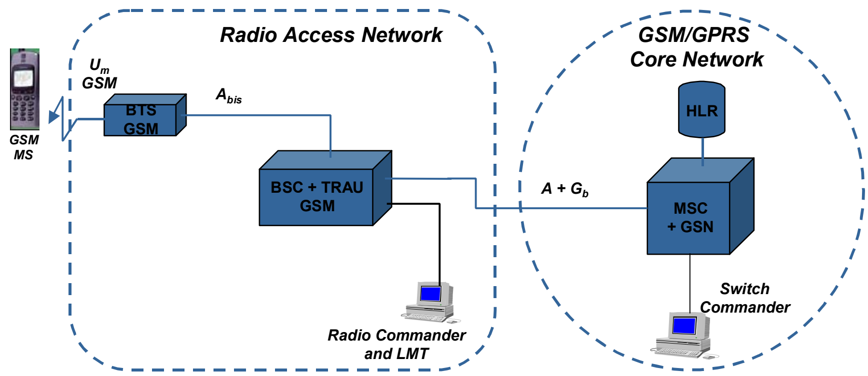
Operators need a full coverage of their market area. Large rural and suburban areas must be covered, where only few base stations can be installed. Urban areas with many obstacles and a high traffic density require a lot more base stations covering moderate cell extensions. Small hot spots at central locations or airports require tiny cells with high capacity for data transmission.

TD-SCDMA covers all of these requirements. Macro cells provide large umbrella coverage. They also provide a solution for high start-up capacity. Micro cells make local coverage possible. In addition, existing macro cell capacity can be expanded. Small pico cells allow indoor coverage and further capacity expansion. They are also suited for corporate networks. TD-SCDMA supports all these radio network scenarios, with an advantage on dense urban areas, which are capacity driven and require high spectral efficiencies.

3.4. An easy Migration Path

TD-SCDMA guarantees a smooth migration from an existing and well-known GSM network to a full-size 3G network. In this way technical risks are reduced and the global amount of investments is lower than for other 3G technologies.

Figure 3.4.1. Existing GSM / GPRS Network

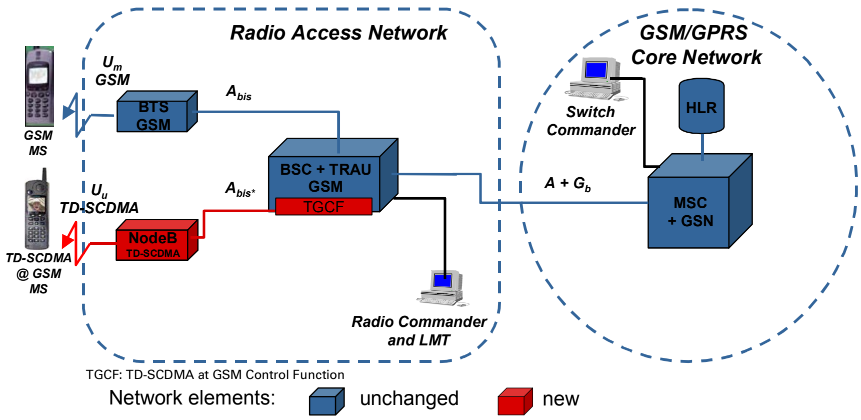


TSM

A GSM operator with large portions of TDD bands available (unpaired TDD bands), can efficiently and cost effectively introduce a complete TD-SCDMA Radio Access Network (RAN) while using the existing GSM core network, including its signaling and protocols and at the same time introducing 3G services. This TD-SCDMA deployment, called **TSM** (TD-SCDMA@GSM Core Network shown in Fig 3.4.2) consists of an enhancement of the existing GSM/GPRS network (Fig 3.4.1) with a TD-SCDMA radio subsystem. In this phase GSM protocol stack (Layer 2-3) is used with TD-SCDMA air interface. The new TD-SCDMA base stations (NodeBs) are connected to the existing GSM BSC upgraded to TD-SCDMA radio subsystems by means of the software TGCF (TD-SCDMA at GSM Control Function). In this way the BSC migrates to a T-RNC. The BSC (software upgraded to TD-SCDMA) are connected to the GSM core network by the existing A and Gb interfaces (Fig 3.4.2).

This seamless integration of a 3G air interface into existing and stable GSM infrastructure results in a short term availability of 3G services without installation of a completely new core network infrastructure. The total investment risk is reduced and at the same time investment in already purchased GSM infrastructure is secured. Inter-system handover between TD-SCDMA and GSM/GPRS assures seamless interworking between the two radio systems.

Fig 3.4.2. TD-SCDMA @ GSM / GPRS Core Network (TSM)

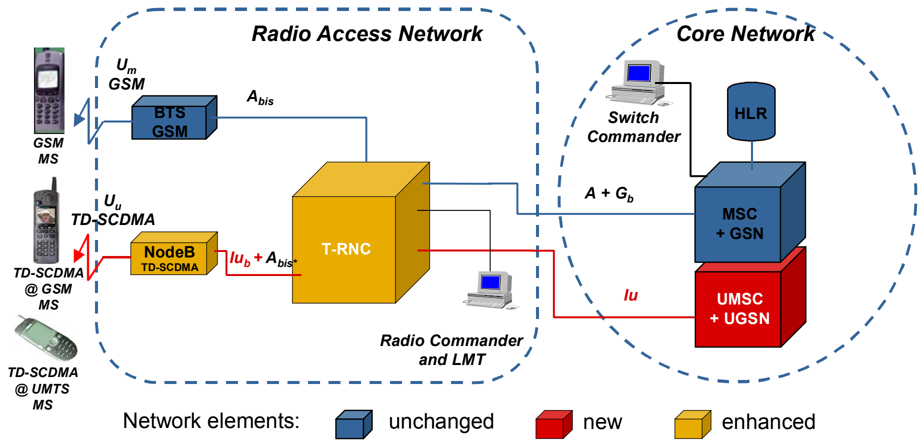


TDD-LCR

An operator with FDD and TDD spectrum can opt to deploy TD-SCDMA as a complement to W-CDMA networks. With TD-SCDMA deployment, called **TDD-LCR**, TD-SCDMA and W-CDMA share the same core network, including the UTRAN signaling and protocol stacks. The TD-SCDMA NodeBs can be upgraded to work with the UMTS core Network. It's important to stress that NodeBs do not have to be replaced, since only an upgrade is required. TDD-LCR enabled RNCs, which support the UTRA interfaces Iub, Iu, (Iur) and the UTRA layer2/layer3 protocols, have to be introduced. The radio subsystem connects directly to a UMTS Core Network via the **Iu** interfaces (Fig 3.4.3)

The W-CDMA network can thus take advantage of TD-SCDMA's performance in dense urban areas, where traffic and service demands require a higher flexibility in the allocation of resources. Inter-mode handover between TD-SCDMA and W-CDMA guarantees service continuity between the two UMTS standard.

Fig 3.4.3. TD-SCDMA @ UMTS Core Network (TDD-LCR)



Evolution toward IP based Mobile Networks

Since the TDMA/TDD principle of TD-SCDMA is extremely well suited for packet data transfer TD-SCDMA based systems are optimized to support transmission of IP traffic. This opens a further smooth migration path to IP-based mobile systems.

In conclusion, TD-SCDMA air interface, with its ability of being perfectly combined with the IP based RAN, is an ideal future proof technology.

3.5. Simple Network Planning

Through Radio Network Planning all possible configurations and amount of network equipment are calculated, according to the operator's requirements. Coverage, capacity and quality of service are estimated and the amount of base stations and core network elements is dimensioned. In CDMA systems **coverage** and **capacity** require a trade-off between the desired quality and overall cost.

Due to the interference caused by the high number of codes used, the more loading is allowed in the system, the larger is the interference margin needed, and the smaller is the coverage area. In other words, the actual cell area is reduced when data rates or number of users grow (***cell-breathing effect***).

In TD-SCDMA only 16 codes for each timeslot for each carrier are used. The intracell interference is eliminated by Joint Detection and inter cell interference is minimized by the joint use of Smart Antennas and Dynamic Channel Allocation.

No cell breathing effect

The traffic load can be increased without reducing coverage: **the cell breathing effect is not an issue anymore.** This has a huge impact on the **overall network costs**, which are considerably reduced, and on **Network Planning**, which is sensibly simplified.

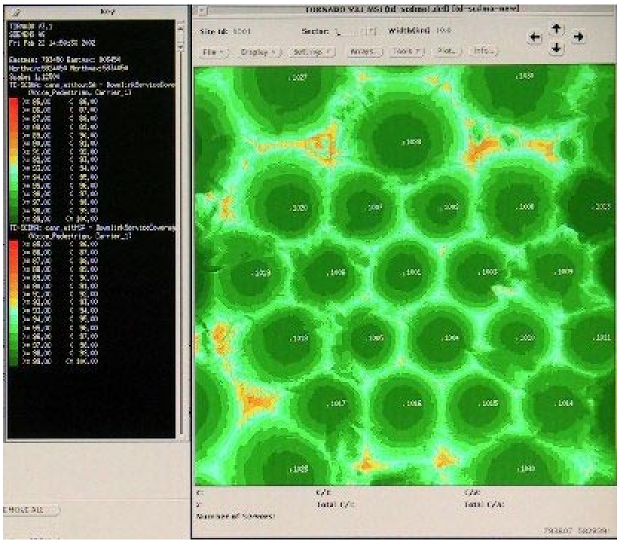
No Soft Handover needed

In order to mitigate the effect of interference and improve the coverage at the cell's edge, 3G systems like W-CDMA and cdma2000 have to use the so-called ***soft handover*** when an ongoing call needs to be transferred from one cell to another as a user moves through the coverage area.
During soft handover, however, the user's terminal has concurrent traffic connections with more than one base station. To handle this increased traffic more channel units and leased lines are required, resulting in higher operating costs. Thanks to joint detection, smart antennas and an accurate terminal synchronization TD-SCDMA does not need to rely on soft handover.

On the contrary, TD-SCDMA, similarly to GSM, uses conventional handover techniques. This leads to a sensible reduction of the cost of leased lines (compared with W-CDMA and cdma 2000) and to a further reduction of the complexity of Radio Network Planning.

In order to facilitate network deployment and optimization, Siemens has ehnanced the capabilities of the Network Planning tool *Tornado* to include the specific features of the TD-SCDMA air interface (Fig.3.4.1). The*Tornado* tool, already used by GSM operators, not only allows network design, but provides also a solution for the build out, optimization and management of a wireless network.

Figure 3.4.1. TD-SCDMA's Network Planning Tool

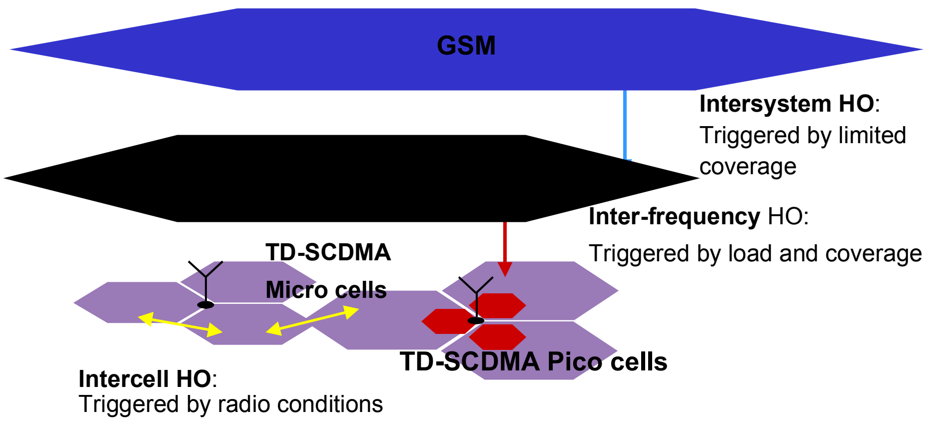


3.6. Seamless Interworking

In order to guarantee seamless interworking and service continuity, TD-SCDMA ensures the inter-system handover to UTRA FDD (W-CDMA) and to GSM/GPRS.

While these handovers are mainly triggered by coverage, **intercell** and **inter-frequency** handover – are triggered by traffic load, coverage and radio conditions (Fig. 4.6.1).

Figure 3.6.1 Service Continuity



3.7. Operator Benefits from TD-SCDMA

Technical Aspects

TD-SCDMA offers a smooth and seamless way of introducing 3G mobile networks and services. When TD-SCDMA base-stations are connected to an existing GSM system the radio network layout utilizes existing GSM sites so that existing transmission links may be reused. Thus, the technical risk when starting from an existing and well-known GSM network is reduced.

The spectral efficiency of TD-SCDMA radio systems is 3 to 5 times higher than that of GSM. Together with the flexibility for symmetric as well as asymmetric services and flexible data rates each single carrier is used very efficiently. This allows high traffic densities within each cell or a lower number of larger cells (when the traffic density is lower).

Operational Aspects

Combining a 3G air interface with a stable and established GSM infrastructure shortens time to market for 3G services. This speeds up implementation of new user applications and quickly makes **Mobile Internet** a reality. Further on additional spectrum can be provided to overcome capacity problems in the GSM spectrum.

With TD-SCDMA it is possible to gradually increase the capacity of existing GSM networks according to thenumber of users and the data throughput per MHz. At the same time the new radio components fit seamlessly into existing network operation and maintenance strategies.

Commercial Aspects

Introducing TD-SCDMA into a stable and established GSM infrastructure gives operators the opportunity to offer 3G services without installing completely new infrastructure. The total migration cost from 2G (GSM) to 3G is considerably reduced, compared to W-CDMA. In addition, the investment is spread out over a longer period of time. The total investment risk is reduced and at the same time investment in already purchased GSM infrastructure is secured.

The GSM-like principle of operation leads to fewer operational costs.

In addition, thanks to joint detection, smart antennas and an accurate terminal synchronization TD-SCDMA does not need to rely on *soft handover*. On the contrary, TD-SCDMA uses *conventional handover* (similarly to GSM) which leads to a **sensible reduction of the cost of leased lines** compared with W-CDMA and cdma2000

The efficient use of spectrum resources allows higher economic utilization of spectrum license fees. Due to early introduction of new 3G-based user applications (Internet, Intranet, Multimedia, ...) revenues are increased earlier.

Early revenues from operation with reduced costs for installation and operation relaxes the overall operator business case.

4 How does TD-SCDMA work?

One of the main challenges for 3G mobile systems is mastering both symmetric circuit switched services such as speech or video as well as asymmetric packet switched services such as mobile Internet access. To face this challenge, TD-SCDMA combines two leading technologies: an advanced **TDMA/TDD** system with an adaptive **CDMA** component operating in **synchronous** mode.

This chapter outlines the basic technological principles on which the TD-SCDMA technology is based:

- **TDD** (**Time Division Duplex**) allows uplink and downlink on the same frequency band and does not require pair bands. In TDD, uplink and downlink are transmitted in the same frequency channel but at different times. It is possible to change the duplex switching point and move capacity from uplink to downlink or vice versa, thus utilizing spectrum optimally. It allows for symmetric and asymmetric data services.
- **TDMA** (**Time Division Multiple Access**) is a digital technique that divides each frequency channel into multiple time-slots and thus allows transmission channels to be used by several subscribers at the same time.
- **CDMA** (**Code Division Multiple Access**) increases the traffic density in each cell by enabling simultaneous multiple-user access on the same radio channel. Yet each user can interfere with another, which leads to multiple access interference (**MAI**).
- **Joint Detection** (**JD**) allows the receiver to estimate the radio channel and works for all signals simultaneously. Through parallel processing of individual traffic streams, JD eliminates the multiple access interference (**MAI**) and minimizes intra-cell interference, thus increasing the transmission capacity.
- **Dynamic Channel Allocation** (**DCA**): the advanced TD-SCDMA air interface takes advantage of all available Multiple Access techniques. Making an optimal use of these degrees of freedom, TD-SCDMA provides an adaptive allocation of the radio resources according to the interference scenario, minimizing intercell interference.
- **Mutual Terminal Synchronization**: By accurately tuning the transmission timing of each individual terminal, TD-SCDMA improves the terminal traceability reducing time for position location calculation and search time for handover searching. Thanks to synchronization, TD-SCDMA does not need soft handover, which leads to a better cell coverage, reduced inter-cell interference and low infrastructure and operating costs.
- **Smart Antennas** are beam steering antennas which track mobile usage through the cell and distribute the power only to cell areas with mobile subscribers. Without them, power would be distributed over the whole cell. Smart antennas reduce multi-user interference, increase system capacity, increase reception sensitivity, lower transmission power while increasing cell range.

4.1. Radio Channel Access

TDMA/TDD

Time Division Multiple Access (**TDMA**) in combination with Time Division Duplex (**TDD**) significantly improves the network performance by radio network resources to process network traffic in both uplink and downlink directions.

TDMA uses a **5ms** frame subdivided into **7** time slots, which can be flexibly assigned to either several users or to a single user who may require multiple time slots.

TDD principles permit traffic to be uplinked (from the mobile terminal to the base station) and downlinked (from the base station to the mobile terminal) using different time slots in the same frame.

Symmetric services

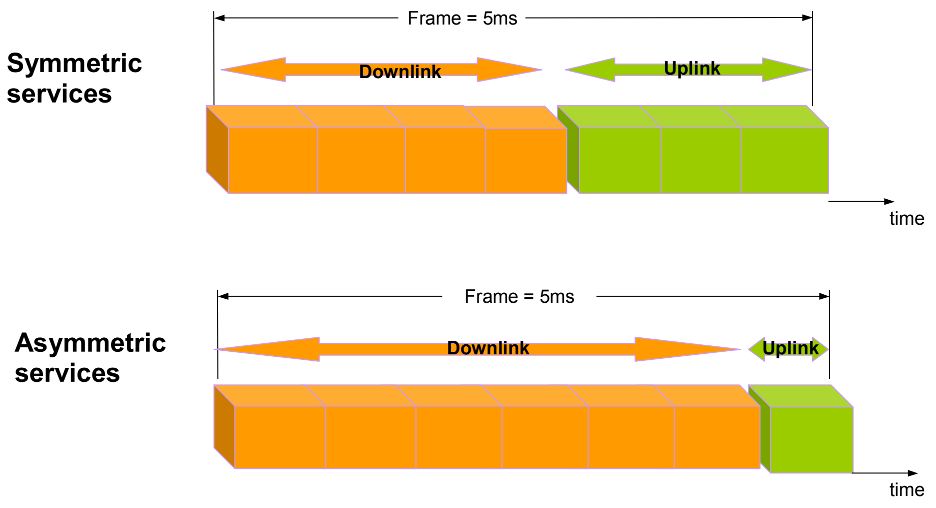
For **symmetric services** used during telephone and video calls (*multimedia applications*), where the same amount of data is transmitted in both directions, the time slots are split equally between the downlink and uplink.

Asymmetric services

For **asymmetric services** used with Internet access (*download*), where high data volumes are transmitted from the base station to the terminal, more time slots are used for the downlink than the uplink.

It is possible to change the switching point between uplink and downlink, depending on the capacity requirement between uplink and downlink.

Fig. 4.1.1. Time Division Duplex (TDD) Operation



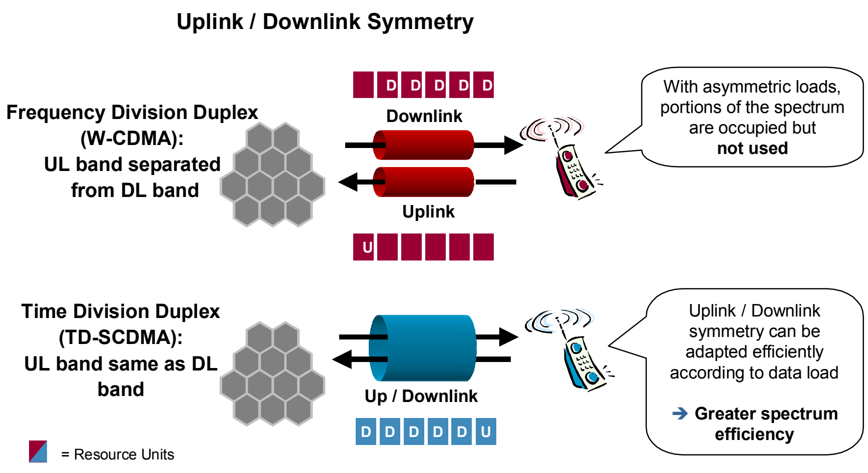
Unpaired band vs. paired bands

The ability of adapting the uplink/downlink symmetry according to data load within a single **unpaired** frequency band optimizes the capacity of the air interface, thus utilizing the spectrum more efficiently.

In contrast, the **FDD** (Frequency Division Duplex) scheme – employed by W-CDMA and cdma2000 – uses a **pair** of frequency bands for up- and downlink; with asymmetric loads, portions of the spectrum are occupied but not used for data transfer. These idle resources cannot be utilized for any other service, leading to an inefficient use of the spectrum.

Future mobile applications will require an efficient use of the available spectrum and the ability to handle strong asymmetric data traffic. TD-SCDMA fits perfectly these requirements and can be considered as the ideal technology for 3G services.

Fig. 4.1.2. Time Division Duplex Operation



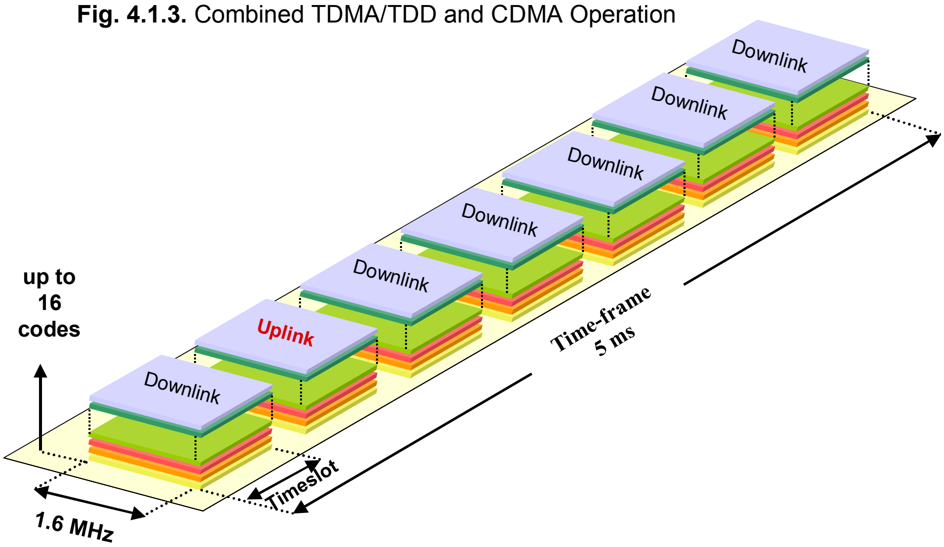
Combined TDMA/TDD and CDMA operation

In addition to the TDMA/TDD principle, TD-SCDMA uses CDMA (Code Division Multiple Access) to further increase the capacity of the radio interface.

According to CDMA, user information bits are spread over a wider bandwidth by multiplying the user data by pseudo-random bits (called chips) derived from CDMA spreading codes. Within each time slot a number of up to 16 CDMA codes may be transmitted (maximum CDMA loading factor). Using a chip rate of **1.28 Mcps** allows a carrier bandwidth of **1.6 MHz**. According to its operating license, the network operator can deploy multiple TD-SCDMA 1.6 MHz carriers[1]. Each radio **resource unit** is thus identified by a particular time slot and a particular code on a particular carrier frequency.

In order to support very high bit rates (up to 2Mbps), the use of variable spreading factor and multicode connections (code pooling) is supported.

Fig. 4.1.3. Combined TDMA/TDD and CDMA Operation



[1] All currently awarded TDD licenses are at least 5 MHz, allowing the deployment of 3 TD-SCDMA carriers.

4.2 Joint Detection

Problems and limitations of CDMA transmission

Mobile radio propagation is affected by multiple reflections, diffractions and attenuations of the signal energy, caused by normal obstacles - such as buildings, hills and so on - as well as by the mobility of the terminals. The resulting effect is the so-called **multipath propagation**, which generates two different kinds of fading: the slow and the fast fading. The fast fading occurs when different delayed paths arrive almost at the same instant; as a result, signal cancellation takes place even if the receiver moves across short distances. During slow fading, mainly caused by shadowing, the signal energy arrives at the receiver across clearly distinguishable time instants

In addition to these signal degradations common to every mobile communications, CDMA transmission is limited by its own "**self-interfering**" nature. Each CDMA signal is overlaid with all others in the same radio carrier and the received (*wide-band*) signal can be below the thermal noise level (Figure 4.2.1 ①). A correlation receiver (Matched Filter Correlator) is used in order to despread and recover the original user signal. Ideally the correlation detection should raise the desired user signal from the interference multiplying it by the spreading factor (Correlation Gain). The orthogonality of the different codes should guarantee a correct detection of the desired signal.

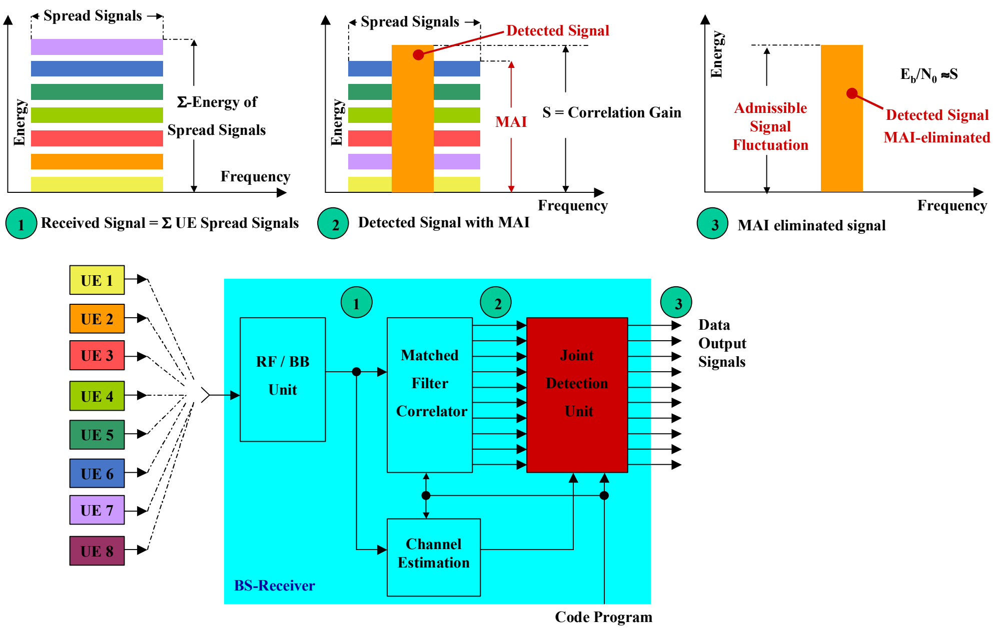
Multiple Access Interference

In fact, in actual CDMA systems the received spreading codes are not completely orthogonal and the correlation process cannot be so efficient. As a result, **Multiple Access Interference** (MAI) is generated in the receiver: the desired signal does not significantly distinguish itself from interfering users whose effect can be modeled as increased background noise. The detected signal, barely emerging from the MAI, has a low Signal to Noise Ratio (Figure 4.2.1 ②). The Multiple Access Interference (MAI) seriously limits the traffic load per radio carrier.

Joint Detection Unit

One effective way to eliminate MAI is to use after the Matched Filter Correlator **a Joint Detection Unit**, an optimal multi-user detection receiver that extracts all CDMA signals in parallel.

Fig 4.2.1. Joint Detection eliminates MAI



TD-SCDMA technology allows an efficient implementation of Joint Detection receivers in the base station as well as in the terminal.

A specific training sequence within each time slot allows the receiver to estimate the quality of the radio channel. Using a specific algorithm a DSP thus extracts all CDMA channels in parallel and removes the interference caused by the undesired CDMA channels (MAI). The result is a clear signal (high signal to noise ratio) for each CDMA code (Figure 4.2.1 ③).

Joint detection increases the level of admissible signal fluctuations and thus allows higher CDMA loading factors.

The result is an **increased transmission capacity per MHz of carrier bandwidth** (≈ **factor 3**) and a more efficient use of the available spectrum**.**

The efficiency of the Joint Detection receiver in TD-SCDMA technology is based on the TDMA/TDD operation and on the limited number of codes employed.

The total number of users per radio carrier is distributed over the different time slots of the basic TDMA frame, so that a maximal number of **16** codes per time slot per radio carrier can be easily processed in parallel and detected.

Due to the high number of codes used by cdma 2000 and W-CDMA the implementation of an optimal multi-user receiver in these systems is difficult, since the implementation complexity is an exponential function of the numbers of codes.

In order to combat MAI, these alternative CDMA technologies employ suboptimal detection schemes, such as the Rake receiver, which do not extract all CDMA codes in parallel.

Power Control

When applying these suboptimal receivers, it becomes essential to employ sophisticated (and expensive) multiple loop **fast power control** mechanisms in order to equalize the received power from all terminals and thus compensate the so-called *near-far effect*.

In CDMA systems a *near-far effect* occurs since different terminals with identical transmission power and operating within the same frequency are separable at the base station only by their respective spreading codes. It happens that the power received from a terminal located near the base station is much higher than that received from a subscriber at the cell's edge. Without an accurate fast power control a single overpowered mobile transmitting close to the base station would block the whole cell. But an efficient power control mechanism is complex, difficult to implement and expensive.

An essential precondition for a successful detection of all different CDMA signals is a balanced mutual signal level with a mutual level deviation ≤ 1.5 dB.

In TD-SCDMA, the elimination of MAI by Joint Detection extends the signal detection range for each signal to an allowed level difference of 20dB. This increases the robustness against fast signal fluctuations and significantly reduces the complexity of the power control mechanism.

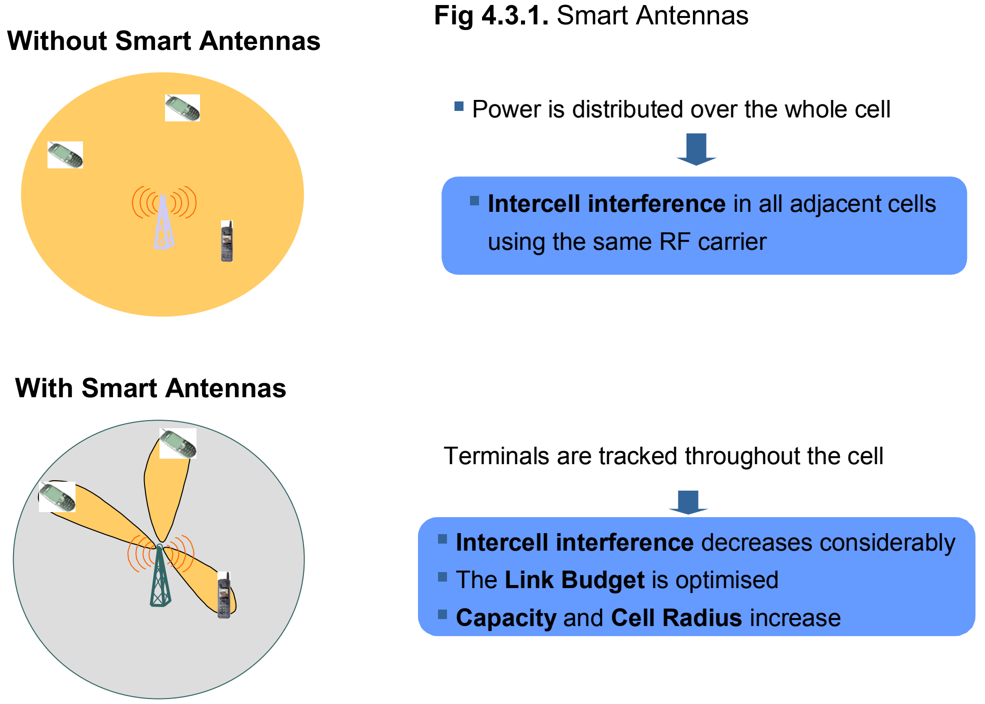
4.3 Smart Antennas

In order to further improve the system robustness against interference, TD-SCDMA base stations are equipped with smart antennas, which use a beam-forming concept.

Using omnidirectional antennas, the emitted radio power is distributed over the whole cell. As a consequence, mutual intercell interference is generated in all adjacent cells using the same RF carrier.

On the other hand, smart antennas direct transmission and reception of signals to and from the specific terminals, improving the sensitivity of the base station receivers, increasing the transmitted power received by the terminals and minimizing **inter and intracell interference**.

Fig 4.3.1. Smart Antennas

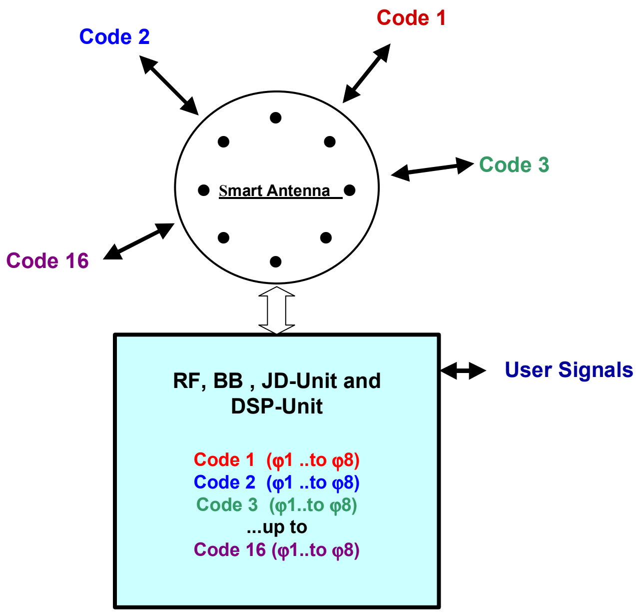


Smart antennas employed by TD-SCDMA technology are not conventional diversity beam-switching antennas but **advanced beam-forming** (and beam-steering) **bi-directional adaptive antenna arrays**.

The maximal individual directivity between base stations and mobile terminals is achieved by a concentric array of 8 antenna elements with programmable electronic phase and amplitude relations. Terminals tracking is performed by fast angle of arrival measurements in intervals of 5 ms 200 times per second.

Fig 4.3.2. TD-SCDMA Smart Antenna

Fig 4.3.3. 8-Element-Antenna-Array



Intercell Interference reduced

In this way the signal-to-interference ratio (**C/I**) is improved in both directions by about **8 dB**, i.e. the interference between cells (*Intercell interference*) is reduced by about **8 dB**.

This leads to an **optimization of the link budget** and a **reduction of the power transmitted by mobile terminals**.

Moreover, **the number of base-stations required in highly dense urban areas** - normally interference restricted – **can be reduced**.

Coverage expanded

Thanks to smart antennas' high directivity, in rural areas with low population density the **radio coverage can be expanded** (≈**8dB**), reducing the number of base-stations required.

The TDD mode of operation of TD-SCDMA offers optimum support for the implementation of smart antennas technology due to the **radio path reciprocity of downlink and uplink** operating on the same carrier in both directions.

On the contrary, in the FDD mode of WCDMA it is rather difficult to achieve optimal performance with smart antennas since the uplink and downlink use different frequencies, and fast fading is uncorrelated with between the uplink and the downlink.

Smart antennas in TDD operation, in combination with Joint Detection, increase the capacity and the spectrum efficiency of the TD-SCDMA radio interface.

4.4 Dynamic Channel Allocation

Intercell Interference minimized

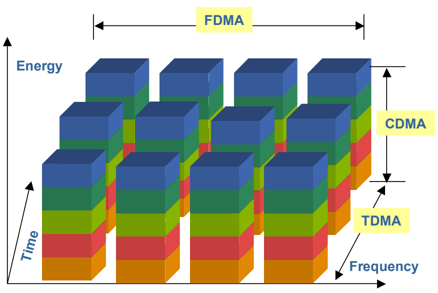
A further minimization of **intercell interference** is achieved by **Dynamic Channel Allocation** (**DCA**). The advanced TD-SCDMA radio interface takes advantage of all the available Multiple Access techniques: **TDMA** (Time Division Multiple Access), **FDMA** (Frequency Division Multiple Access), **CDMA** (Code Division Multiple Access) and **SDMA** (Space Division Multiple Access). Making an optimal use of these degrees of freedom, **TD-SCDMA** provides an optimal and adaptive allocation of the radio resources according to the interference scenario, **minimizing intercell interference**.

The following three different methods of DCA are used:

- **Time Domain DCA (TDMA operation)**
  Traffic is dynamically allocated to the least interfered timeslots.
- **Frequency Domain DCA (FDMA operation)**
  Traffic is dynamically allocated to the least interfered radio carrier (3 available 1.6 MHz radio carrier in 5MHz band).
- **Space Domain DCA (SDMA operation)**
  Adaptive smart antennas select the most favorable directional de-coupling on a per-users basis.
- **Code Domain DCA (CDMA operation)**
  Traffic is dynamically allocated to the least interfered codes (16 codes per timeslot per radio carrier).

Fig 4.4.1 Dynamic Channel Allocation (DCA)

TD-SCDMA **minimises Intercell Interference** by dynamically allocating least interfered resources.

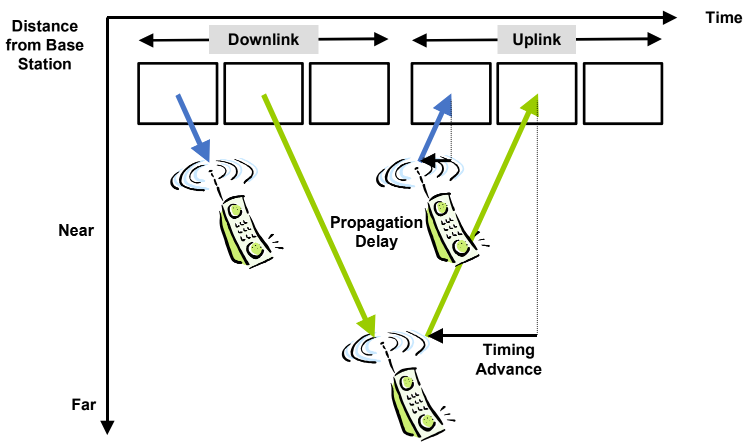


4.5 Terminal Synchronization

Like all TDMA systems (GSM included) TD-SCDMA needs an accurate synchronization between mobile terminal and base station. This synchronization becomes more complex through the mobility of the subscribers, because they can stay at varying distances from the base station and their signal present varying propagation times.

A precise timing advance in the handset during transmitting eliminates those varying time delays. In order compensate these delays and avoid collisions of adjacent time slots, the mobile terminals advance the time-offset between reception and transmission so that the signals arrive frame-synchronous at the base station (Figure 4.51).

Fig 4.5.1 Terminal Synchronization



The effect of this precise synchronization of the signals arriving at the base station leads to a significant improvement in multi user joint detection.

Synchronous deployment offers many advantages over asynchronous deployment.

First of all, the terminal traceability is improved and the time for position location calculations is sensibly reduced. In addition, in a synchronous system, the mobile terminal when non actively receiving or transmitting (*idle timeslots*) can perform measurements of the radio link quality of the neighboring base stations. This results in reduced search times for handover searching (both intra- and inter-frequency searching), which produces a significant improvement in standby time.

Thanks also to synchronization, TD-SCDMA does not need to rely on soft handover to improve coverage at the cell's edge and to reduce interference. On the contrary, TD-SCDMA uses conventional handover, which leads to a sensible reduction of the cost of leased lines.

5 Terminals

Terminal availability is always the key factor to the success of every mobile system. Moreover, 3G terminals have to support also existing second-generation standards because many 3G networks will be first implemented in densely populated areas, with handsets falling back onto 2G networks outside these areas.

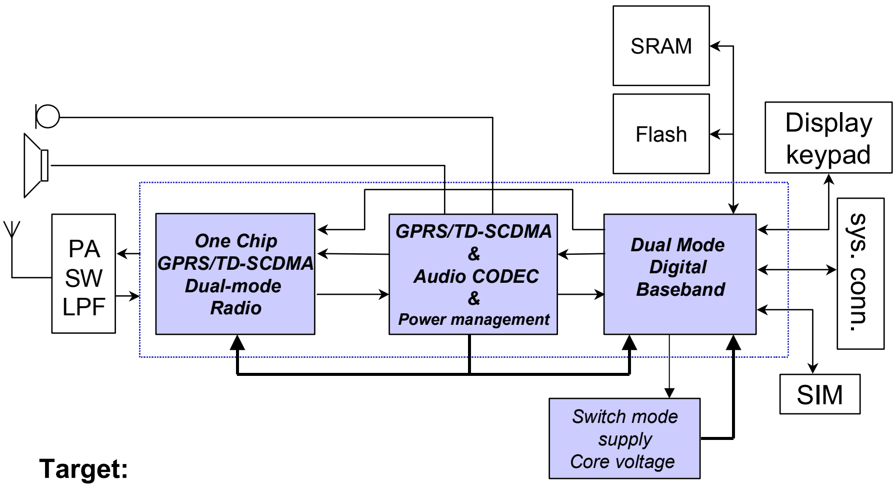
The terminals should be cost-effective, low power consuming, reliable, multi-mode and early available. In particular, simple solutions based on existing technologies should be taken into account.

Dual mode terminal

The first commercial TD-SCDMA handset meets all these requirements: it will be a **dual mode GSM/GPRS/TD SCDMA** based on an high integrated 3 chip solution (Fig 5.1).

This GSM/GPRS/TD-SCDMA terminal maximizes the reuse of a standard GSM/GPRS platform. Since the TSM protocol Stack (Layer 2-3) is very similar to the GSM one, the dual mode GSM/GPRS/TD-SCDMA terminal reuses the GSM L2 and L3 software stack, with few simple modifications.

Fig. 5.1. Dual-mode GPRS/TD-SCDMA Commercial Terminal (2003)



Target:

High level of integration: 3 chip solution.
Dynamic Voltage Scaling of the DSP core voltage for Low-Power operation

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This dual mode terminal guarantees international roaming and seamless handover between GSM and TD-SCDMA.

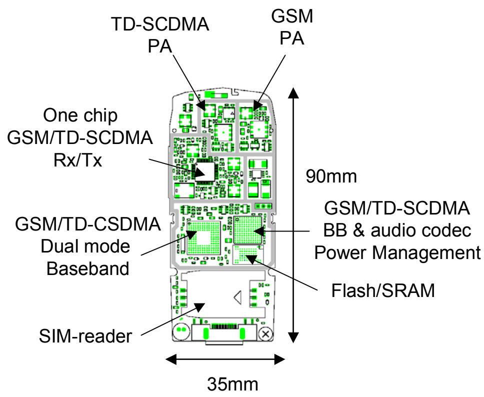
In addition, the high directivity and sensibility of smart antenna together with the fact that terminals transmit power only during active timeslots, contributes to keep the terminal's power consumption low, which leads to more cost effective handsets.

Cost effective (Fig.5.2), **reliable** and **low power consuming** dual mode **TD-SCDMA/GSM** terminals will be available in China by the end of 2003.

Fig. 5.2 RTX GPRS/TD-SCDMA Commercial Handset.

RTX TELECOM

- GSM/GPRS/TD-SCDMA compliant
- Direct conversion Rx and Tx
- Single board handset



DEVELOPMENT TARGETS:

Bill of material	< 70 USD
Size	< 75 ccm
Weight	< 85 g
No. of components	app. 150
No. of RF-chips	1
No. of BB-chips	2 + Memory
Launch	2H 2003

GPRS/TD-SCDMA handsets will be cheaper than GSM/W-CDMA or cdma2000
Cost add up to standard GSM/GPRS handset will be insignificant over time

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Triple mode terminal

A triple mode terminal **GSM/W-CDMA/TD-SCDMA** will be developed later integrating the TD-SCDMA co-processing platform in the GSM/W-CDMA chipset

This triple mode terminal will make international roaming and seamless handover between GSM, TD-SCDMA and W-CDMA possible.

Multi vendor environment

Another important success factor for a wireless system is a **multi vendor environment**. Several chipset and mobile phone manufacturer have already stated their commitment to TD-SCDMA:

- **RTX Telecom** (Scandinavian wireless solution developer), since August 2000 is developing TD-SCDMA terminal platforms.
- **Datang/CATT** is developing TD-SCDMA terminals. The briefcase size terminal called Field Trial Mobile System (**FTMS**), developed by CATT/Datang, is in use in the Field Trials in Beijing. It supports voice and data services and can easily be connected to a PDA/laptop to test 3G applications.
- **Nokia, Texas Instruments, China Academy of Telecommunication Technology (CATT), LG Electronics, China PTIC Information and Industry Corporation** and other 12 foreign and Chinese firms formed a company in China called COMMIT Inc. to develop TD-SCDMA standard wireless handsets.
- **Philips Semiconductors**, CATT/**Datang Telecom** and **China Eastern Communication Wireless Research Center** (**CEC Wireless**) jointly established a joint venture for the development of TD-SCDMA user terminals, chipsets and software.

6 Conclusions

- Adopted by ITU and 3GPP, **TD-SCDMA** is a **full 3G Radio Standard**, which covers all radio deployment scenarios. **voice** and **data** services, **packet** and **circuit** switched transmissions for **symmetric** and **asymmetric** traffic, **pico**, **micro** and **macro coverage** for **pedestrian** and **high mobility** users.
- Optimally suited for **Mobile Internet** and **Multimedia Applications**.
- Beam-steering **smart antennas**, **joint detection**, **terminal synchronization** and **dynamic channel allocation** minimize radio interference leading to **outstanding spectrum efficiency** (3-5 times GSM).
- **Highly dense populated areas** can best benefit from **TD-SCDMA**'s high spectral efficiency.
- TD-SCDMA allows an **easy migration path**: GSM/GPRS/TD-SCDMA. The total migration costs from 2G to 3G is considerably reduced, compared to other 3G standards.
- ***Conventional handover***, instead of **soft handover,** leads to a sensible **reduction of the costs of leased lines**.
- ***Cell breathing effect*** is not an issue for TD-SCDMA: **overall network costs are sensibly reduced and Network Planning is considerably simplified**.
- **Seamless interworking** with GSM/GPRS and W-CDMA is guaranteed
- **Smart antennas** direct power to active mobile terminals only, keeping terminals' power consumption low.
- During the TD-SCDMA field trial in Beijing it has been shown that it was possible to make video calls even at speed of up to **125 km/h** and up to **21 kilometers** from the base station without any noticeable loss in quality.
- The **first deployment of TD-SCDMA** commercial networks will take place in **China in 2003**.
- **Cost effective**, **reliable** and **low power consuming** dual mode **TD-SCDMA/GSM** terminals will be available in China by the end of 2003.
- The mass deployment in the world's largest market will assure significant **economies of scale** to TD-SCDMA and facilitate its worldwide acceptance.
- Jointly developed by Siemens and CATT, TD-SCDMA enjoys today a **multi-vendor environment**.

Appendix A - Abbreviations

3GPP	3rd Generation Planing Partnership Project
CATT	China Academy of Telecommunications Technology
CDMA	Code Division Multiple Access
CWTS	China Wireless Telecommunication Standard Group
DCA	Dynamic Channel Allocation
DL	Down Link
DS-CDMA	Direct Sequence CDMA
FDMA	Frequency Division Multiple Access
FTMS	Field Trial Mobile System
GSM	Global System for Mobile communication
HCR	High Chip Rate
ITU	International Telecommunication Union
kbps	Kilo Bits Per Second
LCR	Low Chip Rate
MAI	Multiple Access Interference
Mbps	Mega Bits per Second
Mcps	Mega Chips Per Second
MCA	Multi Channel Allocation
MCI	Multi Channel Interference
NE	Network Element
RAN	Radio Access Network
RITT	Research Institute of Telecommunications Simulation Network
SDMA	Space Division Multiple Access
TDD	Time Division Duplex
TDMA	Time Division Multiple Access
TD-SCDMA	Time Division Synchronous Code Division Multiple Access
T-RNC	TD-SCDMA Radio Network Controller
TSM	TD-SCDMA System for Mobile Communication
UL	Up Link
UMTS	Universal Mobile Telecommunication System
UTRA	UMTS Terrestrial Radio Access
UTRAN	UMTS Terrestrial Radio Access Network
W-CDMA	Wideband CDMA
Additional Acronym	

Appendix B - *Main TD-SCDMA parameters*

Carrier bandwidth	1.6 MHz[1)]
Min. spectrum	1.6 MHz
Duplex type	TDD
Multiple Access Scheme	TDMA, CDMA, FDMA
Chip rate	1.28 Mcps
Modulation	QPSK, 8-PSK
Max. cell range	**40 km**
Max.[2)] **voice capacity** [Erl.]	EFR[3)]: **55**
Data throuput[2)]	**6** Mbps
Theoretical max. data rate/ user	**2 Mbps**
Max spectral efficiency	**325** Kbit/s/MHz/cell
System asymmetry (DL:UP)	1:6 – 6:1

[1)] Frequency reuse of 1

[2)] Within a 5 MHz spectrum per cell (sector)

[3)] EFR = Enhanced Full Rate (12.2 kbps)

Appendix C - *Contacts*

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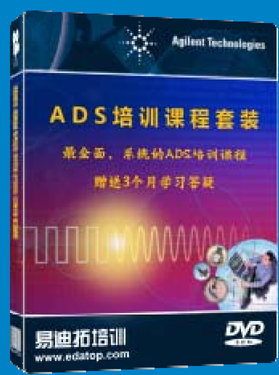

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