WCDMA and TD-SCDMA:

European 3G vs. Chinese 3G

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1. Introduction

There has been a great deal of talks about the third generation mobile systems. People have been trying to predict the killer application that will make 3G successful. But the customers have fallen for the tricks of the operator's market departments.

There have been, and there is, large sums of money invested in the development of 3G technology, and different players tries to promote their technique. In America there is one standard, Europe has another, and China has decided to develop their own standard. The Chinese decision is quite brave, when it exist working techniques on the market. But China has kept going, and now their technique TD-SCDMA is accepted as a world wide standard.

So why do they develop their own standard? Is it something that they have borrowed from the European and American manufacturers, and put their own name on it? Can there be any big differences between the standards, since they all prosper on being the standard for third generation mobile systems?

This paper will focus on the architectural differences and similarities of the European WCDMA alternative and the Chinese TD-SCDMA. What effects will these similarities and/or differences have on the evolution from second generation to third generation? The paper starts with a history of the work towards the third generation mobile telephone technology. It moves on with a look at the technique chosen by Europe, WCDMA. After that focus will be on China and TD-SCDMA. The paper will then make a comparison of the systems and end with a look into the near future.

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2. History of 3G

When you talk about 3G you are really referring to the third generation mobile telephone technology. 3G offers not only voice-traffic to be sent over the network, but also non-voice-data (such as downloading from the Internet, sending and receiving email). The evolution from the second generation mobile telephone technology (2G) to 3G is mainly due to the limited capabilities in 2G, and the needs of the growing market. Second generation systems where design for mainly voice-traffic to be sent over the network. There has been a great deal of efforts in designing solutions for the migration to the 3G standard. Techniques such as GPRS (General Packet Radio Service) are merely stepping stones in the evolution towards 3G. These techniques are sometimes referred to as 2.5G.

ITU (International Telecommunication Union) presented a standard called IMT-2000 which contained the demands of the third generation mobile networks. The idea behind ITUs specification was to make a single worldwide standard. ITU received several proposals based on different technologies, and today IMT-2000 is a set of globally harmonized standards for 3G. The current 3G services and technologies are the answer to the IMT-2000 demands. Future releases of new technologies for 3G will also be in compliance to the IMT-2000 requests.

In the demands from the ITU where, amongst others, to provide multimedia services at three different transmission rates, namely 144 kb/s to devices moving in high speed, devices that is moving in the speed of walking 384 kb/s, and last 2 Mb/s to indoor equipment [1].

The Japanese operator NTT DoCoMo launched the first commercial WCMDA network, called FOMA (Freedom of Mobile Multimedia Access), in 2001 [2]. NTT DoCoMo and Japan promoted the WCDMA technology and presented it to ITU as a candidate for the ITM-2000 standard. ITU added WCDMA to the IMT-2000 standards in May 2000 [2].

Many European countries have adopted the same technology as Japan. But Europe is a couple of years behind Japan in the employment of 3G technologies. The 3G systems in Europe are sometimes referred to as UMTS/WCDMA [3].

There exist other techniques proposed as an answer to the IMT-2000 challenge, and which has been deployed in other countries like USA and Korea. These technologies include CMDA2000 (IMT-MC), UWC (IMT-SC), DECT (IMT-FT), and CDMA-TDD (IMT-TD) which includes TD-CDMA and TD-SCMDA [4].

2.1. China Develops Their Own Standard

The People's Republic of China has chosen a different approach. They have developed their own 3G standard, called TD-SCDMA (Time Division Synchronous Code Division Multiple Access), and developed by Siemens and China Academy of Telecommunications Technology (CATT) [4]. The CWTS (China Wireless Telecommunication Standard group) submitted the TD-SCDMA standard to ITU-R, and got it approved in May 2000 [5]. In March 2001 China joined the 3GPP (3rd Generation Partnership Project), and got TD-SCDMA accepted as a 3G standard [5]. To sort out the different abbreviations, ITU-R calls the technique TD-SCDMA, but 3GPP call the same technique LCR TDD (Low Chip Rate TDD) [6]. The Chinese standard are sometimes also referred to as UTRA TDD [7] (Universal Terrestrial Radio Access, not to be confused with UMTS Terrestrial Radio Access from ETSI). The TD-SCDMA has many names, except the ones mentioned above. In this document I will use the name TD-SCDMA.

The European players chose to evolve the CDMA technique developed by Qualcomm, and thus are required to pay royalty to Qualcomm for using their patents. But the Chinese took their own path and chose to develop their own standard, this way avoiding paying royalties to "the western world" [8]. This has stirred up a lot of feelings. Qualcomm is accusing the backers of the Chinese standard for intellectual properties (IP) infringement. But the supporters of Chinese 3G claims that TD-SCDMA builds on technology developed by the Chinese themselves [9].

3. Europe and WCDMA

3.1. Existing 2G Infrastructure

The operators in Europe let their second generation systems evolve towards third generation systems. In order to achieve this they usually extend their 2G-system with GPRS (General Packet Radio Service). GPRS operates in the GSM band and lets the air-interface use packet-oriented data transfers, rather than permanent channel occupation (circuit-oriented). This opens up for data rates over 100 kbps. The implementation of GRPS into the existing system requires a rather low effort. The next step in the evolution is to deploy Enhanced Data Rates for GSM Evolution (EDGE), which enables much higher data rates. With GPRS and EDGE it is possible to offer third generation services in a second generation system. The last step in the evolution is the GERAN (GSM/EDGE Radio Access Network). The GERAN allows the EDGE radio access network to connect to the core network of a UMTS system. This way real-time (symmetric) and non-real time (asymmetric) services can be fully supported in the 2G-system [10].

3.2. Architecture of European Third Generation Systems

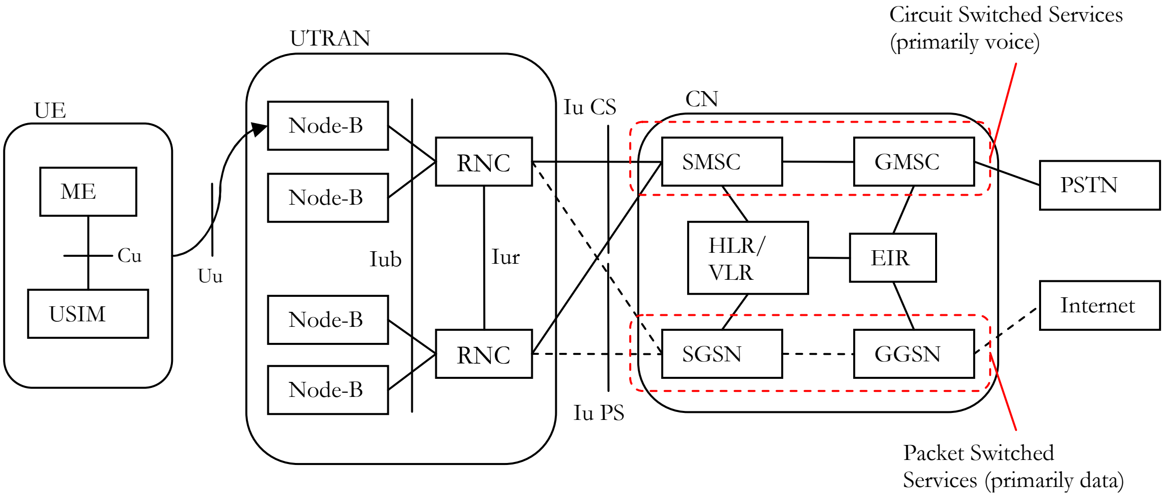

Figure 1 - WCDMA Network Overview

CN – Core Network Cu – Electrical interface between USIM and MS EIR – Equipment Identity Register GGSN – Gateway GPRS Support Node GMSC – Gateway Mobile Switching Centre HLR – Home Location Register Iub – Node-B – RNC interface Iur – RNC – RNC interface Iu CS – UTRAN – CN, Circut Switched interface Iu PS – UTRAN – CN, Packet Switched interface ME – Mobile Equipment	Node-B – Base Transceiver Station PSTN – Public Switched Telephone Network RNC – Radio Network Controller SGSN – Serving GPRS Support Node SMSC – Serving Mobile Switching Centre UE – User Equipment USIM – Universal/UMTS Subscriber Identity Module UTRAN – UMTS Terrestrial Radio Access Network Uu – WCDMA air interface VLR – Visiting Location Register

Table 1 - Abbreviations Found in the WCDMA Network

In the figure above the WCDMA network is divided into three different domains. The UE domain refers to the user mobile terminal and the USIM. The USIM is a smart card that stores the user subscriber information, authentication information, and storage space. The UE communicates with the UTRAN via an air-interface Uu. The Uu-interface is the WCDMA radio interface, through which the UE access the fixed parts of the network [7].

Inside the UTRAN there exists several Node-Bs, which is sometimes referred to as Base Station Transceiver. The functions of the Node-B is air-interface L1 (layer 1) processing, such as channel coding, interleaving, spreading, and so on. The Node-B corresponds logically to the GSM base station [7].

The RNC in the UTRAN is responsible for congestion and load control in a cell. It also controls the soft handovers between different RNCs in the network. The RNCs communicate via the Iur-interface (RNC - RNC Interface). This interface is divided into different modules, and neither of them is described on this paper. The Iub-interface is the one that connects, and allows signalling between, the base stations and the RNC [7].

Between the UTRAN and the Core Network there are two interfaces, together referred to as Iu-interface. This interface divides the system into the UTRAN, which is radio-specific, and the CN that handles the switching, routing, and service control. The variants of the Iu-interface lets the UTRAN connect to the circuit switched part of the CN (Iu CS), or the packet switched part of the CN (Iu PS) [7].

Inside the Core Network the changes from the second generation is not that big. The CN contains two domains, consisting of packet switched traffic and circuit switched traffic. The HLR/VLR contains information about mobile subscribers, services connected to a specific mobile, and information about visiting mobile terminals. The SMSC and SGSN are similar in their behaviour, but serves the different domains they are located in, that is the circuit or packet switched. They connect the CN to the UTRAN. The GMSC and GGSN are also similar, but work in different domains. They enable the core network to communicate with external networks, such as the PSTN or the Internet. The EIR contains information about specific terminals and can be used to block a specific terminal from gaining access to the network [7].

3.3. WCDMA Specifics

Wideband Code Division Multiple Access uses a technique called FDD, Frequency Division Duplex. The WCDMA standard is the air-interface of the UMTS system. This technique spreads the users signal over a wide bandwidth, see Figure 2. In the old GSM system, every User Equipment (UE) had only 200 kHz of bandwidth, but in this system there exists a 5 MHz bandwidth. The signal is split using different codes for different users. This way multiple calls and/or connections can exist on the same frequency. This removes the need of doing frequency planning, as done in the old system, and you can have a frequency reuse factor of 1, that is you can utilize the same frequency in adjacent cells. The WCDMA technique also gives a higher data-rate, more handover choices, adaptive power control, and so on.

WCDMA uses two 5 MHz bandwidth areas (paired spectrum), located at 1920-1980 MHZ and 2110-2170 MHz [7]. The 1929-1980 MHz area is used for the uplink, that is, the connection from mobile device to base station, and the 2110-2170 MHz area is used for the downlink connection, base station to mobile device. See section 5 for assigned frequencies.

WCDMA spreads a signal by multiplying it with a channel code, see Figure 2. This results in a long sequence of information elements that represents a single bit. This spreading factor (SF) varies between 4 and 512, depending on whether it is used in the uplink or downlink. The use of higher SF gives a more robust communication, as every bit is represented by more chips, but it also results in lower data transmission rate to the user. The system can alternate the spreading factor to provide bandwidth on demand [11].

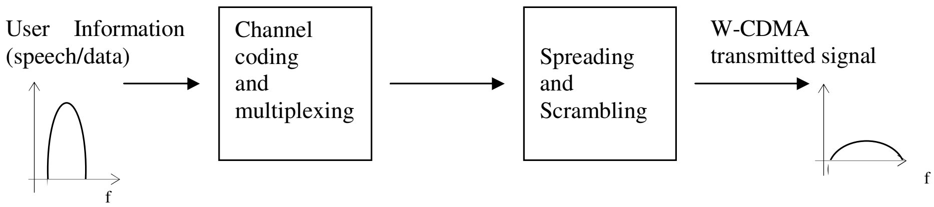

Figure 2 - From user information to W-CDMA signal [12]

3.4. Spatial Division Multiple Access

SDMA allows a single transmitter to provide coverage with a focused radio beam. This way the same frequency may be reused in the same cell. The radio beams may dynamically change with the position of the mobile device. To use this technique a cell needs to be equipped with a multiple directional antenna or a phased array antenna [11]. Compare the SDMA to Smart Antennas in section 4.4.1, and especially Figure 6 - The Idea behind Smart Antennas, which shows how a cell is divided up into several areas.

3.5. Rake Receivers

Multiple signals that take different paths, caused by reflections on obstacles, could be a problem to the base station or the mobile station. This leads to that the base station or the UE could have difficulties recognising the signal. WCDMA uses something called Rake Receivers to tackle this problem. The Rake Receiver is able to decode each signal individually, and then chose which signal to use or to combine them. This way the system has some control over the quality of the signal sent or received [11]. In TD-SCDMA this is called Joint Detection, and is described in section 4.4.2.

4. China and TD-SCDMA

China is a large country, with an area slightly larger than the USA. The population of China is approximately 1300 million people [13]. China had roughly 250 millions mobile subscribers in 2003, with more than 4 million new subscribers every month. These numbers shows that a lot of people is still without a mobile subscription, and that the potentials for a 3G market is huge [14].

4.1. Migration from 2G to 3G

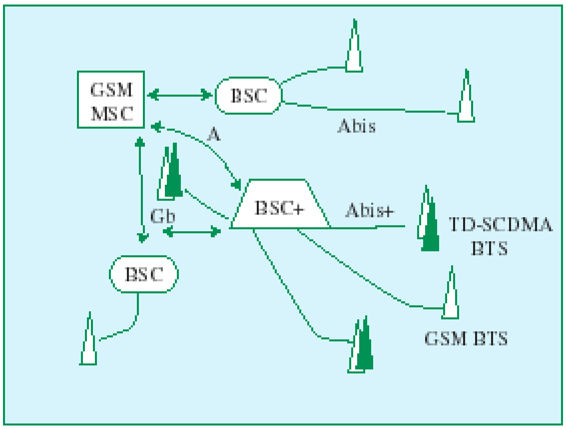

Figure 3 - Schematic Diagram of TD-SCDMA System. Used in GSM Network, Providing 3G Services [15]

Li Shihe thinks that TD-SCDMA is the best technique for a migration from 2G to 3G. His recommendations are also to provide 3G services in the existing 2G network. This is to be achieved by adding extended base station controllers (BSC+) into the GSM network. He also thinks that it is necessary to add TD-SCDMA capable base transceiver stations (BTS, also referred to as Node-B) in user concentrated areas. The users of the 3G technique will have user equipment that can use both 3G and second generation services. The 3G services are available in the areas covered by the TD-SCDMA BTS, and outside the areas GSM will be used. This way an operator can supply 3G services in areas where the 3G demands is greater. When the needs of 3G services rise, and the network is constructed in the way described above, the step towards a pure 3G network is rather easy [15].

4.2. Why Developing Their Own Standard

There is no doubt that it exist a lot of pride in developing their own standard. China felt that they where lagging behind in the technical development in the second generation mobile systems. Because China where dependent on the manufacturers and developers in other countries. But the huge telecom market in China provided the Chinese government with power to bargain with foreign vendors. This lead to many joint venture projects between foreign players and domestic vendors. The Chinese government also provided a great support to the domestic manufacturers, enabling several domestic players to be well established. Riding the wave of success it is only natural that China chose to development an own 3G standard [16].

Another issue is the patents of the standard. Since China was not involved in the development of the GSM technology, they saw their chance to get some patens on their own technology. The mobile market in China is huge and it will probably continue to grow, this is a great opportunity for China to get their share. The TD-SCMDA technology works in the TDD-frequency band, which gives the technology a chance to co-exist with WCDMA or work as a stand alone technique. But since most European and American countries has allocated the TDD-frequency band, the TD-SCDMA technique would work in those countries as well. So this market space gives the TD-SCDMA technique a good potential on the international market. And this is something that the Chinese players (vendors, manufacturers, and government) will take advantage of [17].

4.3. Architecture of Chinese 3G

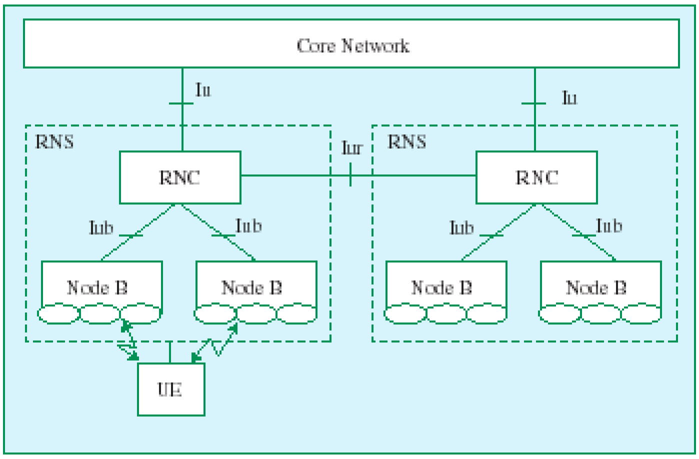

Figure 4 - TD-SCDMA Network Overview [15]

Compared to Figure 1, showing the network overview of WCDMA, the figure above is very similar to that one. In fact, they are almost identical, see section 3.2. The domains of the network are the same, User Equipment (UE), Radio Network Subsystem (RNS), and Core Network (CN). The Iu-interface in the figure above consists of both Iu PS (Packet Switched) and Iu CS (Circuit Switched). The figure above does not show the connection from the CN to the PSTN or the Internet, but it exists.

4.4. TD-SCDMA Specifics

TD-SCDMA uses a TDD scheme (Time Duplex Division), in opposite of WCDMA. They use the same channel as uplink and downlink. The signal is spread in the same way as in WCMDA, but the signalling is controlled by time division. TD-SCDMA uses a chip-rate of 1.28 Mcps (Mega chips per second), and is therefore referred to as Low Chip Rate TDD (LCR TDD) by the 3GPP [18]. TD-SCDMA operates without the needs of a paired spectrum (TDD unpaired band) and works well with asymmetric traffic [18]. The advantage of working without the need of paired spectrum is that it requires a smaller bandwidth, se Figure 5, and better utilization of the spectrum in asymmetric services. This is to be compared to WCDMA that needs a paired spectrum (FDD paired band). TD-SCDMA is also able to cover large areas, up to 40 km [4], and supports high mobility.

The symmetric service consists of speech and video traffic, and the asymmetric traffic is mainly mobile Internet traffic. The symmetric traffic is handled by circuit switched services, and the asymmetric traffic by packet switched services. When handling asymmetric traffic more slots is reserved in the downlink than in the uplink, since more traffic is sent from the base station to the terminal.

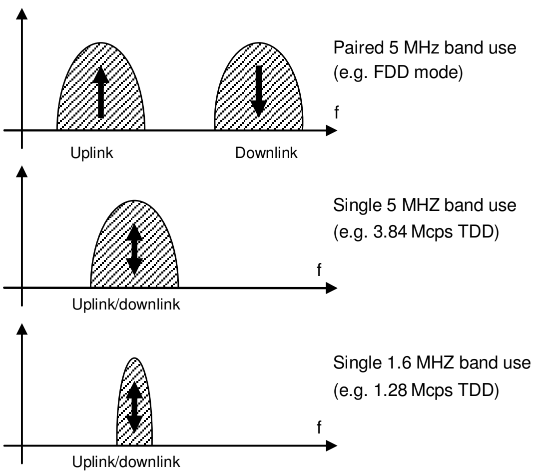

Figure 5 – WCDMA Paired Spectrum and TD-SCDMA Unpaired Spectrum [18]

TD-SCDMA does not employ soft handover, as in the case of WCDMA and other CDMA systems. Instead they use a technique called baton handover, which is something in between soft handover and hard handover. This is due to smart antennas, joint detection and accurate terminal synchronization, which is described in the following sections. [19]

4.4.1. Smart Antennas

The idea behind Smart Antennas (SA) is to distribute the power to the part of the cell that contains mobile subscribers, i.e. active terminals. Not using Smart Antennas results in power being spread over the whole cell, thus creating interference between cells. The SAs is located in the TD-SCDMA base station, and tracks mobile terminals throughout the cell. The antennas contain a concentric array of eight antenna elements. This leads to that the number of base stations in highly dense urban areas can be reduced. The technique also makes it possible to reduce the number of base stations in rural areas with low population density. This is mainly due to that more power can be directed in a certain direction [4].

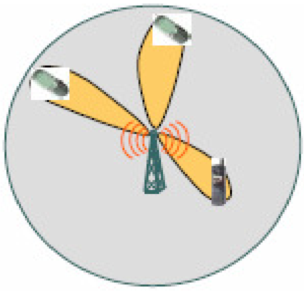

Figure 6 - The Idea behind Smart Antennas

4.4.2. Joint Detection

Another feature of the TD-SCDMA technique is Joint Detection (JD). This technique is used to combat the Multiple Access Interference (MAI) experienced in other CDMA-systems. Both JD and MAI is too technical complex to be described in greater detail in this paper, but a brief explanation follows.

Signals from mobile devices that are received at base stations are affected by multipath propagation. This is due to reflections, diffractions, and attenuation of the signal from buildings, hills, and so on. This results in the same signal arriving from different paths to the base station, but they are slightly out of sync. The signals will then cancel each other out. Signals from different terminals, multi-user access, could also interfere with each other. With a Joint Detection Unit the effect of this phenomenon can be minimized. According to Siemens [4] this leads to better signal detection capabilities and thus getting a better transmission capacity.

The same problem occurs in the WCDMA system, but there you use Rake receivers to fight this problem.

4.4.3. Terminal Synchronization

Terminal Synchronization (TS) is the term used when referring to the technique for tuning the transmission timing of each mobile terminal with respect to its base station. This way the quality of the uplink signal can be greater. This way the localization of a terminal is made easier, and thus making it easier for handovers. The TS also eliminates the need for soft handovers in the system [1], [4].

5. WCDMA vs. TD-SCDMA

	TD-SCDMA	WCMDA
Also called	LCR TDD, IMT-TC,	IMT-DS, UTRA FDD,
Frequency band	2010 MHz – 2025 MHz	1920-1980 MHz and 2110–2170 MHz
Minimum frequency band required	1.6MHz	~ 2x5MHz
Frequency re-use	1 (or 3)	1
Duplex type	TDD	FDD
Chip rate	1.28 Mcps	3.84 Mcps
Frame length [ms]	10	10
Modulation	QPSK or 8-PSK	QPSK
Receiver	Joint Detection	Rake
Power control period	200 Hz	Time slot = 1500 Hz rate
Handovers	Hard, Baton	Hard, Soft, Softer
Physical layer spreading factors	1, 2, 4, 8, 16	4 ... 256 UL, 4 ... 512 DL

Table 2 - Technical Differences of TD-SCDMA and WCDMA

In the table above some features of the different systems is listed. Worth noting is the difference in the frequency band that the two techniques use. There is a significant difference in the minimum required frequency band, with TD-SCDMA having a much narrower band than WCDMA. The two systems operate with two different duplex types, thus enabling them to utilize different spectra's. With the short description made about the receivers in the networks, the Joint Detection technique and Rake Receivers seems to be quite alike. The last difference mentioned here are the different handover types in the systems.

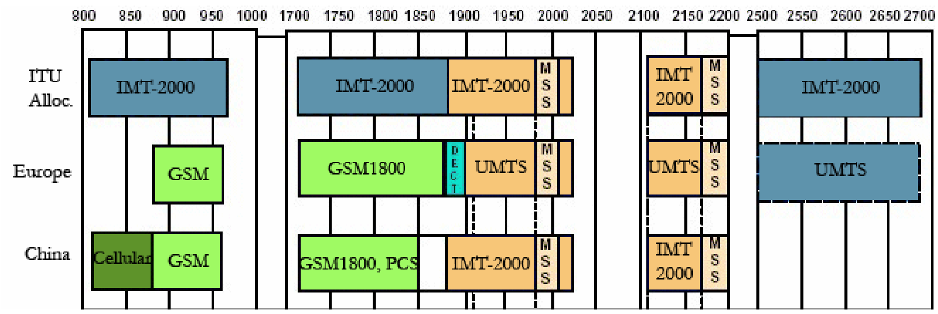

Figure 7 - Frequency Allocations

The WCDMA technique is best suited for high mobility in micro and macro cells, with symmetric services. The TD-SCDMA technique on the other hand has lower cell coverage, several kilometres, and does not work in speeds higher than 120 km/h. WCDMA manages speeds up to 500 km/h and has cell coverage of several tens of kilometres [15].

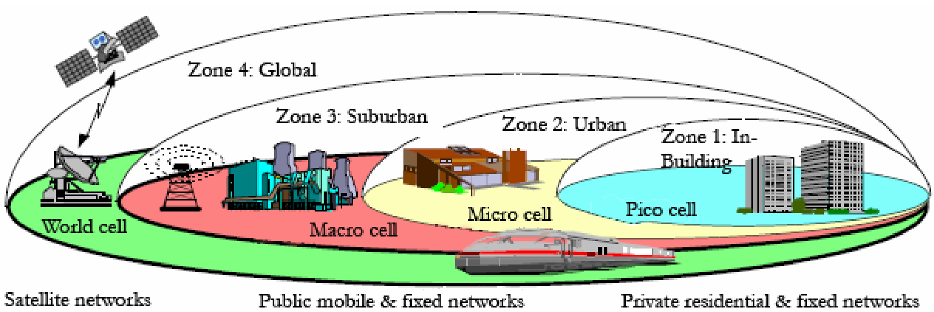

Figure 8 - Coverage Areas

Siemens, who is developing TD-SCDMA together with CATT, says that they have conducted test that shows that speeds up to 125 km/h where successful and that vehicles, at a distance of 21 km from the base station, could receive video data without any significant quality loss. They also state in their white paper about TD-SCDMA that "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" [4].

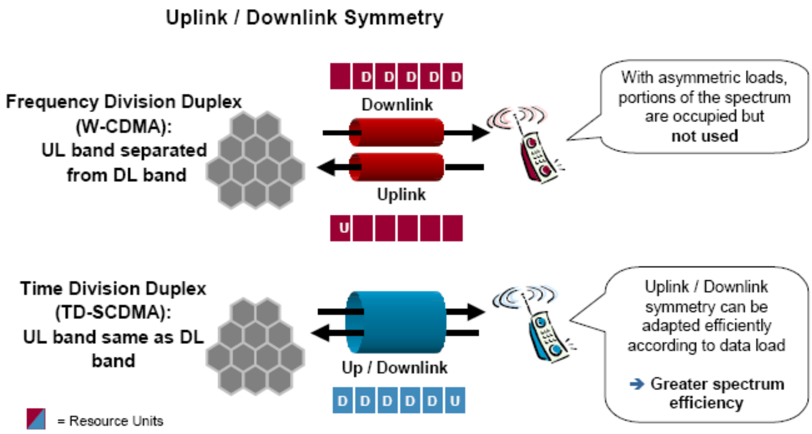

Figure 9 - Uplink and Downlink Differences in TD-SCDMA and WCDMA [4]

But, in contrast to the sayings from the PR-department of Siemens, other people working in the same area thinks that TD-SCDMA will not work well with large area coverage.

Zhang Ping and Xu Guoxin, from the New Radio Technology Lab of Beijing University, think that the TD-SCDMA technique will not be able to network independently. They think that the system will not be suitable for large-area coverage. The reason for this is the guard space (not explained in this paper) used in the TD-SCDMA system. According to them, having a large guard space will introduce longer propagation distances and increase the time delay. To solve this problem existing research shows that a reduction of the number of time-slots, in the uplink and downlink, would enable an increase of the guard space, cell radius and coverage. This leads to a system that is suitable for large-area coverage. The downside of this adjustment would be poorer cell capacity. So, for time being, they think that the TD-SCDMA technique should be used as a complement to the WCDMA technique (see section 6). The WCDMA system would be responsible for the large-area coverage, and the TD-SCDMA system should work on pico and micro cell coverage [17].

There exist many more differences between the Chinese TD-SCDMA and the "European" WCDMA standards. But many of them exist at the physical layer, that is, frame structure and the synchronisation procedure (briefly explained in section 4.4.3), and the link layer. But since the main focus of this paper is on things concerning the architecture of the two systems, the physical and link layer issues will not be described in more detail here.

6. WCDMA Together With TD-SCDMA

As mentioned in section 5, WCDMA vs. TD-SCDMA, the TD-SCDMA technique may not be suitable to network independently. But would it work to set up two systems, one based on TD-SCDMA and one based on WCDMA? And, why not use a pure WCDMA based 3G system?

3GPP has specified in their Release 4 document that a WCDMA system with a complement TD-SCDMA system is referred to as TDD-LCR. One thing that is necessary for an operator to deploy this kind of solution is that they got both FDD-spectrum and TDD-spectrum. That is, both paired spectrum and unpaired spectrum. This way an operator can use the advantages of TD-SCDMA in dense urban areas, where the needs for traffic capacity and the demands of services might be higher [10].

The core network in both technologies is identical. So, it is possible for TD-SCDMA and WCDMA to share CN. The similarities in the RNC are also quite big, making it easy to use similar technique in that domain as well. The biggest difference lies in the base stations of the two systems. They manage radio resources differently, but this problem could be solved, allowing the two systems to co-exist [17].

7. The Future of Chinese and European 3G

The future of the TD-SCDMA system is not set yet. The technique is still in an early stage, and no market deployment has yet been done. But the Chinese Ministry of Information Industry (MII) recently announced that they set the TD-SCDMA as a national technology standard for the telecommunication industry. The ministry also said that a stand-alone network will be built based on the Chinese TD-SCDMA standard [20].

But the government has also stopped operators from building their WCDMA networks. The operators had not the proper permission to apply the WCDMA technique in their trial networks [21].

But several Chinese manufactures and vendors is ready to start building complete TD-SCDMA system, including network and mobile terminals. Some of the companies are Datang Mobile and Alcatel Shanghai Bell. But tests performed by MII on the TD-SCDMA system shows that the technique still needs time to mature, and analysts think that the system will be ready in six months. [22], [23]

In the near future of WCDMA and "European" 3G are High Speed Downlink Packet Access (HSDPA) and IP Multimedia Subsystem (IMS), both techniques describe in 3GPPs release 5. HSDPA, sometimes referred to as 3.5G, extends the WCDMA technique and promises a five times greater data rate. This high speed extension will be deployed over Europe during the spring and summer 2006 [24]. The IMS will try to provide the services provided by Internet in the mobile terminals. IMS uses the IP-protocol, and brings the Internet together with cellular world [25].

8. Conclusions

It is hard to say which of the technologies mentioned in this paper that is better than the other. WCDMA has an advantage since it is a more mature standard, and deployed in more countries. TD-SCDMA on the other hand, if proven to be successful, has an enormous market ahead of it. It could be possible that the TD-SCDMA technique gets so big, thanks to the many subscribers and Chinese vendors, that it is a possible technique in Europe and America market. Maybe not the third generation, but surly the fourth generation mobile telephone technology evolving from TD-SCDMA could be a large competitor in the international telecommunications market. But if a possible future success depends on technical advantages, politics, or low production costs is an interesting question.

Maybe the two standards should not be compared as competitors, but as complements to each other. This has been proposed by many researchers and experts in the area. An area with demands of high bandwidth, and Internet services should maybe be covered by TD-SCDMA, and sparsely populated areas could get a standard coverage from WCDMA.

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