Synchronization of CDMA Base Stations For 3G Network & Wireless Local Loop

Introduction

The third-generation mobile radio networks (so called 3G) and Wireless Local Loop transmissions will provide a multitude of new services, especially multimedia and high-bit-rate packet data. Emerging requirements for higher rate data services and better spectrum efficiency are the main drivers identified for the design of the air interface. The CDMA concept (Code Division Multiple Access) is a very powerful technique which is today selected as the mainstream air interface solution being standardized world-wide by international bodies.

CDMA Standard Bodies & Collaborative Groups

The world-wide harmonization of different CDMA interfaces is achieved by the International telecommunications Union (ITU). Third generation networks are called IMT-2000 (International Mobile Telecommunications-2000). Five radio technology options have been included – three of them based on CDMA - to ensure seamless service evolution from the various 2G mobile standards that are extensively deployed around the world.

In Europe, 3G is called "UMTS" (Universal Mobile Telecommunications System) defined by the 3rd Generation Partnership Project (3GPP) which is a collaboration agreement bringing together a number of telecommunications standards bodies. The UMTS Forum is an open, international body for promoting the global uptake of UMTS mobile systems and services.

The Third Generation Partnership Project 2 (3GPP2) is another collaborative 3G telecommunications standards setting project comprising North American and Asian interests developing global specifications for 3G based on CDMA2000. This CDMA implementation different from UMTS is explained below. The CDMA Development Group (CDG) is a consortium of companies which lead the adoption and evolution of CDMA2000 along with the 3GPP2.

What Are the Air Interface Requirements

The main objectives for 3G & WLL air interface can be summarized as:

- Full coverage and mobility for 144 kb/s, preferable 384 kb/s (3G)
- Limited coverage and mobility for 2 Mb/s (3G & WLL)
- High spectrum efficiency compared to existing systems (3G & WLL)
- High flexibility to introduce new service (3G & WLL)

What is CDMA?

The CDMA is a way to share one transmission frequency among many users. In CDMA each user is assigned a unique code sequence it uses to encode its information-bearing signal. The receiver, knowing the code sequences of the user, decodes a received signal after reception and recovers the original data. This is possible since the cross correlations between the code of the desired user and the codes of the other users are small.

Since the bandwidth of the code signal is chosen to be much larger than the bandwidth of the information-bearing signal, the encoding process enlarges (spreads) the spectrum of the signal and is therefore also known as spread-spectrum modulation.

What are CDMA Benefits?

CDMA has many advantages to ensure an optimized air interface:

- High data rate capability with optimized spectrum efficency
- Multiple Access Capability
- Privacy
- Interference rejection
- Anti-jamming capability
- Low probability of interception

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Different CDMA Techniques

Several attempts have been made to harmonize the different CDMA approaches in search of a unified global air interface. However, due to the evolution of current systems and the strong commercial interests, today the wireless air interface uses two main types of CDMA techniques:

1. **Network asynchronous.** In network asynchronous schemes the base stations are not synchronized. The main implementation of this technique is often called UMTS or WCDMA and emerges as the preferred 3G air interface in European Union. In fact as shown in the Table below, the correct designation should be WCDMA-FDD since other UMTS solutions exist based on TDD modes requiring synchronizing.
2. **Network synchronous.** In network synchronous schemes the base stations are synchronized to each other within a few microseconds. There are three implementations of this technique (see Table below). The most famous one is CDMA2000, which is preferably adopted in countries where 2G is based on CDMA-One/IS-95 standards (mainly North America).

Glossary

BS: Base Station

FDD: Frequency Division Duplexing

IMT-2000: International Mobiel Telecomunication, 3G wireless standard of international Telecommunication Union (ITU-T)

TDD: Time Division Duplexing: well suited to unsymmetrical traffic with higher data rate and reduced mobility (Internet download)

TD-SCDMA: Time Division - Synchronous CDMA

UMTS: Universal Mobile Telecommunication System

UTRA: Universal Terrestrial Radio Access, 3G air interface of UMTS

WLL: Wireless Local Loop

Synchronous	3G usual designation	IMT-2000 designation	Where are the main licenses?	Interoperability with 2G networks	Spectrum mode
No	UMTS/WCDMA FDD (UTRA-FDD)	IMT-DS (Direct Spread)	Europe & Asia Pacific	GSM GPRS - EDGE	FDD
Yes	UMTS/WCDMA TDD (UTRA - TDD high chip rate)	IMT-TC (Time-Code)	Europe	GSM GPRS - EDGE	TDD
	UMTS/TD-SCDMA (UTRA-TDD low chip rate)		China		
	CDMA2000	IMT-MC (Multi - Carrier)	North America & Asia Pacific	CDMA-One/ IS-95	FDD/TDD

TABLE 1 - Main standardized CDMA Air Interfaces

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What are the Synchronization Requirements?

As shown in the above table we can consider the 3 main IMT-2000 designations: IMT-DS (asynchronous) and IMT-TC along with IMT-MC (synchronous)

1. **IMT-DS/UMTS (WCDMA FDD)**

The WCDMA FDD does not required synchronized base stations. This WCDMA FDD is used where symmetrical frequency bands are available for radio downlink (from the base station to mobile) and radio uplink (from mobile to the base station). This is the preferred UMTS standard to provide both wide area speech and data services with symmetrical traffic and high mobility.

2. **IMT-TC/UMTS (WCDMA TDD or TD-SCDMA)**

The WCDMA TDD (IMT-TC) offers an extension to the WCDMA FDD when the available frequency bands are not symmetrical or when higher data rates are required at the cost of a reduced mobility (for instance Internet download, Wireless Local Loop). So WCDMA-TDD systems could typically cover hotspots with high capacity requirements, such as office buildings, airports and hotels.

A system very similar to WCDMA-TDD is TD-SCDMA adopted early 2002 by 3GPP as a 3G mobile technology for the TDD mode. This technology has already been selected by China for its mobile communications.

Within one WCDMA-TDD cell, all users must be synchronized and have the same time division between uplink and downlink in order to avoid interference. In this scheme intercell and inter-operator interference problems are present if the base stations are not synchronized. Synchronization is then strongly desirable. Synchronization accuracy must be at the symbol level (50 μs) but not at the chip level (250 ns).

3- IMT-MC / CDMA2000

The multi-carrier approach is motivated by a spectrum overlay of CDMA2000 with existing CDMA-One/IS-95B carriers. Similar to IS-95B which is a time synchronous system in that all BTS operate from a common time reference, the spreading codes of CDMA2000 are generated using different phase shifts of the same M-sequence. This is possible because of the synchronous network operation. Since UMTS/W-CDMA has an asynchronous network, different long codes rather than different phase shifts of the same code are used for the cell and user separation. The code structure further impacts how code synchronization, cell acquisition, and handover synchronization are performed.

The spread spectrum signal of CDMA2000 requires sophisticated broadcast power management and "soft hand-offs" between base stations. This requires that the base station be precisely timed. The basic synchronization requirement is that each base station must maintain its frequency to within one part in 1010 and the time offset between base stations must be within ±10 μs.

How to Synchronize Base Station?

Previous techniques such as distributing a common clock with extra cabling or installing atomic frequency standards (cesium clocks) are not usually considered for this application due to prohibitive cost.

Presently the most common method of time distribution is to locate a GPS clock - also called GPS timing receiver - at every base station. A GPS clock uses a high stability oscillator (ovenized quartz or rubidium cell) disciplined on GPS signals.

The long term accuracy of GPS compliments the short term stability of the crystal oscillator.

The Global Positioning System (GPS) provides indeed a very accurate time scale which is traceable to the global standard time scale i.e. Universal Time Coordinated (UTC). This GPS time is available worldwide via GPS clocks at no cost for the service. GPS time differs only from UTC time in that leap second adjustments are not used by GPS, which eliminates a-periodic time jumps in the system time reference.

The other purpose of the high stability oscillator is to provide exact time and frequency outputs even when GPS reception is lost. Should anything happen to an antenna or cable the phone companies want every chance for the system to continue working until a service crew can reach it. This requirement, known as "holdover", assures that the time drift is less than 7 μs in a day while operating temperature may vary.

This implies very special know-how to design an optimized algorithm to discipline a properly selected oscillator with low frequency drift ("aging") and low temperature sensitivity. Sometimes it is possible to reduce the requirements of the oscillator and the cost, thanks to the availability of one external accurate frequency coming for instance from the synchronous traffic data network (SDH, SONET).

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Spectracom Systems Solutions

Spectracom proposes the Epsilon® product range which is a full family of GPS clocks to meet the specific CDMA requirements. Among this range two solutions are optimized for CDMA applications.

Epsilon® Board OEM II is a very compact and low cost OEM module synchronized by UTC-GPS reference, broadcast by the GPS satellite constellation all over the world. Time – Receiver Autonomous Integrity Monitoring (T-RAIM) is achieved to discard faulty GPS satellites and then ensures Time integrity.

The Epsiltime® smart predictive slaving algorithm combined with excellent short term stability of the oscillator mitigates the effects of inherent GPS noise and complies to the stringent holdover mode requirements of CDMA when GPS reference is lost.

The **Epsilon® Board OEM II** can be equipped either with an OCXO or with a double oven OCXO. This last solution provides excellent temperature stability and aging (4 µs drift per day in holdover mode).

Furthermore, the 10 MHz frequency reference is cycle locked to the 1 PPS, meaning that there are always exactly 10,000,000 cycles between 1 PPS occurrences. This important feature, not performed in many basic designs, is essential to avoid phase jumps and wander between time and frequency references.

The **Epsilon® Clock 1S** is a compact and low cost stand alone equipment having the same performances than the above OEM solution. This GPS clock is especially well suited for upgrade of existing 2G base stations.

Two optional SMA connectors along with customizable internal module allow a wide range of dedicated versions in terms of performances and functionalities such as 2.048 MHz input for GPS back-up to perform excellent holdover performances with a low cost oscillator.

Application Note TF14

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