Evolution from TD-SCDMA to TD-LTE

Yang Hua
TD-SCDMA Industry Alliance

Abstract: This paper gives the brief introduction to key features of TD-SCDMA and TD-LTE (TDD Long Term Evolution). For the TD-SCDMA system, key technologies such as joint detection, smart antenna and synchronization are described and analyzed. For the TD-LTE system, important technologies such as OFDM, MIMO, uplink timing control, inter-cell interference coordination are applied. It is shown that the TD-SCDMA can be evolved to TD-LTE smoothly.

Key words: TD-SCDMA; TD-LTE; joint detection; smart antenna; synchronization; OFDM; MIMO

1. KEY FEATURES OF TD-SCDMA

TD-SCDMA combines two leading technologies: designed as an advanced TDMA/TDD system with an adaptive CDMA component operating in Synchronous mode. TD-SCDMA is well suited for all 3G applications.

1.1 Frame structure

A 10 ms radio frame is divided into 2 frames of 5ms each, and each frame is comprised of 7 normal time slots (TS) and 3 special time slots: DwPTS (Downlink Pilot time slot), UpPTS (Uplink Pilot Time Slot) and GP (guard period). Guard period is used to avoid the interference between uplink and downlink and forms the DL/UL switching point.

The switching point (at TS3 in above figure), can be placed flexibly after TS1 to TS5 so that the asymmetric service can be supported.

Within each time slot a number of up to 16 CDMA codes may be transmitted. Each radio resource unit is thus identified by a particular time slot and a particular code on a particular carrier frequency.

1.2 3G Service and Functionality

Real-time applications like voice, video conferencing or other multimedia applications require minimum delay during the transmission and generate symmetric traffic. Based on the TDD principle with adaptive switching point between up- and downlink TD-SCDMA can perfectly handle symmetric as well as asymmetric traffic perfectly.

With its inherent flexibility in traffic asymmetry and data rate TD-SCDMA based systems offer 3G services in a very efficient way. TD-SCDMA is optimum suited for mobile Internet and Multi Media applications.

With introduction of HS-DPA, HSUPA and HSPA+ features, the peak data rate and overall throughput is significantly increased. These features are supported with
AMC, HARQ and MIMO technologies.

1.3 Joint Detection

Each particular CDMA code channel must be extracted by correlation. This results in a low signal (low signal to noise ratio) emerging from the MAI (see middle figure below). Since the propagation conditions of the uplink and the downlink are identical, very accurate measurements can be performed. Joint detection efficiently cancels the interference and thus the MAI is removed as shown in the right figure below. The efficiency of Joint detection is supported by the low number of users per time slot (maximum 16) as caused by the user distribution to time slots of the basic TDMA frame scheme.

1.4 Smart Antennas

TD-SCDMA base stations are equipped with smart antenna for beam forming. This directs transmission and reception of signals to and from the specific terminals reducing intercell and intracell interference. The base station tracks the mobiles throughout the cell, so that the signal-to-interference ratio at the mobile is improved.

The TDD component of TD-SCDMA supports the implementation of smart antenna technology optimally due to the radio path reciprocity by downlink and uplink operating on the same carrier. Smart antenna in TDD operation increase the capacity of a TD-SCDMA radio interface.

1.5 Terminal Synchronization

The uplink signals of users distributed within each cell leads to different mutual signal delays at the input of the base station receiver. Those mutual time delays are eliminated by a very precise timing advance in the handset during transmitting.

The spreading sequences of multiple UE CDMA signals are synchronized at the base station. This feature is important in a CDMA system to guarantee the orthogonality of the spreading codes and to virtually remove the co-channel interference from other code channels.

II. KEY FEATURES OF TD-LTE

Important parts long-term evolution (LTE) includes reduced latency, higher user data rates, improved system capacity and coverage, and reduced cost for the operator. Some of the main requirements are listed below:

- Significantly increased peak data rate e.g. 100 Mbps (downlink) and 50 Mbps (uplink)
- Significantly reduced latency
- Scalable bandwidth: 1.4, 5, 10, 20 and possibly 15 MHz
- Efficient support of the various types of services, especially from the PS domain (e.g. Voice over IP, Presence)

2.1 Frame structure

The type 2 frame structure is for TDD mode in LTE as
A 10ms frame is divided into 2 half-frames of 5ms each, which is further divided into 4 normal sub-frames and 1 special sub-frame. A normal sub-frame contains 2 time slots and the first sub-frame is always downlink, which carries the primary synchronization channel (P-SCH) and the broadcast channel similar to TD-SCDMA. The second sub-frame is special sub-frame containing DwPTS, GP and UpPTS. DwPTS carries secondary synchronization channel (S-SCH), GP is a guard period designated for downlink to uplink switching and UpPTS carries the short physical random access channel (PRACH) and/or sounding reference symbols (SRS).

2.2 OFDM

Because of its high-speed data transmission and effectiveness in combating the frequency selective fading channel, OFDM technique is widely used in wireless communication nowadays. The transmission bandwidth is divided into many narrow sub-channels which are transmitted in parallel. Each sub-channel transmits at low data rate, each sub-channel is narrow enough so that the fading it experiences is flat i.e. no ISI. OFDM increases the spectral efficiently by allowing sub-channels to overlap.

2.3 SC-FDMA in uplink

The basic uplink transmission scheme is single-carrier transmission (SC-FDMA) with cyclic prefix to achieve uplink inter-user orthogonality and to enable efficient frequency-domain equalization at the receiver side. Frequency-domain generation of the signal, sometimes known as DFT-spread OFDM, the DFT outputs are mapped to consecutive sub-carriers as shown in the figure below.

2.4 OFDMA in downlink

The user data stream after channel coding and modulation is converted into multiple parallel streams, are mapped to a block of sub-carriers. After IFFT conversion an OFDM symbol is inserted with CP. Different users are allocated in different resource blocks at the same time. The number of size of the resource blocks a user occupies varies according to the transmission data rate.

2.5 MIMO (Multiple Input and Multiple Output) and Beam-forming

MIMO is the technique where there are multiple antennas at transmitting side and receiving side. Multiple data streams are transmitted in parallel simultaneously to significantly increase the system capacity. The MIMO technique is best integrated with OFDM technology since the sub-carriers are narrow and thus the radio channel is flat. LTE also supports beam-forming with UE specific reference symbol. In beam-forming, the same data stream is transmitted from multiple antennae, the transmitted data are weighted according to the channel state information. Beam-forming usually is based on the small-spaced (e.g. 0.5 Lambda) antenna array where as MIMO is based on large-spaced (e.g. 10 Lambda) antenna array.
2.6 Uplink timing control

Upon reception of a timing advance command, the UE shall adjust its uplink transmission timing. The timing advance command is expressed in multiples of 0.52us and is relative to the current uplink timing. For a timing advance command received on sub-frame n, the corresponding adjustment of the timing shall apply from the beginning of sub-frame n+6. Timing Advance (TA) update rate is on a per-need basis, at most 2 Hz. The concept is similar to the concept of terminal synchronization in TD-SCDMA.

2.7 Inter-cell interference coordination (ICIC)

To increase the system efficiency it is generally envisioned that the frequency reuse factor of 1. But the inter-cell interference could be very high especially at cell edge. The interference coordination among the adjacent cells is an effective measure to increase the cell edge performance. The interference avoidance or mitigation can be achieved with frequency hopping (scheduling) or Soft frequency reuse (Fractional Frequency Reuse, FFR). The FFR is realized using the same frequency band at cell center, blue region in figure below, and different frequency band at cell edge, illustrated in different colors.

Ⅲ. CONCLUSION

From above introduction we can see how the TD-SCDMA technology has evolved to TD-LTE. In TD-LTE, OFDM is chosen as basic technology over CDMA which is very obvious. The frame structure is kept similar so that the deployment of both systems in the same geographical region and in the same frequency band is made possible without difficulty. The beam-forming technology is also supported in TD-LTE to exploit the advantage of the TDD system.