Evolution Map from TD-SCDMA to FuTURE B3G TDD

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ABSTRACT

The rapid growth of mobile applications in recent years has created a need for wideband wireless communication. The only predictable trend is that data-rate and QoS requirements will increase rapidly. This demand is pushing Time-division–synchronous code-division multiple access (TD-SCDMA) to evolve in order to provide higher and higher data rates. This article presents the evolution map from TD-SCDMA to Future Terrestrial Universal Radio Environment (FuTURE) TDD in China. The evolution includes four phases: low chip rate (LCR), high-speed downlink/uplink packet access (HSxPA)/TD-SCDMA EV 1x, long-term evolution (LTE) TDD, and FuTURE Beyond 3G TDD. The main features of each phase are described in detail. By introducing the new technologies into the system step by step, for example, multiple input and multiple output (MIMO), orthogonal frequency-division multiplexing (OFDM), TD-SCDMA system can evolve to FuTURE B3G TDD smoothly, and provide high-data-rate services with low cost, low latency, and improved coverage and capacity.

INTRODUCTION

Time-division duplex (TDD) is a very promising duplex mode for cellular communication systems. The reasons for this are: channel reciprocity can be exploited to improve transmission efficiency, no frequency duplexer is needed, the radio resource can be allocated flexibly between downlink and uplink in order to support asymmetrical service efficiently, and the unpaired frequency band can be exploited. As the radio frequency band for cellular communication is becoming rare and the paired frequency band is difficult to find, TDD has become more and more attractive for Beyond 3G (B3G) system.

Time-division–synchronous code-division multiple access (TD-SCDMA) [1] was proposed by the Chinese Academy of Telecommunication Technology (CATT) in 1998, accepted by the International Telecommunication Union (ITU) as a 3G standard in November of 1999, and accepted by the 3G Partner Project (3GPP) as low chip rate (LCR) TDD mode of Universal Terrestrial Radio Access (UTRA) in March 2001. TD-SCDMA is an advanced system, which has adopted many advanced technologies [2] such as synchronous CDMA, smart antenna, joint detection, software-defined radio (SDR), baton handover, dynamic channel allocation (DCA), and so forth.

TD-SCDMA originated in China and is strongly supported by the Chinese government. Compared to the 90 MHz frequency band for FDD (including WCDMA and CDMA2000), the 155 MHz frequency band has been allocated for TD-SCDMA in China (able 1), and its commercial application is very promising.

However, given the rapid growth of mobile applications in recent years, the 2 Mb/s peak data rate of TD-SCDMA will no longer be enough in the coming years. However, the new B3G cellular system for providing 100 Mb/s to 1 Gb/s peak data rate will not be available until 2010 according to the ITU schedule. Although interworking between TD-SCDMA and wireless local access network (WLAN) systems can provide a 54 Mb/s peak data rate for indoor scenarios or hotspots, it cannot support high mobility.

The emerging of WiMax [3], which can provide a 75 Mb/s peak data rate within a 20 MHz bandwidth, has been pushing 3GPP to start its work on long-term evolution (LTE) since November 2004. The target of LTE [4] is to enhance the coverage, capacity, and data rate of the 3GPP cellular system, reduce the cost and latency of services, and improve the user experience. The motivation of LTE is to adopt the matured B3G technologies (e.g., MIMO and OFDM) in current 3G spectrum, partially implement the B3G/4G functionality, evolve to B3G/4G smoothly, and make 3GPP systems sufficiently competitive in the coming years.

Future Terrestrial Universal Radio Environment (FuTURE) B3G TDD [5] is funded by Chinese government to investigate and demonstrate key technologies for air-interface and novel network architectures beyond the 3G/4G TDD system. Its aim is to cover the entire 3G environment and provide 100 Mb/s to 1 Gb/s peak data rates. By adopting multiple input and multiple output (MIMO) and orthogonal frequency division mul-

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	(MHz)	**UL/DL**		**UL/DL**	**Total**
FDD	ITU	1920~2010/2110~2200			90
	China	1920~1980/2110~2170		1755~1785/1850~1880	90
	(MHz)	**UL/DL**	**UL/DL**	**UL/DL**	**Total**
TDD	ITU	1885~1920	2010~2025		50
	China	1880-1920	2010~2025	2300~2400	155

Table 1. *3G spectrum allocation of ITU and China.*

tiplexing (OFDM), the peak data rate of the first release has achieved 100 Mb/s in downlink and 50 Mb/s in uplink within the 20 MHz frequency band, and the spectrum efficiency is 2 to 5 bits/Hz. Taking into account the special features of the abovementioned TDD system, this is a wise choice for TD-SCDMA to evolve towards a LTE/B3G system based on TDD.

This article presents the TDD evolution map from TD-SCDMA to FuTURE B3G TDD. Since the commercial FuTURE B3G TDD system will not be available until 2010 and the data-rate margin between LCR and LTE TDD is so large, a further evolution phase between TD-SCDMA and LTE TDD is necessary. Compared to the evolution of wideband code division multiple access (WCDMA) (release 99, release 4, release 5, release 6, release 7, LTE, and B3G), the evolution of TD-SCDMA involves four phases, LCR [1], high-speed downlink/uplink packet access (HsxPA) [6, 7]/TD-SCDMA Evolution (EV) 1x, LTE TDD, and FuTURE B3G TDD. By introducing advanced technologies into the system step by step, TD-SCDMA can enhance its capacity, coverage, and peak data rate, reduce the latency and cost of the service, and evolve to the FuTURE B3G TDD system smoothly.

REQUIREMENTS FOR THE EVOLUTION OF TD-SCDMA

From the operator's point of view, building a new mobile cellular system requires billions of dollars, so the evolution of the mobile cellular system should proceed smoothly. New features and technologies should be introduced into the system gradually in order to enhance the system performance. Meanwhile, the evolved system should remain compatible with the previous systems.

As a member of 3GPP standards, the evolution target of TD-SCDMA is the same as that of WCDMA [4], which is to provide much higher-data-rate services with low latency, low cost, improved coverage, and capacity. However the evolution of TD-SCDMA does not necessary have to completely follow that of WCDMA for its unique features.

Since the performance margin between TD-SCDMA and LTE TDD is so large, a middle phase is necessary to make the evolution proceed smoothly. Meanwhile, new multiple-access schemes can be adopted to improve system performance (e.g., OFDM) so that the evolution of

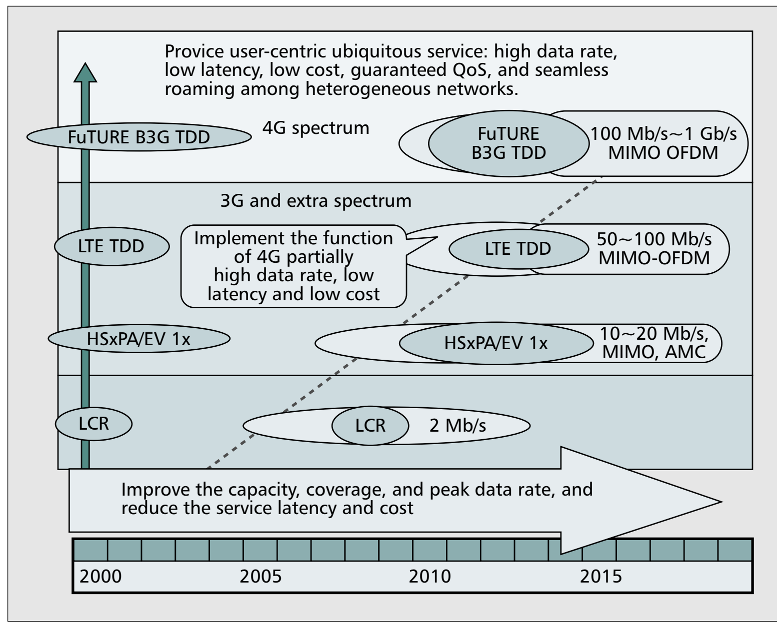

Figure 1. *Evolution map for TD-SCDMA.*

TD-SCDMA will be divided into short-term evolution and LTE.

Short-term evolution is still based on CDMA, and the basic features of the original system are reserved. The coverage and capacity of the deployed system is optimized and modification or enhancement technology is introduced to enhance the system performance, for instance, MIMO, adaptive modulation and coding (AMC), and hybrid-automatic repeat request (H-ARQ). By combining three carriers together, the TD-SCDMA system can provide a 10 to 20 Mb/s peak data rate with either shared or dedicated channel.

For LTE system, new multiple access schemes (e.g., OFDM), wide bandwidth (e.g., 20 MHz), and a modified system architecture will be adopted to greatly improve the system performance and ensure its competitiveness in the coming years.

EVOLUTION MAP FROM TD-SCDMA TO FUTURE B3G TDD

Based on the above considerations, the possible and practical evolution map from TD-SCDMA to FuTURE B3G TDD is shown as Fig. 1. The evolution map includes four phases: LCR, HSxPA/TD-SCDMA EV 1x, LTE TDD, and

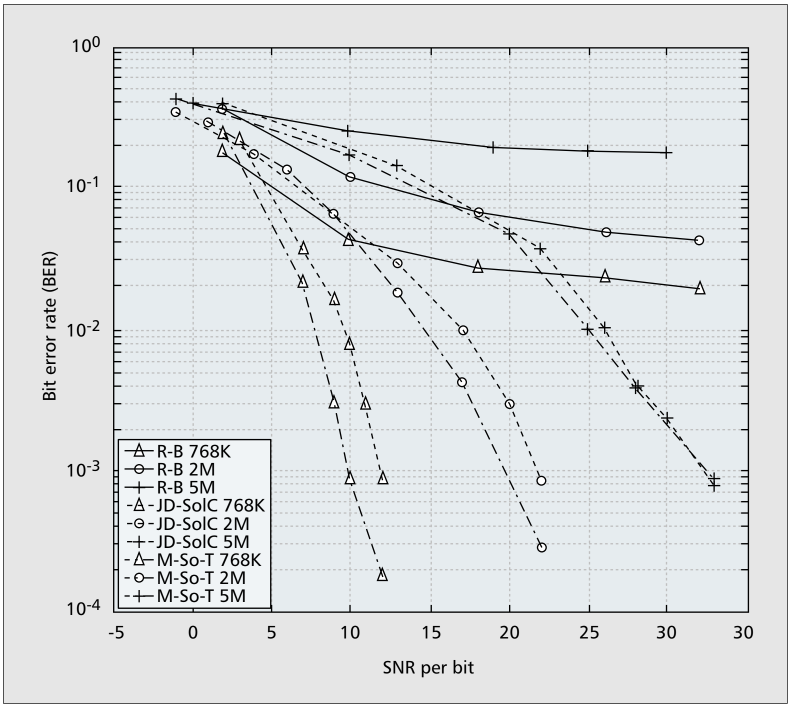

Figure 2. *Performance of RAKE-BLAST, JD-SoIC, and M-So-T.*

FuTURE B3G TDD. The features of each phase will be described in detail as follows.

LCR

LCR [1] is the first phase of the TD-SCDMA, which adopts smart antenna [2], joint detection, SDR, DCA, and the high-layer protocols and core networks of 3GPP; it can interoperate with WCDMA very conveniently. Furthermore, it meets all the requirements for the 3G systems of ITU and 3GPP and targets all 3G environments. The speech-service data rate is 12.2 kb/s, while the peak data rate is 2 Mb/s in hotspots, 384 kb/s with middle vehicular speed, and 144 kb/s with high vehicular speed.

HSxPA/TD-SCDMA EV 1x

The second phase of TD-SCDMA is HSxPA/TD-SCDMA EV 1x. In this phase, an IP-based core network will be built and an IP multimedia subsystem (IMS) will be introduced for providing IP-based QoS; multimedia broadcast and multicast service (MBMS) will be introduced to provide plentiful 3G application. In addition, HSDPA/HSUPA [6, 7] will be deployed to provide a 10 to 20 Mb/s peak data rate in a shared channel with three carriers combined together. Meanwhile, the dedicated channel will also be enhanced so as to provide the same peak data rate as that of shared channel in the 5 MHz bandwidth.

HSxPA — HSDPA and HSUPA are defined in 3GPP to provide packet-based data service in shared channels with best effort. Through AMC, multiuser diversity (or channel-dependant scheduling), H-ARQ, and MIMO [6], the cell throughput of TD-SCDMA will be improved greatly.

In the current release 5, the HSDPA of TDD has been basically finished, and HSUPA is being standardized. Configured with a single antenna at both node B and UE, a 950 kb/s data rate can be offered using 16-QAM modulation and a 3/4 coding ratio on 36 radio resource units (nine codes of four time slots). Currently, voice over HSDPA/HSUPA is also being studied in 3GPP.

In [8], the authors showed that MIMO has great potential for improving the system performance and the transmission capability of wireless communication system through spatial multiplexing, spatial diversity, and beamforming. In particular, when the fading of the different antennas at the transmitter and the receiver are independent, the channel capacity is proportional to the minimum antenna number of the transmitter and receiver. In 3GPP, many MIMO schemes [9], for example, per antenna rate control (PARC), have been proposed to enhance the performance of WCDMA. So far, no MIMO technology has been adopted for TD-SCDMA in 3GPP.

In this article, 2×2 MIMO is adopted to enhance the performance of HSDPA, and the bit error rate (BER) performances of 768 kb/s, 2 Mb/s, and 5 Mb/s service in a 1.6MHz carrier are compared with different detection algorithms [10]. Table 2 gives the simulation parameters.

Figure 2 presents the performance of RAKE-VBLAST, ZF-BLE joint detection with soft interference cancellation (JD-SoIC), and MMSE turbo receiver with soft interference cancellation (M-So-T). From Fig. 2, M-So-T has the best performance, and RAKE-VBLAST is the worst case. The 5 Mb/s data rate can be provided with 16 codes of six timeslots on a 1.6 MHz carrier. The same performance can be achieved in HSUPA. So combined three carriers in a 5 MHz bandwidth, 15 Mb/s peak data rate of HSxPA can be achieved based on the above simulation. If 64-QAM is possible, a higher peak data rate will be achieved.

TD-SCDMA EV 1x — As HSDPA and HSUPA are designed to provide best-effort service in a shared channel, and the capability of the dedicated channel of TD-SCDMA should also be enhanced in order to provide higher-data-rate-services with guaranteed QoS. TD-SCDMA EV 1x aims to enhance the dedicated channel performance and improve the coverage, peak data rate, and support for higher mobility.

As presented in Fig. 2, VBLAST combined with joint detection can also achieve a 15 Mb/s peak data rate on a dedicated channel within the 5 MHz band. The other features of this phase are summarized as follows.

Generalized Distributed Antenna Arrays Combined with Dynamical Channel Allocation — Compared to WCDMA and CDMA2000, the capacity of TD-SCDMA is mainly limited by intercell interference, but not by the intracell interference for the smart antenna with joint detection adopted; thus, the effect of cell breath is not serious. If the intercell interference can be decreased, then the system capacity will be further improved. In [11], a distributed antenna is used to improve the coverage in indoor scenarios and mitigate fast fading. Figure 3 shows the difference between the conventional cell and the generalized distributed antenna arrays (GDAA). Figure 3a shows the conventional cell, where the antenna array is mounted on the central tower. For the GDAA shown in Fig. 3b, the whole cell is divided into several subcells (e.g., three) and every subcell is covered by an independent antenna array centrally. The radio resource of one cell is shared by three of its subcells. Then the transmit power of every subcell is reduced for a small coverage radius and the intercell interference is reduced as well; thus, the capacity can be improved. Furthermore, DCA can be combined with a smart antenna and GDAA so as to improve the system performance using space division multiple access (SDMA).

Improved Joint Detection — Joint detection [12] is one of the key techniques of TD-SCDMA; it can eliminate multiple access interference (MAI) and intersymbol interference (ISI). The enhancement and improvement of joint detection can provide the potential for further performance improvement. When SDMA is implemented with a smart antenna, the same codes can be reused in the same cell and interference may exist between different users who use the same codes, because the smart antenna cannot eliminate the side lobe perfectly. If joint detection can take into account this kind of interference and eliminate it, then SDMA can obtain higher efficiency. Furthermore, if joint detection can eliminate the intercell interference from the neighboring cells, then the system capacity and spectrum efficiency will be improved greatly. So the enhancement of joint detection has potential for improving the system performance.

Higher Spreading Factor and Chip Rate — The potential benefits of higher chip rate include system-level gains from trunking efficiency, link-level gains from the ability to better resolve channel paths, the ability to support more accurate location services, higher peak bit rate and cell throughput, and an improved ability to reject narrowband interferers [13]. Thus with a higher spreading factor and chip rate, for example, SF = 32 and 2.56 Mc/s, more gain from spreading processing, multipath resolution, and interference elimination can be obtained for TD-SCDMA, and better system performance can be expected. In [13], the benefit of 7.68 Mc/s for UTRA TDD was investigated in detail. So a higher spreading factor and higher-chip-rate TD-SCDMA can provide a possible solution for further improving the system performance.

Interworking Between TD-SCDMA EV 1x and a WLAN — In the phase of TD-SCDMA EV 1x, the peak data rate is not high enough, while a WLAN can provide high-data-rate service in low-mobility environments (e.g., IEEE 802.11a can provide up to 54 Mb/s peak data rate). Thus, based on interworking between TD-SCDMA EV 1x and WLAN, high-data-rate service can be provided on the basis of best effort from WLANs to enhance the service-providing capability of TD-SCDMA cellular systems in hotspots.

The basic requirement for interworking between TD-SCDMA and WLAN is that the TD-SCDMA terminal should support both TD-SCDMA and WLAN systems, and some special functionality units should be added to the TD-SCDMA and WLAN systems in order to support the interworking protocols [14]. Since the WLAN chips and the TD-SCDMA chips are all currently available, it is possible to integrate them together in the same terminal. With the configuration of the proper protocol and functionality, interworking between TD-SCDMA and WLAN can be implemented.

In 3GPP, there is a study item on the interworking between 3GPP and WLAN systems [14]. According to the 3GPP specification, the harmonization of TD-SCDMA and a WLAN includes six scenarios step by step. In scenario 1,

Parameters	Value and comments
Carrier hrequency	2 GHz
Chip yate	1.28 Mchips/s
Spreading factor	16
Oversampling	1
Information bit rates	768 kb/s, 2 Mb/s, 5 Mb/s
Antenna number	2 × 2
Interleaving	5 ms
Channel coding	Turbo max-Log-MAP
Modulation	QPSK/16-QAM
Total code ratio	3/4
Codes per TS	16 codes/time slot occupied
Time slot number	6 time slots are occupied
MIMO channel model	3GPP pedestrian A channel, 3 km/h, uncorrelated MIMO
Channel estimation	FFT-based
Detection	RAKE VBLAST(Soft IC) JD ZF (Zero Force) VBLAST JD (MMSE) Turbo VBLAST

Table 2. *System specifications for 5 Mb/s.*

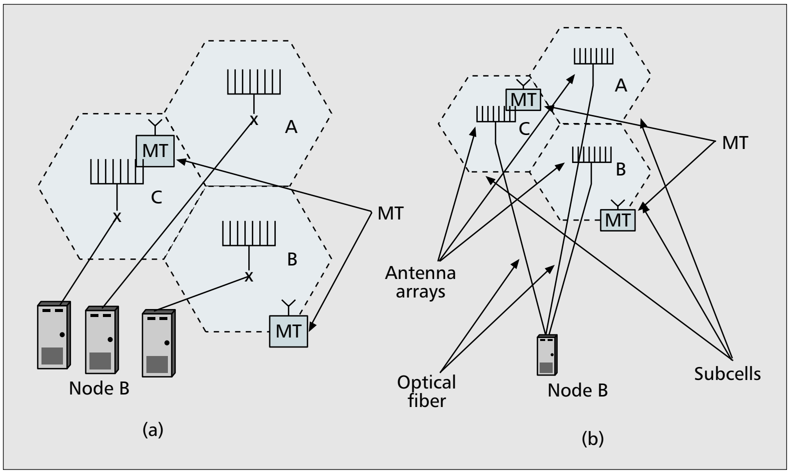

Figure 3. *Comparison of a conventional cell and GDAA.*

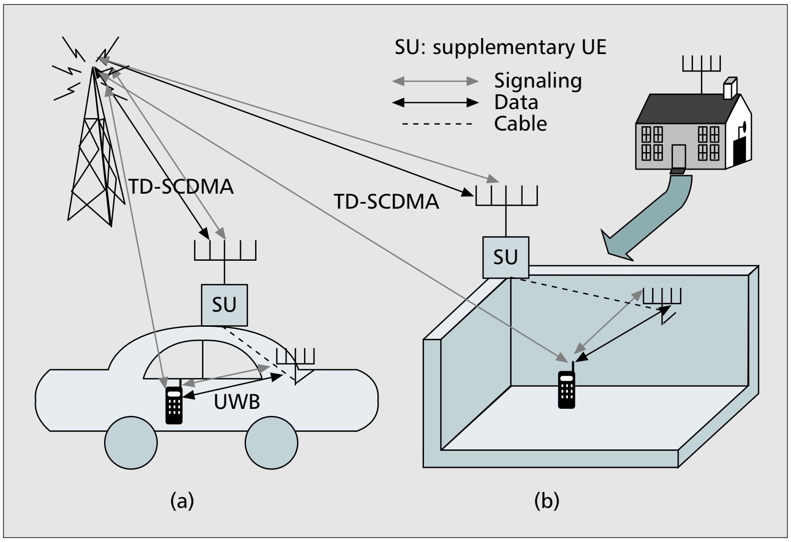

Figure 4. *Fixed supplementary UE.*

the networks are built individually, and only the accounting is unified. In scenario 2, authentication and accounting are unified, and the WLAN only provides IP service. In scenario 3, the WLAN can provide packet service from TD-SCDMA. In scenario 4, the handover and unified service are provided between the WLAN and TD-SCDMA, and certain break and packet losses are permitted, but service resetup is unnecessary. In scenario 5, seamless handover between the WLAN and TD-SCDMA is provided, with QoS as good as that of intrahandover of TD-SCDMA. In scenario 6, the seamless handover of the circuit-switch domain between the WLAN and TD-SCDMA is provided.

Virtual Antenna Array — Usually, due to limited size and cost, it is difficult to mount multiple antennas at the UE. By using a virtual antenna array (VAA) [15], several idle UEs near the master UE can cooperate to work for the master UE, and construct a VAA to improve the system coverage and data-transmission capability. When the distance among UEs is quite large compared to the wavelength, fading on the antennas of VAA is independent and thus the spatial multiplexing and diversity gain can be exploited to improve the system performance. The connection among UEs can be built through Bluetooth or ultra-wideband (UWB) [16] technology in a free-frequency band.

To obtain the gain of the VAA, the received baseband signal of the VAA must be forwarded to the master UE, and processed centrally there.

However, the transmission of the baseband signals from VAA to the master UE requires quite a powerful UWB air interface. Here, two examples of two supplementary UEs with two antennas each are presented. It is assumed the quantification of the base band signal needs 12 bits for one floating number of the I or Q signal. The sampling rate of the baseband signal is 1.28 or 5 MHz, respectively, for these two examples. To forward the baseband signals from the VAAs to the master UE, the data rate needed is calculated as follows.

Example 1:

$$(12 \times 2 \times 1.28M) \times 2(UEs) \times 2(Antenna) = 122.88 \text{ Mb/s} \quad (1)$$

Example 2:

$$(12 \times 2 \times 5M) \times 2 \times 2) = 480 \text{ Mb/s} (2)$$

Taking into account the effect of distance on the performance of the UWB air interface, channel coding should be adopted to guarantee the reliability of the baseband signal. In this way, the information data rate supported by UWB will be less. Thus, example 1 is quite practical, but example 2 requires a much more powerful UWB air interface. VAAs are only applicable for narrow-bandwidth systems with few antennas and few supplementary UEs (SUs).

Cooperative Relaying — The simplest scenario of cooperative relaying is fixed relaying, as shown in Fig. 4, where a supplementary UE (SU) is used as the fixed relaying station. First, the data is transmitted to the SU from node B through a TD-SCDMA EV 1x air interface, or from the UE through the UWB air interface, and then the received data is forwarded to the target UE through Bluetooth or UWB, or to node B through the TD-SCDMA EV 1x air interface of the SU.

This application is very practical in indoor scenarios or in a vehicle, where the power and size of the SU is not a problem, and slightly higher cost is also acceptable. The SU can be configured on the roof of a building or a car with multiple antennas and quite a large antenna distance. Because the fading of each antenna is independent of that of the others, higher capacity can be achieved through MIMO. Hence the transmission capability of the SU of TD-SCDMA EV 1x can be enhanced in this scenario, and thus the peak data rate of the UE can be improved.

A more complicated case is mobile relaying, where a mobile UE works as a relaying station. In this case, the relaying uses two modes to forward the signal. One is regenerative relaying, where the signal is decoded and coded again, and then forwarded to the destination. The other is nonregenerative relaying [17], where the signal is just amplified and forwarded to the destination. The capability of the destination UE is determined by the relaying UE. Usually, the capabilities of the master UE and the relaying UE are quite similar, so the transmission capability of the master UE cannot be improved. But the coverage may be enhanced.

LTE TDD

LTE TDD is the last phase before FuTURE B3G TDD. Its performance and the parameters are quite close to that of FuTURE B3G TDD. More features are introduced to enhance the system further, such as MIMO, OFDM, virtual MIMO (VMIMO) [18], scalable bandwidth (1.25, 1.6, 5, 10, 15, and 20 MHz) [3], and distributed Radio Access Network (RAN) [4]. With MIMO and OFDM, the peak data rate is expected to be 100 Mb/s in downlink and 50 Mb/s in uplink within the 20 MHz band. All the services are transmitted over shared and common channels, and the core network is based on IP. The main features of this phase are summarized as follows.

MIMO-OFDMA — MIMO is a very promising technology to improve the spectrum efficiency. However, as the much broader frequency band will be used, more multipaths will be separated, and thus the conventional single-carrier system will have much higher complexity in MIMO detection. OFDM is a good candidate to solve such problems. Due to the excellent capability of mitigating frequency-selective fading and ISI, OFDM is very suitable for high-data-rate transmission in wideband wireless channels. Meanwhile, the implementation of OFDM is very simple using IFFT/FFT, and AMC on every subcarrier can theoretically make full use of the spectrum. (Factually, AMC on every subcarrier will consume too much signaling; AMC usually is based on a group of subcarriers, called a chunk in 3GPP, in order to reduce the signaling consumption. The optimal size of a chunk is a tradeoff between the AMC efficiency and the signaling consumption.) All these features make OFDM very competitive for LTE and B3G systems. Combining OFDM with MIMO, the frequency-selective fading MIMO channel can be separated into many flat fading MIMO subchannels, and thus MIMO detection can be simplified.

On the other hand, the dynamic range of the service data rate is quite large (e.g., from several kb/s to 100 Mb/s) and flexible multiple access (MA) methods are necessary to provide a flexible data rate (e.g., OFDMA/TDMA).

Currently, the MA schemes for LTE are being discussed in 3GPP [18]. The basic new MA schemes for LTE TDD are OFDMA and single-carrier frequency division multiple access (SC-FDMA). SC-FDMA includes interleaved frequency division multiple access (IFDMA) and DFT-Spread OFDM (DFT-S OFDM). From the current status, DFT-S OFDM is the dominant SC-FDMA scheme, so it is regarded as SC-FDMA instead. In downlink, OFDM is the dominant MA scheme.

When MIMO and channel coding are adopted, OFDMA has a better performance than SC-FDMA [19, 20] but a higher peak-to-average power ratio (PAPR) than the latter. In Fig. 5, the performances of OFDMA and SC-FDMA with 2 × 2 uncorrelated MIMO is compared. VBLAST is used to transmit two independent data streams. The bandwidth is 5 MHz, the FFT size is 512, and the subcarriers used are 300. Turbo code is used and the code ratio is 1/2. The ideal channel estimation is assumed. Zero forcing (ZF) and minimal mean square error (MMSE) equalization are assumed for OFDMA and SC-FDMA, respectively. From Fig. 5, the performance of OFDMA is better than DFT-S OFDM at least 2 dB for QPSK and 6 dB for 16 QAM when the block error rate (BLER) is required to be less than 10^{-2}. The performance difference observed here between OFDMA and DFT-S OFDM is very close to that given in [18] by Nortel.

Since high PAPR will decrease the power efficiency and lead to less coverage for uplink, the PAPR reduction is necessary for OFDMA or even DFT-S OFDM, which will lead to extra complexity for the terminal. So the final determination of the MA schemes for uplink should take into account the trade-off between the link performance and the extra complexity for the PAPR reduction.

VMIMO — As in LTE, at least two antennas will be configured at node B, VMIMO [18] can be built between the node B antennas and several users' antennas, although one antenna is configured at the UE. Through VMIMO, two or more UEs can be served simultaneously on the same radio-resource unit (or a chunk defined in 3GPP) with independent data streams. In downlink, the dirty paper coding (DPC) [21] or zero force beamforming (ZFBF) [22] based on the interference presubtraction can be used to transmit an independent data stream to different users. In uplink, the signals from different users can be separated from each other and their interference can be subtracted via interference cancellation (IC). So the cell throughput can be improved by such SDMA and multiuser diversity. More antennas at node B and more available UEs will lead to better cell throughput.

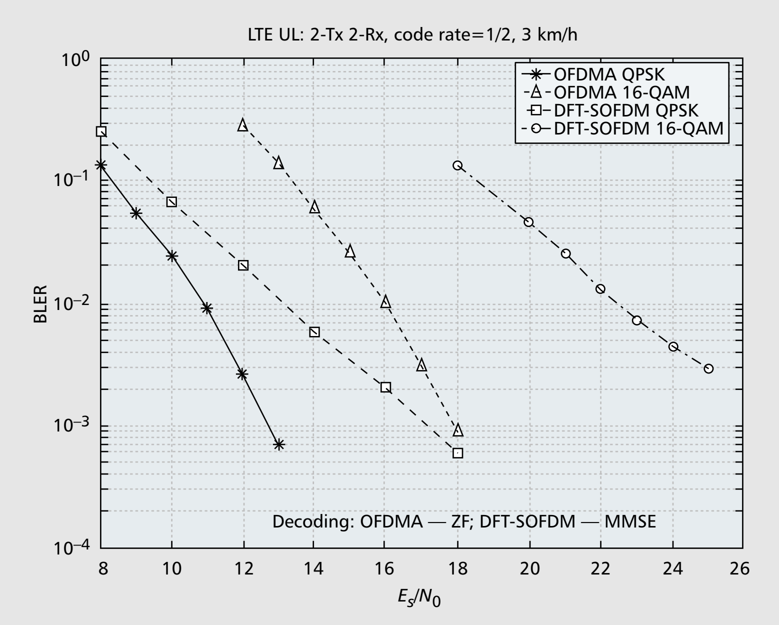

Figure 5. *Performance of OFDMA and SC-FDMA in MIMO.*

Scalable Bandwidth — Scalable bandwidth [4] is necessary for LTE TDD, because an LTE system is required to be able to exploit any available cellular spectrum efficiently, such as current 3G spectrum, extension bands, and migration of the 2G spectrum. Since TD-SCDMA will be deployed in China before the LTE TDD system, 1.6 MHz bandwidth is possible for future frequency migration. In addition to 1.25, 5, 10, 15, and 20 MHz, 1.6 MHz bandwidth should also be taken into account for LTE TDD in China. Thus flexible frequency migration can be adopted to meet the requirement of traffic distribution varying with time and location, and make full use of the available frequency band.

Distributed Network Architecture — Besides the features described above, a distributed and scalable network architecture [4] is required to reduce service latency, avoid the network bottleneck and single point failure, and improve the user experience. The evolution target of the system architecture is the flexible distributed network, where the user plane and control plane are separated in order to decrease service laten-

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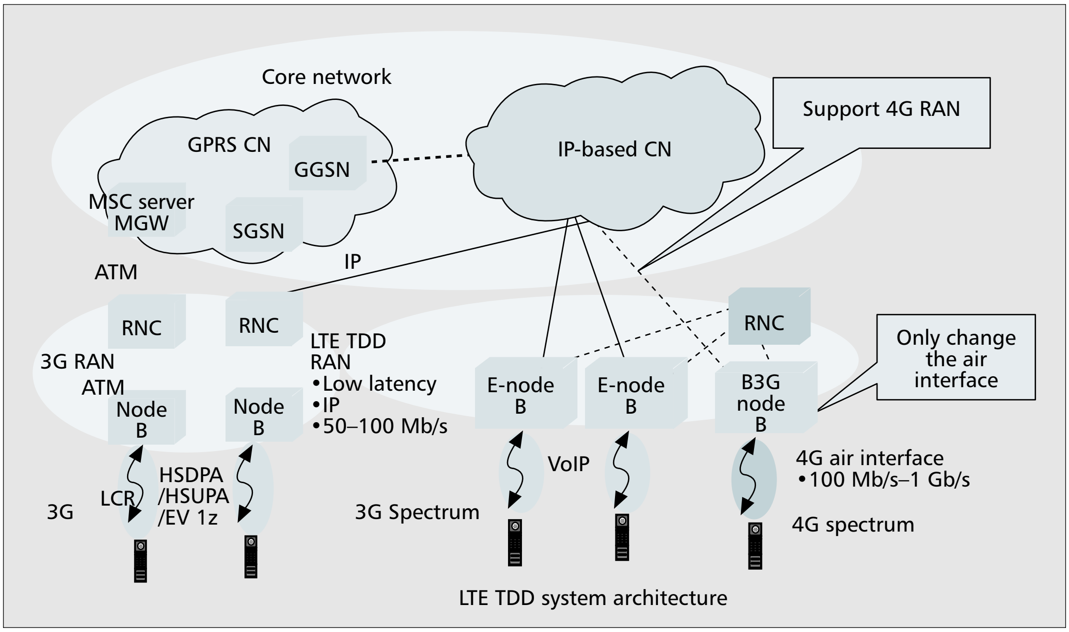

Figure 6. *Distributed RAN architecture of LTE TDD.*

cy and the cost of the system integration and deployment, and make the investment able to be appended as the scale of the network grows, so that investment in the whole network at the beginning of the network deployment can be avoided. The network function is optimized, with the scalable functionality providing flexible and efficient transmission infrastructure. Thus the RAN of B3G or 4G can be introduced into the system easily by changing the air interface at node B and the terminal only [23]. The previous node Bs of LCR, HSxPA/TD-SCDMA EV 1x, can be connected to the IP core network through their RNC or their own gateway of the GPRS serving node (GGSN), and so forth, and thus seamless roaming among heterogeneous networks can be provided by interworking with the previous TD-SCDMA networks, and the total traffic load of the operator can be shared and balanced among different networks.

An example of such an architecture modified from [23] is shown in Fig 6. All E-node Bs are connected to the RNC, where the radio resource allocation information of the node Bs is maintained, and thus the interference coordination among different E-node Bs is possible. The RNC is not connected to the CN directly, and the RRC function is implemented at the E-node B.

FuTURE B3G TDD

By adopting MIMO and OFDM, the FuTURE B3G TDD system targets the 100 Mb/s to 1 Gb/s peak data rate. Currently, 100 Mb/s in the downlink or 50 Mb/s in the uplink within 20 MHz bandwidth has been achieved in the first release [5]. It can be introduced into the LTE TDD system smoothly by only changing the air interface of the node B, since the distributed network architecture based on IP (shown in Fig. 6) has been adopted.

To illustrate the capability of the FuTURE B3G TDD system, the throughputs of a VBLAST-OFDM system with two antennas at the transmitter and four antennas at the receiver are shown in Fig. 7. The bandwidth is 20 MHz, and the data subcarriers are 832 of 1024. The root mean square (RMS) of the channel time-delay spread is 50 ns. Since the CP of every OFDM symbol is 216 samples (10.8 μs) [5], a maximum multipath delay of less than 10.8 μs will not degrade the performance. Based on the frame structure in (c) of [5], the peak data rate of 16-QAM modulation without channel coding is more than 70 Mb/s. With a higher modulation order or more antennas at the transmitter and receiver, a higher data rate of more than 100 Mb/s can be achieved in 20 MHz bandwidth. Although the channel coding may decrease the peak data rate, it can guarantee the reliability of the transmission and decrease the SNR required. So it will be very practical for the FuTURE B3G TDD system to provide more than 100 Mb/s data rate in both uplink and downlink within the 20 MHz bandwidth.

In this phase, user-centric ubiquitous service is provided with guaranteed QoS among the heterogeneous networks (WLAN, 3G, LTE, B3G, and even WiMax). Seamless handover and roaming among the different legacy wireless network is supported, service loading can be shared among different legacy wireless works, and the optimal network can be selected to provide different kinds of services for the best user experience.

Conclusion

The rapid growth of mobile applications in recent years has created a need for wideband wireless communication. The only predictable trend is that the data rate and QoS requirements will increase rapidly. This demand will push TD-SCDMA systems to provide increasingly higher data rates with low latency, low cost, and improved coverage, capacity, and mobility support. This article has presented a map for smooth evolution from TD-SCDMA to FuTURE B3G TDD. As the performance difference between LCR and FuTURE B3G TDD is so large, the middle phase is necessary for smooth evolution. Thus, the evolution from TD-SCDMA to FuTURE B3G TDD includes four phases: LCR, HSxPA/TD-SCDMA EV 1x, LTE TDD, and FuTURE B3G TDD. By introducing new technologies, such as MIMO, OFDM, VAA, cooperative relaying, and so forth into the evolved system, the capabilities of TD-SCDMA can be improved step by step in order to fulfill the subscribers' requirements.

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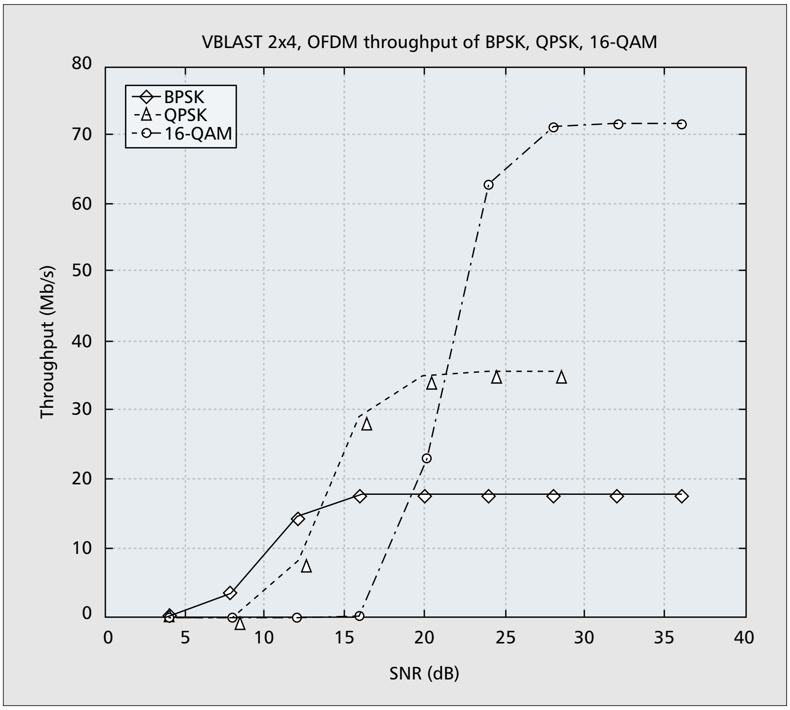

Figure 7. *The throughput of the VBLAST OFDM system.*

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