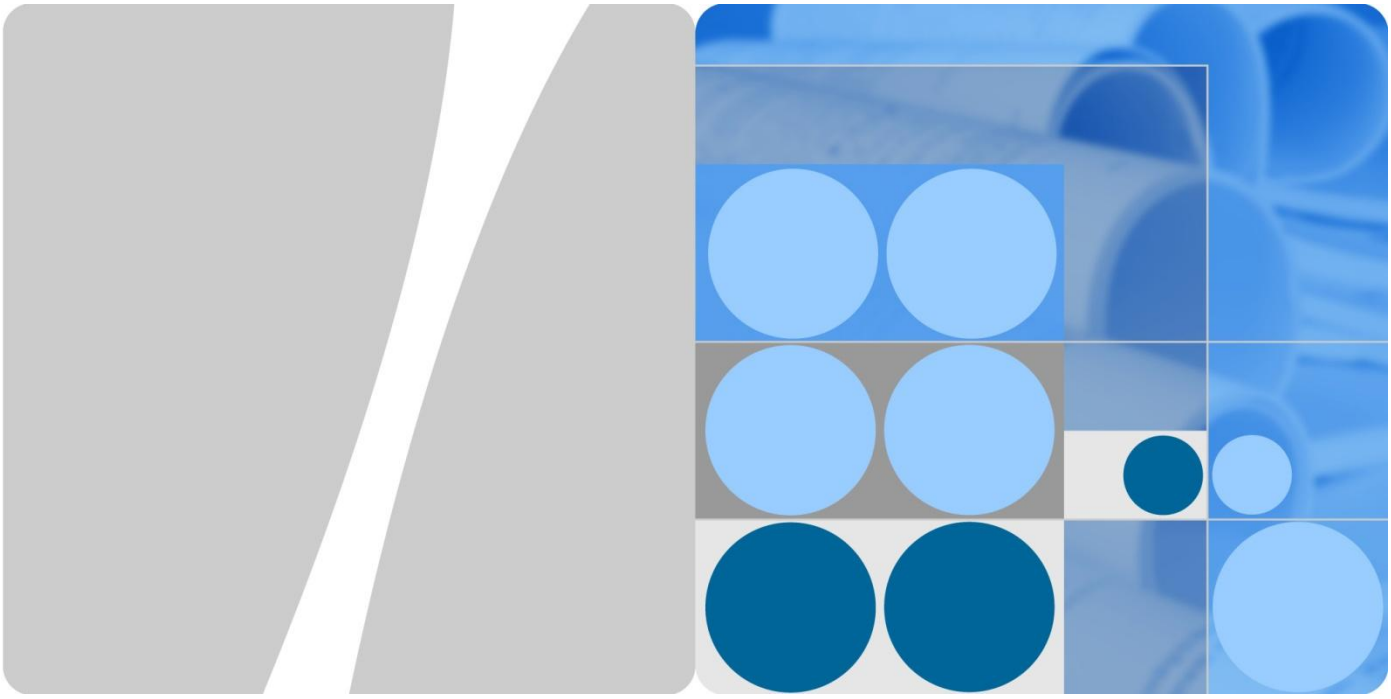


LTE 1800MHz Terminal whitepaper

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HUAWEI TECHNOLOGIES CO., LTD.

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1. Executive Summary

Since 2009 LTE has grown rapidly around the World according to GSA statistics. 17 LTE networks were commercially launched in 2010 and many more are predicted in 2011. 1800MHz is proving to be one of the mainstream spectrums for launching LTE, as it is widely available and already in use for GSM networks that have, or are going to have, declining user numbers. It is also defined as band3 within the 3GPP.

Operators around the world however may have different spectrum combinations available for use. Most operators who own 1800MHz have adopted an interim strategy to use this spectrum range for LTE networks services to provide high-speed data access and will use their 2G/3G networks for voice or lower/median speed data access.

Of major importance for LTE terminals is the ability to roam to different bands and systems, especially during the early stages of rollout where coverage is not equal to the existing 2G/3G coverage. Thanks to the development of IC (Integrated Circuit) technology, chipsets can support both multi-mode and multi-band systems.

Initially LTE terminals will be supplied in the form of dongles, data card and wireless Router's to support data-centric applications. The longer term will see LTE enabled smart phones dominate the market. There are several challenges that vendors need to take into consideration:

- Terminals will need to support MIMO and network interoperability for data/voice handover and load balancing; and
- The need to ensure that these data hungry devices offer a reasonable battery life for consumers.

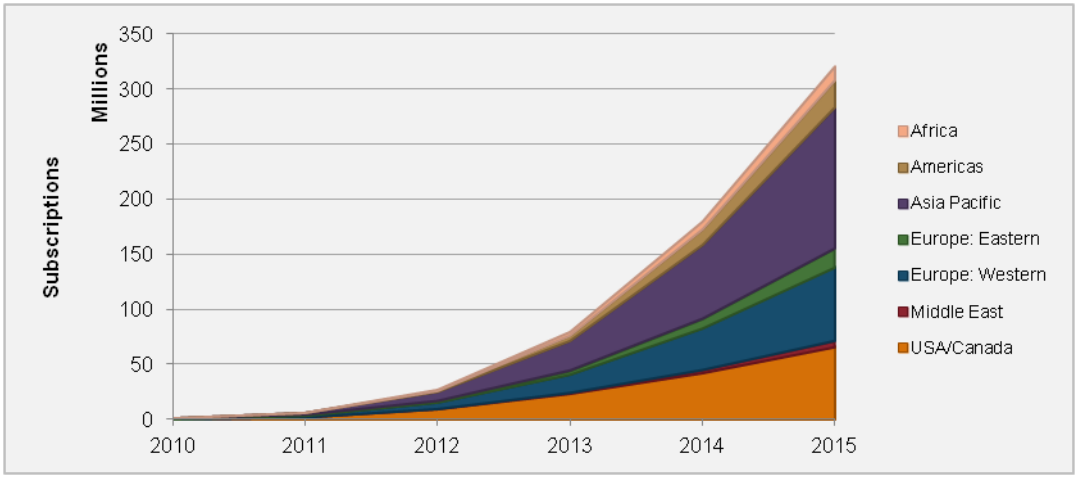
Fortunately LTE terminals will have a much shorter time to market due to recent technology advancement within 3G terminals. Huawei believes many LTE1800 terminals will be available in the market starting from mid-2011.

2. Introduction

2.1. The Trend of LTE

Mobile network operators are increasingly challenged by the explosive growth in mobile data traffic. LTE is favoured by many global operators as the next-generation network. The latest statistics from GSA indicate that at least 73 LTE networks are anticipated to be in commercial service by end 2012. By 2015 LTE customer numbers will have soared to 320 million. See Fig1 below.

Fig1. LTE Global Subscribers Growth, source: Informa, 2010



2.2. Terminal requirements for LTE1800

2.2.1. Frequency combination

Spectrum ranges are both prolific and fragmented in the LTE era. Compared to 2G/3G standards, LTE has a much larger number of spectrum ranges in different frequency bands. Currently over 30 frequency bands are defined in 3GPP for LTE. New spectrum has been, or will be, made available for re-use as part of the digital dividend. Government regulators around the world have a major challenge to clear existing spectrums for reuse by LTE. However there are varying timeframes for these clearances and subsequent auctions to take place for different countries. With 84 operators in 41 countries holding more than 10MHz of continuous 1800MHz spectrum as an asset, this range is seen as the most beneficial frequency with which to initially launch LTE networks. The current, or imminent, decline in users on GSM has, or will leave this spectrum asset potentially underutilised, and refarming into LTE is a way of maximising the value of this asset. An operator with more than 10MHz of 1800MHz spectrum can deploy LTE in 10MHz while

continuing to use the remainder of the spectrum for GSM.

The table below shows combination of LTE/UMTS/GSM in different regions around the world.

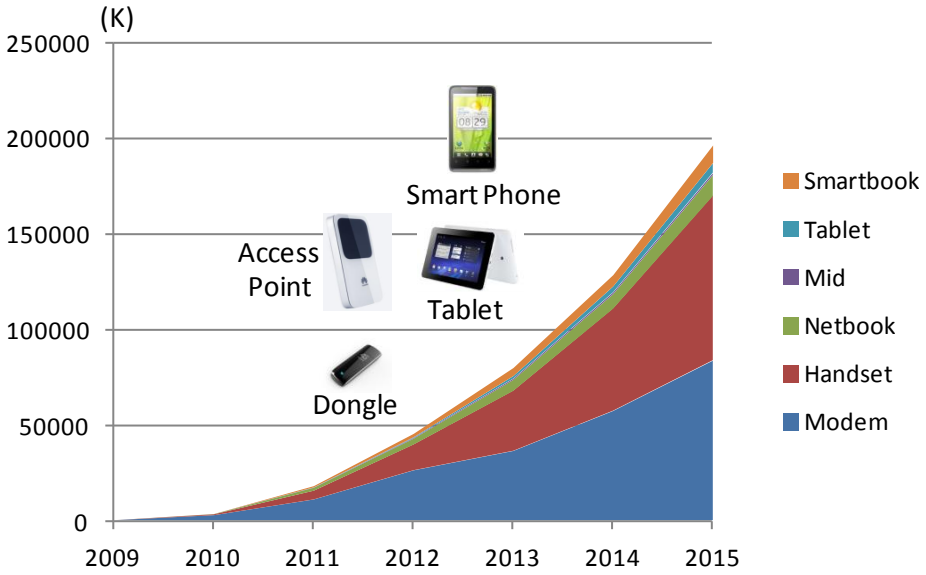
Region \ Technology	LTE	UMTS	GSM
Europe	800/900/1800/2100/2600	900/2100	900/1800
North America	700/2100/AWS	850/1900	850/1900
Latin America	900/1800/AWS/2100	850/900/1900/2100	850/900/1800/1900
Asia Pacific	1800/2300/2600	850/900/2100	900/1800
Africa and Middle East	900/1800/2100	900/2100	900/1800

For those operators who want to refarm1800MHz spectrum, different combinations are or will be planned for LTE. Some operator's idea is "keep it simple". In the initial stage, they use LTE1800 only modems to provide high speed data application. There are other operators that will require terminals that support multi-band LTE and multi-mode. LTE1800 enabled terminals should support all the legacy technologies and bands. For example, in Western European countries like Germany, the legacy networks are GSM900 and UMTS2100 and in the future LTE in the 800MHz band will provide full coverage. LTE1800 and LTE2600 will be deployed for urban coverage. One result of this type of rollout strategy is that tri-band LTE and Tri-mode terminals will be required for this network environment.

2.2.2. Form factors and Trend

In the initial stages of LTE network rollout and adoption it is likely that LTE modems, including USB dongles, Data cards and wireless routers will play the main role in the LTE terminal market. LTE enabled handsets will soon catch up and become dominant in market. The trend is applicable to LTE1800 devices (as a subset of LTE) as well. As 1800MHz spectrum is already an asset held by so many operators, there may be demand pressure to accelerate LTE1800MHz terminal availability. See Fig2 below. As a mainstream LTE spectrum, 1800MHz will see a variety of terminals enter the market in 2011.

Fig2. LTE devices shipment forecast, source: ABI research, 2010



2.2.3. Terminal capability

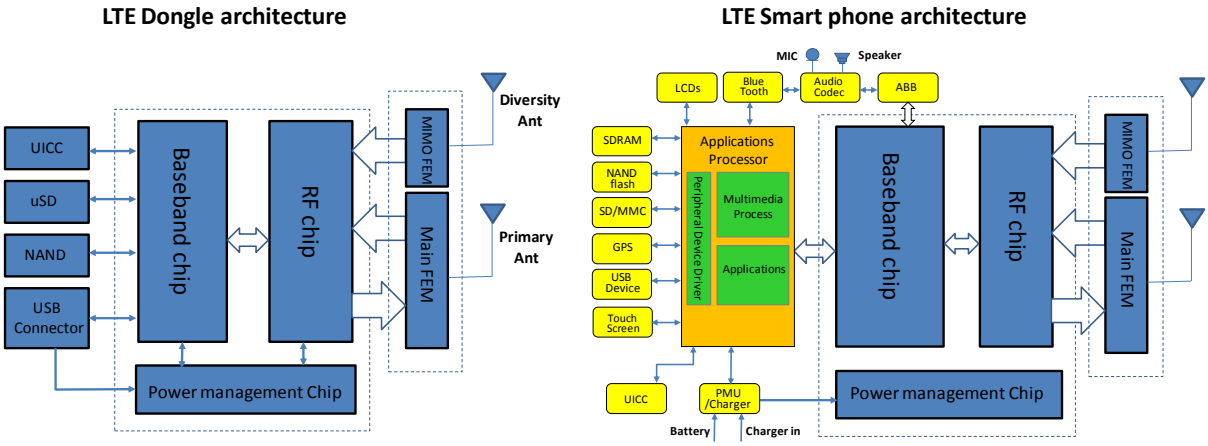
The chipsets determine the capability of terminals. The IC (Integrated Circuit) industry has successfully transformed from 65nm to 45nm technology in the past few years. Since 45nm technology is now widely used in the mobile terminal industry, the LTE chipset with 45nm technology contains more gate arrays to support greater functionality and emit less heat compared with 65nm. It is therefore possible to integrate multi-band and multi-technology into small sized chipsets.

In reality the multi-band and multi-mode chipsets have been available in the market from the end of 2010. For example, Qualcomm's MDM9x00/RNR8600 chipsets can support LTE/UMTS/GSM and various spectrum bands including LTE1800MHz.

With the multi-mode chipsets, the LTE1800MHz function is just an additional frequency band requirement on mobile device manufacturers. Support of interworking with legacy 3G and 2G networks can also be easily achieved.

3. Challenges of LTE1800 Terminals

Two major forms of LTE terminal are dongle and Smart phone. The figure below shows the structures of LTE dongle and Smart phone. The LTE chipsets, the core parts of LTE terminal, usually include 3 parts: the baseband modem, the RF chip and the power management chip. The main challenges of LTE terminal include multi-frequency band support, antenna design, batteries, LCD and CPU processing ability.



3.1. Multi-band RF design

Most terminal vendors use chipsets from chipset vendors. The RF chipset supports multi-band, and the terminal vendor should design multi-front end modules to support the multi-band capability. Connected to digital baseband units as well as one or more antennas, the front end modules manage the RF signal paths into and out of the device, and include numerous components such as filters and amplifiers. Many front end functions are analogue in nature, as befits the radio waves exiting and entering the device. Although baseband module, front end module and antenna performance are closely interrelated, spectrum fragmentation has comparatively more significance on the design and performance of front end modules and antennas than baseband units, due in no small measure to their dependence on the physical layout of the various device elements.

Theoretically, there is no upper limit on the number of frequency bands and modes that can be supported in a LTE mobile device. However, there are very pragmatic limits, driven generally by cost, size and performance issues. For example, an additional frequency band increases the number of RF components required in the device, resulting in bill of material increases as well as additional pressures on space inside the device. With the apparent popularity of LTE, multi-mode and multi-band will become basic features of terminals, and the cost and price will both likely drop with volume and competition, in the same way as the tri-band GSM and the dual-mode UMTS terminals did.

3.2. Antenna design

MIMO is the key technology of LTE. The performance improvement of MIMO is based on uncorrelated signal paths. Mutual coupling is one of the big challenges that is required to be solved. It is caused by the size restriction between MIMO terminal antennas, and leads

to impedance mismatch and power absorption by the coupled antennas and therefore degrades the overall system efficiency.

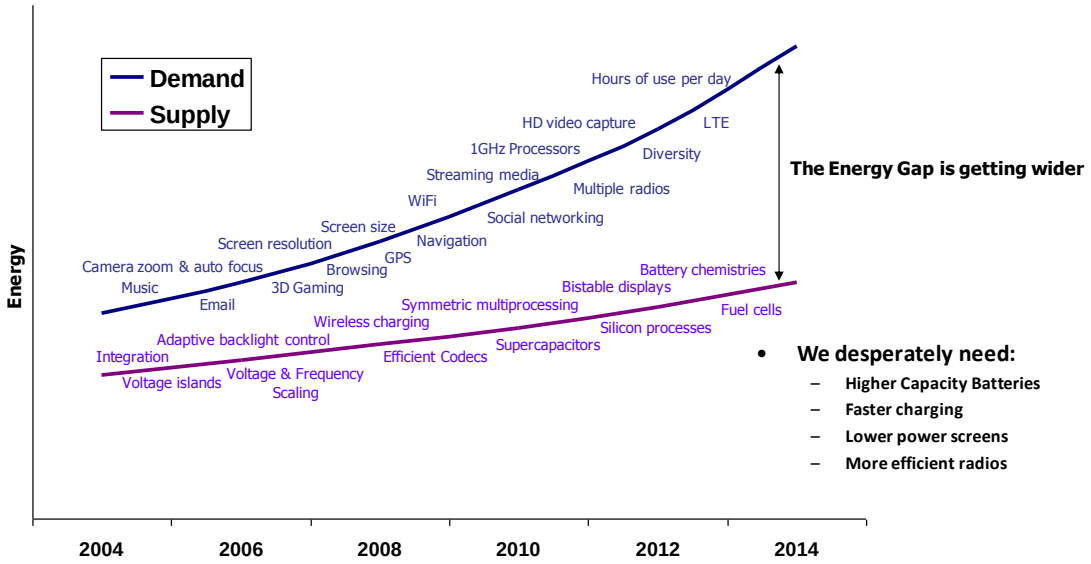
Antenna separation should be first take into consideration when designing the RF part. As a very rough estimate, 0.15~0.3 wavelength separation between antennas is needed to allow a mobile device to achieve its target performance levels. Clearly, there is a sizeable difference between these separation requirements when considering support for different spectrum bands and the consequent impact on the size of the device. In the case of 1800MHz this would mean a physical separation of approximately 2.5~5cm between the antennas. When considering the 700MHz band, this would translate to roughly 6.4~12.8cm.

3.3. Batteries

Although on the uplink of LTE the radio is optimized more for power consumption than efficiency, due to power saving considerations for terminals, the power consumption is still a big challenge for the terminal battery. The LTE dongles and wireless routers do not have battery issues since they are powered by external power sources. For LTE Smart phones, the high speed of data transmission and transaction bring more power consumption and more CPU utilisation. LTE enabled smart phones can be reasonably expected to be equipped with big screens for such applications as high resolution video telephone and video/ image viewing, which affects a terminal's both battery life and CPU utilisation.

However, in terms of the battery technology, the lithium-ion rechargeable battery technology for portable devices in the 1990s was the last major advance in battery technology. In the future, improvements may occur but performance will probably not be exceeded by more than 50 to 100 percent because of the thermodynamic limitations.

The figure below shows the gap between power consumption demanded by handset and ability that battery can supply.



Source: Strategy Analytics' Handset Component Technologies Service, August 2010

One important approach to extend the operating life of LTE portable terminals is to reduce the power consumption of components. Technical improvement of integrated circuitry can reduce chipset power requirements. For example, the 45nm technology chipset consumes approximately 30% less power compared with 65nm technology chipset. The low power consumption LCD technologies have also emerged in the recent few years, i.e. OLED, EPD, etc. These technologies are steps forward in the search for cost-efficient and power saving. Some software tools can also help to save power by monitoring and controlling applications running inside the terminal via optional settings.

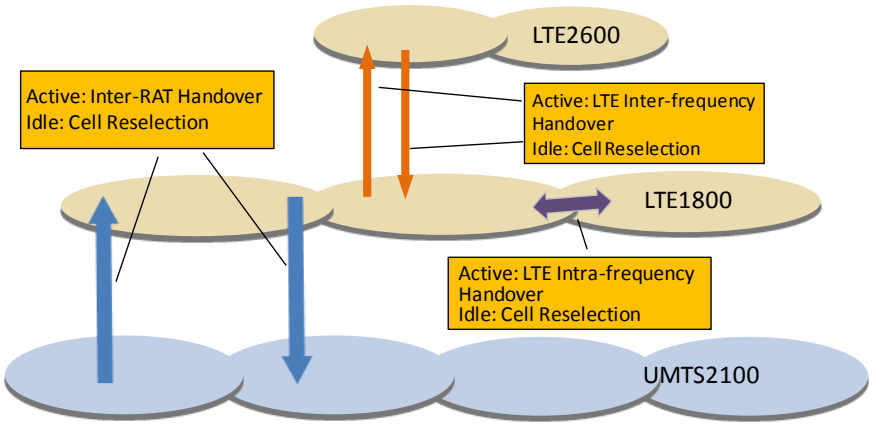
4. Interworking

As mentioned in previous chapters, LTE1800 terminals will support multi-mode. In 3GPP, LTE interworking mechanisms (i.e. mobility between different network technologies and load balancing) are defined in order to guarantee user experience. In this chapter, LTE stands for LTE1800 unless mentioned specifically.

4.1. Interworking for data applications

Assuming LTE1800 is deployed in urban areas as an overlay on the UMTS network; it would carry data traffic only and serve to offload capacity. For LTE, mobility towards UMTS is important to ensure service continuity. The following figure assumes there are 2 LTE networks and 1 UMTS network, LTE1800, LTE2600 and UMTS2100. In the same environments LTE1800 has a coverage advantage because LTE2600 has a 3dB higher

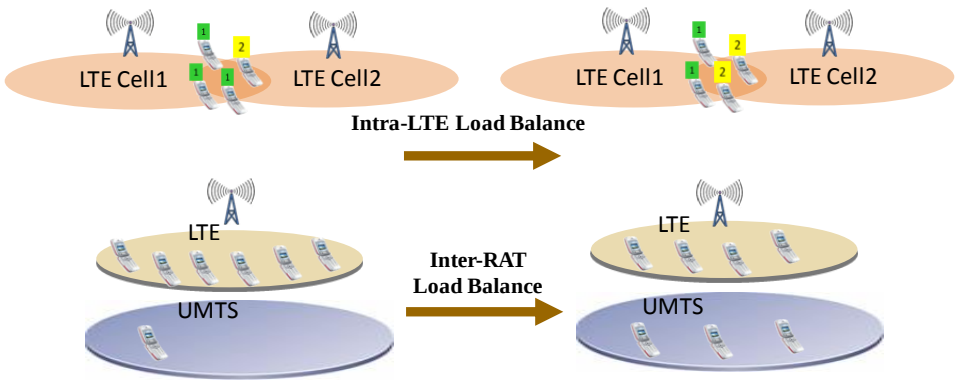
propagation loss. LTE2600 would generally be deployed in areas where greater capacity is needed. The interworking has 3 scenarios for both idle state and RRC connected state: 1.LTE intra-frequency 2. LTE inter-frequency 3. Inter-RAT.



In idle-state, the multi-mode LTE device can be set to camp on LTE1800 network when there is available coverage. Cell reselection to UMTS will be triggered when it goes out of the LTE coverage area, and vice versa with Cell reselection to LTE from UMTS being triggered when it goes into the LTE coverage area.

In connected-state, during a data session the PS handover feature should be supported by both the network and the terminal. The handover will be triggered based on coverage whereby LTE will handover to UMTS when the terminal goes out of LTE coverage and from UMTS to LTE when it goes back into the LTE coverage area. The trigger for the handover will be based on radio link condition measurements provided by RSRP/RSRQ on which the LTE eNodeB will base its decision.

Other than handover based on coverage, there are also other parameters reported by terminal which can be used to trigger inter-RAT handover like load-based handover. The load-based handover applies to both intra-LTE and inter-RAT scenarios. See figure below.

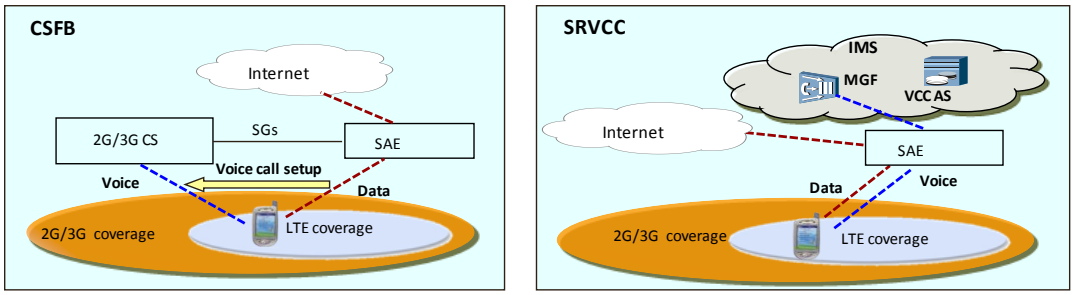


In a load-based handover scenario, the main aim is to provide for load balancing between the LTE and UMTS cells. The LTE cell measures and evaluates the cell load. Then it

decides whether to handover to a neighbouring cell. If the LTE cell's load is beyond the threshold, some of the terminals will handover to UMTS. 3GPP R9 defines the functionality of intra-LTE Mobility Load-Balancing (MLB, listed in TR 36.902) and the basic functionality of intra-RAT MLB. The enhancements that address inter-RAT scenarios and detailed inter-RAT information exchange should be addressed in Rel.10.

4.2. Voice Service Continuity

There are two main features for voice service continuity which are based on CS fallback and Single Radio Voice Call Continuity (SRVCC). Both features are completed as standardisation in 3GPP R8, and optimized in 3GPP R9 and R10. See figure below.



In CSFB, when the UE is in the E-UTRAN and UTRAN coverage overlapping area, any voice calls will fallback to the UTRAN coverage and will be handled in the CS domain. This functionality requires both network and UE support.

In SRVCC, the LTE network supports handover of VoIP calls from LTE to UMTS or GSM on the CS domain. This functionality requires an IMS to anchor the call between both the networks as well as the UE to support the LTE/UMTS/GSM access modes.

5. LTE1800 Case Examples

According to GSA's investigation, in March 2011, ninety eight LTE terminals were available in the market, and of those eight terminals support 1800MHz.

In September 2010 the first phase of Poland's Mobyland and CenterNet's commercial LTE1800 network was deployed. Like other LTE commercial networks, the initial stage of LTE1800 focuses on high speed wireless data applications. Single mode LTE1800 dongles are provided.

At MWC2011, Telstra announced it will launch a commercial LTE1800MHz network in 2011. Multi-mode dongles as well as smart phones supporting LTE1800, UMTS850 and

UMTS2100 will be available soon in the Australian Market.

In April 2011, VHA in Australia also announced it will launch LTE1800 in 2011. The LTE terminals required by VHA will support the same spectrum combination as Telstra.

After launching 2.6GHz LTE in 2010, CSL in Hongkong deploys a 2nd stage LTE1800.Terminals support LTE1800/2600 and UMTS900/2100 will be required.

6. Conclusions

Terminals are an essential part of the LTE1800 ecosystem. Since the 1800 MHz band is widely available throughout Europe, APAC, MEA, and South America, LTE1800 will be a mainstream spectrum for LTE deployments. Terminal vendors will not ignore the opportunity of this huge market in the near future.

With the increasing availability and the technical improvement in RF designs, chipsets, LCDs and batteries, LTE1800-enabled terminals (especially the smart phones) will be cheaper, lighter in weight and have longer operating battery life.

The interworking of LTE1800 with legacy networks is related to an operator’s business strategy that takes into account customer demand for high bandwidth mobile services and the utilisation of an existing asset in the 1800MHz spectrum.

LTE terminals will have a much shorter time to market, benefiting from recent technology advancement within 3G terminals. Huawei believes many LTE1800 terminals will be available in the market starting from mid-2011.

7. Abbreviations

3GPP – Third Generation Partnership Project
APAC – Asia Pacific
CSFB– Circuit Switched Fallback
DL – Downlink
EPD – Electronic Paper Display
FEM – Front End Module
GSA – The Global mobile Suppliers Association
GSM – Global System for Mobile communications
IC – Integrated Circuit
Inter-RAT – Inter Radio Access Technology
LCD – Liquid Crystal Display
LTE – Long Term Evolution (evolved air interface based on OFDMA)

MEA – Middle East and Africa
MHz – Megahertz
MID – Mobile Internet Device
MIMO – Multiple Input/Multiple Output
MLB – Mobility Load Balancing
MWC – Mobile World Congress
OLED – Organic Light-Emitting Diode
RAN – Radio Access Network
Rel. ‘X’ – Release ‘99, Release 4, Release 5, etc. of 3GPP Standards
RF – Radio Frequency
RSRP – Reference Signal Received Power
RSRQ – Reference Signal Received Quality
SRVCC – Single Radio Voice Call Continuity
UE – User Equipment
UMTS – Universal Mobile Telecommunications System
UTRAN – Universal Terrestrial Radio Access Network