Timing the Move to TD-LTE

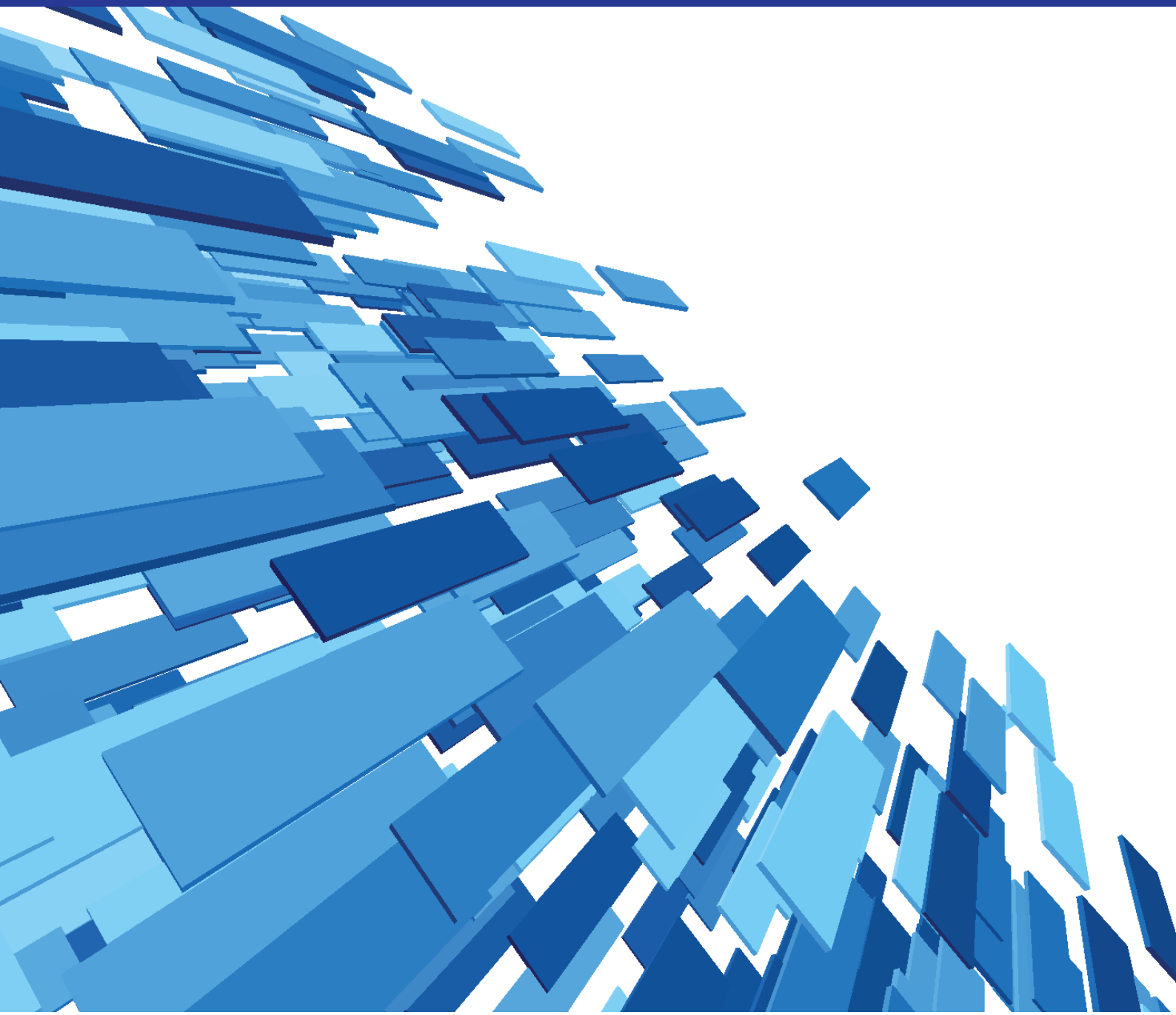

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Table of Contents

Scope

The purpose of this document is to discuss the fast adoption of TD-LTE in the industry and how it is increasingly seen as a viable option for deploying services in an unpaired band. With the solutions for supporting TD-LTE in place, this document discusses the path that operators can take to adopt TD-LTE either as a complementary technology or as an alternative to existing technologies.

Introduction

The demand for data over a mobile broadband connection has been growing exponentially and continues to grow due to the strong influence of both high smartphone adoption rates and the growth of data intensive mobile applications. These trends will be fortified with the adoption of large screen mobile devices including tablets and slate PCs.

According to market trend studies by Cisco, global mobile data traffic is expected to double every year through 2015, increasing 26 times between 2010 and 2015. Mobile data traffic will grow at a compound annual growth rate (CAGR) of 78 percent between 2010 and 2016, reaching 10.5 Exabyte per month by 2016.

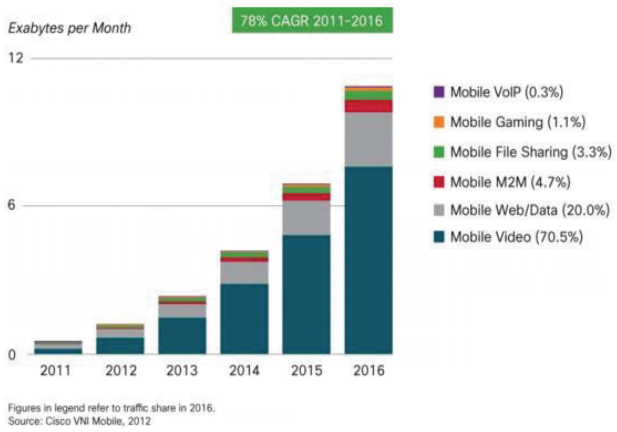

Figure 1. Data Usage Projections

As wireless markets make the transition to data and video-dominated broadband, unprecedented demands are placed on operator networks. Additionally data traffic in the mobile broadband era is largely asymmetric in nature, where data speed or quantity is skewed in one direction over the other. Internet traffic, the number one driver for broadband usage, is a prime example of asymmetric data flow, as typical Internet browsers download much more data than they upload to request a new page. With video-based sites such as YouTube, more users are uploading large quantities of data. But even with this new trend, typically only a few users upload videos, while millions may watch the uploaded content, so downloads still accounts for most of the traffic. The asymmetric data flow is posing additional challenge on the existing networks that are designed for handling symmetric traffic like voice.

Today's networks need to respond effectively to this unprecedented change and growth that is projected. On one hand, operators around the world have invested significant Capex in building 3G infrastructure, so the initial choice for operators would be to fulfill demand using that. On the other hand, it is necessary for operators in a highly competitive environment to deliver the user experience that subscribers expect. The wireless industry is truly at a turning point.

As subscribers demand more data, operators need to provide an efficient network to retain and attract new customers. Operational efficiency for delivering data becomes a key aspect, driving mobile operators to invest significantly in additional frequency spectrum. Considering the asymmetric nature of data demand, many operators increasingly now see unpaired spectrum as a viable complement to paired spectrum. The scarcity of available spectrum to carry greater mobile broadband traffic is a pressing concern, which has led to rising interest in the unpaired spectrum. Moreover, unpaired spectrum, previously unattractive to operators, trades at a much lower cost per MHz per population than paired spectrum bands, making it a less expensive acquisition.

Long Term Evolution (LTE) is designed to meet this huge demand for data and supports both the paired spectrum Frequency Division Duplex LTE FDD) and the Time Division Duplex (known as TD-LTE for unpaired spectrum) modes of operation. Because LTE can deliver data at lower cost than 3G and 2G, operators around the globe are aggressively considering the investment option of adopting LTE when deploying new networks.

Moreover, with nearly 90% commonality between LTE-FDD & TD-LTE technologies and rapid development of unpaired spectrum, new possibilities are opening up for operators to adapt to the data demand. In essence, the availability of low-cost unpaired spectrum, the flexibility to meet the demand for asymmetric data flow and the strong commonalities with FDD-LTE suggest that TDLTE will have similar economies of scale as FDD-LTE and will become an integral part of the LTE ecosystem.

Samsung has an end-to-end eMBMS solution that is ready for commercial service and that can be customized to deliver specific service models.

TD-LTE Overview

Early 3GPP technologies included GSM, EDGE, UMTS and HSPA, all globally successful technologies based on FDD spectrum allocations, using a separate frequency for uplink and downlink. This approach of using separate frequencies for user data has often been used and is well understood. The standardized TDD flavor of LTE has evolved simultaneously with the FDD version and is now at a point where it is attracting global attention and providing new possibilities.

TD-LTE is an evolution path for TD-SCDMA, which is China's 3G standard. China Mobile was the first operator to drive TD-LTE and now the technology has gained a global momentum of strong traction towards TDD spectrum. Interest shown by major markets such as India, Russia, Japan, and the USA has earned TD-LTE a place of consideration on most operators' plans. In fact, since 3GPP approved the TD-LTE project in Dec 2007, the technology has grown from strength to strength and garnered international support, thus driving ecosystem maturity.

LTE specifications define the frequency bands that are considered in any country's spectrum plans. In particular, unpaired spectrum allocations, previously utilized only sparingly for WiMAX or TD-SCDMA, were addressed with TD-LTE. Furthermore, TD-LTE design is highly efficient for applications which do not demand equal bandwidth for the uplink and downlink flow. In several instances, an asymmetric data flow makes more efficient use of the infrastructure and spectrum bandwidth than asymmetric data flow. Since TDLTE uses the same frequency for uplink and downlink, it is inherently well-suited for data traffic, thus matching future operator revenue focus.

From a technical standpoint, few significant differences exist between FDD and TDD on the physical layer and, in particular, with the frame structure. On the higher layers, the differences are limited to configurability of the physical layer and negligible timing relations due to the discontinuous nature of uplink and downlink. Some of the major advantages of TDD follow:

- **Frame structure** TD-LTE supports a special subframe for switching from DL to UL and to ensure coexistence with other TDD systems.
- **Random access** Additional short random access format and multiple random access channels are available in special subframes.
- **Scheduling** Multi-subframe scheduling is supported for the uplink flow.
- **ACK/NACK** Bundling of acknowledgments or multiple acknowledgments are allowed on the uplink control channel.
- **H-ARQ process number** Variable number of H-ARQ processes is possible, depending on UL/DL allocation.

Overall, the biggest benefit of TD-LTE is the flexibility it offers to operators in adjusting the DL/UL ratio. This feature allows operators to configure the DL/UL ratio to suit the traffic ratio on their network.

Figure 2 illustrates how this potential configuration impacts performance, highlighting how TDLTE's spectral efficiency ensures maximization of available bandwidth.

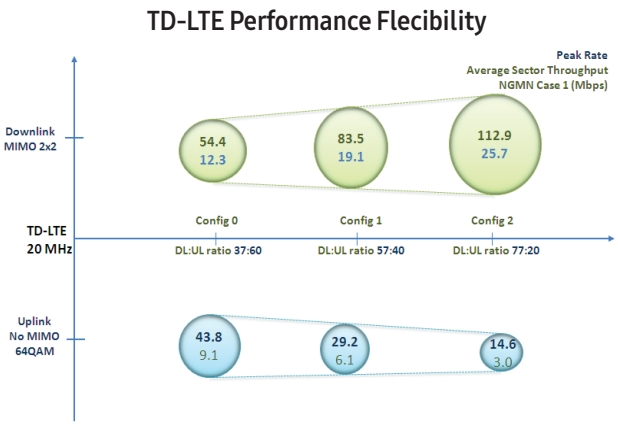

Figure 2. TD-LTE Performance Flexibility

A common perception in the industry is that TDLTE does not match LTE FDD for coverage. It is true that FDD systems transmit data over half the bandwidth, for twice as long as TDD Systems. For example a 2x5MHz FDD system transmits data over 5MHz bandwidth for the entire frame; by comparison, a 10 MHz TDD system will transmit data over a 10 MHz bandwidth for about half of the frame. If both systems transmit at 200 mW, power is more concentrated for FDD (40mW/MHz for FDD, 20mW/MHz for TDD), so the range of an FDD system will be larger than TDD's. To achieve identical range, the power at the antenna of a TDD system needs to be 2x (3dB) higher than the power at the antenna of an FDD system. However, an FDD system transmits 2x longer than a TDD system, so the net energy (Power x Time) transmitted from the antenna is identical for both cases. Neglecting component losses, FDD and TDD systems are identical in terms of energy consumption. Additionally, in an FDD system, as the UL and DL operate in separate frequencies, there is a need for a Duplexer Filter to protect the sensitive receiver from Tx noise. Nonetheless, the duplexer module, based on the duplex spacing, will add to the power consumption of the power amplifier (PA). As there is no need for a duplexer in TDD Systems, typically the TDD systems will have >50% better battery life than FDD systems.

TD-LTE has similar advantages to LTE FDD and can be considered for deployment on unpaired spectrum allocations that are widely unused or were used for deploying WiMAX or TD-SCDMA.

TD-LTE Market Status

Many countries throughout the world have large sections of unpaired unused spectrum. 3GPP has defined 11 TDD bands for LTE operation (as of 2012) including Bands 38, 40 and 41, which are becoming leading global bands. The two key TDD bands are 2.3GHz and 2.5GHz, and are used for major deployments in China, India and the USA. 3GPP later introduced Bands 42 & 43 so that WiMAX Operators operating in 3.5 GHz could consider the move to TD-LTE. The bands supported by 3GPP are captured in the below table.

Band	MHz	Operating Band	Region
33	20	1900-1920	UMTS Core TDD
34	15	2010 - 2025	UMTS Core TDD
35	60	1850 - 1910	US
36	60	1930 - 1990	US
37	20	1910 - 1930	US
38	50	2570 - 2620	2600 TDD Part
39	40	1880 - 1920	China UMTS TDD
40	100	2300 - 2400	China/India TDD
41	194	2496 - 2690	US TDD
42	200	3400 - 3600	IMT 2000
43	200	3600 - 3800	IMT2000

Figure 3. TD-LTE Bands

TD-LTE Networks. As of October 2012, there are 11 commercial TD-LTE networks (Aero2, Mobily, STC, Sky Brasil, Softbank, NBN, Bharti, Hi3G, UK Broadband, Omantel and MTS), with16 more ongoing deployments and at least 23 other operators studying the TD-LTE proposition.

In order to create value for stakeholders across the TD-LTE ecosystem and to foster convergence of TD-LTE and LTE FDD, the Global TD-LTE Initiative (GTI) was founded in 2011 by leading international mobile network operators such as China Mobile, Airtel, Vodafone, and Softbank. This forum has strong representation and has formed multiple workgroups with definitive plans to address key aspects of building an ecosystem, helping to steer the TD-LTE ecosystem as a major standard.

Emerging markets have been leading the charge in raising awareness of the potential of TD-LTE networks, especially in China, where China Mobile sees it as a natural evolution from its existing TDD-based networks. China Mobile is currently conducting large scale trials in many cities and planning to deploy more than 200,000 base stations by end of 2013. In India, where fixed broadband penetration is below 1%, operators aim to complement 3G with TD-LTE. Incumbent operator Bharti deployed TD-LTE services in two major Indian cities in Q1 2012, while new operator RIL is expected to provide TD-LTE in Q1 2013.

The TD-LTE ecosystem will be heavily influenced by China Mobile and RIL, the greenfield Indian operator, as they start commercial deployments in 2013. With that and further plans in China, India & Japan (39% of the world's total population) on track for launch of limited TD-LTE services in late 2012 or 2013, this market has significant potential to attract supply chain vendors. In the US market, Clearwire is leading TD-LTE deployment as it plans to launch services in June 2013. Sprint is expected to follow suit, indicating increasing support for TD-LTE in the North American Region as well.

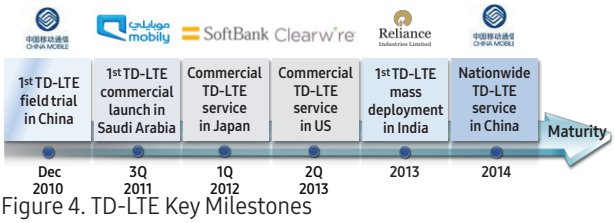

Figure 4. TD-LTE Key Milestones

Compared with TD-SCDMA, TD-LTE has attracted much stronger R&D investment from leading global semiconductor companies. Qualcomm and ST-Ericsson have recently announced the sampling of their multi-mode LTE/3G chipsets, an important milestone towards building LTE products that would support both TD-LTE and FDD LTE. Qualcomm MSM9x00 baseband chipsets are leading mobile processors by offering support for TD-LTE/LTE FDD/EVDO/HSPA+. In terms of infrastructure, product availability is the same as LTE FDD, with most network infrastructure vendors offering a multi-mode platform that includes support for TD-LTE.

Building on strong industry support, the TD-LTE ecosystem is keeping pace with the market and is expected to be mature by 2014.

Evolution to TD-LTE

After an extended period of trials and initial deployments, the TD-LTE ecosystem is now gearing up for accelerated network rollouts. Common 3GPP specifications for both FDD and TDD LTE guarantee upcoming availability of devices that support both interfaces on the same chipset. The ability for TD-LTE to roam to FDD LTE and other 3GPP and 3GPP2 legacy technologies further ensures strong interest in adopting TD-LTE. Viable possibilities now exist, not only for traditional FDD operators but for TDD spectrum holders who want to move toward LTE or enhance their current technologies and benefits from the 3GPP ecosystem.

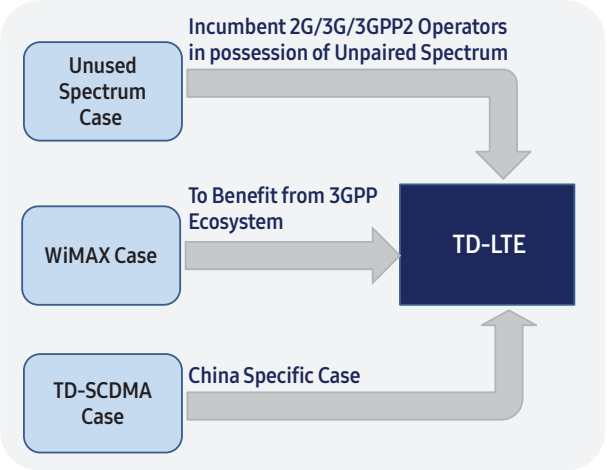

Figure 5. TD-LTE Evolution Path

WiMAX Operators

While the choice of moving to TD-LTE is subject to unpaired spectrum availability for incumbent 2G/3G/3GPP2 vendors, the option of adopting TD-LTE is a potentially difficult decision for Wi-MAX operators. Most WiMAX operators have only recently launched their networks and are busy signing up subscribers as they expand network coverage and capacity and develop new service offerings. Considering that TD-LTE & WiMAX are 4G technologies with comparable services, cost, and performance, it will be difficult for the ecosystem to support both simultaneously. Nonetheless, with a strong commitment from well-financed mobile operators worldwide boasting large subscriber bases, TD-LTE is set to dominate the mobile broadband market within a few years, with WiMAX likely to meet the requirements of niche market segments.

Initially, coexistence of the two technologies seemed appropriate for meeting the market demand, but with the advent of TD-LTE and growing maturity of the ecosystem, this is fast changing and has forced WiMAX operators to re-evaluate their long-term plans. In this context, most Wi-MAX operators are forced to explore the opportunities that TD-LTE offers either as a complementary technology or as an alternative to WiMAX.

Over the next year, many mobile operators will be deploying commercial TD-LTE networks and the first wave of mobile WiMAX operators will consider migrating to popular TD-LTE bands such as 2.5GHz or 2.3GHz. Going further, with the introduction of Bands 42 & 43 in 3GPP, WiMAX
Operators offering services in 3.5GHz have an option of migrating to TD-LTE in a similar fashion as with other popular bands.

As WiMAX operators evaluate whether to move to TD-LTE (or add TD-LTE to their networks), they will want to ensure that they are prepared for the transition. Flexibility will be required to enable transition to TD-LTE at their own pace, without disrupting their existing services. Operators will therefore need strong support from the vendor space, to retain as many elements as possible from their current deployments, not only in their radio access networks (RAN), but also in their core networks, where they manage traffic and subscribers, provision services, and handle billing.

In all cases, the adaptation of TD-LTE is a decision that requires platforms supporting multiple air interfaces and that depends on the availability of affordable multi-mode devices. If the cost and complexity of migrating to a new air interface is reduced, this will make it more attractive for Wi-MAX operators to switch to TD-LTE or to support both WiMAX and TD-LTE.

platform required to support TD-LTE are now available. Operators can now plan the migration to TD-LTE at their own pace without disrupting their existing services.

Why Samsung

Samsung has been delivering innovative solutions to its clients for more than 40 years. Samsung's mission is to deliver innovative technology and thereby provide superior value to its customers. We believe our 4G experience, brand equity, superior technology, customer satisfaction and strong partnerships in the telecom industry enable us to develop a significant presence in the worldwide LTE market. Samsung has a full portfolio of end-to-end LTE products to meet all operators' needs.

Samsung, as a pioneer in OFDMA technology, has been developing and deploying many commercial OFDMA networks over the past decade. The 4G LTE solution is one of the main telecom solutions from Samsung and consists of devices, access base stations, core network equipment, and IMS. Samsung is the undisputed leader in WiMAX deployments with a market share greater than 40%. Similarities in the wireless interface of WiMAX and LTE and a superior OFDM solution have made Samsung one of the leaders in the LTE vendor space. With proven end-to-end LTE solutions (systems and devices) that are widely deployed and extensively used in mature, high data usage markets (exceeding 30% LTE penetration), Samsung has been focusing on designing products that help operators to deploy in a multi-mode, multi frequency environment.

Samsung RAN is an economically viable solution that encompasses GSM, CDMA, WCDMA, Wi-MAX, LTE FDD & TD-LTE technologies with a defined migration path to LTE as well as support for LTE Advanced in the future. Samsung RAN supports all the technologies using a common Baseband and Remote Radio Head platform that can accommodate any access technology. With Samsung's RAN solution, mobile operators can easily build up cell sites to support different access technologies with minimal footprint and lower Capex/Opex.

Differentiated Solution

Samsung has developed a breakthrough interference coordination technology called Smart LTE Networks, for OFDM-based radio deployments. This technology is critical to increase the coverage and capacity of 4G networks deployed in dense urban environments, where inter-cell interference limits coverage and capacity due to the short distances between cell sites. Samsung's Smart LTE network technology allows mobile operators to increase capacity by controlling interference dynamically among cells, using sophisticated centralized resource coordination. This deployment model was recently named

'Most Innovative LTE Commercial Launch' at the 2012 LTE Awards, part of the annual LTE World Summit in Barcelona. Samsung supports this feature on both FDD-LTE and TD-LTE.

Conclusion

Figure 6 Samsung LTE Vision

Deploying LTE, the next generation technology of choice, in an unpaired spectrum is now a reality. TD-LTE matches its FDD counterpart in every aspect – tests and case studies have shown that the performance and coverage of TD-LTE is very similar to FDD LTE. TD-LTE presents a standardized technology alternative that provides operators with multiple options and possibilities. Its attractive spectrum price and efficiency dramatically changes the business case for a wide variety of applications, creating provocative revenue opportunities where once there were none. Its unique and adaptable DL:UL ratio is well suited for asymmetric applications and offers a complementary alternative to FDD-based technologies.

Samsung expects the TD-LTE ecosystem to completely mature by 2014, but the ecosystem will be heavily influenced by China Mobile, RIL(greenfield Indian operator) and Clearwire in the North American market as they start commercial deployments in 2013.

Samsung, with commercial TD-LTE deployment experience and its diverse product portfolio spanning different technologies such as WiMAX, LTE FDD, TD-LTE, CDMA & 2G on a common platform can work with operators to transition to TDLTE at their own pace without disrupting their existing services.

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