Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of	)	
	)	
Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions	)	Docket No. 12-268
	)	
	)	
	)	

COMMENTS OF CLEARWIRE CORPORATION

Cathleen A. Massey
Christiaan Segura
Clearwire Corporation
1250 I Street, NW
Suite 901
Washington, DC 20005
(202) 351-5033

Attorneys for Clearwire Corporation

January 25, 2013

TABLE OF CONTENTS

I. BACKGROUND……..… 1

II. DISCUSSION…… 3

A. The Commission Should Adopt A Technology-Neutral Bandplan and Technical Rules for the Repurposed Broadcast Spectrum....…… … 3

1. In the Past, The Commission has Preferred to Allow the Marketplace to Make Technology Choices…….……. 4

2. TDD Technologies are Particularly Well-Suited for Asymmetric Traffic and Non-Uniform Geographic Spectrum Availability……. 6

B. The Global TDD-LTE Initiative……... 9

III. CONCLUSION……. 11

APPENDIX A -- *TDD LTE - Making the Most of 4G*, P. Solis and J. Saunders, ABI Research (released Sept. 10, 2012)("ABI Research Report").

EXECUTIVE SUMMARY

Clearwire commends the Commission for initiating this notice of proposed rulemaking to make more wireless spectrum available for commercial service. This proceeding continues to build on the Commission's previous actions, helping to address the exponential growth in mobile wireless data usage and meet the National Broadband Plan's goal of freeing up 500 MHz of spectrum for commercial use while also funding FirstNet, the public safety network called for in the 911 Commission Report and the National Broadband Plan. Among the many issues that must be addressed as the Commission establishes the parameters for the highly complex broadcast incentive auction is the band plan and technical rules for the reclaimed 600 MHz spectrum. The Commission's proposed band plans and technical rules anticipate both paired spectrum using Frequency Division Duplexing ("FDD") technologies and a significant amount of spectrum reversed for unlicensed use. In Clearwire's view, one important component of the plan is missing. The Commission should also accommodate unpaired spectrum and Time Division Duplexing ("TDD") technologies while permitting full and flexible use of the new band.

As the architect of the country's first greenfield 4G wireless network, Clearwire capitalized on the Commission's foresight in providing full and flexible use of the 2.5GHz band by choosing to couple unpaired spectrum with WiMAX, a TDD technology. Further, in choosing its platform for the future, Clearwire analyzed both TDD- and FDD- LTE technologies and chose TDD-LTE. TDD technologies have many attributes – including being well suited for asymmetric operations and non-uniform spectrum assets – that also makes it an attractive option for the new 600 MHz band plan. Clearwire, therefore, urges the Commission to accommodate

TDD technologies in the new 600 MHz band and technical rules, rather than focusing solely on identifying paired spectrum blocks for FDD services.

Both FDD- and TDD- LTE networks and hybrid FDD/TDD networks are being deployed across the globe, utilizing the respective advantages of each technology. In considering the appropriate band plan and technical rules for the relinquished broadcast TV spectrum, the Commission should balance the capacity needs of existing voice-centric incumbents that prefer FDD as a building block with the burgeoning, global adoption of TDD technologies by data-centric newcomers such as Clearwire. Consequently, as it has in the past, the Commission should permit full and flexible use of the new spectrum and design a band plan that accommodates both paired and unpaired spectrum use. To do otherwise would be to ignore the superior utility of TDD technologies where traffic is asymmetric and spectrum availability is non-uniform across geographic licensing areas. It would also put the nation out of step with the increasing, global embrace of TDD-LTE as a superior technology option for data-centric networks.

Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of	)	
	)	
Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions	)	Docket No. 12-268
	)	
	)	
	)	

COMMENTS OF CLEARWIRE CORPORATION

Clearwire Corporation ("Clearwire"), pursuant to Section 1.405 of the Federal Communications Commission's rules,[1] submits these comments in response to the Commission's Notice of Proposed Rulemaking ("NPRM") in the above-captioned proceeding.[2]

I. BACKGROUND

Clearwire is a leading provider of 4G wireless broadband services and offers 4G wireless broadband services in 80 markets covering more than 133 million Americans. Clearwire serves retail customers through its own CLEAR® brand as well as through wholesale relationships with some of the leading companies in the retail, technology and telecommunications industries, including Sprint and NetZero.

Since the Commission revised its 2.5 GHz regulations to promote a capacity-rich 4G mobile broadband network,[3] Clearwire has deployed its network at record-breaking speed.[4] As of September 30, 2012, Clearwire's network serves approximately 10.5 million total

[1] 47 C.F.R. § 1.405.
[2] Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions, GN Docket No. 12-268, *Notice of Proposed Rulemaking*, FCC 12-118 (rel. Oct. 2, 2012) ("NPRM").
[3] *See* Amendment of Parts 1, 21, 73, 74 and 101 of the Commission's Rules to Facilitate the Provision of Fixed and Mobile Broadband Access, Educational and Other Advanced Services in the 2150-2162 and 2500-2690 MHz Bands, *Report and Order and Further Notice of Proposed Rulemaking*, WT Docket No. 03-66 (Jul. 29, 2004) ("2.5 GHz R&O").
[4] Clearwire launched its first greenfield 4G network in Portland, Oregon in early 2009.

subscribers.[5] To support deployment, Clearwire relies upon BRS licenses and excess capacity leases from other BRS and EBS licensees.[6]

Clearwire offers a consumer-friendly "no contract" option and unlimited data plans under the brand name CLEAR®. It also offers its advanced wireless broadband service on a non-exclusive wholesale basis.[7] Clearwire continues to position itself as a capacity-rich "off ramp" for other carriers facing spectrum constraints. Beginning this year, Clearwire will start deploying TDD-LTE 4G services designed to provide wholesale capacity in dense urban markets where it is needed most.[8] On December 17, 2012, Sprint and Clearwire announced that they had entered into a definitive agreement by which Sprint will acquire the remaining stock of Clearwire

[5] The 10.5 million subscribers consist of 1.4 million retail subscribers and 9.1 million wholesale subscribers with high-speed residential and mobile Internet and interconnected voice over Internet protocol ("VoIP") services.

[6] As part of its relationship with its EBS lessors, Clearwire assists its EBS lessors in meeting their obligations under FCC rules to use their spectrum to provide essential educational services to schools and colleges across the country.

[7] Clearwire provides the broadband platform serving Sprint's 4G customers along with a group of disruptive upstarts including FreedomPop, NetZero, Karma, Mobile Beacon, Mobile Citizen, Leap Wireless, Cbeyond and Locus Telecommunications. These newcomers are using Clearwire's network to offer innovative pricing models, including free broadband to consumers. *See* Anton Troianovski, *Start-Up Skirts Cellphone Data Plans* (Oct. 1, 2012) , available at http://online.wsj.com/article/SB10000872396390443862604578028452045153628.html?mod=googlenews_wsj; *see also* Myriam Joire, *NetZero Launches '4G' Wireless Service, We Go Hands on* (Mar. 19, 2012), available at http://www.engadget.com/2012/03/19/netzero-launches-4g-wireless-service-we-go-hands-on/; Karl Bode, *Karma Offers Wireless at $14 a Gigabyte, Straight Latest MVNO Attempt to Disrupt Pricing*, available at http://www.dslreports.com/shownews/Karma-Offers-Wireless-at-14-a-Gigabyte-Straight-119948 (Jun. 15, 2012); Tammy Parker, *WiMAX Provider Mobile Beacon Offers Free Wi-Fi Service* (Sep. 23, 2012), available at http://www.fiercebroadbandwireless.com/story/wimax-provider-mobile-beacon-offers-free-wi-fi-service/2012-09-23.

[8] *See* Kevin Fitchard, *Clearwire Breaking Ground on New LTE Network* (Sep. 20, 2012), available at http://gigaom.com/2012/09/20/clearwire-breaking-ground-on-new-lte-network/. Clearwire initially is targeting high demand "hot zones" in 31 major urban centers such as New York City, San Francisco, Los Angeles, Chicago, and Seattle where demand for 4G mobile broadband is high and the need for deep capacity resources is most acute.

that Sprint does not already own. The Sprint-Clearwire agreement is conditioned on the prior consummation of the previously announced SoftBank-Sprint transaction.[9]

II. DISCUSSION

A. The Commission Should Adopt a Technology-Neutral Bandplan and Technical Rules For The Repurposed Broadcast Spectrum

The Commission, almost as an afterthought, asks whether its proposed band plans should include spectrum designated for TDD technologies.[10] In the past, the Commission expressed a preference for permitting the marketplace to determine technology choices and built flexibility into its proposed band plans for technologies relying on both paired and unpaired spectrum assets.[11] Here, rather than focusing solely on prioritizing paired spectrum, the Commission could solve many of its issues with regard to an uncertain amount of returned spectrum and the disposition of "leftover" slices of spectrum by setting aside a TDD-only block in its band plan and by allowing TDD operations throughout the band. TDD technology has many attributes – including being well suited for asymmetric operations and non-uniform spectrum assets – that makes it an attractive option for the new 600 MHz band plan.

In addition, both FDD- and TDD- LTE networks and hybrid FDD/TDD networks are being deployed across the globe, utilizing the respective advantages of each technology. In considering the appropriate band plan for the relinquished broadcast TV spectrum, the Commission should balance the capacity needs of existing voice-centric incumbents that prefer FDD as a building block with the burgeoning, global adoption of TDD technologies by data-centric newcomers such as Clearwire. Consequently, as it has in the past, the Commission

[9] SoftBank has agreed to purchase 70% of Sprint. *See* Applications of Sprint Nextel Corporation, Transferor, and SoftBank Corp., and Starburst II, Inc., Transferees, for Consent to Transfer of Control of Licenses and Authorizations, Public Interest Statement, attached to ULS File No. 0005483246, IB Docket No. 12-343.
[10] NPRM at ¶¶ 183 – 184.
[11] 2.5 GHz R&O at ¶ 132.

should permit full and flexible use of the new spectrum and design a band plan that accommodates both paired and unpaired spectrum use. To do otherwise would be to ignore the superior utility of TDD technologies where traffic is asymmetric and spectrum availability is non-uniform across geographic licensing areas. It would also put the nation out of step with the increasing, global embrace of TDD-LTE as a superior technology option for data-centric networks

1. In the Past, The Commission has Preferred to Allow the Marketplace to Make Technology Choices

The Commission has used a light regulatory touch to foster the growth of mobile broadband and typically has refrained from dictating technology choices for broadband spectrum. In previous rulemakings, the Commission has determined that spectrum bands should be governed by rules that are technology neutral and permit flexible use, allowing the marketplace to determine the appropriate technology and services. For example, in its 2005 Wireless Broadband Access Report, the authors stated:

> We believe that the Commission should ensure that its rules are flexible enough to allow, but not require, pairing between asymmetric bands. Specifically, the Task Force recommends that the Commission ensure that its rules do not prevent an operator from combining multiple spectrum bands to form a single service. In addition, we believe that the Commission should consider innovative ways to assign spectrum that would allow potential licensees to acquire asymmetrically paired spectrum blocks or unpaired spectrum for the deployment technologies such as time division duplex (TDD), which do not require paired bands.[12]

[12] WIRELESS BROADBAND ACCESS TASK FORCE, CONNECTED & ON THE GO BROADBAND GOES WIRELESS 63 (2005) *available at* http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-257247A1.pdf ("Broadband Task Force Report").

In general, the FCC has adhered to this proposal when previously reallocating 700 MHz broadcast spectrum for broadband use.[13] Even in cases where the Commission has anticipated that FDD technologies likely will be utilized, it has provided the flexibility for licensees to choose TDD as well. For example, in the *Lower 700 MHz Report and Order*, the Commission adopted a flexible allocation for the Lower 700 MHz Band which "will allow service providers to select the technology they wish to use to provide new services that the market may demand."[14] The rules governing the 700 MHz band spectrum (both upper band an lower band) state that "licenses may be used for flexible fixed, mobile, and broadcast uses, including fixed and mobile wireless commercial services (including FDD- and TDD-based services); fixed and mobile wireless uses for private, internal radio needs; and mobile and other digital new broadcast operations."[15] In addition, the Commission specifically established two unpaired spectrum blocks in the Lower 700 MHz band, the D and E blocks.

Clearwire itself has benefitted from the Commission's decision in 2004 to provide full flexibility in the 2.5 GHz band, a decision that occurred many years before the technology choices that exist today were even in development.[16] As the Commission stated in its decision regarding the reallocation of the 2.5 GHz spectrum band, "[a]llowing the band to be technology neutral is consistent with our goal to make the spectrum as flexible as possible as it permits licensees and the marketplace to determine which technologies should be utilized."[17] Clearwire was able to rely on this flexibility when it launched the country's first 4G network using

---

[13] *See, e.g.,* reallocation and Service Rules for the 698-746 MHz Spectrum Band (Television Channels 52-69), *Report and Order*, GN Docket No. 01-74 ¶70 (rel. Jan. 18, 2002) ("Lower 700 MHz R&O").
[14] *Id.* at ¶ 1.
[15] The Commission's rules allow non-guard band 700 MHz licensees to provide "any services for which its frequency bands are allocated." 47 C.F.R. § 27.2(a).
[16] 2.5 GHz R&O at ¶ 132.
[17] *Id*.

WiMAX, a TDD technology. Further, in choosing its platform for the future, Clearwire ran extensive trials analyzing both TDD- and FDD- LTE technologies and chose TDD-LTE. As explained below, Clearwire determined that TDD would better suit its new LTE network and permit the company to use its 2.5 GHz spectrum more efficiently.

In establishing a band plan and technical rules for the returned 600 MHz spectrum, the Commission should continue its long history of adhering to policies that promote competition, are technology neutral and provide for flexible use.

2. TDD Technologies are Particularly Well-suited for Asymmetric Traffic and Non-Uniform Geographic Spectrum Availability

From its inception, LTE was designed to converge FDD and TDD into a single technology solution for 4G and beyond.[18] Since many incumbent operators are evolving to 4G by migrating their existing networks which have supported 2G and 3G using FDD spectrum and technologies, FDD-LTE is a natural choice for them. In contrast, newer operators such as Clearwire, that may be deploying greenfield 4G networks, or evolving from earlier 3G/4G technologies which used TDD spectrum, will naturally gravitate to TDD-LTE. Clearwire, which is permitted to deploy FDD or TDD technologies in the 2.5 GHz Band, built its 4G network on a licensing scheme that shares several important characteristics with the returned broadcast spectrum. Clearwire did extensive testing to determine which flavor of LTE best suited its spectrum assets and data-centric business plans. In choosing TDD-LTE, Clearwire noted that TDD is particularly well-suited as a technology choice where there is 1) asymmetry between uplink and downlink transmissions; and 2) where there is lack of uniformity regarding available

[18] The LTE network architecture, protocol stack, radio management, and MAC layers are 100% identical. There are minor differences in about 15% of the physical layer 1 and all of the key features of LTE and LTE-Advanced are identical for both FDD/TDD.

channel blocks across licensed areas. As the Commission explains at length, depending on the outcome of the reverse auction, the Commission anticipates that there will be "non-uniform amounts of relinquished broadcast TV spectrum in each geographic area." Clearwire, similarly, has built its 4G network on a somewhat fractured band plan, because Clearwire owned or leased channels differs from one geographic area to another. Additionally, Clearwire's network has been designed to accommodate intensive and escalating demands for high capacity data services. Similarly, the Commission expects that the relinquished broadcast spectrum will be deployed to address the burgeoning demands of data-centric devices and applications. Both these factors – an uneven spectrum allocation and data-centric demand – point to TDD as a logical technology choice.

First, unlike FDD, TDD allows an operator to configure allocation of channel capacity between uplink and downlink to match traffic demands (at a market level), so for any given amount of spectrum, TDD technologies can be configured to be more spectrally efficient than FDD. It is this configurability that gives TDD technologies a key advantage over FDD and it is the reason why it has proven to be the technology of choice for nearly all Internet-centered or data-centered technologies, including LTE, WiFi, WiMAX, WiBro, Expedience, 802.20, PHS, IP-Wireless, Flarion, iBurst and Navini.

Second, another factor that caused Clearwire to adopt TDD included the ability to use every megahertz of its spectrum and to configure it in different ways depending upon the channels available to it in a particular geographic area. FDD systems typically use a fixed, symmetric ratio of uplink to downlink spectrum that is necessarily separated by a "duplex gap" that is set by regulatory rule.[19] TDD technologies, however, permit the system operator to

[19] See NPRM at ¶ 166-67.

allocate its spectrum resources between uplink and downlink demand and allow for a variety of channel plans depending upon spectrum availability in a particular geographic area. In its LTE trials, Clearwire tested TDD and FDD configurations.[20] In the case of FDD, Clearwire created an artificial guard band between the uplink and downlink channels. Clearwire ultimately chose TDD, in large measure because it would not require a duplex gap, permitting Clearwire to deploy an uninterrupted succession of LTE carriers across the 2.5 GHz band.

In addition to these two key benefits, TDD systems offer relatively lower complexity and more cost-effective design as compared to FDD systems. The fact that paired spectrum is not needed for TDD operation simply eliminates the need for expensive duplexers, which is cost-effective especially for end user devices. TDD systems require relatively less components and lower average PA power, leading to smaller form factors and lower equipment failure rates. In addition, TDD operation allows for accurate channel estimation of the transmit path based on the received signal characteristics. TDD systems are able to leverage this channel reciprocity to efficiently perform channel sounding / channel quality estimation as needed for performance enhancements such as dynamic sub-channel selection and beamforming applications.

Clearwire acknowledges that the Commission should create a path for capacity enhancement for legacy operators with origins rooted in voice services. But a sole focus on paired spectrum, especially given the strong likelihood that perfectly paired spectrum will not be the norm in most geographic regions, would be shortsighted. As discussed below, it would also put the Commission out of synch with an international trend embracing TDD technologies and at

[20] See, e.g., Kevin Fitchard, 4G World: Clearwire paving way for 100 Mb/s, Connected Planet, Oct. 20, 2012, *available at* http://connectedplanetonline.com/3g4g/news/4G-World-Clearwire-paving-way-for-100-Mbs-1020/index.html.

odds with its commitment to "make every effort to provide spectrum opportunities for TDD systems in future allocation and spectrum proceedings . . . "[21]

B. The Global TDD-LTE Initiative

In February, 2011, at the Mobile World Congress, Clearwire, along with founding members Vodafone, China Mobile, Bharti Airtel and SoftBank Mobile, founded the Global TDD-LTE Initiative ("GTI"). The initiative currently includes more than 31 members serving over 1 billion subscribers. Telecommunications analysts have noted that until 2010, the only flavor of LTE under serious discussion was FDD-LTE. But times have changed. In October, 2012, Clearwire released two commissioned research studies by IDC and ABI Research that outline the growing prominence of the global TDD-LTE ecosystem and analyze Clearwire's deployment of TDD-LTE.[22] As the ABI Research Report noted:

> Many people in the industry and press have made the mistake of viewing the LTE-TDD ecosystem as a niche market. This could not be further from the truth. . . ABI Research believes that the device vendors' desire to reduce the number of models required to support different networks, traffic demand on mobile operator networks, and global roaming partnerships will all align to show the true value of TDD spectrum and the importance of mobile networks supporting LTE-TDD, either alone or in combination with LTE-FDD.[23]

Further, the ABI Research Report found that 10 operators have already launched LTE-TDD networks, 22 have LTE-TDD infrastructure in deployment and another 22 have LTE-TDD trials underway.[24] In addition to Clearwire's U.S. network, supporters for TDD-LTE include

---

[21] AWS-1 R&O ¶ 46.

[22] *See* JOHN BYRNE, VALIDATING THE MARKET FOR TDD LTE IN THE U.S. MARKETPLACE *available at* http://files.shareholder.com/downloads/CLWR/2062777294x0x608189/1ce5d47e-f996-48d9-9b19-acdb30919a47/IDC_Clearwire_Whitepaper_August_2012.pdf ("IDC Report"); *see also*, PHIL SOLIS & JAKE SAUNDERS, TDD LTE - MAKING THE MOST OF 4G, *available at* http://files.shareholder.com/downloads/CLWR/2062777294x0x608190/b2ca9d41-fbab-44b7-9e6a-4e40dc11422a/ABI_Research_Clearwire_Whitepaper_September_2012.pdf ("ABI Research Report"). The ABI Research Report is also attached as Appendix A to these comments.

[23] ABI Research Report at 1.

[24] *Id*. at 8.

carriers in India (Bharti Airtel, Tikona, and Intotel), China (China Mobile), Japan (SoftBank), Poland (Aero2), Australia (Vividwireless), Denmark (Hutchison 3), Germany (E-Plus) and Malaysia (Packet 1). It is estimated that global TDD-LTE will cover 4.4 billion pops by 2014 under planned build out schedules.[25]

It is also important to note that both the ABI Research Report and the IDC Report have found that the device manufacturers have noted the escalating adoption of TDD-LTE and it is expected that both FDD-LTE and TDD-LTE will both be widely incorporated into chipsets and devices.[26] For example, Qualcomm has announced a single-chipset solution for both varieties of LTE (TDD and FDD) and legacy technologies (DC-HSPA+, EVDO, and EDGE), permitting a single device to support all of these technologies.[27]

Other analysts have examined world-wide trends and noted that operators tend to see roles for both FDD- and TDD- LTE in their network strategies.[28] For example, a Heavy Reading Report authored by Berge Ayvazian notes that Germany is deploying a hybrid network using FDD-LTE base stations for national/outdoor coverage and TDD-LTE base stations in urban and dense suburban areas where high capacity is required.[29] The Heavy Reading Report goes on to state the following:

> The ideal LTE-TDD deployment scenario (from a cost point of view) is an urban area, where delivering a high traffic handling capacity per square kilometer is paramount. In

---

[25] *Id.*

[26] *See e.g.,* ABI Research Report at 8; *see also* Electronista Staff, *Clearwire and Qualcomm to partner on multi-mode LTE chips,* (May 9, 2012) *available at http://www.electronista.com/articles/12/05/09/clearwire.qualcomm.join.to.unify.lte/.*

[27] Press Release, Qualcomm, Inc., Qualcomm Delivers a Faster Mobile Broadband Experience with New, Higher Speed LTE Devices (Feb. 14, 2011) *available at* http://www.qualcomm.com/media/releases/2011/02/14/qualcomm-delivers-faster-mobile-broadband-experience-new-higher-speed-lte.

[28] Berge Ayvazian, LTE TDD Operator Business Case & Adoption Forecast, HEAVY READING (March 2011) at 16 (the "Heavy Reading Report"). The Heavy Reading Report was commissioned by China Mobile, Alcatel-Lucent, Ericsson, Nokia Siemens Networks and Qualcomm.

[29] *Id.*

> this approach, additional capacity would be deployed using a TDD mico/picocell layer in high traffic urban areas. LTE-TDD femto/picocells can also be used to significantly improve indoor coverage complementing FDD macrocell network coverage.[30]

Similarly, Clearwire has marketed its capacity-rich network as an "off ramp" for spectrum constrained carriers. Beginning this year, Clearwire will start deploying TDD-LTE 4G services designed to provide broadband capacity in dense urban markets where it is needed most.[31] In concept, this will result in a hybrid TDD- and FDD- LTE network, with Clearwire's TDD-LTE network providing capacity resources for traditional, incumbent carriers that run their networks on FDD platforms.

In designing its band plans and technical rules for the relinquished broadcast spectrum, the Commission should be mindful of the global-wide recognition of TDD technologies as high utility choice for data-centric networks. In addition, it should permit full and flexible use of the returned spectrum to create FDD, TDD or hybrid combinations depending upon marketplace demands. A sole focus on FDD technologies would look only to the past rather than preparing for a future where both FDD and TDD technologies will serve important roles. Consequently, Clearwire recommends that the Commission accommodate TDD technologies in its proposed band plans and technical rules and provide for full and flexible use of the returned broadcast spectrum.

III. CONCLUSION

Historically, the Commission has determined that spectrum bands should be governed by rules that are technology neutral and permit flexible use, allowing the marketplace to determine

---

[30] *Id.*

[31] *See* Kevin Fitchard, *Clearwire Breaking Ground on New LTE Network* (Sep. 20, 2012), *available a*t http://gigaom.com/2012/09/20/clearwire-breaking-ground-on-new-lte-network/. Clearwire initially is targeting high demand "hot zones" in 31 major urban centers such as New York City, San Francisco, Los Angeles, Chicago, and Seattle where demand for 4G mobile broadband is high and the need for deep capacity resources is most acute.

the appropriate technology and services. The Commission should adhere to these same principles in this rulemaking and fashion a band plan and rules that accommodate both FDD and TDD technologies. To do otherwise would be to ignore the superior utility of TDD technologies where traffic is asymmetric and spectrum availability is non-uniform across geographic licensing areas. It would also put the nation out of step with the increasing, global embrace of TDD-LTE as a superior technology option for data-centric networks.

Respectfully submitted,

/s/ Cathleen A. Massey

Cathleen A. Massey
Christiaan Segura
Clearwire Corporation
1250 I Street, NW
Suite 901
Washington, DC 20005
(202) 351-5033

Attorneys for Clearwire Corporation

January 25, 2013

APPENDIX A

TDD LTE - Making the Most of 4G, P. Solis and J. Saunders, ABI Research (released Sept. 10, 2012)("ABI Research Report")

Phil Solis: *Research Director, Device, Applications & Content*
Jake Saunders: *Vice President and Practice Director, Core Forecasting*

SEPTEMBER 10, 2012

abiresearch.com

TDD LTE[1] – MAKING THE MOST OF 4G

Operators around the world have started to upgrade their mobile data networks into full-blown mobile broadband networks that are more than a match for any fixed-line DSL network in existence. What is the "secret sauce" that is empowering this network transformation? LTE, which comes in two flavors: LTE frequency division duplexing (FDD) and LTE time-division duplex (TDD). LTE TDD, also known as time-division-LTE (TD-LTE), is the same access technology protocol that has been ratified through the 3GPP standardization process and supports the LTE-Advanced standard. Until 2010, most industry executives had only heard of LTE, which was, strictly speaking, LTE FDD. Initially, LTE TDD was promoted as a future upgrade for WiMAX operators interested in pursuing full 4G mobility. However, the support for LTE TDD has been gaining significant traction as a cost- and spectrum-efficient 4G solution for enterprising greenfield operators and even for incumbent mobile cellular operators.

Little difference exists between the access technology protocol of LTE FDD and LTE TDD. The difference really only comes down to how the technologies utilize the spectrum. While LTE FDD caters to how mobile operators have traditionally managed their spectrum in a paired uplink and downlink scheme, LTE TDD works with unpaired spectrum.

Many people in the industry and press have made the mistake of viewing the LTE TDD ecosystem as a niche market. This could not be further from the truth. LTE TDD is not a separate technology from LTE, but rather just a different mode of operation catering to a single block of spectrum. LTE TDD is part of the same LTE ecosystem as LTE FDD. All the chipsets and devices on the market will be capable of LTE TDD on the baseband side. It is only a matter of which spectrum bands the device vendor includes and whether or not that includes TDD spectrum. ABI Research believes that the device vendors' desire to reduce the number of models required to support different networks, traffic demand on mobile operator networks, and global roaming partnerships will all align to show the true value of TDD spectrum and the importance of mobile networks supporting LTE TDD, either alone or in combination with LTE FDD.

[1] The industry commonly uses the term "LTE TDD"

HOW DIFFERENT IS LTE TDD FROM LTE FDD?

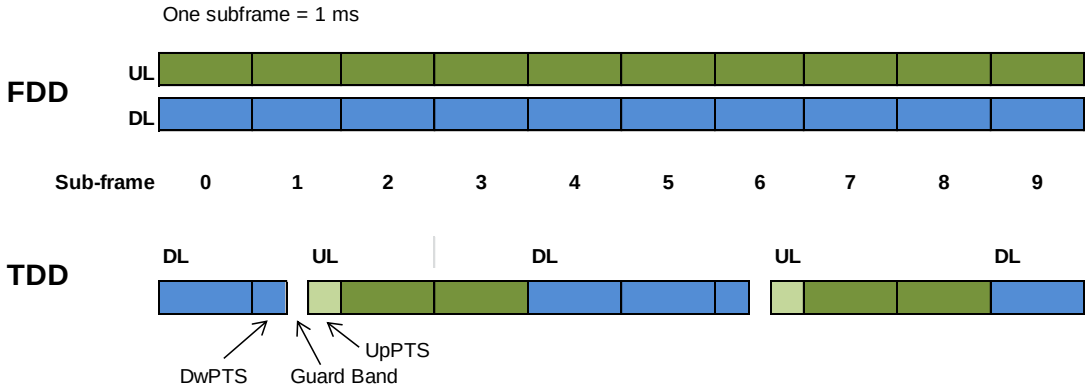
In reality, the underlying technology is the same, but LTE TDD's use of spectrum can pay dividends to the operator and its country. LTE is a 4G mobile wireless air interface technology, which is based on orthogonal frequency division, with a large number of closely spaced, orthogonal sub-carrier signals used to carry data. The prime advantage of orthogonal frequency-division multiple access (OFDMA) over previous schemes is its ability to cope with interference and its higher spectral efficiency.

LTE TDD is LTE that operates in a time-division duplex mode. It is often mistakenly assumed that LTE FDD is the "real" LTE and that LTE TDD is a very different technology. However, LTE is the core technology that can work either in FDD or TDD mode. To keep a consistent nomenclature and to demonstrate the equality of the two access schemes, ABI Research has used the term, "LTE TDD" throughout this paper instead of "TD-LTE".

Traditional mobile wireless technologies use pairs of frequencies close to each other – one for the downlink and one for the uplink. Legacy mobile networks were designed primarily for voice, so the pairs of spectrum were designed to allow for full duplex conversations. Since mobile wireless is increasingly used for data and 4G technologies are all-IP, it does not matter if the transmission works in FDD or in TDD mode. However, for a given amount of spectrum, TDD mode is more spectrally-efficient and has the advantage of allowing mobile operators to decide how much traffic to allocate on the downlink versus the uplink. In many data communications, more traffic is often coming down to the end user than going up to the network. FDD is not as flexible in that regard.

Figure 1: Comparison of FDD LTE Versus TDD LTE

(Source: ABI Research)



© 2012 ABI Research • abiresearch.com
The material contained herein is for the individual use of the purchasing Licensee and may not be distributed to any other person or entity by such. Licensee including, without limitation, to persons within the same corporate or other entity as such Licensee, without the express written permission of Licensor.

PENT-UP DEMAND FOR MOBILE BROADBAND SERVICES

As can be seen from ABI Research's own research, wireless subscriber services have been phenomenally successful. In the United States, total mobile cellular subscriptions stood at 336 million at the end of March 2012 for a 107% penetration and 3G subscriptions represented 74% of the market. However, the demand for high speed mobile broadband is not the preserve of wealthy nations. The average fixed-line broadband penetration in emerging markets is around 10%, which is only growing at 7% CAGR. While Brazil may have a gross domestic product (GDP) per capita that is almost 4 times lower than the United States, cellular penetration stood at 124% and 3G subscriptions took 22% of the market. In China, mobile subscriptions surpassed 1 billion and 3G had a 17% share of the market, while, in India, total cellular subscriptions stood at 925 million and 3G has slowly, but steadily, reached 15% of the market.

Around the world, total mobile subscriptions are expected to eclipse 7.9 billion by 2017. 3G services have done a tremendous job of addressing demand for mobile data services on the go, such as mobile email, browsing, and low-resolution video streaming, but data access is starting to clog up the system. Therefore, mobile operators are looking to LTE to boost data speeds, change the cost equation of delivering mobile broadband services, introduce bold, new services and, just as crucially, add capacity.

© 2012 ABI Research • abiresearch.com

The material contained herein is for the individual use of the purchasing Licensee and may not be distributed to any other person or entity by such.
Licensee including, without limitation, to persons within the same corporate or other entity as such Licensee, without the express written permission of Licensor.

4G IS A GAME CHANGER

The way people use their phones will rapidly change with 4G. 1G started the mobile voice revolution. 2G introduced SMS, mobile email, and other data uses that did not require too much speed. 3G made mobile web browsing and social networking more viable. 4G is bringing about a revolution in inter-active, A/V entertainment as content goes HD and becomes embedded in new end-user experiences. LTE operators, such as SK Telecom of Korea, are starting to see the opportunities for deepening their relationship with the customer through the potential of 4G LTE. Due to the instant "on" video streaming capabilities of LTE, customers can call up any sports, drama, or broadcast TV channel or YouTube clip in HD with no lag. End users do not experience any frustration waiting for video clips to buffer and can speedily jump past sections they have already seen or wish to replay. Not to be outdone, LG U+ of Korea announced in July 2012 that it was introducing an LTE-enabled cloud gaming service that allows customers with smartphones, tablets, or laptops to participate in real-time gaming sessions with friends and family who are playing on their gaming consoles over a fixed-line broadband connection.

3G was meant to bring video chat to life. Unfortunately, the hype could not match the realities of 3G. Latency, constrained bandwidth, and a lack of handsets with front-facing cameras killed off the potential of video-chat before it had the chance to take off. And yet, Skype, with over 660 million subscribers, shows the potential opportunity of video calling. Add to that FaceTime, Google+ Hangouts, and many other third-party video calling services. Mobile operator-provided video over LTE service – a subset of voice over LTE (VoLTE) calling – holds an even greater potential for making the most of LTE.

Another potential innovative business model is provided by LTE TDD, which is very efficient at handling asymmetric traffic, especially for data. As incumbent cellular networks become increasingly congested with traffic, operators are considering data offload strategies. Wi-Fi has been a solution to date, but many end users turn off Wi-Fi when they are not at home or in the office, resulting in the potential benefits of Wi-Fi offloading being squandered as people commute. LTE TDD has the potential to provide an offload mechanism that is always "on," with no need to secure *ad hoc* login/password details and a larger coverage footprint in towns and cities. Clearwire has such a business model for its "Hot Zones" in 31 markets across the United States. A further advantage of LTE TDD for offloading is that public Wi-Fi hotspots, and even carrier-grade Wi-Fi hotspots, do not offer quality of service controls. While this may be acceptable for third-party video calling applications, it would not be acceptable to mobile operators offering their own branded video calling services. This can be especially problematic in very densely populated areas or places where people congregate.

© 2012 ABI Research • abiresearch.com

The material contained herein is for the individual use of the purchasing Licensee and may not be distributed to any other person or entity by such.
Licensee including, without limitation, to persons within the same corporate or other entity as such Licensee, without the express written permission of Licensor.

PENT-UP DEMAND = PENT-UP TRAFFIC?

ABI Research anticipates LTE adoption to be faster than 3G adoption, once LTE handsets become prevalent from a number of vendors and can be supported at subsidized retail price points of $200 to $300. Once LTE handsets fall below that pricing threshold, we expect widespread mass market adoption of LTE handsets, but that may take a couple of years. At the end of March 2012, ABI Research estimates there were 16 million active LTE subscribers worldwide. By the end of 2017, we expect LTE adoption to surpass 660 million, or around 9% of the total cellular market. LTE TDD has had a later start than its LTE FDD counterpart, but the rate of growth is expected to be greater. ABI Research estimates that LTE TDD will show 644% year-on-year (YoY) growth to reach 11 million in 2013 and still show a very respectable 37% YoY growth in 2017 to reach 158 million. Even in 2017, LTE TDD's rate of growth still outstrips LTE FDD by approximately 120%.

Radio spectrum is a finite resource. Equipment manufacturers have been extremely innovative over the years to make the most of this finite resource. Rolling out a cellular radio coverage architecture, combined with more and more advanced modulation and interference management strategies, has succeeded in boosting subscriber capacity. While many networks have already achieved overall subscriber saturation, the growth in mobile broadband traffic has been ramping up alarmingly, on an exponential trajectory. In Korea, the average amount of traffic per 3G user was 1.6 GB/month. In the same country, 4G mobile customers were generating 3 GB of traffic per month. Korean operators are anticipating their networks needing to be able to handle 1 GB per user per day. Around the world, ABI Research estimates annual total traffic will expand from 5.83 Exabytes in 2011 to 103 Exabytes in 2017.

The judicious and careful management of spectrum will become an increasingly important consideration by operators over the next 5 to 10 years. The International Telecommunication Union (ITU) and the World Radio Congress believe an additional 600 MHz to 700 MHz of spectrum could be sourced for LTE, but the spectrum blocks may not be able to provide sufficient spectrum in complementary uplink and downlink of 20 MHz blocks of spectrum. Another challenge is that this additional spectrum may take several years to go through the regulatory hurdles to become available for mobile operators. Essentially, LTE TDD could offer the most efficient use of what is likely to be a limited resource for many operators around the world.

© 2012 ABI Research • abiresearch.com

The material contained herein is for the individual use of the purchasing Licensee and may not be distributed to any other person or entity by such.
Licensee including, without limitation, to persons within the same corporate or other entity as such Licensee, without the express written permission of Licensor.

SPECTRUM PLAYS TO LTE TDD'S ADVANTAGE

The LTE ecosystem is capable of supporting FDD, TDD, or even both modes of LTE in the same market, although guard bands are needed if FDD and TDD are in adjacent spectrum blocks. In fact, mobile devices (smartphones, tablets, USB modems, *etc*.) will be able to hand off from one mode of LTE to another or roam from one mode to the other on a different mobile operator's network.

Do LTE TDD/FDD hardware manufacturers face any challenges? The main gating factor for device manufacturers to support various networks, or to achieve the greatest possible economies of scale with the minimum number of chipset variations, lies in the number of spectrum bands the devices can support.

Roaming is an issue for LTE, since about three dozen LTE bands exist (see Table 1). LTE TDD's 2.3 GHz-2.7 GHz band is well placed to become a potential communications link for LTE end users wishing to access local LTE communications links while travelling for business or pleasure. This advantage stems from the historical development of TDD spectrum. Companies in the industry worked to align certain underused spectrum bands for TDD. The most important bands for WiMAX existed in just two bands: 2.3 GHz and 2.5 GHz. In addition to key mobile operators using TDD spectrum for LTE TDD, ABI Research expects that a large amount of the TDD spectrum that was allocated for WiMAX will be used for LTE TDD either by those operators or re-licensed after WiMAX licenses expire.

Since the 2.3 GHz and 2.5 GHz bands for LTE TDD are likely to be deployed in many of the world's most populous countries, such as China, India, the United States, Japan, Russia, Europe, and Brazil, a strong opportunity exists for LTE TDD to become a key global roaming technology band. LTE TDD networks will exist in many countries since pressure on network capacity created by high data traffic from increasingly powerful mobile devices will cause mobile operators to use whatever spectrum assets they have at their disposal, can acquire through auctions, or can offload to 4G wholesale operators. China Mobile and Clearwire will both have LTE TDD networks on 2.5 GHz spectrum. This will boost the importance of LTE TDD. Indeed, Qualcomm has already announced that its future chipsets, starting in late 2012, will support the 2.5 GHz band. Many smaller chipset vendors already support that band for LTE TDD as well.

© 2012 ABI Research • abiresearch.com

The material contained herein is for the individual use of the purchasing Licensee and may not be distributed to any other person or entity by such.
Licensee including, without limitation, to persons within the same corporate or other entity as such Licensee, without the express written permission of Licensor.

Table 1: Spectrum Bands Allocated to TDD vs. FDD LTE

(Source: ABI Research)

Operat. Mode	Operat Band	Uplink	Downlink	Key Markets Where Allocated
FDD	001	1920 - 1980	2110 - 2170	Asia, Europe, Israel, Japan
FDD	002	1850 - 1910	1930 - 1990	Canada, Latin America, US
FDD	003	1710 - 1785	1805 - 1880	Finland, Germany, Australia, Hong Kong, Japan, Poland, Singapore, South Korea, Eastern Europe, Indonesia
FDD	004	1710 - 1755	2110 - 2155	Canada, Latin America, US
FDD	005	824 - 849	869 - 894	Israel, Latin America, South Korea, Europe
FDD	006	830 - 840	875 - 885	Note: Band 6 is not applicable to LTE anymore
FDD	007	2500 - 2570	2620 - 2690	Canada, Europe, Switzerland, Latin America, Singapore, South-Korea, Hong Kong, Brazil, Malaysia, South Africa
FDD	008	880 - 915	925 - 960	Europe, Latin America
FDD	009	1749.9 - 1784.9	1844.9 - 1879.9	
FDD	010	1710 - 1770	2110 - 2170	Ecuador, Peru, Uruguay
FDD	011	1427.9 - 1447.9	1475.9 - 1495.9	Japan
FDD	012	699 - 716	729 - 746	USA, Canada, Kazakhstan, New Zealand, Taiwan
FDD	013	777 - 787	746 - 756	USA, Canada, Kazakhstan, New Zealand, Taiwan
FDD	014	788 - 798	758 - 768	USA
FDD	017	704 - 716	734 - 746	USA
FDD	018	815 - 830	860 - 875	Japan
FDD	019	830 - 845	875 - 890	Japan
FDD	020	832 - 862	791 - 821	Europe
FDD	021	1447.9 - 1462.9	1495.9 - 1510.9	Japan
FDD	022	3410 - 3490	3510 - 3590	France, Norway, UK, Switzerland, Poland
FDD	023	2000 - 2020	2180 - 2200	
FDD	024	1626.5 - 1660.5	1525 - 1559	
FDD	025	1850 - 1915	1930 - 1995	USA
FDD	026	814 - 849	859 - 894	USA
TDD	033	1900 - 1920		
TDD	034	2010 - 2025		
TDD	035	1850 - 1910		
TDD	036	1930 - 1990		
TDD	037	1910 - 1930		
TDD	038	2570 - 2620		Europe
TDD	039	1880 - 1920		
TDD	040	2300 - 2400		Australia, India, Malaysia, Russia
TDD	041	2496 - 2690		USA, China, Canada, Japan, Poland, Brazil, Mexico, Switzerland, Saudi Arabia, Nigeria
TDD	042	3400 - 3600		Canada, Croatia, France, India, Uruguay
TDD	043	3600 - 3800		

© 2012 ABI Research • abiresearch.com

The material contained herein is for the individual use of the purchasing Licensee and may not be distributed to any other person or entity by such.
Licensee including, without limitation, to persons within the same corporate or other entity as such Licensee, without the express written permission of Licensor.

NETWORKS MOBILIZING LTE TDD

The support that has been building behind LTE TDD is quite remarkable. In the past 2 to 3 years, LTE TDD has built a promising backing from the mobile operator community. Operators are not only innovating to bring on board additional revenue streams, but also to cut operational costs.

As can be seen from Table 2, 10 operators have already commercially launched their LTE TDD networks, while 22 have LTE infrastructure in deployment and another 22 have LTE trials under way. Supporters for LTE TDD include Bharti Airtel, Aircel, Tikona, and Infotel (aka RIL India) in India; China Mobile; Softbank in Japan; Aero2 in Poland; Vividwireless in Australia; Sprint and Clearwire in the United States; Hutchison 3 in Denmark; E-Plus in Germany; and Packet1 in Malaysia. By the end of 2014, ABI Research believes LTE TDD will have achieved commercial status in more than 18 countries. LTE TDD infrastructure support is widespread among companies like Alcatel-Lucent, Ericsson, Huawei, Nokia Siemens Networks, and ZTE.

In terms of major market movers for LTE TDD, Clearwire and China Mobile have provided LTE TDD with a substantial market impetus. Clearwire had established a very respectable footprint for WiMAX (approximately 45% population coverage), but began to see the opportunities for international roaming, greater mobile device choice, and lower infrastructure costs if it were to support LTE TDD. In addition, Clearwire would have a greatly expanded opportunity to service additional MVNO customers, including larger mobile operators who might leverage Clearwire's network for global roaming opportunities, if not also for capacity purposes.

China Mobile has been very much looking for a 4G evolutionary stepping stone for its 3G TD-SCDMA network. To that end, China Mobile installed an LTE TDD trial network at the 2010 Shanghai World Expo. Impressively, reported download and upload speeds were 70 Mbps and 25 Mbps, respectively. China Mobile has followed that up with test trials with 7 global equipment vendors in 6 major Chinese cities. By the end of the year, 20,000 LTE TDD base-stations have been deployed around China in pre-license testing and network rollouts. China Mobile is ordering over 10,000 units of LTE TDD devices for expanded trials. These include USB modems, mobile routers with Wi-Fi, and customer-premises equipment (CPE). China Mobile plans to have 10 models of handsets supporting LTE TDD by mid-2013 and over 100 models by 2014. In July, 2012, China Mobile and Clearwire signed a memorandum of understanding that provides the foundation for international roaming between them.

ABI Research estimates that global LTE TDD coverage will have an addressable population coverage of 4.4 billion by 2014 if network rollouts in key countries are aggressively pursued. LTE TDD coverage could accelerate before then as more mobile operators realize the importance of global roaming by leveraging LTE TDD. In addition, device vendors will look to reduce their SKUs and keep the number of spectrum bands supported to a reasonable number by adopting the LTE TDD bands, which will further attract mobile operator interest.

© 2012 ABI Research • abiresearch.com

The material contained herein is for the individual use of the purchasing Licensee and may not be distributed to any other person or entity by such.
Licensee including, without limitation, to persons within the same corporate or other entity as such Licensee, without the express written permission of Licensor.

Table 2: Status of LTE TDD Operators
Trials, Deployments & Launches, June 2012 *(Source: ABI Research)*

Country	Operator	0.7, 0.8	2.3	2.5, 2.6	3.5 GHz	Start Date	Comments
Commercial Networks							
Australia	NBN Co		X			Apr-12	Intended to serve rural areas
Brazil	Sky Brazil			X		Dec-11	Launched
India	Bharti Airtel		X			Apr-12	Launched
Japan	SoftBank			X		Feb-12	XGP/LTE TDD networks launched
Poland	Aero2			X		May-11	Launched. Dual model FDD/TDD network
Saudi Arabia	Etisalat Mobily			X		Sep-11	Launched
Saudi Arabia	STC			X		Sep-11	Launched
Sweden	3 SWE			X		Dec-11	Launched dual model TDD/FDD network
UK	UK Broadband				X	Jun-12	Commercial
Denmark	3 DK			X		3Q-2012	Hybrid TDD/FDD network
In Deployment							
Croatia	Velatel				X	2Q-2012	In deployment
Hong Kong	China Mobile		X			Expected YE-2012	Acquired BWA TDD & FDD spectrum
Hong Kong	21 Vianet Group		X			Not declared	TDD deployment
Hong Kong	3 HK		X			Not declared	Acquired BWA spectrum for TDD & FDD network
India	RIL		X			Dec-12	In deployment
India	Qualcomm India LTE Venture		X			Not declared	Committed to deployment
India	Tikona Digital		X			Oct-12	Committed to deployment
Malaysia	PacketOne		X	X		Not declared	LTE TDD overlay onto WiMAX network
Malaysia	Asiapace		X			Dec-12	Plans to deploy
Montenegro	Velatel				X	Not declared	In deployment
Nigeria	Zoda Fones				X	Not declared	In deployment
Oman	Omantel		X			Not declared	Plans to deploy
Russia	Rostelecom		X			Dec-13	Planning to deploy
Russia	MTS			X		Not declared	In deployment
Russia	Megafon		X			Not declared	In deployment
Russia	Yota (Scartel)			X		Not declared	Planning to deploy

© 2012 ABI Research • abiresearch.com

The material contained herein is for the individual use of the purchasing Licensee and may not be distributed to any other person or entity by such.
Licensee including, without limitation, to persons within the same corporate or other entity as such Licensee, without the express written permission of Licensor.

Country	Operator	0.7, 0.8	2.3	2.5, 2.6	3.5 GHz	Start Date	Comments
Singapore	IDA (Regulator)			X		2016	Planning to issue LTE TDD spectrum
Uruguay	Dedicado				X	Not declared	Planning to deploy
USA	Clearwire			X		Jun-13	LTE TDD overlay onto WiMAX network
Venezuela	Movilmax			X		Not declared	WiMAX operator plans to deploy
Trials							
Australia	Vivid Wireless		X			2H-2012	Trialing in Sydney
Canada	Xplornet			X	X		Trial under way
China	China Mobile			X		Late 2013, 2014	Trial extended to 20,000 BTS
France	Orange	X		X		Mid 2013	Trial network in Paris supporting TDD & FDD
France	Bollore				X	Not declared	Trial
Germany	E-Plus			X		Not declared	Trial
India	BSNL		X			Not declared	Under consideration
India	MTNL		X			Not declared	Under consideration
Ireland	Communications Regulation		X			Not declared	Conducting a trial with the national regulator
Russia	Voentelecom					Not declared	Trials
Russia	Enforta				X	Late 2012	Trials
Taiwan	Chungwa Telecom			X		Not declared	Intended for railway service. Trialling dual model TDD/FDD
Taiwan	FarEasTone/China Mobile	X				Expected 2013	Trial in Taipei
Taiwan	Global Mobile					Not declared	Requesting switch from WiMAX to LTE TDD trial
Taiwan	FITEL					Not declared	Trials
Thailand	AIS/TOT		X			Not declared	Joint trial

© 2012 ABI Research • abiresearch.com

The material contained herein is for the individual use of the purchasing Licensee and may not be distributed to any other person or entity by such.
Licensee including, without limitation, to persons within the same corporate or other entity as such Licensee, without the express written permission of Licensor.

EVERY LTE DEVICE WILL SUPPORT TDD AND FDD

The adage, "build it and they will come," may work for baseball parks, but not with mobile networks. Mobile devices are the lynchpin. Consumers want choices and are very particular in terms of their needs. Therefore, it is a very promising sign that both LTE FDD and LTE TDD will be widely supported in chipsets and, therefore, in devices. Since TDD is a mode of LTE that works in unpaired spectrum and uses time division, it is already supported in all vendors' LTE baseband chipsets. This means that all devices – smartphones, USB modems, mobile routers, laptops, netbooks, media tablets, e-readers, and other mobile consumer electronics devices – will support LTE TDD. It is simply a matter of what spectrum bands the device vendor chooses to support, rather than whether they plan to support the LTE TDD mode or not.

The support from the semi-conductor chipset manufacturers has been very proactive. Qualcomm, ST-Ericsson, Sequans, and HiSilicon have taped up and put into commercial production a number of single mode LTE TDD or FDD/TDD chipsets, as well as chipsets supporting 2G, 3G, and both modes of LTE. Intel, Nvidia, and Marvell are not far behind in their commercial ramp-up plans. MediaTek and Spreadtrum, normally focused on the white box or "Shanzhai" feature phone market, also have designs on the LTE marketplace.

Commercial LTE FDD/TDD handsets are expected to come to the market in 4Q 2012. In November 2011, ZTE became the first handset vendor to demonstrate a prototype LTE TDD Android handset (the MT73) based on a MediaTek chipset that supports LTE TDD, TD-SCDMA, GSM, and dual SIM. Huawei has officially stated it will be supplying LTE TDD-capable handsets to SoftBank's Wireless City Planning network in 3Q 2012. While ZTE and Huawei may be first to market with LTE FDD/TDD handsets, virtually all the other major handset manufacturers are expected to roll out LTE FDD/TDD handsets within the next year. It is understood that Apple is intending to make sure that its next-generation iPhone 5 is not just capable of LTE FDD/TDD, but also will operate on proposed spectrum bands for the Chinese market.

Currently, 7 LTE chipset vendors are supporting LTE TDD in 15 chipset models that have been released, or will be released soon. At least 15 device vendors have released 68 LTE TDD mobile devices. Also, some of the 3G/LTE FDD devices that are commercially shipping and in use by mobile operators have chipsets that also support LTE TDD spectrum bands, even though that is currently not advertised. A table of LTE TDD-capable chipsets and a table of LTE TDD-capable devices can be found in the Appendix below.

© 2012 ABI Research • abiresearch.com

The material contained herein is for the individual use of the purchasing Licensee and may not be distributed to any other person or entity by such.
Licensee including, without limitation, to persons within the same corporate or other entity as such Licensee, without the express written permission of Licensor.

EXPANDING AND UNIFYING THE LTE ECOSYSTEM

Having operator support is a definite plus, but it is also crucial to build an ecosystem to support it. To that end, the Global TD-LTE Initiative (GTI) was formed in February 2011 to promote cooperation among mobile operators implementing LTE TDD. It was started by key mobile operators, but is meant to promote a healthy market for all companies in the mobile ecosystem looking to support LTE TDD.

The GTI's stated objectives are:

- Energizing the creation of a world-class and growth-focused business environment.
- Delivering great customer experiences and bringing operational efficiencies.
- Promoting convergence of LTE FDD and LTE TDD in order to maximize economies of scale.
- Facilitating multilateral cooperation between and/or among operators.

© 2012 ABI Research • abiresearch.com

The material contained herein is for the individual use of the purchasing Licensee and may not be distributed to any other person or entity by such.
Licensee including, without limitation, to persons within the same corporate or other entity as such Licensee, without the express written permission of Licensor.

Of these four objectives, the last two are crucial. The third objective seeks to ensure that LTE TDD is not a stand-alone ecosystem, but rather part of the whole LTE ecosystem, along with LTE FDD. The fourth objective ensures that LTE TDD mobile operators align their interests for their own benefit and also encompasses work on roaming policies and forming roaming agreements. The GTI has 48 mobile operator members as shown in Table 3.

Table 3: List of GTI Members
48 Operators, July, 2012 *(Source: ABI Research)*

Western Europe	Eastern Europe	Asia-Pacific	North America	Latin America	Middle East	Africa
Datame (Finland)	Antares (Russia)	Bell Tell Communications (Philippines)	Clearwire (USA)	NII Holdings (Chile, Mexico, Brazil)	Omantel (Oman)	8ta (South Africa)
E-Plus (Germany)	Smoltelecom (Russia)	Bharti Airtel (India)	Direct TV (USA)	Telecommunications Services of Trinidad and Tobago		iBurst (South Africa)
Imagine Group (Ireland)	Soyuz Telecom (Russia)	China Mobile	Dish Network	VelaTel Global Communications (Peru)		
Tellhigh Telecom	Voentelecom (Russia)	Cybernet (Pakistan)	Horizon Wi-COM (USA)	WIND (Dominica)		
UK Broadband		Far EasTone (Taiwan)	NextWave Wireless (USA, Canada)	VTR (Chile)		
Vodafone (UK & global)		FITEL (Taiwan)	Sprint (USA)			
		Global Mobile (Taiwan)	Xplornet Communications (Canada)			
		Indochina Telecom (Vietnam)				
		KT (Korea)				
		NBN Co (Australia)				
		Optus (Australia)				
		Packet One Networks (Malaysia)				
		SK Telecom (Korea)				
		Softbank Mobile (Japan)				
		Tatung InfoComm (Taiwan)				
		VelaTel Global Communications (China)				
		Vividwireless Group (Australia)				
		Woosh (New Zealand)				

© 2012 ABI Research • abiresearch.com

The material contained herein is for the individual use of the purchasing Licensee and may not be distributed to any other person or entity by such.
Licensee including, without limitation, to persons within the same corporate or other entity as such Licensee, without the express written permission of Licensor.

In addition to the mobile operators, there are 27 GTI partners that come from a variety of hardware, IP, and software vendor backgrounds. They are outlined in Table 4.

Table 4: List of GTI Partners
27 Partners, July, 2012 *(Source: ABI Research)*

Company	Profile
Alcatel-Lucent Shanghai Bell	A joint venture based in China that has access to Alcatel-Lucent's wireless and wireline technologies and develops products for the Chinese market
Altair Semiconductor	Chipset vendor providing high performance chipsets supporting both TD-LTE and FDD-LTE technologies.
Anite Telecoms	Anite offers simplified device testing, to ensure faster routes to market for new devices.
Anritsu Corporation	The company has test and measurement solutions covering wireless, optical, microwave/RF and digital instruments, operations support systems
CATR	China Academy of Telecom Research (CATR) is an independent research organization that offers standardization, consultancy and test services in China.
Comba Telecom Systems(China)	Provides infrastructure and solutions to mobile operators and enterprises to enhance and extend their wireless communications networks
Datang	Datang is a state-owned enterprise with a product and service portfolio ranging from wireless mobile telecommunications, circuit design and manufacturing, to information security.
Ericsson	Infrastructure vendor dedicated to delivering services, software and infrastructure within Information and Communications Technology for telecom operators and other industries.
Multi-Micro (Fujian) Electronic Tech	Focusses on R&D and manufacturing of smaller/lighter/smarter RF & microwave products for LTE communications.
Fujitsu Semi-Conductor	Innovates in RF transceivers for mobile cellular handsets and other portable wireless devices.
Gemtek Technology	Provider of Wireless Broadband solutions, offering a wide range of products such as WiFi, WiMAX, LTE, Femto cell, IP STB, IP Camera, IAD ,etc. from residential to enterprise.
Hisilicon Technologies	HiSilicon provides ASICs and solutions for communication network and digital media.
Huawei	Huawei is a comprehensive ICT solutions provider that address the needs of carrier networks, enterprise, consumer, and cloud computing clients.
HOJY Wireless	HOJY's products cover mobile hotspots (MIFI) and dongles, ranging from TD-SCDMA and WCDMA to LTE.
Marvell Semiconductor	Marvell is a fabless semiconductor company, with expertise in microprocessor architecture and digital signal processing.
MOBI Antenna Technologies	Designs and manufactures a wide range of Antenna, RF devices and Wireless Coverage Solutions.
NEC	The vendor offer solutions that allow integration of IT and network technologies that benefit businesses and people around the world.
Nokia	Nokia manufacturers mobile handsets and smartphones and develops software and apps.
Nokia Siemens Networks	NSN, a telecoms infrastructure vendor is dedicated to the mobile broadband market.
Rohde & Schwarz	Rohde & Schwarz delivers test and measurement, broadcasting, secure communications, radio monitoring and radiolocation solutions to its clients.
Sequans Communications	Supplies LTE, WiMAX, and dual-mode LTE/WiMAX semiconductor solutions to original design manufacturers and original equipment manufacturers worldwide.

© 2012 ABI Research • abiresearch.com

The material contained herein is for the individual use of the purchasing Licensee and may not be distributed to any other person or entity by such.
Licensee including, without limitation, to persons within the same corporate or other entity as such Licensee, without the express written permission of Licensor.

Company	Profile
Spreadtrum Communications	A fabless semiconductor company that develops mobile chipset platforms for mobile devices, supporting 2G, 3G and 4G wireless communications standards.
ST-Ericsson	Offers design and development of cutting-edge mobile platforms and semiconductors across the broad spectrum of wireless technologies.
Tongyu Communication	Tongyu has a portfolio of products from base station antennas, microwave antennas, microwave components, to indoor & outdoor and terminal antennas.
Xi'an Sunnada Haitian Antenna	Has developed a wide range of antennas including 2G/3G Ultra Wideband VEDT Antennas, LTE/WiMAX Antennas, TD-SCDMA and TD-LTE Smart Antennas.
ZTE	Multinational telecommunication company that address the telecom infrastructure and mobile device market.

The GTI's working groups are ensuring that many of the issues surrounding LTE TDD in the earlier stages of the LTE market are addressed. 6 of the 10 topics are led by Clearwire and China Mobile (with three each), but other operators are also helping spearhead the necessary product and service innovation to make LTE TDD a success. Vodafone is responsible for Evolved Node B (base-stations) Product Planning & Specification; SoftBank has Dynamic eMBMS (evolved Multimedia Broadcast Multicast Services); and Bharti is taking care of Voice Solution for LTE-TDD handsets.

The GTI continues to grow. Most recently, Nokia Siemens Networks, which has seven commercial LTE TDD deals around the world and is in trials with China Mobile, joined the group in June 2012. More companies are expected to join.

© 2012 ABI Research • abiresearch.com

The material contained herein is for the individual use of the purchasing Licensee and may not be distributed to any other person or entity by such.
Licensee including, without limitation, to persons within the same corporate or other entity as such Licensee, without the express written permission of Licensor.

LTE TDD IS A CRITICAL PART OF THE LTE ECOSYSTEM

It is important to recognize that LTE TDD is not a separate ecosystem from LTE FDD, but rather an integral part of it. From chipsets to devices to networks, LTE TDD can, and will be, easily supported. The issue of support for LTE TDD is a matter of supporting LTE TDD spectrum bands, rather than the baseband technology itself. Key LTE TDD bands are harmonized around the world, being used in mobile operator networks and being strongly supported by Clearwire, China Mobile, Bharti-Airtel, Softbank, as well as other mobile operators around the world. Based on current commitments, ABI Research estimates that at least 158 million LTE TDD subscribers will exist globally by 2017 and an estimated 85% will be using the 2.3 GHz to 2.7 GHz bands. With a potential addressable population of 4.4 billion, the eventual adoption profile could be even higher. Mobile operators will have to leverage all their spectrum assets they have, or can obtain, so many LTE networks will most likely end up supporting both FDD and TDD modes, even if the mobile operator does not at present have TDD spectrum.

LTE TDD will not only be highly relevant, but will be crucial to solving the extreme spectrum fragmentation that LTE suffers in general. Many FDD bands will be used for roaming, but too many FDD bands exist that will be specific to certain regions or countries. Far fewer TDD bands exist for LTE and, of those, a number of them are present in several regions and key markets, making LTE TDD effectively global in nature. The 2.3 GHz to 2.7 GHz bands will end up being critical for global LTE roaming. Mobile operators with such spectrum bands will play a key role in global LTE roaming, not just for their own subscribers, but for subscribers of partnering mobile operators as well. Mobile operators deploying LTE TDD with an extensive amount of spectrum can potentially offer wholesale services to MVNOs, including other major mobile operators looking for capacity relief through various forms of offloading. This will reinforce LTE TDD by making it, and its associated spectrum bands, even more important for inclusion into devices.

© 2012 ABI Research • abiresearch.com

The material contained herein is for the individual use of the purchasing Licensee and may not be distributed to any other person or entity by such.
Licensee including, without limitation, to persons within the same corporate or other entity as such Licensee, without the express written permission of Licensor.

APPENDIX

Table 5: List of Available LTE TDD-capable Chipsets
July, 2012
(Source: ABI Research)

Vendor	Model	Launched	Capabilities
Qualcomm	MDM9200	Mid-2011	Single Mode: LTE (TDD/FDD), SVLTE-DB, DC-HSPA+, 1x EV-DO Rev. A/B. ARMv7 Cortex A5
Qualcomm	MDM9600	Mid-2011	World-mode: LTE (TDD/FDD), SVLTE-DB, DC-HSPA+, 1x EV-DO Rev. A/B. ARMv7 Cortex A5
ST-Ericsson	THOR M7400	2Q-2011	LTE FDD/TDD, HSPA+, TD-SCDMA, EDGE. Radio supporting up to 8 LTE/WCDMA/GSM bands
Innofidei	LTE Phase 1	1Q-2010	Based on 65 nm process, and supports LTE TDD
Innofidei	P3A Chip	Oct-10	Supporting TDD-LTE
Innofidei	Warp drive 5000	Sep-11	Based on 40 nm process, and supports LTE TDD and FDD
Altair	FourGee 3100/6200	4Q-2011	Supports FDD+TD-LTE on a single chipset on any band between 700-2700 MHz
MediaTek	Not released	2Q-2012	TD-LTE+TD-SCDMA/GSM Chipset. Embedded in the first LTE TDD handset prototyped by ZTE (the MT73) intended for the China Mobile network
Huawei	Hi6910	4Q-2011	Supports single mode TDD 2300/2600 MHz & FDD 800/1800/2600 MHz. Present in the Huawei Vodafone B1000 LTE Router
Sequans	SQN3010	Mar-10	Sequans' first LTE chip. Supports TDD and FDD LTE in the 2.5, 2.3 and 2.6 GHz bands
Sequans	SQN3110, SQN3120	Oct-11	Based on a 40 nm fabrication process. Supports TDD and FDD LTE in the 2.5, 2.3 and 2.6 GHz bands
Sequans	SQN3120	Oct-11	Supports WiMAX 2.3, 2.5 and 3.5 GHz bands and TD-LTE band classes 2.5, 2.3, 2.6, 3.4, and 3.6 GHz bands
Sequans	SQN5120	Oct-11	Based on a 40 nm fabrication process. Supports TDD and FDD LTE and WiMAX

© 2012 ABI Research • abiresearch.com

The material contained herein is for the individual use of the purchasing Licensee and may not be distributed to any other person or entity by such.
Licensee including, without limitation, to persons within the same corporate or other entity as such Licensee, without the express written permission of Licensor.

Table 6: List of Available LTE TDD-capable Devices
July, 2012

(Source: ABI Research)

			Bands Supported (GHz)					
Vendor	**Model**	**Type**	**0.7, 0.8**	**1.8**	**1.9**	**2.1**	**2.3**	**2.5**
Altair	AOL-T190, TD-LTE Multi-Mode Outdoor CPE	CPE		X			X	X
Altair	ALM-F190, TD-LTE Multi-Mode MIFI	Mobile router		X			X	X
Altair	ALT-C186, Altair TD-LTE Multi-Mode Dongle	USB modem	X				X	X
ATEL	USB Dongle	USB modem					X	X
DaTang/Leadcore	USB Dongle	USB modem					X	X
Huawei	B593 Indoor CPE	CPE					X	X
Huawei	E589 Mobile Wi-Fi	Mobile router					X	X
Huawei	E398 LTE TDD/FDD Dual Mode	USB modem					X	X
Huawei	Multi-mode USB Dongle	USB modem					X	X
Huayu	TD-LTE Multi-Mode mobile router	Mobile router		X			X	X
Innofidei	TD-LTE CPE	CPE					X	X
Innofidei	TD-LTE miniCard	miniCard					X	X
Innofidei	LTE dongle	USB modem					X	X
Innofidei	TD-LTE USB Dongle	USB modem					X	X
Nokia	TD-LTE Booklet	netbook					X	X
Nokia Siemens	Smart Robot	Robot					X	X
NSN	CPEi 7212 Indoor CPE	CPE					X	X
NSN	CPEo 7210 Outdoor CPE	CPE					X	X
NSN	TD-LTE MIFI	Mobile router					X	X
NSN	USB-LTE 7210	USB modem					X	X
Qualcomm	USB Dongle	USB modem					X	X
Quanta	TD-LTE NK1	Media tablet					X	X
Quanta	Mobile Router	Mobile router	X	X	X	X	X	X
Quanta	USB dongle	USB modem					X	X
Samsung	USB Dongle	USB modem					X	X
Sequans	Indoor CPE SQN3010	CPE					X	X
Sequans	TD-LTE USB Dongle	USB modem					X	X
ZTE	CPE MF29T	CPE					X	X
ZTE	CPE MF91T	CPE					X	X
ZTE	LTE Phone	Handset					X	X
ZTE	MF820T USB Modem	USB modem					X	X
ZTE	MF880 USB Modem	USB modem					X	X

© 2012 ABI Research • abiresearch.com

The material contained herein is for the individual use of the purchasing Licensee and may not be distributed to any other person or entity by such.
Licensee including, without limitation, to persons within the same corporate or other entity as such Licensee, without the express written permission of Licensor.

ACRONYMS

2G	Second Generation
3G	Third Generation
4G	Fourth Generation
Addressable Population Coverage	This is based on the population of each country that either has allocated spectrum for LTE TDD, or will do so by 2014. It is therefore different from "Population Coverage" which reflects radio access network infrastructure deployed to provide 4G cellular coverage. Addressable Population Coverage therefore represents a maximum potential addressable market.
ASIC	Application-specific Integrated Circuit
A/V	Audio / Video
CAGR	Compound Average Growth Rate
CPE	Customer-Premises Equipment
DSL	Digital Subscriber Line
eMBMS	evolved Multimedia Broadcast Multicast Services
Exabyte	A measure of electronic data stored or downloaded onto a PC or mobile device. 1×10^{18}, i.e. 1 followed by 18 zeros.
FDD	Frequency Division Duplex. In this scheme the transmitter and receiver operate in different frequency blocks.
GB	Gigabyte. A measure of electronic data stored or downloaded onto a PC or mobile device. 1×10^{9}, i.e. 1 followed by 9 zeros.
GDP	Gross Domestic Product
GTI	Global TD-LTE Initiative
HD	High Definition
ICT	Information and Communications Technology
IP	Internet Protocol
IT	Information Technology
ITU	International Telecommunication Union
LTE	Long Term Evolution. A 4G mobile access technology. Used as the umbrella term for LTE TDD and LTE TDD networks.
LTE FDD	Often what is strictly speaking "LTE TDD" is in fact referred to as just "LTE" in the media. This is because when LTE was first proposed, it was presumed 4G LTE would be deployed in its FDD configuration.
LTE TDD	Similarly, "LTE TDD" has been loosely referred to as "TD-LTE." To keep a consistent nomenclature, and to demonstrate the equality of the two schemes, ABI Research has elected to use "LTE TDD" throughout this paper.
OEM	Original Equipment Manufacturer
OFDMA	Orthogonal Frequency-Division Multiple Access
SIM	Subscriber Identity Module
SKU	Stock-keeping Units. Refers to how many (e.g., handset) models and/or variants are needed to support the needs of its target markets.
SMS	Short Messaging Service
STB	Set-top Box
TDD	Time Division Duplex. In this scheme the transmitter and receiver operate in the same frequency block and use a strict timing mechanism to keep traffic on the downlink and uplink separate.
TD-LTE	See "LTE TDD".
USB	Universal Serial Bus
VoLTE	Voice over LTE
WCDMA	Wideband Code Division Multiple Access
WiMAX	Worldwide Interoperability for Microwave Access. A 4G mobile access technology.
YoY	Year-on-Year

© 2012 ABI Research • abiresearch.com

The material contained herein is for the individual use of the purchasing Licensee and may not be distributed to any other person or entity by such.
Licensee including, without limitation, to persons within the same corporate or other entity as such Licensee, without the express written permission of Licensor.

TABLE OF CONTENTS

TDD LTE – MAKING THE MOST OF 4G 1
HOW DIFFERENT IS LTE TDD FROM LTE FDD? 2
PENT-UP DEMAND FOR MOBILE BROADBAND SERVICES 3
4G IS A GAME CHANGER 4
PENT-UP DEMAND = PENT-UP TRAFFIC? 5
SPECTRUM PLAYS TO LTE TDD'S ADVANTAGE 6
NETWORKS MOBILIZING LTE TDD 8
EVERY LTE DEVICE WILL SUPPORT TDD AND FDD 11
EXPANDING AND UNIFYING THE LTE ECOSYSTEM 12
LTE TDD IS A CRITICAL PART OF THE LTE ECOSYSTEM 16
APPENDIX 17
ACRONYMS 19
TABLE OF CONTENTS 20
Sources and Methodology 21
Notes 21

© 2012 ABI Research • abiresearch.com

The material contained herein is for the individual use of the purchasing Licensee and may not be distributed to any other person or entity by such.
Licensee including, without limitation, to persons within the same corporate or other entity as such Licensee, without the express written permission of Licensor.

SOURCES AND METHODOLOGY

An analyst was assigned to coordinate and prepare this Research Report. Research and query specialists helped lay the data and information groundwork for the analyst, who also developed a focused interview strategy.

ABI Research teams follow a meticulous process when examining each market area under study. The three basic steps in that process are: information collection, information organization, and information analysis.

The key element in ABI Research's information collection process is developing primary sources, that is, talking to executives, engineers, and marketing professionals associated with a particular industry. It is from these conversations that market conditions and trends begin to emerge, free from media hype.

Analysts use secondary sources as well, including industry periodicals, trade group reports, government and private databases, corporate financial reports, industry directories, and other resources.

Analysts' conclusions take several forms. The text addresses hard data and well-defined trends and is supported by forecast tables and charts. The text also addresses issues and trends that are difficult to quantify and present in neat, tabular form. Lying at the margins of an industry, they are often precursors of the next technology wave.

NOTES

CAGR refers to compound average annual growth rate, using the formula:

CAGR = (End Year Value ÷ Start Year Value)$^{(1/\text{steps})}$ – 1.

CAGRs presented in the tables are for the entire time frame in the title. Where data for fewer years are given, the CAGR is for the range presented. Where relevant, CAGRs for shorter time frames may be given as well.

Figures are based on the best estimates available at the time of calculation. Annual revenues, shipments, and sales are based on end-of-year figures unless otherwise noted. All values are expressed in year 2012 U.S. dollars unless otherwise noted. Percentages may not add up to 100 due to rounding.

© 2012 ABI Research • abiresearch.com

The material contained herein is for the individual use of the purchasing Licensee and may not be distributed to any other person or entity by such.
Licensee including, without limitation, to persons within the same corporate or other entity as such Licensee, without the express written permission of Licensor.

Published September 10, 2012
Updated September 26, 2012
Updated October 24, 2012

©2012 ABI Research
PO Box 452
249 South Street
Oyster Bay, NY 11771 USA
Tel: +1 516-624-2500
Fax: +1 516-624-2501
http://www.abiresearch.com/analystinquiry.jsp

ALL RIGHTS RESERVED. No part of this document may be reproduced, recorded, photocopied, entered into a spreadsheet or information storage and/or retrieval system of any kind by any means, electronic, mechanical, or otherwise without the expressed written permission of the publisher.

Exceptions: Government data and other data obtained from public sources found in this report are not protected by copyright or intellectual property claims. The owners of this data may or may not be so noted where this data appears.

Electronic intellectual property licenses are available for site use. Please call ABI Research to find out about a site license.

The material contained herein is for the individual use of the purchasing Licensee and may not be distributed to any other person or entity by such.
Licensee including, without limitation, to persons within the same corporate or other entity as such Licensee, without the express written permission of Licensor.