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Unravelling Long Term Evolution (LTE) Ownership and Adoption Challenges

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Abstract

LTE short for Long Term Evolution is most widely used 4G technology today. It is in the process of deployment around the world. It is used as a wireless communication of high-speed data for mobile phones and data terminals. More and more companies are developing it as per their own requirements. Despite of so much development, LTE faces some concerns. This paper is a means to study the ownership of LTE network, concerns faced by service providers and measures to solve them.

Keywords: 3GPP, Downlink, Global System for Mobile Communications (GSM), Long Term Evolution (LTE), Quality of Service (QoS), Spectrum, Uplink

1. Introduction

Nowadays, the use of devices like Laptops, smart phones, tablets etc. that offer the ease and convenience of internet applications like Email and Web browsing on the go is widespread. As these devices become common, user expectations also rise in terms of high data rates, instant internet connectivity and a much larger variety of applications to play with. 4G technologies are what make the promise of such expectations real. Long Term Evolution (LTE) is a 4G technology offering services and it is currently in the process of being deployed around the world. LTE is a 3rd Generation Partnership Project (3GPP) and it stands for Long Term Evolution. It is a wireless data communications technology standard and an evolved version of UMTS/GSM standards. LTE is used as a standard of wireless communication of high-speed data for mobile phones and data terminals.

The paper is organized as follows: In section 2, LTE is discussed. In section 3, LTE architecture is explained. In section 4, Companies that provide LTE Network is provided with detailed description of 5 companies. These are Motorola, Samsung, Nokia, Ericsson and Sony. Section 5 shows, Company that adopted LTE in a world map with operators' list of Asia. In section 6, barriers to LTE adoption is provided. Section 7 shows key operator considerations and measures to realize them and Section 8 concludes the paper.

2. Objective

LTE is in the process of deployment around the world. It is used as a wireless communication of high-speed data for mobile phones and data terminals. More and more companies are developing it as per their own requirements. Despite of so much development, LTE faces some concerns. The objective of this paper is a means to study the ownership of LTE network, concerns faced by service providers and measures to solve them.

3. Literature Review

3.1 Long Term Evolution (LTE)

LTE is part of the GSM evolutionary path for mobile broadband following EDGE, UMTS, HSPA (HSDPA and HSUPA combined) and HSPA Evolution (HSPA+)[1] (Figure 1).

With the help of DSP (Digital Signal Processing) techniques and modulations, LTE increases the capacity and speed of wireless data networks.

LTE provides:

- 100 Mbit/s for downlink
- 50 Mbit/s for uplink
- QoS provisions, that permits a transfer latency of 10-15 ms which is evolving beyond 300 Mbps.

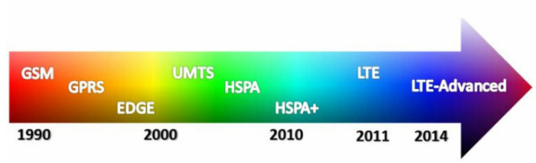

Figure 1. 3GPP Family Technology Evolution[1].

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LTE can manage fast-moving mobiles as well as multicast and broadcast streams.

LTE supports:

- Carrier Bandwidth scalable from 1.4 to 20 MHz Frequency Division Duplexing (FDD)
- Time Division Duplexing (TDD).

LTE standard can be used with different frequency bands and their deployment is increasing rapidly among the world.

Through Table 1 it is evident that, frequencies vary in different continents. Therefore, phones supporting LTE from one country may not work in other countries. Moreover, availability of LTE network is operator-dependent and may vary from area to area within a country[2].

Radio access of LTE is known as Evolved UMTS Terrestrial Radio Access Network (E-UTRAN).

It is expected to:

- Improve end-user throughputs and sector capacity.
- Reduce user plane latency
- Improved user experience with help of full mobility.

With the help of Internet Protocol (IP), LTE will support IP-based traffic with end-to-end QoS (Quality of service). Voice traffic is supported as Voice over IP (VoIP) and enables better integration with other multimedia services (Table 2).

On the downlink, LTE uses Orthogonal Frequency Division Multiple Access (OFDMA) which offers high peak data rates in high spectrum bandwidth. And for Uplinks it uses Single Carrier FDMA (SC-FDMA)[1] (Table 3).

Table 1. LTE Band deployment around the world

Countries' Name	Bands present
Asia	850, 1500, 1800, 2100, 2300 and 2600 MHz
Australia	1800 MHz
Europe	800, 900, 1800, 2600 MHz
North America	700, 850, 1900 and 1700/2100 MHz
South America	700, 1700/2100 and 2600 MHz

Table 2. Requirements for LTE performance

Metric	Value
Coverage(cellsize)	5-100 km
Control plane capacity	> 200 users per call
Control plane latency	<100 ms
Mobility support	Upto 500kmph
Peak data rate	Downlink: 100Mbps Uplink: 50Mbps
Spectrum flexibility	1.25, 2.5, 5, 10, 15 and 20 MHz
User plane latency	<5 ms

Table 3. LTE capabilities[1]

Metric	Functionality
Downlink data rate	Up to 326 Mbps
Downlink bandwidth	20 MHz
Operate in	TDD and FDD
Bandwidth	1.4, 3, 5, 10, 15 and 20 MHz
Latency	up to 10 milliseconds (ms) round-trip between user equipment and the base station < 100 ms from inactive to active

LTE relies on physical layer technologies like:

- Multiple-Input Multiple-Output (MIMO) systems
- Orthogonal Frequency Division Multiplexing (OFDM)
- Smart Antennas, to achieve these targets.

3.2 Main Objectives of LTE

- Allow flexible spectrum deployment within existing or new frequency spectrum
- Exist peacefully with other 3GPP Radio Access Technologies (RATs).
- Minimize System and User Equipment (UE) complexities

Number of people with access to LTE technology rose from zero to more than 200 million people. Also there are 40 live LTE networks in 24 countries.

LTE has been purposely designed to work flexibly across paired and unpaired, FDD and TDD spectrum. It supports bands ranging from 1.4 MHz up to 20 MHz. Also it works seamlessly with 3G technologies[3].

3.3 LTE Patents Filed by Service Operators[4,10,15]

Details of who pays whom for the rights to create LTE handsets aren't public, but Peter Misek, of Jefferies & Co., checked 1,400 patents related to the next-generation mobile communications standard and advised investors (and Forbes) of the resultant calculated ownership breakdown. LTE is the preferred 4G standard. Every LTE handset will have to pay royalties to those with the patents. LG Electronics has the biggest share of the spoils with 23 per cent of the pot. Qualcomm comes second with 21 per cent. After the biggies, there is Motorola, which is now the property of Google and InterDigital. Chinese companies are also catching up with the patent thing. Nortel's patents are owned by a cross-licensing consortium of manufacturers including Apple and Microsoft, which do not appear anywhere else in the analysis. The analysis only covers the core radio technologies, rather than covering interface or design where both the companies are amply represented[14] (Figures 2 and 3).

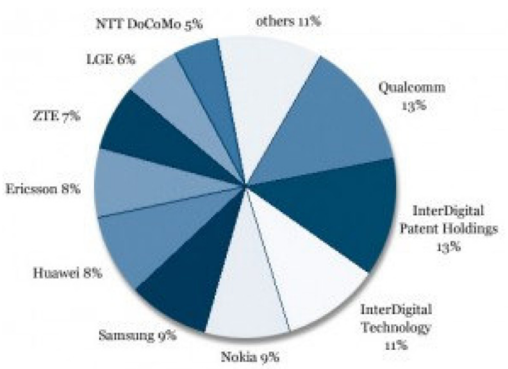

Figure 2. Distribution of patents[10].

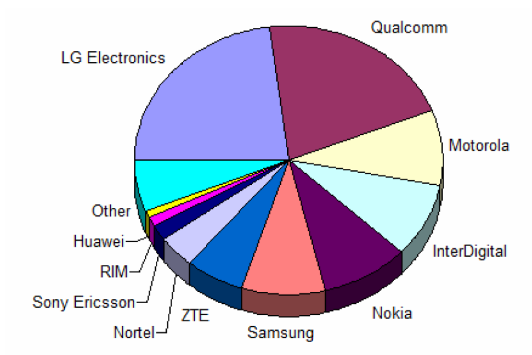

Figure 3. Peter Misek's analysis of who owns LTE ?[14].

3.4 LTE User Devices' Market Share

LTE User Devices' market share by Aug 2013 is shown in Figure 4.

3.5 LTE User Device Segmentation

LTE User Device Segmentation of 3 years is shown in Figure 5.

4. LTE Architecture

The architecture (Figure 6) has following functional elements:

a. Evolved Radio Access Network (RAN for LTE) consists of a single node, eNodeB (or eNB) that interfaces with the UE.
b. Serving Gateway (SGW) routes and forwards user data packets and also acts as the mobility anchor during inter eNB handovers and between LTE and other 3GPP technologies.
c. Mobility Management Entity (MME) is the key control node for the LTE access network. It is responsible for idle mode UE tracking and paging procedure including retransmissions.
d. Packet Data Network Gateway (PDN GW) provides connectivity to UE with external packet data networks by being the only entry or exit point for traffic for UE.

Features of LTE include:

i) S1-flex Mechanism: This concept provides support for network redundancy and load sharing of traffic across all network elements in the CN, MME and SGW. This is done by creating pools of MMEs and SGWs and allowing each eNB to be connected to multiple MMEs and SGWs in a pool.
ii) Network Sharing: LTE architecture enables service providers to reduce the cost of owning and operating the network by allowing the service providers to have separate CN (MME, SGW, PDN GW). The E-UTRAN (eNBs) is one and is jointly shared by them[5].

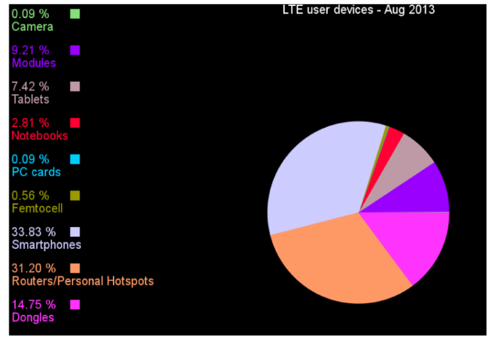

Figure 4. LTE User Devices' market share by Aug 2013.

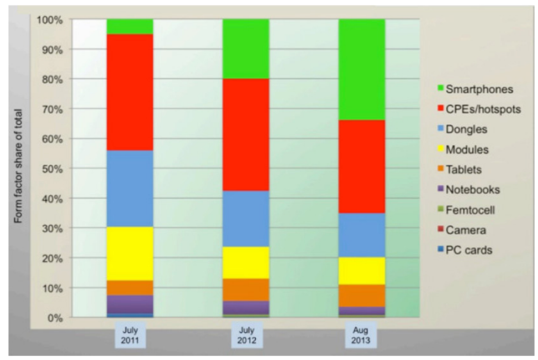

Figure 5. LTE User Device Segmentation of 3 years.

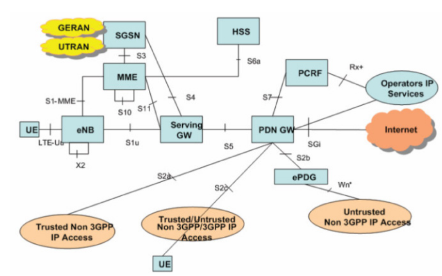

Figure 6. High level architecture for 3GPP LTE[5].

5. Data Discussion and Methodology

Companies that Provide LTE

Following companies support LTE Network:

Alcatel, Apple, Asus, AVM, BlackBerry, Casio, D-Link, HTC, Huawei, LG, Motorola, NEC, Netgear, Nokia, Nokia Siemens

Networks, Novatel Wireless, Option, Pantech, Samsung, Sony, Sierra Wireless and ZTE[6].

5.1 Motorolla[5]

Motorola has been very active in the development of LTE standards and is pushing for an architecture in which all the radio-specific functions are present at eNB, cellular specific control functionality is contained in control-plane nodes and CN user-plane nodes can be based on generic IP routers.

Motorola has made important contributions on following:

- Flat Radio Access Network (RAC) architecture
- Termination of RLC and PDCP protocol layers in the eNB
- Distributed radio resource management using direct eNB to eNB interaction
- Control-plane and user-plane separation which resulted in the split between MME and serving gateway
- Efficient TA conception for idle mode mobility
- Use of IETF mobility protocols, specifically (proxy) Mobile IP for mobility on the different interfaces
- MBMS and SFN operation.
- Enabling SGW sharing between service providers
- Mobility solutions in active mode which includes context transfer at RLC/PDCP layers, location of packet reordering function etc.

Motorola's position on the LTE architecture has been motivated by maximizing reuse of components and network elements across different technologies. Our position has been driven by the desire to reuse generic routers and IETF-based mobility protocols and network elements, such as, Home Agent (HA) and Foreign Agent (FA).

A key issue that has been decided as per Motorola's preference is, placement of user-plane encryption and header compression functionality at the eNB. Motorola is also actively supporting mobility between 3GPP and non-3GPP networks such as, WiMAX, to enable seamless mobility of dual-mode devices across these technologies.

They also helped in eliminating a centralized server for inter cell RRM and also suggested that it can be performed in a distributed fashion at eNBs. It was done by showing that a centralized server requires frequent measurement reports from the UE. When RRM is distributed, eNBs can report their load information to neighboring cells on the basis of events like load of cell reaching 90%. This load information can then be used by neighboring eNBs to decide whether handover to this particular eNB should be allowed or not.

5.2 Ericsson[3]

Ericsson services for LTE include:

- Consulting,
- systems integration and managed services,
- network deployment and integration,
- education and support services.

Operators that took up managed services for LTE from Ericsson are:

1. TDC, Denmark
2. Verizon
3. MetroPCS, USA

Ericsson's services for LTE helped deliver excellent user experience by smartphone audits. The company is working regularly with device manufacturers to ensure that new models perform to their best in tandem with new network features.

Delivering a consistent LTE user experience requires:

- Handsets
- Radio network
- End-to-end knowledge of how various IP nodes interact across the network.

Ericsson's strategy for LTE was to deliver a high-speed and responsive network that delivers significantly better user experience.

5.3 Samsung Smart LTE Network[7]

Samsung's innovation played a major part in the efficiency of the network. It delivers an enhanced mobile broadband capability to support the connectivity requirements of mobile users across the world. Its network has transformed user experience by changing the way in which information and content was received and consumed. This is achieved by increasing network throughput for subscribers by reducing running costs for operators.

Reduced interference provides the network with increased data transfer speed and smooth handover between cells, which resulted in an enhanced all-round performance. Samsung's Network comes in three configurations, namely centralised, distributed and hybrid. All of them are available for both Frequency Division Duplexing (FDD) and Time Division Duplexing (TDD).

Samsung Smart Cluster enhanced network connectivity by reducing inter-cell interferences and boosting the network's operational performance. It can be easily deployed using Ethernet backhaul. This resulted in the significant reduction in capital expenditure (CAPEX) and operational expenditure (OPEX), as well as it also decreased the number of cell sites required. Improvement in cell-edge capacity offers smoother handover across cells.

5.4 Nokia Siemens Network[8]

Nokia has LTE centers in markets all around the world. They work closely with suppliers to ensure smooth implementation and operation. They supply LTE (FDD mode) and TD-LTE to world markets.

With close cooperation with the leading LTE device suppliers they ensure an end-to-end interoperability. Their 4G devices complement infrastructure solutions and help operators to launch better LTE services.

Nokia provides these benefits to business:

- Delivers a very fast broadband for customers
- Operates on a global standard
- Offers efficient delivery
- Offers smooth implementation

Nokia has provided LTE support to roughly half of the communications' service provides. The service providers have commercially launched LTE including advanced mobile broadband markets in North Europe, South Korea and Japan.

Nokia had deployed LTE on all major frequency bands. By September 12 2013, they had 92 commercial references in place for the delivery of LTE.

5.5 Sony[9]

LTE networks are getting very common, allowing us to browse web, stream content, or download movies at high-speed. LTE support can be found on a number of Xperia smartphones also.

Xperia smartphones that support LTE includes:

- Xperia ion (LT28i)
- Xperia TL (LT30at)
- Xperia T (LTE30a)
- Xperia V (LT25i)
- Xperia SX (SO-0SD)
- Xperia AX (SO-01E)
- Xperia Z (C6603)
- Xperia ZL (LTE C6503, C6506)

6. Countries Adopted LTE

Figure 7 and 8 is categorized as:

- The countries in Red have commercial LTE services. These are: Canada, USA, Brazil, Uruguay, Russia, Australia, New Zealand, Angola, Spain, Saudi Arabia Jordan, Iraq, Bahrain, Portugal, Finland, Sweden, Norway, UK, Germany, Poland, Japan, India, Sri Lanka, Austria, Hungary, Haiti and South Korea.
- Countries in Dark Blue have on-going or planned commercial LTE network deployment. These are: China, Nepal, Myanmar, Laos, Vietnam, France, Monaco, Ireland, Mexico, Costa Rica, Colombia, Nigeria, Indonesia, South Africa, Namibia, Lesotho, Paraguay, Romania, Bulgaria, San Marino and Taiwan.

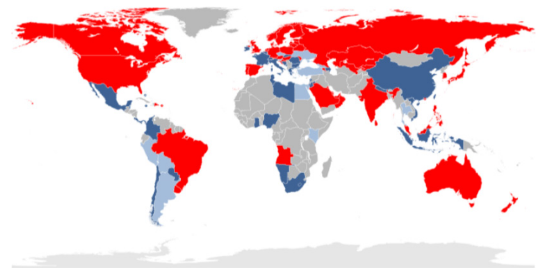

Figure 7. Adoption of LTE technology as of June 26, 2013 [11].

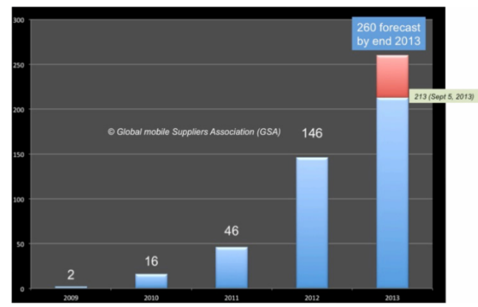

Figure 8. Commercial LTE Networks[15].

- Countries in Light Blue have trial or pre-committed LTE networks. These are: Ukraine, Czech Republic, Turkey, Georgia, Israel, Egypt, Uganda, Thailand, Malaysia, Peru, Bolivia and Argentina.

Some operators in Asia are shown in Table 4.

7. Results and Discussions

Barriers to LTE Adoption[13]

Main barriers to LTE adoption can be largely categorized as, technical, regulatory, ecosystem driven and ROI.

7.1 Technical Challenges

- *Complexity and Backward Compatibility*

For operators considering a network update, selecting the right technology is a major concern. They have two options, either upgrade to evolved versions of 3G such as HSPA and HSPA+ or go for LTE. While upgrades within the 3G family may not require too many network architectural changes but transformation to LTE requires new radio access technology and core network expansion. This method is cost intensive and highly complex. Moreover since existing 2G and 3G networks will not be phased out anytime soon, there is an additional burden on operators: to maintain two networks, support interoperability, seamless roaming, and handovers across multiple CSPs.

Table 4. Some operators in Asia[12]

Country	Operator (Duplex mode)	Launched	Frequency	Band
India	Bharti Airtel (TDD)	Apr 2012	2300	40
	MTNL	Planned 2014	2300	40
China	China Mobile (TDD)	Apr 2013 (Trial)	1900, 2300, 2600	38, 39, 40
Japan	NTT Docomo (FDD)	Dec 2010	700, 800, 1500, 1800, 2100	1, 3, 19, 21, 28
	SoftBank Mobile	Feb 2012	900, 1500, 2100	1, 8, 11
Sri Lanka	Dialog (TDD, FDD)	Dec 2012	1800, 2300	3, 40
	Etisalat (FDD)	2013	2100	1
	Mobilet (FDD)	Jun 2013	1800	3
Hong Kong	China Mobile Hong Kong (FDD)	Apr 2012	1800, 2300, 2600	3, 7, 40
	CSL (FDD)	Aug 2012	1800, 2600	3, 7
	Hong Kong	FDD May 2012 TDD Planned	1800, 2300, 2600	3, 7, 40
	PCCW	FDD May 2012, TDD Planned	1800, 2600	3, 7

- *Backhaul*

LTE will ignite the surge in mobile data traffic due to applications and services demanding increased consumption of bandwidth. This will exert additional strain on the existing backhaul capacity of operators. Operators will need to upgrade their existing backhaul capacity if not done it can negatively impact the end-user experience and the quality of service. Most popular options for telcos to upgrade their backhaul infrastructure are: T1/E1 leased lines, fiber, and microwave. Backhaul networks are expected to be a hybrid of microwave, fiber, and leased line depending on certain factors like available capital, capacity requirements, and type of terrain.

- *Voice over LTE*

A key benefit of LTE is its ability to carry all types of voice, video and data traffic. Most of the developments in deployment of LTE have been focusing towards providing faster data access but the voice standards are still in immature phase. This is due to unavailability of terminal devices and the existence of multiple standards for voice.

There are three main approaches for operators to offer voice over LTE:

- IMS-based "One Voice" approach
- Voice over LTE via Generic Access (VoLGA
- Circuit Switched Fallback (CSFB).

7.2 Ecosystem Related Challenges

- *Availability of Terminal Devices*

As operators start deploying and commercializing their LTE networks, one of the key questions they face is the ready availability of LTE enabled devices. Most operators are rolling out their data-only LTE networks on limited devices such as USB modems due to the lack of a mature device ecosystem. Multi-mode and multi-band support is another factor which has slowed down the availability of LTE devices.

- *Chipset Compatibility*

LTE chipsets ecosystem needs to address key barriers around selection of specific technologies and chipset performance improvement. Support for multiple technical parameters, backward compatibility, and reducing power consumption and chip size are some of the key challenges for chipset vendors.

7.3 Return on Investment (ROI)

The biggest challenge for an operator is to justify the ROI and business case for high investments made in LTE network deployment. Today, while wireless carriers provide an access channel for provisioning content and various multimedia services on a large number of mobile devices, they hardly earn any share of the revenue pie. Most of the revenues on such services are scooped away by content developers and over-the-top players. Thus, one of the key operator challenges is to introduce innovative services and pricing models which leverage their advanced LTE network capabilities.

8. Key Operator Considerations and Measures to Realize Them[13]

Although LTE provides an efficient, future proof, and cost effective long-term solution to wireless operators for upgrading their networks, the road towards LTE is not without its challenges. Following is the list of challenges faced by LTE along with measures to realize them.

8.1 Customer Proposition

8.1.1 Service Positioning

From a customer perspective, the higher speeds and lower latency enabled by LTE is the key USP of this technology. As voice and SMS standards gradually evolve, operators should eventually offer these services as well. Also they need to position LTE as a faster and superior broadband access technology.

8.1.2 Pricing

In order to manage network traffic volumes effectively and justify the high costs of network capacity upgrades, it is critical for operators to get their LTE data price model right.

Strategies that Operators Could Follow

- They should price their LTE offering at a significant premium over existing mobile data plans and focus on maintaining a very high service quality. For example, LTE data plan of TeliaSonera in Sweden is priced at an 88% premium over its existing regular 3G subscription.
- Entry level customers should be able to surf the net at lower prices albeit with slower speeds and lower data caps, whereas heavy users and business customers should have access to higher priced faster plans with higher data caps.
- Should try to adopt a value-based pricing model where customers pay a premium for superior experience. Operators such as TeliaSonera and Vodafone have already announced the launch of such plans in the future.

8.1.3 Rollout Strategy

Operators can either choose to extensively reuse their existing network infrastructure by adding LTE capability over their 3G network or plan and build a network from scratch by swapping out current infrastructure to a single RAN network. While the former method results in high cost savings and faster rollout, the latter promises a more flexible, clean, and stable upgrade for long term benefits.

In most cases, a full-scale nationwide rollout strategy may not make economic sense, since the returns on data rich LTE services in rural and semi-urban areas may not be as attractive as in urban areas. Therefore, a phased deployment strategy, targeting affluent data hungry customers in the densely populated urban areas first, makes a stronger business case. MetroPCS has rolled out its 4G LTE services in five major metropolitan cities where it anticipated maximum demand, and will gradually expand to other urban areas.

In order to increase coverage in rural areas, operators can forge partnerships with local wireless providers, and companies having towers and backhaul capabilities. Verizon is currently planning to adopt this strategy for the rural rollout of its LTE network.

8.2 Cost Savings

8.2.1 Network Sharing

In order to minimize the large investments required in LTE network rollout and maximize returns from its deployment, cost savings should be one of the foremost priorities for operators. Operators should not only go for passive sharing of sites and tower masts but also engage in active network sharing, to effectively reduce their financial burden. LTE networks are technically more suited to active sharing due to their flat all-IP network architecture and operators sharing their active network elements can save more than 40% in CAPEX and OPEX, in a five year time, as compared to their counterparts striking only passive site-sharing deals.

8.2.2 Data Offloading

Mobile Data Offloading (MDO) is another strategy which operators can adopt to achieve cost efficiencies. MDO is the use of complementary network technologies such as WiFi, femtocell, mobile CDNs, and media optimization for offloading data originally targeted for cellular networks, thereby reducing costs and minimizing load on core operator network. It is expected that offloaded mobile data will increase threefold from 16% in 2010 to 48% in 2015.

8.2.3 Spectrum Policy

LTE can be deployed in many different frequency bands, with each band supporting multiple channel bandwidths. Operators will need to carefully evaluate the frequency bands and channel bandwidth in which to deploy LTE, based on factors such as spectrum availability and price, rollout costs, and coverage.

- *Which Spectrum Band?*

Higher frequency bands such as 2.6 GHz are readily available and have been auctioned in many parts of the world. Low

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frequency bands such as 800 MHz and 700 MHz allow signals to travel farther and provide better in-building coverage than higher frequencies. Therefore, from a coverage point of view, a network built at 700 MHz is likely to require less than a tenth of the number of sites required for the same coverage at 2.6 GHz. This will translate to lower costs and enable operators to gain an edge on the pricing front. Given the high costs and competition involved in the acquisition of LTE spectrum, operators can also consider the option of re-farming their existing licensed frequencies, if regulation permits, to offer LTE. The main concern with re-farming will be clearing enough spectrums to facilitate an acceptably efficient implementation of LTE while maintaining enough capacity in the remaining spectrum to support non-LTE traffic on legacy technology.

- *What Channel Bandwidth?*

LTE can be implemented in multiple channel bandwidths ranging from 1.4 MHz to 20 MHz. It is technically possible to implement LTE as a Single Frequency Network (SFN) or using a frequency reuse pattern. In the case of SFN, bandwidth will likely to be in the order of 18 Mbit/s, but is available only over a very limited coverage area with the potential bit rate falling sharply at the cell edges. In the frequency reuse case, the bandwidth will be lower at around 7 Mbit/s, but available over a much wider area. Therefore, operator decision on channel bandwidth needs to be based on a speed versus coverage tradeoff. In dense urban areas, they can implement LTE as SFN where as in rural areas they can adopt the frequency reuse pattern.

9. Conclusion

LTE presents an attractive technology choice for operators to mitigate their most significant concerns around increase in demand for wireless broadband. However, the path towards LTE is not without its set of challenges and the decision to migrate is not easy to make. LTE is in a nascent stage with standards still evolving and its ecosystem still maturing. Moreover operators have other wireless technology options also, some of which may be more cost effective in the short term than LTE. To reap the true potential benefits offered by LTE and successfully mitigate the challenges, operators should adopt the right strategies around pricing, cost savings, and rollout.

10. Future Scope

LTE has come a long way since its early development. But still a lot of work need to be done to make it work everywhere around the world. LTE operators offer different frequencies across the world which limits portability of one network from one part of world to the other. A lot of work needs to be done to bring whole world under one network so that anyone can travel anywhere and still remain connected to everyone.

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