Long Term Evolution

LTE Opportunities and Challenges for Telcos

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1 Abstract

The mobile networks of most operators are witnessing an unprecedented rise in data traffic, due to an increasing consumer demand to access bandwidth intensive content on-the-go and the proliferation of a large number of mobile devices such as smartphones and tablets. This trend is exerting extremely high pressure on the capacity constrained network of operators. Faced with this challenge, wireless providers need to upgrade their network infrastructure in order to keep up with data traffic volumes and deliver bits more cost-effectively. When compared to some other upgrade options such as HSPA[1], HSPA+, and WiMAX[2], Long Term Evolution (LTE) provides operators with a technically superior and cost effective solution to deliver true mobile broadband experience. Although LTE standards and the ecosystem have not yet evolved fully and an upgrade requires significant capital investment, operators can still reap tremendous benefit by formulating the right migration strategy. A focus on key priorities such as pricing, rollout strategy, network sharing, and spectrum policy will be instrumental in the successful rollout of LTE. Having realized its potential, several operators across the globe have already deployed LTE commercially and many more are in the fray.

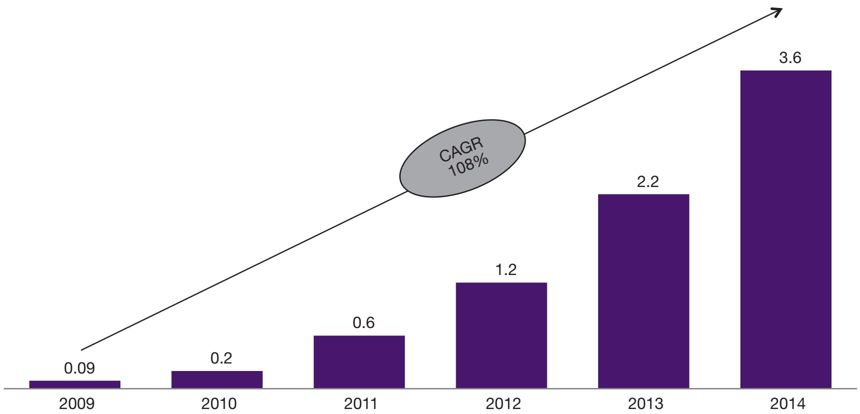
1 High Speed Packet Access is the amalgamation of two mobile telephony protocols, High Speed Downlink Packet Access (HSDPA) and High Speed Uplink Packet Access (HSUPA).
2 Worldwide Interoperability for Microwave Access.

2 The Need for LTE

The explosion of mobile data traffic is exerting unprecedented demand on networks

The increasing proliferation of a range of Internet enabled mobile devices, such as tablets, smart-phones, and e-readers has added to the rising consumer need to access rich content on the go. This phenomenon has resulted in the explosion of mobile data traffic exerting an unprecedented demand on the network of wireless operators (see Figure 1). Driving this boom will be the increasing consumption of mobile video, which will consume nearly 66% of all mobile data traffic by 2014[3]. Bandwidth intensive applications, especially those based on video, expose the capacity bottlenecks and the gap which customers are increasingly facing between peak rates in perfect conditions and real everyday experiences. It is, therefore, imperative for operators to ensure that the average user's mobile experience is not compromised especially in high traffic areas.

Figure 1: Global Mobile Data Traffic, Exabytes[4] per Month, 2009-2014



Source: Cisco Visual Networking Index: *Global Mobile Data Forecast Update,* 2009-2014

In order to enhance subscriber experience, prepare access networks for the onslaught of data intense applications, and reduce operational expenditure, operators will need to upgrade their networks sooner or later. For doing so, they have multiple technology options such as WCDMA[5], HSPA, HSPA+, CDMA2000 EV-DO[6], WiMAX and LTE to choose from. The migration strategy of each operator is likely to be different and will be based on several factors such as the existing state of their networks, current and projected data demand, costs considerations, and spectrum availability. In Japan, while NTT DoCoMo is skipping HSPA+ and migrating straight to LTE, SoftBank Mobile believes there are still significant opportunities with 42Mbps HSPA+[7].

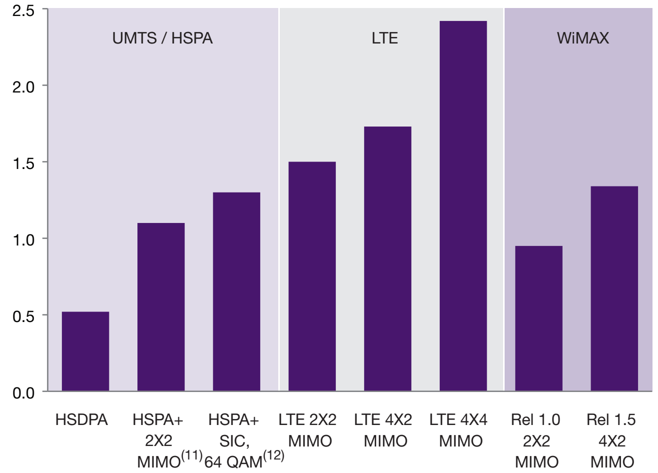
Video will represent nearly 66% of all mobile data traffic by 2014

However, given the various migration options, LTE seems to offer the most efficient, cost effective (in terms of TCO[8] and OPEX[9] savings), and future proof solution for operators, who can reap considerable long term benefits by leveraging an early mover advantage.

3 Cisco Visual Networking Index, *Global Mobile Data Traffic Forecast Update*, 2009-2014.
4 One Exabyte is equal to 1 billion Gigabytes.
5 Wideband Code Division Multiple Access.
6 Evolution Data Optimized.
7 Telecomasia.net, *HSPA v LTE: the debate continues,* May 2010.
8 Total Cost of Ownership.
9 Operating Expenditure.

Figure 2: Comparison of LTE Peak Theoretical Throughput, Latency, Spectral Efficiency and Relative Cost per Bit Parameters with Other Mobile Network Technologies

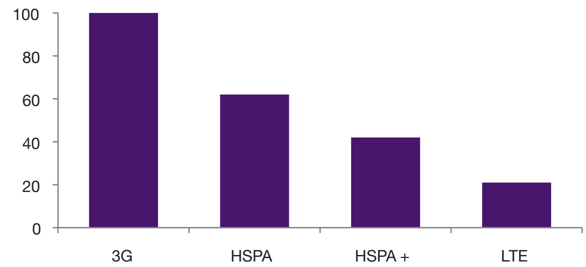
Downlink Spectral Efficiency (bits per second/Hz/sector)



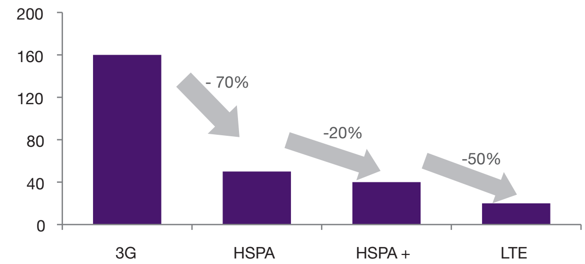
Downlink and Uplink Peak Throughput (Mbps)

UMTS Release	Antenna Technology		Downlink Speed (Mbps)			Uplink Speed (Mbps)
	Type	Qty	5 MHz	10 MHz	20 MHz	
R6 HSPA	SIMO	1x1, 1x2	14.4	–	–	5.76
R7 HSPA+ 64-QAM	SIMO	1x1, 1x2	21.6	–	–	11.5
R7 HSPA+	MIMO	2x2	28.8	–	–	11.5
R8 LTE	MIMO	2x2	43	86	173[13]	58
R8 LTE	MIMO	4x4	82	163	326[13]	86

Relative Cost per bit of Transmitted Data



Latency (ms)



Source: Capgemini TME Strategy Lab Analysis; Motorola Whitepaper, *Upgrade Strategies for Mass Market Mobile Broadband*, 2009; 3G Americas, *HSPA to LTE Advanced*, September 2009; Morgan Stanley Research

LTE is a pure packet switched evolution of UMTS[10] 3G technology which offers significant advantages such as higher spectral efficiency, lower cost of transmission per megabyte, higher throughput, and lower latency when compared to existing wireless network technologies (see Figure 2). It is also backward compatible with the CDMA[14] family of technologies and thereby enables even CDMA operators to move to this technology. Furthermore, by deploying LTE SON[15] telcos can significantly improve operational efficiency and reduce OPEX. Thus, LTE offers the best potential to address one of the most significant priorities of wireless operators, which is, upgrading their capacity constrained networks.

Having realized the potential, telcos across the globe have already taken the first steps towards the deployment of LTE networks (see Figure 3). In December 2009, by launching services in Sweden and Norway, TeliaSonera became the first operator in the world to offer LTE. In September 2010, Metro PCS, a prepaid service provider in the US, became the second operator to launch LTE services. It offers its service on the first commercially available 4G enabled handset in the

10 Universal Mobile Telecommunications Service.
11 Multiple Input Multiple Output: MIMO uses multiple antennas at both the transmitter and receiver to improve communication performance.
12 Quadrature Amplitude Modulation.
13 3GPP TR 25.912 V7.2.0.
14 Code Division Multiple Access.
15 The Next Generation Mobile Networks (NGMN) Alliance and the Third Generation Partnership Project (3GPP) have standardized a set of capabilities known as Self-Organizing Networks (SON). With SON operators can automate previously manual steps throughout the lifecycle of a network — from planning and deployment to optimization and operations.

world, the Samsung Craft[16]. While TeliaSonera, which is a GSM operator, offers its LTE services over USB dongles, Metro PCS, a CDMA2000 player, provides unlimited and contract less LTE services over a handset. It is noteworthy how LTE can be delivered by both large and small operators, irrespective of their existing wireless technology, over multiple devices.

With over 100 commitments by service providers around the world to deploy LTE networks, the worldwide LTE infrastructure market is set to grow tenfold to reach US$11.5 billion[17]. Going by the trends, LTE seems to be the technology of choice for most operators across the world.

In this paper, we evaluate the technology options within LTE, the most significant barriers regarding its uptake, and recommend the best approach for different operators.

16 Company Press Release.

17 Infonetics Research, *LTE Infrastructure Forecasts Up, Along With Operator Commitments to LTE Networks*, November 2010.

3 Technology Options for Operators

LTE offers the most efficient, cost effective, and future proof solution for operators to upgrade their networks

The technical advantages of LTE which render significant benefits over other wireless technologies can be attributed to its superior access and antenna technologies. The use of technologies such as OFDM[18], SC-FDMA[19], MIMO, and multiple channel bandwidths results in attributes such as high throughput, low power consumption, high spectral efficiency, and improved coverage and cell performance. LTE can be deployed in both paired spectrum for Frequency Division Duplex (FDD) and unpaired spectrum for Time Division Duplex (TDD), and we witness a greater adoption of FDD in initial deployments (see Figure 3). In this section, we will primarily focus on the TDD and FDD technology deployment options for operators.

Figure 3: Commercial LTE Deployments and Technology Adopted

Operator	Country	Deployment Date	Frequency Band	Duplex Scheme
TeliaSonera	Sweden	December 2009	2.6GHz	FDD
TeliaSonera	Finland	May 2010	2.6GHz	FDD
Tele2 / telenor	Sweden	November 2010	2.6GHz	FDD
metroPCS	USA	September 2010	1.7/2.1GHz	FDD
verizon	USA	December 2010	700MHz	FDD
NTT docomo	Japan	November 2010	2.1GHz	FDD
MOBYLAND	Poland	September 2010	1.8GHz	FDD
中国移动通信 CHINA MOBILE	China	May 2010[20]	2.6GHz	TDD

Source: Capgemini TME Strategy Lab Analysis; Company Websites

Both FDD and TDD have their own advantages and disadvantages (see Figure 4), and decisions on which duplex scheme to adopt can be taken depending on the operator's business requirements. In the subsequent subsections, we detail these choices.

18 Orthogonal Frequency Division Multiplexing: Used for downlink. The available spectrum is divided into many thin carriers each on a different frequency.

19 Single Carrier Frequency Division Multiplexing Access: For uplink, LTE uses a pre-coded version of OFDM called Single Carrier Frequency Division Multiple Access (SC-FDMA) which reduces power consumption, improves coverage and the cell-edge performance.

20 China Mobile has deployed 11 LTE trial networks across China. The first of these trial networks was launched in May 2010.

Figure 4: Relative Advantages and Disadvantages of FDD LTE vs. TDD LTE

Parameter	FDD LTE	TDD LTE	Remarks
Spectrum Flexibility	Medium	Very High	• The adaptable Downlink: Uplink ratio means that TD LTE ensures maximization of available bandwidth
Spectrum Costs	Medium	Very High	• TDD spectrum is traditionally auctioned for lower US$/MHz/population
Hardware and User Equipment Costs	High	Medium	• Economies of scale in favor of FDD will lead to lower hardware and user equipment costs • However, the push from China Mobile and emerging interest from leading operators in Europe and US is expected to bridge this gap
Coverage	High	Medium	• TDD LTE has poor coverage (up to 40% less) compared to FDD and requires base station synchronization to avoid cross slot interference
Ease of Migration	High	Medium	• Most of the current 3G deployments are based on paired spectrum and as a result are easier to migrate to FDD LTE • However, TD LTE is expected to provide effective upgrade path for technologies such as TD-SCDMA, TD-HSPA and WiMAX
Ecosystem Support	High	Medium	• Though network and device vendors as well as major mobile operators are committed to support both FDD and TD LTE technology, higher push is towards FDD
Suitability for Data Applications	Medium	High	• TDD LTE is more suitable for IP-based data applications which are mostly asymmetric in nature

Favorability Legend: Very High, High, Medium, Low, Very Low

Source: Capgemini TME Strategy Lab Analysis; venturaTeam, *Has Hi3G played a shrewd hand in the recent Danish Auctions*, 2010

FDD LTE

FDD LTE transmits the downlink and uplink traffic in separate frequency bands. FDD thus requires paired spectrum with sufficient frequency separation to allow simultaneous transmission and reception. The paired spectrum of FDD LTE is most suited to support voice as well as symmetric data applications such as peer-to-peer file transfer and video conferencing.

In addition, when compared to TDD LTE, FDD LTE offers advantages both in terms of higher coverage and better compatibility with existing 3G networks, which are mostly based on paired spectrum. As a result, FDD LTE is expected to be the logical migration path for most operators who have deployed 3G networks. In fact in most geographies the majority of the spectrum which has been auctioned is FDD. Most early and planned deployments of LTE from operators such as TeliaSonera, Tele2, and Verizon have also been on FDD. Other major operators are also expected to roll out their LTE macro networks on FDD bands in order to easily meet their business objectives for mobile broadband and multimedia services.

TDD LTE (TD-LTE)

TDD LTE (also known as TD-LTE), transmits the uplink and downlink traffic within the same unpaired frequency band and is predominantly a mobile broadband technology. TDD LTE offers flexible and adaptable (real-time) uplink and downlink traffic ratio, which makes this technology suitable for asymmetric data applications such as HD video download and content upload.

TD-LTE can provide an effective upgrade path for existing technologies such as TD-SCDMA, TD-HSPA and WiMAX. China Mobile is one of the major proponents of TD-LTE, with 11 TD-LTE trial networks in place, and plans to roll out eight more by the end of 2011. The Chinese operator has entered into partnerships with eight international telecom operators to jointly promote the development of TD-LTE industry.

Many countries have TDD spectrum available and operators in Europe have already auctioned unpaired spectrum for LTE. Being a niche technology, TD-LTE is expected to fetch a lower price per MHz per population compared to the FDD equivalent. In Sweden while 2x10 MHz FDD spectrum was auctioned for 296.6 million SEK, 50 MHz of unpaired spectrum went for 159.25 million SEK[21]. The lower spectrum costs and higher spectral flexibility of TD-LTE makes it an attractive option for greenfield operators in both emerging and developed markets to make a quick transition to TD-LTE mobile broadband. This is evident from the strategy of operators such as Reliance Communications, Augere, and Clearwire who are focusing primarily on TDD bands, banking on the abundance of available and low cost unpaired spectrum.

TD-LTE is not only witnessing traction from pure play mobile broadband providers but also from existing 3G operators in developed markets as they try to focus on a capacity-centric rather than a coverage-centric network strategy. This was evident in the latest spectrum auction in Denmark which witnessed operators such as Telenor, Telia, and 3, bidding for paired as well as unpaired spectrum. For such operators, TD-LTE can act as a complimentary solution to LTE FDD to serve the increasing demand for broadband. Operators can roll out their LTE macro networks on FDD bands while deploying a small-cell[22] (picocells and femtocells) second layer on TDD spectrum, thereby not only providing enhanced capacity to indoor users but also offloading demand from the existing macro cell network.

The considerable interest in TD-LTE is expected to help build the ecosystem support and bridge the gap with FDD LTE. Major network and device vendors have already committed to developing TD-LTE technology, and live network trials are already underway. Although the adoption of LTE FDD will be the more widespread, it is reasonable to assume that TD-LTE will also witness significant uptake.

21 Swedish Regulator.

22 Small cell base stations such as picocells and femtocells are low-power, small wireless access base stations that sit inside the customer premise, whether at home or at work. They are expected to play a vital role in LTE deployment by helping mobile operators provide indoor coverage to their subscribers, while at the same time, relieving backhaul and infrastructure costs.

4 Challenges in LTE Implementation

LTE certainly stands out in terms of its technical superiority and spectral efficiency. However, being an evolving standard it poses some significant challenges ahead of operators. The main barriers to LTE adoption can be largely categorized as, technical, regulatory, ecosystem driven, and ROI[23] related. We detail these challenges in the subsequent subsections.

Technical Challenges
Complexity and Backward Compatibility
For operators considering a network update, selecting the right technology is a major concern. They can 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, transformation to LTE requires new radio access technology and core network expansion. This is not only cost intensive, but also highly complex. In addition, since existing 2G and 3G networks will not be phased out anytime soon, there is additional burden on operators to maintain two networks, support interoperability, seamless roaming, and handovers across multiple CSPs[24].

Backhaul
The advent of LTE will further ignite the surge in mobile data traffic due to increasing consumption of bandwidth hungry applications and services. This will exert additional strain on the existing backhaul capacity of operators. In Western Europe wireless backhaul capacity will more than triple between 2010 and 2014, to nearly 60,000 Gbps[25]. Traffic from LTE applications is expected to account for more than half of last-mile backhaul demand in North America by 2014[26]. Operators need to upgrade their existing backhaul capacity as failure to do so can negatively impact the end-user experience and the quality of service.

T1/E1 leased lines, fiber, and microwave are the most popular options for telcos to upgrade their backhaul infrastructure (see Figure 5). Backhaul networks, however, are expected to be a hybrid of microwave, fiber, and leased line depending on factors such as available capital, capacity requirements, and type of terrain.

23 Return on Investment.
24 Communication Service Providers.
25 In-Stat research, *Wireless Backhaul: The Network Behind LTE, WiMAX, and 3G*, October 2010.
26 In-Stat research, *Wireless Backhaul: The Network Behind LTE, WiMAX, and 3G*, October 2010.

Figure 5: Backhaul Options and their Suitability to Meet Future Demand

Backhaul Options	CAPEX Per Site	Operational Expense	Flexibility/ Scalability	Flexibility/ Scalability	Overall Rating to Meet Future Demand
T1/E1 Leased Lines	● N/A as they are leased	○ ~100-500 €/ month/site	● Infrastructure already exists	◔ Range 1-3km, bandwidth 2Mbps (E1)	◔ Uneconomical to meet expected increase in demand
Microwave	◕ ~20-50K €	◕ Negligible	◕ Issues like LOS, site geography, etc.	◕ Range 10-30km, bandwidth 100-200 Mbps	◕ Effective where DSL and Fiber cannot reach
Fiber	○ ~125K €	◑ High for leased and low for own deployment	○ Requires digging	● Unlimited range and capacity	◕ Operators plan to replace leased lines with fiber in densely populated regions

● Most Favorable ○ Least Favorable

Source: Capgemini TME Strategy Lab Analysis; JP Morgan, *Power of Mobile broadband*, May 2008; Ofcom, *Future Options for effective backhaul*, January, 2007

Voice over LTE

One of the key benefits of LTE is its ability to carry all types of voice, video and data traffic. However, most of the developments in deployment of LTE have been focused towards providing faster data access, and voice standards are still immature. This is partly due to the unavailability of terminal devices and the existence of multiple standards for voice. There are three main approaches for operators to offer voice over LTE, namely, IMS-based "One Voice" approach[27], Voice over LTE via Generic Access (VoLGA)[28], and Circuit Switched Fallback (CSFB)[29].

It is expected that CSFB will be a short term solution for operators given significant drawbacks such as high call set up times, coverage concerns, and low battery life. Though VoLGA is being backed by T-Mobile, it has received limited operator and vendor support and is expected to see limited adoption. The "One Voice" approach is expected to be the LTE voice standard of the future and has support from all ecosystem players including the GSMA.

Regulatory Challenge

LTE networks across the world are being deployed on disparate frequency bands as different regulators free up and auction different spectrum bands. For instance, while TeliaSonera has deployed its LTE network in the 2.6 GHz band, NTT will initially launch services on the 2.1 GHz band and extend coverage using 1.5 GHz; Finland and Hong Kong have allocated the GSM 1800 spectrum for LTE, and 700 MHz is the primary candidate in the US. In fact, even within geographies, there might be a disparity in LTE deployment frequencies. For example, in the US, while Verizon and AT&T are using the 700 MHz band for their LTE roll-out, Clearwire is testing in the 2.6 GHz band.

Despite a global technical standard, LTE deployments lack regulatory consensus on a standard frequency band globally. This poses a real challenge and increases complexity for operators, device manufacturers, and chipset vendors in terms of factors such as roaming difficulties and multi-band support for devices and chipsets.

27 One Voice utilizes the IMS (Internet Multimedia Subsystem) network overlay to send voice calls and SMS over LTE network.
28 The voice call is carried over the LTE network using VoIP and over the GSM/UMTS network using circuit-switched technology.
29 Operators use the LTE packet-switched network for data communications and the 2G/3G circuit-switched network for voice communications.

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. For instance, although Verizon has announced the launch of its LTE data services by the end of 2010, it maintains, that the first LTE phone would be available only by the middle of 2011. The unavailability of LTE compatible phones, smartphones, and tablets is an opportunity lost for operators in terms of revenue they could have earned from premium pricing.

Multi-mode and multi-band support is another factor which has slowed down the availability of LTE devices. For instance, TeliaSonera launched its first dual mode LTE and 3G modem a whole 6 months after the launch of its LTE network. Multi-mode (GSM-HSPA-LTE) support is critical for the device to appeal to early technology adopters and help operators acquire a large subscriber base. Similarly, multi-band capabilities are critical for roaming handovers, as LTE will be deployed in multiple RF[30] bands.

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 (see Figure 6). There is a direct correlation between the availability of chipsets and the launch of new LTE capable devices. As the chipset ecosystem for LTE gradually matures, we will see a large number of devices being introduced.

Figure 6: Key Technical Challenges for the LTE Chipset Ecosystem

1 Support for Multiple Technical Parameters

- LTE technology at present has a number of different configurations such as a range of different frequency bands, varied antenna systems like 2X2 MIMO, 4X4 MIMO, etc.
  - This puts a severe strain on the chipmakers with respect to specific technologies to be supported and the allocation of R&D budget
  - Supporting too many different configurations pushes up the price of the chipsets, thereby affecting adoption

2 Backward Compatibility

- Integration with 2G and 3G will be a major requirement for all LTE chipsets, especially during the early days of LTE deployments
  - This will allow modems and handsets to be interoperable with existing networks, and thus function in the case of selective rollouts
  - For example, Qualcomm's MDM9600 series of chipsets support dual-carrier HSPA+ and multi-mode 3G/LTE

3 Reducing Power Consumption and Chip Size

- The power consumption levels of current LTE chipsets are very high, due to their use of technologies like MIMO and use of multiple components
  - This severely limits the usage of these chipsets, as the battery life of the LTE devices is limited
- A number of LTE chipsets available in the market are currently bulky, thereby adversely affecting the size and shape of the devices

Source: Capgemini TME Strategy Lab Analysis; cellular-news, *Qualcomm Now Sampling Dual-carrier HSPA+ and Multi-Mode 3G/LTE Chipsets*, 2009; MobiledevDesign, *4G Terminal Chipsets Present Challenges And Opportunities*, December 2009

30 Radio Frequency.

Return on Investment (ROI)

Migration to LTE entails high CAPEX[31] investments when compared to HSPA or HSPA+, due to the high spectrum costs and upgrades in network infrastructure required. Typically, a tier one mobile operator in the UK would need to invest US$750 million in the first year to deploy an LTE network, while an upgrade to HSPA+ may cost just US$250 million[32]. Even TeliaSonera, which reused nearly 70%[33] of its existing network infrastructure, had to invest a total of US$1.95 billion on its networks[34] in 2009 to deploy LTE and plans to invest an additional US$70 million in 2010[35].The biggest challenge therefore for an operator is to justify the ROI and business case for these high investments in LTE network deployment.

Today, while wireless carriers provide the 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. Therefore, one of the key operator challenges is to introduce innovative services and pricing models which leverage their advanced LTE network capabilities.

In the next section, we look into some key strategies which operators can adopt in order to successfully mitigate these challenges and maximize their return on investment.

31 Capital Expenditure.
32 Aircom International, *LTE not the only option for mobile operators today, says AIRCOM*, May 2010.
33 Dailywireless, *TeliaSonera: Go Directly to LTE*, September 2010.
34 Large part of it was driven by LTE.
35 Reuters, *TeliaSonera sees no investment boost from LTE*, April 2010.

5 Next Steps for Telcos

Operators need to position LTE primarily as a much faster and superior broadband access technology

As discussed, although LTE provides wireless operators with a more efficient, future proof, and cost effective long-term solution for upgrading their networks, the road towards LTE is not without its challenges. However, by adopting the most relevant strategy around the rollout, cost savings, customer proposition, and spectrum policy, telcos can succeed in their quest. In this section we evaluate these key operator considerations and propose measures to realize the true potential of LTE.

Customer Proposition
Service Positioning
From a customer perspective, the higher speeds and lower latency enabled by LTE is the key USP[36] of the technology. As voice and SMS standards gradually evolve, operators should eventually offer these services too. However, they need to position LTE primarily as a much faster and superior broadband access technology.

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.

First, telcos should price their LTE offering at a significant premium over their existing mobile data plans and focus on maintaining a very high service quality. For instance the LTE data plan of TeliaSonera in Sweden is priced at an 88%[37] premium over its existing regular 3G subscription.

A one-size-fits-all data pricing strategy is no longer economically sustainable for operators

Second, all-you-can-eat pricing strategies need to give way to pay-for-what-you-use models where mobile data is charged based on bandwidth and volume. Since different customers have widely varying consumption[38] pattern, and a one-size-fits-all data strategy is no longer economically sustainable for operators, subscribers need to be charged differently. 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. A look at the LTE price plans of existing offerings indicates similar trend (see Figure 7).

Lastly, in the long-term, operators should try and adopt a value-based pricing model where customers pay a premium for superior experience. For instance a professional photographer trying to send a photo of a winning goal at a football match could pay extra to ensure he would have access to the network ahead of the many football fans sending texts. Operators such as TeliaSonera and Vodafone have already announced the launch of such plans in the future. As part of its new "supermobile" strategy, Vodafone plans to introduce "staircase" pricing so that customers can pay extra for a guaranteed level of superior service or pay less for limited data browsing.

36 Unique Selling Proposition.
37 Company Website; Computer World *On the Streets of Stockholm with LTE*, August 2010.
38 Both bandwidth and data volume.

Operators should try and adopt a value-based pricing model where customers pay a premium for superior experience

Figure 7: Comparison of LTE Price Plans of Commercial Offerings

Operator	Price Per Month	Data Allowance	Bandwith
TeliaSonera	599 SEK (US$87)	Capped at 30 GB per month	10 to 80 Mbps
	369 SEK (US$54)	Capped at 20 GB per month	10 to 20Mbps
	299 SEK (US$44)	Capped at 10 GB per month	5 to 10 Mbps
Tele2	299 SEK (US$44)[39]	Unlimited	Not tiered by network speed
Telenor Sweden	549 SEK (US$80)	Unlimited	Not tiered by network speed
Verizon	US$50	Capped at 5 GB per month (US$10 per gigabyte overage fee)	Not tiered by network speed
	US$80	Capped at 10 GB per month (US$10 per gigabyte overage fee)	Not tiered by network speed
MetroPCS	US$55	Unlimited	Not tiered by network speed
NTT DoCoMo	1000 JPY (US$12)	Capped at 3 GB per month	Not tiered by network speed
	7980 JPY (US$95)	Capped at 5 GB per month	Not tiered by network speed

Source: Company Websites; Light Reading *NTT Docomo Sets LTE Date*, November 2010; Light Reading *Swedish LTE Challengers Wield Unlimited Offers*, November 2010

Rollout Strategy

In terms of 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 results in higher cost savings and faster rollout, the latter promises a more flexible, clean, and stable upgrade for long term benefits.

It is imperative for operators to justify their investments in LTE with ROI. 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. For instance 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.

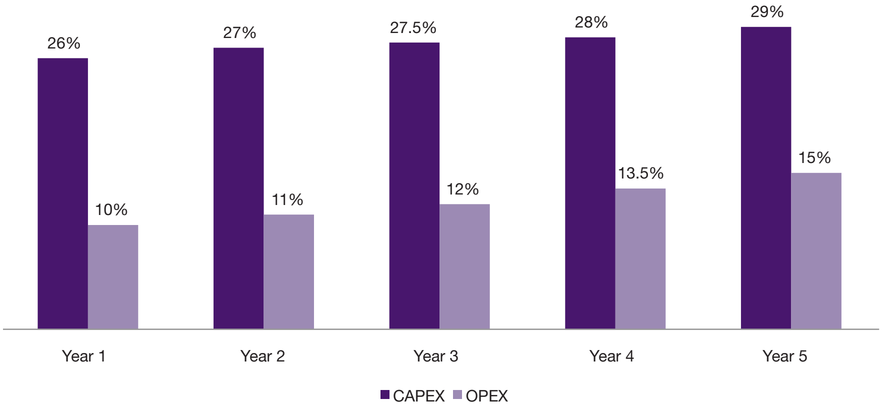
Cost Savings

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. It is estimated that LTE infrastructure CAPEX alone will reach US$14 billion globally in 2015[40]. Therefore 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. Two operators jointly rolling out an LTE network of 2,500 sites in a developed economy can potentially save nearly 30% in CAPEX over a 5 year period, if they share radio access networks (RANs)[41](see Figure 8).

39 For the first 12 months of an 18-month contract, after which the price goes up to 499 SEK.
40 Total Telecom, *LTE Business Models: LTE: sharing the burden*, July 2010.
41 Analysis Mason, *Wireless infrastructure sharing saves operators 30% in CAPEX and 15% in OPEX*, May 2010.

Figure 8: Accumulated CAPEX and OPEX Savings (%) from Network Sharing



Source: Analysis Mason *Wireless infrastructure sharing saves operators 30% in CAPEX and 15% in OPEX*, May 2010

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 at least 40% more in CAPEX and OPEX, over a five-year period, compared to their counterparts striking only passive site-sharing deals[42].

Operators should also get into agreements to share their backhaul costs which may account for nearly 50% of the CAPEX needed to deploy LTE RAN equipment in urban and metropolitan areas.

Some telcos have already taken the first steps towards network sharing to lower the costs of their rollout. For instance, in Canada, Telus and Bell have formed an agreement to overlay their EVDO networks with a joint HSPA network by 2010 that will more efficiently prepare for an LTE migration expected between 2011 and 2012. Similarly, in Sweden, Tele2 and Telenor built the LTE network together through their network-sharing joint venture, Net4Mobility.

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[43], 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%[44] in 2015.

Each of these offload technologies can solve a particular problem and will coexist. For instance, while WiFi is effective in covering limited areas having many users, such as train stations and sports venues, femtocell is a good solution for targeting small numbers of heavy data users. Mobile CDNs alleviate the problem of frequently-accessed content, for example a viral video, by caching the content locally rather than loading it onto the network for each download request.

Many suppliers such as BelAir Networks (WiFi), Akamai (CDN), Ubiquisys (femtocell), and Openwave (media optimization) offer a range of MDO solutions which operators can leverage.

Spectrum Policy

LTE can be deployed in many different frequency bands, with each band supporting multiple channel bandwidths (see Figure 9).

42 ABI Research, *Active Radio Access Network (RAN) Sharing Amounts to a US$60 Billing Cost Saving Potential for Operators*, April 2009.
43 Content Delivery Networks.
44 ABI Research *Mobile network offloading*, August, 2010.

Figure 9: Primary Candidate Bands for LTE

Band Description	Uplink (UL) Operating Band (MHz)	Downlink (DL) Operating Band (MHz)	Channel/Carrier Bandwidths (MHz) Supported	Potential Deployment Region(s)	Comments
Digital Dividend	791-821 MHz	832-862 MHz	5, 10, 15, 20	Europe	Strong push from European Union Spectrum auctioned in Germany
GSM 900	880-915	925-960	1.4, 3, 5, 10	Europe	Spectrum can be re-farmed
GSM 1800	1710-1785	1805-1880	1.4, 3, 5, 10, 15, 20	Europe, Asia	Spectrum can be re-farmed Finland and Hong Kong have allocated for LTE
UMTS Core, '2100'	1920 - 1980	2110 - 2170	5, 10, 15, 20	Europe, Asia	Available for LTE in Japan
IMT Extension, '2.6 GHz'	2500-2570	2620-2690	5, 10, 15, 20	Europe	Focus of most operators in Western Europe
700 MHz	Multiple bands	Multiple bands	1.4, 3, 5, 10	US	Primary candidate for LTE launch in US
AWS (US)	1710-1755	2110-2115	1.4, 3, 5, 10, 15, 20	US, Canada	US auctions completed in September 2006
Cellular 850 (US)	824-849	869-894	1.4, 3, 5, 10	US, Canada	Can be re-farmed after 700MHz and AWS is consumed in the US
PCS, '1900'	1850-1910	1930-1990	1.4, 3, 5, 10, 15, 20	US, Canada	Can be re-farmed after 700MHz and AWS is consumed in the US

Source: Capgemini TME Strategy Lab Analysis; Regulator Websites

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. In the subsequent subsections we detail the parameters based on which operators should determine their spectrum policy.

Which Spectrum Band

Although the decision on the choice of band in which to deploy LTE depends upon the availability of spectrum, operators will still generally have more than one option to choose from.

The higher frequency bands such as 2.6 GHz are readily available and have been auctioned in many parts of the world. Therefore, 2.6 GHz is expected to be the spectrum of choice for most operators considering LTE deployment. However, lower frequency bands have certain distinct advantages which are likely to be of considerable interest to operators. Low frequency bands such as 800 MHz and 700 MHz allow signals to travel farther and provide better in-building coverage than higher frequencies. For instance, cell radius at 700 MHz could be between three and four times larger than at 2.6 GHz. 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[45]. This will translate to lower costs and enable operators to gain an edge on the pricing front.

However on the flip side, there is a high level of regulatory uncertainty, especially in Europe, on the availability of low frequency digital dividend band. This along with the fact that these bands are expected to be priced significantly higher weakens their proposition. While the price per MHz per population for the 2.6 MHz spectrum in Norway was US$0.00043, in Germany, it was US$0.19 for the 800 MHz spectrum[46].

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. For example, Mobyland in Poland has launched the world's first LTE network in the 1800 MHz spectrum[47]. The main concern with re-farming will be clearing enough spectrum

45 Wray Castel, *Training the Telecom World, LTE – Where's the Spectrum?*, November 2009.
46 KB Spectrum Blog.
47 Company Website.

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. For instance while TeliaSonera uses a 2x20 MHz channel, Verizon has used 2x10 MHz channel for deployment. It is technically possible to implement LTE as a Single Frequency Network (SFN) or using a frequency reuse pattern. For example an operator with 15 MHz of spectrum can use it either as a single channel or split it into three 5 MHz channels. In the SFN case, the bandwidth would likely be in the order of 18 Mbit/s, but 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[48].

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.

In conclusion, LTE presents an attractive technology choice for operators to mitigate their most significant concerns around explosion in demand for wireless broadband. However, the path towards LTE is not without its set of challenges and the decision to migrate is not an easy one to make. LTE is in a nascent stage with standards still evolving and the ecosystem still maturing. Moreover operators have other wireless technology options, some of which may be more cost effective in the short term. Therefore, operators need to carefully evaluate the need and business case for LTE deployment, before giving a green flag. 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.

48 Wray Castel, *Training the Telecom World, LTE – Where's the Spectrum?*, November 2009.

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