ISLAMIC UNIVERSITY OF TECHNOLOGY (IUT)

COMPARISON AMONG DIFFERENT MIGRATION PATHS FOR CELLULAR DEPLOYMENT IN BANGLADESH

In collaboration with

grameenphone

By

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ABSTRACT

The thesis work is a collaboration between Islamic University of Technology and the leading cellular operator of Bangladesh, Grameenphone Ltd. (Telenor) and aims to provide a thorough technological analysis and business case comparison for different migration paths to the next generation technology for the operator.

There has been a tremendous growth in service quality and competition among the cellular operators and a continuous demand for network up gradation to a better and efficient cellular technology. Worldwide 3G networks roll out began since 2000 to cater the ever increasing data demand for mobile broadband solution. But unfortunately in Bangladesh, due to regulatory issues, 3G technology couldn't have been implemented till now. After so many years, The Bangladesh Telecom Regulatory Commission (BTRC) has finished all the required ground works and is expected to arrange a spectrum frequency auction in Q1 of 2013 where in total 5 concessions will be allocated in 2.1 Ghz band, 10 MHz each. Each concession will be a technology neutral one. All the cellular operators of the country are expected to bid on that auction including Grameenphone.

Technology neutrality allows the operator to choose and deploy the technology best suited for their business. Till now (October 2012), the next generation technology LTE has been successfully rolled out in 105 networks. So, whether to deploy 3G or go for the next generation technology LTE bypassing 3G/UMTS remains a question any operator, in this case Grameenphone. This thesis tries to answer this question in accordance with Bangladesh's cellular market perspective taking into considerations the technological aspects as well as a cost revenue analysis done by data provided by Grameenphone Ltd. for both migration paths- 3G (UMTS/HSPA) and LTE.

TABLE OF CONTENTS

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We would like to express our special gratitude to LTS and Broadband Department of Grameenphone Ltd. for making the whole collaboration possible. This dissertation could not have been possible without their extraordinary support and industry information which they provided us from time to time.

We would also like to thank our parents for making us the persons who we are today.

List of Abbreviations

HSPA	High Speed Packet Access
HSPA+	HSPA Evolution
LTE	Long Term Evolution
UMTS	Universal Mobile Telecommunications System
CAPEX	Capital Expenditure
OPEX	Operational Expenditure
EBITDA	*Earnings Before Interest, Taxes, Depreciation and* Amortization
RAN	Radio Access Network
RNC	Radio Network Controller
BTS	Base Transciever Station
MV	Microwave
MNO	Mobile Network Operator
VoHSPA	Voice over HSPA
CS	circuit-switched
PS	Packet Switched
IP	Internet Protocol
IMS	IP Multimedia Subsystem
CSoHS	CS voice over HSPA
DCH	Dedication Transport Channel
WCDMA	*Wideband Code Division Multiple Access*
AMR	Adaptive Multi-Rate
VoIP	Voice over IP
VoLTE	Voice over LTE

SRVCC	Single Radio Voice Call Continuity
QoS	Quality of Service
OTT	Over The Top
NGMN	*Next Generation Mobile Networks*
CSFB	Circuit Switched FallBack
VoLGA	Voice over LTE via Generic Access
UMA	Universal Mobile Access
GAN	Generic Access Network
MMTel	MultiMedia Telephony
IRAT	Inter-Radio Access Technology
ICS	IMS Centralized Services
DRx	Discontinuous Reception
MIMO	Multiple Input Multiple Output
SON	Self-Organizing Network
ANR	Automatic Neighbor Relation
MLB	Mobility Load Balancing
RRM	Radio Resource Management
MME	Mobile Mobility Entity
MRO	Mobility Robustness Optimization
HO	Handover
ICIC	Inter-Cell Interference Coordination
CCO	Coverage and Capacity Optimization
SINR	Signal to Interference and Noise Ratio
GSA	Global mobile Suppliers Association

APAC	Asia Pacific
DC-HSPA	Dual Carrier HSPA
TD-SCDMA	Time Division Synchronous Code Division Multiple Access
TDD	Time Division Duplex
FDD	Frequency Division Duplex
M2M	Machine to Machine
PTP	Point to Point
PMP	Point to Multipoint
AP	Access Point
TCO	Total Cost of Ownership
UE	User equipment
BPSK	Binary Phase Shift Keying
EPC	Evolved Packet Core

CHAPTER ONE

In this chapter a brief discussion about our dissertation topic, its history and how we conducted the research for this dissertation is discussed.

1.1 Objective

There has been a tremendous growth in wireless communication technology over the past decade. New bandwidth consuming applications and the significant increase in subscribers and traffic have been placing new demands on capacity. The answer to the capacity demand is the provision of newer spectrum and the development of newer technologies. By 2015, 94% and 79% of traffic will be data in developed and developing regions of the world respectively.

The rapidly growing demand for bandwidth in cellular communication has impelled the 3GPP authorities to introduce high performing and cost-effective platforms. GSM/GPRS/EDGE (2G) is still an extensively deployed cellular technology around the world. On top of 2G, UMTS/HSPA (3G) has been deployed since the beginning of this century. In order to provide solutions for next generation wireless broadband, the industries have demonstrated strong support for Long Term Evolution (LTE). The advent of LTE is regarded as the latest upgrade in 3GPP technologies after GSM/GPRS/EDGE and UMTS/HSPA/HSPA+. The first version of LTE is documented in Release 8 of the 3GPP specifications. Release 9 enhanced specifications for various features and also, introduced several new features. At least 49 LTE networks have already been launched commercially in 29 countries. It is widely anticipated that the majority share of cellular networks will be based on LTE/LTE-Advanced platform within a decade. It is envisioned that by 2015, LTE services will account for about 250 million mobile connections globally. Western Europe and developed Asia will lead this growth with the developed region accounting for over 65% of the connections.

Thousands of technical features are getting stronger along with the upgrade path of the overall technologies. For example, in terms of the modulation order, GSM/GPRS supports GMSK, EDGE supports GMSK/8-PSK, and UMTS supports QPSK in both downlink and uplink. HSDPA supports

QPSK and 16-QAM, HSUPA supports BPSK, and HSPA+ additionally supports 64-QAM in downlink and 16-QAM in uplink. LTE supports QPSK, 16-QAM, and 64-QAM in both downlink and uplink.

The network architecture with co-existence of GSM-UMTS-LTE technologies is shown in Figure 1.a

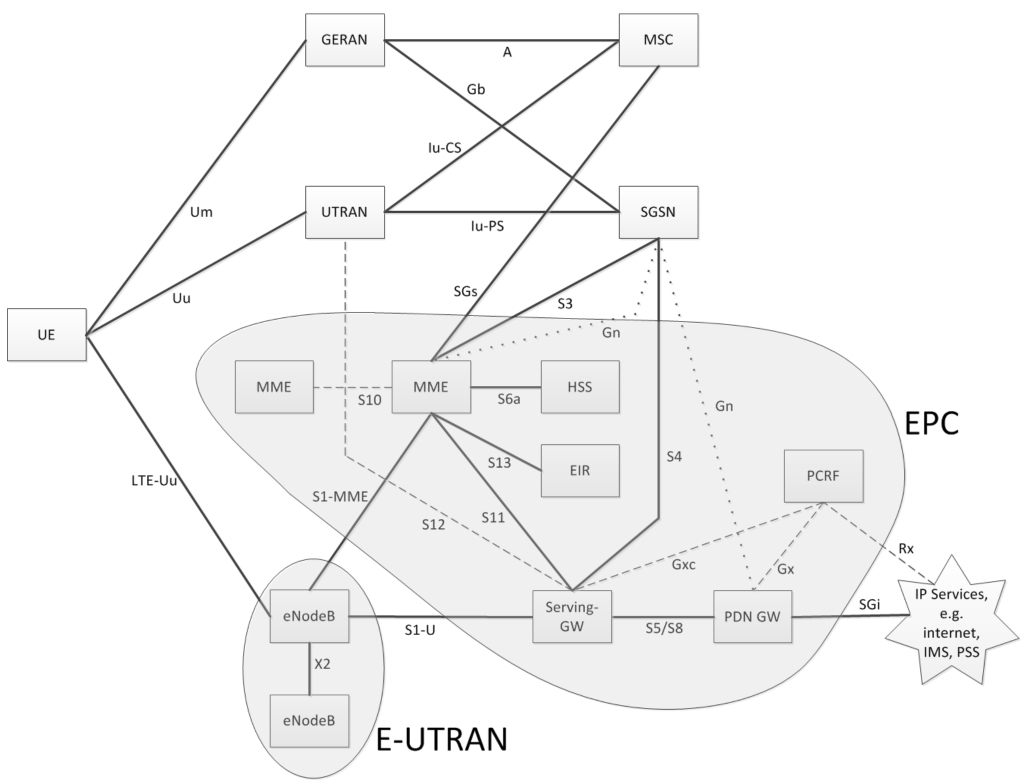


Figure 1.a

For the cases where UMTS/HSPA has not yet been rolled out, the ultimate upgrade to LTE can occur in the following two ways.

A. An evolution from GSM/GPRS/EDGE through LTE FDD or LTE TDD via UMTS/HSPA as shown in Figure 2(a).

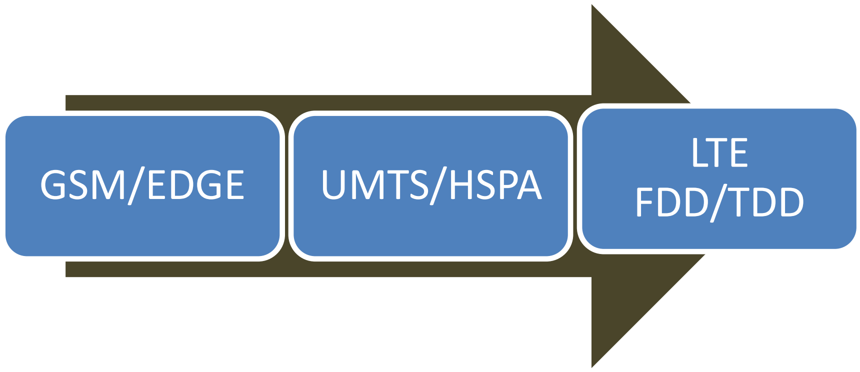


Figure: 1.b

B. Bypassing UMTS/HSPA and moving directly to LTE FDD or LTE TDD from GSM/GPRS/EDGE as shown in Figure 1.c

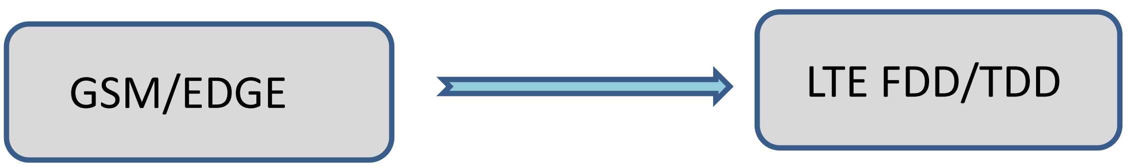


Figure: 1.c

The first option seems more popular as upgrading to UMTS/HSPA does not usually imply major network upgrades and is typically a smaller investment compared to evolution to LTE. However, the second option may prove relevant for operators in select markets as it is more CAPEX efficient to entirely leapfrog UMTS/HSPA.

The research attempts to compare the above two options based on the analysis of a detailed business case from the viewpoint of an operator in Bangladesh (Grameenphone). The analysis includes but not limited to the following items.

1. Demand for data speeds and capacity in a market as a function of time
2. CAPEX and OPEX constraints
3. User Equipment (UE) evolution
4. Bandwidth/spectrum used, Acquisition of new spectrum or re-farming the existing spectrum
5. Method of voice calls support
6. Impact of network sharing.
7. Rigorous technological comparison among the migration paths.

1.2 HISTORY OF CELLULAR COMMUNICATION IN BANGLADESH

Cellular mobile phone company Pacific Bangladesh Telephone Limited and Bangladesh Telecom got the first ever license for launching CDMA cellular technology in 1989. Then in 1996, Grameenphone got cellular mobile Telephone license and launched 2G GSM cellular service in the country. In the same year Telecom Malaysia International Bangladesh also received their 2G license and launched as Aktel. In 2004, the state owned telecom operator 'Teletalk' launched its operation. The following year, Egypt based Orascom acquired Sheba Telecom and renamed the company to Banglalink. In 2005, Warid Telecom International obtained a 15 year GSM license to operate in Bangladesh, but in 2009 Bharti Airtel acquired 70 percent stake in Warid Telecom. So currently there are five cellular operators operating in the country-

1. Grameenphone (Telenor-Grameen)
2. Banglalink (Orascom)
3. Robi (Axiata-NTT Docomo)
4. Airtel (Warid-Bharti Airtel)
5. Teletalk
6. Citicell (CDMA).

The percentage share of these operators are shown in the figure 1.

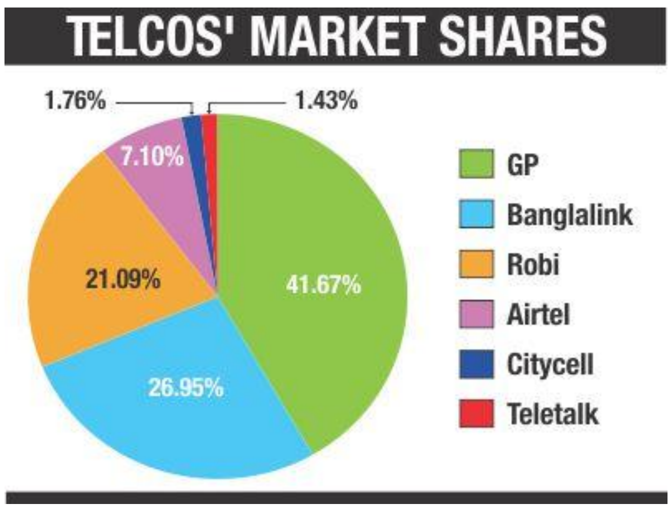


Figure: 1.d

Bangladesh now has 9.55 crore mobile users which was 8.5 crore in December last year, according to BTRC website.

Mobile operator Grameenphone has the highest 3.98 crore users, while Banglalink has 2.57 crore users, Robi 2.14 crore, Airtel 67.84 lakh, Citycell 16.83 lakh and state-owned Teletalk has 13.67 lakh users.

The telecommunication sector is making rapid progress as well as generating huge revenue and is one of the most established sectors in Bangladesh's corporate arena.

There is a tremendous demand for high speed mobile broadband service as well as reliable voice and VAS services which can be ensured by a better and advanced technology like 3G/LTE.

1.3 TECHNOLOGY NEUTRAL LICENSE AUCTION

Mobile operators in Bangladesh will get technology neutral spectrum licences for high-speed internet operations through an auction to be held in Q1, 2013. BTRC, the regulatory body will issue five technology neutral concessions of 10 MHz each in 2.1 GHz spectrum band. Followings are the key points of the 2.1 GHz licensing guideline according to the BTRC.

- One license for the state owned teletalk
- One for a new foreign entrant
- Three licenses for the privately owned mobile operators.
- Base price of per MHz will be $30 million and each concession will be for a 10MHz band.
- Each operator has to spend TK 0.61 million as license renewal fees each year.
- The license will be a technology neutral one which gives the operator the choice of rolling out the preferred technology.

1.4 Collaboration with Grameenphone

The research has primarily been conducted by the research team at IUT. The team updated Grameenphone on the progress of the research work periodically.

Grameenphone assisted the research team at IUT in the research. The types of assistance was contingent upon the various requirements that came up during the research which included data for the cost revenue estimation, forecast of the internet data demand in Bangladesh's perspective etc.

The output of the research work is jointly owned by IUT and Grameenphone.

CHAPTER 2

In this chapter, we have discussed a little about the background of the two cellular technologies we are comparing in this dissertation. A short history of both LTE and 3G LTE/UMTS is discussed here and also their working principles are described briefly.

2.1.1 History of 3G Technology

With the most popular cellular technology till date, GSM being developed and deployed, the eyes of the development community started to look at the next cellular developments which would provide greater more functionality and greater levels of efficiency. The UMTS 3G history shows how these basic ideas turned into reality and changed the way in which mobile telecommunications was used.

The UMTS 3G history shows that despite many set backs, UMTS was able to become established as the major 3G technology providing new standards in cellular telecommunications performance, functionality, and convenience. The 3G history shows that UMTS became the dominant 3G technology, setting the foundations for a single worldwide 4G standard in future years.

2.1.2 3G beginnings and IMT-2000

The International Mobile Telecommunications-2000, IMT-2000 standard is actually a family of standards for third generation (3G) wireless communications. It defines the broad outlines and requirements for standards that can be called 3G standards. It was set in place by the International Telecommunications Union (Radio Communications section), ITU-R.

In the 1980s work started on looking at, what was termed in the ITU-R the "Future Public Land Mobile Telecommunications System". However with the deployment on GSM and other 2G technologies the impetus for the development of the next generation system was not present.

It was not until the early 1990s that progress was seen. A working group was set up and also the 1992 World Administrative Radio Conference (WARC'92) allocated 230 MHz of spectrum between 1885 and 2025 and 2110 and 2200 MHz.

A number of organizations recognized the need for a global standard for the next generation of mobile telecommunications services. ETSI in Europe moving towards what they termed their Universal Mobile Telecommunications System, UMTS and in Japan the forerunner of the Association of Radio Industries and Businesses, ARIB undertaking a study. To enable a single standard to be adopted the ITU-R requested each regional Standards Development Organisation (SDO) to submit proposals for a Radio Transmission Technology.

As a result, between 1996 and 1998 companies and regional SDOs worked towards their proposal submissions.

A total of 17 different proposals were submitted. Of these eleven were for terrestrial systems and the remain six were for satellite systems. The evaluation of the proposals was completed during 1998 but during early 1999 it was necessary to gain some form of consensus. Once this was complete, by the end of 1999 the specification for the radio Transmission Technology was released by the end of 1999.

Although many proposals were submitted there were several that were considerably more important than others. These included:

- ***UMTS / WCDMA:*** The Universal Mobile Telecommunications System using wideband CDMA was the successor to the highly successful GSM system that was initially deployed around Europe, but was spreading rapidly worldwide.
- ***CDMA2000:*** This scheme was the successor to the cdmaOne system defined under Interim Standard IS-95 which was the first system to be deployed using CDMA technology.
- ***TDS-CDMA:*** This was a scheme developed in China that adopted many elements of the GSM / UMTS technology but was optimised for Time Division Duplex.

NB: The GSM evolution, EDGE also complied to the IMT-2000 definition for a 3G standard, although it was more commonly referred to as a 2.75G standard.

Of the main IMT-2000 systems, history has shown that UMTS has became the most widely deployed of the 3G systems. It offered global roaming as well as being designed to enable more applications than many of its competitors. Also as it followed on from GSM, it had a very wide base on which to build.

2.1.3 3GPP and 3GPP2 history

In 1998 the various SDOs interested in UMTS banded together to form the 3rd Generation Partnership Programme, 3GPP by signing the 3rd Generation Partnership Project Agreement. Historically, the scope of 3GPP was to produce technical specifications and reports for a 3G system based on evolved GSM core networks, and the resulting radio access technology, i.e. both FDD and TDD versions of UMTS [Radio-electronics.com].

The work on the UMTS standard progressed rapidly and the first release, known as Release 99 took place in 1999. Further releases have appeared periodically since then to incorporate additional changes and additions to the standards including High Speed Packet Downlink Access - HSDPA, High Speed Packet Uplink Access - HSUPA and Long Term Evolution - LTE.

The success of 3GPP subsequently lead to the organisation taking on the maintenance and development the GSM, GPRS and EDGE technical specifications and reports. Ore recently it has undertaken the development of the 3G LTE and LTE Advanced technical specifications and reports.

A similar organisation, known as the 3rd Generation Partnership Programme 2, 3GPP2, was set up to develop and manage the standards and reports for the CDMA2000 cellular telecommunications system.

3G HSPA of High Speed packet Access is the combination of two technologies, one of the downlink and the other for the uplink that can be built onto the existing 3G UMTS or W-CDMA technology to provide increased data transfer speeds.

The original 3G UMTS / W-CDMA standard provided a maximum download speed of 384 kbps. With many users requiring much high data transfer speeds to compete with fixed line broadband services and also to support services that require higher data rates, the need for an increase in the speeds obtainable became necessary. This resulted in the development of the technologies for 3G HSPA.

2.1.4 3G HSPA benefits

The UMTS cellular system as defined under the 3GPP Release 99 standard was orientated more towards switched circuit operation and was not well suited to packet operation. Additionally greater speeds were required by users than could be provided with the original UMTS networks. Accordingly the changes required for 3G HSPA were incorporated into many UMTS networks to enable them to operate more in the manner required for current applications.

3G HSPA provides a number of significant benefits that enable the new service to provide a far better performance for the user. While 3G UMTS HSPA offers higher data transfer rates, this is not the only benefit, as 3G HSPA offers many other improvements as well:

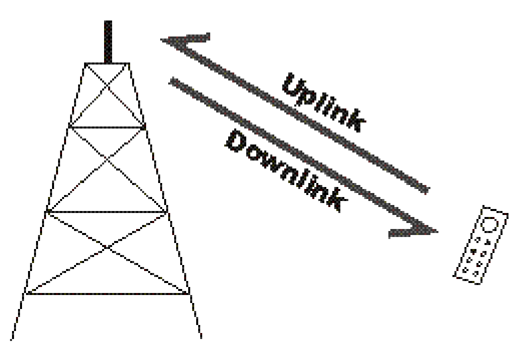
1. ***Use of higher order modulation:*** 16QAM is used in the downlink instead of QPSK to enable data to be transmitted at a higher rate. This provides for maximum data rates of 14 Mbps in the downlink. QPSK is still used in the uplink where data rates of up to 5.8 Mbps are achieved. The data rates quoted are for raw data rates and do not include reductions in actual payload data resulting from the protocol overheads.
2. ***Shorter Transmission Time Interval (TTI):*** The use of a shorter TTI within 3G HSPA reduces the round trip time and enables improvements in adapting to fast channel variations and provides for reductions in latency.
3. ***Use of shared channel transmission:*** Sharing the resources enables greater levels of efficiency to be achieved and integrates with IP and packet data concepts.

4. ***Use of link adaptation:*** By adapting the link it is possible to maximize the channel usage.
5. ***Fast Node B scheduling:*** The use of fast scheduling within 3G HSPA with adaptive coding and modulation (only downlink) enables the system to respond to the varying radio channel and interference conditions and to accommodate data traffic which tends to be "bursty" in nature.
6. ***Node B based Hybrid ARQ:*** This enables 3G HSPA to provide reduced retransmission round trip times and it adds robustness to the system by allowing soft combining of retransmissions.

For the network operator, the introduction of 3G HSPA technology brings a cost reduction per bit carried as well as an increase in system capacity. With the increase in data traffic, and operators looking to bring in increased revenue from data transmission, this is a particularly attractive proposition. A further advantage of the introduction of 3G HSPA is that it can often be rolled out by incorporating a software update into the system. This means that the use of 3G HSPA brings significant benefits to user and operator alike.

2.1.4 3G UMTS HSPA constituents

There are two main components to 3G UMTS HSPA, each addressing one of the links between the base station and the user equipment, i.e. one for the uplink, and one for the downlink.



Uplink and downlink transmission directions

The two technologies were released at different times through 3GPP. They also have different properties resulting from the different modes of operation that are required. In view of these facts they were often treated as almost separate entities. Now they are generally rolled out together. The two technologies are summarised below:

- ***HSDPA - High Speed Downlink Packet Access:*** HSDPA provides packet data support, reduced delays, and a peak raw data rate (i.e. over the air) of 14 Mbps. It also provides around three times the capacity of the 3G UMTS technology defined in Release 99 of the 3GPP UMTS standard.
- ***HSUPA - High Speed Uplink Packet Access:*** HSUPA provides improved uplink packet support, reduced delays and a peak raw data rate of 5.74 Mbps. This results in a capacity increase of around twice that provided by the Release 99 services.

2.1.5 3G UMTS HSPA and 3GPP standards

The new high speed technology is part of the 3G UMTS evolution. It provides additional facilities that are added on to t e basic 3GPP UMTS standard. The upgrades and additional facilities were introduced at successive releases of the 3GPP standard.

- ***Release 4:*** This release of the 3GPP standard provided for the efficient use of IP, a facility that was required because the original Release 99 focussed on circuit switched technology. Accordingly this was a key enabler for 3G HSDPA.
- ***Release 5:*** This release included the core of HSDPA itself. It provided for downlink packet support, reduced delays, a raw data rate (i.e. including payload, protocols, error correction, etc) of 14 Mbps and gave an overall increase of around three over the 3GPP UMTS Release 99 standard.
- ***Release 6:*** This included the core of HSUPA with an enhanced uplink with improved packet data support. This provided reduced delays, an uplink raw data rate of 5.74 Mbps and it gave an increase capacity of around twice that offered by the original Release 99

UMTS standard. Also included within this release was the MBMS, Multimedia Broadcast Multicast Services providing improved broadcast services, i.e. Mobile TV.

- ***Release 7:*** This release of the 3GPP standard included downlink MIMO operation as well as support for higher order modulation up to 64 QAM in the uplink and 16 QAM in the downlink. However it only allows for either MIMO or the higher order modulation. It also introduced protocol enhancements to allow the support for Continuous Packet Connectivity (CPC).
- ***Release 8:*** This release of the standard defines dual carrier operation as well as allowing simultaneous operation of the high order modulation schemes and MIMO. Further to this, latency is improved to keep it in line with the requirements for many new applications being used.
- Release 7, MIMO deployments can benefit from the DC-HSDPA functionality as defined in Release 8.
- Release 8, DC-HSPDA operates on adjacent carriers
-
- Release 9, paired cells can operate on two different frequency bands, possible to use DC-HSDPA in combination with MIMO.
-

2.1.6 Beyond 3G HSPA

With the elements of 3G HSPA launched, further evolutions were in the pipeline. The first of these was known as HSPA+ or Evolved HSPA. The evolved HSPA or HSPA+ provides data rates up to 42 Mbps in the downlink and 11 Mbps in the uplink (per 5MHz carrier) which it achieves by using high order modulation and MIMO (multiple input, multiple output) technologies.

In addition to 3G HSPA, and its evolutions, the next evolution for 3G UMTS is known as LTE - Long Term Evolution. This uses a completely different air interface that is based around OFDM as the modulation format. While many operators have opted to migrate directly from UMTS to LTE, the majority are using 3G HSPA to upgrade their existing 3G networks.

2.2 Introduction of LTE

The mobile communications industry, a decade after the introduction of broadband wireless communication systems known as 3G, decided to redesign the whole cellular based communication technology and nonlinearly migrate from the existing hybrid wireless system towards a fully packet based broadband communication network.

The access part of this network is known as *3GPP Long Term Evolution* while the core network framework structured under the *Service Architecture Evolution* concept is commonly referred to as the *Evolved Packet Network*.

LTE Enhances the Mobile Broadband Experience

One of the main reasons for the communication industry's reassessment of the present mobile telecom broadband situation is the fact that the world is very different today than it was when 3G first came out. Fixed broadband connectivity is now common with impressive and ever increasing speeds being offered by DSL, fiber and cable based technologies.

In contrast with the year 2000, today every consumer can admit to being broadband literate, and the broadband experience is shaping consumer attitudes and behaviors; broadband is not only accepted by consumers, but expected as well.

2.2.1 LTE and the GSM Family

In January 2009 there were over 4 billion wireless subscribers, over 254 operators and over 110 countries supporting Wideband CDMA (WCDMA) access technologies. *Wireless intelligence* reported in July that the total number of wireless GSM based connections has surpassed the 5 billion mark with WCDMA connections rising to about 12 percent of the global total in the second quarter of 2010.

2.2.2 The motivation for LTE

- Need to ensure the continuity of competitiveness of the 3G system for the future
- User demand for higher data rates and quality of service
- Packet Switch optimised system
- Continued demand for cost reduction (CAPEX and OPEX)
- Low complexity
- Avoid unnecessary fragmentation of technologies for paired and unpaired band operation

2.2.3 Short History of LTE

The concept of the Long Term Evolution of today's WCDMA or 3G access network was discussed in detail in 2004 in a Radio Access Network workshop that took place in Toronto Canada.

The workshop was attended and received technical and architectural contributions from over 40 telecom operators, internationally recognized technical institutes and well known universities, as well as 3GPP and non 3GPP institutions.

The result was a feasibility study launched by 3GPP on the plausibility of designing and implementing in a timely way a high speed packet optimized wireless data network with low latency and quick turnaround times. This network would present a user the equivalent broadband experience enjoyed in today's fixed environment: with the addition of the mobility factor.

The first notable LTE release included specifications for HSPA+- an enhanced version of HSPA and the connecting link between 3G HSPA and LTE- as well as an all IP based flat network effectively bringing the merits of internet connectivity to the edge of the broadband mobile network.

Finally LTE Advanced is currently being standardized and will be rolled out under 3GPP Release 10

2.2.4 LTE Overview

LTE or the E-UTRAN (Evolved Universal Terrestrial Access Network) is the access part of the Evolved Packet System (EPS). The main requirements for the new access network are high spectral efficiency, high peak data rates, short round trip time and frequency flexibility. [LTE OVERVIEW-3gpp]

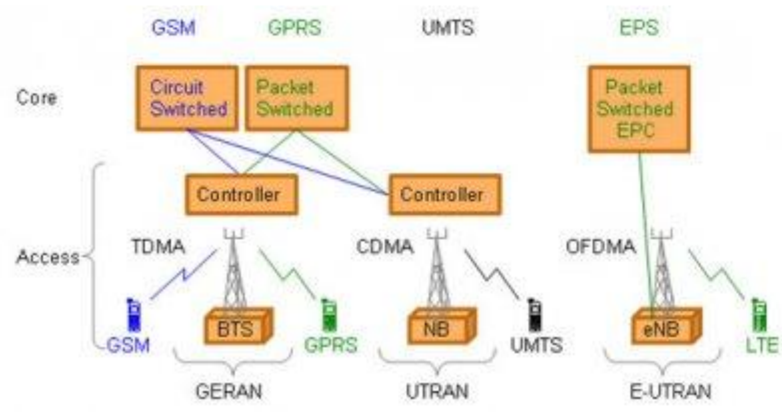


Figure: Network Solutions from GSM to LTE [*By Magdalena Nohrborg, for 3GPP*]

GSM was developed to carry real time services, in a circuit switched manner (in blue in fig.1), with data services only possible over a circuit switched modem connection, with very low data rates. The first step towards an IP based packet switched (in green in fig.1) solution was made with the evolution of GSM to GPRS, using the same air interface and access method, TDMA (Time Division Multiple Access).

To reach higher data rates and data volume UMTS was developed with a new access network, based on CDMA (Code Division Multiple Access). The access network in UMTS emulates a circuit switched connection for real time services and a packet switched connection for datacom services (in black in fig.1). In UMTS the IP address is allocated to the UE when a datacom service is established and released when the service is released. Incoming datacom services are therefore still relying upon the circuit switched core for paging.

The Evolved Packet System is purely IP based. Both real time services and datacom services will be carried by the IP protocol. The IP address is allocated when the mobile is switched on and eventually the IP address is released when the mobile is switched off. The new access solution, LTE, is based on OFDMA to be able to reach even higher data rates and data volumes. High order modulation (up to 64QAM), large bandwidth (up to 20 MHz) and MIMO transmission in the downlink (up to 4x4) is also a part of the solution. The highest theoretical data rate is 170 Mbps in uplink and with MIMO the rate can be as high as 300 Mbps in the downlink.

The core network EPC is prepared to work with other access technologies not developed by 3GPP, like WiMAX and WiFi. Non 3GPP developed access solutions are divided in trusted and non-trusted. This division is not based on the technical solution but the business relation/agreement between the operators. The LTE access network is simply a network of base stations, evolvoed NodeB (eNB), generating a flat architecture (figure 1). There is no centralized intelligent controller, and the eNBs are normally inter-connected by the X2-interface and towards the core network by the S1-interface (figure 2). The reason for distributing the intelligence amongst the base-stations in LTE is to speed up the connection set-up and reduce the time required for a handover. For an end-user the connection set-up time for a real time data session is in many cases crucial, especially in on-line gaming. The time for a handover is essential for real-time services where end-users tend to end calls if the handover takes too long.

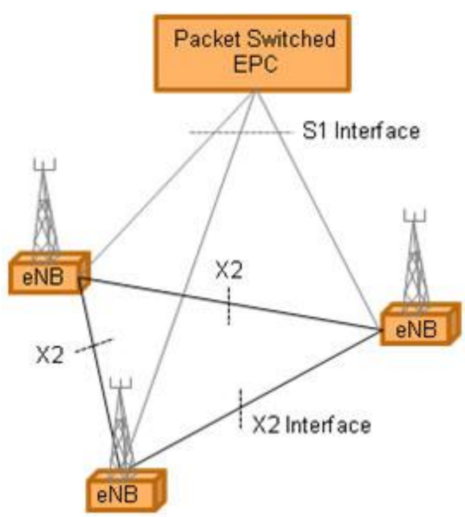


Figure: X2 and S1 Interfaces

Another advantage with the distributed solution is that the MAC protocol layer, which is responsible for scheduling, is represented only in the UE and in the base station leading to fast communication and decisions between the eNB and the UE. In UMTS the MAC protocol, and scheduling, is located in the controller and when HSDPA was introduced an additional MAC sub-layer, responsible for HSPA scheduling was added in the NB.

The scheduler is a key component for the achievement of a fast adjusted and efficiently utilized radio resource. The Transmission Time Interval (TTI) is set to only 1 ms.

During each TTI the eNB scheduler shall:

- consider the physical radio environment per UE. The UEs report their perceived radio quality, as an input to the scheduler to decide which Modulation and Coding scheme to use. The solution relies on rapid adaptation to channel variations, employing HARQ (Hybrid Automatic Repeat Request) with soft-combining and rate adaptation.
- prioritize the QoS service requirements amongst the UEs. LTE supports both delay sensitive real-time services as well as datacom services requiring high data peak rates. To schedule a low data rate, real-time service leads to a pleased customer but a low utilized radio spectrum.
- inform the UEs of allocated radio resources. The eNB schedules the UEs both on the downlink and on the uplink. For each UE scheduled in a TTI there will be a Transport Block (TB) generated carrying user data. In DL there can be a maximum of two TBs generated per UE – if MIMO is used. The TB will be delivered on a transport channel. In LTE the number of channels is decreased compare to UMTS. For the user plane there is only one shared channel in each direction. The TB sent on the channel, can therefore contain bits from a number of services, multiplexed together. In theory the highest number of users that can be scheduled during 1 ms is 440, presuming 20 MHz band and 4x4 Multi User MIMO.

To achieve high radio spectral efficiency a multicarrier approach for multiple access was chosen by 3GPP. For the downlink, OFDMA (Orthogonal Frequency Division Multiple Access) was selected and for the uplink SC-FDMA (Single Carrier - Frequency Division Multiple Access) also known as DFT (Discrete Fourier Transform) spread OFDMA.

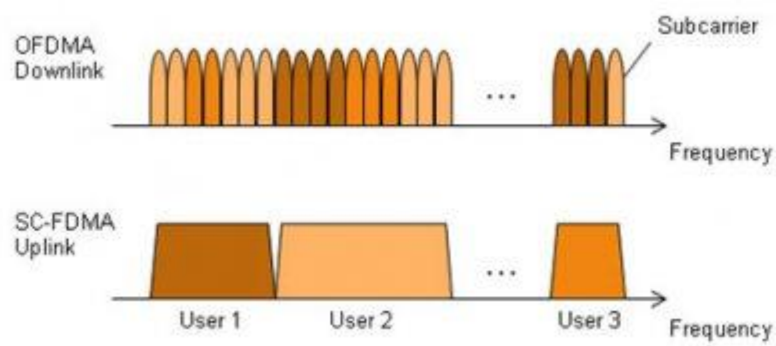
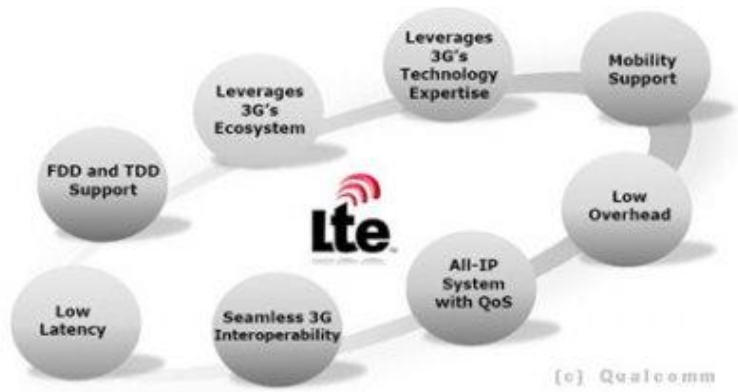


Figure : OFDMA and SC-FDMA

OFDM is a multicarrier technology subdividing the available bandwidth into a multitude of mutual orthogonal narrowband subcarriers. In OFDMA these subcarriers can be shared between multiple users. This solution is achieving very high spectral efficiency, but requires fast processors. It makes it possible to exploit variations in both frequency and time domains. The OFDMA solution leads to high peak-to-average power ratio requiring expensive power amplifiers with high requirements on linearity, increasing the battery consumption. This is no problem in the eNB, but would lead to very expensive handsets. Hence a different solution with lower requirement on the handset was selected for the UL.

To enable possible deployment around the world, supporting as many regulatory requirements as possible, LTE is developed for a number of frequency bands, ranging from 800 MHz up to 3.5 GHz. The available bandwidths are also flexible starting with 1.4 MHz up to 20 MHz. LTE is developed to support both the time division duplex technology (TDD) as well as FDD.

Since LTE provides high spectral efficiency, supports high data rates and implements a flexible access architecture, it is proven to become a success amongst operators as well as customers.



CHAPTER 3

In this chapter we try to make a rigorous comparison between 3G HSPA and LTE in terms of technological parameters as well as operational point of view. By analyzing the parameters and advantages, disadvantages of both rollout scenario we can make a clear understanding of what the future of cellular technology trend would be in Bangladesh.

3.1 Network architecture differences between 2G/3G and LTE

There are quite a few key differences in a LTE network which enable more flexibility in its architecture than in a 2G/3G network. In Figures 1 and 2 the key components of these two architectures are shown.

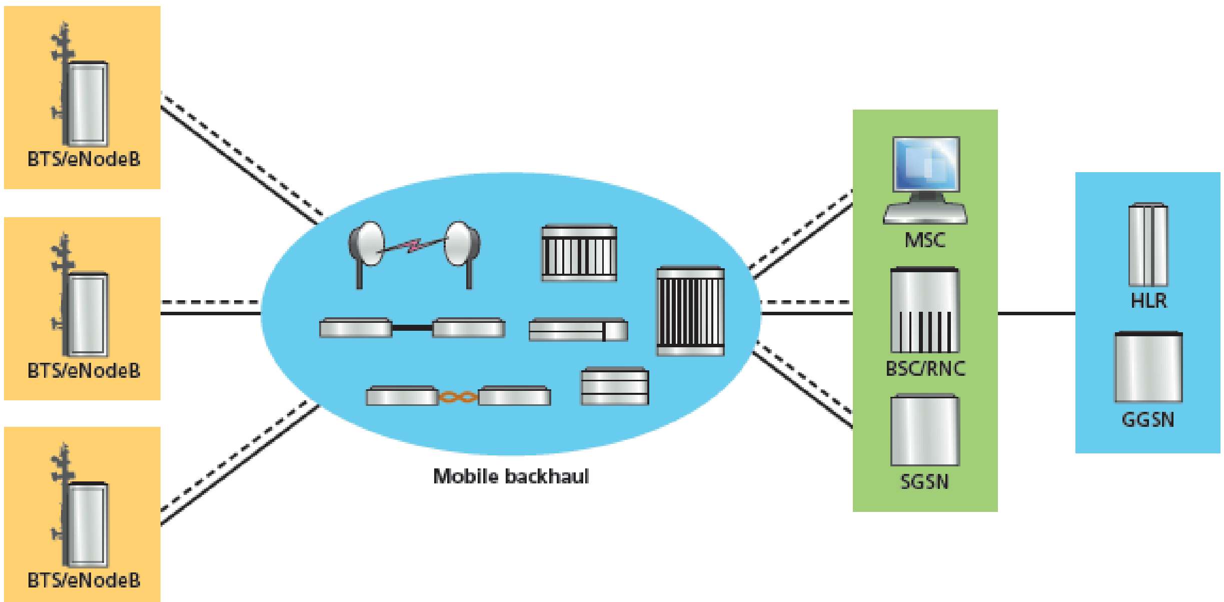


Figure: 2G/3G network architecture [alcatel-lucent: Interworking LTE EPC with W-CDMA Packet Switched Mobile Cores]

A functional representation of 2G/3G network architecture is shown in Figure 1. In this network, the Base Terminal Station (BTS)/NodeBs aggregate the radio access network (RAN) traffic and transport it over a mobile backhaul network to the Radio Network Controllers (RNCs)/Base Station Controller (BSCs). Typically this transport is over T1/E1 copper facilities. If fiber is available at or near the cell site, then the cell traffic is transported over SDH/SONET rings or, more recently, a carrier Ethernet network when the eNodeBs are equipped with IP/Ethernet interfaces. The bearer traffic from a number of RNCs/BSCs is multiplexed at the Mobile Telephone Switching Office (MTSO) and then transported via direct tunneling to the Gateway GPRS Serving Nodes (GGSNs) in the hub data center. This transport is normally over a

SDH/SONET ring or a carrier Ethernet network. This tiered aggregation and transport structure lends itself to a point-to-point network topology to minimize both the amount of aggregation equipment required and the transport backhaul expense.

In a 2G/3G pre-Release 8 network, the RNCs and SGSNs are designed to support both the signaling and bearer plane processing and bandwidth requirements. The emphasis in the design for these network elements is in providing the processing necessary to support the high subscriber counts and Packet Data Protocol PDP contexts as the bandwidth requirements for delivery of the initial 2G/3G data services (text and e-mail) were not significant. Since the data services that typically ran over these systems is not real-time neither QoS or latency was an issue. Therefore, the placement of these elements is usually in locations that primarily meet the PDP context and network latency requirements. Thus, the current 2G/3G packet core architecture is typically a centralized network design with the GGSNs deployed in major data centers, and all the data services are backhauled from the SGSNs which are strategically deployed in regional serving offices. Because the aggregate bandwidth for these services did not increase significantly until the past few years, the backhaul transport costs were manageable and could be supported with leased TDM or lower rate OC-n/STM-n interfaces.

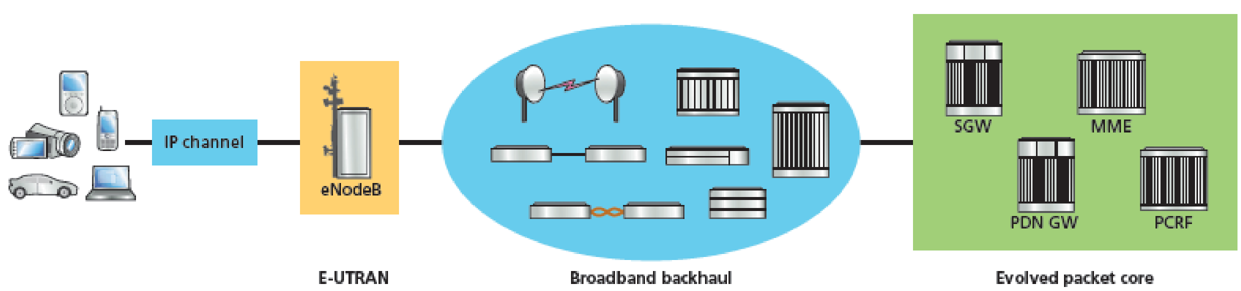


Figure 2

Figure 2 provides a high-level functional representation of a LTE network. This network is composed of three major sub-networks: the Evolved Universal Terrestrial Radio Access Networks (eUTRAN), which provides the air interface and local mobility management of the user equipment (UE), the evolved packet core (EPC), and the broadband backhaul network that

provides the aggregation of cell traffic and transport back to the EPC. The 3GPP LTE standards defined the EPC as a set of logical data and control plane functions that can be implemented either as integrated or as separate network elements. The four EPC functions are: the Serving Gateway (SGW), the Packet Data Network Gateway (PGW) that supports the data or bearer traffic; and the Mobility Management Entity (MME) and the Policy Charging and Rules Function (PCRF) which support the dynamic mobility management and policy control traffic. The backhaul network either is owned by the wireless operator or is leased from a third party backhaul access provider. Any number of transport technologies can be used for backhaul including packet microwave, packet optical, Carrier Ethernet, IP/MPLS, GPON and xDSL.
[alcatel-lucent whitepaper]

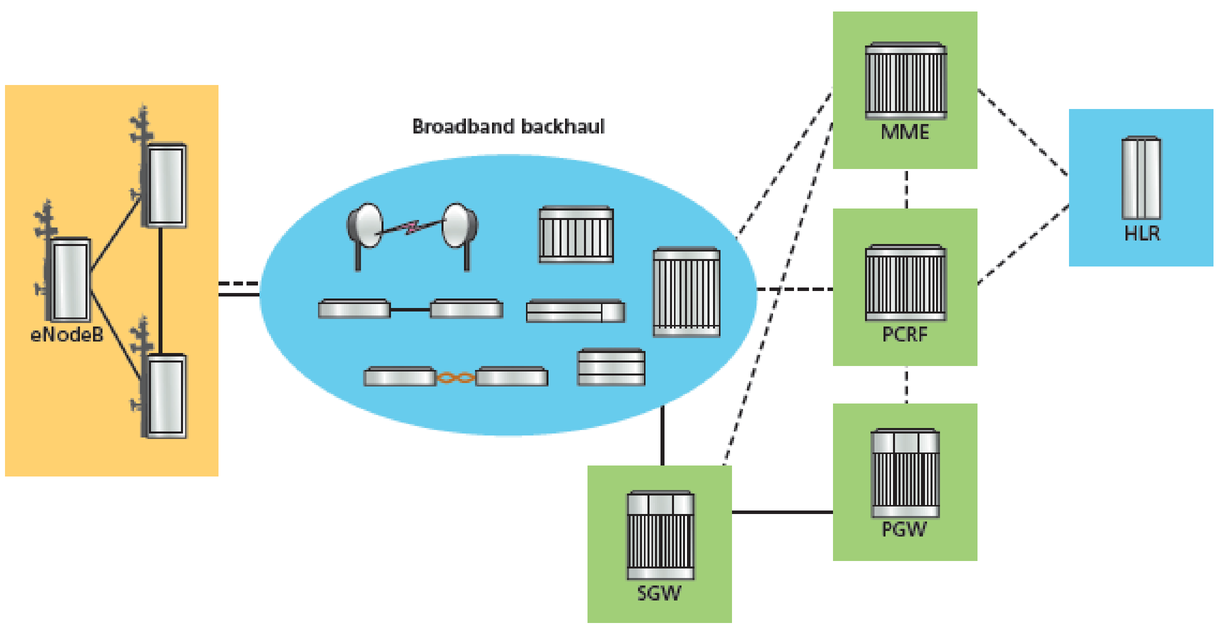


Figure: LTE EPC Network Architecture

Figure 3 provides additional details of the LTE network architecture, showing the signaling and bearer paths from the eNodeB to each of the EPC functional elements.

- Adjacent eNodeBs in the LTE E-UTRAN form a partial mesh network by connecting directly with each other for inter-eNodeB handovers rather than through the serving gateway.
- There are no RNC/BSC network elements in LTE networks. These functions have been distributed to either the eNodeB or MME and so there are fewer layers of aggregation and backhaul required.
- IP is used as the end-to-end network layer protocol between all LTE network elements. This reduces the levels of hierarchy (and different protocols) that exists in 2G/3G packet networks and simplifies the design and the management of the individual sub-domains (E-UTRAN, backhaul, EPC and backbone networks) as end-to-end IP.
- Another difference is in the functional decomposition of the LTE packet core elements themselves where the control plane and bearer plane functions are separated into individual network elements, each purpose built and functionally optimized to support its own role in the core network. By taking this building block approach in designing the EPC network, wireless operators can deploy EPC bearer and control plane network elements only where and when they are needed. This flexibility enables them to design their LTE core network in ways that were previously impractical with previous generations of mobile core equipment. This maximizes performance, scalability and operational efficiency of the EPC.
- More remote maintenance can be performed.
- Full IP network simplifies network provisioning.
- CS domain is no longer present, both voice and data service is operated in PS domain.

With LTE, new real-time mobile broadband services will be offered. This will require additional levels of QoS to differentiate them from other non-real-time services. The bandwidth for these services will also increase. Backhauling all this high bandwidth traffic to a centralized data center may be cost prohibitive especially when the up take for these high-speed services increase. By distributing the EPC gateways in the network rather than being centralized, the backhaul transport costs associated with these new high bandwidth services can be reduced.

For these real-time services QoS and latency will require a more flexible packet core network architecture, one that meets the specific service and geographical needs of the wireless operator while optimizing performance and minimizing transport costs.

3.2 Advantages of LTE over 3G UMTS/HSPA:

3.2.1 High Spectral Efficiency

As the wireless data market grows, deploying wireless technologies with high spectral efficiency will be of paramount importance. Keeping all other things equal such as frequency band, amount of spectrum, and cell site spacing, an increase in spectral efficiency translates to a proportional increase in the number of users supported at the same load per user—or, for the same number of users, an increase in throughput available to each user. Delivering broadband services to large numbers of users can best be provided with high spectral-efficiency systems.

Frequency resources are scarce and stupendously expensive.
The ever increasing price for spectrum demands an efficient and intelligent use of the resources, in which LTE is superior.

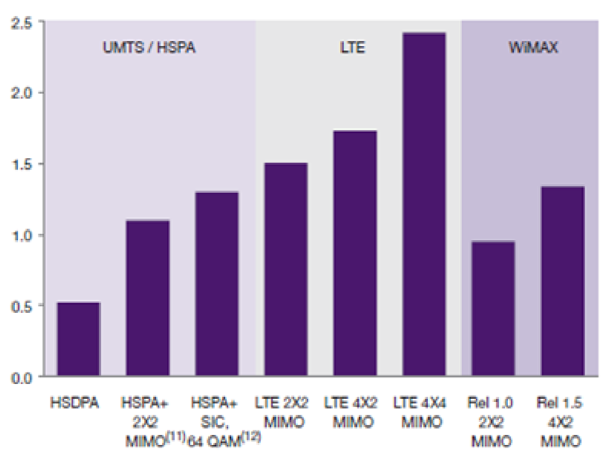


Figure LTE Spectral Effieciency

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

3.2.2 Highest Cell Throughput in LTE

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

Figure 3

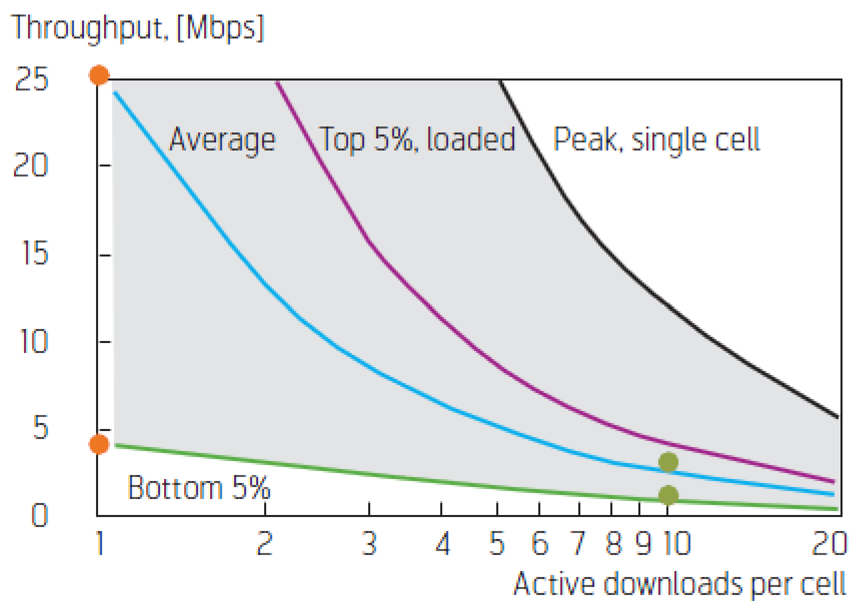
The performance of LTE in terms of user data rates and overall cell throughput is significantly better compared to UMTS/HSPA especially when the channel bandwidth goes over 5 MHz.

For a tier 1 US operator Verizon, the expected LTE characteristics is shown below

Attribute	Expected LTE Performance
Peak Data Rates	Peak Rates over 2x10 MHz DL (2x2): 86 Mbps; UL (1x2): 28 Mbps
Average User Throughputs	DL: 5 to 12 Mbps UL: 2 to 5 Mbps
(Average) Sector Throughput	DL 2x2: 15 Mbps UL 1x2: 5 to 6 Mbps
Latency (one-way)	15 ms

Figure LTE expected characteristics for Verizon Wireless (Source: Verizon Whitepaper)

The higher cell throughput in LTE can better satisfy the rapidly growing demand of wireless bandwidth



3.2.3 Lowest latency in LTE

Lower latency in LTE contributes to a better user experience. In the control plane, LTE supports a transition time of less than 100 ms from a camped state (idle mode) to an active state, such that a user plane is established. LTE also supports a transition time of less than 50 ms between dormant state and active state.

In the user plane, the delay is defined as the one-way transit time between a packet being available at the IP layer in the UE/evolved Node B (eNB) and the availability of the packet at IP layer in the eNB/UE. LTE enables a user plane latency of about 15 ms.

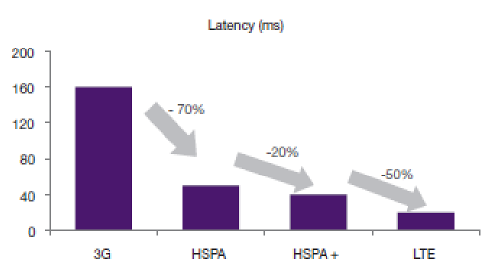


Figure: LTE latency superiority

The very low latency in LTE offers great advantage in case of highly immersive and interactive application environments, such as multiplayer gaming and rich multimedia communications

3.2. 4 Higher capacity with LTE for the same number of cell sites.

A typical comparison is shown next. With 10,000 sites, the radio network can support up to 5 million data subscribers with HSPA and up to 22 million data subscribers with LTE. With 20,000 sites, the capacities would be 10 million HSPA subscribers and 45 million with LTE.

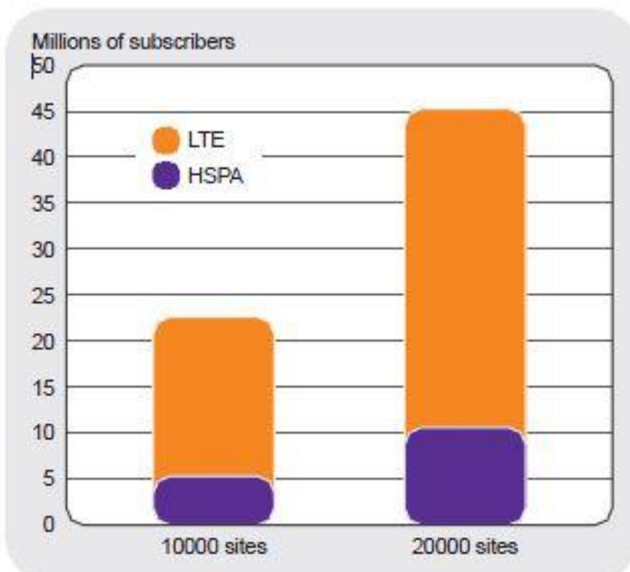


figure: maximum number of subscribers each consuming 5 GB/month

Figure by “Mobile broadband with HSPA & LTE-capacity and cost aspects by Nokia Siemens Network

The higher traffic support in LTE offers saving in both CAPEX and OPEX

3.2.5 Scalable Bandwidth in LTE

Six different bandwidths ranging from 1.4 to 20 MHz are defined in LTE. The capacity of the system is also scaled accordingly. This allows spectrum refarming and helps operators to use the available resources properly.

Bandwidth (MHz)	**1.4**	**3**	**5**	**10**	**15**	**20**
RB	6	15	25	50	75	100

UMTS/HSPA uses a fixed bandwidth of 5 MHz.

LTE adapts easily to different spectrum allocations in different frequency bands and makes provision for spectral refarming

3.2.6 Always-on IP connectivity in LTE

In LTE, a default EPS bearer that enables always-on IP connectivity to the UE, remains established all the time between the UE and the PDN GW. This simplifies and speeds up the connectivity. In the case of UMTS, the UE attaches to the network and is authenticated initially. There is no always-on connectivity and so, for establishment of data services, the connectivity between the UE and the network needs to be set up using a second procedure. This introduces a delay in access and reception of services and consequently limits network performance. In the case of UMTS, up to 30 signaling messages are required to establish a connection whereas only 7-13 messages establish a connection in LTE

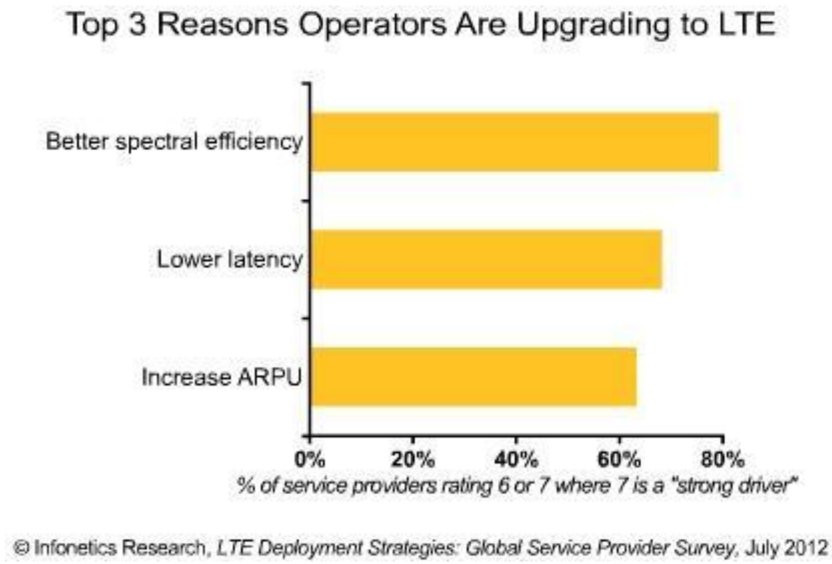
3.2.7 HARQ reordering is easier in LTE

In LTE, the HARQ reordering does not need an additional sequence number and reception buffer. Also, reordering is performed only at the RLC, layer. In case of HSPA, reordering is performed at both the RLC and MAC layers. And the two reordering operations increase delay in the HSPA. This benefit has again been possible in LTE because of locating both the HARQ and ARQ entities in the eNodeB.

The MAC layer implements HARQ operation to retransmit and combine received data blocks (transport blocks) and generate ACK or NACK signaling in case of CRC failure. HARQ attempts to correct data by combining multiple transmissions of the data even as every single transmission has errors. In case this does not succeed in retrieving the correct data, the ARQ function at the RLC is invoked to initiate retransmissions and re-segmentation for any affected PDUs. LTE uses synchronous HARQ on the uplink where retransmissions occur at a predefined time relative to the initial transmission and asynchronous HARQ on the downlink where retransmissions can occur at any time relative to the initial transmission thereby requiring additional information to indicate the HARQ process number to enable the receiver to associate a retransmission with its corresponding transmission. While the actual retention and re-combination of data is done by the PHY, the MAC performs the management and signaling [LTE in a Nutshell: Protocol Architecture whitepaper]

3.2.8 Saving current CAPEX in long term

An upgrade to LTE via UMTS/HSPA would incur CAPEX at two stages – for both *UMTS/HSPA* and *LTE*. Bypassing UMTS/HSPA can save overall CAPEX.



It is more CAPEX efficient in long term to entirely leapfrog UMTS/HSPA

3.2.9 LTE - Not Whether, but When

LTE is not a revolutionary technology, nor it is meant to be. The goal of the technology is to be able to meet the future demand of wireless broadband access, and thus satisfy customer expectations of improved data transmission performance, as well as voice transmission, without having to pay more money. It should not be thought of primarily as a vehicle for new services that will bring in significant additional revenue streams. LTE offers a superior combination of network performance and cost savings for meeting future demand for mobile data services. In order to mitigate the risk of not keeping up with that demand, every operator must analyze in detail its current network capacity and geographic footprint, build future demand scenarios, forecast its resulting future network capacity requirements, and devise a strategy for taking advantage of newly available spectrum. Ultimately, every operator has a choice: Move now to begin the transition to LTE and capture the early cost advantage, or wait until demand rises to the point where LTE investments become necessary. The current economic crisis will no doubt motivate many operators to defer some investments; still, the decision is not whether to shift to LTE, but when.

- ***If there is no compromise with putting LTE in the road map, then why not LTE now?***
- ***New LTE network rollout is costly, not a trivial problem, and takes both time and human resources. But due to the improved service levels, efficiency, and the need to stay competitive in the market, many operators won't have a choice but to upgrade to LTE sooner rather than later.***

3.2.10 LTE EVOLUTION

While HSPA+ was the peak of 3G technology, the current variation of 4G LTE is only the first step in this next stage, It is somewhat strange that advances in LTE technology are already being spoken about when the "original" standard networks aren't even close to being fully established. Yet, that is the rapid speed in which the tech world progresses.

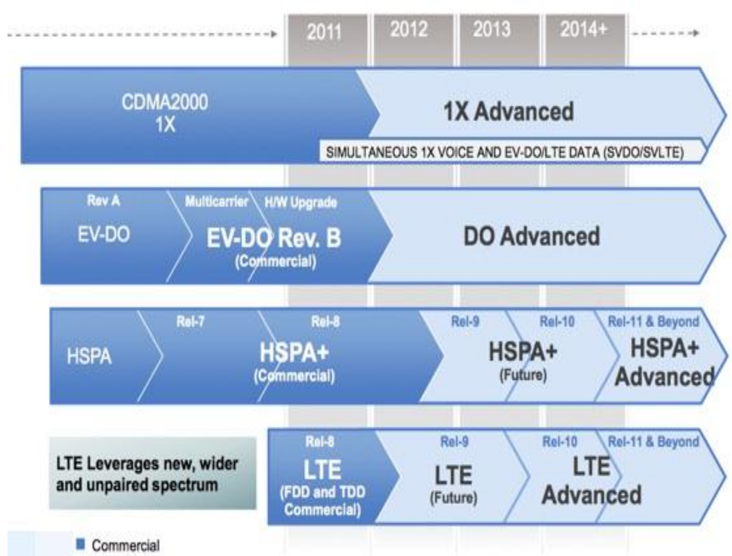


Figure LTE and HSPA evolution map

LTE Advanced: LTE Advanced is a further evolution of current LTE networks which brings with it theoretical peaks of 1Gbps download speeds, increased spectrum efficiency (up to 3 times more bandwidth), and reduced latency. Like the upgrade from HSPA to HSPA+, a move from LTE to LTE-Advanced is also a software deployment upgrade.

- ***LTE opens up numerous possibilities for much further advancement in this field.***

<u>3.2.11 Popularity of LTE</u>

NTT-Docomo launched LTE refarming their 2.1 GHz spectrum in Japan in 2010 and their current LTE subscribers is more than 2 million.

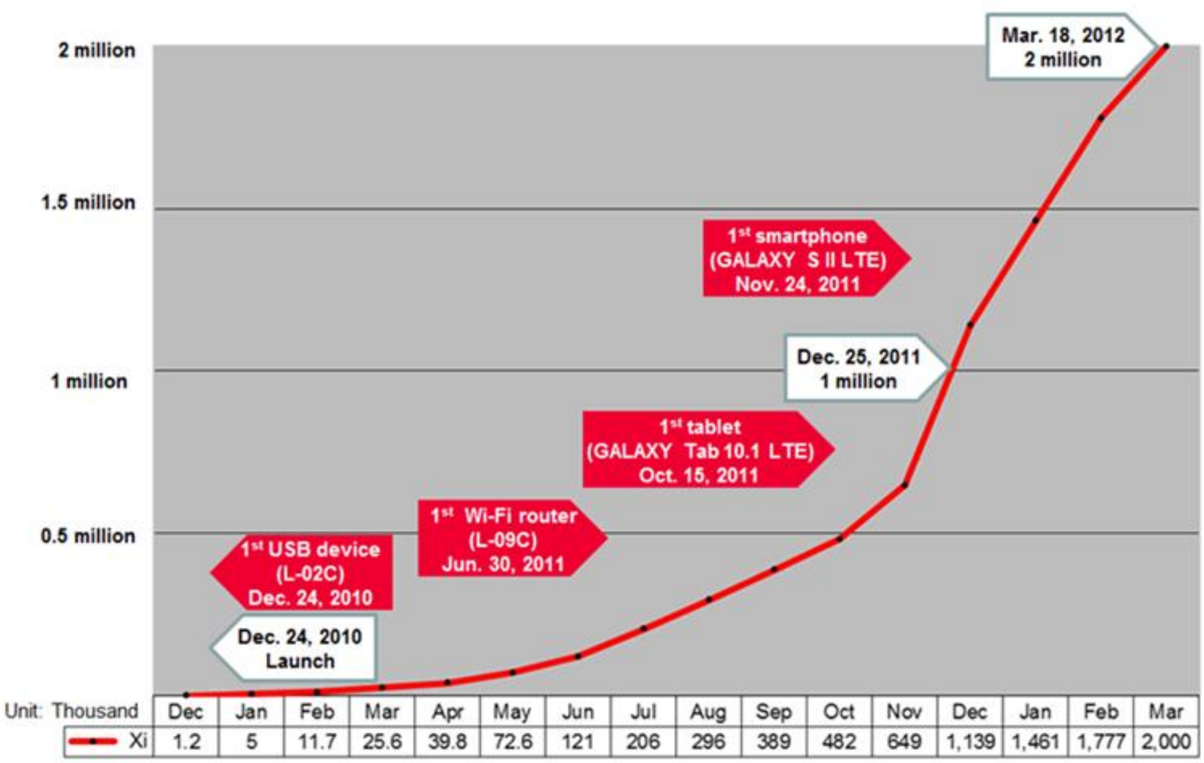


Figure: LTE subscribers rise for NTT docomo (Source: NTT docomo)

3.2.12 Saving CAPEX and OPEX by the use of Self-Optimizing Networks (SON) in LTE

Self-Configuration is a broad concept which involves several distinct functions that are covered through specific SON features, such as Automatic Software Management, Self Test and Automatic Neighbor Relation configuration.

The Self-Configuration algorithm should take care of all soft-configuration aspects of the eNodeB once it is commissioned and powered up for the first time. It should detect the transport link and establish a connection with the core network elements, download and

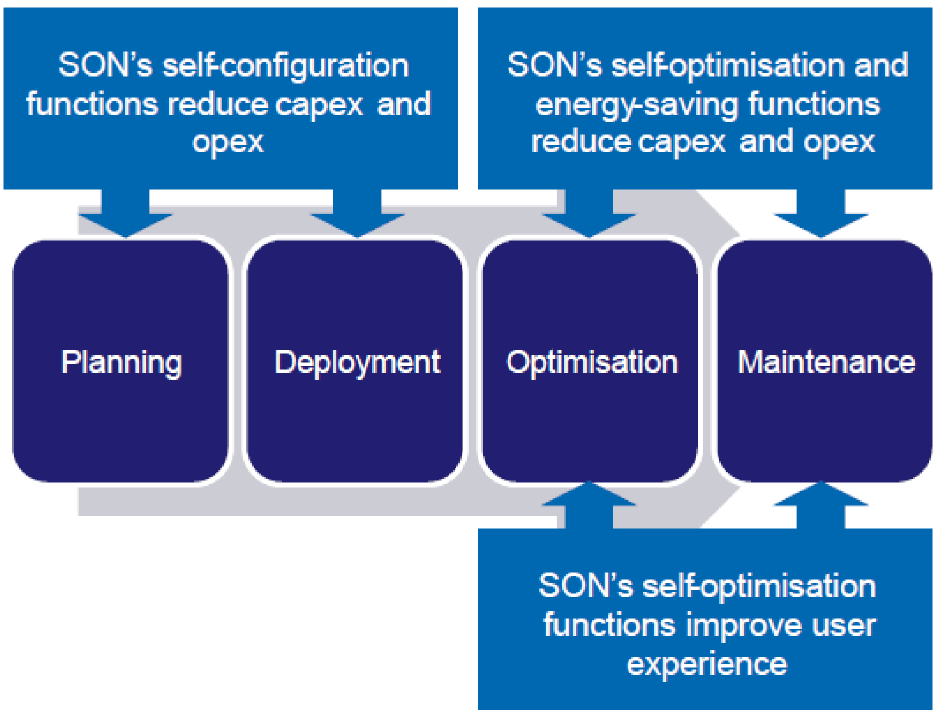


Figure SON functions [Aircom international]

upgrade the corresponding software version, setup the initial configuration parameters including neighbor relations, perform a self-test and finally set itself to operational mode.

- 3GPP standardizing self-optimizing and self organizing capabilities for LTE in Rel. 8, 9 and beyond

- LTE SON leverages network intelligence, automation and network management features in order to automate the configuration and optimization of wireless networks, thereby lowering costs and improving network performance and flexibility Lowering costs and improving network performance and flexibility
- A key goal of LTE SON standardization is the support for multi-vendor network environments, which has resulted in the definition of standard messaging formats to convey information between entities that can be used to implement a given SON algorithm
- Strong operator interest in LTE SON is evident from the significant SON contributions coming from organizations such as the Next Generation Mobile Networks Alliance (NGMN), and examples of the deployment of various SON use cases by LTE operators in their respective networks
- The net benefits of SON for the LTE fraction of the network come from a combination of energy savings, automated cell and network configuration, and from features providing human oversight and control over the automated system.

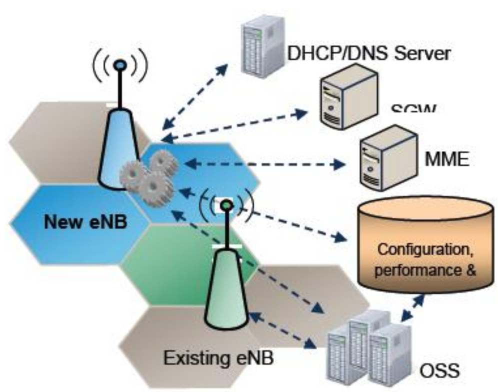


Figure **Self-Configuration of eNodeB in LTE.**

LTE SON SAVINGS:

- Deploying ANR algorithms in Distributed location for LTE has significant savings as reduces deployment/optimisation costs

- CCO for LTE provides less saving than UMTS as capacity is more easily managed in LTE

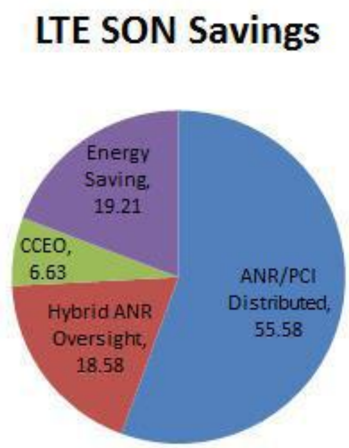


Figure LTE SON savings, aircom international

- ES has less benefit in LTE as newer LTE equipment is already more power efficient than UMTS

3.2.13 UMTS/HSPA SON limitation

Back in 2010, the vendors started back porting the SON features of LTE in UMTS/HSPA. Some of the features available in HSPA SON is

- Adaptive transmit power for coverage optimization,
- 2G/3G neighbor lists for cell reselection and handovers,
- Selection of optimal primary scrambling code

But HSPA technology doesn't support many advanced features of LTE SON.

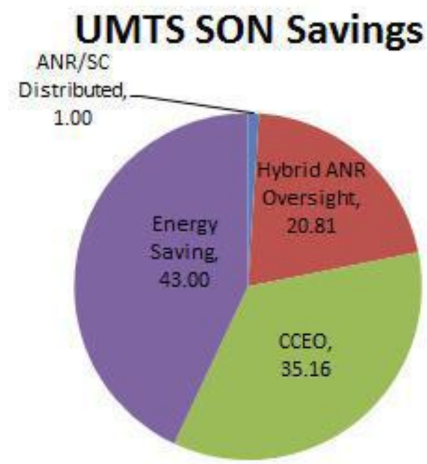


Figure UMTS SON Savings, Aircom international

3.2.14 Network sharing- LTE has advantage

LTE and HSPA is rapidly emerging as the world's most dominant mobile broadband technology, taking mobile broadband to unprecedented performance levels. To meet expectations and predictions for even higher data rates and traffic capacity , a densified infrastructure is needed. That is why network sharing has become an imperative in developed and emerging markets. Operators can achieve significant savings in cost and faster coverage rollout through sharing of network assets. In mature markets with limited or no revenue growth, cash flow can only be increased through cost reduction. Hence,the recent surge in sharing infrastructure has come into the picture.

Examples of network sharing are there for both UMTS/HSPA and LTE. But LTE is one step ahead in this case dur to their all-IP network infrastructure. In case of UMTS, there is scope limitation for network sharing.

The benefits

The greatest benefit of network sharing are substantial reductions in cash expenses:

- ✓ Roll-out capex can be reduced, thus yielding immediate cash flow benefits.
- ✓ Lower network opex can be achieved, providing a long term saving and hence higher EBITDA margins.
- ✓ Network sharing can speed up coverage roll-out, notably for mobile broadband services, using higher frequency bands.
- ✓ National roaming provides an attractive option for new market entrants and operators who do not have lower band spectrum. In some markets regulators have mandated national roaming to aid new entrants.
- ✓ Shared networks also mean shared investment risk particularly in the case of mobile broadband.

Network sharing can deliver network CAPEX and OPEX savings upto 40%. Potential cost savings from the network sharing can be modeled like the following one:

Sharing model	Savings in roll-out CAPEX	Savings in network OPEX (operation & maintenance)
Site / Mast Sharing ✓ Civil works, some passive RAN ✓ Site rents	5-10%	5-10%
Transmission Sharing ✓ Backhaul	5-15%	5-15%
RAN Sharing		

✓ Passive and active RAN ✓ Site rents ✓ Transmission CAPEX/OPEX	20-25%	20-25%
TOTAL	Up to 40%	Up to 40%

Models of network sharing:

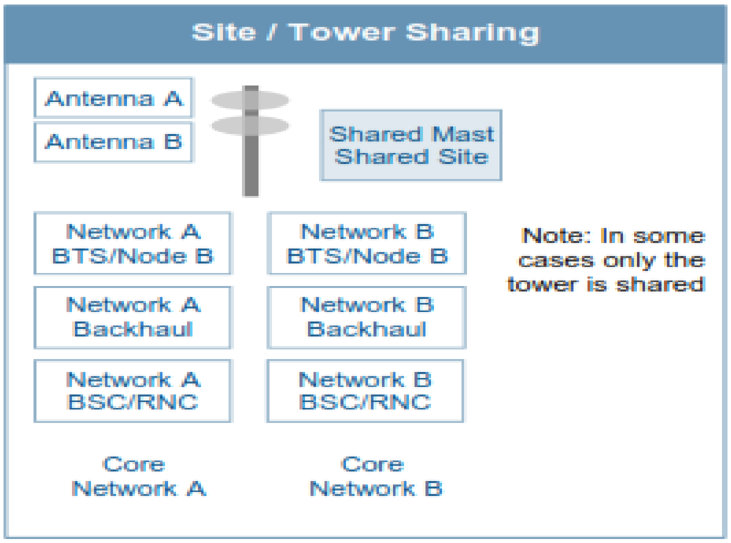
There are three main models of network sharing:

- ✓ site sharing and / or tower sharing is the most common form of network sharing.
- ✓ Backhaul / backbone sharing, suitable where mobile operators have to build their own transmission rather than lasing capacity from a fixed network operator.
- ✓ Full RAN sharing, including backhaul transmission.

Recently network sharing has moved to the top of many operators' agendas. The main drivers are:

- ✓ In mature mobile markets revenue growth is limited or total industry revenue may even decline. In this situation the only way to grow cash flow is to reduce OPEX and future CAPEX.
- ✓ Mobile operators are now building mobile broadband networks, notably HSPA and LTE. These require considerable investment in the RAN and there are costs in acquiring new spectrum (2.6 GHz, 700 / 800 MHz). Given that there are significant demand and technology uncertainties, operators are keen to minimize CAPEX associated with mobile broadband.
- ✓ It is much easier to agree network sharing for new networks i.e. mobile broadband, than to introduce sharing in existing 2G networks.

Tower/site sharing



Site sharing is favored in urban areas, due to complexity and the expense of finding new sites and therefore reduces lead times to improve coverage. When site sharing also involves tower or mast sharing, the economics are even more compelling. The civil works of mast sites can account for 65% of RAN CAPEX in suburban and rural areas.

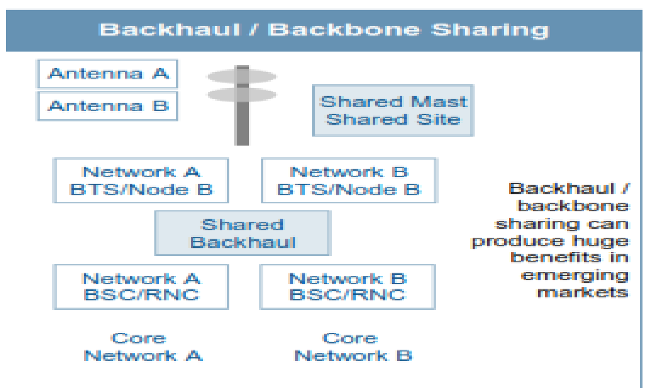
Some deployment examples are:

- ✓ In France 20-40% of sites are shared, depending on the operator.
- ✓ T-Mobile and O2 share sites for their 2G networks since 2001 and for 3G networks in Germany since 2003.
- ✓ In India, operators have created jointly owned tower companies (e.g. Indus Towers) and over 40% of all sites are shared, often with multiple networks tenants on one site.
- ✓ In the US and the UK independent tower companies host several operators on the same site.

The benefits of such passive sharing includes:

- ✓ Reduced site acquisition times for new entrants
- ✓ Access to locations of strategic importance, e.g. where space for new sites is limited
- ✓ Increased likelihood of obtaining planning permission for new sites
- ✓ Reduced OPEX (site lease)
- ✓ Reduced site acquisition and build completion times

Backhaul sharing



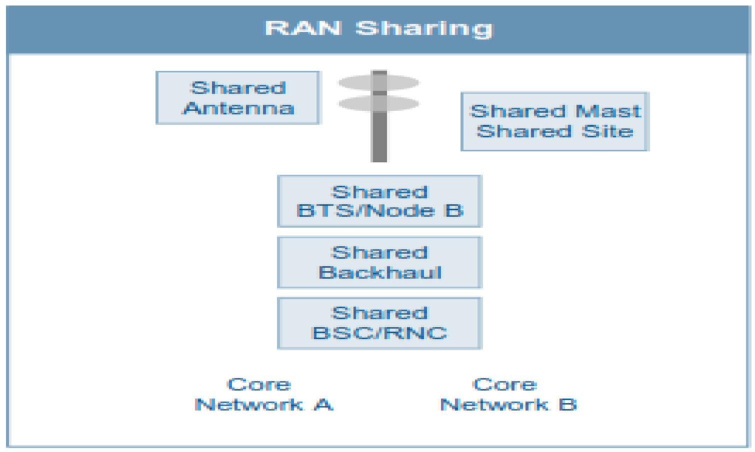
The growth in mobile data traffic dues to HSPA and in future LTE means operators have invest massively in backhaul. Here big savings can be had, particularly if fibre is deployed . This can lead to huge savings particularly in difficult geographies. Indonesia and the Philippines are prime examples.

The benefits of shared backhaul are:

- ✓ Shared build cost, particularly in emerging markets

- ✓ Shift forward the point where deployment of fibre rather than MV is economic.

RAN Sharing:



RAN sharing implies sharing the entire Access Network, including backhaul transmission. Traffic is split at the point where the MNO's core networks take over. Where RAN sharing is introduced in an existing network, the main driver is to reduce OPEX, for example by decommissioning sites. RAN sharing can be an attractive way of reducing CAPEX to cover rural areas, for example to fulfill regulatory requirements. Sharing the RAN increases the savings potential and the roll-out of mobile broadband provides an opportunity to realize these savings.

Examples of RAN include:

- ✓ In December 2007,T-Mobile and 3 formed Mobile Broadband Network Ltd, a JV to build and operate a joint network in the UK.
- ✓ Following the 2008 Advanced Wireless Services (AWS) spectrum auction in Canada, in 2009 Bell & Sasktel and Rogers & MTS respectively agreed to build joint HSPA networks.
- ✓ In Sweden, Telenor and Tele2 are jointly rolling out an LTE network.

The benefits of RAN sharing are:

- ✓ Fewer sites and masts for the same coverage
- ✓ Reduced environmental and visual impact
- ✓ Reduced CAPEX and OPEX, very important if fiber backhaul upgrade is considered.

3.3 ADVANTAGES OF DEPLOYING HSPA BEFORE LTE

Mobile broadband data has proved to be a successful offering that has attracted a large number of users enjoying high-quality data services via laptops, notebooks and smartphones. In many advanced HSPA markets, the data volume is more than ten times that of voice in terms of transferred gigabytes.

HSPA has transformed mobile networks from being voice-dominated to data-dominated in just a few years. It has been deployed in more than 150 countries by more than 350 communications service providers (CSP) on multiple frequency bands and is now the most extensively sold radio technology globally.

HSPA will continue to be deployed in parallel with the introduction of LTE. The need for higher data rates and volume growth continues to drive advances in radio technology. Many of the same performance-boosting innovations can be applied to both HSPA and LTE, though the effectiveness of those implementations remains a question

Currently there are clearly many advantages of HSPA over LTE for which many operators may opt for HSPA first while migrating from GSM/EDGE to a higher generation technology because of the fact that HSPA is actually enough to meet the current demand, though in future it may fall short of LTE's superiority. Some of the advantages of implementing UMTS/HSPA before LTE is described below.

<u>3.3.1 Satisfactory performance wit HSPA</u>

In current deployments, HSPA users regularly experience throughput rates well in excess of 1 Mbps under favorable conditions, on both downlinks and uplinks, with 4 Mbps downlink speed commonly being measured

Technology	Uplink	Downlink
HSPA Rel-6	5.6 Mbps (QPSK)	14 Mbps (16QAM)
HSPA Rel-7	11 Mbps (16QAM)	21 Mbps (64QAM) 28 Mbps (16QAM+2x2 SU-MIMO)
HSPA Rel-8	11 Mbps (16QAM)	42 Mbps (64QAM+2x2 SU-MIMO) 42 Mbps (64QAM+DC-HSDPA)
HSPA Rel-9	23 Mbps (DC-HSUPA)	84 Mbps (DC-HSDPA+2x2 SU-MIMO)
LTE Rel-8	86 Mbps	172 Mbps (2x2 SU-MIMO)

Figure: *Peak rates for selected HSPA and LTE versions*
[3GAmericas]

- ***The migration to UMTS/HSPA will allow to meet or surpass the present deman***

3.3.2 SAVING CURRENT CAPEX IN RAN

Much less CAPEX required for migration to UMTS/HSPA because Many existing GSM BTS equipment already supports HSPA – but only the software needs to be upgrade. So, ***The migration to UMTS/HSPA will be a budget friendly choice in short term***

3.3.3 SAVING CURRENT CAPEX IN CORE NETWORK

Much less CAPEX required for migration to UMTS/HSPA.

- UMTS/HSPA doesn't require significant change in core network than the existing GSM core. This means that all core-network elements above the Serving GPRS Support Node (SGSN) and Mobile Switching Center (MSC)—the Gateway GPRS Support Node (GGSN), the Home Location Register (HLR), billing and subscriber administration systems, service platforms, and so forth—need, at most, a software upgrade to support 3G UMTS-HSPA. And while early 3G deployment used separate 2G/3G SGSNs and MSCs, all-new MSC and/or SGSN products are capable of supporting both GSM and UMTS-HSPA radio-access networks.
- LTE needs upgrading the core networks to support LTE-SAE. LTE is an all IP-based network and it requires an upgraded system architecture.
- LTE requires upgraded back haul system to support the huge data transport.

3.3.4 Quicker Deployment possible with UMTS/HSPA

In case of migrating to UMTS/HSPA, upgrading RAN, core and backhaul system won't be too cumbersome like LTE, so easier and swift migration is possible. Many of the existing RAN operational in GSM/EDGE supports UMTS/HSPA and only a software upgrade will make a successful migration.

- ***The migration to UMTS/HSPA will be a less time consuming choice***

3.3.5 HSPA+ can keep UMTS/HSPA satisfactory for a long period of time

HSPA+, a simple upgrade to the HSPA networks today, protects and enhances an operator's infrastructure investment; 43 percent of all HSPA operators have upgraded to HSPA+ and it is expected that nearly all will evolve their networks. The first phase of HSPA+ with 64 QAM is deployed on a majority of the 190 commercial HSPA+ networks today, providing a peak theoretical downlink throughput rate of 21.6 Mbps in 2X5 MHz of spectrum; typical user speeds are 1.9 Mbps to 8.8 Mbps for the downlink and 1 Mbps to 4 Mbps for the uplink. HSPA+ enhancements, such as dual-carrier (DC) operation (2X10 MHz of spectrum), will double user-achievable peak throughput rates. There are currently 50 commercial HSPA+ (DC) networks offering theoretical downlink rates of 42 Mbps (Jan 2012). HSPA+ peak theoretical downlink speeds up to 84 Mbps are expected to follow in 2012. Based on Release 10 standard, with features such as multicarrier operation, Multiple-Input Multiple-Output (MIMO), and higher-order modulation implemented, HSPA+ peak theoretical downlink rates can reach 168 Mbps. Current 3GPP Release 11 study items indicate a further evolution of HSPA+ to peak theoretical speeds up to 336 Mbps.

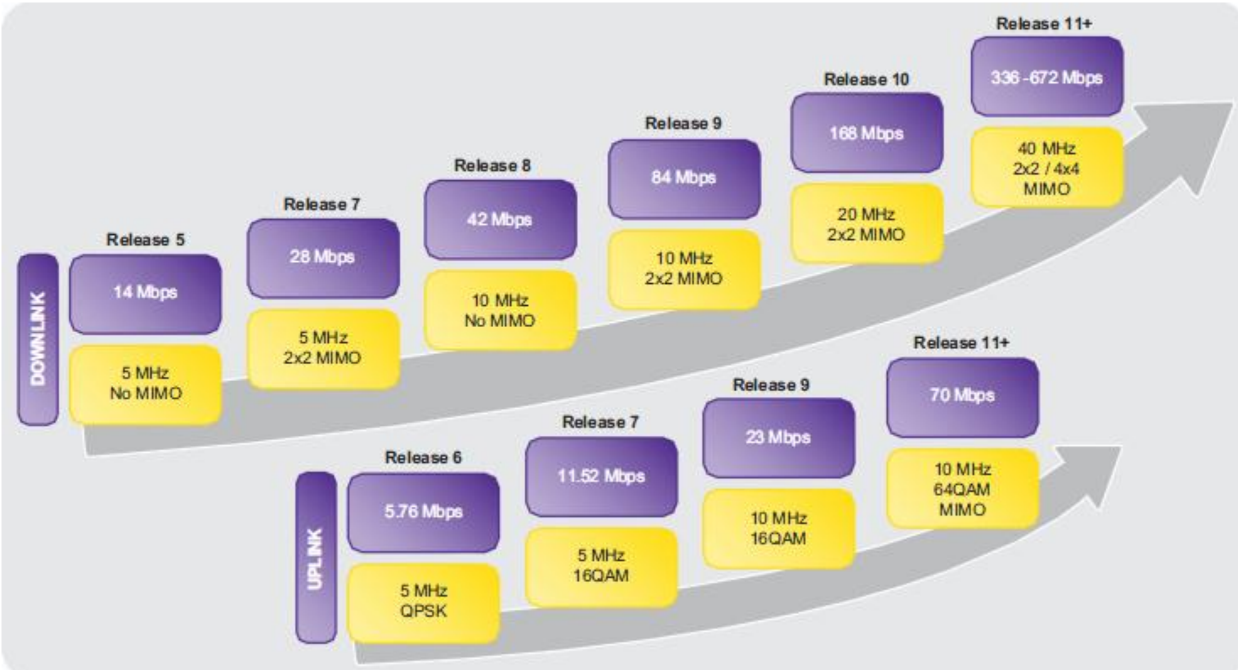


Figure: Projected HSPA peak data rate evolution with increased bandwidth and number of antennae.

- ***HSPA+ provides a strategic performance roadmap advantage with only incremental investment***

3.3.6 Data forwarding required to avoid the loss of data in LTE

In case of LTE, in order to avoid the loss of data, the source eNodeB forwards data to the target eNodeB over the X2 interface temporarily during the handover action until the data transfer begins between the UE and the target eNodeB. Such data forwarding is not required in the case of the HSPA because the RLC layer is implemented in RNC that can keep data for retransmission after handover.

3.3.7 UMTS/HSPA has a larger and developed ecosystem compared to LTE

- UMTS/HSPA Deployment is well-developed, optimized and robust while LTE is yet to be properly tuned.
- Experienced and skilled manpower is available
- Many solutions are available for a particular problem
- Multiple vendors are available providing a healthy and economic situation

3.3.8 UE Availability in the Market

Many customers already own UEs that support UMTS/HSPA and so they can keep using their UEs if upgraded to UMTS/HSPA.

There are 3071 HSPA devices from 262 suppliers and 2318 HSPA devices among them operate in the 2100 MHz band. The device types include USB dongles, smart phones, embedded laptops, data cards and routers including personal MiFi.

Most smart phones and tablets (3G versions) released in the last 2 years or so can access the faster speeds offered by HSPA+ networks.

3.4 Voice implementation

3.4.1 Voice over HSPA (VoHSPA)

Up to now, mobile voice services have been delivered by service providers using traditional circuit-switched (CS) technology. The benefits of leveraging Packet Switched (PS) and Internet Protocol (IP) technologies have been absent. Now operators are willing to apply these technologies. Once deployed, both mobile network operators and consumers stand to benefit significantly from more innovative, robust and efficient services.

This paper describes the technological features that are being developed to make Voice over HSPA(VoHSPA) a reality. It describes the two potential options for VoHSPA. The first option leverages IP Multimedia Subsystem (IMS) technology developed in conjunction with Long Term Evolution (LTE), and is referred to as IMS Voice over HSPA or simply IMS Voice. The other option delivers voice by modifying existing circuit-switch based techniques so that those communications can be transmitted over an HSPA infrastructure, and is referred to as CS Voice over HSPA (CSoHS).

CSoHS:

The traditional mechanism of mapping the CS voice connection over a Dedication Transport Channel (DCH) in the radio network has been in place from the very beginning of UMTS/W-CDMA standard. Subsequently a number of voice related optimizations were introduced to HSPA, enabling Voice over HSPA (VoHSPA), initially designed to carry digital CS voice traffic over the PS HSPA radio layer (CSoHS). This promised to be significantly more efficient than the traditional CS voice over DCH service, both in terms of system capacity and UE power consumption. From a radio perspective there is little difference whether data bits flow over a

CS or PS connection. Thus, in order to be able to benefit from voice related HSPA improvements, the limitation preventing CS connections from being mapped to the HSPA radio layer was removed in the Rel-8 specifications.

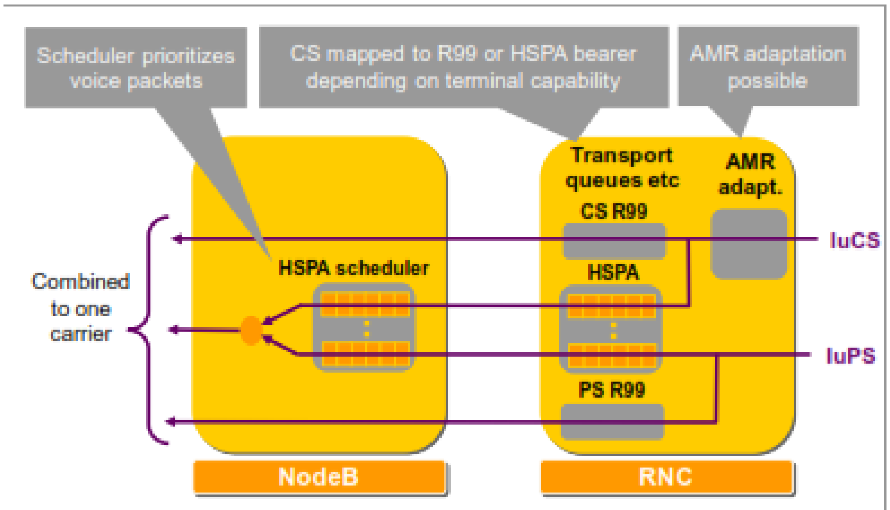


Figure 5. Illustration of CSoHS Implementation

In CSoHS, the already digitized voice packets use HSPA channels for transport back to the existing CS infrastructure immediately beyond the radio access network at the Radio Network Controller (RNC).

IMS voice:

Another option for moving voice traffic over these high-speed data channels has emerged more recently. This approach will carry voice natively using IP (that is, VoIP) in conjunction with IP Multimedia Subsystem (IMS) technology standardized in Rel-8. The graphic below highlights the distinctions between traditional Rel-99 CS Voice, CSoHS and IMS Voice approaches.

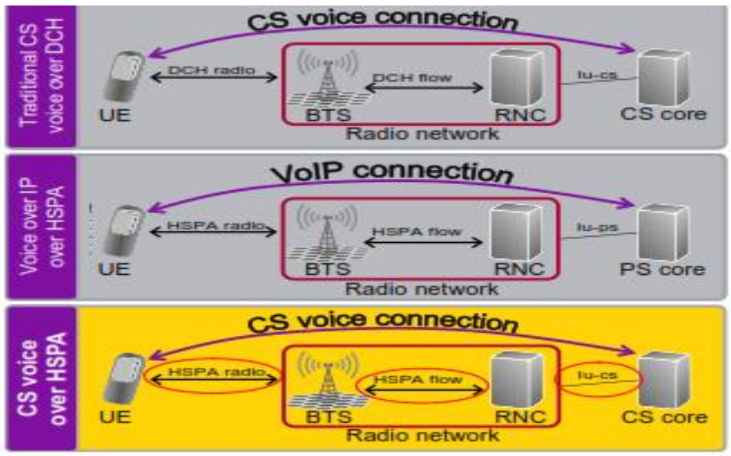


Figure 6. Illustration of CSoHS relation to IMS Voice and traditional CS voice (Note "BTS" synonymous with "NodeB" in HSPA)

IMS voice will allow operators to increase system capacity even further than with CSoHS, while permitting the consolidation of their infrastructure on an IP based platform and enabling innovative new applications that combine voice with data functions in the packet domain.

Status of VoHSPA realization:

Vendors provided information about different features of VoHSPA that would be available from them. "Availability" in this case means when these features are available to mobile network operators for testing and validation. Vendor responses were aggregated
in order to arrive at the timelines given in the Feature Availability Matrix below.

Features	Availability in CSoHS	Availability in IMS Voice

Non-Radio Features A. Generic IMS features (SIP registration, authentication, call establishment and termination, etc.) B. IMS Media C. Other functionalities (IPv4 & v6, Emergency Services, Roaming, etc.)	A. N/A B. N/A C. N/A	A. 1Q2012 B. 1Q2012 C. 1Q2012
Radio (& related packet core) features A. RoHC (IMS Voice only) B. HSPA Radio Capabilities C. Bearer Management D. P-CSF Discovery E. Inter-RAT Mobility	A. N/A B. 1Q2012 C. 2H2012 D. N/A E. 2H2012-EY2013	A. 2Q2012-EY2013 B. 1Q2012-EY2012 C. 2H2012 D. 1Q2012 E. 2H2012-EY2013

3.4.2 Voice over LTE (VoLTE)

VoLTE is one of the most ultimate applications in LTE. It is the most demanding and at the same time the most difficult challenge for LTE technology. The purpose of VoLTE is to open new doors of communication which are not possible with present mobile technologies. In this era of smartphone, VoLTE will make the multimedia services more attractive than ever.

In the core network, the mobile industry has aligned on IP Multimedia Subsystem (IMS) technology to deliver VoLTE service. The best practice for mobile operators will be to relate VoLTE and IMS implementation side by side so that they can launch rapidly with less difficulties and technological risk.

In case of voice implementation, VoLTE is lagging behind VoHSPA in many constraints such as:

- ✓ VoLTE is technically very difficult process. Full defined procedure of VoLTE is yet to come. Also it is much financially challenging project than VoHSPA.

- ✓ VoHSPA is already on the move while it will take time for VoLTE to come into the picture. VoLTE launch by phase in different regions is shown here. This will make the point clear.

REGION	VOLTE LAUNCH	VIDEO, RCS	SERVICE CONTINUITY	EMERGENCY CALLING
US CDMA	Mid 2012	At VoLTE launch	Not needed	Using CS initially, then VoLTE
US UMTS	2013	At VoLTE launch	Yes, SR-VCC	Using VoLTE
Advanced Asia/Pacific	2H12	At VoLTE launch	Yes, SR-VCC	Not known
Europe	2013-2014	RCSe begins in 3G – 1H12	Yes, SR-VCC	Using VoLTE

Source: Alcatel-Lucent, Heavy Reading

- ✓ VoLTE deployment will be dependent on the number of devices supporting it. At the moment, LTE chipsets are emerging but most of them do not support VoLTE. However, there are LTE devices that support VoLTE with QoS but no emergency calling and in-call handover to 2G/3G.

Alternatives to VoLTE

As features of VoLTE (IMS based) has not been fulfilled yet, most of the cases voice over LTE has been performed by following two alternatives. One is Circuit Switched FallBack (CSFB) and the other is Over The Top (OTT) technology. These two methods are very common practice for mobile operators.

CSFB

CSFB is the 3GPP standard solution for early LTE deployment stages, where no IMS voice service is available. Through CSFB, the terminal is directed to WCDMA/GSM to initiate or take a voice call, and the call remains in the CS domain until it is completed. This solution is currently recommended by the Next Generation Mobile Networks (NGMN) Alliance as a minimum roaming requirement for LTE terminal vendors and LTE operators that provide a CS voice service over WCDMA/GSM. As CSFB only provides support for voice and SMS, it is considered an intermediate step in the evolution towards fully fledged multimedia communication services.

OTT

OTT solutions, such as Skype and Google Talk, are being pre-installed in high-end phones. As mobile barriers for OTT players are gradually disappearing and smartphone penetration is expected to flourish over the next few years, OTT solutions will probably drive competition in the mobile domain as we saw in the fixed domain. However, because OTT solutions cannot provide a satisfactory user experience in non-continuous LTE coverage (due to the lack of a handover mechanism to the CS network), the adoption of OTT clients will depend on mobile broadband coverage. Therefore, if operators react soon, it should be possible to consolidate a global voice over LTE solution even before the LTE coverage is fully deployed.

VoLGA

Voice over LTE via Generic Access (VoLGA) specified by the VoLGA Forum, is perhaps the best-known alternative in the CS over PS family. The main idea is to adapt Universal Mobile Access / Generic Access Network (UMA/GAN) for LTE, and reuse the 3GPP Single Radio Voice Call Continuity (SRVCC) mechanism for handover from LTE to 2G/3G CS. It has very low impact on the existing CS core, but does not offer the possibility of evolving toward a full multimedia service experience. Therefore, VoLGA has been positioned as an interim alternative that addresses pre-IMS LTE deployments. However, the VoLGA solution is not standardized by 3GPP, and after GSMA adopted the One Voice initiative for GSMA VoLTE, VoLGA has been constantly loosing traction in the industry.

For simplicity we can arrange three difeerent coverage aspects over which VoLTE can be implemented. These three phases can be regarded as:

- ✓ In the first expansion phase, for mobile broadband purposes, the chosen operator introduces spotty LTE coverage.
- ✓ In the second phase, the operator expands LTE coverage and builds areas of continuous LTE coverage for all types of services.
- ✓ In the third and final phase the operator bridges the remaining gaps in the LTE coverage – or complements it with other PS access technologies – building a complete packet based network for all types of services.

Phase 1 – Spotty lte Coverage

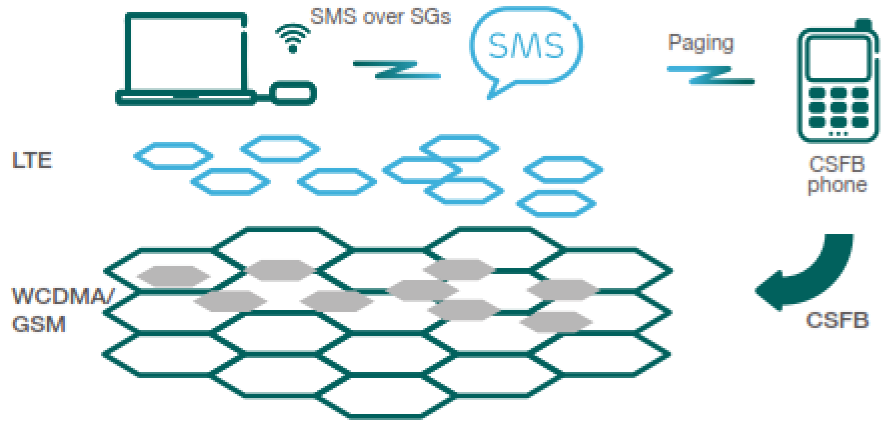


Figure 1: Spotty LTE coverage scenario

Since the LTE coverage is not continuous, the selected solution is the 3GPP SMS over SGs mechanism which allows for the transfer of SMS to/from terminals that are attached to LTE via the SGs interface (without performing fallback to WCDMA/GSM). When LTE smartphones are launched, operators can introduce CSFB to simplify the LTE introduction by reusing the existing WCDMA/GSM CS voice service. By using CSFB, operators avoid the problem of frequent handovers between the CS and the VoIP domain, which may arise in an initial LTE deployment scenario with IMS voice over spotty LTE coverage. Through CSFB, the terminal always shifts to WCDMA/GSM to initiate or take a voice call, and the call remains in the CS domain until it is completed.

Phase 2: area with continuous LTE coverage

MMTel-based voice is introduced in this phase as an evolutionary step toward multimedia services, following a standard solution that provides full service coverage and continuity even if the LTE network is not yet perfected.

The deployed CSFB solution will also be required in this phase to support inbound LTE roamers that do not have an IMS voice service. Similarly, for outbound roamers CSFB support, in combination with ICS, will be required when they visit non-IMS LTE networks, allowing the reuse of existing CS roaming agreements.

Phase 3: Full LTE coverage

Post deployment, GSMA VoLTE is supported in the whole network through Inter-Radio Access Technology (IRAT) PS handover between different PS access domains (see Fact Box 6). As before,

CSFB will be retained to support inbound LTE roamers without an IMS voice service.

For outbound roaming (own subscribers), it is expected that many other operators will already have IMS support, so IMS roaming agreements would be in place. In visited networks that do not yet have full LTE coverage, IMS Centralized Services (ICS) and enhanced SRVCC mechanisms will be needed to support call handovers to CS.

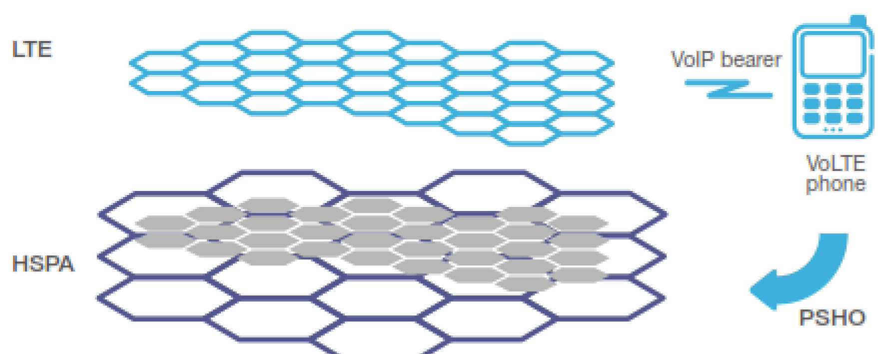


Figure 2: Full LTE coverage

3.5 UE battery life: UMTS is better option

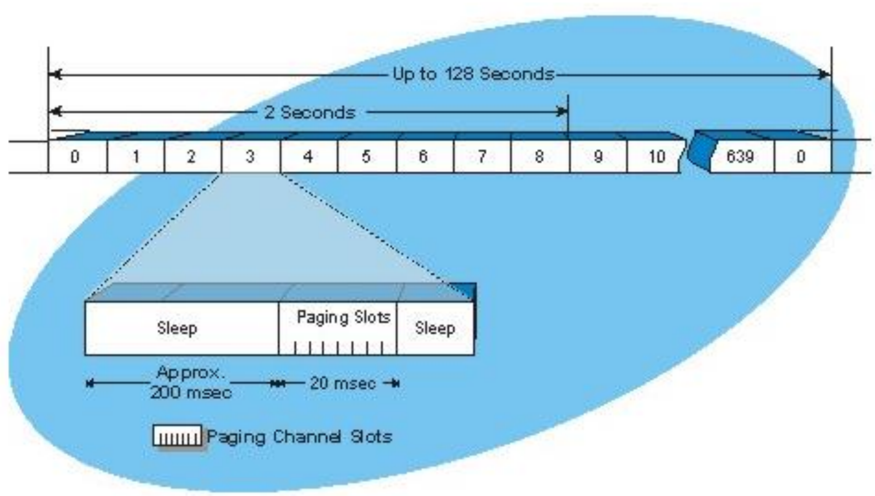
3.5.1 For UMTS case

UE power consumption is one noteworthy case which has to be considered by mobile operators. It can play important role as it makes difference in choosing migration paths. UE battery life is mostly dependent on two things:

- ✓ Discontinuous Reception (DRx) cycle
- ✓ Radio links conneted to UE

Discontinuous Reception (DRx)

Discontinuous reception (DRx) is a process of turning off a radio receiver when it does not expect to receive incoming messages. For DRx to operate, the system must coordinate with the mobile radio for the grouping of messages. The mobile radio (or pager) will wake up during scheduled periods to look for its messages. This reduces the power consumption which extends battery life. This is sometimes called: sleep mode.



This shows how paging groups can be used to provide for discontinuous reception capability. This diagram shows that the paging channels can be divided into 200 msec groups and that paging groups are typically associated with the last digit of the mobile devices telephone number. This provides for 10 groups with a typical maximum delay of 2 seconds.

In case of UMTS, DRx cycle for UE the largest which makes it user friendly as it extends the battery life of mobile devices.

Radio links

Number of radio links connected to UE is much lesser for UMTS case. Besides, radio signal is not always on like 4G handsets which makes UMTS sets less power consuming than any other mobile device.

3.5.2 For LTE case

LTE phones are fast, but they can also suck a battery dry in a few hours. Nokia Siemens Networks did some preliminary studies on LTE phone’s power drain versus their HSPA (3G) counterparts and found that LTE devices consume from 5 percent to 20 percent more than previous-generation phones, depending on the application used. The radio is the single biggest source of power drain in any device apart from the LED screen, but unlike the display, the radio is always on. And LTE is particularly hungry.

There are mainly following five reasons why LTE devices are such power hungry:

- ✓ First of all, DRx cycle length for LTE devices is very short. So sleeping mode gets a very tiny period which makes UE battery life to decay.

- ✓ All LTE devices sold today use a technology called MIMO, which doesn't just send or receive a single signal, but rather multiple parallel transmissions. Today's devices support two such paths – future devices will support more — which means each phone has two antennas, each of which requires its own power amplifier.

- ✓ LTE phones are constantly pining for the network. That means its periodically scans the airwaves around it to determine which tower it should tether itself to. The more networks there are to choose from the more scans it must make. With the typical operator sporting some combination of GSM, HSPA, CDMA and EV-DO systems — often multiple version of each in different frequency bands — there are a lot of other networks for an LTE device to flip between.

- ✓ Operators haven't built out their new LTE footprints densely yet. With cells spaced much further apart, devices have to reach further – and thus boost their transmission power — to latch onto a tower. And since there are still plenty of coverage holes in these networks, phones are dropping in and out of LTE coverage quite often, initiating new rounds of scans and taxing the battery further.

The 64 state Quadrature Amplitude Modulation (QAM) and Orthogonal Frequency Division Multiplexing (OFDM) techniques used in LTE is very complicated. The more complex the waveform, the more computing power phone processors use up modulating and demodulating that radio wave.

CHAPTER 4

In this chapter, we are going to discuss about the worldwide deployment scenario for both LTE and 3G HSPA. We will also cover the UE availability and the trend of the growth of ecosystems' of both the technologies.

4.1: HSPA

4.1.1: Commercial networks:

Widespread consumers of dongles, HSPA-enabled netbooks and notebooks, and the rapid increase of smartphones have pushed data consumption to unprecedented levels. That is why HSPA deployment is getting more and more popular for the operators across the world. GSA confirms that HSPA is the leading mobile broadband technology with

- ✓ 499 HSPA operator commitments in 189 countries
- ✓ 472 commercial operator launches in 183 countries
- ✓ 279 operators have committed to HSPA+ deployment
- ✓ 234 HSPA+ operators are now in commercial service across 112 countries

And the peak download performances are noted as:

1.8 mbps peak = 42 networks
3.6 mbps peak = 63 networks
7.2 mbps peak = 98 networks
10.2 mbps peak = 1 networks
14.2 mbps peak = 34 networks
HSPA evolution (HSPA+) = 234 networks
TOTAL = 472 commercial networks

499 network commitments in 189 countries are divided as:

- ✓ Americas = 116 networks
- ✓ APAC = 97 networks
- ✓ Europe = 178 networks
- ✓ Middle East/Africa = 108 networks

And here is the view of all the 183 countries in which HSPA is commercially deployed:

472 commercial HSPA operators in 183 countries/territories

Americas: Argentina, Aruba, Bahamas, Barbados, Bermuda, Bolivia, Bonaire, Brazil, British Virgin Isles, Canada, Cayman Isles, Chile, Colombia, Costa Rica, Curaçao, Dominican Republic, Ecuador, El Salvador, Fr. Guiana, Guadeloupe, Guatemala, Guyana, Honduras, Jamaica, Martinique, Mexico, Nicaragua, Panama, Paraguay, Peru, Puerto Rico, Saba, St-Barthelemy, St-Eustatius, St-Martin, Suriname, Trinidad & Tobago, Turks and Caicos Islands, Uruguay, USA, Venezuela

APAC: Afghanistan, Australia, Bhutan, Brunei, Cambodia, China, East Timor, Fiji, French Polynesia, Guam, Hong Kong SAR, India, Indonesia, Japan, Laos, Macau SAR, Malaysia, Maldives, Mongolia, Nepal, New Zealand, N. Korea, Philippines, Samoa, Singapore, Solomon Isles, S. Korea, Sri Lanka, Taiwan, Thailand, Vanuatu, Vietnam

Europe: Abkhaz, Aland, Albania, Andorra, Armenia, Austria, Azerbaijan, Belarus, Belgium, Bosnia - Herzegovina, Bulgaria, Croatia, Cyprus, Cyprus (N), Czech Rep., Denmark, Estonia, Faroes, Finland, France, Georgia, Germany, Gibraltar, Greece, Greenland, Guernsey, Hungary, Iceland, Ireland, I of Man, Italy, Jersey, Kazakhstan, Kyrgyzstan, Latvia, Liechtenstein, Lithuania, Luxembourg, Macedonia, Madeira, Malta, Moldova, Monaco, Montenegro, Netherlands, Norway, Poland, Portugal, Romania, Russia, Serbia, Slovak Rep, Slovenia, Spain, Sweden, Switzerland, Tajikistan, Turkey, Turkmenistan, UK, Ukraine, Uzbekistan

MEA: Angola, Bahrain, Botswana, Cape Verde, Congo Rep., Djibouti, Egypt, Ethiopia, Ghana, Iran, Israel, Jordan, Kenya, Kuwait, Lebanon, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Nigeria, Oman, Qatar, Reunion, Rwanda, Sao Tome & Principe, Saudi Arabia, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, Syria, Tanzania, Tunisia, UAE, Uganda, Zambia, Zanzibar, Zimbabwe

4.1.2: HSPA devices:

This latest HSPA Devices Survey, completed by **GSA on August 19, 2012** confirms at least 3,847 HSPA user devices have been announced. These products are all out in the market. There are 1,677 phones (including carrier and frequency variants), which is more than 25% higher than a year ago. Among them 289 dual-mode LTE-HSPA devices are also confirmed.

1,677	Mobile phones including smartphones
668	USB modems
509	Notebooks, netbooks
514	Wireless routers/gateways, mobile hotspots
308	PC data cards (PCMCIA cards, ExpressCards, embedded modules)
48	Personal Media Players, UMPCs
27	Femtocells
12	E-book readers
8	Cameras
76	Mobile tablets
Total **3,847**	*(August 19, 2012: GSA HSPA Devices survey)* *© Global mobile Suppliers Association (GSA)*

HSPA devices by form factor
© Copyright – Global mobile Suppliers Association (GSA)

HSPA 2100 MHz band summary

• 3362 HSPA devices from 271 suppliers

• 2563 HSPA devices operate in this band

• Device types include USB dongles, smartphones, embedded laptops, data cards and routers including personal MiFi

HSPA 1800 MHz band summary

• 1 UMTS/HSPA 1800 trial network identified in France

• No commercial services found

HSPA 900 MHz band summary

• 32 Global and 20 European UMTS900 commercial networks in operation as of June 2011

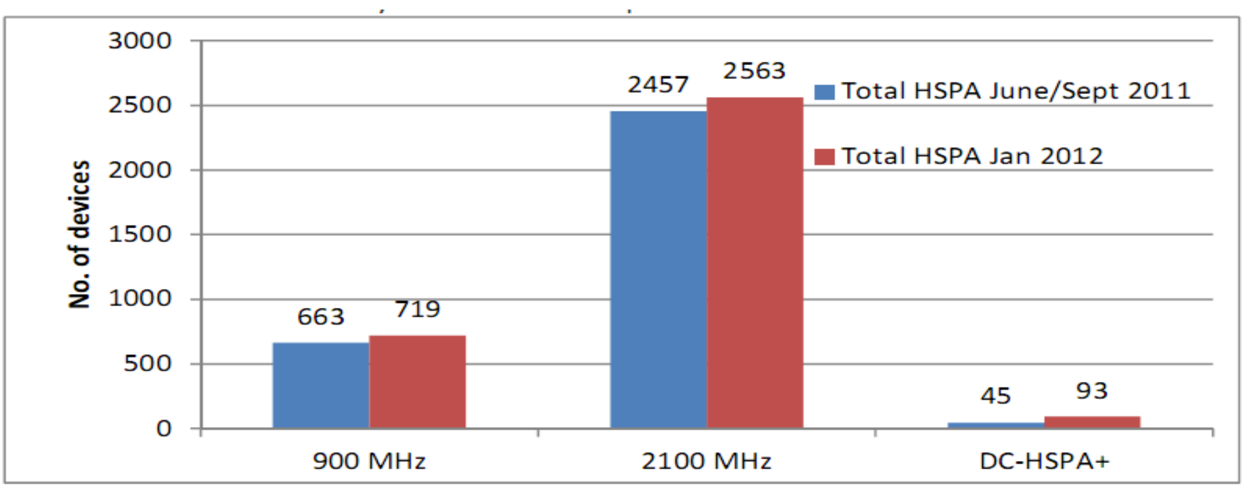
• 719 HSPA devices available for use in this band which includes: Apple iPhone 4 S, iPad2 and iPad3, Samsung Galaxy S, Blackberry Playbook, Nokia N8, HTC HD7 etc.

• 93 DC-HSPA+ devices available from January 2012 including BandRich PR40 series pocket router, Novatel Wireless USB modem Ovation MC545 capable of supporting 42 Mbps. This number has doubled in the last 6 months

• Number of UMTS900-HSPA user devices launched has increased slightly by 10% in the last 6 months

• O2 has upgraded to HSPA+ in 2012 delivering speeds up to 42 Mbps

The growth in HSPA devices across 900 MHz and 2100 MHz from the Q3 2011 to Q1 2012 can be seen in the following figure. Device manufacturing and development has reached maturity in terms of HSPA and HSPA+ in these bands. However, there has been growing development in DC-HSPA+ devices which have doubled in availability.



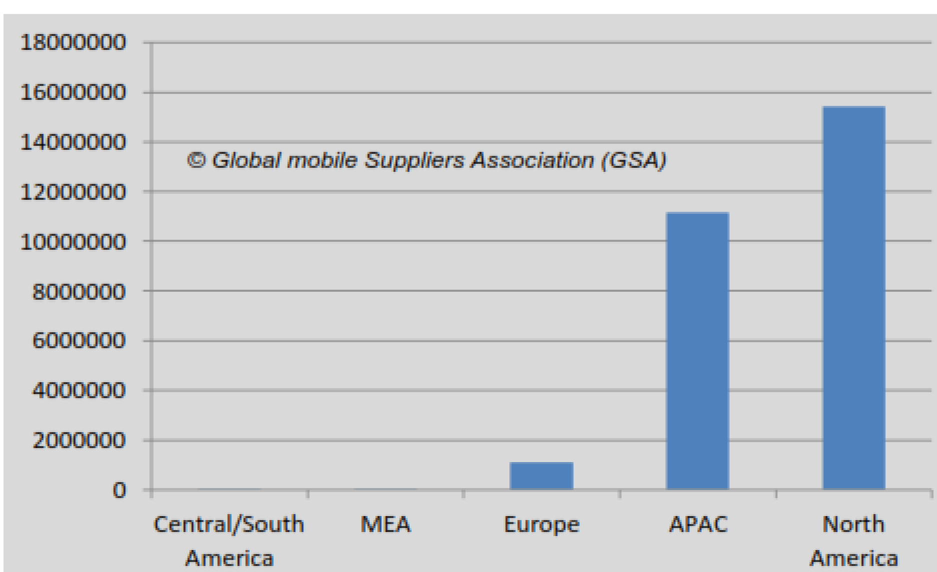
HSPA device growth in different frequency bands

4.2: LTE

4.2.1: LTE networks

More uplink/downlink performance, better capacity and additional multimedia features have guaranteed LTE as the fastest growing mobile technology ever. Current status shows that LTE is entering as a mainstream technology by the end of the year 2012.**GSA** confirms that

Worldwide regional share of LTE subscriptions for Q2 2012 shows the following analysis:



The key findings are-

- ✓ **56% of LTE subscriptions are in North America**
- ✓ **40% of LTE subscriptions are in Asia Pacific region**

4.2.2: LTE devices

The **GSA's 'Status of the LTE Ecosystem' report (July 3, 2012)** confirmed that 67 manufacturers have announced 417 LTE-enabled user devices. The report includes devices for FDD and TDD modes, form factors, frequencies, and support for fallback technologies when outside LTE coverage areas (i.e. HSPA, HSPA+, DC-HSPA+, EV-DO, or TD-SCDMA).

Multi-band, multi-mode LTE-TDD dongles and CPEs are commercially available from all major chipset and device manufacturers.

Many LTE user devices support both FDD and TDD modes, e.g. there are 19 FDD tri-band 800/1800/2600 MHz user devices which also support LTE TDD band 38 (2.6 GHz) and most of them also support DC-HSPA+ and EDGE.

LTE 2100 MHz band

- Currently supports a collection of 8 different devices
- 6 out of the 8 devices support multi-frequency
- All devices support multi-mode with a mixture of HSPA, HSPA+ and DC-HSPA+

LTE 1800 MHz band summary

- Supports a well-established mix of devices with a total of 75 different devices including dongles, tablets and handsets
- All devices support multi frequency
- More than half out of the 75 devices support multi-mode with a mixture of HSPA, HSPA+ and DC-HSPA+

LTE 900 MHz band summary

• Currently supports more than 6 devices with a small mix of modules, routers and USB modems

• All devices support multi frequency

• All devices support multi-mode with a mixture of HSPA, HSPA+ and DC-HSPA+

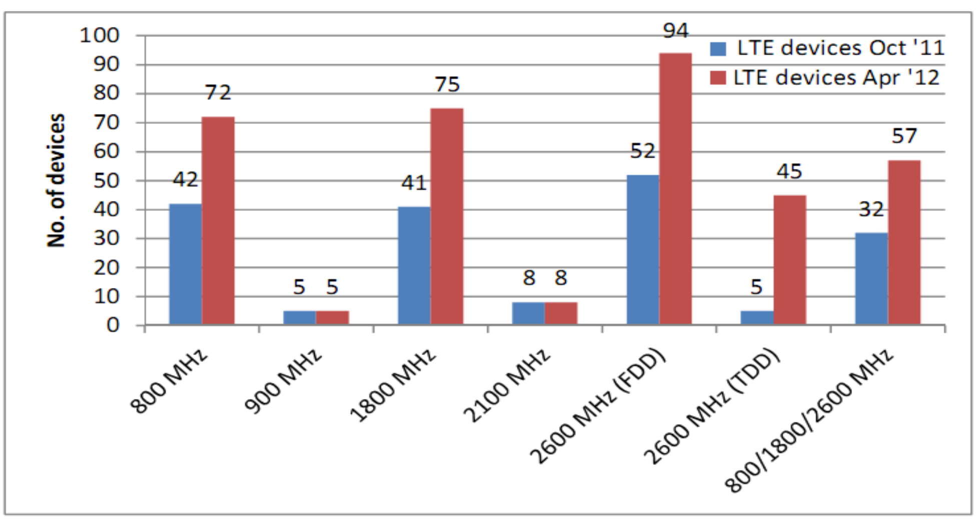
LTE 800 MHz band summary

• Currently supports a growing mix of devices with a total 72 different devices including dongles, tablets and handsets

• More than 57 out of the72 devices support multi frequency

• More than half out of the 72 devices support multi-mode with a mixture of HSPA,HSPA+ and DC-HSPA+

Figure below shows the growth in LTE devices in different frequency bands from october 2011 to april 2012 timeline and it shows that in some of the bands like 800 MHz, 1800 MHz and 2600 MHz bands, the growth is developing rapidly.

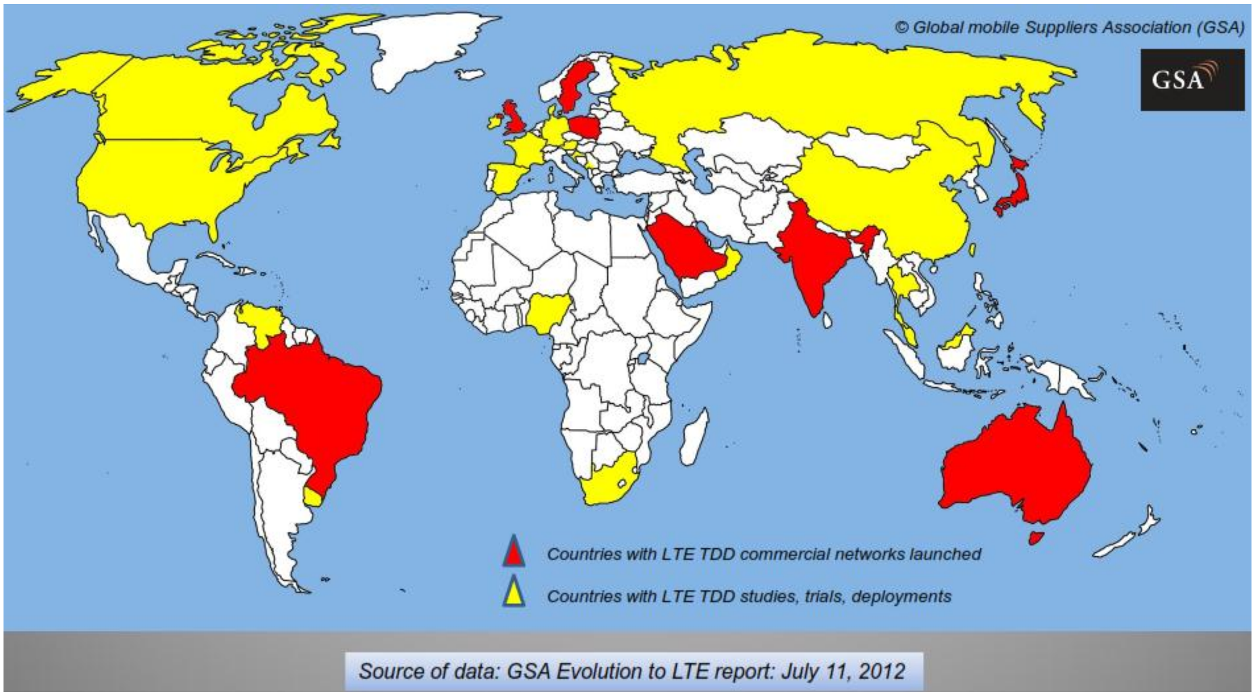


4.3: LTE TDD & FDD:

4.3.1: Current status:

As LTE can support both TDD and FDD modes, it is important to discuss their current status as well. Mobile operators have traditionally shown little interest in TDD spectrum and tried to stop additional TDD allocations to prevent WiMAX players to enter in their markets. With TD-LTE, however, they may finally have a way to use TDD spectrum and benefit from it.

TD-LTE, with its reduced cost and adaptable bidirectional support, offers cost-effective solution, allowing operators to support utilities with large area coverage, an all IP network, advanced security for customer information, quality of service and policy enforcement. These facts caused TD-LTE as a suitable option for many operators recently which can be seen from the following analysis:



- ✓ There are 9 commercial TD-LTE deployments around the world:

Nine commercial LTE TDD systems are launched

Country	Operator	Frequency	3GPP band
Poland	Aero2 (FDD and TDD)	2.6 GHz	Band 38
Saudi Arabia	Mobily	2.6 GHz	Band 38
Saudi Arabia	STC	2.3 GHz	Band 40
Brazil	Sky Brasil Servicos	2.6 GHz	Band 38
Japan	Softbank Mobile XGP/LTE TDD	2.6 GHz	Band 38
Australia	NBN Co	2.3 GHz	Band 40
India	Bharti Airtel	2.3 GHz	Band 40
Sweden	3 Sweden (FDD and TDD)	2.6 GHz	Band 38
UK	UK Broadband	3.5 GHz, 3.6 GHz	Bands 42, 43

Source: Evolution to LTE report – GSA – July 11, 2012

- ✓ the recent broadband wireless access (BWA) auctions as well as the availability of existing licenses in the 2.3 GHz and 2.6 GHz bands in Asia-Pacific, Europe, the Middle East and Africa, and the Americas; WiMax service providers' increasing interest in

LTE TDD as a way to evolve their networks; and the interest by operators, particularly in Western Europe and North America, in using LTE TDD as a way to increase network capacity and offload data traffic by using FDD for their macro networks and TDD for picocells.

- ✓ According to the survey, 19 percent of operators surveyed plan to lead with an LTE TDD network; another 12 percent plan both FDD and TDD LTE deployments within three years; 45 percent of respondents will lead with FDD with potential to add TDD in the long/medium term; and 25 percent of respondents plan to lead with FDD and are unlikely to use TDD.

- ✓ For TDD systems, the devices do not require duplexer systems to allow simultaneous transmission and reception like FDD systems. This enables simpler and economical eNBs and UEs.

LTE TDD	
2300 MHz *Band 40*	53 devices
2600 MHz *Band 38*	59 devices
2600 MHz *Band 41*	5 devices

4.3.2: Comparison

Most LTE deployments use paired spectrum (FDD). The LTE TDD mode for unpaired spectrum is complementary and the perfect choice for providing high speed mobile broadband access in unpaired spectrum. LTE TDD is an integral part of the 3GPP standards implementing a maximum of commonalities with LTE FDD and offering comparable performance characteristics and similar high spectral efficiency. There are several fields where LTE TDD is making remarkable progress which helped it to gain market traction globally

- **Spectral efficiency**

  One reason TD-LTE is a favorable choice for more carriers is its efficient spectrum usage,

  given that TDD does not require paired spectrums as FDD does and spectrum is a finite and limited important resource for telecommunication services.

  The availability and attractive prices of TDD spectrum around the world is another cause. The recently concluded auctions in Germany are a good example: TDD spectrum sold for about one-third the cost of its FDD counterpart in the 2.6GHz band.

  TD-LTE is spectral efficient but FDD provides better coverage than TD-LTE for reasons of power efficiency. According to one report by Qualcomm, FDD covers an 80% larger area than TDD for 2:1 downlink/uplink allocation and assumes the same transmitting power and same 2.6GHz frequency.

- **LTE TDD and WiMAX**

  Carriers can choose to deploy LTE networks either in FDD or TDD versions. Since WiMax is a TD technology and shares more assets with the latter, TD-LTE presents a more efficient migration option for WiMax operators. Those with broad spectrum rights have the option of dividing up that spectrum between WiMax and TD-LTE so that they can enter the LTE market without cutting off their existing subscriber base.

  But a small carrier with limited spectrum will not be able to maintain both business lines, and will have to decide between the two platforms.

The increasing availability of base stations that can be cost-effectively upgraded will make it possible and relatively inexpensive for WiMAX operators to transition to TD-LTE using the same spectrum allocation. The transition will still require substantial efforts and be justified only in some cases, but it will make it easier for WiMAX operators to have roaming deals and to have access to the same devices that LTE operators have.

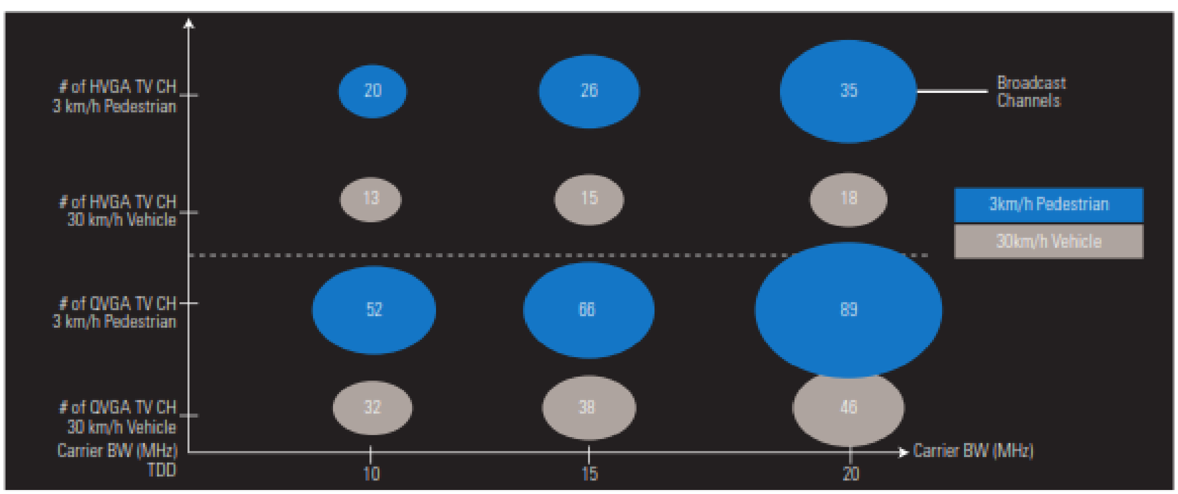
- ✓ **Asymmetry**

TD-LTE’s adaptable DL: UL ratio offers operators a significant throughput advantage for asymmetric applications. The ability to configure TD-LTE to match the traffic demand means greater efficiency, delivering more than 30% better utilization for traffic with a 90/10 downlink/uplink demand profile.

Since broadband communications are data-centric and essentially asymmetric in nature, TD-LTE can exploit efficient scheduling schemes to support data services.One of the best examples of this feature is Mobile Broadcast TV Channels.

MOBILE BROADCAST TV CHANNELS ON TD-LTE

Serving Millions of Subscribers and Off-Loading Video Traffic from FDD Network



- ✓ **Video delivery**

Another business case that TD-LTE makes more attractive is video delivery. A number of TDD networks (mostly WiFi Mesh) are being used successfully to deliver uplink-biased surveillance videos.

- ✓ **M2M applications**

Machine to machine (M2M) is another application that TD-LTE will make more practical. The next 100 billion subscribers are smart machines and their day is fast approaching. Consumers demand for smart machines is on the rise. This means that demand for M2M communication is also set to grow. While M2M is not an immediate play for TD-LTE, to meet the upcoming M2M demand operators have to plan from now on.

CHAPTER 5

In this chapter we will show a generalized cost-revenue estimation for a 5 year period for both LTE and HSPA rollout cases. Most of the data used for the analysis is collected by the help of Grameenphone and some data we've assumed based on the market scenario. The objective is to provide the operator a rough estimation of the probable cost and revenue generation on both roll out scenarios in Bangladesh from an operator's point of view. The analysis done here is simple as it doesn't aim at 100% accuracy rather aims at an estimation of the market growth for each rollout scenario.

5.1 Typical Breakdown of a Wireless Broadband Network Expenses

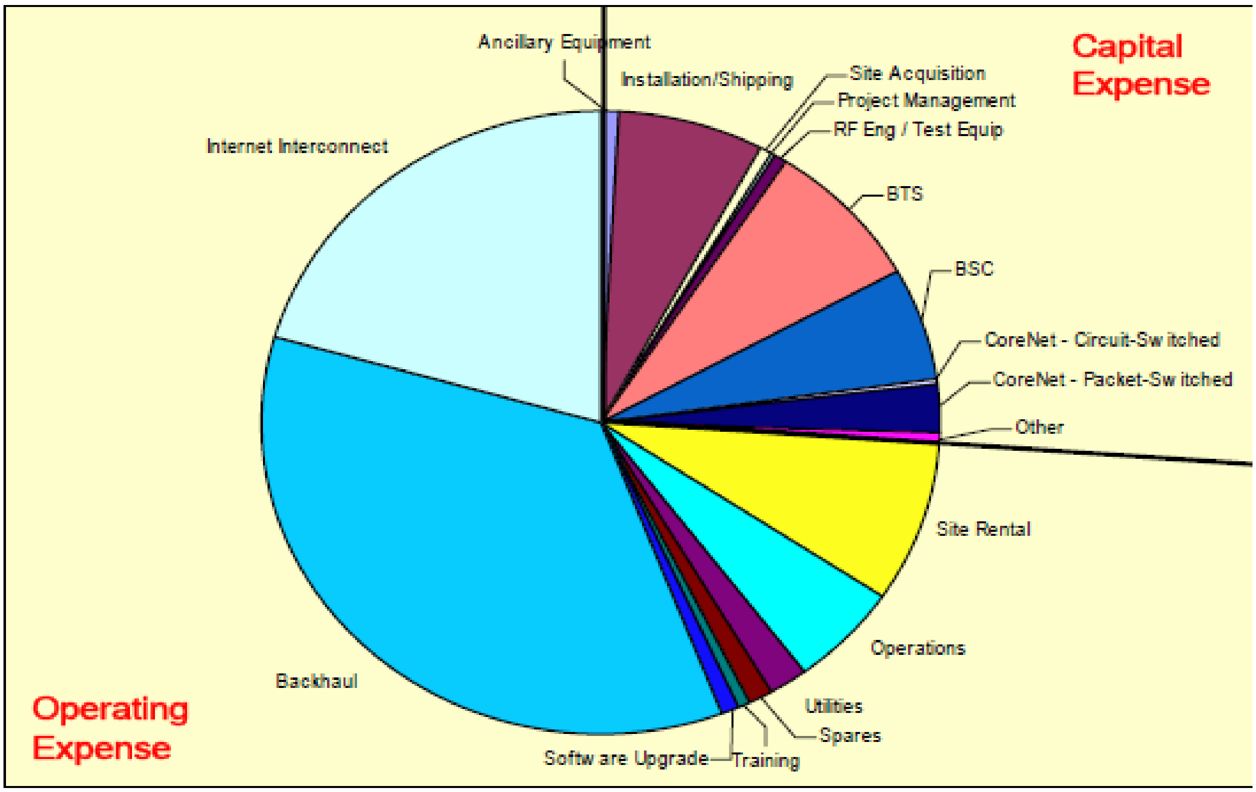


Figure: Typical Cost Breakdown of a wireless broadband network [Source: Qualcomm whitepaper]

The above figure indicates the cost for a mobile wireless broadband network deployment. Bulk of the cost required is for backhaul which includes the bandwidth cost that has to be paid to the IGW. Radio Access Network (RAN) and Core network (CN) also has a major share in it. Apart from these, Spectrum cost is requires a huge percentage of total deployment cost which hasn't been shown in the above figure. The rest of the costs can be termed under OPEX.

5.2 Backhaul cost

In a cost-revenue research for cellular deployment, mobile backhaul cost estimation is a very crucial part. As it is mentioned earlier that backhaul data cost comprises a large part in total cost of a cellular migration. Operators around the world are very keen to find a way to reduce the cost specially OPEX – the largest contributor in backhaul cost. Some of the popular choices for mobile backhaul are first described here and later on, a cost assumption will be made among these choices in the perspective of Bangladesh.

5.2.1 Choices

Leased fiber in this case is known by all as a common backhaul deployment. But backhaul prominence will rise further with the deployment of small cells, and with the associated increase in the number of cell sites, mostly in challenging urban locations and requiring a wireless backhaul link. For operators that do not own a fiber network or lack affordable access to leased circuits, wireless solutions provide the capacity, performance, flexibility, and cost-effectiveness that they need to backhaul 3G and 4G traffic.

In this section, addition to leased fiber, following two microwave solutions are also discussed for the cost analysis:

- ✓ **Microwave PTP** requires a symmetric link to connect each RAN site to a hub that is in turn connected to the backbone. If the RAN site is too far from the hub or there is no LOS, the backhaul may have to include two hops. Traditionally, PTP links are deployed using a star topology in which all RAN sites are connected directly to the hub. Increasingly, PTP links are organized in tree-and-branch and ring networks, which can increase the efficiency, reach, and reliability of the backhaul (Figure 1). To operate a PTP link, operators typically lease spectrum on a per-link basis.

- ✓ **Microwave PMP** allows one access point (AP) in the hub to connect to multiple RAN sites and, as a result, it does not require a dedicated symmetrical link for each backhauled cell site. This results in fewer radios and a potential for higher utilization of backhaul resources. PMP spectrum is most commonly allocated as a long-term license within a country or an area within a country.

5.2.2 Assumptions

Here our target is to compute the TCO(Total Cost of Ownership) for mobile data backhaul which is nothing but the summation of the CAPEX and OPEX. For this we are going to calculate 1st year CAPEX and OPEX and by assuming some increment we are going to find these parameters for 5 years. From that a 5 year TCO calculation will be made. Then the average cost for a year will be taken for the total cost analysis case.

To make this done, following network assumptions will be the basis for our analysis:

	LTE Macro cells	3G Macro cells
Max throughput per base station (sector)	80 mbps	20 mbps
Sectors/base station per RAN site	3	3
Number of RAN sites	24	48

Here in the analysis some more basic assumptions are done:

- ✓ The cost assumptions are based on median values (Table 3) that, although not modeled on a specific market or operator
- ✓ To reduce the complexity of the comparison across technologies, here it is taken as a greenfield operation.
- ✓ Because the TCO model compares different solutions and does not directly estimate the traffic load operators should expect based on their subscribership, it computes the backhaul requirements on the basis of the RAN sites' maximum throughput; this provides a useful basis for a comparison over a five-year period
- ✓ Because mobile operators typically use multiple backhaul solutions across their networks, the model computes the costs for small backhaul network configurations and then extrapolates the cost on a per-RAN site or per mbps basis; this enables operators to easily scale the model's results to the desired deployment size. While the model is

RAN-technology neutral, our scenarios make assumptions about RAN throughput that are typical of LTE macro cells and 3G macro cells.

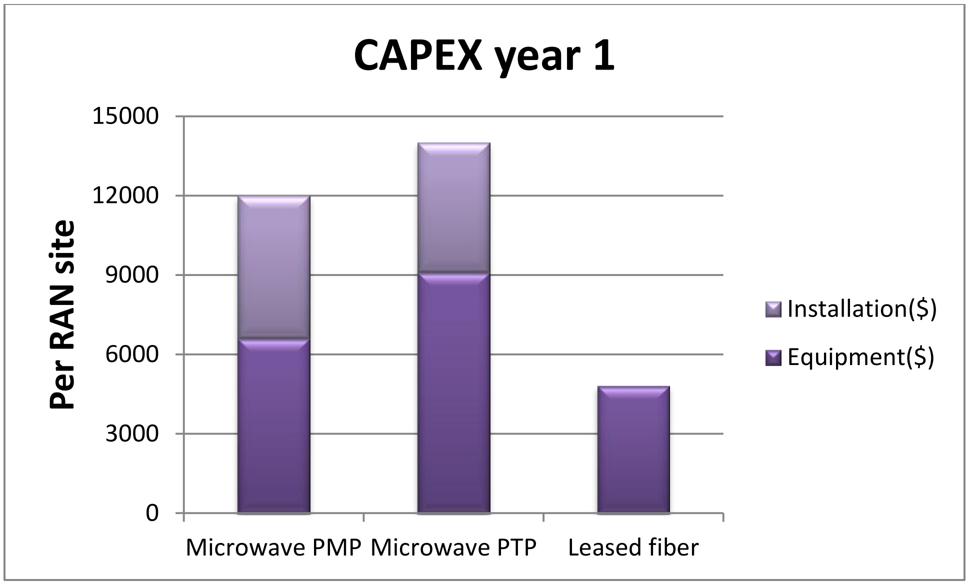
5.2.3 CAPEX analysis

Here per mbps cost is assumed 20$ (leased fiber) to 58$ (micro PTP) and hence CAPEX to provide backhaul to RAN site varies from 4800$ to 14000$.

CAPEX for year 1 for LTE macro cell

	Microwave PMP($)	Micro PTP($)	Fiber($)
Equipment	6600	9100	4800
Installation	5400	4900	0

Here equipment contributes 55% (Micro PMP) to 65%(Micro PTP) as number of radios is higher in PTP case.

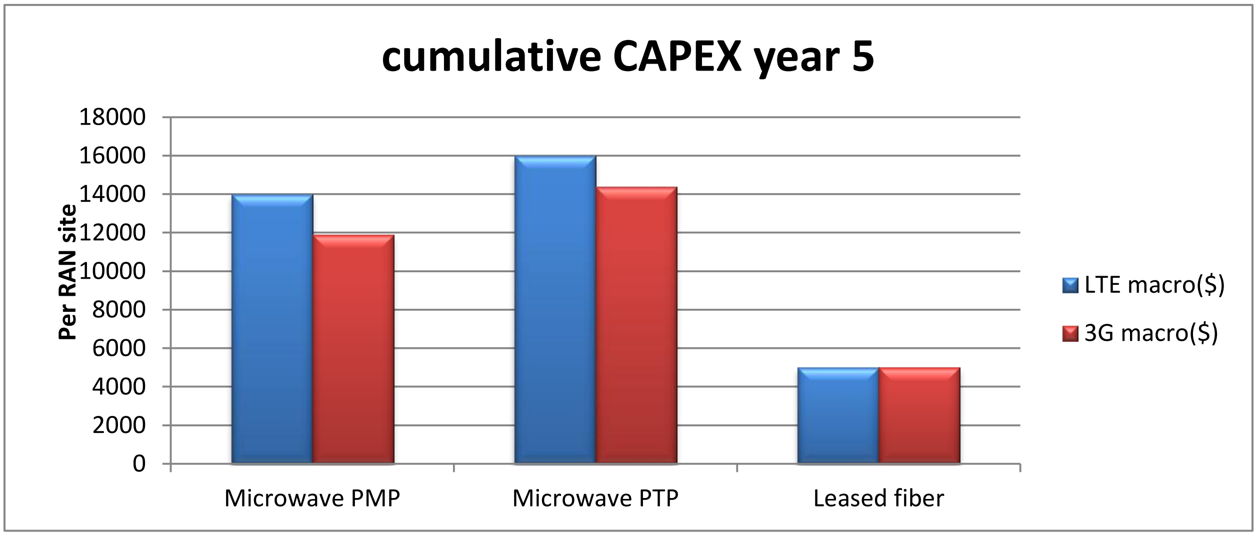


Fiber has the lowest CAPEX, because the operator has to pay only for terminal equipment fees to set up the service – even though in some cases operators have to commit to multi-year contracts, or have to pay high installation costs (however, either of these is not included in the TCO model).

Now CAPEX for 5 year will be estimated by assuming an increment of 30% for the 2nd year and 20% for the rest.

Cumulative CAPEX year 5

	LTE macro($)	3G macro($)
Microwave PMP	14000	11900
Microwave PTP	16000	14400
Leased fiber	5000	5000



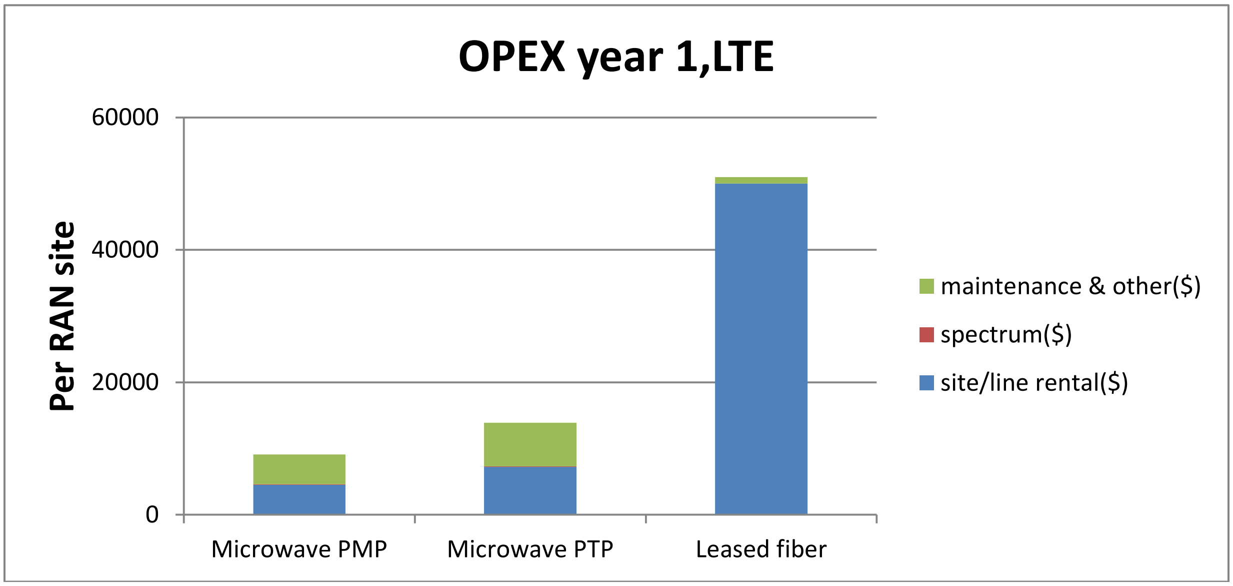
The CAPEX per RAN site is dependent on the average number of radio links per site. As the change in average number of radios are lesser in PMP case, we see that PMP CAPEX is 15% less in 3G than LTE and PTP CAPEX is 10% less than LTE.

<u>5.2.4 OPEX analysis:</u>

The OPEX per RAN site presents a markedly different trade-off than the CAPEX. The leased fiber option, assuming the operator is leasing from a third party and cannot secure below-market prices, is by far the most expensive. This counteracts the much lower initial CAPEX expenditure.

OPEX at year 1 for LTE macro cell

	site/line rental($)	spectrum($)	maintenance & other($)
Microwave PMP	4500	90	4500
Microwave PTP	7200	100	6600
Leased fiber	50000	0	1000

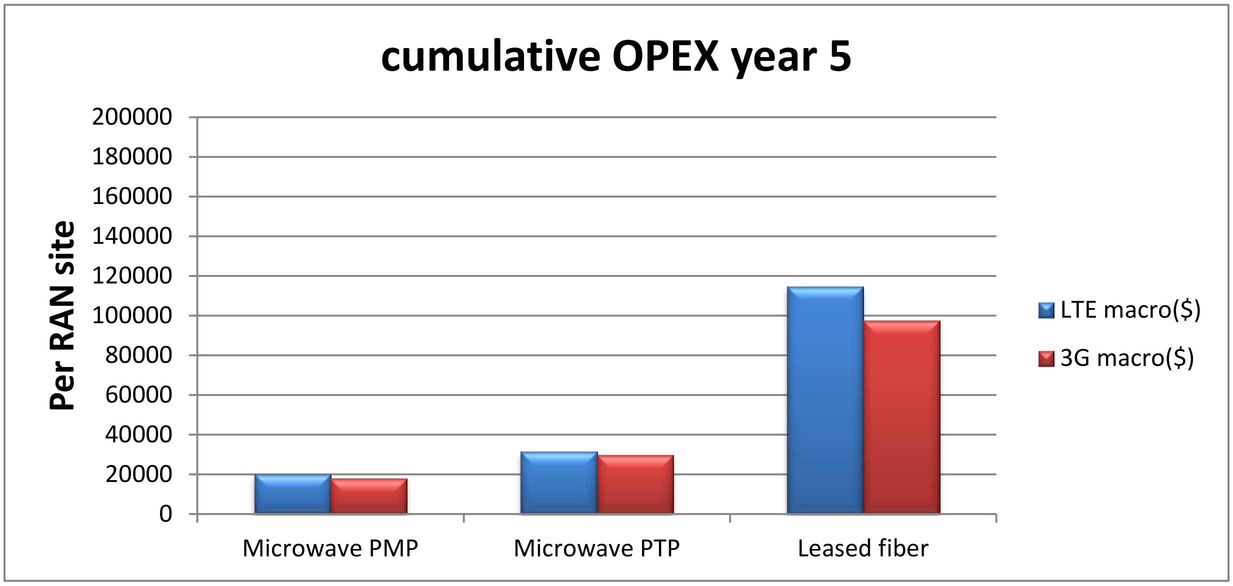


According to market median value, site rental for microwave PMP is assumed to be 1500$ per sector and maintenance cost is assumed to be 4500$. Lighter demand of radios in PMP saves 60% on its site rental and 45% on its maintenance & other things compared to PTP case. In both cases, spectrum contributes very low percentage.

For OPEX estimation over 5 years, same increment as CAPEX is assumed here also.

Cumulative OPEX at year 5

	LTE macro($)	3G macro($)
Microwave PMP	20000	18000
Microwave PTP	31400	29800
Leased fiber	114570	97400



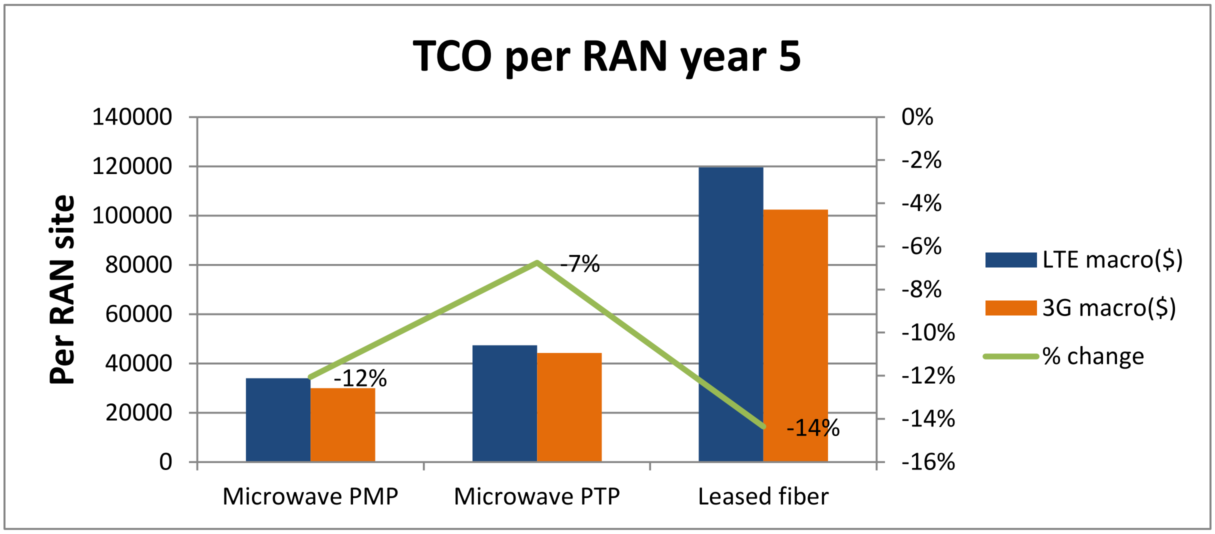
From here we can see that PMP is 15% less in 3G than in LTE, PTP and leased fiber both are less than 3G by 5% and 10% respectively.

5.2.5: TCO calculation

From the above calculations we can now estimate the TCO over 5 year period per RAN site

Cumulative TCO at year 5

	LTE macro($)	3G macro($)	% change
Microwave PMP	34000	29900	-12%
Microwave PTP	47400	44200	-7%
Leased fiber	119570	102400	-14%



From the TCO calculation over 5 years, two things can be noticed:

- ✓ Microwave PMP is the best possible solution in terms of cost
- ✓ In each case, 3G has better cost savings.

Now we are eager to calculate average TCO per year so that we can apply it for estimating total cost for divisional cities here in Bangladesh.

By taking average we can find average TCO per year for migration paths:

for microwave PMP in LTE macro: 6800$

in 3G macro: 5800$

for microwave PTP in LTE macro: 9480$

in 3G macro: 8840$

for leased fiber in LTE macro: 23914$

in 3G macro: 20480$

site numbers for divisional cities(urban case only) according to the information provided by **Grameenphone** are:

City	**No. of sites**
Dhaka	1429
Barisal	36
Sylhet	122
Rajshahi	56
Khulna	84
Chittagong	222
Rangpur	41

Now we can calculate total TCO for all the divisional cities in both migration paths:

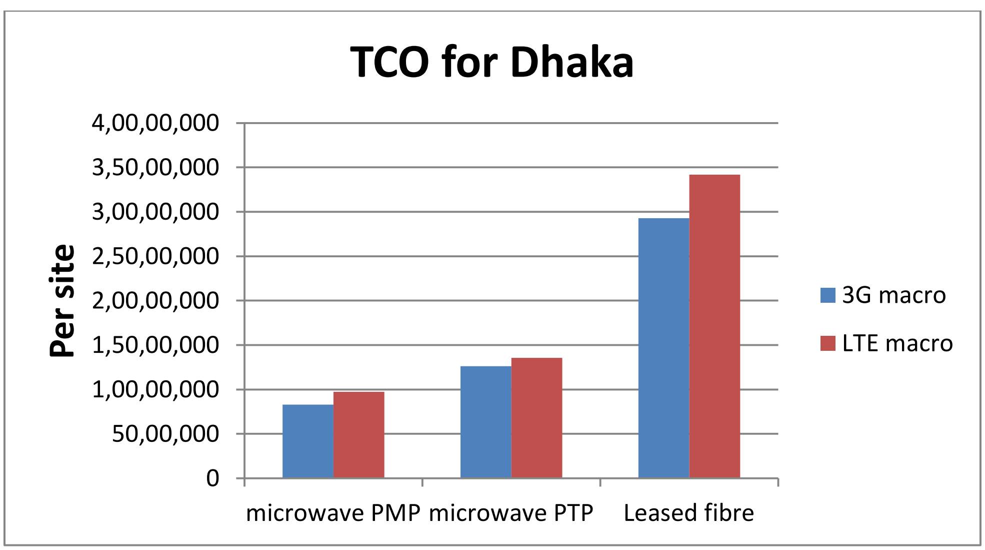
		for 3G case	
	Microwave pmp	Microwave PTP	Leased fibre
Dhaka	8,288,200	12,632,360	29,265,920
Barisal	208,800	318,240	737,280
Sylhet	707,600	1,078,480	2,498,560
Rajshahi	324,800	495,040	1,146,880
Khulna	487,200	742,560	1,720,320
Chittagong	1,287,600	1,962,480	4,546,560
Rangpur	237,800	362,440	839,680
TOTAL	11,542,000	17,591,600	40,755,200

		for LTE case	
	microwave PMP	microwave PTP	Leased fibre
Dhaka	9,717,200	13,546,920	34,173,106
Barisal	278,800	341,280	860,904
Sylhet	829,600	1,156,560	2,917,508
Rajshahi	380,800	530,880	1,339,184
Khulna	571,200	796,320	2,008,776
Chittagong	1,509,600	2,104,560	5,308,908
Rangpur	278,800	388,680	980,474
TOTAL	13,566,000	18,865,200	47,588,860

To make the picture more clearer, here the case for Dhaka city only is shown:

TCO for Dhaka city

	3G macro($)	LTE macro($)
microwave PMP	8,288,200	9,717,200
microwave PTP	12,632,360	13,546,920
Leased fibre	29,265,920	34,173,106



In practical case, only one of these solutions are not used for all the sites. Operators usually use multiple solutions according to the requirement of the location. So they use both microwave and fiber solution. Where available, fiber is better suited to operators who prefer to allocate backhaul costs to OPEX, or that have access to low line-rental fees. In perspective of Bangladesh, fiber is mostly used solution because of availability and its low leasing price as operators use their own fiber in different locations. So taking 80% of the microwave cost and 20% of the fiber cost, total cost for backhauling data for all the divisional cities would be:

- FOR 3G HSPA CASE,
  - Cost of Backhaul up gradation- $32,606,960

- FOE LTE CASE,
  - Cost of Backhaul up gradation- $38,074,088

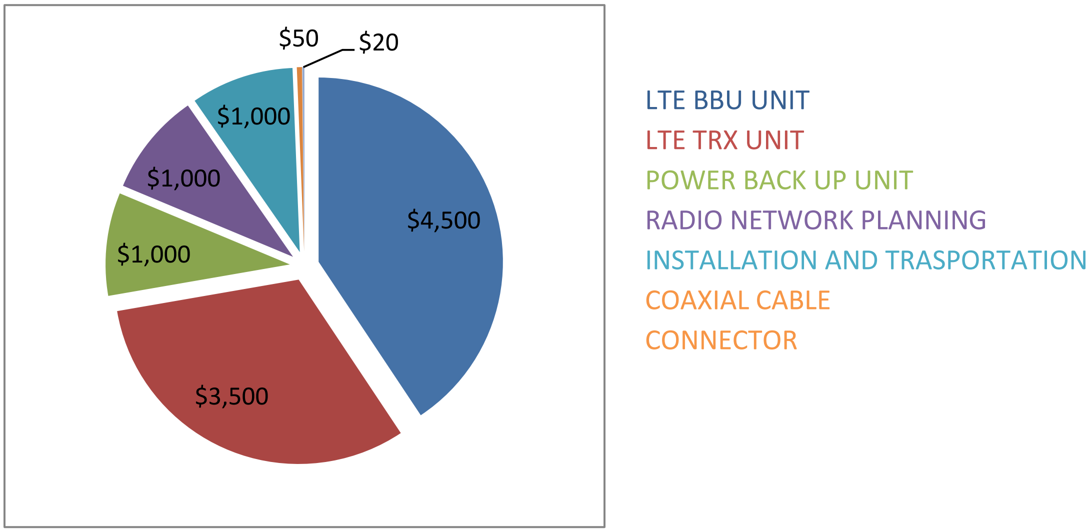
5.3 Cell Up gradation Cost

The up gradation cost of GP's all the cell sites in the 7 divisional cities of Bangladesh is calculated. The number of cell sites in different divisional cities are shown below:

NUMBER OF CELLS IN DHAKA	1429
NUMBER OF CELLS IN BARISAL	36
NUMBER OF CELLS IN SYLHET	122
NUMBER OF CELLS IN RAJSHAHI	56
NUMBER OF CELLS IN KHULNA	84
NUMBER OF CELLS IN CITTAGONG	222
NUMBER OF CELLS IN RANGPUR	41
TOTAL NUMBER OF SITES IN DIVISIONAL CTIES	1990

5.3.1 Cell up gradation cost to LTE

A typical cost breakdown is shown for a unit GSM cell site up gradation to LTE eNodeB.



Name of the equipment	ESTIMATED COST
LTE BBU UNIT	4500
LTE TRX UNIT	3500
POWER BACK UP UNIT	1000
RADIO NETWORK PLANNING	1000
INSTALLATION AND TRASPORTATION	1000
COAXIAL CABLE	50
CONNECTOR	20
TOTAL cost for unit Cell	11070

TOTAL NUMBER OF SITES IN DIVISIONAL CITIES IS 1990

- So total cell up gradation cost to LTE is $11070 * 1990 = **$22029300**

5.3.2 Cell Up gradation cost to 3G HSPA:

A typical cost breakdown is shown for a unit GSM cell site up gradation to HSPA NodeB is shown below.

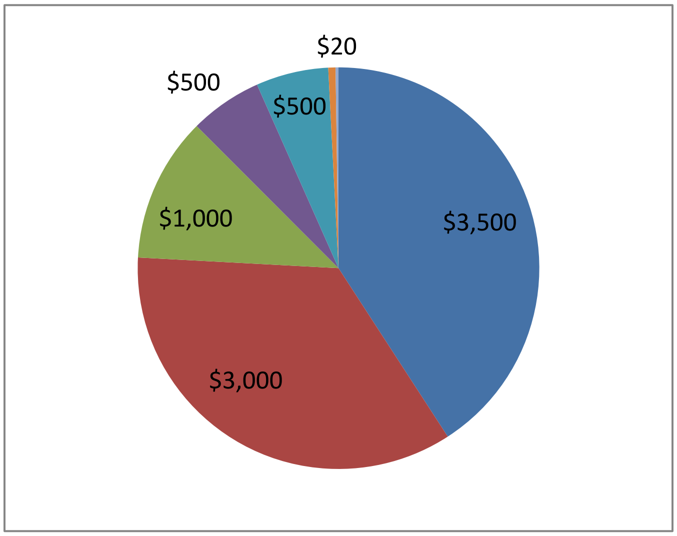


Fig: Unit cell Up gradation Cost breakdown for HSPA

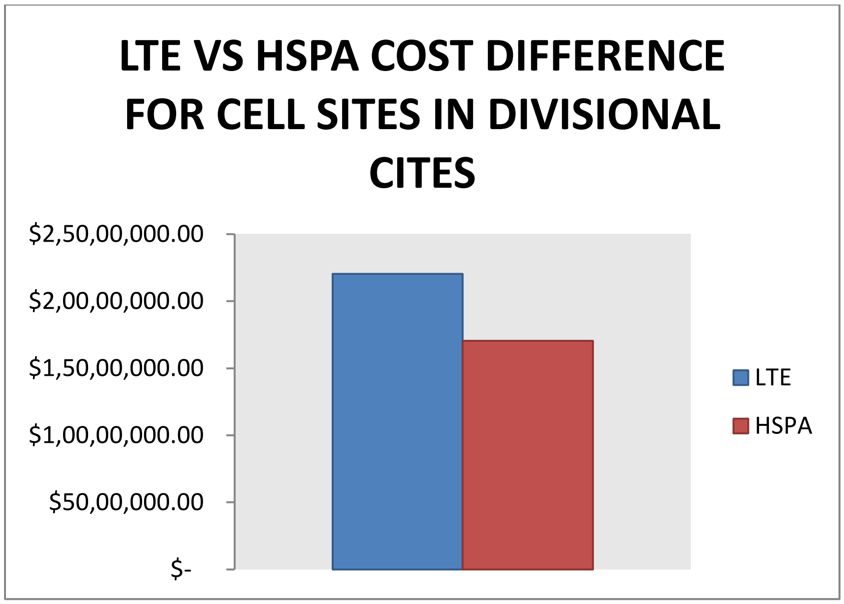
Name of the equipment		ESTIMATED COST
HSPA BBU UNIT		3500
HSPA TRX UNIT		3000
POWER BACK UP UNIT		1000
RADIO NETWORK PLANNING		500
INSTALLATION AND TRASPORTATION		500
COAXIAL CABLE		50
CONNECTOR		20
TOTAL cost for unit Cell		8570

TOTAL NUMBER OF SITES IN DIVISIONAL CITIES IS 1990

- So total cell up gradation cost to LTE is $8570 * 1990 = **$17412500**

KEY POINTS:

- Cost difference per unit cell up gradation is $2500
- LTE requires $4975000 more than HSPA for all the cell sites in divisional cities.



5.4 Core Network Up gradation Cost

- ✓ LTE has higher initial core cost due to its flat ALL-IP Architecture, but will reduce considerable amount of OPEX in the long run.
- ✓ HSPA will run smoothly on existing GSM core for the moment but may get outdated in future.

According to Grameenphone's data sought from ITU, it is mentioned that LTE core up gradation cost is 20% higher than HSPA core. We assume the core network up gradation cost based on this analysis and from market observation.

- **Investment required for LTE Core up grade is**
  = $600000

- **Investment required for HSPA Core up grade is**

  = $5000000

5.5 Spectrum Cost:

As the spectrum concessions will be technology neutral so the price for spectrum is same for LTE and HSPA. BTRC has set the base price for per MHz spectrum as 240 Cr. BDT. So for a 10 MHz concession the base price will be 2400 Cr. BDT. We assume that 2500 Crore BDT will be at least be required for winning a 10 MHz concession on the auction which if converted to US dollar is **$ 292682926**.

5.6 Operation & Maintenance

We assume a 10% of the total will be required for regular maintenance, optimization and operation.

5.7 REVENUE ESTIMATION

A simplified revenue estimation for the 5 year period (2013-2018) is shown in this section. In the estimation, the data provided by GP and also the data available on the internet is used. There might be some irregularities with the actual scenario, but we can afford that as this is just a preliminary attempt to explore the two different migration paths.

5.7.1 3G HSPA REVENUE ESTIMATION

In this section, we've estimated a rough revenue earning for HSPA rollout case in all the divisional cities in Bangladesh. The data and user forecast was provided by Grameenphone. We've introduced a 20% multiple sim factor which we omitted from the user forecast. Analyzing GP's share in total number of mobile subscribers, we have taken a gradual decrease in percentage of GP's subscriber starting from 68% (2013) and ending at 52% (2018) due growing intensity in competition in the mobile operator market.

The HSPA device penetration forecast was provided by Grameenphone. The average user data rate is the mathematical average of the different data rates used by the HSPA users. An average yearly revenue is calculated based on the current pricing policy and future trend of data package cost.

The starting number of 3G users is much higher as there are many existing subscribers using 3G enabled handsets currently. Also there are many cheap 3G enable UEs available in the market. But due to intense competition and advancement in technology, at the later years 3G subscribers' percentage will fall below the LTE subscribers' percentage.

Year	2013	2014	2015	2016	2017	2018
Unique Mobile Users (Bangladesh) (40% multiple sim)(mn)	65.57	70.47	74.56	78.12	81.33	84.30
Percentage share of Grameenphone	68%	65%	63%	60%	55%	52%
Grameenphones users prediction(mn) (omitting 20% of multiple sim)	3,56,70,080	36644400	37578240	37497600	35785200	35068800
Percentage of Users in Dhaka and Divisional City	70%	65%	60%	58%	54%	52%
Number of Users in Dhaka and Divisional City	2,49,69,056	23818860	22498560	21748608	19324008	17534400
% of user with 3G devices	20%	25%	32%	39%	46%	53%
Number of 3G subscribers in Dhaka City	4993811	5954715	7199539	8481957	8889044	9293232
Avg. user data rate provided (Mbps)	0.256	0.512	0.512	1	1.5	2
Avg. yearly revenue per user	60	80	80	120	150	175
Total Revenue from Divisional Cities	$29,96,28,672	$47,63,77,200	$57,59,63,136	$1,01,78,34,854	$1,33,33,56,552	$1,62,63,15,600

- TOTAL HSPA REVENUE IN 5 YEAR PERIOD = **$5,32,94,76,014**

5.7.2 LTE Revenue Analysis

In this section, we've estimated a rough revenue earning for LTE rollout case in all the divisional cities in Bangladesh. The data and user forecast was provided by Grameenphone. We've introduced a 20% multiple sim factor which we omitted from the user forecast. Analyzing GP's share in total number of mobile subscribers, we have taken a gradual decrease in percentage of GP's subscriber starting from 68% (2013) and ending at 52% (2018) due growing intensity in competition in the mobile operator market.

The LTE device penetration is assumed based on the trend of LTE's ecosystems maturing. In the early years, their will be less number of users as the number of available LTE UE penetration to the customers is very low. But as the ecosystem matures

The average user data rate is the mathematical average of the different data rates used by the LTE users. An average yearly revenue is calculated based on the current pricing policy and future trend of data package cost.

LTE revenue generation for next 5 years is shown in below:

Year	2013	2014	2015	2016	2017	2018
Unique Mobile Users (Bangladesh) (40% multiple sim)(mn)	65.57	70.47	74.56	78.12	81.33	84.30
Percentage share of Grameenphone	68%	65%	63%	60%	55%	52%
Grameenphones users prediction(mn) (omitting 20% of multiple sim)	3,56,70,080	36644400	37578240	37497600	35785200	43836000
Percentage of Users in Dhaka and Divisional City	70%	65%	60%	58%	54%	50%
Number of Users in Dhaka and Divisional City	2,49,69,056	23818860	22546944	21748608	19324008	21918000
% of user with LTE devices	10%	18%	30%	40%	55%	60%
Number of LTE subscribers in Dhaka and Divisional City	2496906	4287395	6764083	8699443	10628204	13150800
Avg. user data rate provided (Mbps)	0.512	1	1.5	2	2.5	2.5
Avg. yearly revenue per user	80	120	150	175	200	180
Total Revenue from Divisional Cities	$19,97,52,448	$51,44,87,376	$1,01,46,12,480	$1,52,24,02,560	$2,12,56,40,880	$2,36,71,44,000

TOTAL REVENUE GENERATED IN 5 YEAR PERIOD IS = $7,74,40,39,744

- **LTE has the potential to earn $2,41,45,63,730 more revenue than HSPA**

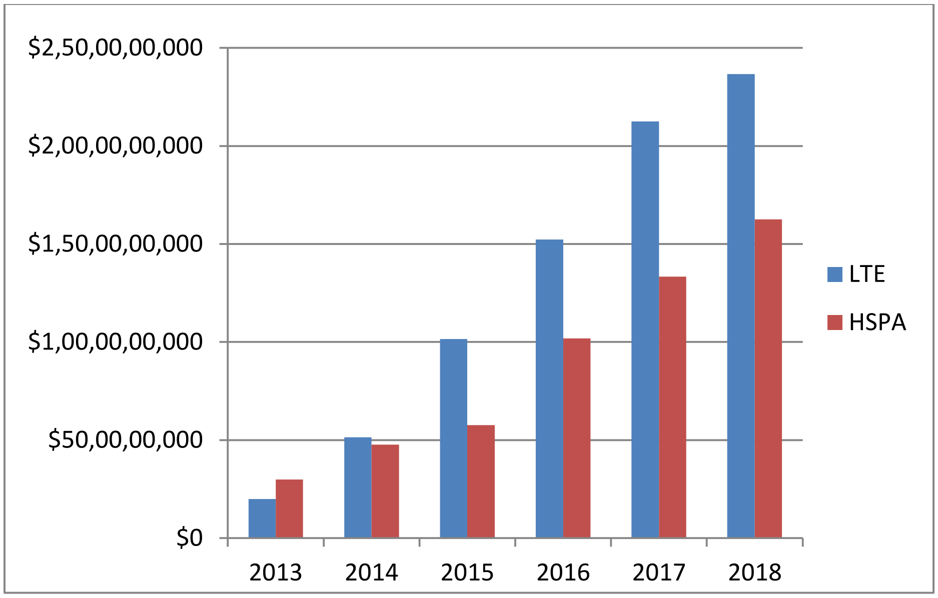
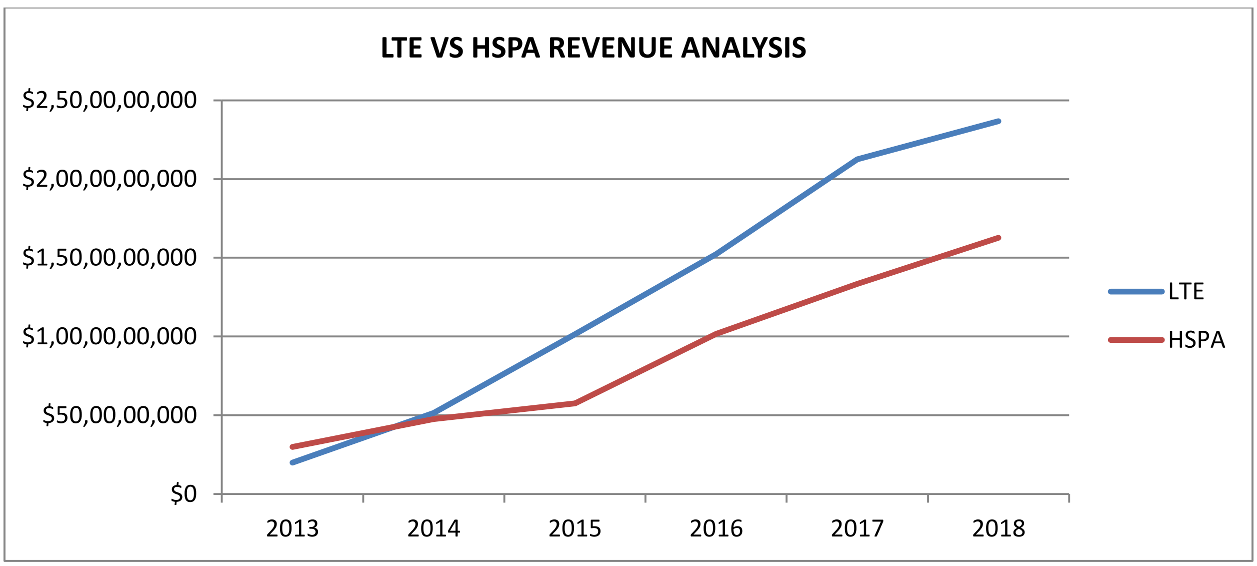


Figure: LTE VS HSPA REVENUE



5.8 COST ESTIMATION

In this section we estimate the total cost required both rollout strategy. We've already estimated the Backhaul cost, Cell site up gradation cost, Core Network Up gradation cost, Spectrum cost and O&M cost. Here we estimate the bandwidth required for the number of subscribers mentioned above for the LTE and HSPA cases and calculate the cost required.

5.8.1 Cost of the Bandwidth

We use an OBF (over booking factor) of 20 for each of the rollout scenario. The required bandwidth can be obtained by the following formula:

Over all Data Rate = Number Of Users*Peak Data Rate* Over booking Factor

Also we've assumed the cost of per Mb bandwidth as per the current market trend, (Gradually decreasing as year goes by).

The rough estimation of the Bandwidth cost for LTE is shown below. OBF taken for LTE is 20%.

OBF	15	15	15	15	15	15
Subscribers	1248453	3572829	5636736	7177041	9662004	13150800
Avg. data rate	0.512	1	1.5	2	2.5	2.5
Bandwidth Req(MB)	95881	535924	1268266	2153112	3623252	4931550
Cost per MB	600	550	500	450	420	380
Total Cost	57528705	294758393	634132800	968900486	1521765630	1873989000

- **TOTAL COST FOR BANDWIDTH for LTE = $ 53,10,75,014**

The rough estimation of the Bandwidth cost for HSPA is shown below. OBF taken here is 15%.

OBF	20	20	20	20	20	20
Total Subscriber	4993811	5954715	7874496	8699443	9662004	10520640
Avg Data Rate per Sub	0.256	0.512	0.512	1	1.5	2
Bandwidth req (Mb)	255683	609763	806348	1739889	2898601	4208256
Per Mbps Cost	600	550	500	450	420	380
Yearly Bandwidth Cost	153409880	335369549	403174195	782949888	1217412504	1599137280

- **TOTAL COST FOR BANDWIDTH for HSPA = $44,9,14,53,296**

5.8.2 OPEX & Maintenance

Considered as 10% of the CAPEX investment, excluding spectrum fees.

- Total estimated O & M cost **$1,14,08,48,887**

5.8.3 Total Cost for Deployment

By summing up all the costs we calculate the total cost for GP to deploy both LTE and HSPA in all the divisional cities of Bangladesh.

	LTE	HSPA
Bandwidth Cost	5351075014	4491453296
BTS	2202930	17054300
CORE	6000000	50,00,000
BACKHAUL	3,80,74,088	3,26,06,960
SPECTRUM	292682926	292682926
O&M	539735203	454611456
Total($)	6229770161	5293408938

- LTE has higher deployment cost than 3G HSPA by **$93,63,61,223**

5.9 COST VS REVENUE

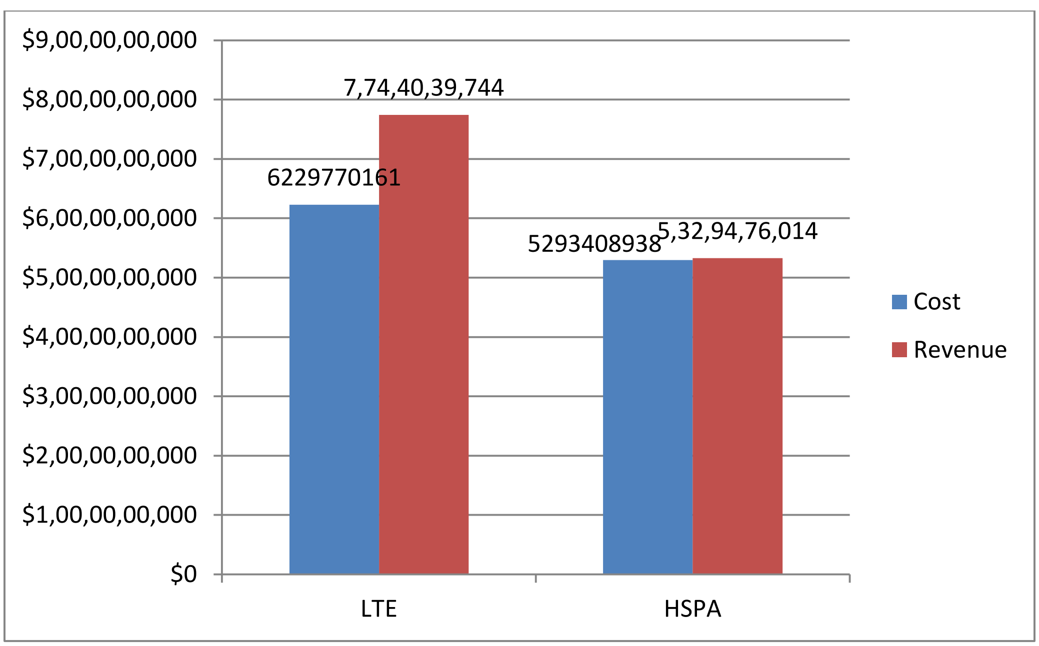


Figure LTE VS HSPA (Cost Revenue Comparison)

From the above figure we can see that LTE despite having higher deployment cost has the potential to earn higher revenue than HSPA in a given period of 5 years. (2013-2018). The key points are-

- LTE can recover the huge investment and even gain a profit of **$1,51,42,69,583** in just 5 years.

- 3G HSPA on the other hand has the potential to recover its required investment and a very small profit gain of **$3,60,67,076.**

CHAPTER SIX - Conclusion

From the cost revenue analysis of chapter six, we see that LTE being the next generation technology has the potential to generate more revenue than its main competitor 3G HSPA, provided that a supportive market environment will be available. On the other hand, HSPA is a proven technology, has a vast ecosystem and already the mainstream and is almost certain of generating the estimated revenue. But as the global trend for mobile broadband data is soaring up towards the sky it is safe to say that a next generation technology LTE can deliver better performance for a long period of time.

Eventually all the major telecom operators will switch to LTE because of its superiority. The question is when will they? Bangladesh is actually an interesting market as there hasn’t been 3G launched yet. And now the technology neutrality will allow to launch either 3G or 4G LTE in the country. So, in our opinion the operator, Grameenphone, can take a risk by leapfrogging 3G HSPA and launch LTE which will save a lot of investment for the future and can also earn more revenue than any other cellular technology.

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