SPECTRUM MANAGEMENT POLICY FRAMEWORK FOR MOBILE BROADBAND IN SRI LANKA

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Degree of Master of Science in Telecommunication

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DECLARATION

I declare that this is my own work and this thesis does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

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Signature of the supervisor: Date

Name of the supervisor: Eng. A.T.L.K. Samarasinghe

ABSTRACT

Spectrum Management Policy Framework for Mobile Broadband in Sri Lanka

Spectrum management has become an important aspect of regulation as part of industry broadband growth and foster innovation. The statutory framework that exists currently in Sri Lanka for mobile broadband spectrum management is elementary and outdated. Therefore, the current regulations fall short of driving the exponential broadband growth in the telecommunications industry, promoting investment and innovation in the provision of services which ultimately results the consumers to use poor quality broadband services and products.

This research is mainly focused to identify the most suitable spectrum policy changes required to foster the mobile broadband growth in Sri Lanka; solutions to the existing spectrum management problems, what steps need to be taken to be taken to avoid these problems in the future; What actions need to be taken to foster innovation and spectrum best practices around the globe. There are few steps used to gather information for the policy framework. A survey was conducted among the all mobile operators/TRCSL/Main equipment vendors covering the 360 landscape of the mobile telecommunication industry in Sri Lanka. Then a study was done about the already implemented broadband policy frameworks in south Asian developed countries. And also, it was thoroughly analyzed the spectrum policy frameworks introduced by ITU and regional regulators

Finally, spectrum policy recommendations to Sri Lankan industry context were suggested in three main pillars of spectrum policy concepts namely Spectrum Planning, Spectrum Management and Spectrum Licensing with each concept having three main areas of study.

Keywords: *Spectrum, Broadband, Mobile telecommunication, Policy*

DEDICATION

To my loving wife Uththara and my three little princesses – Sethuni/Sanumi/Keyara

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LIST OF ABBREVIATIONS

Abbreviation	Description
2G	2nd Generation
3G	3rd Generation
3GGP	3rd Generation Partnership Project
4G	4th Generation
5G	5th Generation
APT	Asia Pacific Telecommunity
ARPU	Average revenue per user
ASEAN	Association of Southeast Asian Nations
BB	Broadband
CA	Carrier Aggregation
CAGR	Compound Annual Growth Rate
CAPEX	Capital expenditures
CBD	Central Business District
CEPT	European Conference of Postal and telecommunication Administration
CITEL	Inter-American Telecommunication Commission
DAS	Distributed Antenna System
DECT	Digital Enhanced Cordless Telecommunications
DL	Downlink
DoT	Department of Telecommunications
E-GSM	Extended Global System for Mobile
eMMB	Enhanced Mobile Broadband
EU	European Union
FCC	Federal Communications Commission
FDD	Frequency Division Duplex
GDP	Gross Domestic Product
GSM	Global System for Mobile
GSMA	Global System for Mobile Association
GSR	Global Symposium for Regulators
HSPA	High Speed Packet Access
HSUPA	High Speed Uplink Packet Access
ICT	Information and Communications Technology
IMT	International Mobile Telecommunications
IoT	Internet of Things
ITU	International Telecommunication Union
KPI	Key Performance Indicator
LSA	Licensed Shared Access

LTE	Long Term Evolution
LTE-A	Long Term Evolution - Advance
MIMO	Multiple Input Multiple Output
NB	Narrow Band
NBCC	National Broadband Consultative Committee
NR	New Radio
OPEX	Operational expenditure
PEST	Political,Economical,Social,Technological
PIM	Passive Inter Modulation
QAM	Quadrature amplitude modulation
QOS	Quality of Service
RCC	Regional Commonwealth in the field of Communications
ROI	Return on Investment
RRU	Radio Resource Unit
RTWP	Receive Total Wideband Power
SAARC	South Asian Association for Regional Cooperation
SATRC	South Asian Telecommunication Regulators Council
SDCCH	Stand Alone Dedicated Control Channel
SMS	Short Message Service
TCH	Traffic Channel
TCP	Transmission Control Protocol
TDD	Time Division Duplex
TRAI	Telecom Regulatory Authority of India
TRCSL	Telecommunications Regulatory Commission of Sri Lanka
TV	Television
UE	User Equipment
UL	Uplink
UL	Uplink
UMTS	Universal Mobile Telecommunications System
UTRAN	Universal Terrestrial Radio Access Network
WCDMA	Wideband Code Division Multiple Access
Wi-Fi	Wireless Fidelity
WLL	Wireless Local Loop
WRC	World Radio-communication Conference

1. INTRODUCTION

1.1 Importance of Broadband

Many of the previously published empirical studies shows that Broadband has a will have a positive influence on socio-economic progress. In addition, when the network infrastructure is developing it impacts on the wider economy which can improve productivity, innovation and create new business opportunities as well as providing improved access to personalized healthcare, online services and facilitating smart cities. Empirical studies show the socio-economic impact of mobile broadband growth of 10% will results to GDP increase between 0.26% and 0.92% [1]

Furthermore, in terms of jobs creation, the research data indicates that the addition of 1000 new broadband connections will generate up to 33 new jobs. [1] Initially new jobs are generated as a result of direct implementation of broadband penetration, as an example, jobs created for broadband network infrastructure development. When these jobs get reduced the indirect job creation comes in to play outside telecommunication domain.

Table 1.1 gives the summary of GDP growth and Job creation due to the broadband infrastructure development in the South Asian region.

Table 1.1 : GDP growth and Job creation due to Broadband

	Country	ICT maturity	Δ broadband connections penetration (percentage points) (2013-20)	Cumulative GDP increment (USD billion)	Cumulative new jobs added (thousand)
Emerging	China	4.18	43	855	19 321
	India	2.21	35	290	14 722
Developed	Australia	7.90	37	11	287
	Hong Kong	7.92	61	7	146
	Singapore	7.65	43	5	80
	South Korea	8.57	36	17	593
	Total	**N/A**	**N/A**	**1185**	**35 149**

Source: Analysis Mason

From the above Table 1.1 it is clear that mobile broadband will offer a significant benefit to the countries' economy. This impact is maximized when the sufficient spectrum is available to deploy quality broadband network in terms of coverage and capacity.

1.1 Global Trend of Broadband

Mobile devices are increasingly considered an essential commodity in life. The past decade has experienced exponential growth in data traffic, and there's an expectation that mobile broadband usage will continue growing. Even though the speed of increase in subscriber numbers is slowing some niches, the number of data traffic transported by mobile networks is exponentially rising, as the growing data is consumed by more subscribers on average.

Consumers are now heavily accessing their mobile devices to the same variety of services which they can get through the fixed internet. Driven with this expanding usage of mobile devices, it is forecasted around 3 billion cellular broadband connections (3G and 4G) from the Asia--Pacific region by 2020, consuming more than 50 000 petabytes of data each year. [1]

In the recent years the prices of growth in mobile broadband have surpassed the fixed data broadband in several markets, and predictions imply that mobile data usage will continue the growth. Globally, the amount of mobile connections (excluding machine to machine) reached nearly 7 billion in 2014 and will continue to grow exponentially up to 2018 as shown in Figure 1.1 below. [1]

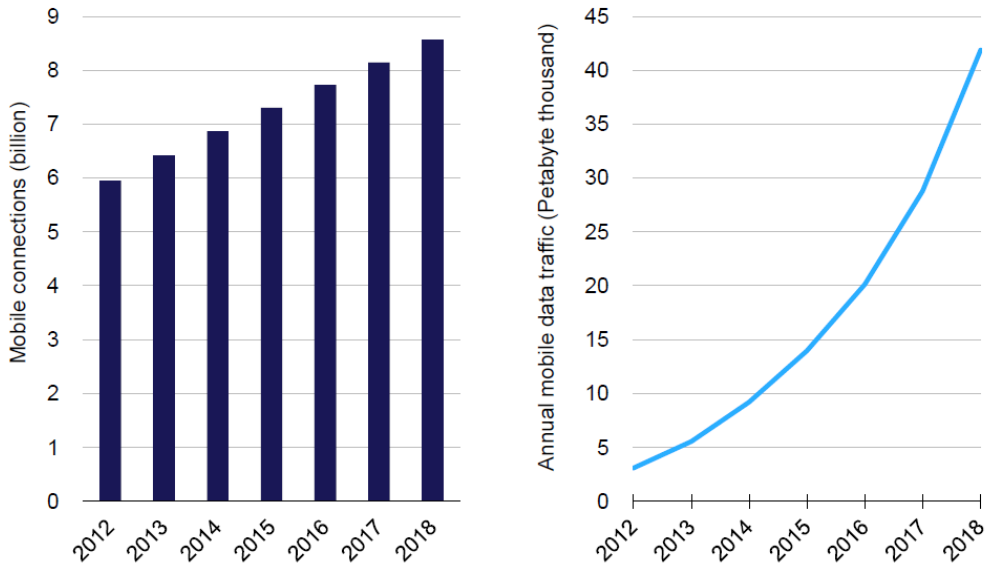


Figure 1.1: Forecast of mobile connections globally (2014-2018)

Source: Analysis Mason

There are various different forecasts for how the number of mobile connections, and the traffic generated by mobile use will grow in the future as depicted in figure 1.2 by Cisco which suggests the same outcome which is the exponential growth in mobile broadband connection number and volume in Asia pacific region.

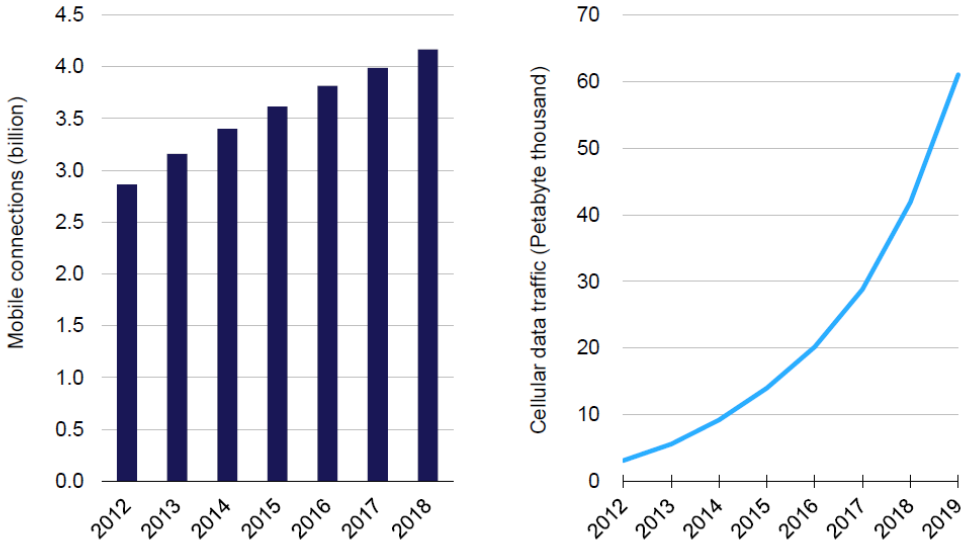


Figure 1.2: Forecast growth in mobile connections Asia pacific region (2014 – 2018)

Source: Cisco Visual Networking Index

Inside the Asia--Pacific area there are important differences in the market and financial standing of nations, as shown in Table 1.2. These gaps have determined how mobile broadband have grown in different markets and, specifically, the speed of migration from 2G to 3G/4G along with also the quantities of spectrum which are being deployed for broadband (and 4G specifically).

Table 1.2: Key demographic and economic indicators

	Population (million)	Population density (people per km^2)	GDP per capita (USD)
Australia	24	3	67 468
China	1356	145	6807
Hong Kong	7	6845	28 124
India	1256	421	1499
South Korea	51	516	25 977
Singapore	6	7713	55 182

Source: Analysis Mason, World Bank, EIU

These inherent factors have influenced the uptake and utilization of mobile services, leading to a variety of traffic and subscriber volumes and within their prediction development. The developed Asia--Pacific markets with GDP per capita of over USD 25,000 have a mobile penetration of over 100 percent and subscriber growth is now slowing down. By comparison, in China and India, penetration prices are predicted to continue to rise quickly in CAGRs of 4.9% and 6.3% respectively. [1]

when mobile data traffic is considered there is a difference in the rates of growth between most advanced Asia–Pacific economies and emerging economies. The high populations in China and India, together with significant investment in their still developing mobile industries will result a higher traffic origination. It is expected to reach 14,700 and 11,600 petabytes respectively in 2019. Also when we consider the developed economies the traffic growth will be slower due to the device saturation. It is expected to grow between 31% and 38% between 2014 and 2019. This is depicted in the figure 1.3 below. [1]

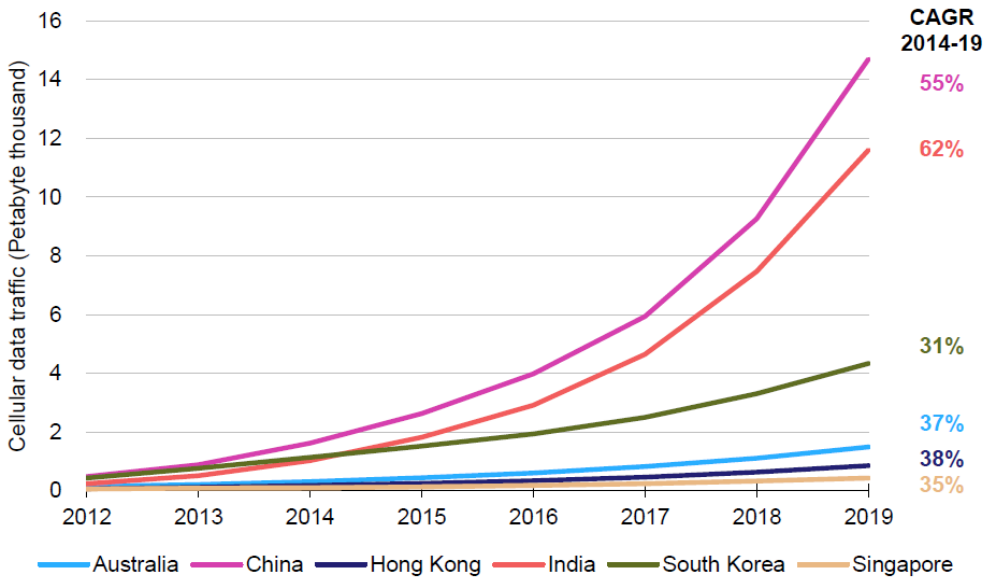


Figure 1.3: Traffic growth rate comparison between developing and developed countries

Source: Analysis Mason

1.2 Broadband Status in Sri Lanka

Telecommunication industry reforms in Sri Lanka started in 1980 using the de-linking of government owned posts and telecommunications providers. After that, the industry experienced drastic changes together with all the restructuring and partial privatization of this state-owned incumbent operator; allowing market entrance in the mobile telecom market; competition from the wireless local loop (WLL) section of the fixed marketplace; and the constitution of a five-member regulatory commission with its own finance and also comparatively more viable liberty than a normal government division in Sri Lanka. These policy initiatives, at least up into the late 1990s, represented a commitment on the part of policy makers to pro-competitive reforms, together with Sri Lanka's telecommunication industry being viewed among the more spacious among developing nations in the Asia Pacific area, with a massive potential for expansion.

With the conclusion of the civil war in 2009 Sri Lanka entered a post-conflict stage. There were positive indications of an overall improvement in the nation's social and financial well-being from 2013/2014. And, although facing challenges, the telecom

industry in particular was beginning to enter a new development stage. The generally improving economy environment has witnessed the nation's telecom industry nicely positioned for continuing exponential growth. The modern and innovative telecommunications business is definitely high on the list of priorities for additional growth and development. The government was encouraging such initiatives since the e-Sri Lanka job. In addition, it has established the National Broadband Consultative Committee (NBCC), a special committee made to accelerate and encourage the access to low cost high speed broadband internet in the nation.

In the meantime, the nation's mobile phone services have continued on a positive growth path. As a powerful and efficient alternative to the fixed-line networks, the mobile telephon quickly turned into a popular and essential support. The nation's five competing mobile operators -- Dialog Axiata, Mobitel, Etisalat Sri Lanka and Hutchison Lanka and Bharti Airtel Lanka competes in an extremely competitive market.

In 2007, the Mobitel and Dialog launched its 3.5G HSPA network - the first 3.5G network in South Asia which other mobile operators also followed the main two operators. Then Mobitel and Dialog began their rollout in 2013 from 4G LTE service deploying their latest wireless network technology that enabled the most advanced mobile broadband experience to its customers. This was only followed by Hutch-Etisalat merger equity recently on June 2019 where still Airtel has not been able to launch the advanced 4G technology due the lack of spectrum. Furthermore, in 2016 Mobitel and Dialog successfully launched 4.5G LTE-Advanced technology capable of achieving speeds exceeding 1Gbps yet again for the first time in South Asia keeping ahead with peers in the region. In 2018 Mobitel and Dialog were the first to launch Sub-1G Mobile Broadband network by using low band 900MHz spectrum in Sri Lanka giving larger broadband penetration specially in the rural segment.

Mobitel and Dialog publicly revealed Sri Lanka's first 5G deployment over 3.5GHz Spectrum band. This 5G demonstrated showcased the use of MIMO technology by using 64x64 MIMO configuration with commercially accessible user equipment.

In Sri Lanka, the mobile broadband is currently playing a very significant role in driving digital divide and economic growth throughout the country. The amount of

mobile subscribers has increased from 5.4 million in 2007 roughly 26.0 million in 2017 (reaching 126% unique subscriber penetration), at an average yearly increase rate of 10%. Total mobile industry earnings were $947 million in 2017, equal to 1.1% of Sri Lankan GDP. Mobile operators donated approximately $298 million of direct economic value to Sri Lanka in 2017 (0.4% of GDP), while also encouraging a wider mobile ecosystem which has mobile content developers, mobile retail and distribution chain. [2]

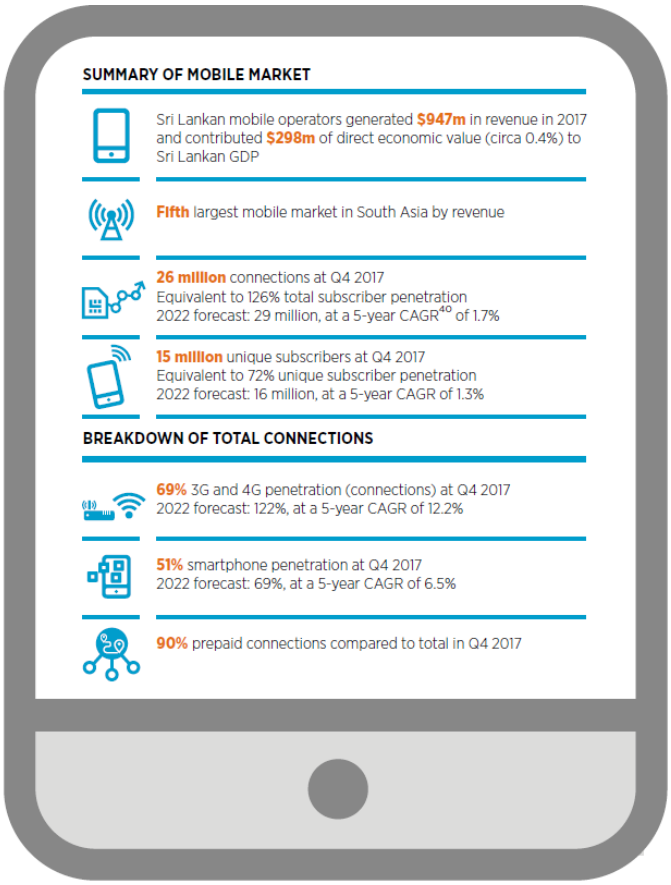
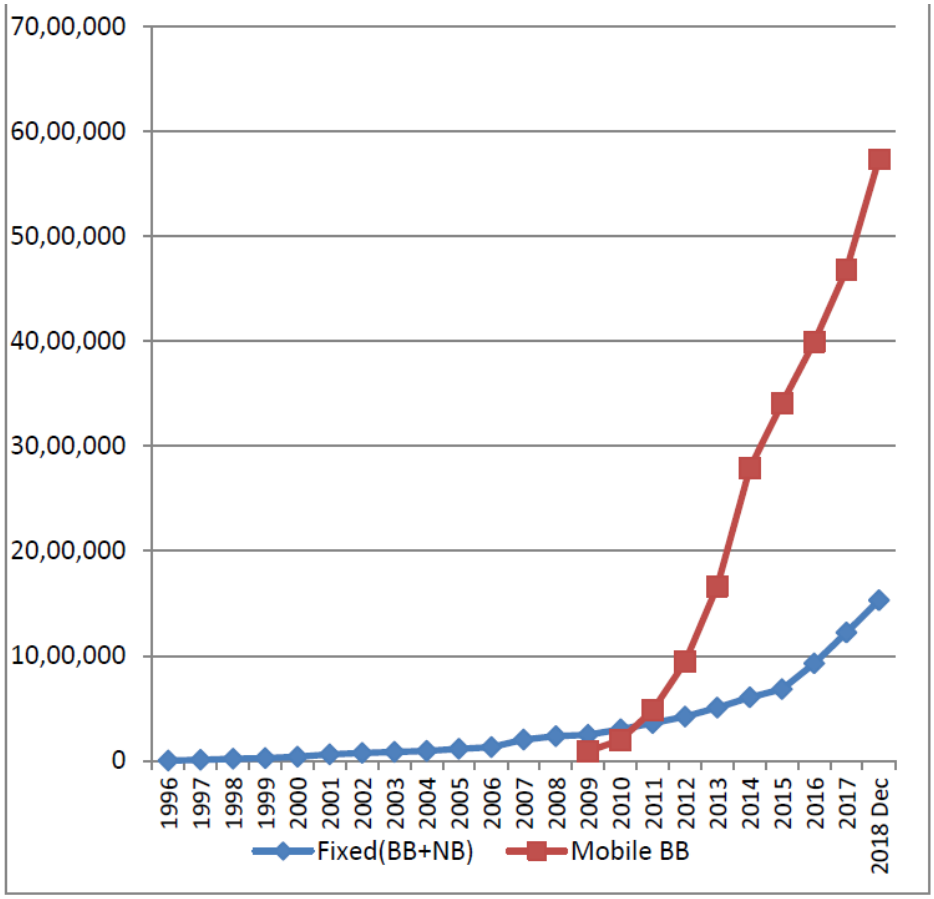


Figure 1.4: Mobile Industry statistics, Sri Lanka
Source: GSMA Intelligence, EY analysis

Furthermore, when it comes to broadband in Sri Lanka there is a high growth rate seen in the mobile broadband in comparison to the fixed wireless business. This trend follows the global trend where people want internet on the go in mobility. With the smart phone adoption and the stiff competition in the mobile market, we can see a tremendous growth rate in the mobile broadband.



Note: BB – Broadband, NB – Narrow Band

Figure 1.5: Mobile and Fixed broadband growth in Sri Lanka

Source: TRCSL

This rapid expansion was facilitated by investment in the mobile industry in Sri Lanka, using GSM and broadband population coverage expansion plans as a mainstream driver but whilst the coverage penetration is large, there's still substantial room for new broadband technology adoption. 49% of the population still does not own a smart phone and only around 10% is using 4G technology as at Q4 2017 though the 4G technology is being available from 2013.This lack of adoption of smartphones plays a major hurdle in high demand drive network expansions. [2]

However, though there is a high demand and drive in the mobile networks and market a significant portion is still not connected to broadband. Unique subscriber penetration in Sri Lanka is favorably high in compared to its South Asian allies, however, only 40% of subscribers is connected to broadband in Sri Lanka, which implies there is a high potential for broadband growth as depicted in the figure 1.6 [2]

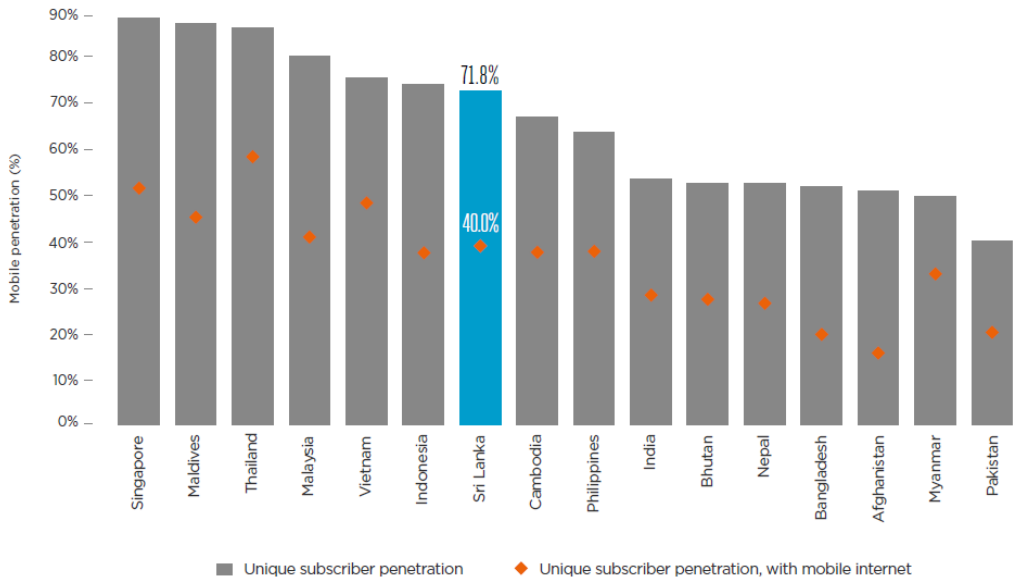


Figure 1.6: Mobile Broadband penetration Asian countries, 2017

Source: GSMA Intelligence

1.3 Importance of Spectrum Management for Broadband growth

Spectrum is a scarce resource necessary for supplying wireless broadcasting and telecommunication solutions. Spectrum mission and usage is connected with significant social and financial trade-offs which have to be cautiously considered. From a technical standpoint, wireless spectrum, generally referred to in telecommunications as" spectrum", is the section of the electromagnetic spectrum whose frequencies varies from 3Hz into 3000 GHz range. Furthermore, frequency range from 300 MHz to 3 GHz, is ideal for telecommunications services. This spectrum Bandwidth increases with greater frequencies, but with low coverage. Therefore, higher frequencies are more acceptable for dense regions that need high speeds, whereas lower frequencies are more suitable for coverage requirement for policy purposes, as fewer base stations need to give deploy in any certain area. [3]

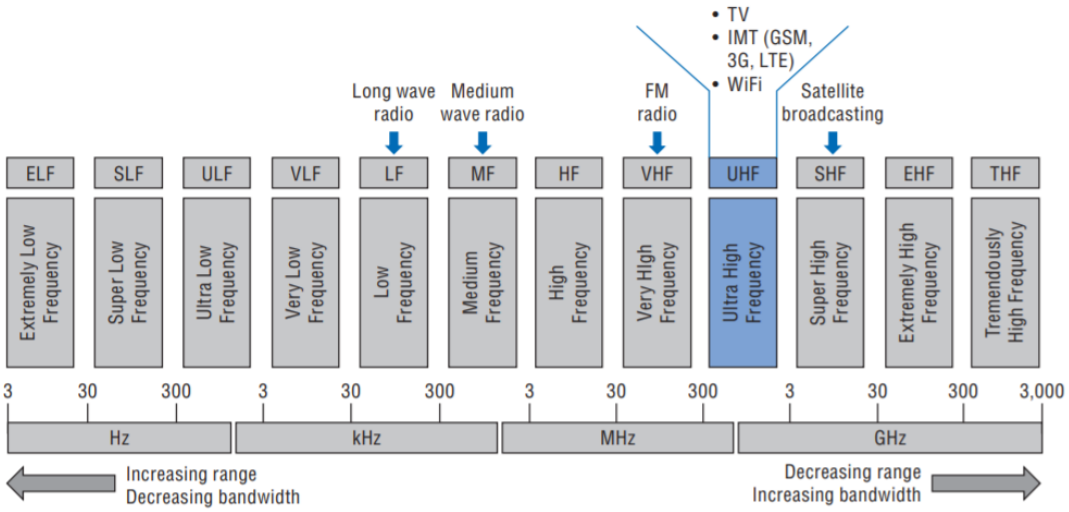


Figure 1.7: Electromagnetic Spectrum portfolio

Source: ITU (2011), Telecommunication Regulation Handbook

In an economic standpoint, spectrum is a scarce source in any certain time or place, which means that only a limited quantity of spectrum may be utilized. It can't be stored, instead of many other rare resources like oil or minerals, and it can't be transported, though, at least in concept, it may be traded, provided that the rights of usage can be transferred. As spectrum is employed for its delivery of solutions which are deemed necessary, public authorities have an inherent obligation to ensure it is utilized in the most effective way. Only efficient management can strike a balance involving licensing procedures and conditions (spectrum price), in addition to coverage, requirement and QOS obligations linked to the spectrum, together with market competition. Hence management is vital for optimizing the usage of the spectrum, both economically and socially.

1.4 Research Problem

In this thesis, I have examined how the spectrum should be managed to foster the growth in mobile broadband in Sri Lanka. Sri Lanka has large potential for growth in mobile broadband market. Majority of the broadband users are using mobile phones as the majority medium to connect.

Sri Lankan government acknowledges the potential of broadband in advancing fiscal accessibility, improving information, and increasing productivity in the economy. It has launched significant flagship programs like Digital Sri Lanka along with Smart Cities such as “Port City” which heavily rely on broadband infrastructure. Sri Lanka, however, should boost its broadband infrastructure and its spectrum policy to achieve the vision of digital Sri Lanka. While spectrum availability is a worldwide challenge faced with markets, it is serious in Sri Lanka as a developing country. Given the critical role of the telecommunications business in Sri Lanka's future vision, solving these challenges is essential for economic development and social addition.

Sri Lanka has high levels of 3G (90%) and 4G coverage (69%) coverage availability from the operator side but still the broadband penetration is only 40% of the total population. We need to find the reasons for this significant gap.

The current framework for Spectrum Policy regulation for Mobile Broadband in Sri Lanka is elementary and outdated in relation to the telecommunications environment today. There is no specific policy frame work for Mobile broadband spectrum management.

Hence, a detailed study and analysis should be done to foster the growth in the telecommunications landscape, promoting investment and innovation in the provision of broadband services, and empowering consumers to experience a quality product

1.5 Objectives

In this study, it is expected to identify any shortfalls in Sri Lankan broadband spectrum policy stance and legislation. There by attention of policy and legislation setting parties can be directed to areas which need to be addressed in future amendments.

- Obtaining an in depth knowledge on spectrum policy setting and regulatory studies.
- Analyzing current Sri Lankan legislation giving focus to mobile broadband spectrum management and studying Sri Lankan government policies
- Examining broadband spectrum management policy frame works from around the world.
- Identified pros and cons on the current policy frame work.
- The final outcome of the full research will be to recommend a suitable policy framework for Sri Lanka in order to achieve the above identified country's long term goals.

1.6 Scope

Research will be cover following;

- Analysis of existing spectrum management which cover broadband plans, policies and initiatives of Sri Lanka
- Analysis and review of successful case studies of broadband spectrum policies of developed countries in the literature survey
- Collect data from broadband services providers
- Collect data from TRCSL
- Identify spectrum initiatives for broadband promotion and development which have been taken by broadband operators and government.
- Carrying out an environmental scanning based on the collected data in order to identify issues which operators face in taking above initiatives
- Provide recommendations to overcome above issues.
- Identify and propose set of spectrum policies to suit Sri Lanka

2. ANALYSIS ON STRUCTURE OF THE POLICY FRAMEWORK

2.1 Policy Formulation

2.1.1 What is policy?

Policy is a course of action, pursued and embraced by an entity or a person. Policy includes vision, goals, principle and plans that guide the activities of different parties. It will provide a framework for choices, which makes the process coherent. Policies exist for countries, governments, businesses, organizations, social groups, families and even for individuals.

A policy would provide an entity or person in terms of their goals with instructions and help to identify the current status of achieving that objective. It will offer a framework for choices. As there's consistency and recognized goal, acquiring a policy would make it a lot easier to define the activities towards the target and above all, keep them intact without changing during the course of time. It is going to always ease advancement, since gap between supreme goal and status is clear.

Policies can be written or written. Written policies in general may appear in rules and regulations. Unwritten policies could be reflected in customs and traditions. They'll be revealed from the choices made by and emphasized in expectancy, principles in addition to understandings.

2.1.2 Framework for public policy making

Public policy should address an entire country, a nation or the society as a whole. Therefore, government will be responsible for public policy making most of times. It helps towards establishing the rules which governs the state and society.

When formulating policy, the initial and most crucial step is to identify megatrend, in terms of space and time, of the specific sector. Policy could be made to align with this once megatrend is recognized. Policy can be made contrary to the tendency, but nevertheless, it can be difficult and need radical changes. In order to identify the megatrend PEST tool can be used as follows in figure 2.1

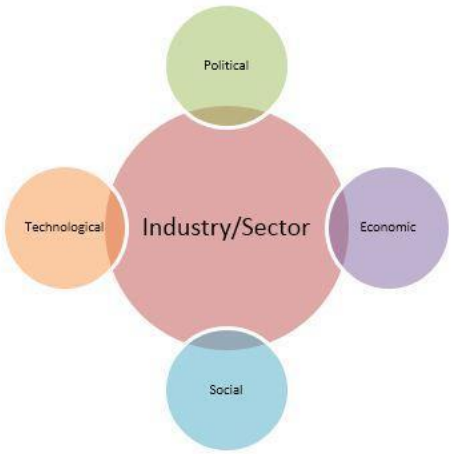


Figure 2.1: PEST Analysis

Source: Author

When formulating public policy, notions from several diverse parties have to be gathered. A think tank has to be shaped including representation from each possible part of the current society. Representation from entire society is vital to address most of the problems fairly and equally and to eliminate bad motives. In any case, effect of policy involving every category of society could be best recognized by members of the society. The tank will iron out extremes and also invent the most acceptable alternative. This procedure can be shown as follows from Figure 2.2.

Figure 2.2: Policy making process

Source: Author

2.1.3 Phases of policy making process

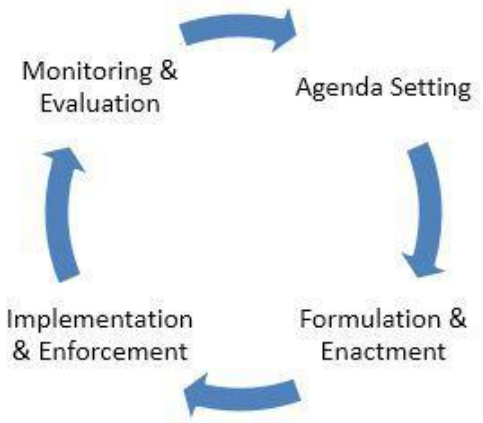


Figure 2.3: Policy making stages

Source: Author

Public policy making is a cyclical process, as illustrated as in above Figure 2.3, for every stage identified alternative solutions and, in measure answers have to be assessed in enactment and formula period. By considering implications of each alternative can the best policy decision can be derived. Finally, these suggestions have to be passed to the branch or agency of government in order to create laws and the regulations.

At the implementation stage, the government body will prepare the activity plan. Based on that action program, enactment of mandatory laws and regulations can be carried out at suitable moment. Once imposed, policy's application and effects are monitored and assessed, which will cause additional alterations and progress.

2.1.4 Broadband Spectrum Policy

Spectrum management policy have been the topic of reform and discussion over the past decade and this agile behavior is likely to continue in the future. Spectrum management practices have been firmly diverging from administrative approach is now changing into a greater reliance on market mechanisms. This new approach is the most widespread in the globe of licensing and spectrum assignment in which the use of auctions and flexible spectrum authorizations. Also service and technology flexible licenses are becoming more common.

Good Spectrum policy can aid the authorities and National Regulatory Authority by leading the development and acceptance, after extensive stakeholder input and consultations, of governing spectrum use, its licensing, spectrum costs, and re-farming. Policies are essential for decisions to be made thereby lowering the danger of market and regulatory collapse. Spectrum policies include declarations on regulatory leadership for the following:

- Spectrum should be allocated to the maximum value users to ensure maximum benefits to society
- Mechanisms should be put in place to allow and encourage spectrum to shift to its highest value use
- Greater access to spectrum will be facilitated when the use the lowest cost and flexible approach is chosen in achieving spectrum management goals and objectives
- Regulators need to promote both certainty and flexibility for investment attraction
- Tradeoff the cost of interference with the benefits of gained from high spectrum utilization.

Harmonized spectrum usage with international and regional allocations and standards will reap additional benefits concerning access and economies of scale

2.2 Mobile Broadband Spectrum Policy: The ITU Framework

International spectrum management is governed by the radio division of the International Telecommunications Union (ITU). Radio division of the International Telecommunications Union (ITU). Each three to four years' cycles, telecom regulators from all corners of the world convene from the ITU's World Radio-communication Conference (WRC) to talk and agree about 'Radio Regulations'.

This critical process Enables governments to create more spectrum available for services that are undergoing consumer need. As an instance, one of the best agenda items at WRC 2015 was to promote more spectrum to meet up together with the rocketing demand for broadband.

The ITU divides the world into three areas, which each has its Own set of frequency allocations as part of their 'Radio Regulations'. This is achieved so as to manage spectrum and promote harmonization across large areas of the world.

The world divides into three areas from the ITU, which each has its Particular set of frequency allocations as part of their 'Radio Regulations'. This market harmonization and make simple to manage the spectrum whilst aligning with the social and economic developments goals in regional level.

- Region 1: Europe, the Middle East, Africa, Russia and Mongolia;
- Region 2: The Americas including Greenland and some of the Eastern Pacific Islands; and
- Region 3: Asia-Pacific including most of Oceania.

We can find a number of regional classes that aim to induce Long-term progress in telecommunications providers. From a spectrum Standpoint, they supply a forum for regulators work with one another to make sure The changes occur and to organize their range policies.

Figure 2.4: Regional spectrum management authorities

Source: GSMA

From the ITU framework there are 3 main broad approaches in spectrum allocation and management as follows,

1. The administrative strategy: The process in which a regulator has total management, like choosing which operators are assigned spectrum and it's used. The assignment process That's most common is that the beauty competition where their support is summarized by firms and the ruler chooses the one with the Best Socio-economic Advantages

2. Market-based strategy: utilizes the marketplace to determine the supply of spectrum. Spectrum is thought to be a private advantage so licenses are generally sold in auction and can, in principle, be exchanged or rented out by their owners later to guarantee market forces continue to ensure that spectrum is distributed and used efficiently.

3. The spectrum commons approach: Unlicensed range or license-exempt, this version enables anyone to use a specific band without prior permission so long as the transmission technologies adhere to specific rules occasionally called ‘politeness protocols' which handle interference.

The reality is that regulators normally adopt strategies that are distinct for different applications. For example, most retain overall direction, permitting them to protect public interest providers (e.g. emergency services), but a great deal of regulators features market forces (especially for mobile services), allow some permit holders to exchange their own selection, and allow short-range radio technology, for example Wi-Fi or Bluetooth, to be wholly unlicensed.

Globally is a significant transition happening between the legacy model of a liberalized version and spectrum management. It's advised that countries considering wireless broadband masterplans should adopt and manage them. This means a use model with mechanics that allocate spectrum with their very best use and spectrum trading rights. This is depicted in Figure 2.5. [5]

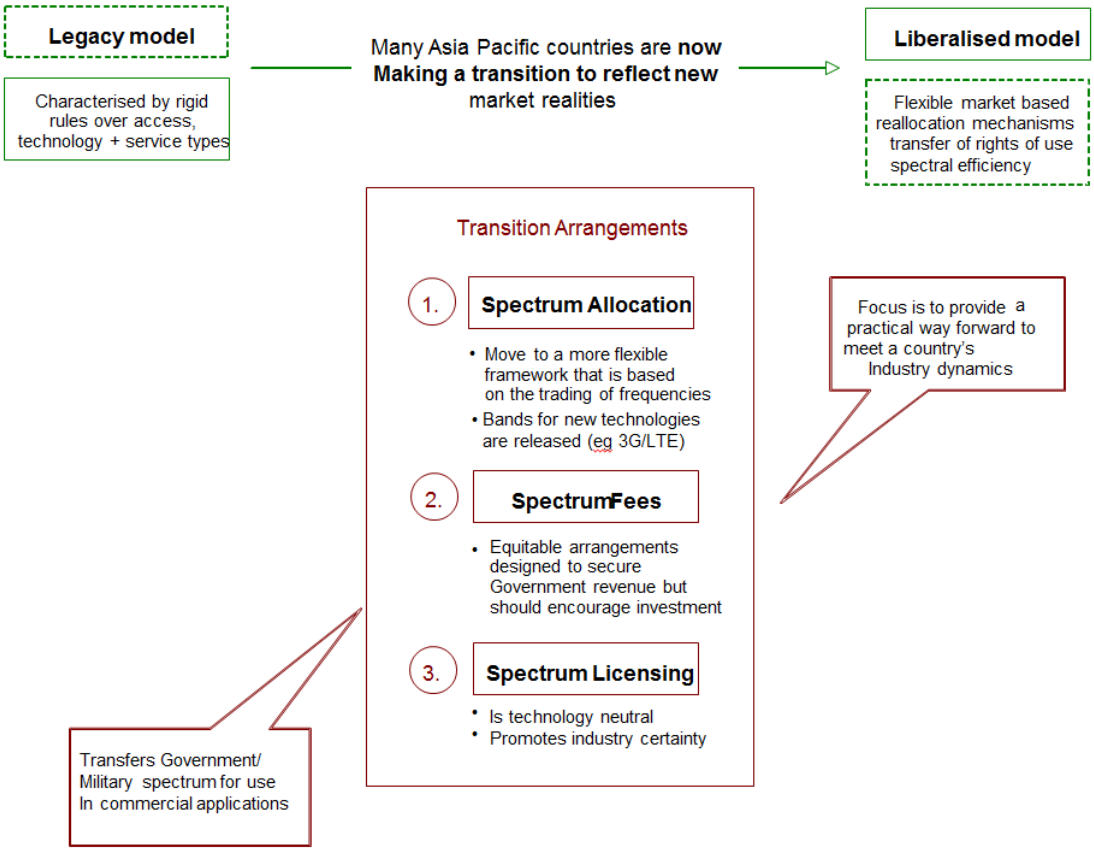


Figure 2.5: ITU Transition to market based liberalized spectrum management models

Source: Windsor Place Consulting, 2010

ITU Global Symposium for Regulators drafted a set of best practice tips for spectrum management to market broadband access. This set of guidelines continues the tradition of best practices agreed to at The GSR conventions in 2003 and 2004 on promotion of universal accessibility, and low Cost broadband solutions respectively. A summary of the 2005 GSR Guidelines are set out as a reference point in Table 2.1. [6]

Table 2.1: ITU Spectrum guidelines

No	Guideline objectives	Key Provisions
1	Facilitate the deployment of innovative broadband services and technologies	• Reduce unnecessary restrictions on spectrum use • Adopt harmonized frequency plans defined by ITU-R recommendations • Reduce or remove regulatory barriers to market entry • Ensure operators have access to as wide a choice as possible for spectrum
2	Promote transparent and nondiscriminatory spectrum management policies	• Consult widely and publicly • Implement stable decision making processes • Publish forecasts of spectrum usage and allocation needs • Publish frequency allocation plans and overview of assigned spectrum • Clearly define and implement stable and predictable spectrum authorization rules and decision-making processes and procedures
3	Embrace technology neutrality	• Facilitate spectrum use for fixed and mobile services • Provide guidelines to mitigate inter-operator interference • Adapt to technological convergence and avoid picking winners
4	Adopt flexible use measures for wireless broadband services	• Avoid onerous rollout and coverage obligations • License conditions that allow operators to provide a full range of converged services • Provide incentives for smaller new operators to deploy infrastructure at low cost • Adopt lighter regulation for rural and isolated areas • Allow secondary spectrum trading • Promote spectrum sharing
5	Ensure affordability	• Set reasonable spectrum fees • Design tender or auction processes to ensure affordability of services
6	Optimize spectrum availability	• Facilitate the effective and timely access to spectrum • Spectrum pricing should not be pushed up due to restrictive supply • Accommodate new and emerging technologies
7	Manage spectrum efficiently	• Ensure reliance on market forces, economic incentives and technical innovation • Allocate spectrum in an economically efficient manner • Promote and encourage usage of spectrum efficient technologies
8	Ensure a level playing field	• Prevent spectrum hoarding: regulators should set a maximum limit to the amount of spectrum one operator may obtain
9	harmonize regional and international standards and practices	• Reflect global technical and security standards in national arrangements • Ensure inter-operability for global roaming • Implement policies and allocations that are consistent with regional and global best practice and standards
10	Adopt a broad approach to promote access	• Introduce supporting regulatory measures such as competitive safeguards, open access and universal service incentives • Lower or remove import duties on broadband wireless access equipment • Coordinate spectrum management policy and practice with other regulatory instruments (i.e. competition and trade policy, universal service measures etc.)

Source: ITU, GSR 2005 Best Practice Guidelines for Spectrum Management to Promote Broadband Access, www.itu.int/bestpractices

2.3 Mobile Broadband Spectrum Policy: Regional Initiatives

There are regional initiatives in relation to spectrum and ICT policies which frame the debate in terms of wireless broadband services depending on a country's membership of a regional organization. Regional groupings include the Association of Southeast Asian Nations (ASEAN) in South East Asia and the South Asian Association for Regional Cooperation (SAARC) in South Asia.

2.3.1 ASEAN 2020 ICT Masterplan

The masterplan is a broad, overarching policy-framework that is intended to guide ASEAN Member State ICT development during the next five years. The policy has guidance for any wireless broadband program embraced by the member countries within the context of this ICT mixture and strive for consistency.

Table 2.2: ASEAN Master plan 2020

Action Point	Description	Target/Project
Harmonize Telecommunication Regulations – Develop Guidelines for ASEAN Spectrum Regulatory Cooperation	Recognizing the potential for cross border spectrum conflict in light of new technologies such as unlicensed and dynamic spectrum allocation, this aims to develop a guideline, based on best practices, for managing such developments regionally	1.Promote spectrum management harmonization in ASEAN (e.g. 700 MHz band, International Mobile Telecommunications (IMT) and related next versions) 2. Study spectrum usage for newly emerging technologies and strengthen cross-border spectrum management and coordination

Source: ASEAN master plan 2020, ICT in the ASEAN single market

2.3.2 SAARC ICT Initiative

The SAARC Action Plan aims at addressing the technical problems and challenges of common concern to its members which arise as a result of market dynamics, technological progress, and innovations within the field of information and communications in order to exploit their whole potential for the benefit of utilizing the expertise and financial resources accessible from within its member nations.

The two working groups of the SATRC worked very efficiently and developed the outcomes as planned in a timely manner. [7]

1. **Working Group Policy, Regulation and Services:** to deal with the issues related to policy, regulation and service development of Telecommunication and ICT sector in the region

2. **Working Group on Spectrum:** to deal with the issues related to spectrum management, monitoring, sharing and coordinated efficient use of spectrum for different service in the region

Table 2.3: SATRC-19 final policy

Sl. No	Activities	Methodology	Work Items	Remarks
1.	**Working Group Spectrum**	Working Group chaired by India. Afghanistan and Islamic Republic of Iran will provide Vice-Chairmen. At least one expert from each SATRC Country. One physical meeting per year. Electronic meetings will be organized monthly/bi-monthly basis. Working Group will define the scope of each work item and expected outputs in defined time frame	1. Assessment of current practices in spectrum management and developing spectrum roadmap 2. Spectrum re-farming 3. Spectrum considerations for the deployment of IoT	One fellowship will be granted for each SATRC Member for attending Working Group Meeting.
2.	**Capacity Building**	Three workshops will be organized. The topics would be related to the activities of the SATRC Working Group and recent trends. Consultation will be conducted in order the select the themes for the workshops.	1. Workshop on policy, regulation and service related issues 2. Workshop on Spectrum 3. Workshop on recent trend and technologies	Two fellowships for each SATRC Member will be granted. One of the Workshops will be funded by the Extra Budgetary Contributions by the Government of Japan.

Source: 19th Meeting of the South Asian Telecommunication Regulators Council (SATRC-19) 13 – 15 December 2018, Islamabad, Pakistan

2.4 Mobile Broadband Spectrum Policy: GSMA Framework

The GSMA has a similar land scape for Mobile broadband spectrum management policy as discussed in the ITU and regional regulators. It has three main pillars. [8]

1. Spectrum Planning
2. Spectrum Management
3. Spectrum Licensing

SPECTRUM PLANNING	SPECTRUM MANAGEMENT	SPECTRUM LICENSING
Band plan harmonization	Spectrum efficiency	Auctions and cost of access
Minimize Cross-border interference	Spectrum Sharing	License obligations
Spectrum road map	Spectrum Trading	Technology Neutrality

Figure 2.6: GSMA Spectrum Management Policy lands scape

Source: Spectrum Management Trends & Challenges - Joe Guan, Spectrum Policy & Regulatory Affairs Advisor, Asia Pacific, GSMA

2.4.1 Spectrum Planning

Spectrum Planning has 3 dimensions.

1. Band Plan Harmonization
2. Cross border Interference
3. Spectrum Roadmap

2.4.1.1 Band Plan Harmonization

Spectrum harmonization refers to the uniform allocation of radio frequency bands, under common technical and regulatory regimes, across entire regions. Adherence to internationally identified spectrum bands offers many advantages:

- Lower costs for consumers - Device manufacturers can mass-produce devices and network equipment’s that function in multiple countries on a single band.
- Availability of a wider portfolio of devices, driven by a larger, international market.
- Roaming ability
- Fewer issues in cross-border interference.

A recent case of these issues, triggered by the strategy of several device makers, is that the inability of consumers in several Asian and European states to utilize LTE services on the iPhone. Because, for some devices, the iPhone's LTE connectivity doesn't compatible for the 800 MHz and 2.6 GHz bands which used for LTE in several European nations. Additionally, Apple has manufactured three different iPhone models, which makes carrier switching and worldwide roaming harder. Other main device manufacturers made a different decision and affirmed the 2.6 GHz and European 800 MHz harmonized bands for LTE and takes the advantage of scale

Even though brand new wireless technologies, like LTE, permit a more flexible utilization of their various spectrum bands, in contrast to 2G or 3G technologies, which prevent spectrum fragmentation, the importance of spectrum harmonization is significant. As stated by the GSMA's Wireless Intelligence, by 2015 there'll be 200 LTE networks, deployed over 38 various spectrum frequency mixes. Device interoperability issues will be raised by this and might lead to spectrum fragmentation. It might decrease the benefits of economies of scale and increase equipment costs, which might lead to end-users in some specific regions being excluded in the most recent developments in wireless technologies.

Governments who align utilization of the spectrum together with group plans prevent interference and will attain the best benefits for customers. At the very least, harmonization of spectrum bands in the regional level is essential. Tiny variations on band up plans may lead to device manufacturers needing to develop high cost devices, with impact the consumers.

All markets should harmonize regionally wherever possible, since this benefits the whole telecom ecosystem. There is no benefit in going it alone. Cognitive radio

technology won't reduce the need for harmonized spectrum. Adhering to internationally recognized band plans is the only method to economies of scale.

2.4.1.2 Cross Border Interference

Because radio communication services have the capacity to create transmissions that extend beyond national boundaries, global coordination is needed to protect service support and avoid interference. This protection is accomplished through bilateral and multilateral treaties and agreements. When the new radio communication solutions are manufactured, negotiations with countries that are affected are necessary to develop the agreements. After the agreement is finished radio communication service will be subject to the procedures in the agreement to be able to shield their service regions and avoid interference.

Furthermore, when the band harmonization is achieved it'll minimize the cross border interference effect. Considering the rapid pace of the higher requirement for wireless technologies at the border region economies, there should be close relationship between nations to minimize the interference level. Throughout the many cross-border regional groups should have close negotiations with spectrum deployment approaches with its neighbors to market effective spectrum management.

2.4.1.3 Spectrum Road Map

A spectrum roadmap is pivotal to ensure there is sufficient spectrum to meet the surging demand for mobile broadband. It enables the government to forecast future trends and handle its work and risks. It also boosts the confidence in the investors on industry with certainty regarding the government allocation plans and management of wireless spectrum and maximize the revenues for government.

Key themes for a spectrum roadmap is as follows,

- Identifies the challenges and opportunities to radio spectrum management framework and approach, at least 3 – 5 years into the future
- recognize future technological trends and drivers, and assess their impact on spectrum policy and planning

- A roadmap is an evolving document, to be reviewed and updated regularly (annual review is recommended)

Furthermore, there are some key challenges that should be addressed when developing a spectrum road map

- What spectrum will be available and when - To plan the spectrum for operators which need to invest near-to-long term to meet exponential growing broadband demand (this should include about coverage & capacity bands, existing and future bands)
- Regulatory positions - e.g. allocation methodologies, renewal procedure, projects and program
- Licensing process - e.g. re-farming, resource pricing, spectrum sharing and trading
- Harmonized future spectrum - To reduce device and equipment costs, limit interference and enable roaming

2.4.2 Spectrum Management

This area is divided in to 3 main parts as follows,

1. Spectrum Efficiency
2. Spectrum Sharing
3. Spectrum Trading

2.4.2.1 Spectrum Efficiency

Spectral efficiency denotes the data rate that can be transmitted over a bandwidth in a communication system. It is a measure of how effectively a limited frequency spectrum can be utilized from the physical layer protocol, and at times from the media access control (the channel access protocol).

Measuring how well the spectrum is used is vital to measure the term efficiency. Efficiency has two dimensions as occupancy and data rates but we fail to account for certain critical aspects mostly associated with the spectrum value created (e.g. public

safety and emergency). Nevertheless, measuring periodically how spectrum is being used (e.g. number of consumers, intensity of usage, data rates, data transported, investment) provides a reasonable picture of how efficiently the spectrum is utilized, especially when compared among players using similar groups credited to identical or similar services. There are no standard methods to measure spectrum efficiency thoroughly but several indicators have to be quantified and normalized, taking into account the specific characteristics of each market.

Additionally, the nature of the spectrum blocks plays a major role in spectrum efficiency. The fragmented spectrum blocks are not spectrum efficient in comparison with the continuous spectrum blocks.

Furthermore, when we are evolving to higher broadband technologies, Spectrum efficiency increases significantly. Hence it is recommended to always allow new technologies to use the spectrum so that the spectrum efficiency is maximized.

2.4.2.2 Spectrum Sharing

Spectrum sharing is just another policy which could increase spectrum efficiency usage. In principle, spectrum sharing means multiple wireless systems which can operate simultaneously in the same frequency band, without causing interference to other users, through with one of the sharing dimensions (time, distance or geography) Spectrum sharing can be administrative, technical or market-based.

According to a European study (Werbach and Mehta, 2014), the average occupancy rate for a dedicated spectrum band was below 10% of the allocated capacity. Hence there's significant space to increase the utilization. As concerns over spectrum scarcity, spectrum sharing might well become the standard, as it increases supply and provides increased access to a scarce spectrum resource. Sharing enables, a process of continuous spectrum reallocation, such as even reallocation to different services, like broadcasting and data. Obviously, if well implemented, sharing reduces waste and boosts spectrum efficiency.

One of the principal criticisms of spectrum sharing is that the limitations of managing interference between different users. This is the main reason why spectrum has traditionally been licensed for private usage. It's frequently noted that, absent usage

principles, sharing can lead to the "tragedy of the commons", whereby increasing the number of users results in a lower QOS for everyone. However, technological improvements (e.g. cognitive radios, which are designed to be able to use several spectrum channels), regulation (e.g. principles of "etiquette" and co-operative approaches that govern ordinary use), and economic incentives (penalties and pricing) are helping to alleviate most of the existing concerns. A long road lies ahead, but sharing promises to address the requirement for greater spectrum for broadband services.

There are a variety of forms of spectrum sharing including:

1. Licensed Common Accessibility: A suggested sharing strategy which allows the permit holder to voluntarily offer access to spectrum which has been underused in some specific places or at particular times. The principal advantage is that availability could be guaranteed hence supplying guaranteed QOS. As operators normally don't have unused spectrum in crowded areas where data traffic is growing fastest, the source of this shared spectrum could normally be from another provider (e.g. the army). But to be prosperous, the range has to be available at the ideal time and location, for the correct price, and for a period that warrants community investment.

2. Licensed-exempt Range: Frequency rings which may be used by numerous users provided that in the tech meets categorized ‘politeness protocols' to lessen disturbance. On the other hand, the resulting providers are best effort since there's not any limit on the amount of Wi-Fi networks users in any 1 area, which could lead to unpredictable congestion and, thus, poor-quality providers. This implies cellular operators normally simply use license-exempt spectrum to match their private licensed spectrum.

3. TV white distance: Such solutions face challenges as a consequence of potential interference, security areas which are small, no quality of support, limited spectrum availability and device service. Furthermore, air travel service operators must use their spectrum efficiently to remove white space, and free up spectrum That Could be utilized for federal broad cellular LTE broadband options, with exceptional rural and in construction coverage

4. Shared licensed Range: A method in which a couple of cellular Operators may discuss their wireless spectrum. This sharing could be consented to unite Their own

coverage and capability, or as a condition of the licensing process. However, this approach may negatively impact market competition and provided service Solutions which won't be distinguished and may dissuade network investment.

2.4.2.3 Spectrum Trading

Spectrum trading facilitate license holders to move their spectrum use rights. In consequence, this implies that license holders using an excess of spectrum may benefit from shifting to people who don't possess enough spectrum. Trades don't require substantial involvement so long as the license's agreement aren't violated and does not reduce the market competitiveness. Trading generates a method of spectrum vision which adjusts to changes in demand and, most importantly, can make sure that spectrum doesn't fall short.

Many nations have adopted policies for leasing and spectrum trading for a means giving a fiscal incentive to talk about their spectrum and increase spectrum utilization. EU, USA have enabled spectrum trading. But only Australia and New Zealand has enabled this from the south Asian region. While these policies don't replace the necessity to spectrum shortage in the growing broadband demand. It can be helpful way forward in some specific situations where incumbent consumers are hesitant to talk about their spectrum (e.g. from the United Kingdom that the Ministry of Defense has suggested both leasing and selling its a few of its spectrum)

All these policies suggest transferring the rights of usage (as well as the license obligations), either temporarily or permanently (until the expiration of the spectrum license) and are filled with regulatory and economic hurdles. Administrative processes are lengthy and complex, regulatory approval is generally required, and incentives for current holders are low as a result of spectrum shortage (either because spectrum may be worth more in the future or as they might need it for future growth).

2.4.3 Spectrum Licensing

Spectrum licensing has 3 main broad areas as follows,

1. Auctions and cost of Access
2. License obligations
3. Technology neutrality

2.4.3.1 Auctions and Cost of Access

This Is the most widely method of assigning spectrum licenses for mobile operators. Well-designed auctions are a means for authorities to assign spectrum to the business which values it most highly, and generates financial incentives for them to use it efficiently.

However, there are other mission approaches which may be appropriate in market circumstances. By means of example, embarking in an auction procedure may be unnecessary if the bidders are wholly understood and there is sufficient spectrum to satisfy their demands. In such circumstances, administrative approaches, like a beauty competition, may be more effective.

Auctions Are more appropriate approach when there is sufficient competition when demand exceeds supply. In the mobile sector, regulators can Find an insight from the following in an auction scenario,

- The quantity and spectrum bands to be auctioned (e.g. is there sufficient spectrum for mobile broadband solutions and is it internationally harmonized?)
- The expected demand for the spectrum out of consumers
- The level of competition expected for the available spectrum
- License spectrum worth.

Regulators Place a'reserve price' to be able to guarantee a minimum sum is paid at the spectrum auction. This reserve price should underline the socio-economic worth of this spectrum, promote it to be utilized efficiently and offer decent ROI into the state.

Putting A suitable reserve price is complex, but is crucial. When set too low, it may boost lively bidding, an inadequate fiscal return to the country and responsibilities in which the winner has little incentive to utilize it efficiently. When set too big, the purchase price will discourage participation leading to restricted spectrum uptake as well as unsold spectrum, thus squandering a precious, in-demand resource. In the last few decades, many auctions have contributed to spectrum being unsold because of this

such as sub-1 GHz spectrum that operators appreciate most tremendously because those very low frequency bands give exceptional coverage.

When Operators are made to cover high reservation prices, this restricts the amount they are able to Purchase the networks which could result in lower quality and more expensive Options for consumers

The process in depicted in following figure 2.7

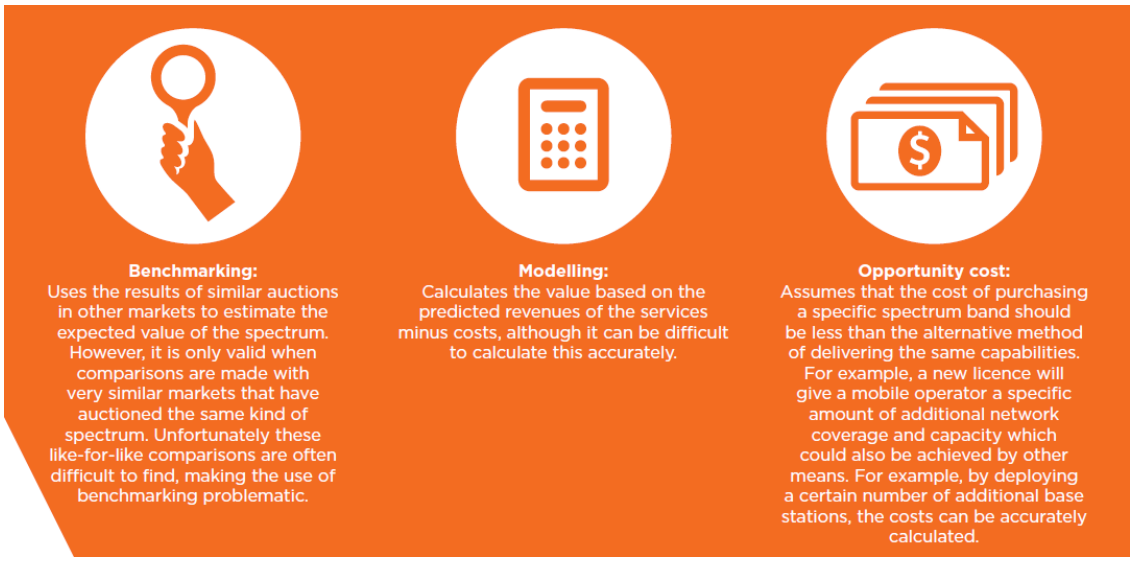


Figure 2.7: Spectrum valuation process

Source: GSMA

2.4.3.2 License Obligation

Regulators usually specify obligations with the spectrum license with most frequent following points

- Services Vs frequency band (e.g. only mobile services)
- Technologies vs frequency band (e.g. GSM, UMTS, LTE or technology neutral)
- QOS targets
- Coverage obligations (e.g. 90% population coverage). This will be mandatory in coverage spectrum bands (i.e. sub-1 GHz)
- The time period of the license (e.g. 20 years).

All these Conditions and terms will make sure services are guarded and meet specific quality standards. As an example, if license holders might unexpectedly change the sort of service functioning in the group (e.g. with a cell service to broadcasting) then improper levels of national and worldwide hindrance could be generated along with the crucial spectrum harmonization process will be interrupted.

A Spectrum permit is generally valid for a particular duration. When this has deciphered the regulator decides if to maintain the current requirements or change them and may then award it into the existing license holder or to another party. The period of the renewal and permit requirements might have a massive influence on the caliber, in addition to the coverage of mobile networks.

By Awarding permits for more time period no less than 15 to 20 decades, authorities can market top quality alternatives, and bring substantial network investment. This gives time to understand that a monetary yield to operators. In case the permit period is brief, operators are discouraged to spend more because their accessibility of spectrum in the future is not guaranteed.

When The whole period of the permit has elapsed, police can make unique changes involving if the license remains available for mobile use or any different wireless provider, how big frequency group it applies to, the terms surrounding its usage, the length the permit, as well as the annual fee etc.

As A number of the 2G spectrum licenses which are first are due for renewal, that can be This may ultimately interrupt Makes and services network investment insecure. To Have the Ability to Prevent this outcome, Authorities are advised to employ a more transparent and predictable strategy. Where necessary that the process should start a Couple of Years prior to the permit

2.4.3.3 Technology Neutral

Spectrum licensing can be too prescriptive and limit the chance for license holders to innovate and, as a result, limit the chance for end consumer. For example, many of the original mobile licenses were issued for a particular technology, for example 2G technology such as CDMA or GSM, which operators aren't permitted to alter.

This usually means that 2G cannot be upgraded to faster 3G or 4G technologies that add vital added information capacity to mobile networks, giving users faster mobile broadband solutions. This process of changing the technology, known as re-farming, is critical because 2G bands typically utilize low frequencies that would provide broadband coverage widely in rural and in-building situations

This didn't matter when technology and markets changed gradually. But services have undergone rapid technology innovation and market change regulation has often not kept up the correct speed with these changes and this has imposed costs on consumers and industry. Eg: Obligation in 3G technology could block an early opportunity to deploy technically more efficient LTE technology.

In response authorities are currently converting spectrum license as 'technology neutral' which enable the license holder to transmit any technology that is non-interfering. In practice, this means regulators specify that licenses must be used for particular services (Broadcasting, cellular, satellite) but don't restrict the underlying technologies that need to be used for the service.

As a consequence, there is now a trend around the world towards issuing flexible, technology neutral licenses that allow operators to choose when new technologies and service innovations should be introduced. For example, all spectrum licenses for mobile services in Australia and the US are technology neutral. In Europe regulators are expected to liberalize the use of technology specific 2G licenses and new licenses are expected to be technology flexible whilst meeting the least restrictive technical conditions specified in European harmonization measures.

Therefore, there's currently a trend towards issuing flexible, technology neutral licenses that enable operators to select the new technology and service according to the market demand. When we compare the globe, all spectrum licenses for cellular services in Australia and the US are technology neutral. In the Europe regulators are in the process of making all licenses technology neutral which fosters the innovation. This is depicted in figure 2.8

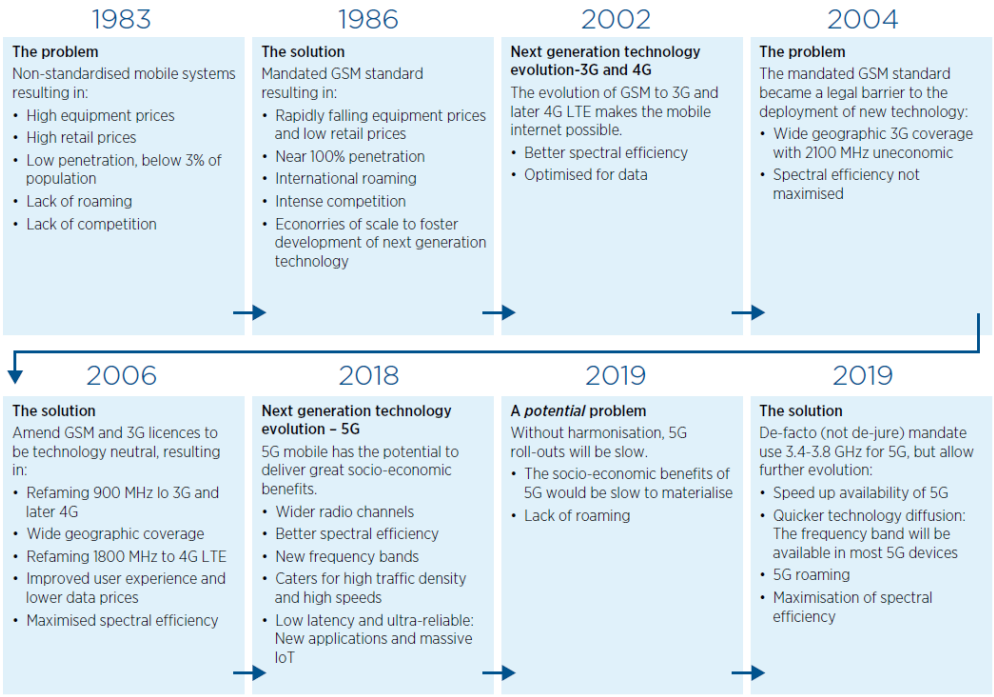


Figure 2.8: Regulating mobile technology use in European union

Source: Coleago consulting

2.5 Review of Mobile Broadband Spectrum Standards in Sri Lanka

Telecommunications services in Sri Lanka are governed by the Sri Lanka Telecommunications Act No. 25 of 1991 as amended by the Sri Lanka Telecommunications Amendment Act No. 27 of 1996 by the TRCSL. [9]

Currently TRCSL does not have a broadband spectrum policy frame work and through the literature survey following key points are found in the spectrum management domain.

- Spectrum is managed as to make it as widely available as possible and to optimize the efficient use of radio spectrum that include radio systems which consume low power, minimize interference to other systems and do not require additional protection from other users
- Spectrum license conditions are developed so as to enable the economic potential of the radio spectrum to be maximized as highest extent possible where technology neutral licensing are adopted as much as practicable and reduce regulatory barriers to radio frequency access
- Create a conducive environment to promote competition among the industry players in order to ensure innovative and efficient use of the radio spectrum and promote economic and social benefits for all spectrum users
- Appropriate spectrum engineering tools and techniques are utilized to ensure the efficient and effective assignment of radio spectrum
- An appropriate re-farming is adopted in circumstances where there is a justified requirement to re-farm the use of particular frequency band to another service deployment
- Spectrum charges are determined to recover the direct & indirect costs incurred in managing the radio spectrum and in a manner which will enable efficient use of this scarce national resource and optimum pricing of spectrum is adopted to discourage wastage or speculative acquisition of spectrum
- Adequate spectrum provision is provided to support emergency telecommunications services in the case of a national emergency or in the case of natural disasters
- Reserve appropriate spectrum for future innovative technologies and emergency services

3. LITERATURE SURVEY ON EXISTING MOBILE BROADBAND SPECTRUM POLICIES

More efficient use of spectrum can sometimes be reached by relaxing regulatory limitations on the way. Limitations on the investing of spectrum, the sharing of spectrum or the service or technology deployed could block activities by operators to improve the spectrum efficiency. Even though there can be prices to creating modifications, spectrum management regularities in North America, Europe and Asia Pacific nations have all proceeded to adopt more liberal approaches as follows,

- Re-farm spectrum to new technologies without any cost
- Spectrum sharing between operators
- Sharing spectrum held by other services
- Spectrum trading and leasing
- Technology neutrality

Spectrum re-farming of 2G spectrum is a key trend that has been largely operator-driven in several markets. Spectrum in the 850MHz, 900MHz and 1800MHz bands is proving to be quite useful for 3G and 4G setup, to complement 3G coverage provided using low bands (e.g. 900/850MHz) and to supply extra 4G capacity (e.g. with the 1800/2100 MHz band). There's considerable market interest in re-farming 1800MHz spectrum to be used by LTE platforms, also 1800MHz remains the most popular band for 4G/LTE deployment globally, ahead of other bands like 700/800MHz and 2.6GHz.

Even though there are many reasons for mobile operators to migrate customers from 2G networks, it should be noted it is difficult for operators to turn 2G networks off entirely. 2G networks continue to be important in several nations and the speed of migration away from 2G is determined by local market conditions. 2G networks are crucial for some types of use Eg: M2M, for example. In the Asia-Pacific region, the rate of migration away from 2G has been very fast in some countries Eg: Japan, Singapore and South Korea but in different countries 2G networks account for nearly all mobile connections, and are often seen as being crucial to appeal for certain services like voice, and to accommodate international roaming. In this thesis I have analyzed

three countries (India, China and Indonesia) on their broadband spectrum policy initiatives which complemented the mobile broadband growth.

3.1 India

India, has a large population of over 1.2 billion, with the lowest GDP per at USD 1,500. As shown in Figure 3.1. India has a low ICT rank on the region which is due to the factors international broadband bandwidth of 5Mbit/s per internet user, with 12.6% of the population using the internet. [1]

Demographics	
Area (km^2)	3 287 590
Population (million)	1256
Population density (people per km^2)	421.1
Economy	
GDP (USD billion)	1877
GDP/per capita (USD)	1499
Human Development Index	0.596 (135th out of 187)
Labour force (million)	493
Relative size of employment sectors (agriculture/industry/services)[30]	51.1/22.4/26.6
ICT Indicators	
ICT Development Index (2012)	2.12 (121st of 157)
Broadband connections penetration 2013	9%
Broadband connections penetration 2020	44%
Δ broadband connections penetration (2013–2020) (percentage point)	35%

Figure 3.1: India country profile

Source: Analysis Mason, World Bank, EIU 2014

The Indian mobile market is enormous, which contains 13 network operators competing for market share, many of whom only hold spectrum in one frequency band

as shown in Figure 3.2. Current LTE roll-outs are limited to those of Aircel and Bharti Airtel in the 2.3GHz band due to a lack of suitable spectrum availability.

Operator	Technologies	Spectrum holdings
Aircel	2G, 3G, 4G	900MHz, 1800MHz, 2100MHz, 2.3GHz
BSNL	2G, 3G	800MHz, 900MHz, 2100MHz
Bharti Airtel	2G, 3G, 4G	900MHz, 1800MHz, 2100MHz, 2.3GHz
Idea	2G, 3G	900MHz, 1800MHz, 2100MHz
Loop	2G	900MHz
MTNL	2G, 3G	900MHz, 1800MHz, 2100MHz
Quadrant	2G	800MHz, 1800MHz
RCOM	2G, 3G	900MHz, 1800MHz, 2100MHz
RJIL	4G	1800MHz, 2.3GHz
SSTL	2G, 3G	800MHz
Tata	2G, 3G	800MHz, 1800MHz, 2100MHz
Uninor	2G	1800MHz
Videocon	2G	1800MHz
Vodafone	2G, 3G	900MHz, 1800MHz, 2100MHz

Figure 3.2: Mobile operators and technologies

Source: Analysis Mason

Although mobile broadband growth is increasing quickly (in a CAGR of 23%), broadband penetration remains low in 2%, expected to rise to 5% in 2018. Nevertheless, mobile broadband connections overtook fixed broadband in 2012 and the slower growth rate of fixed broadband (CAGR of 11%) signifies that the gap is increasing. [1]

3.1.1 Spectrum policy and predictions

National Telecom Policy published by DoT in 2012 suggested a number of activities regarding spectrum release to mobile in order to encourage rural broadband. The policy said the need to create a full of 300MHz available for IMT services by 2020 by a further 200MHz plus 2017. Specifically, it includes proposals to make available sufficient globally harmonized IMT range in the 450MHz, 700MHz, 1800MHz, 1910MHz, 2.1GHz, 2.3GHz, 2.5GHz and 3.5GHz bands, as well as some other bands to be identified by ITU for commercial mobile services. [1]

The National Telecom Policy 2012 envisions a central role for mobile communications and rural broadband enhancement and included following key points in the vision as,

- Periodic audit will be carried out for spectrum use and every five years a spectrum roadmap will be prepared
- More spectrum will be made available for broadband. 300 MHz of spectrum will be made available for IMT services by 2017 and a further 200 MHz by 2020
- Spectrum use will be liberalized in terms of the technology and service
- Spectrum pooling, sharing and later trading will be permitted through the development of an appropriate regulatory framework
- Use of white spaces by low power devices will be considered and bands that may be used by low power devices on a license exempt basis will be identified.

The Indian government has moved to approve spectrum sharing and trading among mobile operators. Operators who have under-utilized capacity will be allowed to share/trade it with other companies. As an example, if an operator is not using some of its spectrum, it can be leased for period of five years for a fee. This will help firms deal with fragmented spectrum holdings and therefore lead to faster speeds and high QOS. This decision will help improve spectrum management.

3.1.2 Challenges in the Spectrum policy

India requires more spectrum to take advantage of new possibilities for social and economic improvement. With demands for mobile technology expected to rise in future decades, it is imperative that more spectrum should be released for expansion of broadband.

With so many opportunities available in mass marker like India, there are some key challenges in spectrum management approaches.

1. **Lack of available spectrum**

Spectrum availability is a big problem because there are insufficient bands for the growing mobile demands in India. As shown in tables 3.1 and 3.2, The access to licensed spectrum in India is much lower compared to the U.S. and Europe, and also

significantly lower than other developing nations such as Brazil and China. It is particularly acute in India while spectrum availability is a problem that is bigger.

Table 3.1: Summary of total licensed spectrum in various countries

Country	Current	Pipeline	Hz/ Subscriber
USA	608	55	2.1
Australia	478	230	22.8
Brazil	554	0	2.0
China	227	360	0.5
France	555	50	9.3
Germany	615	0	6.2
Italy	540	20	5.9
Japan	500	10	3.3
Spain	540	60	11.8
U.K	353	265	7.9
India	221	10 (estimate)	0.2

Source: International data – FCC (2013), Indian data – COAI (2015)

Table 3.2: Spectrum availability in commonly deployed bands

Band	Europe	USA	India
900 MHz	70	64	12.4
1800 MHz	150	130	97.6
2/2.3 GHz	120	90	60
2.6 GHz	190	194	20
800 MHz	60	70	27.5
Total	**590**	**548**	**217.5**

Source: FCC and DoT India

One measure of spectrum capacity in a country is the amount of spectrum per subscriber. As Table 3.1 highlights, India has very low capacity at 0.2 Hz per subscriber compared to the other giants

2. High Access Cost

Critics have reported that "spectrum price" in India is among the greatest on the region. The spectrum pricing runs about "25 times more expensive compared to countries like U.S., France, Singapore, Germany, Spain and Sweden." Operators complain that spectrum is scarce, fragmented, overpriced, and rigid. By having permits which operate only for 20 years, government policies induce operators into costly infrastructure investments without adequate time to reap the ROI. While low tariffs and higher usage reflect high customer surplus, the price structure from the Indian telecom industry predicts that these gains will probably be short term. With greater

congestion and restricted spectrum capacity, there's very likely to be a severe decrease in quality of broadband services.

3. Fragmented and Inflexible Usage

Spectrum's quality is a problem because some spectrum bands are reserved for specific applications. Mobile operators' complaint that spectrum is underutilized and because it is occupied by the Defense Ministry. When government agencies offered on unused spectrum, it creates an artificial shortage for businesses that want to innovate and squeezes the spectrum that is available for consumer and commercial applications. This keeps prices high for the remaining spectrum. There are some reassuring statements from the Telecom Ministry at January 2015 on swapping spectrum away from Defense for commercial use.

Furthermore, the present spectrum has been allocated at a manner that was inflexible and fragmented. Some allocations were done by auctions with the "liberalized" model, while others have been assigned administratively (the "un-liberalized" model) with very little flexibility in terms of the technology or service.

The government doesn't require the adoption of any technology that is particular and is technology agnostic. But in a few cases, the government decides uses for bands and it's hard for firms to adapt to new demands or new solutions. They must operate within the confines of present policies, and this has limited their options. Consumers end up with merchandise and options which lag the market.

4. Auction Outcomes

Spectrum auctions have led to price and accessibility problems. In 2008, the 2G spectrum awards generated significant political dispute and legal actions. After analyzing the government's decisions, the India Supreme Court condemned them as "arbitrary ", "unconstitutional," and "illegal" Critics say because the 2G licenses were offered at below market prices that billions in potential earnings were lost to Indian government.

India's previous experience with spectrum market has frequently revealed that the authorities was shortsighted on short term revenue maximization. It was at the cost of long term healthy development of the business and possibly long run earnings

maximization for the authorities through greater tax earnings by a flourishing telecom industry. High reserve spectrum price for mobile operators and jointly with elevated levels of competition from the industry will inevitably impact consumer surplus negatively in the long term. It would lead to low innovation within the industry and poor quality of service.

3.2 China

China has the highest population and biggest labor force; with an area of 9.7 million square kilometers. It has a relatively low population density (as shown in Figure 3.3) and with a GDP per capita below USD10, 000. [1]

There are three wireless operators in China – China Mobile, China Unicom and China Telecom – and each operator provides 2G, 3G and 4G services to their customers using a range of technologies as shown in Figure 3.4. Though it is a one of largest country in the world it has a high internet penetration around 50% and it is expected to grow to 90% in 2020 which suggests China should have a strong broadband policy. [1]

Demographics	
Area (km^2)	9.7 million
Population (million)	1360
Population density (people per km^2)	140
Economy	
GDP (USD billion)	9200
GDP/per capita (USD)	6800
Human Development Index	0.719 (91st out of 187)
Labour force (million)	800
Relative size of employment sectors (agriculture/industry/services)[26]	36.7/28.7/36.4
ICT Indicators	
ICT Development Index (2012)	4.18 (78th of 157)
Broadband connections penetration 2013	50%
Broadband connections penetration 2020	93%
Δ broadband connections penetration (2013– (percentage point)	43%

Figure 3.3: China country profile

Source: Analysis Mason, World Bank, EIU, ITU 2014

Operator	Technology	Launch date	Spectrum used
China Mobile	GSM→GPRS→ EDGE	1997	900/1800MHz
	TD-SCDMA	2009	2000MHz
			1900MHz
	TD-LTE	2013	2300MHz
			2600MHz
China Telecom	CDMA→ CDMA2000	2002	800MHz
	1xEV-DO Rev A	2009	1900MHz
	1xEV-DO Rev B	2009	850/2100MHz
	TD-LTE	2014	2600MHz
China Unicom	GSM→GPRS	1995	900MHz
	W-CDMA→ HSPA+→ DC-HSPA	2009	2100MHz
	TD-LTE	2014	2600MHz

Figure 3.4: Mobile operators and technologies

Source: Analysis Mason

3.2.1 Spectrum policy and predictions

In China 3G spectrum concessions had been allocated in January 2009, letting the launching of broadband services after that year. 4G services were established in 2014 with TDD-LTE technologies which is utilizing time-division duplex (TDD) in unpaired spectrum as opposed to frequency-division duplex (FDD) as primarily everywhere. Both cellular broadband devices and smartphone penetration have increased significantly in their 2009 degree of 35.5 million to 483.1 million in 2013, and anticipated to continue to rise to 854.7 million in 2018, at which stage there'll be 3.5 times as many mobile broadband connections as static broadband connections. [1]

China's spectrum policy is targeted at constructing a further one billion mobile towers to boost broadband capacity for dense urban and towns, as well as rural villages. Operators who come up with good plans for this rural segment don't have to spend money on the spectrum. For example, for 3G spectrum, further reductions to annual spectrum fees have been granted, provided coverage rollout targets are met by licensees.

Furthermore, China Mobile and China Unicom are listed on the Hong Kong Stock Exchange, and both have a significant foreign strategic partnership. But the Chinese government did not try to exploit them and get financial benefits. Instead, over the past

two decades their spectrum policy has been consistent, in accordance with the government's strategic decision to prioritize investment in long-term federal infrastructure and the associated long-term economic benefits over short-term revenue production from the authorities via spectrum fees.

Because of the government strategic vision, the Chinese mobile operators have achieved 99.5% population coverage in a land area of 9.5 million square kilometers and coverage of villages with a population of 20 or more. One-third of mobile revenue is coming from data revenue.

Regardless of the significant usage of Wi-Fi in China, there is a requirement for additional spectrum. ITU forecast a total of 570-690MHz is going to be demanded for IMT services by 2015 and 1490–1810MHz by 2020. This highlights there is an increase of 93–213MHz and 1013–1333MHz from the 477MHz currently available in 2015 and 2020 respectively. The government is also considering spectrum from within both the L-band and C-band for TD-LTE allocation to meet future demand for mobile broadband.

3.3 Indonesia

For Indonesia the industry must secure access to spectrum bands that are essential. Internet access remains an integral barrier for taxpayers' full participation in the digital society of the country. While 3G (at 900 MHz) has been effective in expanding basic mobile broadband to the unconnected, the technology will not be able to cope with the substantial traffic growth anticipated within the next 10 years. Mobile network operators are using 1800 MHz spectrum for 4G rollout, but allocating the 700 MHz band quickly and in sufficient volume would encourage their efforts to expand coverage, despite the challenges, and help lessen the prevailing digital divide. Mobile broadband penetration is comparatively high in the Asian region. It contains 52% penetration in the area and has over 100% penetration into the market and there are 6 mobile operators in Indonesia as depicted in figure. [10]

OPERATOR	SUBCRIBER	RADIO ACCESS NETWORK	TECHNOLOGY
TELKOMSEL	118.140.245	850/900/1800/2100 (52,5 MHz)	2G/3G/4G
indosat ooredoo	50.846.707	850/900/1800/2100 MHz (40 MHz)	2G/3G/4G
XL axiata	45.000.000	900/1800/2100 MHz (45 MHz)	2G/3G/4G
3	25.102.343	1800/2100 MHz (20 MHz)	2G/3G/4G
smartfren	2.438.843	850/2300 MHz (30 MHz)	2G/3G/4G
Ceria	52.402	450 MHz (7,5 MHz)	2G/4G

Figure 3.5: Indonesia Mobile operators and Spectrum use, 2016

Source: Ministry of Communication and Information Technology, Indonesia

Indonesian mobile market shows a healthy trend in terms of revenue and new technology adoption.

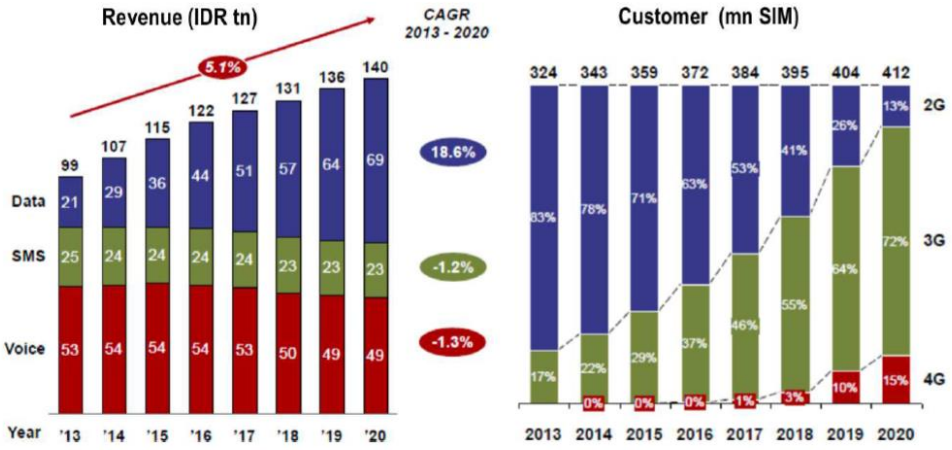


Figure 3.6: Indonesia Revenue and Technology Trend

Source: Ministry of Communication and Information Technology, Indonesia

We can see the voice and SMS are now in the saturation status and the data is growing in the exponential manner. Also the customers are quickly adopting to the higher technology which shows positive trend. [10]

One factor for this healthy trend is the spectrum pricing. Indonesia has a very low spectrum pricing compared to the Asian countries. This attracts the investment for

telecom industry and the benefit of low cost of the spectrum is passed to the end customers.

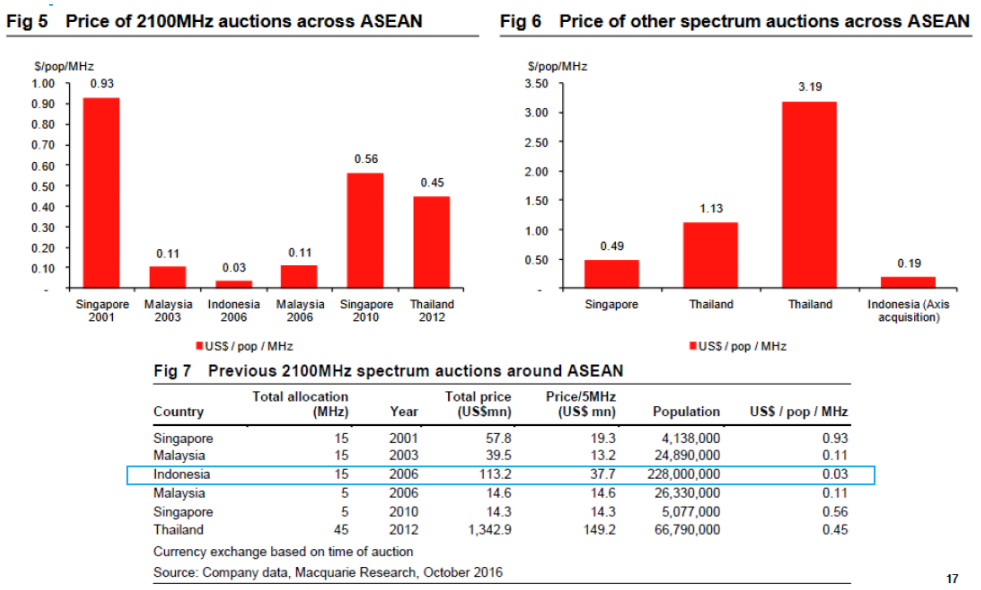


Figure 3.7: Spectrum prices for ASEAN countries

Source: Macquarie research, 2016

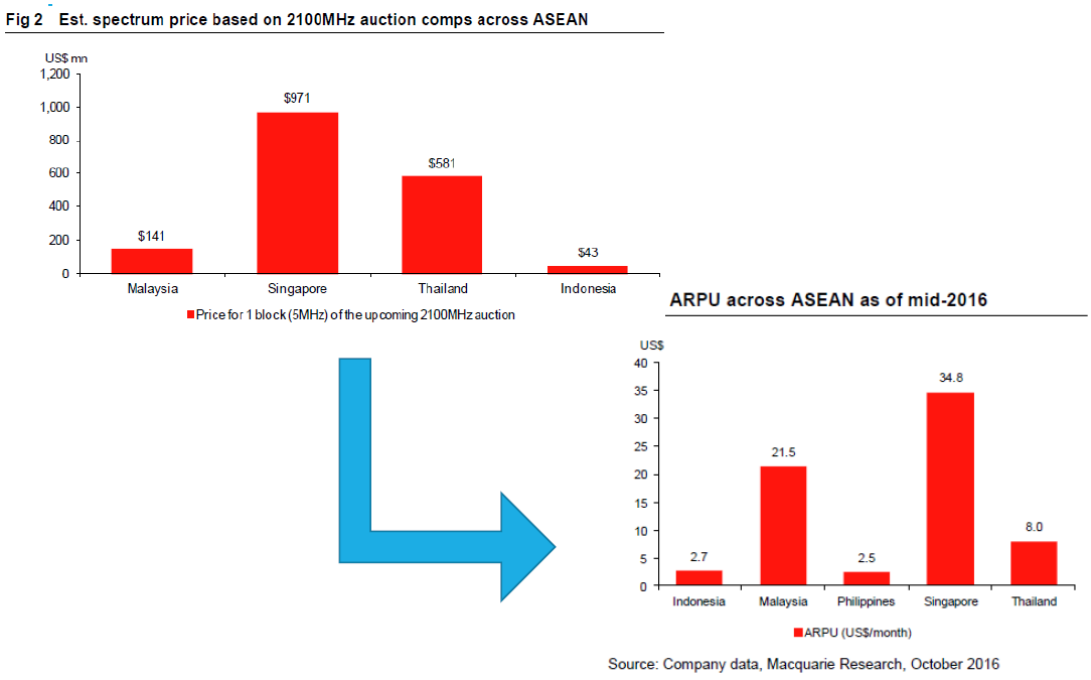


Figure 3.8 : Spectrum prices Vs ARPU for ASEAN countries

Source: Macquarie research, 2016

Another success story is that the spectrum is released in time for the new technology adoption. On June 2015, The Minister of ICT in Indonesia stipulated a spectrum strategical plan for year 2015 to 2019. The spectrum goal was achieved in 2019 which supplied 350 MHz of spectrum for mobile broadband. This target is planned to gradually achieved in cumulative approach. [10]

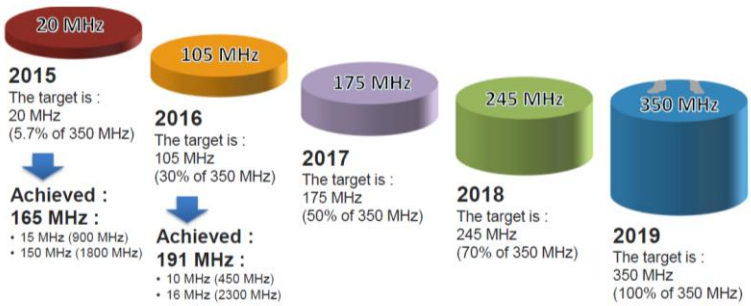


Figure 3.9: Spectrum Road map Vs achieved Targets

Source: Ministry of Communication and Information Technology, Indonesia

Indonesia is trying their best to release spectrum for broadband. With the introduction of LTE there are many bands released for the deployment and some are on the pipe line for future deployment.

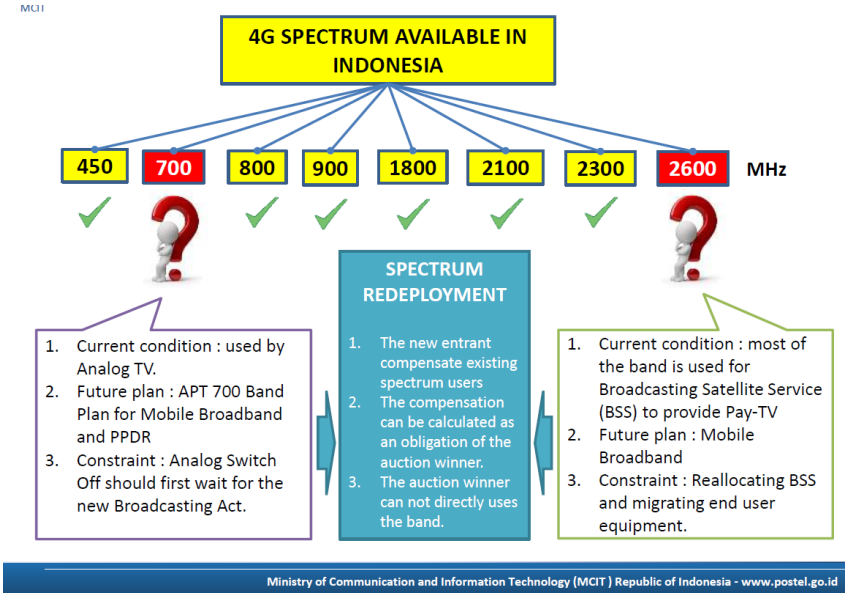


Figure 3.10: LTE spectrum availability in spectrum bands in Indonesia

Source: Ministry of Communication and Information Technology, Indonesia

Another key milestone achieved by the Indonesian government is that they have increase the spectrum efficiency by spectrum rearrangement to make it continuous so that the fragmented spectrum is effectively utilized. They performed this activity for both 1.8 GHz and 2.1GHz spectrum bands. [10]

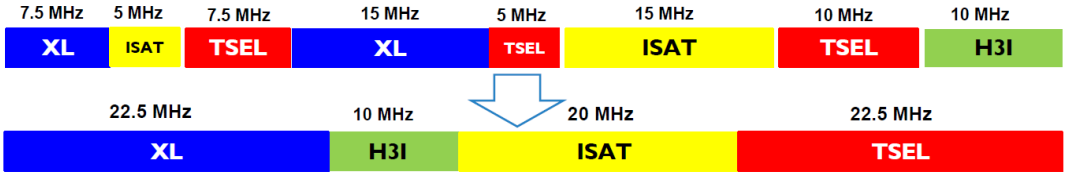


Figure 3.11: Spectrum realignment for 1800 MHz continuous operation

Source: Ministry of Communication and Information Technology, Indonesia

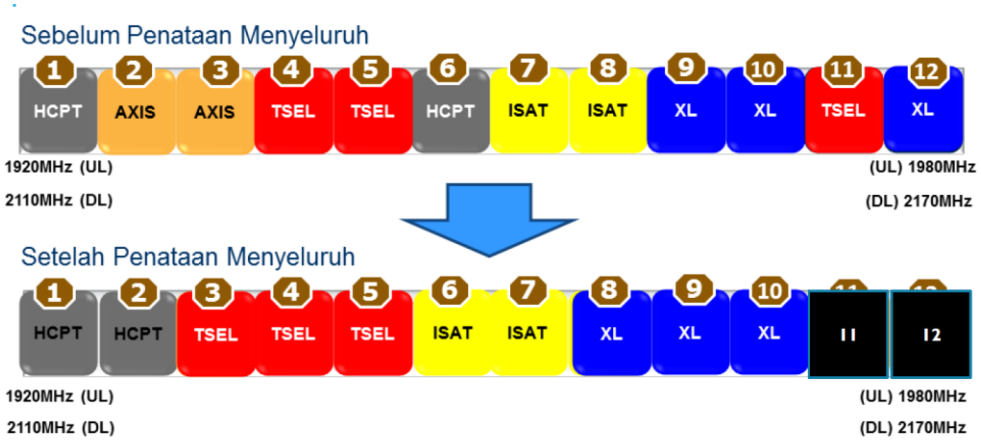


Figure 3.12: Spectrum realignment for 2100 MHz continuous operation

Source: Ministry of Communication and Information Technology, Indonesia

Spectrum neutrality is also introduced in Indonesia where the operators are encouraged to innovate and bring the latest technology to the market with minimum barriers.

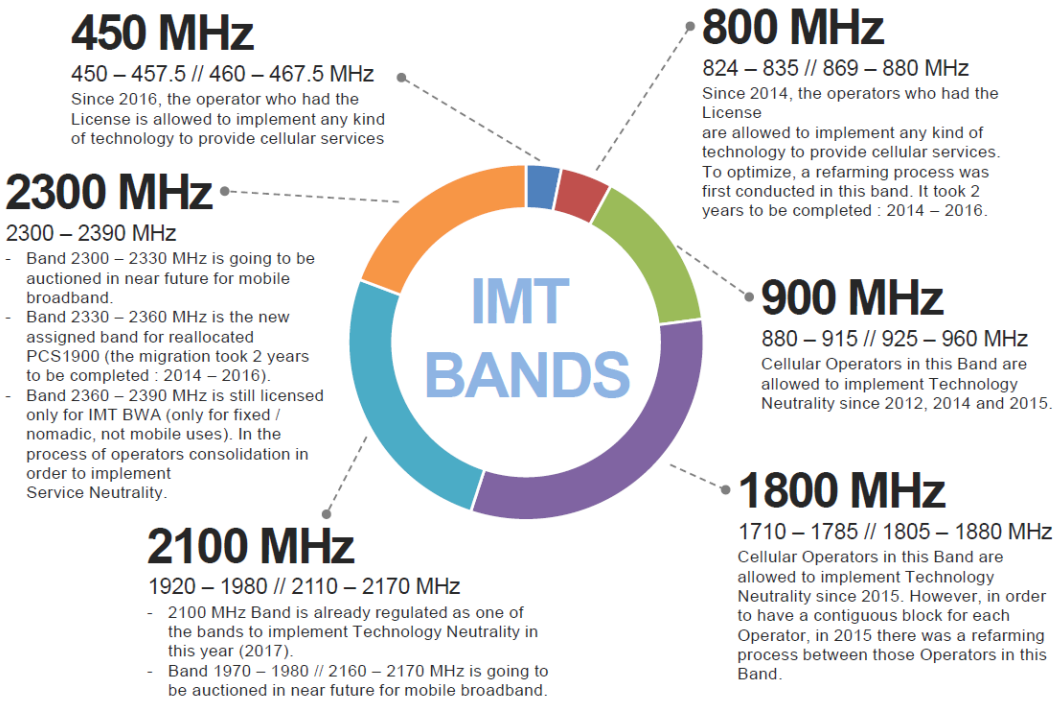


Figure 3.13: Spectrum Neutrality in Spectrum Bands, Indonesia

Source: Ministry of Communication and Information Technology, Indonesia

Also the regulatory body is encouraging the spectrum sharing policy in the rural and moderate business potential areas.

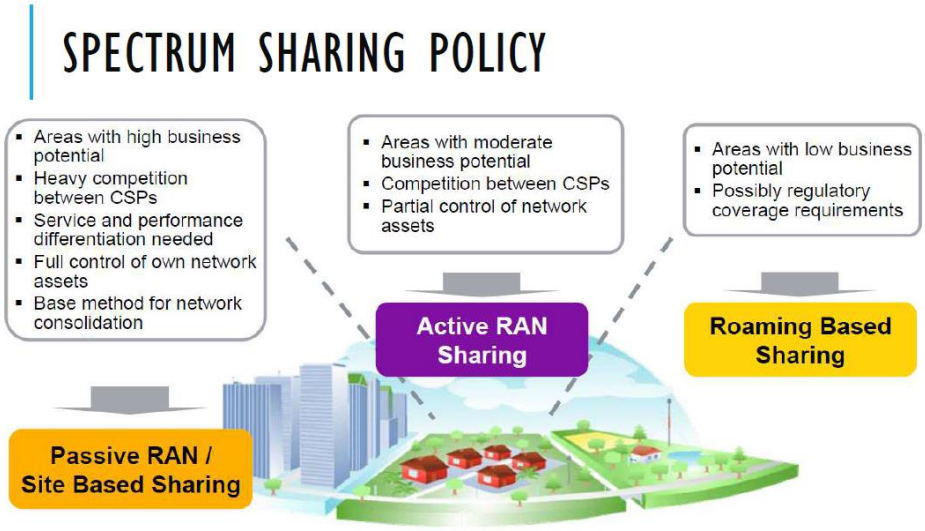


Figure 3.14: Spectrum Sharing policy

Source: Ministry of Communication and Information Technology, Indonesia

3.4 Spectrum Policy Comparison

Table 3.3: Spectrum Policy Comparison

SPECTRUM PLANNING	SPECTRUM MANAGEMENT	SPECTRUM LICENSING
Band plan harmonization India – Good China – Good Indonesia – Good	**Spectrum efficiency** India – Good China – Good Indonesia – Good	**Auctions and cost of access** India – Poor China – Average Indonesia – Good
Cross-border interference India – Good China – Good Indonesia – Good	**Spectrum Sharing** India – Good China – Average Indonesia – Good	**License obligations** India – Average China – Good Indonesia – Good
Spectrum road map India – Average China – Good Indonesia – Good	**Spectrum Trading** India – Good China – Average Indonesia – Good	**Technology Neutrality** India – Good China – Good Indonesia – Good

Source: Author

4. METHODOLOGY

There should be a clear mechanism to gather the information required for any kind of policy framework. In this research project, it was required to consider few subcategories as mentioned in the earlier chapters. The first point is to identify the most suitable spectrum policy initiatives to assist the exponential broadband growth. Then the second subcategory is to apply those in the Sri Lankan market context and analyze the pros and cons.

4.1 Research Methodology

Research is a process of collecting, analyzing and interpreting information to answer questions. Data Collection is an important aspect of any type of research study. Inaccurate data collection can impact the results of a study and ultimately lead to invalid results. A formal data collection process is necessary as it ensures that data gathered are both defined and accurate and that subsequent decisions based on arguments embodied in the findings are valid. Generally, there are three types of data collection and they are;

1. Surveys: Standardized paper-and-pencil or phone questionnaires that ask predetermined questions.

2. Interviews: Structured or unstructured one-on-one directed conversations with key individuals or leaders in a community.

3. Focus groups: Structured interviews with small groups of like individuals using standardized questions, follow-up questions, and exploration of other topics that arise to better understand participants.

It was chosen the first method to gather the data for the research. The methods involved in survey data collection are any of a number of ways in which data can be collected for a statistical survey. The important factors to be considered in this kind of surveys are;

1. Selecting a correct sample of resource persons to give the set of questions
2. Define the correct set of questions

After gathering all the required data, it is possible to analyze them and come to a conclusion. Finally, I include those results to the proposed policy framework and finalize it with clear procedures.

4.2 Select the Resource Persons to Produce the Set of Questions

It is very important to select a correct set of resource persons to produce the predefined set of questions. Therefore, I took every possible action to choose them by covering the almost all part of the mobile telecommunication industry. The sample of resource persons can be categorized in to two major groups.

1. Professionals from the mobile telecommunication industry
2. Professionals from the broadband equipment vendors

Summary of the sample group can be shown by the following table.

Table 4.1: Survey sample

Company/ Institute	Type of business
Mobitel (Pvt) Ltd	Operator
Dialog Axiata PLC	Operator
Hutch/ Etisalat Lanka (Pvt) Ltd	Operator
Bharati Airtel Lanka	Operator
TRCSL	Regulator
Huawei Technologies Lanka Co.,(Pvt) Ltd	Equipment vendor
ZTE Lanka (Pvt) Ltd	Equipment vendor

Source: Author

4.3 Define the Set of Questions

A set of questions were prepared to give to above mentioned professionals to get their ideas and that was covered the all required fields wanted to fulfill the data collection. The set of questions can be listed as following. From the literature review I have found the GSMA spectrum management policy frame work highlights all the relevant spectrum management techniques in the emerging telecom industries in the South Asian region. Hence my research will be centered on this frame work to identify the strengths and weaknesses in the current Sri Lankan broadband policy. I have derived the questionnaire to address the concepts and variables in the following frame work. During the questionnaire I have mapped the main 3 concepts and each variable in the concepts to several questions where I can get a detail understanding on each variable and concepts in the Sri Lankan context

SPECTRUM PLANNING	SPECTRUM MANAGEMENT	SPECTRUM LICENSING
Band plan harmonization	Spectrum efficiency	Auctions and cost of access
Minimize Cross-border interference	Spectrum Sharing	License obligations
Spectrum road map	Spectrum Trading	Technology Neutrality

Figure 4.1: Spectrum Policy Frame Work, GSMA

Source: Spectrum Management Trends & Challenges - Joe Guan, Spectrum Policy & Regulatory Affairs Advisor, Asia Pacific, GSMA

Table 4.2: Survey Questionnaire for Spectrum Policy Frame, Sri Lanka

Concept	Variable	Question	
SPECTRUM PLANNING	Band plan harmonization	Q1	Do you thing Spectrum bands should be harmonized at international and regional levels? Please state the importance of this in the Sri Lankan context?
		Q2	How cost is effected by band harmonization?
		Q3	Is there any correlation to cross border interference?
	Cross-border interference	Q1	What is the impact of cross border interference?
		Q2	What is the effect of this to Quality of service?
		Q3	What are the steps need to take to minimize this in Sri Lanka?
	Spectrum road map	Q1	Does TRCSL need to have a Spectrum Road map?
		Q2	How soon this plan need to executed?
		Q3	What is the importance of this?
		Q4	What is the importance of sub 1GHz frequency band in the broadband domain?
		Q5	How the spectrum bands should be planned to cater the broadband coverage and capacity in the Rural, Sub urban and Urban areas?
		Q6	What other steps can be taken to increase the amount of commercially available spectrum for mobile broadband?
		Q7	How soon 5G technology should be deployed in Sri Lanka?
		Q8	What are spectrum bands used for 5G now and future?

Concept	Variable	Question	
SPECTRUM MANAGEMENT	Spectrum efficiency	Q1	What should be done to encourage efficient use of spectrum by TRCSL?
		Q2	What is the advantage of having a continues spectrum for single operator?
		Q3	Does the technology has a relationship with spectrum efficiency?
	Spectrum Sharing	Q1	What is the use case for spectrum sharing?
		Q2	What do see the benefits of Licensed Shared Access(LSA)?
		Q3	How to we share the spectrum assigned for different services? Eg: TV White Spacing?
		Q4	What is the future in Cognitive Radio Technologies?
	Spectrum Trading	Q1	What are the benefits of spectrum trading?
		Q2	can it use to increase the spectrum utilization?
SPECTRUM LICENSING	Auctions and cost of access	Q1	Is auction the best way to release spectrum?
		Q2	What is your perception about spectrum cost in Sri Lanka?
		Q3	Do we have enough consultation with mobile operators and other stakeholders?
		Q4	Does Auction need to be fair and transparent to all stakeholders?
	License obligations	Q1	What are the coverage targets with new spectrum?
		Q2	What are the QOS targets with new spectrum?
		Q3	What are the new technology targets with new spectrum?
		Q4	What are the conditions in the license renewal process?
	Technology Neutrality	Q1	Is spectrum should be free from Technology
		Q2	How this effects to new technology deployments?
		Q3	How does this promote innovation in the market?

Source: Author

5. RESULTS AND ANALYSIS FOR SRI LANKAN CONTEXT

The next step of this research is to summarize and analyze the results obtained through the survey and convert those data to valuable information. My analysis will follow the GSMA spectrum policy frame work and where Sri Lanka stands in this frame work.

5.1 Spectrum Planning

As discussed earlier this has 3 dimensions.

1. Band Plan Harmonization
2. Cross border Interference
3. Spectrum Roadmap

5.1.1 Band Plan Harmonization

Spectrum harmonization at the international level is a desired target which has the potential to enhance economies of scale for both device manufacturing and network deployment. This overall objective has to be put against other spectrum management goals like group harmonization at the regional level, the marketing of spectrum trading and flexibility for all players to adopt innovative technological solutions and the security of critical government services. Additionally, it must take into consideration constraints like interference mitigation global frequency co-ordination and the uses. This plays a critical role in allowing the utilization of spectrum resources for communication services and in promoting spectrum performance in present or future spectrum groups used for those solutions.

In Sri Lanka, when we consider the 5 mobile operators we can clearly see Extended GSM 900 band have not been harmonized in the regional level. Sri Lankan GSM 900 band (E GSM) has an overlapping interference with the Indian LTE 850 band. Part of Up-Link (Airtel & Mobitel) in Sri Lankan GSM900 Operation is Overlapping with Indian LTE 850 downlink Operation. Because the interference happens to the uplink of the GSM 900 Sri Lankan band the quality of service drops drastically. There are numerous call drops and quality related complaints coming from the Mobitel and Airtel customers.

5.1.2 Cross border Interference

As discussed earlier since we have not harmonized our Extended GSM band to Indian LTE 850 band we get a severe interference across the sea borders of India and Sri Lanka. Though Sri Lanka is an island we get the interference signal through the see due to the ducting effect of the electromagnetic waves. Hence this interference has a seasonal effect. When the interference is present, it is affecting the uplink frequency band of the Mobitel and Airtel network. Therefore, it blocks the decoding of uplink signals received by mobile phones to the tower, creating many unwanted effects to the network. Following are some of the evident effects caused by high uplink interference.

- Voice call and Signaling session drops (TCH and SDCCH)
- SMS and SMS related application (e.g. reloads, activation) failures
- Voice quality degradation
- Poor accessibility due to inability to decode signaling channels
- Handover failures

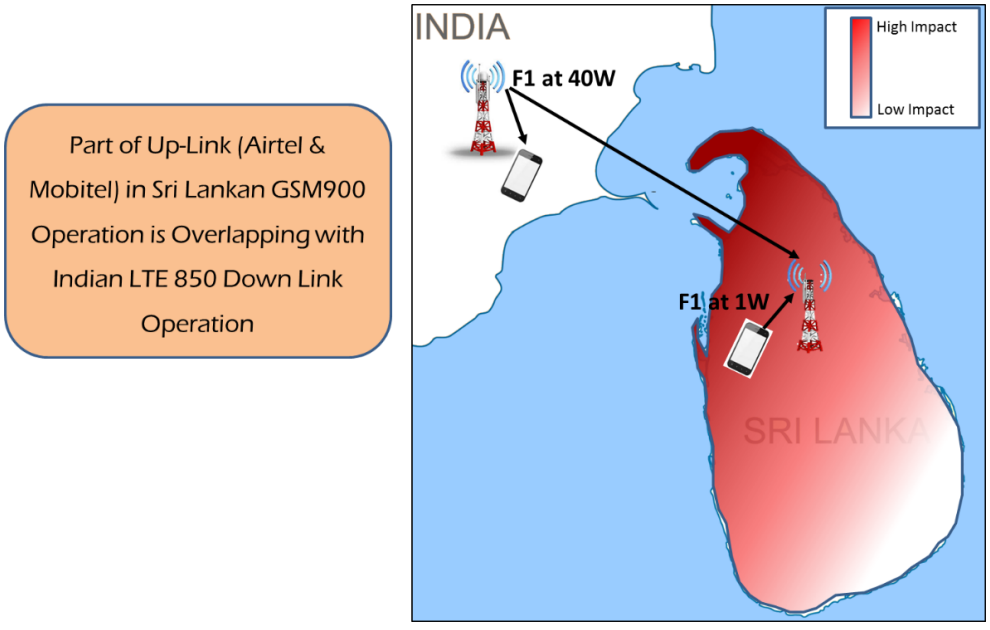


Figure 5.1: Indian Interference effect to Extended E GSM band

Source: Author

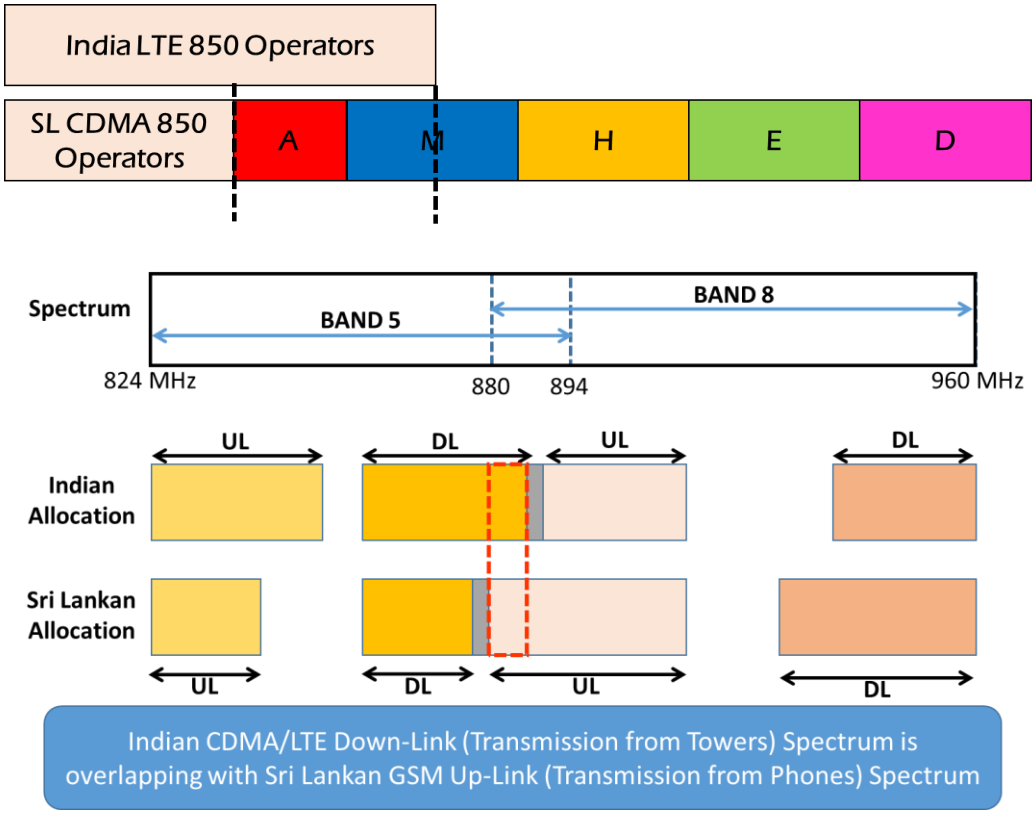


Figure 5.2: Interference effect between Band 5 and 8

Source: Author

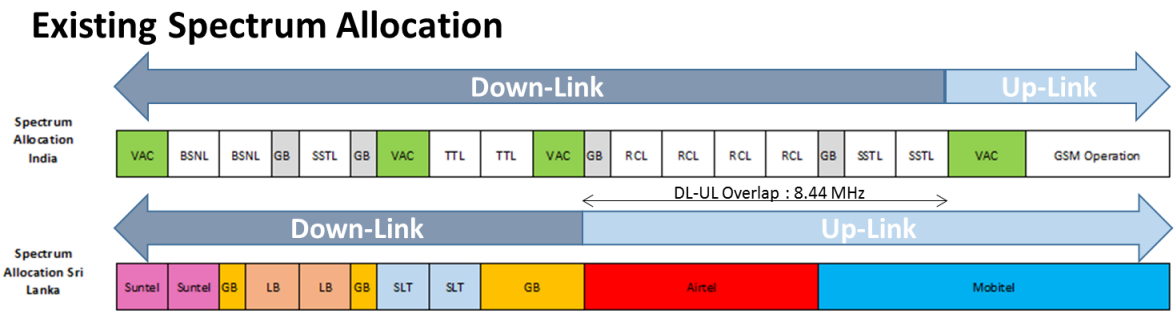


Figure 5.3: Spectrum allocation in Sri Lanka and India

Source: Author

During the interview of the TRCSL representative I found that the decision to go for GSM 900 was taken during the north east war period in Sri Lanka and justified this interference effect is severe only in the northern part of Sri Lanka. We can clearly see the impact of not harmonization can lead to severe long term problems.

During the interview with Mobitel representatives I found that they are going to convert the EGSM 900 band to LTE 850 band which will solve the band harmonization problem. They have received the necessary approvals to deploy L850 network and the project is ongoing. However, I didn't get a positive response from the Airtel representative about this solution and they are still having discussion with the TRCSL. The final solution for this interference problem is to convert all the E GSM 900 band to L850 so then the bands gets regionally harmonized and the interference gets minimized.

Furthermore, there is another interference coming to Mobitel 2.1 GHz 3G frequency bands from DECT 6.0 cordless phones which are supposed to use in Latin America/USA/Canada etc. This cordless phone signal directly overlaps with the Mobitel 3G uplink for two 5MHz carriers resulting a QOS problem for both voice and data services. Increased RTWP (Receive Total Wideband Power) affected the 3G customers,

- HSUPA (High Speed Uplink Packet Access) uploading is very slow with higher RTWP
- page loading delay, upload data rates are poor
- Download speed with TCP sessions is reduced
- Download sessions break and may have to restart
- Higher number of call drops due to uplink loss by 3G site
- Heavy call drops, call establishment failures, mute calls & disturbance
- Higher battery draining of mobile phones due to higher UE (User Equipment) Transmit power

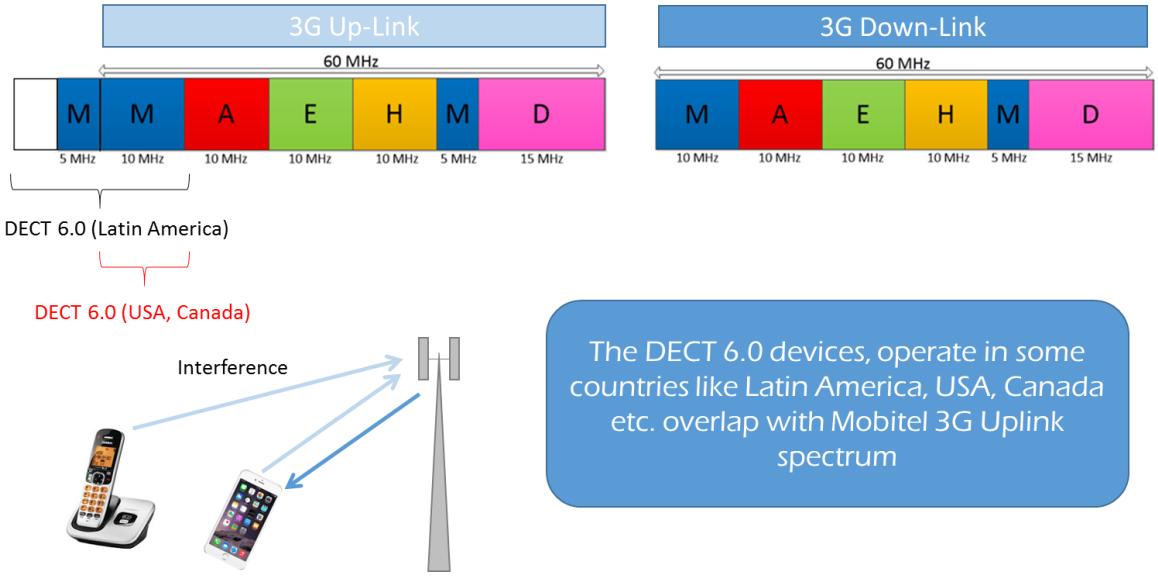


Figure 5.4: Cordless interference to Mobitel 3G network

Source: Author

The problem is severe in the Colombo CBD area and some main towns couple of districts. During the interview, it was identified that Mobitel is carrying out a special project in Wellawatta area to locate the cordless interfered phone locations and replacing them with free 2.4G SLT cordless phones. The initial results show some progress but it consumes lot of time and effort.

Also from the interview with Dialog I found that there is an interference to Dialog 2.3 LTE GHz TDD system from Indian 2.3 GHz LTE operator Reliance Jio. The band 2.3 uses TDD technology to separate DL and UL. Depending on the traffic demand the DL and UL slot interval changes. The interference is coming to Dialog because the Indian operator and Dialog uses two different slot interval configuration in the 2.3 GHz LTE band. Hence as explained earlier due to the ducting effect Indian DL can have an interference to Dialog UL seasonally.

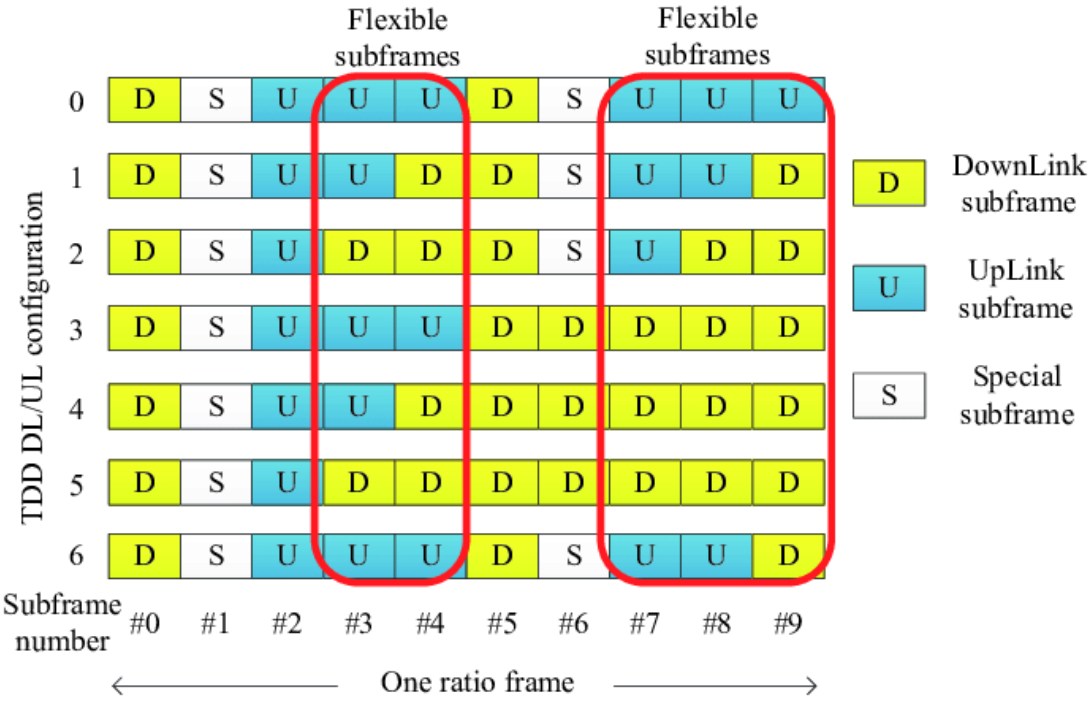


Figure 5.5: TDD LTE Operation

Source: 3GPP

Hence this TDD operation should be carefully designed for 5G system because the same interference of DL and UL can happen in the 5G systems in India and Sri Lanka.

5.1.3 Spectrum Roadmap

In the spectrum road map, the regulator must have a good spectrum strategy to cater the demand for coverage and capacity both. Also the spectrum release for new technologies like 5G should start beforehand for smooth technology adoption. When the standards (ITU/3GGP) get finalized the spectrum should get released as soon as possible for fast market introduction. Eg: The 5G eMMB 3GPP standardize was completed on November 2018

Following table shows the currently used bands for LTE broadband technologies in Sri Lanka. Spectrum should be planned properly to cater the traffic in dense urban, urban and rural market. Also special attention should be given for spectrum planning in IBS sites to minimize the PIM (Passive Inter Modulation) effect.

Table 5.1: Broadband technologies and spectrum details in Sri Lanka

Operator	Operation	Frequency Band	Bandwidth for Operator	Total Bandwidth Available in the band	Remaining Bandwidth
Mobitel	Mobile	Band 3 (1800 FDD)	27.5 MHz (15MHz for LTE)	75 MHz	None
Dialog	Mobile	Band 3 (1800 FDD)	25 MHz (15MHz for LTE)		
Hutch/Etisalat	Mobile	Band 3 (1800 FDD)	15 MHz (5 MHz for LTE)		
Mobitel	Mobile	Band 5 (850 FDD)	3 MHz for LTE	11 MHz	None
Dialog	Mobile	Band 8 (900 FDD)	7.5 MHz (3 MHz for LTE)	35 MHz	*5 MHz
Hutch/Etisalat	Mobile	Band 8 (900 FDD)	15 MHz (3 MHz for LTE)		
SLT	Fixed	Band 38 (2600 TDD)	30MHz	190 MHz	160 MHz
Dialog	Fixed	Band 40 (2300 TDD)	70-75MHz	100MHz	None
Lanka Bell	Fixed	Band 40 (2300 TDD)	20-25MHz		

*Note: 5 MHz 900 spectrum to be released after the merger of Hutch and Etisalat.

Source: TRCSL

5.1.3.1 Importance of Sub 1GHz Broadband for Sri Lanka

When we consider operator's broadband coverage maps we can see a very high level of population coverage percentage deployed by the operators. In Sri Lanka there are four operators who provides mobile Broadband coverage in Sri Lanka.

Table 5.2: Mobile Operator's Technologies and coverage penetration

Operator	Mobile Broadband Technologies	BB coverage Penetration
Dialog	LTE/3G	85%
Mobitel	LTE/3G	80%
Hutch/Etisalat	LTE/3G	60%
Airtel	3G	55%

Source: TCRSL, Interview data

But when we consider the actual users who are connected to the internet, it shows a very low value around 32% as follows.

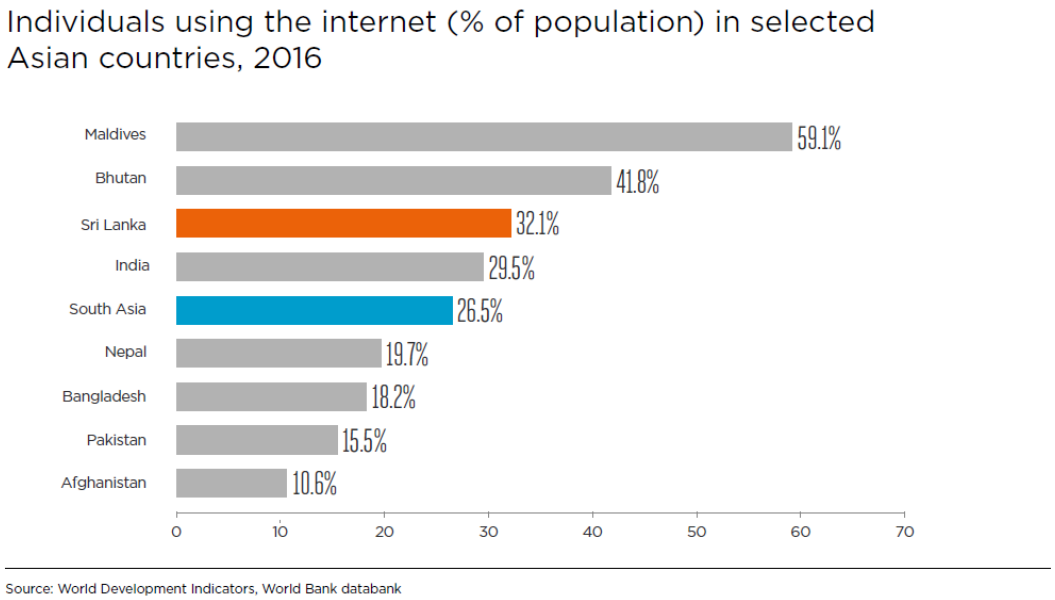


Figure 5.6: Internet penetration (% Population) in selected Asian countries 2016

Source: World development indicators, World Bank databank

Hence there is a big gap between the operator's actual coverage penetration – 85% vs internet penetration – 32%. During interview with operators it was found that operators invest broadband network mainly in the urban and semi urban areas and the rural market investment is done carefully with ROI based. Mobile traffic in remote, rural areas is expected to be relatively low in Sri Lanka due to low population density and low incomes. Because of the low ROI operators have very low investment in the rural segment.

Another key factor identified in the interviews is the absence of the sub 1GHz broadband spectrum for operators. The operators have given broadband coverage through high frequency bands of LTE and 3G.

- LTE – 1800/2100 MHz
- 3G – 2100 MHz

But these bands are ideal for high capacity demand in the urban and semi urban segments but not economical for rural segment because of the low coverage

penetration. With higher frequencies, number of required sites increase significantly to cover indoor users or to provide higher bit rates. (Figure 5.7)

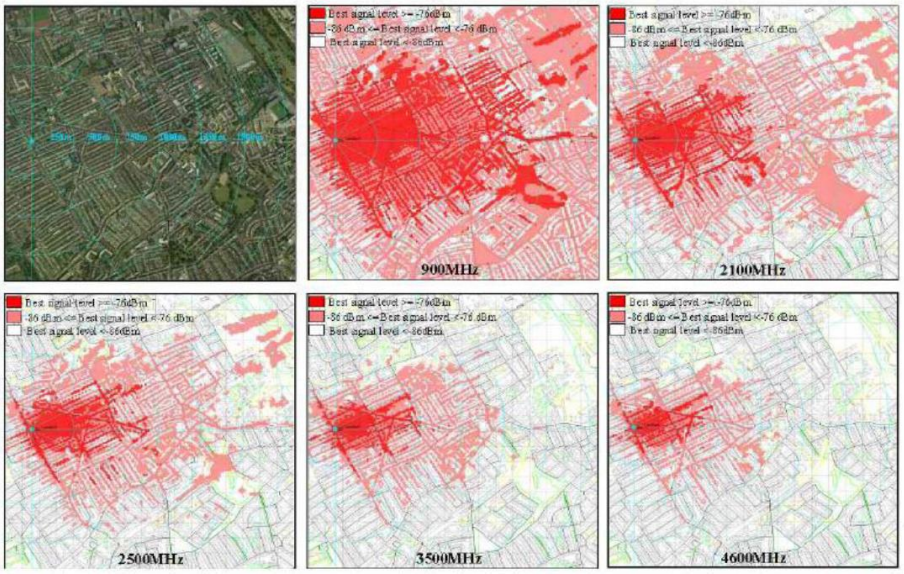


Figure 5.7: Frequency Vs Coverage prediction

Source: Vodafone research 2015

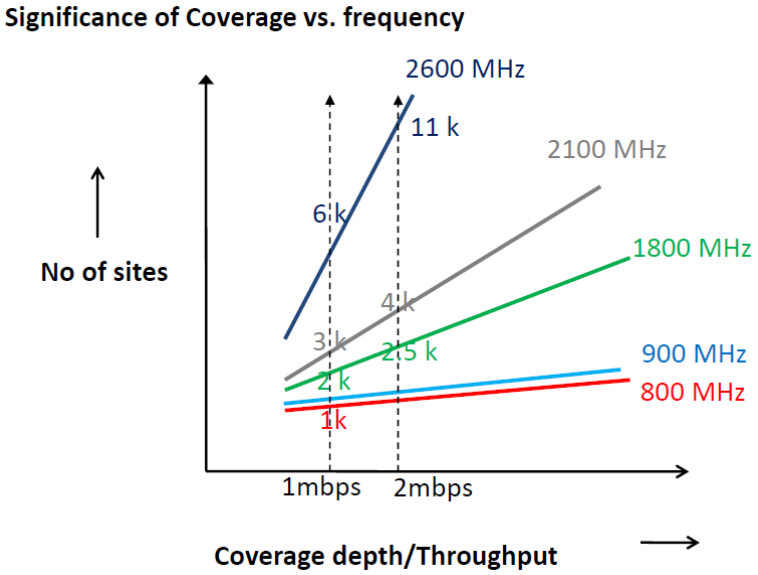


Figure 5.8: CAPEX/Number of sites Vs Planning frequency

Source: Ofcom research 2015

The 900/850/800 MHz bands are currently widely used to provide 2G voice service in most countries' rural areas due to the fact that they experience lower attenuation and radio waves travel a longer distance. From the above graph (Figure 5.8) it is evident

that in order to cover a geographic region with 1 Mbps speed you need 2 times site quantity in 1800 MHz spectrum and 3 times site quantity in 2100 MHz spectrum vs 900/850/800 MHz sub 1GHz spectrum.

Figure 5.9 illustrates a demographic picture of Sri Lanka. Sri Lanka has the highest rural population in South Asia, at 81.6%. This value suggest that we need a very strong broadband spectrum policy for rural market. This is the main reason for low broadband penetration in Sri Lanka. The crucial task for policy makers and operators is, therefore, to provide sufficient coverage to ensure that broadband services are available in the rural market segment.

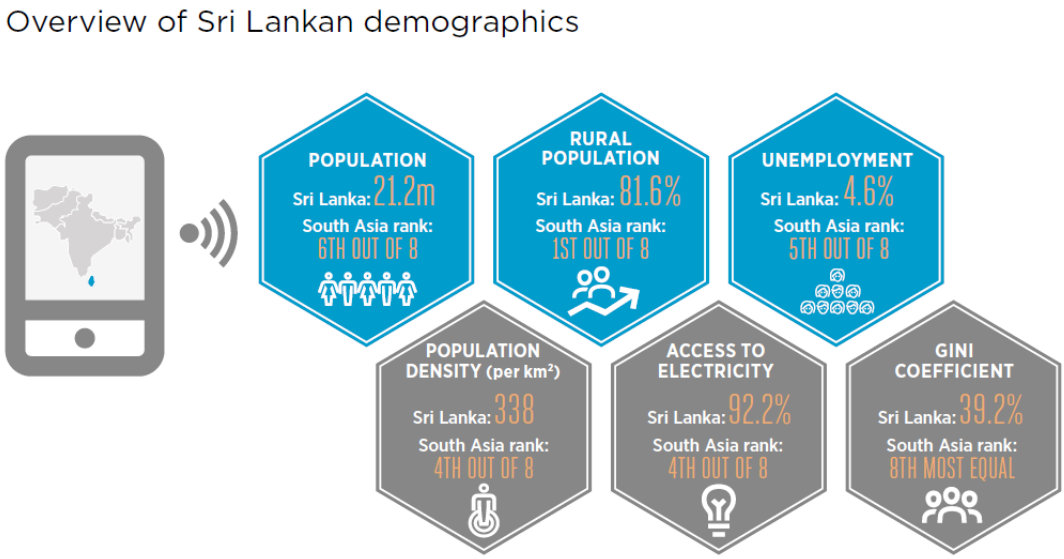


Figure 5.9: Overview of Sri Lankan demographics

Source: Oxford Economies database, World Bank, EY analysis

Through the interviews I found that recently Dialog and Mobitel have plans on deploying LTE on sub 1GHz bands by re framing GSM 900 spectrum and some deployment projects are work in progress. Also Hutch and Etisalat merger entity has plans to deploy Sub 1GHz LTE by combing their 900 spectrum. But unfortunately Airtel does not have any vacant Sub 1GHz band and they are waiting for any 900 MHz spectrum release for the Hutch and Etisalat merger.

While re-farming has happened in most of the high-income countries as customers migrate from 2G to 3G and 4G technology, the problem is different in ASEAN and South Asian countries with large rural populations as 2G devices will be employed by

nearly all low-income rural customers for voice and SMS providers and this is very likely to last for a while. Thus the Sub 1GHz capability will be limited.

Short term repurposing of bandwidth in the 850 MHz and 900 MHz bands (a total of less than 2x60 MHz compared to 2x60 MHz in the 2100MHz band alone) on a large scale could, therefore, have an adverse impact on basic services for significant proportions of the population. Equally, offering rural broadband services over the 1.8 GHz or 2.1 GHz bands is unlikely to be economically attractive for operators. While in principal operators might reduce the impact of re-farming on 2G users by sharing some of their spectrum below 1 GHz to jointly provide broadband services this is likely to be difficult to achieve both in regulatory and business terms, and a simpler approach could be for regulators to increase the availability of additional harmonized sub-1GHz spectrum.

Short-term re-farming of bandwidth at the 850 MHz and 900 MHz bands on a huge scale could, therefore, have a negative effect on fundamental services for significant proportions of the population. Equally, offering rural broadband solutions across the 1.8 GHz or 2.1 GHz bands is not likely to be economically attractive for operators. While in principal operators may reduce the impact of re-farming on 2G consumers by sharing some of their spectrum below 1 GHz to collectively offer broadband solutions, is also difficult to attain both in regulatory and business terms, and a more straightforward approach could be for TRCSL to increase the access to additional harmonized sub-1GHz spectrum. Eg: 700 MHz spectrum for LTE broadband

Internet access remains a barrier for citizens' full involvement in the country's digital society. While LTE (in 900/850 MHz) has been effective in expanding basic mobile broadband in to the rural market, the technology won't have the ability to cope with the significant traffic growth expected within the next 10 years. Mobile network operators are using 1800 MHz spectrum for 4G rollout, but allocating the 700 MHz band quickly and in sufficient quantity would encourage their own efforts to expand coverage, regardless of the geographical challenges, and help lessen the digital divide that is prevailing.

The Asia Pacific Telecommunity (APT) has defined the 700MHz band for the both FDD - LTE and TDD – LTE as depicted in table 5.3

Table 5.3: 3GPP standardize band plans for APT – 700 MHz band allocation

3GPP Band	Duplex	Uplink Frequency	Downlink Frequency
28[4]	FDD	703 – 748 MHz	758MHz – 803MHz
44[5]	TDD	703 – 803MHz	703 – 803MHz

Source: APT band plans, 2014

Typical the coverage is uplink limited due to the low power transmit capability in the hand held device. A comparison is made based on the uplink edge rate from dense urban to rural environments and the coverage radius of a single site utilizing 700MHz, 800MHz, 1.8GHz, 1.9GHz, 2.1GHz, and 2.6GHz is depicted in Table 5.4.

Table 5.4: Uplink coverage simulation for different LTE frequencies

Morph		Dense Urban	Urban	Suburban	Rural
Cell Edge User Throughput	kbps	512	256	128	64
700MHz					
UL Cell Range	km	0.70	1.21	3.37	8.48
Coverage Area	Km2	0.95	2.84	22.16	140.37
800MHz					
UL Cell Range	km	0.63	1.09	3.04	7.65
Coverage Area	Km2	0.78	2.33	18.06	114.22
1.8GHz					
UL Cell Range	km	0.38	0.64	1.67	4.40
Coverage Area	Km2	0.27	0.80	5.42	37.71
1.9GHz					
UL Cell Range	km	0.36	0.61	1.58	4.17
Coverage Area	Km2	0.25	0.72	4.87	33.84
2.1GHz					
UL Cell Range	km	0.32	0.55	1.43	3.77
Coverage Area	Km2	0.21	0.60	4.00	27.69
2.3GHz					
UL Cell Range	km	0.30	0.51	1.31	3.44
Coverage Area	Km2	0.17	0.50	3.35	23.08
2.6GHz					
UL Cell Range	km	0.27	0.45	1.16	3.04
Coverage Area	Km2	0.14	0.40	2.63	18.06

Source: ZTE 700 MHz spectrum coverage benefit, 2015

From the simulation results, a single site coverage area using the 700MHz band in various scenarios is the equivalent of 7 to 8 times that of the 2.6GHz band. In the other words, to cover the same area, the number of sites used for 2.6GHz will be 7 to 8 times what is used for 700MHz. If the operator will be utilizing multiple bands for the network deployment, there is no doubt that 700MHz is the best choice for nationwide coverage to save network deployment costs and to speed up deployment.

In the simulation results, one site coverage area with the 700MHz spectrum band in the most market segments is the equivalent of 7 to 2 times the 2.6GHz spectrum band. Therefore, the CAPEX requirement for the exact same area using 700 MHz band is reduced by 7 to 2 times. Hence this is ideal for the Sri Lankan rural market universal access purpose.

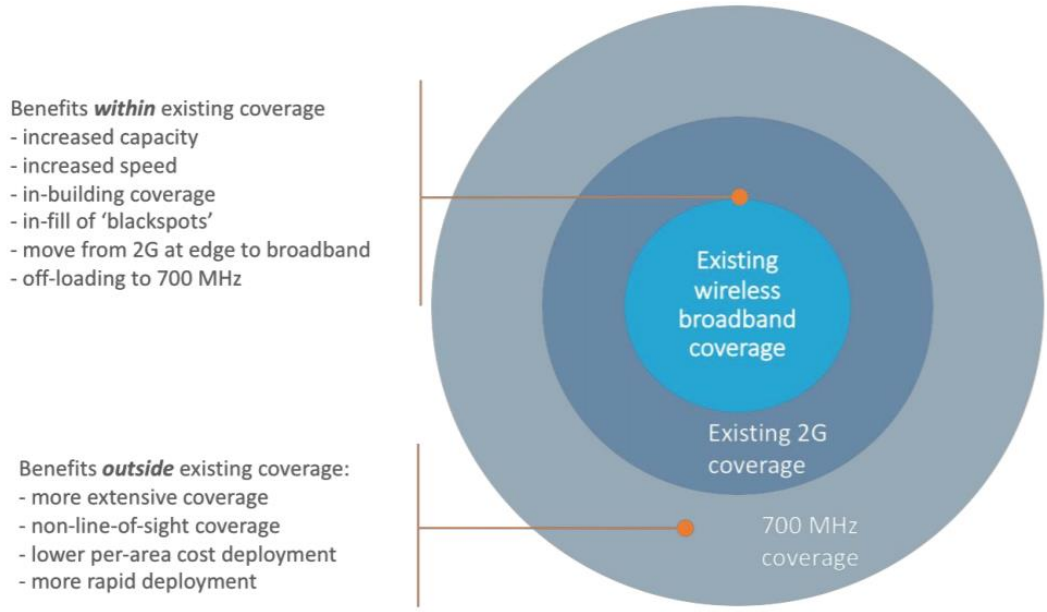


Figure 5.10: Conceptual representation of the benefits of 700 MHz deployment over exiting IMT spectrum bands

Source: Benefits of 700 MHz, GSMA

During the interview with the TRCSL it was found that this band is halted due to the conversion delay of Analog TV to Digital TV. This was on the pipe line for a significant amount of time but the project is still on halt and the valuable 700 MHz spectrum for Broadband is blocked due to this.

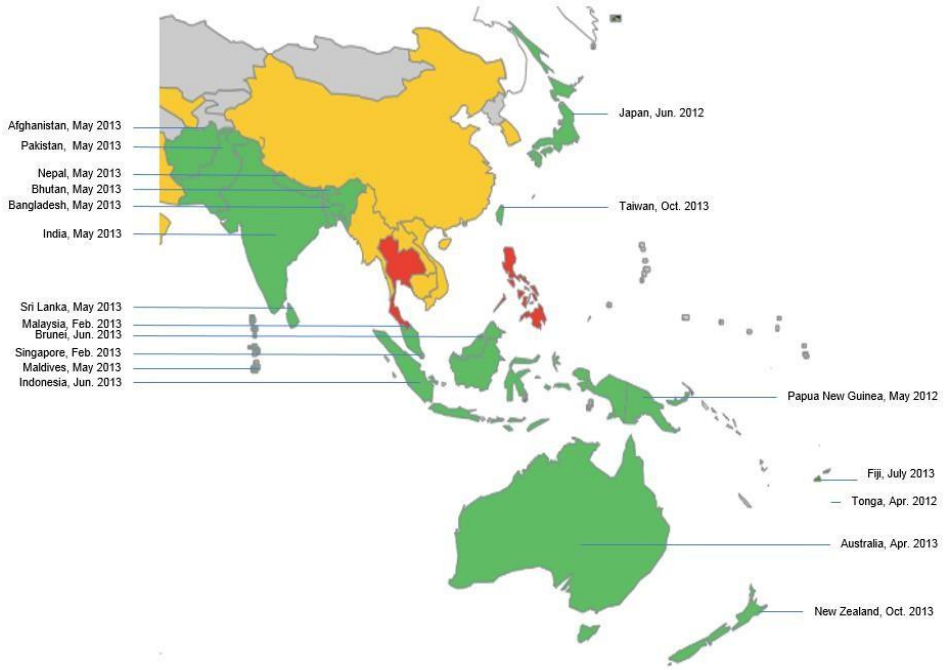


Figure 5.11: Digital TV conversion status, South Asia

Source: Broadband in 700 MHz, GSMA 2013

5.1.3.2 Capacity Bands for broadband LTE

In the current context the mobile operators in Sri Lanka has only 1800 MHz/2100 MHz bands for LTE capacity deployment which is not sufficient to cater the exponential data growth rate in the dense urban and urban segments.

In developing countries like Sri Lanka, mobile networks are being used to provide broadband solutions to many rural communities beyond the reach of the restricted fixed-line infrastructure. Mobile networks have the potential to attain universal access in the country. But for mass-market usage of broadband, particularly in densely urban or urban areas, good quality broadband services can be offered only if mobile network have a sufficient capacity spectrum band is available.

It's very important that regulators allocate the precious 190MHz from the 2.6 GHz for mobile broadband services. The 2.6 GHz LTE band is heavily used as a capacity band all around the globe, with economies of scale enabling lower cost from device and network equipment. Currently only 30 MHz of this band is issued to SLT, a fixed

broadband service provider and the rest of the 160 MHz is unused which can be allocated on urgent basis for mobile broadband services. There is another 2.3 GHz (100 MHz) capacity LTE band available but it is fully utilized for Dialog and Lanka Bell.

After analyzing the interview data, I can conclude the final bands should be placed as follows to cater the capacity and coverage requirement in the urban, Semi urban and rural segments.

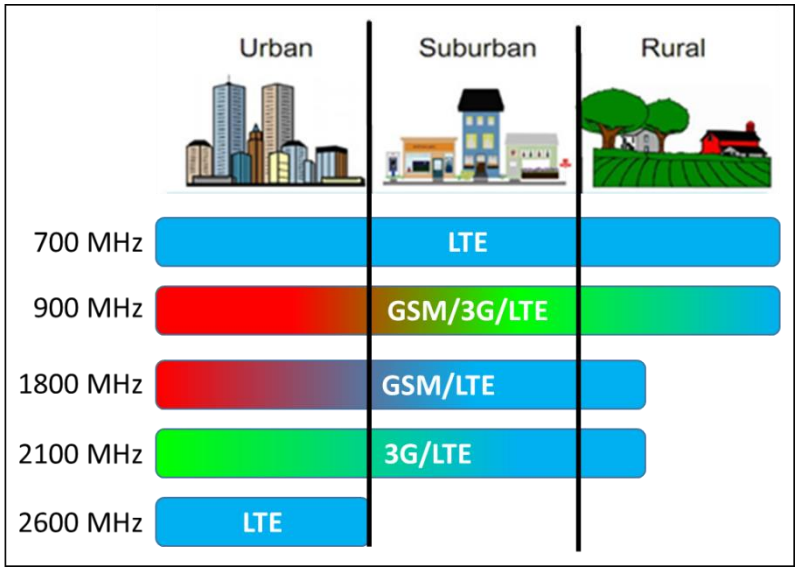


Figure 5.12: LTE spectrum band plan for different demographics in Sri Lanka

Source: Author

5.1.3.3 Spectrum requirement for 5G

5G is the next generation of wireless and mobile broadband technology, effective at ultra-fast rates, low latency and excellent reliability. 5G networks will provide fixed and mobile broadband services to end customers “on the go", in the home or in the workplace. The 5G New Radio (5G NR) interface, using capability for low latency and ultra-reliable connections will handle an enormous number of devices with very different connectivity demands that make up the Internet of Things (IoT), such as industrial applications, innovative logistics and utility programs.

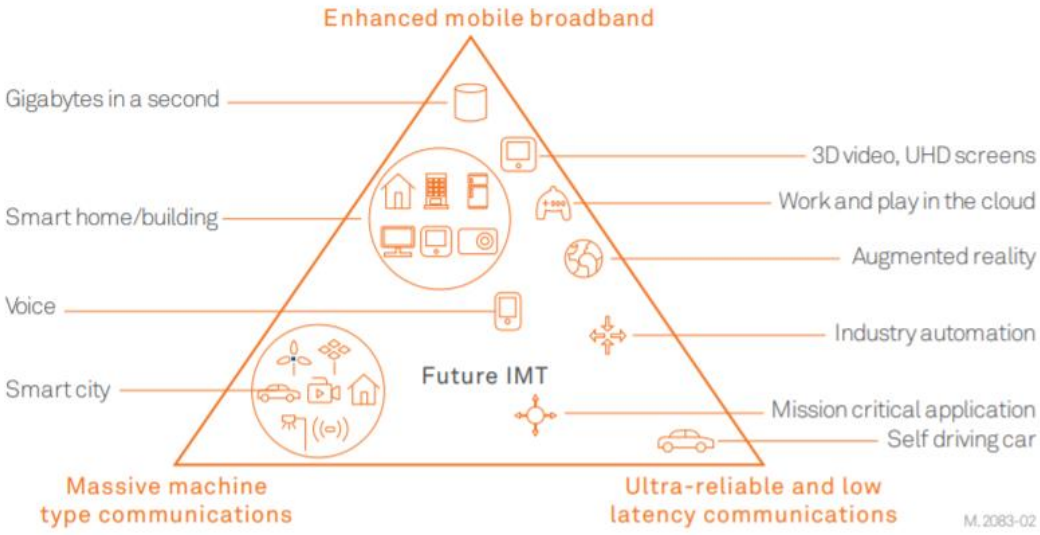


Figure 5.13: 5G Spectrum use cases

Source: 5G Spectrum policy, Huawei

Spectrum availability for IMT in the 3300-4200 and 4400-5000 MHz spectrum ranges is growing globally. The 3400-3600 MHz frequency band is allocated to Mobile Service on a basis in almost all countries throughout the world. Administrations will make available unique portions of their 3300-4200 and 4400- 5000 MHz ranges at several times building neighboring blocks. The 3GPP 5G NR specification will encourage 3300-3800 MHz from the start, using a TDD access scheme. In accord with the release plans from many nations, the 3300-3800 MHz band will be the primary 5G band with greatest potential for international harmonization over time it is recommended that at least 100 MHz of contiguous bandwidth from this group be allocated to each 5G network. Please refer the figure 5.14. [11]

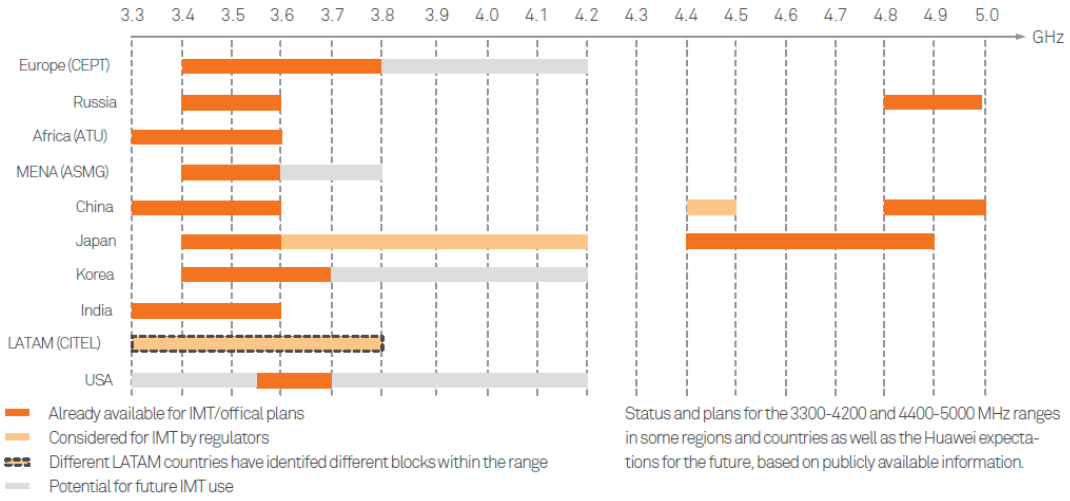


Figure 5.14: Global availability and planning of the 3300-4200 MHz and 4400-5000 MHz frequency ranges

Source: Huawei

Also for capacity 5G bands, the World Radiocommunication Conference 2015 (WRC-15) developed the way for the future development of IMT on higher frequency groups by identifying many frequencies for study over the 24.25-86 GHz range (Figure 5.15) for possible identification for IMT under WRC-19. The 24.25-27.5 and 37-43.5 GHz bands are prioritized within the continuing ITU-R work in preparation for WRC-19; all areas and countries are recommended to encourage the identification of these two bands for IMT throughout WRC-19 and should aim to harmonize technical requirements for use of these frequencies in 5G.

Group 30 (GHz)	Group 40 (GHz)	Group 50 (GHz)	Group 70/80 (GHz)
24.25-27.5 31.8-33.4	37-40.5 40.5-42.5 42.5-43.5	45.5-47 47-47.2 47.2-50.2 50.4-52.6	66-71 71-76 81-86

Figure 5.15: Candidate frequency bands of WRC – 19

Source: Huawei

The 24.25-29.5 and 37-43.5 GHz spectrum bands are the most promising frequencies for the early deployment of 5G millimeter wave systems, and also many leading markets are contemplating portions of both of these ranges for early deployments (Figure 5.16), and also both bands are being specified in 3GPP Release 15. It's

encouraged that at least 800 MHz of spectrum each network from such ranges be assigned for the installation of 5G. For states that plan to release 26.5-27.5 GHz as first measure, it's encouraged that at least 400 MHz of contiguous spectrum per network be delegated; the remaining 24.25-26.5 GHz needs to be allocated as soon as practicable and particular provisions should be added to avoid fragmented assignments across the entire 24.25-27.5 GHz range.

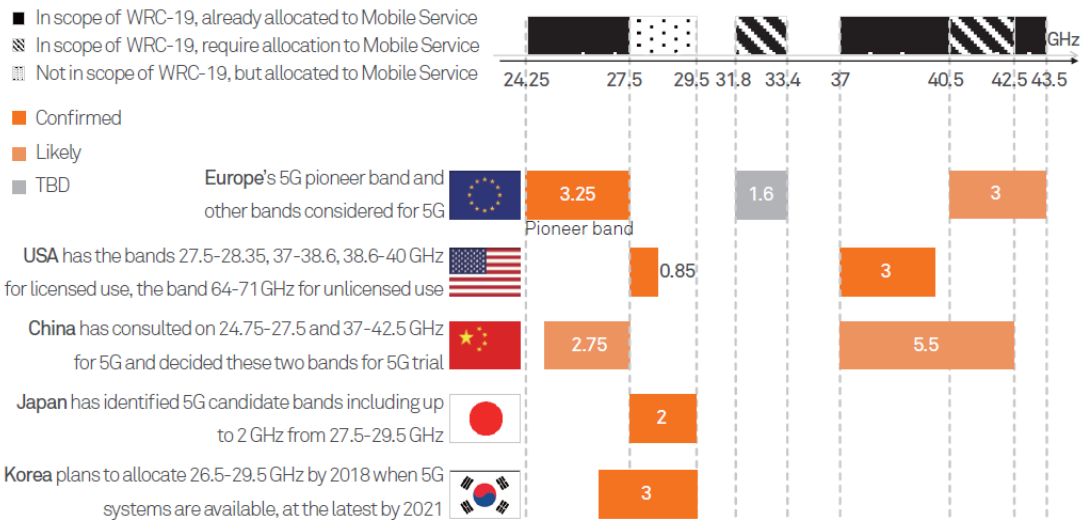


Figure 5.16: Frequency bands for early deployment of 5G millimeter wave systems

Source: Huawei

Hence a multi-layer spectrum approach is required to address such a wide range of 5G usage scenarios and requirements:

• The "Coverage and Capacity Layer" will be on spectrum in the 2 to 6 GHz range (e.g. C-band) to deliver the best compromise between capacity and coverage.

• The "Super Data Layer" relies on spectrum above 6 GHz (e.g. 24.25-29.5 and 37-43.5 GHz) to address specific use cases requiring ultra-high data rates.

• The "Coverage Layer" will use spectrum below 2 GHz (e.g. 700 MHz) providing wide-area and deep indoor coverage.

5G networks will leverage the availability of spectrum from these three layers at the same time: Regulators need to focus on making available contiguous spectrum in all layers in parallel, to the greatest extent possible to make 5G successful.

Table 5.5: 5G Spectrum options

Layer	Addressed Area	Frequency Range	Example	Min BW requirement
"Super Data Layer" eMBB	Use cases requiring extremely high data rates	Above 6 GHz	24.25-29.5 37-43.5	1 GHz (contiguous)
"Coverage & Capacity Layer" eMBB, URLLC, mMTC (wide-area but no deep coverage)	Best balance between capacity and coverage	2 – 6 GHz	C-band	100 MHz (contiguous)
"Coverage Layer" mMTC, eMBB, URLLC	Wide-area and deep indoor coverage	Sub 2 GHz	MHz	up to 20 MHz paired / unpaired

Source: 5G Spectrum policy, Huawei

Regulatory frameworks will need to promote the 5G tech innovation. The accessible mobile communication bands need to be assessed and new frameworks need to be created for 5G frequency bands. All these frameworks will facilitate innovation by eliminating any potential barriers to the introductions of crucial 5G innovations. For instance:

• Should adopt the principle of technology and service neutrality

• Regulatory framework should be revised to support the statistical nature of massive MIMO antenna systems

• Incentives for network synchronization in 5G networks should be considered

• Provisions to support duplex flexibility should also be considered as the next step allowing for a more flexible use of the spectrum resource.

A globally harmonized spectrum framework for 5G will enable economies of scale, facilitating cross-border coordination and drifting for users. Consistent spectrum launch timelines and harmonization steps are key enablers for 5G's success. Licenses offering exclusive use of nationwide available bandwidth stay the primary and

preferred authorization model for obtaining 5G spectrum, bringing certainty for investments, predictable network performance and quality for end-user connectivity.

In the current context Dialog and Mobitel both have planned to deploy the initial 5G in the C band (3.3-3.8 GHz) which follows the global trend. After getting some maturity in the 5G domain we can go for the mm wave band in 28GHz for super data layer. This is ideal for a market like Sri Lanka where the investment need to carefully done and coverage plays a major role in the internet penetration.

Also during the TRCSL interview it was found that there is another good potential in 2-6 GHz band in the 2.6 GHz range. This band is currently occupied only by SLT, using only 30MHz from a total bandwidth of 190 MHz. China Telecom, which is a leading operator in China also uses this band for their initial 5G deployment. However, this need to carefully analyzed because we need to use harmonized bands for 5G since it will be beneficial in the long run as stated earlier in this spectrum policy frame work.

5.2 Spectrum Management

As discussed earlier this has 3 dimensions.

1. Spectrum efficiency
2. Spectrum sharing
3. Spectrum Trading

5.2.1 Spectrum efficiency

5.2.1.1 Which technology to use for broadband?

As stated in the earlier chapters, we must always allow to use the higher technology to increase the spectral efficiency. In Sri Lanka we have two primary technologies to offer broadband (3G and LTE). But from the following table 5.6, it is clear that LTE's spectral efficiency is 4 times larger than the 3G technology. Hence the operators must always for the currently available higher technology for broadband deployments. From the interviews I found that Dialog and Mobitel has heavily invested on LTE network deployments and will be done in the future as well. Hutch/Etisalat merger entity is now started deploying LTE but the Airtel has no spectrum bands to initiate the LTE deployments.

Table 5.6: Technology vs Spectrum Efficiency

Higher the Technology

Technology	Spectrum Efficiency (bits/S/Hz)
GSM	0.4
WCDMA	0.5
HSPA+	4.2
LTE	16.3
LTE-A	30

Higher the BW Efficiency

Source: 3GGP

We also can further increase the spectrum efficiency using carrier aggregation techniques and MIMO (multiple Input and Multiple Output) two technologies. These features are included releases 10 - 12 for LTE standard, that comprise LTE-Advance. In MIMO multiple paths are used to increase the throughput. Furthermore, Carrier Aggregation (CA) is a popular method to increase the spectrum utilization specially when the spectrum is fragmented. In CA Both intra- and inter-band is supported. Initial LTE-A CA deployments have utilized two carriers to improve peak download rates. This is a change on how the spectrum has been employed by operators, and empowers the operator to combine different spectrum and provide higher throughputs. But still the device penetration which support 4.5G is very low.

The accessibility of larger contiguous blocks of spectrum therefore makes it possible for operators to move to more complex technology releases, offering higher rates to consumers. By way of instance, a move from 4×4MIMO to 8×8 MIMO leads to a doubling of peak rates (see Figure 5.17 under).

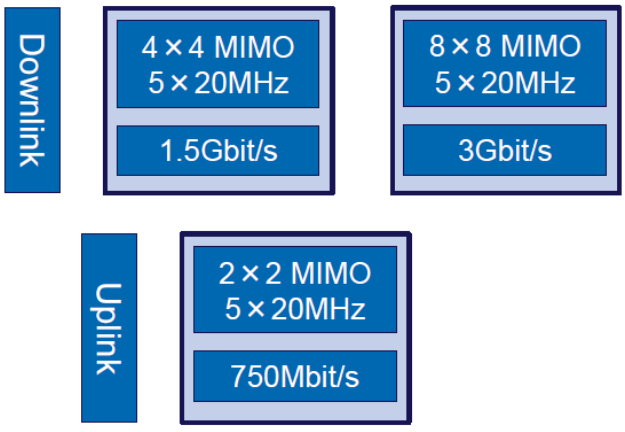


Figure 5.17: Evolution of the peak theoretical downlink speeds

Source: Huawei

I did a calculation for Mobitel and Dialog network spectrum and found that with following LTE A features we can achieve 300+ Mbps speeds in the macro network.

- 4x4 MIMO
- CA with 1800 MHz 4x4 MIMO+ 2100 MHz 2x2 MIMO+ 3 MHz 2x2 MIMO
- 256 QAM (Near site speeds)

5.2.1.2 The importance of continuous spectrum band for broadband

During the interviews and data analysis I found that two dominant broadband spectrum of 1800 MHz and 2100 are both having fragmented spectrum blocks as follows,

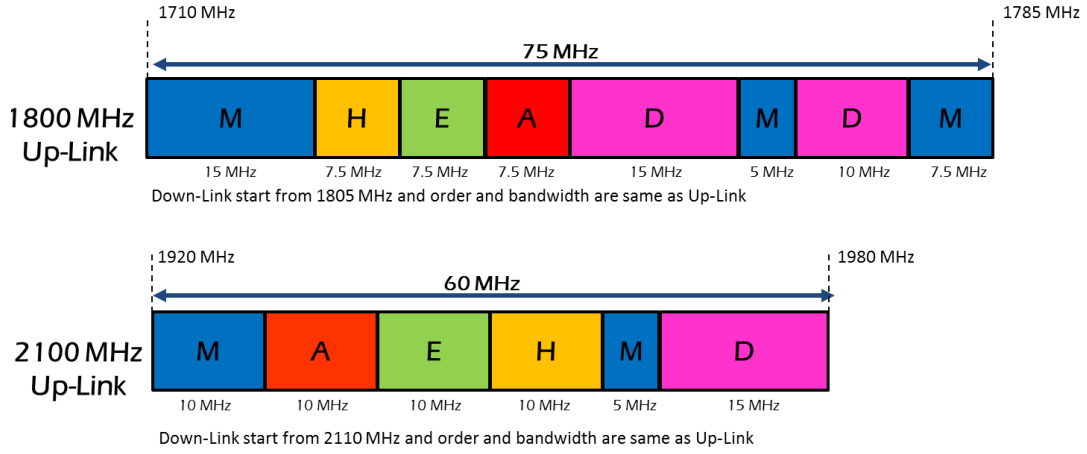


Figure 5.18: 1800 and 2100 MHz spectrum allocation, Sri Lanka

Source: TRCSL

This fragmented spectrum blocks have a severe effect to Mobitel and Dialog data speeds offered to customers. The maximum speed is effectively reduced by half due to this in the 1800 LTE spectrum of Mobitel. I have analyzed this problem for Mobitel operator and found the limitation of fragmented spectrum.

The RRU (Radio Resource Unit) is used to transmit the RF signal and it has two power amplifiers for both GSM 1800 and LTE technologies. Also this power amplifier has an instant bandwidth which means the range of frequencies it can cover at one time.

Hence as depicted in the picture when we use GSM and LTE both in the same RRUs we can use the 2x2 MIMO feature. Because if we define the GSM 1800 frequencies in

one power amplifier it cannot define the far away spectrum of LTE band in the same power amplifier due to the limitation of the instantaneous Bandwidth of the power amplifier. Hence the LTE effective speed gets reduced by half due to this. If we want to define LTE with 2x2 MIMO we need to shut down GSM 1800 or need to use an additional RRU for that purpose which will increase the CAPEX and OPEX in that same time. This is highly inefficient use of the spectrum where all the Mobitel users speed gets half due to the spectrum fragmentation.

- LTE 15 SISO (1x1 MIMO) – Max Speed 52 Mbps
- LTE 15 MIMO (2x2 MIMO) – Max Speed 102 Mbps

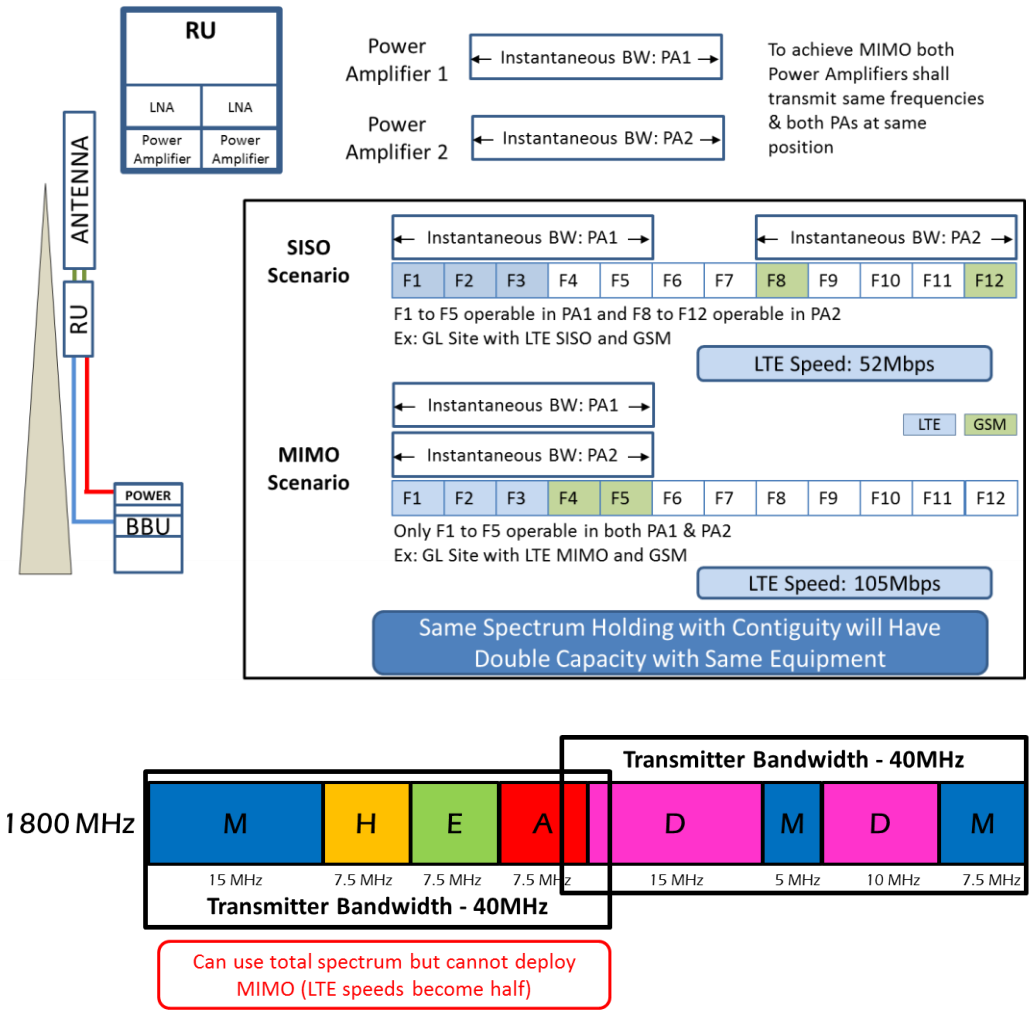


Figure 5.19: Mobitel LTE speed problem due to 1800 MHz fragmented spectrum

Source: Author

Furthermore, if the spectrum gets continuous both Mobitel and Dialog can upgrade their LTE speeds to 20 MHz 2x2 MIMO configuration by re-farming the GSM spectrum for LTE release and enhance the LTE speeds as follows to all their customers. Because when the spectrum is continuous operators can do innovative initiatives for higher LTE speeds.

- Dialog from 15 MHz 2x2 MIMO (102 Mbps) → 20 MHz 2x2 MIMO (200 Mbps)
- Mobitel from 15 MHz 1x1 MIMO (52 Mbps) → 20 MHz 2x2 MIMO (200 Mbps)

Also there is another key drawback with the fragmented spectrum blocks in 1800 and 2100 MHz. It can lead to PIM (Passive inter-modulation). PIM is very common in the networks systems. It shows up when two or more RF signals are mixed together via the nonlinear devices (Figure 5.20). If the nonlinearity is caused by the passive device, such as connectors, antennas, cables and any contact of dissimilar metals, the inter-modulation is called passive inter-modulation, or PIM.

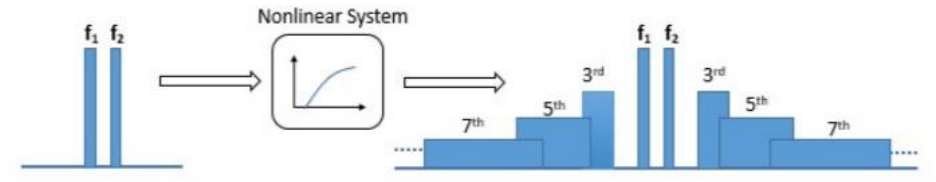


Figure 2.1 Inter-modulation of Two Carries

Figure 5.20: Inter-modulation of two carriers

Source: PIM analysis, Ericsson

I have analyzed the PIM effect to Sri Lankan mobile operator's bands and found the problem is severe in the IBS (In building systems) where all the RF signals of all operators gets mixed in the DAS (Distributed Antenna System) where severe interference is caused to inter operators and intra operator bands.

From the below PIM table, I found many combinations of PIM with intra operator bands and inter operator bands.

- Intra Operator bands PIM effect

1. Mobitel LTE band (First 15 MHz) and GSM 1800 (Mid 5 MHz)
2. Mobitel GSM 1800 (Mid 5 MHz) and 2100 3G first two carriers

- Inter operator PIM effect – Mobitel LTE Band and Dialog GSM 1800

Table 5.7: PIM Effect to Sri Lankan Mobile operators

1800M	TX		RX		2100M	TX		RX	
1800 SubBand1	1805.0	1820.0	1710.0	1725.0	2100 SubBand1	2110.0	2120.0	1920.0	1930.0
1800 SubBand2	1857.5	1862.5	1762.5	1767.5	2100 SubBand2	2150.0	2155.0	1960.0	1965.0
1800 SubBand3	1872.5	1880.0	1777.5	1785.0					

	1805	1806	1807	1808	1809	1810	1811	1812	1813	1814	1815	1816	1817	1818	1819	1820	1857.5	1858	1859	1860	1861	1862	1862.5	1872.5	1873	1874	1875	1876	1877	1878	1879	1880	2110	2111	2112	2113	2114	2115	2116	2117	2118	2119	2120	2151	2152	2153	2154	2155
1805	1805	1804	1803	1802	1801	1800	1799	1798	1797	1796	1795	1794	1793	1792	1791	1790	1752.5	1752	1751	1750	1749	1748	1747.5	1737.5	1737	1736	1735	1734	1733	1732	1731	1730	1500	1499	1498	1497	1496	1495	1494	1493	1492	1491	1490	1459	1458	1457	1456	1455
1806	1807	1806	1805	1804	1803	1802	1801	1800	1799	1798	1797	1796	1795	1794	1793	1792	1754.5	1754	1753	1752	1751	1750	1749.5	1739.5	1739	1738	1737	1736	1735	1734	1733	1732	1502	1501	1500	1499	1498	1497	1496	1495	1494	1493	1492	1461	1460	1459	1458	1457
1807	1809	1808	1807	1806	1805	1804	1803	1802	1801	1800	1799	1798	1797	1796	1795	1794	1756.5	1756	1755	1754	1753	1752	1751.5	1741.5	1741	1740	1739	1738	1737	1736	1735	1734	1504	1503	1502	1501	1500	1499	1498	1497	1496	1495	1494	1463	1462	1461	1460	1459
1808	1811	1810	1809	1808	1807	1806	1805	1804	1803	1802	1801	1800	1799	1798	1797	1796	1758.5	1758	1757	1756	1755	1754	1753.5	1743.5	1743	1742	1741	1740	1739	1738	1737	1736	1506	1505	1504	1503	1502	1501	1500	1499	1498	1497	1496	1465	1464	1463	1462	1461
1809	1813	1812	1811	1810	1809	1808	1807	1806	1805	1804	1803	1802	1801	1800	1799	1798	1760.5	1760	1759	1758	1757	1756	1755.5	1745.5	1745	1744	1743	1742	1741	1740	1739	1738	1508	1507	1506	1505	1504	1503	1502	1501	1500	1499	1498	1467	1466	1465	1464	1463
1810	1815	1814	1813	1812	1811	1810	1809	1808	1807	1806	1805	1804	1803	1802	1801	1800	1762.5	1762	1761	1760	1759	1758	1757.5	1747.5	1747	1746	1745	1744	1743	1742	1741	1740	1510	1509	1508	1507	1506	1505	1504	1503	1502	1501	1500	1469	1468	1467	1466	1465
1811	1817	1816	1815	1814	1813	1812	1811	1810	1809	1808	1807	1806	1805	1804	1803	1802	1764.5	1764	1763	1762	1761	1760	1759.5	1749.5	1749	1748	1747	1746	1745	1744	1743	1742	1512	1511	1510	1509	1508	1507	1506	1505	1504	1503	1502	1471	1470	1469	1468	1467
1812	1819	1818	1817	1816	1815	1814	1813	1812	1811	1810	1809	1808	1807	1806	1805	1804	1766.5	1766	1765	1764	1763	1762	1761.5	1751.5	1751	1750	1749	1748	1747	1746	1745	1744	1514	1513	1512	1511	1510	1509	1508	1507	1506	1505	1504	1473	1472	1471	1470	1469
1813	1821	1820	1819	1818	1817	1816	1815	1814	1813	1812	1811	1810	1809	1808	1807	1806	1768.5	1768	1767	1766	1765	1764	1763.5	1753.5	1753	1752	1751	1750	1749	1748	1747	1746	1516	1515	1514	1513	1512	1511	1510	1509	1508	1507	1506	1475	1474	1473	1472	1471
1814	1823	1822	1821	1820	1819	1818	1817	1816	1815	1814	1813	1812	1811	1810	1809	1808	1770.5	1770	1769	1768	1767	1766	1765.5	1755.5	1755	1754	1753	1752	1751	1750	1749	1748	1518	1517	1516	1515	1514	1513	1512	1511	1510	1509	1508	1477	1476	1475	1474	1473
1815	1825	1824	1823	1822	1821	1820	1819	1818	1817	1816	1815	1814	1813	1812	1811	1810	1772.5	1772	1771	1770	1769	1768	1767.5	1757.5	1757	1756	1755	1754	1753	1752	1751	1750	1520	1519	1518	1517	1516	1515	1514	1513	1512	1511	1510	1479	1478	1477	1476	1475
1816	1827	1826	1825	1824	1823	1822	1821	1820	1819	1818	1817	1816	1815	1814	1813	1812	1774.5	1774	1773	1772	1771	1770	1769.5	1759.5	1759	1758	1757	1756	1755	1754	1753	1752	1522	1521	1520	1519	1518	1517	1516	1515	1514	1513	1512	1481	1480	1479	1478	1477
1817	1829	1828	1827	1826	1825	1824	1823	1822	1821	1820	1819	1818	1817	1816	1815	1814	1776.5	1776	1775	1774	1773	1772	1771.5	1761.5	1761	1760	1759	1758	1757	1756	1755	1754	1524	1523	1522	1521	1520	1519	1518	1517	1516	1515	1514	1483	1482	1481	1480	1479
1818	1831	1830	1829	1828	1827	1826	1825	1824	1823	1822	1821	1820	1819	1818	1817	1816	1778.5	1778	1777	1776	1775	1774	1773.5	1763.5	1763	1762	1761	1760	1759	1758	1757	1756	1526	1525	1524	1523	1522	1521	1520	1519	1518	1517	1516	1485	1484	1483	1482	1481
1819	1833	1832	1831	1830	1829	1828	1827	1826	1825	1824	1823	1822	1821	1820	1819	1818	1780.5	1780	1779	1778	1777	1776	1775.5	1765.5	1765	1764	1763	1762	1761	1760	1759	1758	1528	1527	1526	1525	1524	1523	1522	1521	1520	1519	1518	1487	1486	1485	1484	1483
1820	1835	1834	1833	1832	1831	1830	1829	1828	1827	1826	1825	1824	1823	1822	1821	1820	1782.5	1782	1781	1780	1779	1778	1777.5	1767.5	1767	1766	1765	1764	1763	1762	1761	1760	1530	1529	1528	1527	1526	1525	1524	1523	1522	1521	1520	1489	1488	1487	1486	1485
1857.5	1910	1909	1908	1907	1906	1905	1904	1903	1902	1901	1900	1899	1898	1897	1896	1895	1857.5	1857	1856	1855	1854	1853	1852.5	1842.5	1842	1841	1840	1839	1838	1837	1836	1835	1605	1604	1603	1602	1601	1600	1599	1598	1597	1596	1595	1564	1563	1562	1561	1560
1858	1911	1910	1909	1908	1907	1906	1905	1904	1903	1902	1901	1900	1899	1898	1897	1896	1858.5	1858	1857	1856	1855	1854	1853.5	1843.5	1843	1842	1841	1840	1839	1838	1837	1836	1606	1605	1604	1603	1602	1601	1600	1599	1598	1597	1596	1565	1564	1563	1562	1561
1859	1913	1912	1911	1910	1909	1908	1907	1906	1905	1904	1903	1902	1901	1900	1899	1898	1860.5	1860	1859	1858	1857	1856	1855.5	1845.5	1845	1844	1843	1842	1841	1840	1839	1838	1608	1607	1606	1605	1604	1603	1602	1601	1600	1599	1598	1567	1566	1565	1564	1563
1860	1915	1914	1913	1912	1911	1910	1909	1908	1907	1906	1905	1904	1903	1902	1901	1900	1862.5	1862	1861	1860	1859	1858	1857.5	1847.5	1847	1846	1845	1844	1843	1842	1841	1840	1610	1609	1608	1607	1606	1605	1604	1603	1602	1601	1600	1569	1568	1567	1566	1565
1861	1917	1916	1915	1914	1913	1912	1911	1910	1909	1908	1907	1906	1905	1904	1903	1902	1864.5	1864	1863	1862	1861	1860	1859.5	1849.5	1849	1848	1847	1846	1845	1844	1843	1842	1612	1611	1610	1609	1608	1607	1606	1605	1604	1603	1602	1571	1570	1569	1568	1567
1862	1919	1918	1917	1916	1915	1914	1913	1912	1911	1910	1909	1908	1907	1906	1905	1904	1866.5	1866	1865	1864	1863	1862	1861.5	1851.5	1851	1850	1849	1848	1847	1846	1845	1844	1614	1613	1612	1611	1610	1609	1608	1607	1606	1605	1604	1573	1572	1571	1570	1569
1862.5	1920	1919	1918	1917	1916	1915	1914	1913	1912	1911	1910	1909	1908	1907	1906	1905	1867.5	1867	1866	1865	1864	1863	1862.5	1852.5	1852	1851	1850	1849	1848	1847	1846	1845	1615	1614	1613	1612	1611	1610	1609	1608	1607	1606	1605	1574	1573	1572	1571	1570
1872.5	1940	1939	1938	1937	1936	1935	1934	1933	1932	1931	1930	1929	1928	1927	1926	1925	1887.5	1887	1886	1885	1884	1883	1882.5	1872.5	1872	1871	1870	1869	1868	1867	1866	1865	1635	1634	1633	1632	1631	1630	1629	1628	1627	1626	1625	1594	1593	1592	1591	1590
1873	1941	1940	1939	1938	1937	1936	1935	1934	1933	1932	1931	1930	1929	1928	1927	1926	1888.5	1888	1887	1886	1885	1884	1883.5	1873.5	1873	1872	1871	1870	1869	1868	1867	1866	1636	1635	1634	1633	1632	1631	1630	1629	1628	1627	1626	1595	1594	1593	1592	1591
1874	1943	1942	1941	1940	1939	1938	1937	1936	1935	1934	1933	1932	1931	1930	1929	1928	1890.5	1890	1889	1888	1887	1886	1885.5	1875.5	1875	1874	1873	1872	1871	1870	1869	1868	1638	1637	1636	1635	1634	1633	1632	1631	1630	1629	1628	1597	1596	1595	1594	1593
1875	1945	1944	1943	1942	1941	1940	1939	1938	1937	1936	1935	1934	1933	1932	1931	1930	1892.5	1892	1891	1890	1889	1888	1887.5	1877.5	1877	1876	1875	1874	1873	1872	1871	1870	1640	1639	1638	1637	1636	1635	1634	1633	1632	1631	1630	1599	1598	1597	1596	1595
1876	1947	1946	1945	1944	1943	1942	1941	1940	1939	1938	1937	1936	1935	1934	1933	1932	1894.5	1894	1893	1892	1891	1890	1889.5	1879.5	1879	1878	1877	1876	1875	1874	1873	1872	1642	1641	1640	1639	1638	1637	1636	1635	1634	1633	1632	1601	1600	1599	1598	1597
1877	1949	1948	1947	1946	1945	1944	1943	1942	1941	1940	1939	1938	1937	1936	1935	1934	1896.5	1896	1895	1894	1893	1892	1891.5	1881.5	1881	1880	1879	1878	1877	1876	1875	1874	1644	1643	1642	1641	1640	1639	1638	1637	1636	1635	1634	1603	1602	1601	1600	1599
1878	1951	1950	1949	1948	1947	1946	1945	1944	1943	1942	1941	1940	1939	1938	1937	1936	1898.5	1898	1897	1896	1895	1894	1893.5	1883.5	1883	1882	1881	1880	1879	1878	1877	1876	1646	1645	1644	1643	1642	1641	1640	1639	1638	1637	1636	1605	1604	1603	1602	1601
1879	1953	1952	1951	1950	1949	1948	1947	1946	1945	1944	1943	1942	1941	1940	1939	1938	1900.5	1900	1899	1898	1897	1896	1895.5	1885.5	1885	1884	1883	1882	1881	1880	1879	1878	1648	1647	1646	1645	1644	1643	1642	1641	1640	1639	1638	1607	1606	1605	1604	1603
1880	1955	1954	1953	1952	1951	1950	1949	1948	1947	1946	1945	1944	1943	1942	1941	1940	1902.5	1902	1901	1900	1899	1898	1897.5	1887.5	1887	1886	1885	1884	1883	1882	1881	1880	1650	1649	1648	1647	1646	1645	1644	1643	1642	1641	1640	1609	1608	1607	1606	1605
2110	2415	2414	2413	2412	2411	2410	2409	2408	2407	2406	2405	2404	2403	2402	2401	2400	2362.5	2362	2361	2360	2359	2358	2357.5	2347.5	2347	2346	2345	2344	2343	2342	2341	2340	2110	2109	2108	2107	2106	2105	2104	2103	2102	2101	2100	2069	2068	2067	2066	2065
2111	2417	2416	2415	2414	2413	2412	2411	2410	2409	2408	2407	2406	2405	2404	2403	2402	2364.5	2364	2363	2362	2361	2360	2359.5	2349.5	2349	2348	2347	2346	2345	2344	2343	2342	2112	2111	2110	2109	2108	2107	2106	2105	2104	2103	2102	2071	2070	2069	2068	2067
2112	2419	2418	2417	2416	2415	2414	2413	2412	2411	2410	2409	2408	2407	2406	2405	2404	2366.5	2366	2365	2364	2363	2362	2361.5	2351.5	2351	2350	2349	2348	2347	2346	2345	2344	2114	2113	2112	2111	2110	2109	2108	2107	2106	2105	2104	2073	2072	2071	2070	2069
2113	2421	2420	2419	2418	2417	2416	2415	2414	2413	2412	2411	2410	2409	2408	2407	2406	2368.5	2368	2367	2366	2365	2364	2363.5	2353.5	2353	2352	2351	2350	2349	2348	2347	2346	2116	2115	2114	2113	2112	2111	2110	2109	2108	2107	2106	2075	2074	2073	2072	2071
2114	2423	2422	2421	2420	2419	2418	2417	2416	2415	2414	2413	2412	2411	2410	2409	2408	2370.5	2370	2369	2368	2367	2366	2365.5	2355.5	2355	2354	2353	2352	2351	2350	2349	2348	2118	2117	2116	2115	2114	2113	2112	2111	2110	2109	2108	2077	2076	2075	2074	2073
2115	2425	2424	2423	2422	2421	2420	2419	2418	2417	2416	2415	2414	2413	2412	2411	2410	2372.5	2372	2371	2370	2369	2368	2367.5	2357.5	2357	2356	2355	2354	2353	2352	2351	2350	2120	2119	2118	2117	2116	2115	2114	2113	2112	2111	2110	2079	2078	2077	2076	2075
2116	2427	2426	2425	2424	2423	2422	2421	2420	2419	2418	2417	2416	2415	2414	2413	2412	2374.5	2374	2373	2372	2371	2370	2369.5	2359.5	2359	2358	2357	2356	2355	2354	2353	2352	2122	2121	2120	2119	2118	2117	2116	2115	2114	2113	2112	2081	2080	2079	2078	2077
2117	2429	2428	2427	2426	2425	2424	2423	2422	2421	2420	2419	2418	2417	2416	2415	2414	2376.5	2376	2375	2374	2373	2372	2371.5	2361.5	2361	2360	2359	2358	2357	2356	2355	2354	2124	2123	2122	2121	2120	2119	2118	2117	2116	2115	2114	2083	2082	2081	2080	2079
2118	2431	2430	2429	2428	2427	2426	2425	2424	2423	2422	2421	2420	2419	2418	2417	2416	2378.5	2378	2377	2376	2375	2374	2373.5	2363.5	2363	2362	2361	2360	2359	2358	2357	2356	2126	2125	2124	2123	2122	2121	2120	2119	2118	2117	2116	2085	2084	2083	2082	2081
2119	2433	2432	2431	2430	2429	2428	2427	2426	2425	2424	2423	2422	2421	2420	2419	2418	2380.5	2380	2379	2378	2377	2376	2375.5	2365.5	2365	2364	2363	2362	2361	2360	2359	2358	2128	2127	2126	2125	2124	2123	2122	2121	2120	2119	2118	2087	2086	2085	2084	2083
2120	2435	2434	2433	2432	2431	2430	2429	2428	2427	2426	2425	2424	2423	2422	2421	2420	2382.5	2382	2381	2380	2379	2378	2377.5	2367.5	2367	2366	2365	2364	2363	2362	2361	2360	2130	2129	2128	2127	2126	2125	2124	2123	2122	2121	2120	2089	2088	2087	2086	2085
2151	2497	2496	2495	2494	2493	2492	2491	2490	2489	2488	2487	2486	2485	2484	2483	2482	2444.5	2444	2443	2442	2441	2440	2439.5	2429.5	2429	2428	2427	2426	2425	2424	2423	2422	2192	2191	2190	2189	2188	2187	2186	2185	2184	2183	2182	2151	2150	2149	2148	2147
2152	2499	2498	2497	2496	2495	2494	2493	2492	2491	2490	2489	2488	2487	2486	2485	2484	2446.5	2446	2445	2444	2443	2442	2441.5	2431.5	2431	2430	2429	2428	2427	2426	2425	2424	2194	2193	2192	2191	2190	2189	2188	2187	2186	2185	2184	2153	2152	2151	2150	2149
2153	2501	2500	2499	2498	2497	2496	2495	2494	2493	2492	2491	2490	2489	2488	2487	2486	2448.5	2448	2447	2446	2445	2444	2443.5	2433.5	2433	2432	2431	2430	2429	2428	2427	2426	2196	2195	2194	2193	2192	2191	2190	2189	2188	2187	2186	2155	2154	2153	2152	2151
2154	2503	2502	2501	2500	2499	2498	2497	2496	2495	2494	2493	2492	2491	2490	2489	2488	2450.5	2450	2449	2448	2447	2446	2445.5	2435.5	2435	2434	2433	2432	2431	2430	2429	2428	2198	2197	2196	2195	2194	2193	2192	2191	2190	2189	2188	2157	2156	2155	2154	2153
2155	2505	2504	2503	2502	2501	2500	2499	2498	2497	2496	2495	2494	2493	2492	2491	2490	2452.5	2452	2451	2450	2449	2448	2447.5	2437.5	2437	2436	2435	2434	2433	2432	2431	2430	2200	2199	2198	2197	2196	2195	2194	2193	2192	2191	2190	2159	2158	2157	2156	2155

Source: Author

5.2.1.3 Several Options for Band 3 (1800 MHz) continuous plan

As highlighted earlier the spectrum need to be continuous to reap the best benefits out of it. following are two spectrum realignment options which need to deployed on urgent basis. With both Options Dialog and Mobitel can instantly convert the existing LTE Bandwidth from 15 MHz to 20 MHz and improve the majority of the Broadband user speeds from 100 Mbps to 150 Mbps.

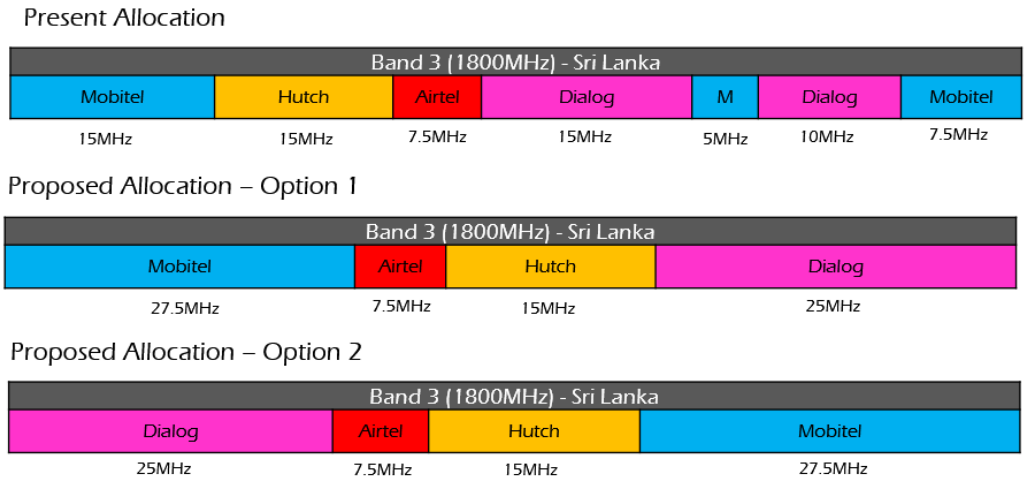


Figure 5.21: Spectrum continuous options

Source: Author

5.2.1.4 Combination of Mobile and Fixed Broadband

Another important factor identified during the interviews is that there is a significant spectrum inefficiency caused due to the divide of mobile and fixed wireless broadband. During the TRCSL interviews I discovered that fixed broadband is introduced to cover give broadband to the rural segment and there are 3 fixed operators now currently at the business.

Table 5.8: Fixed Broadband Sri Lankan operators Spectrum details

Operator	Operation	Frequency Band	Bandwidth for Operator	Total Bandwidth Available in the band	Remaining Bandwidth
SLT	Fixed	Band 38 (2600 TDD)	30MHz	190 MHz	160 MHz
Dialog	Fixed	Band 40 (2300 TDD)	70-75MHz	100MHz	None
Lanka Bell	Fixed	Band 40 (2300 TDD)	20-25MHz		

Source: TRCSL

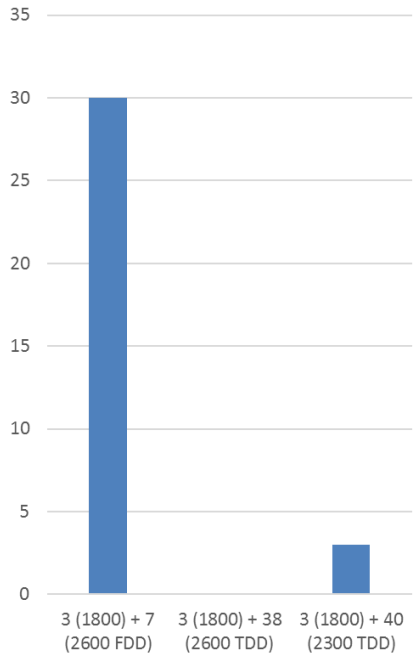
From the spectrum bands we can see clearly lot of unused spectrum especially in the 2.6 GHz band. Also the LTE standard defines only a maximum of 20 MHz for the spectrum bands so Dialog is using the excess frequency carriers to improve the network quality.

Another problem is the band offered for fixed broadband is 2.3/2.6 GHz which are typically used for capacity bands in dense urban and urban areas. Hence the objective of the TRCSL is not significantly met with the fixed broadband services.

When we compare the statistics of internet user in Sri Lanka we can clearly see people adopt mobile broadband heavily compared to fixed broadband. Hence we should release the unused spectrum for mobile use and remove this fixed and mobile demarcation for broadband spectrum release. During the literature survey I found all the developed countries adopt this strategy. They don't have a demarcation for fixed wireless broadband. During the carrier aggregation features also we can see most popular bands are LTE 1800 MHz and 2.6 GHz/2.3 GHz bands (Please refer Table 5.8). With this capacity bands we can cater the broadband demand in the dense urban and urban segments.

Table 5.9: LTE CA deployment bands

Source: GSA Report, October 2015



No.	Contry	Operator	3 (1800) + 7 (2600 FDD)	3 (1800) + 38 (2600 TDD)	3 (1800) + 40 (2300 TDD)
1	Albania	Albania Telekom	✓		
2	Australia	Optus			✓
3	Austria	3	✓		
4	Denmark	3	✓		
5	Denmark	Telenor	✓		
6	Estonia	Elisa	✓		
7	Estonia	EMT	✓		
8	Finland	DNA	✓		
9	Finland	Elisa	✓		
10	Finland	TeliaSonera	✓		
11	France	Bouygues Telecom	✓		
12	France	Free	✓		
13	Germany	DT	✓		
14	Greece	Vodafone	✓		
15	Hong Kong	CSL	✓		
16	Hong Kong	3 HK	✓		
17	Hong Kong	Smartone	✓		
18	Hungary	Magyar Telekom	✓		
19	Indonesia	Smartfren			✓
20	Italy	TIM	✓		
21	Italy	Vodafone	✓		
22	Latvia	Bite	✓		
23	Latvia	LMT	✓		
24	Lithuania	Bite	✓		
25	Maldives	Dhiraagu	✓		
26	New Zealand	Spark	✓		
27	Norway	Telenor	✓		
28	Poland	Polkomtel Plus	✓		
29	Portugal	Meo	✓		
30	Portugal	Vodafone	✓		
31	Romania	Orange	✓		
32	Russia	MTS	✓		
33	Saudi Arabia	STC			✓
34	Singapore	M1	✓		
35	Singapore	StarHub	✓		
36	Slovak Rep	Slovak Telekom	✓		
37	Slovania	Telekom Slovenije	✓		
38	South Africa	Telekom Mobile	✓		
39	Spain	Movistar	✓		
40	Spain	Vodafone	✓		
41	Switzerland	Salt	✓		
42	Switzerland	Swisscom	✓		
43	UK	EE	✓		

Source: GSA report, 2015

5.2.2 Spectrum Sharing

From the interviews I found that the regulator has not allow sharing of spectrum in any form. I had a detailed discussion with the TRCSL and they emphasize that this should be done on command control method. I analyzed the results for spectrum amount vs subscriber number in each operators and found that the spectrum is not effectively used specially the bottom end operators. Please refer figure 5.21 for more details.

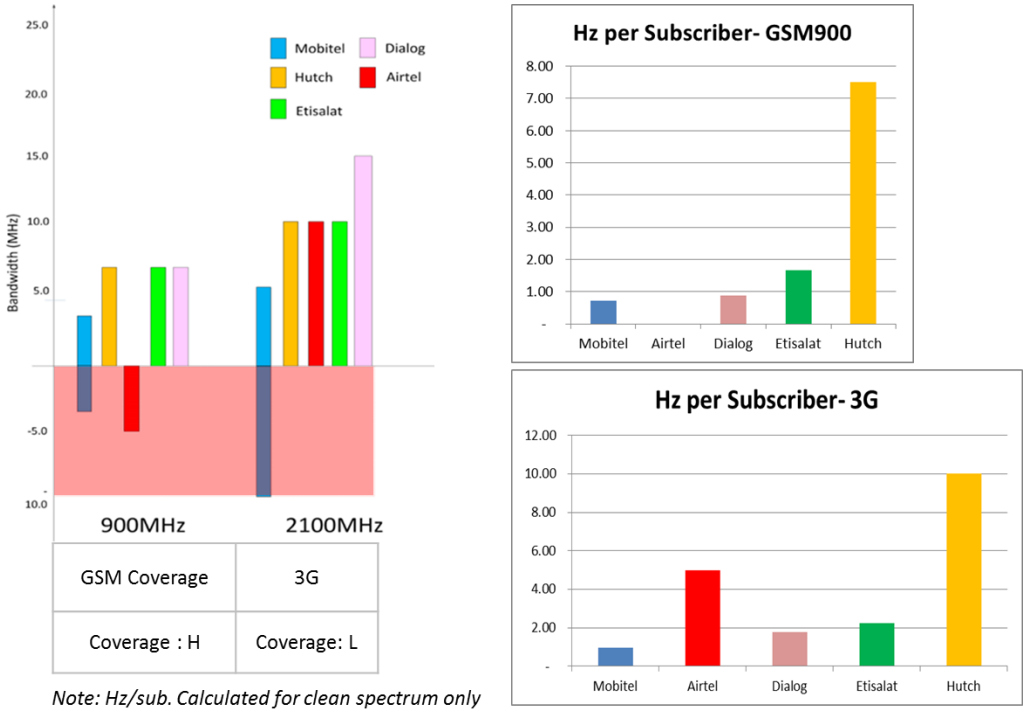


Figure 5.22: Spectrum utilization in different operators, Sri Lanka

Source: TRCSL

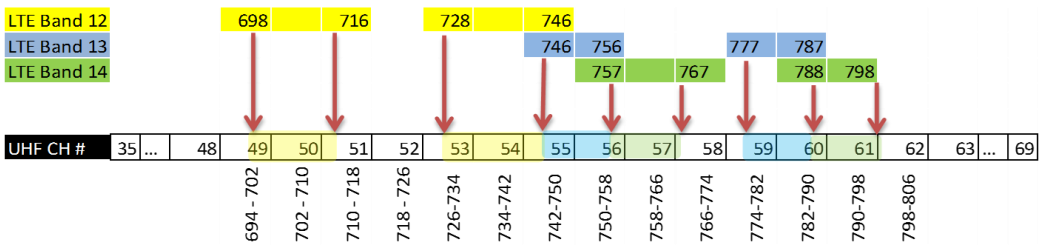
With the above results there is a serious quality impact on the high customer owned operators like Dialog and Mobitel. The low end operator's spectrum is not efficiently used. But with the TRCSL discussion it was concluded if we allow spectrum sharing with operators the leading operators will acquire more spectrum from the low end ones with subsidized prices and the gap between the leading and the bottom ones will further increase creating an imbalance between the completion of all the operators.

But they agreed that if the low end operators can share their spectrum with each other with the guidance of TRCSL and increase the spectrum utilization. With the Hutch and Etisalat merger they are planning to use the existing GSM 1800 and 900 spectrums together so that they can launch LTE in the 1800 and 900 both bands. Also with the merger they have to release the redundant 5 MHz of spectrum on 900 band which can be given to a smaller operator like Airtel. Then Airtel can also launch a sub 1GHz LTE to cover the rural market in economical manner.

5.2.2.1 TV white spacing concept to Sri Lankan market

White Space describes the broadcasting frequencies in the wireless spectrum. Television networks leave gaps between stations for buffering purposes, and this space can be used for 4G LTE to deliver shared broadband internet. White Space may travel up through plants, vegetation, and other barriers up to 10 Km. Spectrum range varies according to the region, however, White Space spectrum ranges from 470 MHz to 790 MHz.

This technology can be used in Sri Lanka also but in a very effective manner because in the rural market all the TV channels does not get transmitted and we can use special gaps to transmit LTE 700 Broadband in these areas. Also we have some reserved bands which are not in the operational mode where some bandwidth can be allocated as LTE band 12,13 and 14 to transmit the LTE 700 signals. This can be ideal solution until the fully fledge analog to digital conversion happens to minimize the digital dividend.



Channel #	Owner	Area of operation	Status
49	Voice of Asia (Pvt.) Networks	N' Eliya	Reserved
50	Dialog Television (Pvt.) Ltd.	Gongala, Kalutara, Magalkanda	Reserved
50	Dialog Television (Pvt.) Ltd.	Colombo	Operational
51	MTV	Hunnasgiriya, Kandy	Operational
51	SLRC	Kalutara	Operational
51	VIS Broadcasting (Pvt.) Ltd.	Nayabedda	Reserved
52	SLRC	Colombo, Kalutara, Namunukula	Operational
52	IWS Holdings	Kandy	Operational
53	People's Media Network (Pvt.) Ltd.	Colombo	Operational
53	Television & Radio Network	Hunnasgiriya, Nayabedda	Operational
54	Dialog Television (Pvt.) Ltd.	Badulla, Madulsima	Reserved
54	Shri Global Television Company (Pvt.) Ltd.	Colombo, Kandy	Reserved
54	VIS Broadcasting (Pvt.) Ltd.	Karagahatenna	Reserved
55	VIS Broadcasting (Pvt.) Ltd.	Colombo, Gongala, Kandy, Nayabedda	Reserved
56	VIS Broadcasting (Pvt.) Ltd.	Gongala, Ratnapura	Reserved
56	Power House Ltd.	Kalutara	Operational
56	MGM Networks (Pvt.) Ltd.	Kandy	Operational
57	Digital Broadcasting Services	Islandwide	Reserved
58	MTV	Colombo, Hunnasgiriya	Operational
59	Digital Broadcasting Services	Islandwide	Reserved
60	E.W. Balasuriya & Company Ltd.	Colombo	Operational
61	SLRC	Islandwide	Reserved
62	Shri Global Television Company (Pvt.) Ltd.	Gongala	Reserved
62	Sumathi Holdings	Colombo	Operational

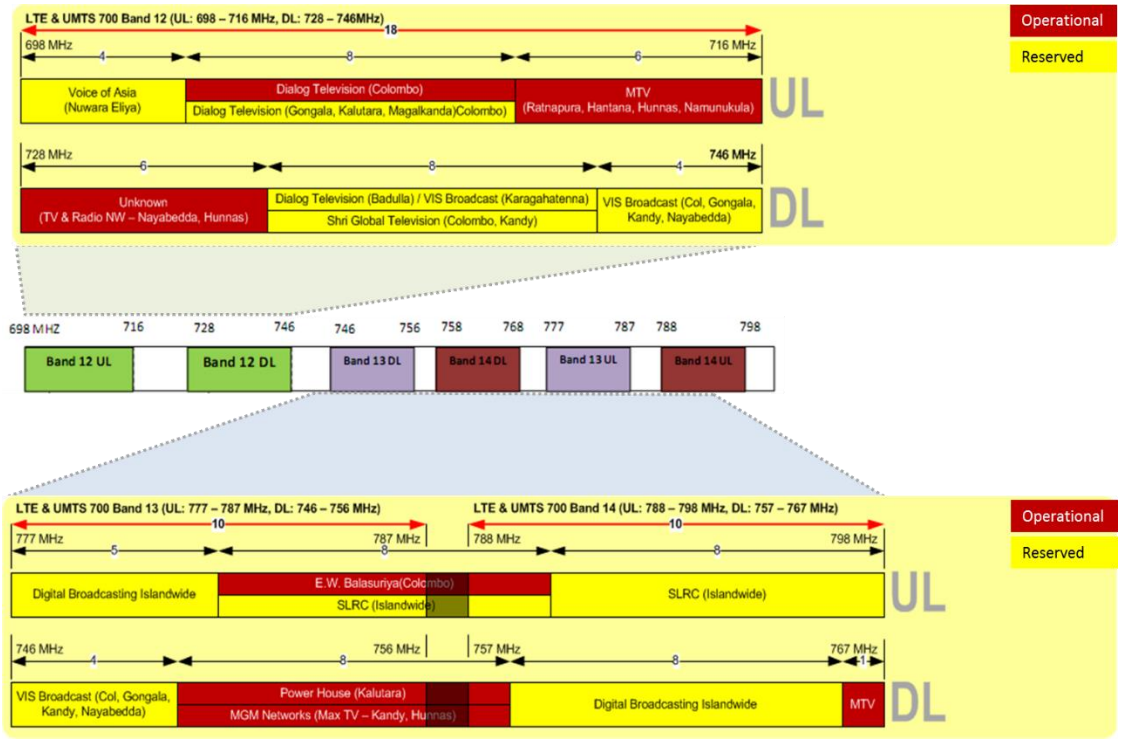


Figure 5.23:TV broadcast spectrum vs possible LTE spectrum bands

Source: TRCSL

5.2.2.2 Licensed Shared Access

LSA was developed as a method of providing access to licensed bands which otherwise wouldn't be possible in certain European nations. A lot of the work on LSA thus far has been around for the 2.3 GHz band where LSA is going to be high utilized in the Europe region. Table 5.9 shows a forecast on the impact of LSA for broadband coverage population.

Table 5.10: Opening the 2.3 GHz band with LSA

Parameter	2015	2020	2025	2030
Equivalent population coverage with LSA	71%	83%	84%	84%
Equivalent population coverage without LSA[9]	1%	17%	17%	17%

Source: Plum study, 2015

Sri Lanka also have the opportunity to use LSA with different operators to increase the spectrum utilization but from the interview data it is concluded that this need to done with proper TRCSL guidance.

5.2.2.3 Cognitive Radio as a spectrum sharing technique

Cognitive Radio is fairly a new technology which is still under research and will be beneficial to Sri Lanka in the future. However, there are some features in the LTE 3GGP releases that LTE and GSM can interoperate and share the spectrum within each technology. Hence when the GSM traffic is low the LTE bandwidth gets increased from 3 MHz to 5 MHz and increase the date speeds. Dialog and Mobitel both have deployed this feature in the Sub 1 GHz LTE deployments.

5.2.3 Spectrum Trading

Spectrum trading ensures that spectrum doesn't lie fallow and creates improved flexibility in company planning, but instead is used to provide valuable solutions. Spectrum trading agreements are governed by law and subject to the rules. They may be subject to evaluation under law.

It makes sense for authorities to be notified of spectrum trading agreements and also to grant acceptance. Notification requirements maintain transparency, which makes it clear which entities maintain spectrum use rights and ensuring that trading arrangements aren't anti-competitive. Governments need to implement appropriate and effective methods for managing notification requests of range trading agreements.

During the interviews I found out that that some spectrum is offered to low end operators for subsidized price hence there is some risk for the high end operator to acquire this subsidized spectrum and make profit out of it. TRCSL should carefully monitor this and need to encourage genuine spectrum trades only. Also they should maintain the right balance between the leading and lower end operators otherwise the market competition will collapse.

But if the spectrum is used by another entity like TV broadcasters it can easily make this trade and improve the broadband presence in the country. By trading both parties get benefited hence some restrictions which have for spectrum release can be

accommodated easily with this trading strategy. But TRCSL intervention is necessary at the beginning because once you give coverage it will be very hard to restore the coverage if the spectrum need to be returned to the original owner.

5.3 Spectrum Licensing

As discussed earlier this has 3 dimensions.

1. Auction and cost of access
2. License obligations
3. Technology neutrality

5.3.1.1 Auction and cost of access

During the pre-commercial mobile era, spectrum allocation was done on following three methods

1. First Come First Served: Giving license to the first applicant for it, if that is the only one
2. Beauty contests: Asking applicants to make written requests for the license, and allocating the licenses to those making the most convincing case
3. Reserving particular entity: Specially for which there was excess demand at a zero or negligible price (sometimes referred to as lotteries)

But with the dawn of mobile technology the Auction has displaced earlier methods. Here, licenses are awarded to the highest bidders in the auction which generated the highest income to the government.

From the interview data I have summarized the advantages of using Auction as a spectrum allocation mechanism which is best suited for a developing country like Sri Lanka.

- More demand than available spectrum
- Generates substantial revenue for the state
- Efficient spectrum usage - In an auction, firms are betting on their ability to make a profit on the license. If they over bid, they have deceived themselves,

and will pay the price. This should mean that licenses tend to go to those best able to exploit them

- Want a mechanism that is fair, transparent and robust (none have been legally challenged yet)
- TRCSL put license conditions and if license condition is not met TRCSL can revoke the spectrum

But during the interviews I found that auctions is not the best approach to assign spectrum in Sri Lanka. Because when we analyze the past auction data we see that there is high chance that only the leading operators bid a high value and acquire the spectrum at any cost. They are looking for the future benefits of this spectrum and often over value the spectrum. Hence the low end operators do not have a chance to acquire spectrum through an auction. Hence auction should not be the only way of spectrum allocation. Administrative allocation is encouraged to create fair grounds for all operators. Auction should be used for demand management

To provide high quality, widespread and cheap mobile solutions, mobile operators need predictable and affordable access to radio spectrum. Spectrum coverage is a vital input for a market that is flourishing. Good spectrum pricing policies will improve social and consumer welfare in developing nations. Policies that attempt to maximize state revenues may have a negative impact such as high cost broadband packages and reduced network investment. On average, between 2010 and 2017, spectrum prices in developing markets were three times more than the developed countries. Regulators and governments play a vital part in increasing spectrum costs. Including directly setting high closing rates, placing high auction reserve prices, restriction the distribution of spectrum. A study by GSMA, discovered moderate reserve prices in developing nations were greater than five times those of developed nations over the period considered, after income levels are taken into consideration. Governments appear to be driving these higher prices to maximize state revenues, especially when they are highly indebted or face challenges in accessing financial markets.

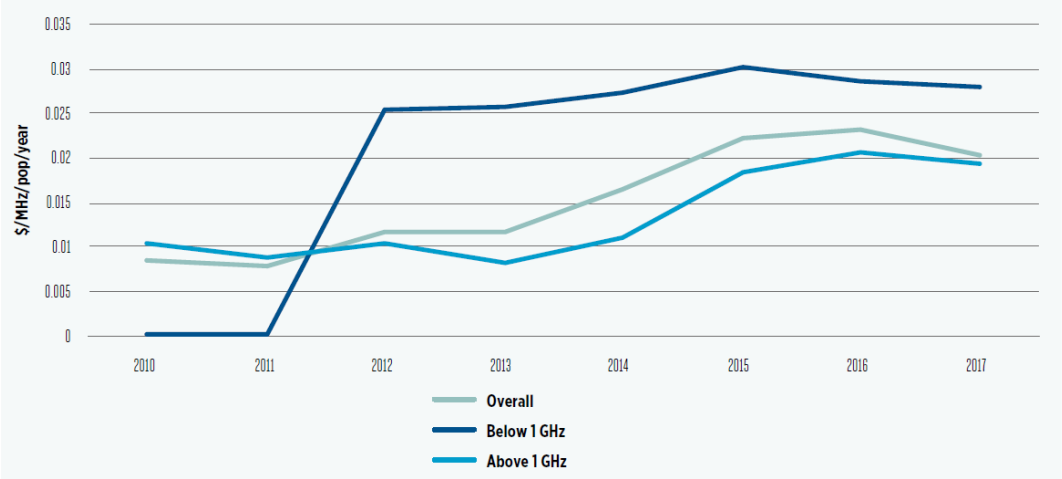


Figure 5.24: Different spectrum prices on developing nations

Source: GSMA Intelligence

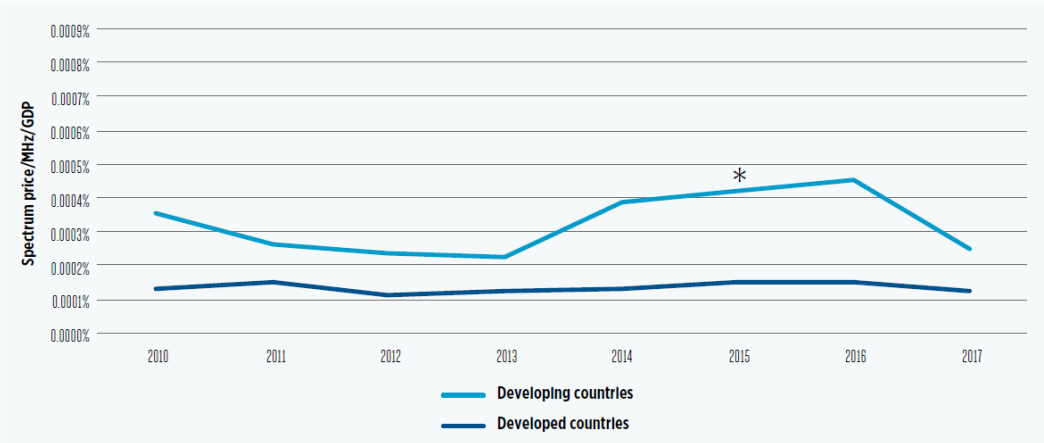


Figure 5.25: Spectrum prices compared on developing vs developed countries

Source: GSMA Intelligence

Although high profits from spectrum assignments increase public capital to help facilitate short term public sector fiscal pressures, there can be significant effects for the mobile broadband market, with mobile services that are much more expensive, lower quality. This prevents societies from using technology to accelerate development and cripples the evolution of the mobile broadband.

High spectrum prices in developing countries are linked to more expensive, lower quality mobile broadband services. From the figure 5.25 we can clearly see the DL and UL speeds gets reduced when the spectrum access cost increases.

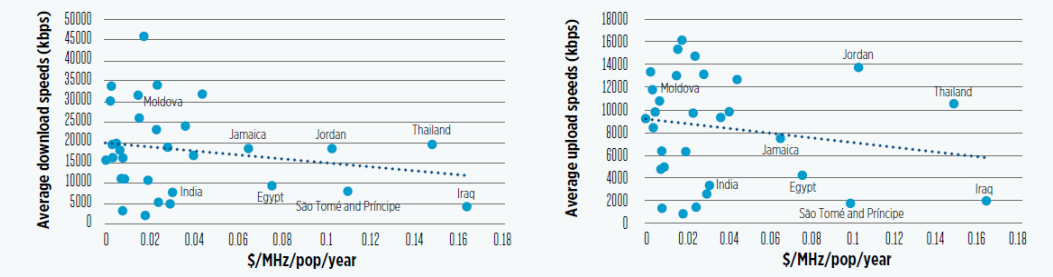


Figure 5.26: Spectrum prices vs Broadband network Quality

Source: GSMA Intelligence

The situation is same in Sri Lanka and fueled more due to the severe competition in the telecom market. As a nation who is struggling with lot of debts, the government use the spectrum to attract short term cash to the economy. Hence we must be very careful at least in future because the higher price will ultimately hinder the broadband investment and quality in the long run.

This will be crucial in the 5G spectrum award scenario because since the 5G spectrum is planned to use a higher frequency band (C band) the operators need more sites compared to the traditional 4G network deployment. Hence high spectrum price on 5G can lead to an unhealthy balance in the 5G total eco system. From the operator interviews they highlighted the need of subsidized price for 5G spectrum.

5.3.1.2 License obligations

Accreditation Governments impose obligations on licensees targeted at achieving policy objectives that are specific. These may include obligations relating to universal accessibility, such as coverage and service commitments.

In Choosing whether to impose such obligations, licensing authorities should consider:

- The benefits and costs of these duties
- Whether there are less costly means to achieve the objectives.

Whether There's a different regulatory obligation required to support universal availability goals will be determined by the market circumstances. Contest frequently compels the access to cheap mobile services given that policy and cost are key elements that operators try to gain a competitive edge over their competitors.

Stringent Coverage or service demands carry risks. Obligations may induce operators to deploy networks and services quicker than commercially or economically practical way. By way of instance, this might arise where technology is still in an early phase with a number of technical flaws remaining or where equipment costs are comparatively high before more widespread worldwide take-up. Obligations may additionally induce operators to incur losses (e.g. by deploying systems in advance of adequate demand for those services) which can cause financial issues particularly for entrants without recognized cash flows.

Some Authorities have sought alternative ways to ensure accessibility in rural areas while avoiding ineffective network duplication as follows,

- The German regulator imposed a shared responsibility on all operators that acquired 800 MHz to organize to ensure coverage in rural regions before rolling out to urban regions
- 800 MHz licenses in Sweden included an obligation to provide broadband to places Currently lacking access to other types of broadband.

During my interviews I found TRCSL also follows the global license obligations during spectrum awards,

1. Coverage targets with spectrum
2. QOS targets with spectrum
3. Broadband Volume
4. New technology targets with spectrum
5. Number of sites deployed with the new spectrum

During the investigation I found that operators are not adhering the coverage targets to the maximum level. They are specifying two parameters as population and geographic coverage percentage. But the rural market is ignored to some extent due to the low ROI. This can be economically achieved in the operator's Sub 1 GHz broadband deployments. Hence in the sub 1GHz spectrum release special attention should be given for the rural market coverage expansion. With that we can come close to the universal coverage targets.

5.3.1.3 Technology neutrality

Technology neutral spectrum licensing is broadly considered as a best practice when assigning spectrum to cellular operators. It empowers mobile operators to re-farm spectrum used for GSM (2G) or 3G to 4G and 5G according to the market demand. This maximizes spectral performance in a specialized sense and maximizes efficient utilization of spectrum. Because of this, users benefit from greater mobile broadband policy, with higher data rates and lower mobile data prices. Additionally, whenever the new technologies come, the previous technology gets underutilized hence that the operator is forced to put new technology at the present spectrum bands.

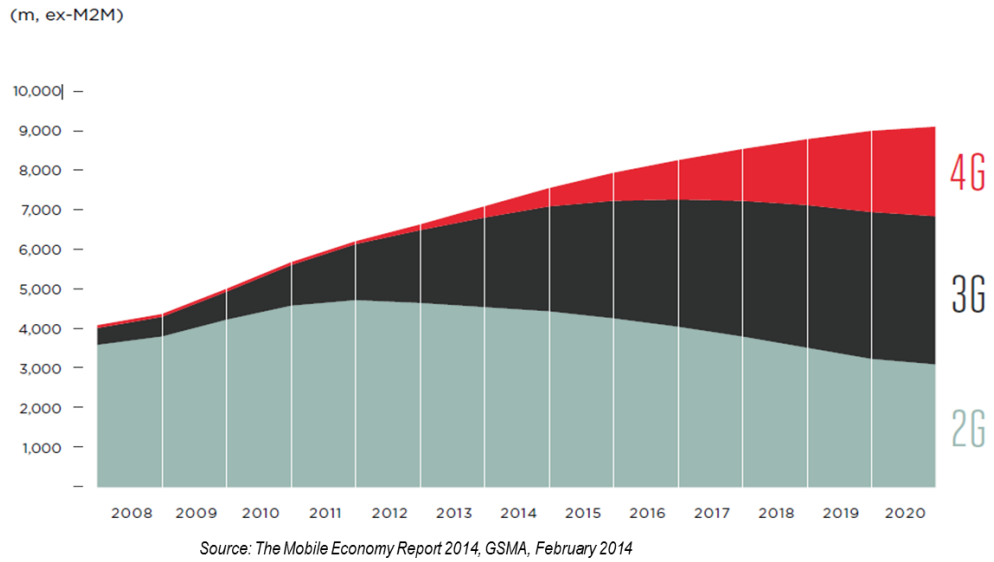


Figure 5.27: Global connections by technology

Source: The Mobile Economy Report, GSMA

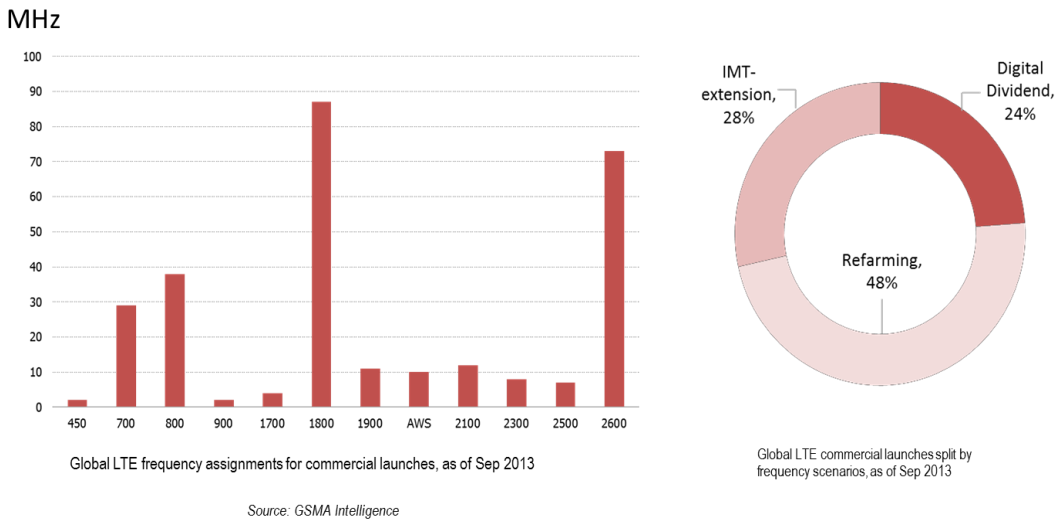


Figure 5.28: Global LTE deployment spectrum bands and assignment

Source: GSMA Intelligence

The spectral efficiency of 4G combined with MIMO is such that re-farming 850 MHz or 900 MHz spectrum from 2G to 4G with 4x4MIMO delivers a 15-fold increase in mobile data capacity. For 1800 MHz, where higher orders of MIMO could be deployed, moving from GSM to 4G delivers a bits/Hz improvement of up to 26 times. Hence technology neutrality plays a key role when formulating policy, pricing and technical requirements for mobile spectrum licenses.

Spectrum re-farming will push the technology from legacy 2G/3G to latest 4G and 5G technologies which delivers significant benefits concerning spectral efficiency and effective use of spectrum. Thus, telecoms regulators should take action to make all spectrum licenses technology neutral.

From the analysis I found that Sri Lanka don't have technology neutrality in the spectrum bands. The operators have to pay a capex amount in order to change the technology in the current spectrum portfolio. This has created a big hurdle to the operators specially the low end ones when they try to deploy a new technology like LTE from their exiting bands. Hence this is must to foster the innovation in the Sri Lankan mobile broadband market.

6. CONCLUSION

The main objective of this research project is to prepare a policy framework to mobile broadband spectrum management for Sri Lanka. after gathering data from the interviews of all parties my final policy suggestions are as follows.

Table 6.1: Mobile Broadband spectrum Policy recommendation

Concept	Variable	SL Policy Recommendations	Impact Analysis
SPECTRUM PLANNING	Band plan harmonization	All spectrum allocation should be done by harmonized bands by ITU and regional body APT	**Pros** 1.All spectrum bands will be free from interference with different technologies 2.Cost of equipment in the total ecosystem will go down due to economies of scale
	Cross-border interference	Extended GSM 900 to be converted to L850 to eliminate Indian ducting interference	**Pros** GSM 900 interference to Airtel and Mobitel will be cleared
		Regional level harmonization is mandatory to eliminate the interference	**Pros** Regional level interference will be eliminated
	Spectrum road map	All mobile operators should deploy Sub 1GHz broadband using LTE 900/850 technologies to increase the rural market Broadband penetration	**Pros** 1.Rural BB penetration will be dramatically improved 2. Good economical BB model will be maintained
		Quick adoption to the LTE 700 for universal access in Sri Lanka	**Pros** Universal BB penetration in the whole country with high capacity
		2.3/2.6 GHz should be released for mobile broadband for dense urban capacity requirement	**Pros** Will fill the future BB capacity demand in the future
		5G spectrum allocation enhanced Broadband as follows 1. Coverage and Capacity Layer: Sub 1 - 6 GHz --> C band (3.3 - 3.8 GHz). This is to be released on urgent basis. 2. Coverage layer for mMTC, eMBB, URLLC: Sub 2 GHz --> This is for massive IoT and Ultra reliable/Low latency applications. Operators can be given the freedom to re-farm the existing spectrum for this purpose 3. Super data layer: Above 6 GHz --> mm wave in 28,40,66-71 GHz. This one to release when 5G network capacity is matured in SL	**Pros** 1.Early release of the spectrum will enable the smooth 5G deployment and customer migration in the country 2. a good 5G network in the country will increase the process automation and increase efficiency in the economy 3. Many new services will be introduced over 5G which will have a positive impact in the country

Concept	Variable	SL Policy Recommendations	Impact Analysis
SPECTRUM MANAGEMENT	Spectrum efficiency	Always use the highest technology for Broadband.	**Pros** Spectrum efficiency will be increased which is mandatory due to the nature of its scarcity
		Spectrum should be continuous to maximize the utilization	
		Should remove the demarcation of mobile and fixed wireless broadband and allow 2.3/2.6 GHz to be used by both parties	
	Spectrum Sharing	- Spectrum sharing for low end operators should be allowed to maximize the utilization - TV white spacing technology should be allowed for mobile operators - LSA should be allowed for mobile operators - Cognitive radio technologies should be encouraged to use	**Pros** Underutilized spectrum will be allowed to use for maximum benefit
	Spectrum Trading	- Spectrum trading to be allowed with the guidance of regulator	**Pros** Underutilized spectrum will be allowed to use for maximum benefit **Cons** Spectrum gap between strong and weak operators can increase and reduce the market competition

Concept	Variable	SL Policy Recommendations	Impact Analysis
SPECTRUM LICENSING	Auctions and cost of access	Auction is not entirely suitable for Sri Lanka. Need to have balance with administrative assignment and auction allocation	**Pros** Spectrum distribution between operators becomes fair and foster good competitive environment
		Need to bring down the high cost in spectrum pricing	**Pros** Cost will down in the total ecosystem of BB which includes the customer BB
		Need to consider the 5G spectrum award for subsidized price for operators	**Pros** Becomes of the high frequency spectrum plan the number of sites in the network in 5G will increase hence the subsidized spectrum will bring down the cost of 5G total ecosystem
	License obligations	Careful monitoring system to introduce to check whether the operators are meeting the license obligations	**Pros** Ensures the given spectrum is utilized effectively to benefit the citizens of the country
		Special attention should be given for rural market broadband penetration enhancement	**Pros** Increase the BB penetration in the rural market where the operators have a low ROI
	Technology Neutrality	All spectrum bands should make technology neutral	**Pros** 1. Increase the spectrum efficiency 2. Makes the operators become innovative 3. New technologies are deployed without any delays benefiting the customers

Source: Author

6.1 Further Research Opportunities

There are few opportunities can be identified to continue this research in future to fulfill all the regulatory aspects related to broadband spectrum management. Since this research is focused only to the mobile broadband, it is possible to do a same kind of research for the fixed wired networks and IoT technologies based on the conclusion made in this thesis. The broadband technologies are growing in a rapid way according to the data requirement in the modern world and the networks are also expanded quickly by the operators to face the competence. Therefore, it is essential to do the researches to find the what should be included and excluded to the broadband policy in the future.

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Appendix A: Survey Responses

Survey Response 01

Resource Person : Manager - Radio Planning and Optimization

Company : Mobitel PVT LTD

Band plan harmonization

1. **Do you thing Spectrum bands should be harmonized at international and regional levels? Please state the importance of this in the Sri Lankan context?**

   Yes, we should use ITU harmonized bands for mobile broadband and it should again be harmonized in the regional level from APT.

2. **How cost is effected by band harmonization?**
   When we harmonize the scale increases and the cost per network equipment and devices gets reduced.
3. **Is there any correlation to cross border interference?**
   If we don't harmonize regionally unwanted interference can effect. Mobitel' s Extended GSM 900 has an interference with the LTE 850 operator in India. The interference is happening due the ducting effect on the Indian – Sri Lanka sea border and it effects seasonally.

Cross-border interference

4. **What is the impact of cross border interference?**
   When we have cross border interference we can get unwanted interference between operator's which hampers the QOS of the customers. Normally if this occurs we need to
5. **What is the effect of this to Quality of service?**
   Since the interferences effects our GSM 900 UL the main KPIs drastically get effected.

- Voice call and Signaling session drops (TCH and SDCCH)
- SMS and SMS related application (e.g. reloads, activation) failures
- Voice quality degradation

- Poor accessibility due to inability to decode signaling channels
- Handover failures

6. **What are the steps need to take to minimize this in Sri Lanka?**
   Band harmonization in the regional level is mandatory to minimize this effect.

Spectrum road map

7. **Does TRCSL need to have a Spectrum Road map?** Yes
8. **How soon this plan need to executed?** Before 3-5 years to the new technology launch.
9. **What is the importance of this?** To keep Sri Lanka up to date with global deployments
10. **What is the importance of sub 1GHz frequency band in the broadband domain?**
    Sri Lanka is a leading position in terms of 2G/3G/4G/5G deployments globally. Sri Lanka' mobile penetration is more than 100% but internet penetration is around 35%. Since Sri Lanka has a majority of population in the rural segment. The most economical way to increase penetration in this segment is Sub 1GHz broadband availability.
11. **How the spectrum bands should be planned to cater the broadband coverage and capacity in the Rural, Sub urban and Urban areas?** High band (1 – 6 GHz) for capacity and below sub 1GHz for rural market
12. **What other steps can be taken to increase the amount of commercially available spectrum for mobile broadband?**
    Currently LTE is the dominant broadband volume driver hence it is critical to introduce a capacity LTE band to support the growing demand. Eg: 2.3/2.6/2.1 GHz
13. **How soon 5G technology should be deployed in Sri Lanka?**
    Commercial deployment should start on 2020 and customer migration to 5G should be mandated by 2022.
14. **What are spectrum bands used for 5G now and future?** C band (3.3-3.8 GHz) / mm Wave above 28 GHz

Spectrum efficiency

15. What should be done to encourage efficient use of spectrum by TRCSL?

- Spectrum allocation should be contiguous and TRC should advocate spectrum contiguity in an event of operator merger.
- Spectrum should be used for technology with highest benefit Eg: LTE over CDMA, LTE over analog TV.

16. What is the advantage of having a continues spectrum for single operator?

- Operator CAPEX requirement per site is reduced. This result in more aggressive CAPEX expansions.
- High speeds for users

17. Does the technology have a relationship with spectrum efficiency?

Yes

Spectrum Sharing

18. What is the use case for spectrum sharing?

- Small players in the market can make use of spectrum sharing to provide technology competition to large players which will help to avoid monopoly in the telecom market.
- Technologies with low spectrum efficiency can be shared within minimal spectrum making way for better technologies with more spectrum efficiency. Eg: combine 1800 bands to pave way for LTE

19. **What do see the benefits of Licensed Shared Access(LSA**)? yes
20. **How to we share the spectrum assigned for different services? Eg: TV White Spacing?** As an intermediate step this option is ideal for rural broadband until digital TV migration is completed.

21. What is the future in Cognitive Radio Technologies?

We have deployed cloud radio features on this category. Also if we had continuous spectrum we can use this feature more efficiently.

Spectrum Trading

22. What are the benefits of spectrum trading?

This is good approach in terms of business but should be strongly regulated because this could lead to monopolistic behavior of large operators in Sri Lanka

23. Can it use to increase the spectrum utilization?

Yes.

Auctions and cost of access

24. Is auction the best way to release spectrum?

Auction should not be the only way of spectrum allocation. Administrative allocation is encouraged to create fair grounds for all operators. Auction should be used for demand management

25. What is your perception about spectrum cost in Sri Lanka?

It is very high compared to developed countries. Base prices should be re considered allowing all operators to participate in competitive bidding by TRCSL

26. Do we have enough consultation with mobile operators and other stakeholders?

Yes, but encouraged to factor in the global and local market trends.

27. Does Auction need to be fair and transparent to all stakeholders?

Yes

License obligations

28. What are the coverage targets with new spectrum?

Coverage target should be set on a time line allocating for business take up

29. What are the QOS targets with new spectrum?

Global and regional benchmark values should be used. The QOS target need to be normalized with ARPU.

30. **What are the new technology targets with new spectrum?**

The technology to be used with the new spectrum release

31. What are the conditions in the license renewal process?

- Coverage targets with spectrum
- QOS targets with spectrum
- New technology targets with spectrum
- Number of sites deployed with the new spectrum

Technology Neutrality

32. Is spectrum should be free from Technology?

Yes

33. How this effects to new technology deployments?

When new technology comes the older technology usage decreases. Hence the utilized spectrum should be used for new technologies without any barriers Eg: Re-farming GSM 1800 spectrum for LTE band 3 deployments

34. How does this promote innovation in the market?

When the spectrum restriction is removed operator can innovate and introduced new technologies without any delays.

Survey Response 02

Resource Person : Senior Manager - Radio Planning and Optimization

Company : Dialog Axiata

Band plan harmonization

1. **Do you thing Spectrum bands should be harmonized at international and regional levels? Please state the importance of this in the Sri Lankan context?**

Yes, it should be harmonized in the global and regional level. Also he pointed out that among the local operator bands should be harmonized to minimize the interference

2. **How cost is effected by band harmonization?**

Through economies of scale the prices get reduced

3. **Is there any correlation to cross border interference?**

Yes. When the band is not harmonized we can get interferences.

Cross-border interference

4. **What is the impact of cross border interference?**

There is an interference to our Dialog 2.3 LTE GHz TDD system from Indian 2.3 GHz LTE operator Reliance Jio. The band 2.3 uses TDD technology to separate DL and UL. Depending on the traffic demand the DL and UL slot interval changes. The interference is coming to Dialog because the Indian operator and Dialog uses two different slot interval configuration in the 2.3 GHz LTE band. Hence as explained earlier due to the ducting effect Indian DL can have an interference to Dialog UL seasonally.

5. **What is the effect of this to Quality of service?**

Since the interference happens to our UL. The QOS of our LTE fixed broadband network drops drastically. Many complaints are present and we are unable to restore their services.

6. **What are the steps need to take to minimize this in Sri Lanka?**

Band harmonization is a must. Also with the TDD systems there should be separate standards to mitigate the interference between DL and UL for different operators.

Spectrum road map

7. **Does TRCSL need to have a Spectrum Road map?** Yes
8. **How soon this plan need to executed?** At least before 2 years.
9. **What is the importance of this?** The new technology adoption can be delayed.
10. **What is the importance of sub 1GHz frequency band in the broadband domain?**

This is must to cover the rural broadband market. We have re-farmed from GSM 900 and allocated 3 MHz LTE. This BW is limited and can't cater the total demand. TRCSL should take actions to release more spectrum in sub 1GHz domain.700 LTE should be expedited.

11. **How the spectrum bands should be planned to cater the broadband coverage and capacity in the Rural, Sub urban and Urban areas?**

High band (1 – 6 GHz) for capacity and below sub 1GHz for rural market.

Also he pointed out that PIM should be taken in to account when spectrum is divided between operators. This is critical when IBS sites are deployed where the RF signal are transmitted through a shared antenna system.

12. **What other steps can be taken to increase the amount of commercially available spectrum for mobile broadband?**

With the high broadband growth LTE 1800 carrier is getting heavily congested in the near future. Hence the 2.6/2.3 GHz spectrum should be allocated to mobile operators also.

13. **How soon 5G technology should be deployed in Sri Lanka?**

Commercial deployment should start on 2020

14. **What are spectrum bands used for 5G now and future?**
    - C band (3.3-3.8 GHz)
    - mm Wave above 28/40/66/71 GHz

Spectrum efficiency

15. What should be done to encourage efficient use of spectrum by TRCSL?

- Spectrum allocation should be contiguous

16. What is the advantage of having a continues spectrum for single operator?

Can deliver high speeds to consumers. Spectrum re-framing can be efficiently used.

17. Does the technology have a relationship with spectrum efficiency?

Yes. Higher technology has higher spectral efficiency. Still we are using analog TV for broadcast purposes which is a very inefficient technology which consumes larger BW. If we convert to digital TV we need very less BW with high quality.

Spectrum Sharing

18. What is the use case for spectrum sharing?

- Spectrum is efficiently utilized.
- Sri Lankan community can benefit ultra-high speed internet
- Promotes innovation

19. **What do see the benefits of Licensed Shared Access(LSA**)? Wi-Fi can be used to load balance the LTE traffic in the hot spot areas in dense urban segment.
20. **How to we share the spectrum assigned for different services? Eg: TV White Spacing?** This is a good suggestion to give rural broadband service. Also since the delay of digital TV conversion.

21. What is the future in Cognitive Radio Technologies?

Good technology research is still ongoing. But we have deployed some features in both GSM 1800 and LTE both which allocates more BW to LTE when the GSM traffic is low.

Spectrum Trading

22. What are the benefits of spectrum trading?

Spectrum should be free from regulation as much as possible. With spectrum trading we can have benefits to both seller and the buyer.

23. Can it use to increase the spectrum utilization?

Yes, definitely

Auctions and cost of access

24. Is auction the best way to release spectrum?

Auction is one of the best ways to allocate resources which have over demand. But it should not be the only way of awarding spectrum

25. What is your perception about spectrum cost in Sri Lanka?

Prices are very high compared to develop countries. When the operator pays a premium price we need to pass that to the end customer. Hence it is not a sustainable model. 5G on the way TRCSL should allocate the spectrum in a subsidize manner.

26. Do we have enough consultation with mobile operators and other stakeholders?

No

27. Does Auction need to be fair and transparent to all stakeholders?

Yes. But some spectrum is allocated in an administrative manner to some operators ignoring the market dynamics.

License obligations

28. What are the coverage targets with new spectrum?

- Population penetration
- Geographic penetration

29. What are the QOS targets with new spectrum?

DL&UL Speeds/Latency etc.

30. **What are the new technology targets with new spectrum?**

New technology deployed site count vs district should be mentioned.

31. What are the conditions in the license renewal process?

- Coverage targets with spectrum
- QOS targets with spectrum

Technology Neutrality

32. Is spectrum should be free from Technology?

Yes

33. How this effects to new technology deployments?

New technology deployments can be deployed with minimum time to market.

34. How does this promote innovation in the market?

When the operator is free from technology they can innovate and deploy technologies according to market demand.

Survey Response 03

Resource Person : Manager - Radio Planning

Company : Hutch/Etisalat

Band plan harmonization

1. **Do you thing Spectrum bands should be harmonized at international and regional levels? Please state the importance of this in the Sri Lankan context?**

Yes. We are a developing country hence we should ideally our investment can be of costly. We need to lower both our CAPEX and OPEX cost structures. Hence we should get the harmonized bands to minimize the cost structure.

Also for roaming requirement bands should be harmonized.

2. **How cost is effected by band harmonization?**

When the band get harmonized the use scale gets high which will reduce the unit cost.

3. **Is there any correlation to cross border interference?**

Yes. When we use harmonized bands we can minimize the interference. Countries wise regulators should have close relationship

Cross-border interference

4. **What is the impact of cross border interference?**

   When the bands are not harmonized we can get unwanted interferences across the borders. Also when the operators are from different nations, it is very hard to troubleshoot the interference.

5. **What is the effect of this to Quality of service?**

   When there is an interference happens QOS gets drastically reduced.

6. **What are the steps need to take to minimize this in Sri Lanka?**

We must use the harmonized bands as much as possible. Also we should keep a close eye on the Asian giants of India and China since those two make a huge contribution for the band harmonization.

Spectrum road map

7. **Does TRCSL need to have a Spectrum Road map?** No
8. **How soon this plan need to executed?** When the standards (ITU/3GGP) get finalized spectrum should be released ASAP.
9. **What is the importance of this?** Existing spectrum need to be considered when introducing new technology
10. **What is the importance of sub 1GHz frequency band in the broadband domain?**

    This is critical for rural broadband. We are now combining both Hutch and Etisalat 900 spectrum and carrying out re-farming activity to release 3 MHz for LTE broadband rural deployments.
11. **How the spectrum bands should be planned to cater the broadband coverage and capacity in the Rural, Sub urban and Urban areas?**

    Rural – Sub 1GHz – High coverage/ Low Capacity

    Urban – 1.8/2.1 GHz – High capacity

    Dense Urban – 1.8/2.1/2.3/2.6 GHz – Ultra high capacity
12. **What other steps can be taken to increase the amount of commercially available spectrum for mobile broadband?**

    Fixed and mobile demarcation can be removed to allocate more spectrum for mobile BB which has the highest demand than fixed wireless BB.
13. **How soon 5G technology should be deployed in Sri Lanka?**

    5G deployment is not matured in the global scale. The device eco system is also still not ready. Hence we must start this on 2021.
14. **What are spectrum bands used for 5G now and future?**
    - C band (3.3-3.8 GHz) – This is the ideal band to start the 5G deployment because of coverage requirement
    - mm Wave – As a super data layer

Spectrum efficiency

15. **What should be done to encourage efficient use of spectrum by TRCSL?**

- Use of spectrum efficient new technologies.

16. **What is the advantage of having a continues spectrum for single operator?**

Spectrum re-framing can be done easily. Spectrum efficiency is high. Can use single RRUs for multi technologies. This saves both Capex and Opex. Eg: 1800 GSM and LTE 1800 in one RRU.

17. Does the technology have a relationship with spectrum efficiency?

Yes. Higher technology has higher spectral efficiency.

Spectrum Sharing

18. What is the use case for spectrum sharing?

- Spectrum efficiency is increased.
- Underutilize areas spectrum can be shared with other operators

19. **What do see the benefits of Licensed Shared Access(LSA**)? Wi-Fi and LTE Can be both share the traffic in hot spot areas in Sri Lanka.
20. **How to we share the spectrum assigned for different services? Eg: TV White Spacing?** Some spectrum used for other technologies are not efficiently used. Eg: 700 MHz use for broadcast TV is using analog TV which is not efficient.

    Also TV spectrum need to be continuous and align so that some spectrum can be released for BB.

21. What is the future in Cognitive Radio Technologies?

We are testing cloud air features for simultaneous operations of GSM 1800 and LTE 1800

Spectrum Trading

22. What are the benefits of spectrum trading?

Spectrum should be free from regulation as much as possible. With spectrum trading we can have benefits to both seller and the buyer.

23. Can it use to increase the spectrum utilization?

Yes, definitely

Auctions and cost of access

24. Is auction the best way to release spectrum?

Small player like us don't have a chance in an Auction. Hence TRCSL must consider a fair playing ground by an administrative approach in spectrum allocation. There should have a base spectrum allocation to all operators and the rest of the spectrum can be auctioned according to the demand.

25. What is your perception about spectrum cost in Sri Lanka?

Spectrum price is very high. Especially if it comes under an auction the price gets multiplied by 2 or 3 times the base price. High price gets transfer to the end customer hence not sustainable model.

26. Do we have enough consultation with mobile operators and other stakeholders?

No

27. Does Auction need to be fair and transparent to all stakeholders?

Yes

<u>License obligations</u>

28. What are the coverage targets with new spectrum?

- Minimum coverage percentage

29. What are the QOS targets with new spectrum?

Standard QOS KPIs

30. **What are the new technology targets with new spectrum?**

New technology deployed site count vs district should be mentioned.

31. What are the conditions in the license renewal process?

- Coverage targets with spectrum
- QOS targets with spectrum
- Should not misuse the spectrum

<u>Technology Neutrality</u>

32. Is spectrum should be free from Technology?

Yes

33. How this effects to new technology deployments?

Fast deployment of new technologies

34. How does this promote innovation in the market?

Operator is free to trial and deploy technologies to the market

Survey Response 04

Resource Person : Senior Manager - Radio Planning and Optimization

Company : Bharati Airtel Lanka

Band plan harmonization

1. **Do you thing Spectrum bands should be harmonized at international and regional levels? Please state the importance of this in the Sri Lankan context?**

Yes. When the spectrum gets harmonized cost is reduced and also reduce the possible interferences between operators.

2. **How cost is effected by band harmonization?**

Due to economies of scale cost is reduced.

3. **Is there any correlation to cross border interference?**

Yes. We have a severe interference from the Indian 850 LTE operator. Their DL gets coincide with out GSM 900 UL. Due to this we have dimensioned our network from 1800 MHz frequency. This has severely affected our profitability because our CAPEX and OPEX is very high compared to other operators.

Cross-border interference

4. **What is the impact of cross border interference?**

   When the bands are not harmonized we can get unwanted interferences across the borders. Our GSM900 interference is a classic example for this scenario

5. **What is the effect of this to Quality of service?**

   Our GSM 900 voice network QOS severely downgraded during the interference

6. **What are the steps need to take to minimize this in Sri Lanka?**

We must use the harmonized bands as much as possible. TRCSL should coordinate with the Indian regulators and should take necessary steps to mitigate this interference

Spectrum road map

7. **Does TRCSL need to have a Spectrum Road map?** No
8. **How soon this plan need to executed?** When the standards get finalized spectrum should be released ASAP.
9. **What is the importance of this?** If we delay this new technology deployment will be delayed
10. **What is the importance of sub 1GHz frequency band in the broadband domain?**

    This is critical for rural broadband. But we don't have any spectrum to deploy this. Our current 900 spectrum has only 5 MHz which cannot be further reduced for LTE
11. **How the spectrum bands should be planned to cater the broadband coverage and capacity in the Rural, Sub urban and Urban areas?**

    Rural – Sub 1GHz

    Urban – 1.8/2.1 GHz

    Dense Urban – 1.8/2.1/2.3/2.6 GHz
12. **What other steps can be taken to increase the amount of commercially available spectrum for mobile broadband?**

    Fixed and mobile demarcation can be removed to allocate more spectrum for mobile BB. Since we don't have a LTE band. If the TRCSL allocate some spectrum in the 2.6GHz band, we are ready to deploy LTE in that band.
13. **How soon 5G technology should be deployed in Sri Lanka?**

    5G deployment is not matured in the global scale. The device eco system is also still not ready.
14. **What are spectrum bands used for 5G now and future?**
    - C band (3.3-3.8 GHz)
    - mm Wave – As a super data layer

<u>Spectrum efficiency</u>

15. **What should be done to encourage efficient use of spectrum by TRCSL?**

- Use of spectrum efficient new technologies.

16. **What is the advantage of having a continues spectrum for single operator?**

    Spectrum re-framing can be done easily.
17. **Does the technology have a relationship with spectrum efficiency?**

Yes. Higher technology has higher spectral efficiency.

Spectrum Sharing

18. What is the use case for spectrum sharing?

- Spectrum efficiency is increased.
- Small operators need to have the flexibility to share their spectrum and give completion to the market leaders.

19. What do see the benefits of Licensed Shared Access(LSA)? Spectrum utilization can be increased

20. How to we share the spectrum assigned for different services? Eg: TV White Spacing? 700 MHz spectrum is ideal for universal broadband service in Sri Lanka. TRCSL should speed up the digital TV conversion

21. What is the future in Cognitive Radio Technologies?

There are some new features in the 3GGP releases which supports spectrum sharing concepts like this.

Spectrum Trading

22. What are the benefits of spectrum trading?

Since there is a severe scarcity in the spectrum. TRCSL should consider giving spectrum from other services.

23. Can it use to increase the spectrum utilization?

Yes

Auctions and cost of access

24. Is auction the best way to release spectrum?

Small player like us don't have a chance in an Auction. Hence TRCSL must consider a fair playing ground to all operators otherwise the gap between the big and small players will increase.

25. What is your perception about spectrum cost in Sri Lanka?

Spectrum price is very high. Prices should make low for developing countries like Sri Lanka.

26. Do we have enough consultation with mobile operators and other stakeholders?

No

27. Does Auction need to be fair and transparent to all stakeholders?

Yes

<u>License obligations</u>

28. What are the coverage targets with new spectrum?

- Coverage targets should be based on the target market of the business plan

29. What are the QOS targets with new spectrum?

Population/Geographic coverage%,

30. What are the new technology targets with new spectrum?

New technology deployed site count

31. What are the conditions in the license renewal process?

- Coverage targets with spectrum
- QOS targets with spectrum

<u>Technology Neutrality</u>

32. Is spectrum should be free from Technology?

Yes

33. How this effects to new technology deployments?

Fast deployment of new technologies

34. How does this promote innovation in the market?

Operator is free to trial and deploy technologies according to market demand

Survey Response 05

Resource Person : Deputy Director – Spectrum Management

Company : TRCSL

Band plan harmonization

1. **Do you thing Spectrum bands should be harmonized at international and regional levels? Please state the importance of this in the Sri Lankan context?**

Yes. When the spectrum gets harmonized cost and interference both gets reduced.

2. **How cost is effected by band harmonization?**

Due to economies of scale cost is reduced.

3. **Is there any correlation to cross border interference?**

Yes. We have one case for Mobitel and Airtel where the Sri Lankan E GSM 900 band gets interfered from the Indian LTE 850 band. This interference is mainly happening in the northern part of Sri Lanka. During the GSM release there was a civil war going in the northern part hence this issue was not addressed at the initial stage. This has resulted regional harmonization conflict.

Cross-border interference

4. **What is the impact of cross border interference?**

   When the bands are not harmonized we can get unwanted interferences across the borders.

5. **What is the effect of this to Quality of service?**

   QOS will drastically drop

6. **What are the steps need to take to minimize this in Sri Lanka?**

We must use the harmonized bands globally and regionally as much as possible. Also we must have a close tie and harmonized with the regional giants like India and China because their deployments plans have a big impact to the total South Asian region.

Spectrum road map

7. **Does TRCSL need to have a Spectrum Road map?** Yes
8. **How soon this plan need to executed?** When the ITU/3GGP standards get finalized and need to wait for the correct demand. If we release the spectrum soon the total ecosystems will collapse. But need to have the right balance. Too much of delay can become a big problem
9. **What is the importance of this?** If we delay this new technology deployment will be delayed
10. **What is the importance of sub 1GHz frequency band in the broadband domain?**

    This is critical for rural broadband. Our plans are to give all the mobile operators at least 3MHz of sub 1 GHz band from 900/850 bands. The only operator who does not have plans is Airtel and we are checking possibility of accommodating it to them.
11. **How the spectrum bands should be planned to cater the broadband coverage and capacity in the Rural, Sub urban and Urban areas?**

    Rural – Sub 1GHz

    Urban – 1.8/2.1 GHz

    Dense Urban – 1.8/2.1/2.6 GHz
12. **What other steps can be taken to increase the amount of commercially available spectrum for mobile broadband?**

    We are now working with operators to release some spectrum for mobile BB. Further information cannot be provided.
13. **How soon 5G technology should be deployed in Sri Lanka?**

    We have given trial licenses to Mobitel and Dialog in C band and commercial spectrum release is WIP
14. **What are spectrum bands used for 5G now and future?**
    - C band (3.3-3.8 GHz) – Initially we are planning to release from this band
    - 2.6 GHz – We have vacant spectrum in this band. We are checking the possibility of releasing this spectrum to 5G as a coverage band.
    - mm Wave – This will be given later

Spectrum efficiency

15. What should be done to encourage efficient use of spectrum by TRCSL?

- Use of spectrum efficient new technologies.

16. What is the advantage of having a continues spectrum for single operator?

Spectrum re-framing can be done easily.

17. Does the technology have a relationship with spectrum efficiency?

Yes. Higher technology has higher spectral efficiency.

Spectrum Sharing

18. What is the use case for spectrum sharing?

We can't allow this for big operators but for small players, spectrum sharing has some way forward.

19. **What do see the benefits of Licensed Shared Access(LSA**)? Spectrum utilization can be increased
20. **How to we share the spectrum assigned for different services? Eg: TV White Spacing?** This is stuck with the Digital TV conversion. This spectrum will not be released any time sooner.

21. What is the future in Cognitive Radio Technologies?

Operators are encouraged to use these within their licensed spectrum limits

Spectrum Trading

22. What are the benefits of spectrum trading?

This is not ideal for a country like Sri Lanka. If we allow this big player will get more spectrum from the small players and the competition will reduce.

23. Can it use to increase the spectrum utilization?

Yes

Auctions and cost of access

24. Is auction the best way to release spectrum?

TRCSL must consider a fair playing ground to all operators otherwise the gap between the big and small players will increase. Hence we will initially allocate a base spectrum for all the operators. Further spectrum will be allocated through auctions with the market demand.

25. What is your perception about spectrum cost in Sri Lanka?

Spectrum price is gazette in the parliament. We are following

26. Do we have enough consultation with mobile operators and other stakeholders?

Yes, thorough consultation of all parties are taken before a decision is made.

27. Does Auction need to be fair and transparent to all stakeholders?

Yes

License obligations

28. What are the coverage targets with new spectrum?

- Population coverage %
- Rural coverage %

29. What are the QOS targets with new spectrum?

Standard KPIs

30. **What are the new technology targets with new spectrum?**

- New technology deployed site count vs District
- Rural BB penetration

31. What are the conditions in the license renewal process?

- Coverage targets with spectrum
- QOS targets with spectrum
- Broadband Volume
- New technology targets with spectrum
- Number of sites deployed with the new spectrum

Technology Neutrality

32. Is spectrum should be free from Technology?

Should be yes, but due to current market completion operators can change the technology in a spectrum by investing one-time payment and getting the approval from TRCSL

33. How this effects to new technology deployments?

Fast deployment of new technologies

34. How does this promote innovation in the market?

Operator is free to trial and deploy technologies according to market demand

Survey Response 06

Resource Person : Manager – RF Service Department

Company : Huawei technologies Lanka company pvt ltd

Band plan harmonization

1. **Do you thing Spectrum bands should be harmonized at international and regional levels? Please state the importance of this in the Sri Lankan context?**

Yes, it should be harmonized in the global and regional level. We can smooth out our supply and installation of the network equipment manufacturing process. We can have a right balance in the device and network ecosystem.

2. **How cost is effected by band harmonization?**

Through economies of scale the prices get reduced in both device and network equipment. The operator gets the benefit of this.

3. **Is there any correlation to cross border interference?**

Yes. When the band is not harmonized we can get interferences.

Cross-border interference

4. **What is the impact of cross border interference?**
   This impact the network quality.
5. **What is the effect of this to Quality of service?**
   When the interference is present the QOS gets reduced and many customer complaints comes.
6. **What are the steps need to take to minimize this in Sri Lanka?**
   Band harmonization is a must.

Spectrum road map

7. **Does TRCSL need to have a Spectrum Road map?** Yes
8. **How soon this plan need to executed?** When the relevant standard gets finalized.

9. **What is the importance of this?** Since we are the equipment manufacturer we need to take the risk and start the network equipment manufacturing. If the spectrum release gets delayed it will hamper the total ecosystem.
10. **What is the importance of sub 1GHz frequency band in the broadband domain?**

This is ideal to cover the rural broadband market. The low frequencies signal travel far and have good in building coverage. This is a good economical way to cover the rural segment which has low population density where do not need high capacity.

11. **How the spectrum bands should be planned to cater the broadband coverage and capacity in the Rural, Sub urban and Urban areas?**

High band (1 – 6 GHz) for capacity and below sub 1GHz for rural market.

12. **What other steps can be taken to increase the amount of commercially available spectrum for mobile broadband?**

With the high broadband growth LTE 1800 carrier is getting heavily congested in the near future. Hence the 2.6/2.3 GHz spectrum should be allocated to mobile operators also.

13. **How soon 5G technology should be deployed in Sri Lanka?**

Commercial deployment should start on 2020

14. **What are spectrum bands used for 5G now and future?**
    - C band (3.3-3.8 GHz)
    - mm Wave above 28/40 GHz

Spectrum efficiency

15. **What should be done to encourage efficient use of spectrum by TRCSL?**

- Spectrum allocation should be contiguous

16. **What is the advantage of having a continues spectrum for single operator?**

Can deliver high speeds to consumers. Spectrum re-framing can be efficiently used.

17. **Does the technology have a relationship with spectrum efficiency?**

Yes. Higher technology has higher spectral efficiency.

Spectrum Sharing

18. What is the use case for spectrum sharing?

- Spectrum is efficiently utilized.
- Promotes innovation

19. **What do see the benefits of Licensed Shared Access(LSA**)? Wi-Fi can be used to load balance the LTE traffic in the hot spot areas in dense urban segment.
20. **How to we share the spectrum assigned for different services? Eg: TV White Spacing?** This is a good suggestion to give rural broadband service. Operators can have universal access through this spectrum band.

21. What is the future in Cognitive Radio Technologies?

We have many cloud air features in LTE which can simultaneously use spectrum for both LTE and GSM.

Spectrum Trading

22. What are the benefits of spectrum trading?

Spectrum should be free from regulation as much as possible. With spectrum trading we can have benefits to both seller and the buyer.

23. Can it use to increase the spectrum utilization?

Yes, definitely

Auctions and cost of access

24. Is auction the best way to release spectrum?

Auction is one of the best ways to allocate resources which have over demand. But it should not be the only way of awarding spectrum

25. What is your perception about spectrum cost in Sri Lanka?

Prices are very high compared to develop countries. When the operator pays a premium price to spectrum his investing capability gets reduced for network infrastructure which can be harmful in the long run.

26. Do we have enough consultation with mobile operators and other stakeholders?

N/A

27. Does Auction need to be fair and transparent to all stakeholders?

N/A

License obligations

28. What are the coverage targets with new spectrum?

- Population penetration
- Geographic penetration

29. What are the QOS targets with new spectrum?

DL&UL Speeds/Latency etc.

30. **What are the new technology targets with new spectrum?**

New technology deployed site count vs district should be mentioned.

31. What are the conditions in the license renewal process?

- Coverage targets with spectrum
- QOS targets with spectrum

Technology Neutrality

32. Is spectrum should be free from Technology?

Yes

33. How this effects to new technology deployments?

New technology deployments can be deployed with minimum time to market.

34. How does this promote innovation in the market?

When the operator is free from technology they can innovate and deploy technologies according to market demand.

Survey Response 07

Resource Person : Head – RF supply and delivery

Company : ZTE Lanka pvt ltd

Band plan harmonization

1. **Do you thing Spectrum bands should be harmonized at international and regional levels? Please state the importance of this in the Sri Lankan context?**

Yes, it should be harmonized in the global and regional level. We can use the economies of scale and the price will be reduced to the total region. It is easy for our future roadmaps. Eg: when the spectrums get harmonized we can plan the future Hardware units with ease.

2. **How cost is effected by band harmonization?**

Through economies of scale the prices get reduced in both device and network equipment.

3. **Is there any correlation to cross border interference?**

Yes. When the band is not harmonized we can get interferences.

Cross-border interference

4. **What is the impact of cross border interference?**
   This impact the network quality.
5. **What is the effect of this to Quality of service?**
   When the interference is present the QOS gets reduced and many customer complaints comes.
6. **What are the steps need to take to minimize this in Sri Lanka?**
   Band harmonization is a must. Operators within Sri Lanka need to get the band harmonization. Then the interference effect is minimized

Spectrum road map

7. **Does TRCSL need to have a Spectrum Road map?** Yes

8. **How soon this plan need to executed?** When the relevant standard gets finalized.
9. **What is the importance of this?** The technologies can be deployed with minimum time to market
10. **What is the importance of sub 1GHz frequency band in the broadband domain?**

This is ideal to cover the rural broadband market in Sri Lanka. Also this is very economical for operators. Eg: LTE 900 can be easily deployed using the same RRUs for GSM. Hence additional network investment is minimized. Also operator gets the benefit of covering more area from less number of sites.

11. **How the spectrum bands should be planned to cater the broadband coverage and capacity in the Rural, Sub urban and Urban areas?**
    - Rural – Sub 1GHz
    - Urban – 1.8/2.1 GHz
    - Dense Urban – 1.8/2.1/2.6 GHz
12. **What other steps can be taken to increase the amount of commercially available spectrum for mobile broadband?**

Some spectrum bands are still not released. Those can be released on urgent basis for mobile broadband Eg: 2.6 GHz band for LTE

13. **How soon 5G technology should be deployed in Sri Lanka?**

Commercial deployment should start on 2020

14. **What are spectrum bands used for 5G now and future?**
    - C band (3.3-3.8 GHz)
    - mm Wave above 28/40 GHz

Spectrum efficiency

15. **What should be done to encourage efficient use of spectrum by TRCSL?**

- Spectrum allocation should be contiguous

16. **What is the advantage of having a continues spectrum for single operator?**

    Can deliver high speeds to consumers. Spectrum re-framing can be efficiently used.

17. Does the technology have a relationship with spectrum efficiency?

Yes. Higher technology has higher spectral efficiency.

Spectrum Sharing

18. What is the use case for spectrum sharing?

- Spectrum is efficiently utilized.
- Promotes innovation

19. What do see the benefits of Licensed Shared Access(LSA)?

Spectrum utilization can be increased.

20. How to we share the spectrum assigned for different services? Eg: TV White Spacing? This is a good suggestion to give rural broadband service.

21. What is the future in Cognitive Radio Technologies?

many cloud air features are available in LTE which the spectrum can be simultaneously for both LTE and GSM.

Spectrum Trading

22. What are the benefits of spectrum trading?

Spectrum should be free from regulation as much as possible. With spectrum trading we can have benefits to both seller and the buyer.

23. Can it use to increase the spectrum utilization?

Yes, definitely

Auctions and cost of access

24. Is auction the best way to release spectrum?

Auction is one of the best ways to allocate resources which have over demand. But it should not be the only way of awarding spectrum

25. What is your perception about spectrum cost in Sri Lanka?

Prices are very high compared to develop countries. When the operator pays a premium price to spectrum his investing capability gets reduced for network infrastructure which can be harmful in the long run.

26. Do we have enough consultation with mobile operators and other stakeholders?

N/A

27. Does Auction need to be fair and transparent to all stakeholders?

N/A

License obligations

28. What are the coverage targets with new spectrum?

- Population penetration
- Geographic penetration

29. What are the QOS targets with new spectrum?

DL&UL Speeds/Latency etc.

30. What are the new technology targets with new spectrum?

New technology deployed site count vs district should be mentioned.

31. What are the conditions in the license renewal process?

- Coverage targets with spectrum
- QOS targets with spectrum

Technology Neutrality

32. Is spectrum should be free from Technology?

Yes

33. How this effects to new technology deployments?

New technology deployments can be deployed with minimum time to market.

34. How does this promote innovation in the market?

When the operator is free from technology they can innovate and deploy technologies according to market demand.