Telecommunications Authority of Trinidad and Tobago

Consultative Document

on the

Spectrum Management Framework

(First Round)

(Version 2.0)

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List of Abbreviations

ACMA	Australian Communications and Media Authority
BWA	broadband wireless access
DTT	digital terrestrial television
GHz	gigahertz
IMT	International Mobile Telecommunications
ITU	International Telecommunication Union
kHz	kilohertz
MHz	megahertz
NSP	National Spectrum Plan
TATT	Telecommunications Authority of Trinidad and Tobago

1 Introduction

1.1 Rationale

Since 2015, the Government of the Republic of Trinidad and Tobago (GORTT) has implemented a series of initiatives that, collectively, seek to further develop and transform the national economy, leading to the development of an information society and the attainment of developed country status. The aim is to support the *National Development Strategy (NDS) 2016–2030,* also known as Vision 2030, which outlines the country's aspiration to attain "first world nation status" by 2030.

One of the major initiatives undertaken was the drafting of a *National Information and Communications Technology Plan* (NICT) for the period 2018 to 2022, branded as the ICT Blueprint, in which several programmes aimed at the development of the information and communications technology (ICT) sector were identified.

The pertinent thematic area of the ICT Blueprint: Improving Connectivity focuses on advancing the deployment of ICT infrastructure to support securely connected people, businesses and government. The need to manage the radio frequency spectrum efficiently and effectively, consistent with the objects of the Telecommunications Act, Chap. 47:31 (the Act), aligns with this thematic area.

Consequently, a key regulatory framework of the Telecommunications Authority of Trinidad and Tobago (the Authority) is the *Spectrum Management Framework* (the Framework), to guide the planning, authorisation and monitoring of the national spectrum resource.

1.2 Purpose

The Framework:

i. identifies the new and emerging technologies that promote the efficient and effective use of the spectrum.

ii. identifies the spectrum that is to be made available for the constantly evolving radio spectrum needs, and the spectrum management system.

iii. determines the optimal spectrum policies, rules and regulations for the planning, authorisation and monitoring of the national spectrum resource.

This Framework sits above the *National Spectrum Plan* (NSP) and provides the foundation for the NSP. The NSP offers a framework for the regulation of the spectrum, in an orderly and efficient manner, as outlined in figure 1, in accordance with the Authority's mandate.

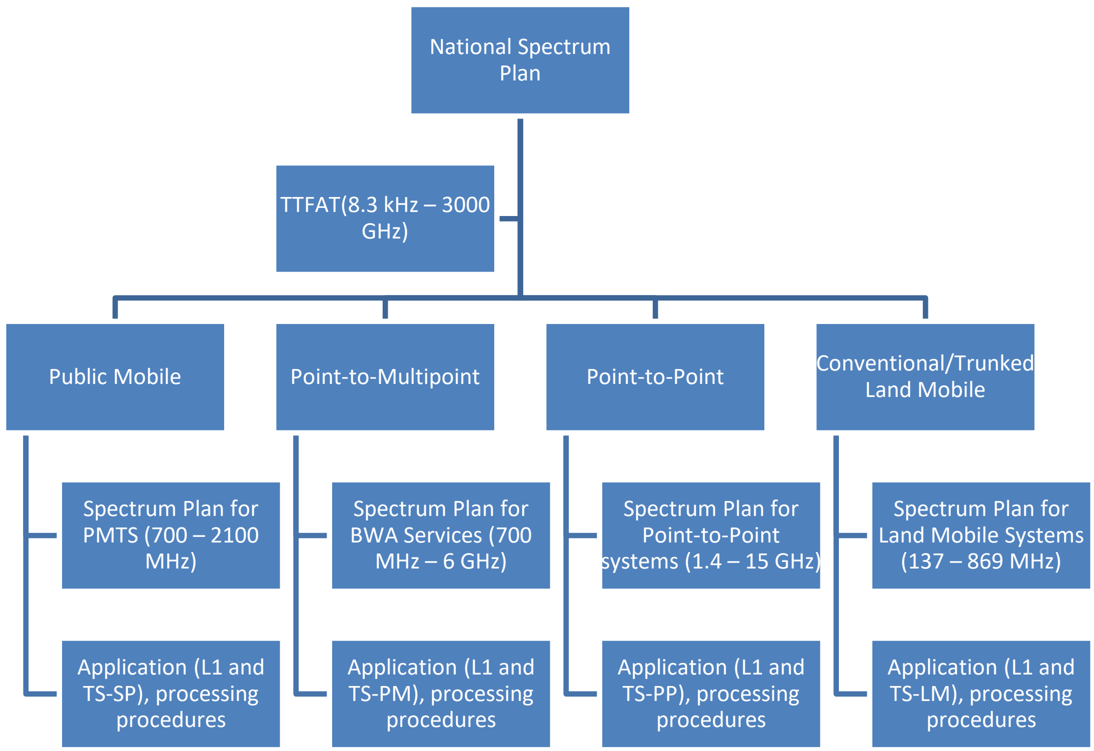

Figure 1: The national spectrum planning structure

1.3 Background

The radio frequency spectrum (hereafter called spectrum) is a scarce national resource that is essential to the provision of a wide range of activities, including national defence, public safety, air, land and sea transportation, broadcasting and commercial telecommunications services. Careful management of the spectrum is essential to ensure that the unique social and economic benefits that it provides are fully realised.

Under the Act, spectrum is defined as "the continuous range of electromagnetic wave frequencies used for telecommunications". The allocated radio spectrum, as defined in the International Telecommunication Union (ITU) Radio Regulations, covers the frequency range from 8.3 kHz to 3,000 GHz.

The use of the spectrum is indispensable for the provision of a wide range of telecommunications services. Over the past few years, developments in telecommunications technologies and the demand for new telecommunications services have placed an even greater demand on the use of the spectrum. The importance of mobility whilst communicating and "cutting the cord" for connecting devices are also driving the exponential use of the spectrum.

Some of the telecommunications services facilitated through the use of the spectrum include voice, data and multimedia services and other services such as national security, public safety, disaster warning, weather forecasts, aeronautical and marine communications.

It is widely acknowledged that the availability of a good telecommunications infrastructure and high-quality, cost-effective telecommunications services are essential to the social and economic development of a country. It is therefore imperative that the radio spectrum resource is effectively managed, to optimise the delivery of telecommunications services in Trinidad and Tobago, and facilitate the achievement of the country's social and economic goals.

ITU defines spectrum management as "the combination of administrative, scientific and technical procedures necessary to ensure efficient operation of radio communication services without causing harmful interference".

1.4 Objectives

The primary objectives of this Framework are to:

i. derive an effective mechanism for the management of the spectrum in an era of converged technologies and telecommunications services, so that a wide range of services can be made available to the public.

ii. provide a responsive, effective and flexible approach to meeting the needs of users of the spectrum.

iii. ensure there is adequate provision of spectrum for national security, law enforcement and emergency services.

iv. promote the economic and orderly utilisation of the spectrum for the operation of all means of telecommunications.

v. allocate spectrum resources for the provision of telecommunications services in an effective and efficient manner.

vi. recover the cost incurred in the management of the spectrum and realise an adequate economic benefit to the country for the use of the spectrum resources.

vii. provide an efficient, equitable and transparent system for the establishment of the fee regime for the use of the spectrum, taking into account both the commercial and non-commercial use of the spectrum.

viii. promote the country's interest at regional and international fora with respect to the use of the spectrum.

1.5 Relevant Legislation

The relevant sections of the Act which were taken into consideration in the drafting of the Framework are stated hereunder.

"Section 18(1)(i):

"Subject to the provisions of this Act, the Authority may exercise such functions and powers as are imposed on it by this Act and in particular –

(i) plan, supervise, regulate and manage the use of the radio frequency spectrum, including–

(i) the licensing and registration of radio frequencies and call signs to be used by all stations operating in Trinidad and Tobago or on any ship, aircraft, or other vessel or satellite registered in Trinidad and Tobago;

(ii) the allocation, assignment and reallocation or reassignment of frequency bands where necessary.

Section 36(1):

Subject to subsection (2), no person shall –

(a) establish, operate or use a radio-communication service;

(b) install, operate or use any radio transmitting equipment; or

(c) establish, operate or use any radio-communication service on board any ship, aircraft, or other vessel in the territorial waters or territorial airspace of Trinidad and Tobago, other than a ship of war or a military aircraft or satellite registered in Trinidad and Tobago

without a licence granted by the Authority.

Section 41:

(1) The Authority shall regulate the use of the spectrum in order to promote the economic and orderly utilisation of frequencies for the operation of all means of telecommunications and to recover the cost incurred in the management of the spectrum.

(2) The Authority shall develop a spectrum plan in order to regulate the use of the spectrum.

(3) The National Spectrum Plan shall be made available to the public in the manner prescribed by the Authority.

(4) The National Spectrum Plan shall state how the spectrum shall be used and the procedures for licensing frequency bands.

(5) The procedures referred to in subsection (4) may include, but are not limited to -

(a) procedures for licensing frequency bands by auction;

(b) procedures for licensing frequency bands by tender;

(c) procedures for licensing frequency bands at a fixed price; or

(d) procedures for licensing frequency bands on stated criteria.

Section 42:

(1) Subject to subsection (2), the Authority may, in accordance with the spectrum plan allocate and re-allocate frequency bands.

(2) In the allocation or assignment and re-allocation or reassignment of frequency bands by the Authority priority shall be given to the needs of the State in respect of matters of national security.

Section 43:

The Authority, in exercising the functions under Sections 36 to 42, shall take into account-

a) the objects of the Act;

b) the impact of the spectrum plan on existing and future use;

c) the efficient use of the spectrum;

d) the Convention;

e) applicable international standards, conventions and other agreements; and

f) any other relevant matters having regard to the circumstances of the case."

1.6 Review Cycle

This Framework will be modified as deemed necessary by the Authority to adapt to the needs of the telecommunications industry and to meet changing circumstances. When the need for modification is identified, the Authority will announce its intention to review the Framework and any interested party or entity in the telecommunications sector or any appropriate industry forum may suggest changes to the Framework. Questions or concerns regarding the maintenance of this Framework may be directed to the Authority via e-mail consultation@tatt.org.tt.

1.7 The Consultation Process

In accordance with its *Procedures for Consultation in the Telecommunications Sector of Trinidad and Tobago (ver. 2.0, 2010)*, the Authority sought the views of the general public and other stakeholders regarding the proposals made in this Framework.

Versions 0.3 and 0.4 of the Framework were released for public consultation in June 2005 and September 2005, respectively. In revising the document, the comments and recommendations received during both rounds of consultation were considered. In November 2005, the Framework (version 1.0) was approved and published in the form of a recommended spectrum management policy to support spectrum management regulations and submitted to the Authority's line Ministry -- the then Ministry of Public Administration and Digital Transformation.

In May 2021, the Framework was revised based on changes in the industry for the introduction of new spectrum management policies for public telecommunications services. The revised consultative document (version 2.0) will be made available for the first round of public consultation on October 8, 2021, for a period of four weeks.

1.8 Relevant Documents

This Framework is prescribed alongside other policies, plans and regulations prepared by the Authority, including the following:

i. *Authorisation Framework for the Telecommunications and Broadcasting Sectors of Trinidad and Tobago.*

ii. *Radio Spectrum Regulations.*

iii. *Trinidad and Tobago Frequency Allocation Table.*

iv. *Price Regulation Framework for Telecommunications Services in Trinidad and Tobago.*

v. *Telecommunications (Fees) Methodology.*

2 Current Spectrum Management Regime in Trinidad and Tobago

The radio spectrum continues to play a vital role in the provision of a broad variety of radiocommunications services – public, private and governmental. Effective management of the spectrum is closely associated with national law, policy statements, radio regulations and having a long-term spectrum plan.

Following the proclamation of the Act, the general procedural framework adopted for spectrum management in Trinidad and Tobago was generally in conformity with the *Table of Frequency Allocations* established by ITU and, except in certain cases, specifically in accordance with the allocations for Region 2.

2.1 Spectrum Planning

The Authority has developed the NSP as the framework for regulating the use of the spectrum and allowing its efficient use in an orderly manner. The NSP serves as an umbrella document for the various spectrum plans, commencing with the *Trinidad and Tobago Frequency Allocation Table* (TTFAT) that governs the use of the radio spectrum for specific radio services and/or public telecommunications networks and services based on established spectrum management policies[1].

Trinidad and Tobago is classified by ITU under Region 2, which covers the Americas and some of the eastern Pacific Islands. From the ITU Radio Regulation *Table of Frequency Allocations* for Region 2, the Authority decides for each frequency band which service(s) to adopt based on national requirements and priority. Inputs to the spectrum planning process are shown in figure 2.

[1] https://tatt.org.tt/AboutTATT/SpectrumManagement/SpectrumPlanning.aspx

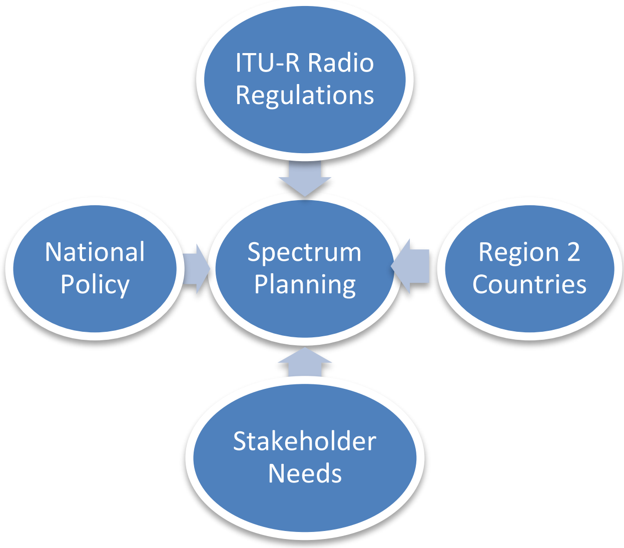

Figure 2: Spectrum planning in Trinidad and Tobago

Other spectrum plans developed by the Authority to regulate specified radiocommunications services include:

i. *Spectrum Plan for the Accommodation of Point-to-Point Radiocommunications Systems*
ii. *Spectrum Plan for the Accommodation of Land Mobile Radiocommunications Systems*
iii. *Spectrum Plan for the Accommodation of Broadband Wireless Access Services*
iv. *Spectrum Plan for the Accommodation of Public Mobile Telecommunications Services*
v. *Spectrum Plan for the Accommodation of Radio and Television Broadcast Auxiliary Services*

For the purpose of assignment, the spectrum plans are further divided into a number of channels to develop the channelling plans. Once the necessary border coordination has been successfully carried out, the frequencies or channels are then assigned to eligible users.

The spectrum assigned to wireless apparatus[2] for the provision of telecommunications and broadcasting services is based generally on the Region 2 allocations, on a "first come, first served" basis.

[2] "Wireless apparatus" means any apparatus, appliance, or instrument used or capable of use in wireless communications.

2.2 Spectrum Authorisation

Since 2004, spectrum authorisation or licensing in Trinidad and Tobago has been traditionally classified according to the following two approaches, in accordance with the *Authorisation Framework for the Telecommunications and Broadcasting Sectors of Trinidad and Tobago, 2005*, namely, individual licences and class licences.

2.2.1 Individual Licences

The individual licence approach to spectrum authorisation gives exclusive right to the use of the spectrum, in addition to the right via administrative process (comparative selection), market mechanisms (auction), or the right to trade spectrum in secondary markets. Under this approach, licensees follow the rules established by the Authority.

Individual licences are generally customised and detailed, with the Authority requiring that telecommunications and/or broadcasting services are provided in a particular manner by a particular service provider. Individual licences granted by the Authority are station licences and spectrum licences.

A station licence is also known as the “command and control” approach to spectrum authorisation and is issued for a particular transmitter at a particular location for a particular use. The licence gives “first in time” priority to the holder of the licence against any other entity in relation to any disputes over interference. Stations licences are normally acquired “over the counter” and tend to be short term in nature, typically between three and five years. An administrative pricing arrangement usually applies, often in the form of annual fees plus an up-front application fee. Station licences do not confer exclusivity, so they have little intrinsic value (except providing a right to operate a particular transmitter).

Commonly referred to as the “property rights” approach to spectrum authorisation, a spectrum licence was created to allow licensees, or in some cases, persons authorised by a licensee, to operate radiocommunications devices within a specified frequency band (and/or time and/or geographic area, as required). There is flexibility with respect to changing equipment, such as antennas. This type of licence is seen as technology-neutral, subject to compliance with certain technical limits in order to avoid harmful interference. Spectrum licences give the holder of the licence the exclusive right to use and manage the frequency band in a pre-determined geographic area – typically for mobile networks. These licences are long term in duration, i.e., 10 to 20 years. They are intended to correspond with the expected life of a mobile network.

2.2.2 Class Licences

Class licences allow the use of specific radiocommunications devices, as long as they operate within specific technical and operational parameters. This type of licensing applies to low-power, mass consumer market devices, such as cordless telephones, cellular mobile handsets and citizen's band two-way radios, which do not need to be individually co-coordinated to minimise the potential for interference to other systems and services.

In some jurisdictions, class-licensed frequency bands may also be referred to as "unlicensed" bands or open authorisation, which is effectively exemption from the need for an individual licence, or "right of use". There is an increasing trend towards global allocations of the spectrum for such systems (e.g., 2.4 GHz and 5 GHz).

Interference is a common problem for class-licensed devices, although technologies are evolving towards devices that employ digital signal processing which enables coexistence without interference.

2.3 Mechanisms for Granting Licences

Different spectrum licensing mechanisms are necessary for dealing with the distinct needs of individual radio users and the time period that a frequency band may be open for licensing (ITU-R 2015).

The mechanisms used for authorising telecommunications services, networks and resources on the national and international levels, include:

i. First come, first served
ii. Comparative valuation or "beauty contest"
iii. Lotteries
iv. Auctions
v. Hybrid

2.3.1 First Come, First Served (FCFS)

The first come, first served (FCFS) mechanism is a process by which the first request that is received is served. Spectrum is assigned in the order of receipt of applications, on the basis of the availability of the frequency, the appropriate spectrum management functions being completed, and the applicant meeting the application criteria.

The FCFS method is appropriate when there is no shortage of spectrum and it has to be assigned to a potentially large number of users or over a long period. This is most commonly used with national budget financing or spectrum usage fees and is likely to remain the most effective for the foreseeable future, although it may be linked (with or without cost recovery) to methods for regulating demand (e.g., administrative pricing).

Advantages of FCFS:

i. Simple and least burdensome of all methods
ii. Fast, practical and inexpensive
iii. Little subjectivity is involved, therefore the opportunity for favouritism is minimised

Disadvantages of FCFS:

i. Successful applicants may not be the entities that would most value economically the authorisation.
ii. Not appropriate for competitive or economically desirable markets

2.3.2 Comparative Evaluations or Beauty Contests

The comparative evaluation or "beauty contest" method of authorisation involves an assessment of competitive applicants based on predetermined criteria and public objectives. Each criterion is weighted, and the weightings are made known to the applicants prior to selection. Applicants are selected based on their rank after evaluation.

Competing applicants' proposals would typically include information on population coverage, quality of service, speed of implementation, and the operator's business plan. For broadcasting, there would be information on programmes such as the number of hours of children's programmes; educational programming and news services. Proposals are usually prepared in response to the criteria established and published by the regulatory authority.

The review of the proposals can be time consuming and resource intensive, and the decision-making process may not be transparent. The review might be subjective and, unless the reasons for the rejection of the losing applicants are clear and conform to the published criteria, those applicants may apply for a judicial review. Any legal challenge can have a significant impact on the general timescales for starting the service and may require a repeat of the whole tendering process.

This method of authorisation is most suitable when there are a small number of applicants for a limited number of licences.

Advantages of a Beauty Contest:

i. Ensures that the successful applicant will make the best use of the opportunity – socially, financially and technically

ii. Keeps spectrum costs low compared to an auction, ensuring lower service prices for consumers
iii. Enables policymakers to utilise specific requirements in the evaluation process to achieve social goals

Disadvantages of a Beauty Contest:

i. Can be a slow and costly process if a proper mechanism is not put in place to deal with complex applications and the effort involved in objectively evaluating applications.
ii. Subjective, may give rise to problems of transparency. The regulator's capacity to identify the best proposal is limited, it's difficult to justify the selection of best proposals and there is a possibility for political or other interferences.
iii. Successful applicants may not be able to fulfil the proposals made in applications.
iv. Does not provide a clear way of choosing between two applicants who are equal in quality
v. Applicants may propose systems that appear appealing or innovative but may not be well suited to the marketplace, resulting in higher prices for consumers.

2.3.3 Lotteries

This method of authorisation involves a very large number of applicants and is based on selecting the winners at random from the competing applicants. In its simplest form, a lottery is quick and transparent but the spectrum may be assigned to someone who does not value it.

As there is no subjective decision required in the assignment of the spectrum and no need to review the applicants, there is little possibility of a legal challenge to the decision.

Regulators may decide to impose a fee for entry to the lottery, and possibly other entry criteria, to ensure the winning applicant is capable of providing the service. These additional constraints may restrict the number of applicants and may also recover some of the value of the spectrum. The mechanism of lotteries has not been used much.

Advantages of a Lottery:

i. Fast, inexpensive and transparent

ii. Fair for selecting among applicants of substantially equal standing

Disadvantages of a Lottery:

i. Will not guarantee that the best service provider is awarded the licence/concession. The regulator can minimise this risk by using a pre-qualification process. However, this adds to the time, complexity and cost of the process, thereby negating the principal advantages of the lottery.

2.3.4 Auctions

Auctions are an authorisation method where, at the end, the applicants determine the amount of money to be paid. In this way, the eventual price of the spectrum is determined by market forces and the frequencies are assigned to the winning bidder.

Allocation of spectrum through auction leads to efficiency, as the spectrum is sold to those who value it the most. It can be an open or closed single-round auction or a multi-round auction that can be held consecutively or simultaneously.

In most cases, the regulatory authority would set criteria for applicants to enter the auction. These criteria may be similar to the types of entry conditions set in comparative bidding or lottery. Selection is then made from a list of qualified applicants, based on their willingness and capability to pay for the spectrum resource.

The main advantages of an auction, which explain the widespread adoption of this method, are as follows:

i. Provides an efficient, transparent and objective means of awarding spectrum licences to bidders who most value the resource
ii. Can be conducted quickly and efficiently in the assignment of the spectrum compared to traditional tender procedures or comparative bidding
iii. Can accommodate large numbers of applicants and can be considered an objective and transparent licensing procedure
iv. Provides information on the economic value of resources

v. Excess revenues generated can be used by the government to fulfil universal and other social objectives
vi. Discourages spectrum hoarding
vii. Reduces the opportunity for favouritism. Transparency of the process reduces the possibility of a legal challenge.

Disadvantages of an Auction:

i. The more criteria or conditions the process contains, the more it affect the value of the licences (auction price may go down).
ii. Due to the high fees paid, it may be harder to roll out the network as quickly as proposed.
iii. Smaller players may be discouraged to enter the market.
iv. High costs may be passed on to the consumer, which can result in reduced service penetration.
v. Governments can exploit the process for revenue purposes only, without taking into consideration the policy impacts.
vi. Auction designs can be complex, depending on the nature of the award. An improper design can yield results that do not maximise economic benefits.

2.3.5 Hybrid

This is a mixture of one or more of the above.

2.4 Spectrum Monitoring and Enforcement

Spectrum monitoring supports the Authority's spectrum management process, including frequency assignment, spectrum planning and enforcement of licensed operating conditions such as radio frequency (RF) output power, modulation, and frequency accuracy.

Spectrum monitoring, consisting of spectrum occupancy measurements, enables the Authority, inter alia, to:

i. correlate the actual level of use associated with the assignment registers records (e.g., channel occupancy and band congestion).
ii. verify proper technical and operational characteristics of transmitted signals and the detection and identification of illegal transmitters.
iii. assist in the resolution of electromagnetic spectrum interference, whether on a local, regional or global scale, so that radio services and stations may coexist compatibly.
iv. assist in ensuring an acceptable quality of radio and television reception by the general public.

The Authority carries out routine frequency monitoring, spectrum audits and tracing of unauthorised radiocommunications transmissions. The unauthorised use of the spectrum is identified and regularised before stricter enforcement actions are considered.

Interference complaints are treated in accordance with the guidelines outlined in the *Technical Coordination Manual*. This ensures an interference-free environment for licensed RF users.

3 Current and Emerging Trends in Wireless Technologies – New Demands for Spectrum

The development of wireless technologies and the associated services are influencing the way spectrum is allocated and reallocated regionally, globally and within national borders. However, technology is only one element in the complex process of spectrum management. The development of technologies and the associated policy and regulatory regimes that govern their use are closely coupled.

Wireless technology plays a key role in today's communications, and new forms of it will become central to emerging economies around the world and to technologies such as robots, drones, self-driving vehicles and new medical devices.

Traditional wireless technologies offer several distinct advantages when compared to wired networks. The primary and most obvious advantage of using wireless technology is the mobility it offers (portability and freedom of movement). While the underlying core of the Internet remains wired, several alternative forms of Internet access utilise wireless technologies to connect homes and businesses, for example, public Wi-Fi networks and satellite Internet.

New and emerging technologies such as IMT-2020 and agile radios show great promise with respect to enabling more effective use of the spectrum. These evolving technologies are making RF communications much more efficient and spectrum policy will need to be adjusted, so that the benefits from these new technologies can be realised.

The relatively less demanding infrastructure requirements of wireless technologies support the use of these technologies to provide backhaul and last-mile access in less densely populated areas at a lower cost than fixed wireline networks.

As personal wireless communications and related data services are improved, the demand for spectrum to be used by individuals and devices shall continue to increase. To meet this growing demand, spectrum management authorities (SMAs) in developing countries have started to update their spectrum management approach in support of shared spectrum use, dynamic spectrum access, harmonising of regional and global spectrum standards, etc. Spectrum sharing among different services is now a common practice and is implemented by SMAs adopting regulations consistent with ITU Radio Regulations and ITU-R Recommendations, and through technical solutions developed in partnership with industry and international standards organisations.

Additionally, significant policy changes in recent decades reflect efforts to adjust to new technologies and to decrease reliance on a centralised spectrum management system.

3.1 Emerging Technologies

The trend is clear: technological innovation will continue to increase at an even faster rate in the future. This is particularly true in communications as RF technology becomes ubiquitous in daily life. RF engineering is incorporated into almost everything that transmits or receives a radio wave across the whole RF spectrum in Trinidad and Tobago (8.3 kHz to 3000 GHz), including mobile phones, radios, Bluetooth and Wi-Fi.

Some of the main wireless technologies and associated services that are influencing the way spectrum is allocated and reallocated within national borders include:

i. Contemporary technologies – increased processing power in radio receivers:
   a. 3G and 4G
   b. WiMAX
   c. Wi-Fi
   d. DTT
   e. Digital radio
   f. Smart antennas

ii. Emerging technology – improved spectrum utilisation:
   a. Software-defined radio (SDR)
   b. Dual-polarised massive MIMO
   c. LTE-Advanced
   d. IMT-2020 (5G)
   e. Dynamic spectrum access (DSA)

f. Internet of Things (IoT)
g. High-altitude platform station (HAPS)

3.1.1 3G and 4G

3G (Third Generation) enabled services such as web browsing, multimedia, and navigation. Based on CDMA (Code Division Multiple Access), this allows multiple users to use a single channel. 3G technology allows typical data rates of 500–700 kbps with a peak rate of about 3 megabits per second (Mbps). 3G is also known as IMT-2000 (ITU-R M.2012-4, 2019). 3.5G introduced high-speed packet access (HSPA) technology to improve data speeds and achieved typical data rates of 1–3 Mbps and a peak rate of 14.4 Mbps.

4G (Fourth Generation) is based on Long Term Evolution (LTE) and LTE Advanced (LTE-A) standards, developed by the 3rd Generation Partnership Project (3GPP[3]) and codified in ITU-R Recommendation M.2012-4 (2019). The LTE standards are based on orthogonal frequency-division multiple access (OFDMA) and offer higher throughput, low latency, and improved quality of service (QoS). 4G systems can achieve typical data rates of 3–5 Mbps and peak rates of 100–300 Mbps.

3.1.2 WiMAX

The Worldwide Interoperability for Microwave Access (WiMAX) is a standards-based technology aimed at providing wireless data over long distances in a variety of ways, from point-to-point links to full mobile cellular type access[4]. It is based on the IEEE 802.16 standard, which is also called WirelessMAN.

The WiMAX Forum established in June 2001 describes WiMAX as "a standards-based technology enabling the delivery of last-mile wireless broadband access as an alternative to cable and DSL".

[3] 3GPP is a partnership project bringing together national standards development organisations (SDOs) from around the world, initially to develop technical specifications for the 3rd generation of mobile, cellular telecommunications, UMTS.

[4] http://4g5gworld.com/wiki/worldwide-interoperability-microwave-access-wimax

The forum claims up to 50 km service area range where a line of sight is available and a typical working range of 5–8 km under non-line of sight conditions, with data rates of up to 280 Mbps per base station.

There are two main versions of WiMAX, namely, 802.16d and 802.16e. The former is intended for fixed (indoor or outdoor) access, similar to existing fixed wireless access (FWA) services, while the latter provides mobility, (albeit limited, more properly described as “nomadic”, in that features like seamless handover are not available). There is no uniform global licensed spectrum for WiMAX, although the WiMAX Forum has published three licensed spectrum profiles: 2.3 GHz, 2.5 GHz and 3.5 GHz.

3.1.3 Wi-Fi

The standards for Wireless Fidelity (Wi-Fi) are established by the Institute of Electrical and Electronic Engineers (IEEE), and devices are certified for these new standards by the Wi-Fi Alliance. The current wireless networking standard is referred to as IEEE 802.11ac. The upcoming standard is called IEEE 802.11ax, or Wi-Fi Certified 6.

Wi-Fi 6 provides the capacity, efficiency, coverage and performance required by users today in the most demanding Wi-Fi environments. Wi-Fi offloading of mobile traffic enables cellular networks to maintain their high data rates, by not having to accommodate all the additional traffic they would otherwise face.

Wi-Fi is tightly coupled to 5G and is expected to play a key role in forthcoming 5G fixed wireless services, with the cellular signal being converted to a Wi-Fi signal for delivery to the host of Wi-Fi-enabled devices on which individuals and corporations have come to rely.

Wi-Fi 6 is optimised for the transmission frequencies of both 2.4 GHz and 5 GHz bands. Two of its marquee features are multi-user, multiple-input, multiple-output technology (MU-MIMO) and OFDMA. 5G is designed to make use of unlicensed spectrum, even more than previous generations of mobile wireless technology. 5G better integrates and coexists with Wi-Fi 6 systems.

3.1.4 Digital Terrestrial Television (DTT)

The transition from analogue television broadcasting to digital terrestrial television (DTT) broadcasting is currently one of the major undertakings in spectrum management in all regions of the world, to improve broadcasting services. Where a single analogue programme can only be broadcast on one transmission channel of 6 to 8 MHz bandwidth, the same transmission channel can now carry a multiplex of up to 20 digital programmes of equivalent quality. Most digital TV standards allow the extension of single frequency networks (SFNs), thereby permitting the reuse of the same spectrum over much larger areas and further increasing spectrum efficiency compared to analogue networks.

Given the gains in the spectrum which may result from the transition, there is a growing interest in how these gains might be distributed. Consequently, the concept of digital (television) dividend has emerged, which may be defined as the spectrum that becomes available over and above what is required to accommodate the existing analogue television services in a digital form.

Once completed, the transition to digital broadcasting shall enable the release of additional spectrum in the UHF bands as part of the digital dividend and possible reallocation to the mobile service. Thus, the bands that can be made available for mobile broadband through the digital dividend in Trinidad and Tobago are the favourable bands to provide coverage for mobile broadband.

3.1.5 Digital Radio

Digital radio is the transmission and reception of sound processed into patterns of numbers, or "digits", hence the term "digital radio". In contrast, traditional analogue radios process sounds into patterns of electrical signals that resemble sound waves[5].

Digital radio reception is more resistant to interference and eliminates many imperfections of analogue radio transmission and reception. FM digital radio can provide clear sound comparable

[5] https://www.fcc.gov/consumers/guides/digital-radio

in quality to CDs, and AM digital radio can provide sound quality equivalent to that of standard analogue FM. Using their existing FM frequency, FM digital radio also allows broadcasters to offer additional audio channels to the public.

3.1.6 Smart Antennas

One way of increasing the capacity and reliability of a radio network is to focus on improving the ability of the radio to “listen”, via its antenna and the radio’s signal processing power. Building better antennas are one way to drastically increase the overall efficiency of a network.

Radio systems with “smart” antennas utilise digital signal processing techniques that seek to ascertain the particular locations from which signals are being received and, as a consequence, determine the specific direction to which signals should be transmitted. Once the approximate location of a particular user is determined, several other technologies can help send and receive “better-targeted” transmissions.

Two techniques used are:

i. Switched beam antennas:
   In this application, the sensitivity of the antenna can be adjusted to a specific “sector” coincident with the direction of the received signal.

ii. Adaptive array antennas:
   This application, as the name implies, uses an adaptive approach and can continuously and dynamically adjust the sensitivity of the antenna based on the actual direction of the received signal and not on any specific “sector”.

Smart antenna technologies such as switched beam and adaptive array antennas can significantly reduce the amount of radiofrequency interference in a given area. When combined with spread spectrum technologies such as ultra-wideband, these technologies can greatly increase spectrum capacity while limiting interference.

Smart antennas are being deployed in some fixed wireless and mobile networks to increase the capacity and speed of the rollout of the networks. Smart antennas effectively combat multipath –a situation where signal “echoes” cancel out the direct signal and the transmission is disturbed.

3.1.7 Software-Defined Radio (SDR)

A software-defined radio (SDR) is a wireless communications device in which the transmitter modulation is generated or defined by a computer, and the receiver uses a computer to recover the signal intelligence (ITU 2004). To select the desired modulation type, the appropriate programs must be run by microcomputers that control the transmitter and receiver.

These radios show great promise due to their ability to be re-programmed on the fly to accommodate different regulatory structures (e.g., different countries), by adjusting frequencies, bandwidth, modulation type, directionality, and so on. SDRs can be upgraded by changing software, similar to a firmware upgrade.

A specific type of SDR that ensures efficient spectrum utilisation is the agile radio which searches for available spectrum within a given band and then proceeds to use this available spectrum. When it senses that another radio is attempting to use this spectrum, the radio moves to another part of the band which is temporarily “free”.

3.1.8 Dual-Polarised Massive MIMO (Increased Capacity)

The massive multiple-input multiple-output (MIMO) system is a key notable 5G technology that increases energy efficiency, spectral efficiency robustness, and reliability via a very large number of transmit antennas. The dual-polarised massive MIMO system is the future for the massive MIMO system, to reduce the transmit-array size and minimise performance degradation due to polarisation mismatch.

Dual-polarised transmit and receive antennas are used for the base station (BS) and IoT devices, respectively, to achieve higher performance when compared to a single-polarised antenna in identical spaces. By utilising dual-polarised antennas, two different linearly polarised antennas co-locate in one physical antenna position, reducing the antenna array space by half.

The dual-polarised massive MIMO system is very effective in reducing the size of a transmit array by utilising the extra polarisation domain. Dual-polarised antennas offer several advantages, these include but are not limited to:

i. reduction of transmit-array size by half compared to a spatially separate single-polarised transmit-array.
ii. achieve twice the performance compared to a conventional single-polarised transmit-array of the identical size.

The dual-polarised massive MIMO system can be operated by space-polarisation division multiple access (SPDMA), which increases spectral efficiency by utilising both space and polarisation domains.

3.1.9 LTE-Advanced

Long Term Evolution (LTE) is a broadband mobile communications standard set by 3GPP. While work on the LTE standard draws to an end, the direction switches to developing LTE-Advanced, also referred to as 3GPP Release 10. The LTE/LTE-Advanced technology is continuously being enhanced by the addition of either new technology components or by the improvement of existing ones. LTE-Advanced, as specified in 3GPP Release 12, comprises a number of these enhancements or additions.

At the ITU Radiocommunications Assembly in Geneva in January 2012, the specifications for next-generation mobile technologies (IMT-Advanced) were agreed upon. ITU determined that LTE-Advanced and WirelessMan-Advanced should be accorded the official designation of IMT-Advanced.

Based on ITU's requirements for IMT-Advanced systems, 3GPP outlined the requirements for LTE-Advanced in its technical report, TR 36.913, version 9.0. These include a peak data rate of 1 Gbps for downlink (DL) and 500 Mbps for uplink (UL).

3.1.10 IMT-2020 (5G)

In 2015, ITU, which designates 5G as International Mobile Telecommunication 2020 (IMT-2020), laid out a vision for IMT-2020 and has since been refining the requirements for IMT-2020. With more and more people embracing smartphones around the world, the demand for data will continue to rise, and legacy bandwidth ranges, which run below 6 GHz, will not be enough to meet this challenge.

IMT-2020, or 5G, is the emerging next generation of mobile communications that will improve current systems and services by offering, among other things, increased data rates (up to 20 Gbps), lower latency and better mobility.

IMT-2020 networks will play an integral role in increasing the speed of wireless communications, perfecting virtual reality, and connecting millions of devices we use today. They will be the key to ushering in the Internet of Things (IoT), in which countless household products, handheld electronics, wearable devices, robotics, sensors, self-driving vehicles and more will be connected through network speeds unheard of today.

At the World Radiocommunication Conference 2019 (WRC-19), additional globally harmonised (millimetre wave) frequency bands for IMT, including IMT-2020, were identified. ITU's early work laid out the following three broad classes of usage scenario for IMT-2020:

i. Enhanced mobile broadband (eMBB). This is similar to the services offered by 4G and 4.5G mobile networks. It involves faster data rates, more universal spatial coverage, and more tolerance for mobility. It also covers use cases such as hotspots with low mobility and high user density.

ii. Ultra-reliable and low-latency communications (uRLLC). This includes applications such as industrial control, vehicle safety and remote medical practice that do not need very high data rates but require very low latency, high reliability and high mobility.

iii. Massive machine-type communications (mMTC). This includes IoT applications such as smart homes, buildings, cities, utilities, etc. It does not require high data rates or low latency but requires energy efficiency and high connection density.

Recently, two additional broad classes of use have been added to the discussion, namely, fixed wireless (an early 5G use), and enhanced vehicle-to-everything (V2X) (a high-profile motivator for advanced 5G capabilities).

3.1.11 Dynamic Spectrum Access (DSA)

Dynamic spectrum access (DSA) is a policy that provides the capability for both licensed users (primary users) and unlicensed (secondary users) to share the wireless channel in an opportunistic manner (IGI Global, 2021), for example, with white space devices. The primary users (PUs) will get first priority and secondary users (SUs) are allowed to utilise the licensed bands whenever it would not cause any interference to the PUs, resulting in high spectrum use.

DSA is considered an advanced approach to spectrum management that is closely related to other management techniques such as flexible spectrum management and spectrum trading. DSA opens the possibility of highly efficient reuse of the spectrum. It involves unitising the spectrum in terms of time slots and/or geographically. Users are allowed to access a particular piece of spectrum for a defined period or in a defined area, which they cannot exceed without reapplying for the resource.

A key characteristic of DSA is its ability to exploit knowledge of the electromagnetic environment, in order to adapt its operation and access spectrum. DSA permits communications to work by:

i. monitoring to detect unused frequencies.
ii. agreeing with similar devices on which frequencies will be used.
iii. monitoring frequency use by others.
iv. changing frequency bands and adjusting power as needed.

DSA is often associated with, although not exclusively dependent on, technologies and concepts such as SDR and cognitive radio.

3.1.12 Internet of Things (IoT)

The Internet of Things (IoT) has been defined in Recommendation ITU-T Y.2060 as "a global infrastructure for the information society, enabling advanced services by interconnecting things (physical and virtual) based on existing and evolving interoperable information and communication technologies".

Things in IoT are objects of the physical world (physical things) or the information world (virtual world) which are capable of being identified and integrated into communications networks. Things have associated information, which can be both static and dynamic.

Physical things exist in the physical world and are capable of being sensed, actuated and connected. For example, physical things include the surrounding environment, industrial robots, goods and electrical equipment.

Virtual things exist in the information world and are capable of being stored, processed and accessed. For example, virtual things include multimedia content and application software.

A device is a piece of equipment with the mandatory capabilities of communication and optional capabilities of sensing, actuation, data capture, data storage and data processing. Devices collect information of various kinds which is sent to the information and communications networks for further processing.

IoT devices have sensors and software that enable the collection and exchange of data via the Internet. IoT objects can be controlled remotely to allow direct integration with computer systems, which results in economic benefit and improved efficiency for users.

3.1.13 High-Altitude Platform Station (HAPS)

High-altitude platform stations (HAPSs) are aircraft, usually unmanned airships or airplanes, positioned above 20 km in the stratosphere in order to create a telecommunications network or perform remote sensing. The most common types of aircraft used as HAPS are airplanes, airships and balloons.

HAPS is defined in the ITU Radio Regulations (RR) No. 1.66A as a radio station located on an object at an altitude of 20–50 kilometres and at a specified, nominal, fixed point relative to the earth.

The main HAPS applications are in telecommunications and remote sensing. In the area of telecommunications, HAPS is used to provide both fixed broadband connectivity for end users and transmission links between mobile and core networks for backhauling traffic. Both applications enable wireless broadband deployment in remote areas, including in mountainous, coastal and desert areas.

Some advantages of HAPS in relation to terrestrial networks (relay towers) are larger coverage area, less interference caused by obstacles (buildings, ground elevations) and shorter time to deployment.

For remote sensing, HAP has important advantages over satellites. Mainly, they:

i. can remain continuously over an area for very long periods (persistence).
ii. permit better resolution images because they are closer to the covered areas.

In some situations, HAPS may be rapidly deployed for disaster recovery communications, particularly because the use of inter-HAPS links allows the provision of services with minimal ground network infrastructure[6].

[6] https://www.itu.int/en/mediacentre/backgrounders/Pages/High-altitude-platform-systems.aspx

4 Economic Considerations for Spectrum Management

The overarching aim in the management of any scarce resource is economic efficiency. Economic efficiency, as it relates to national spectrum resources, can be defined as the allocation of frequency bands to specific groups, through the use of various economic and technical assignment mechanisms[7], which maximise the benefits of the citizens of Trinidad and Tobago.

The mechanisms used to pursue the economically efficient management of the spectrum resource are generally categorised in three approaches: command and control, property rights (flexible rights of use) and open access (DCMS Barwise, Cave 2015).

The three subsections below review these economic approaches to spectrum allocation.

4.1 Command and Control

The command and control approach to spectrum management refers to scenarios where regulators allocate non-overlapping frequency bands to specific uses and assigns usage rights to licensees. Historically, the allocation of frequency bands to specific uses has been based primarily on considerations of technical and global harmonisation parameters, with lower priority given to extracting total economic value[8] or maximising total welfare. This approach may be considered suitable where there is significant surplus of the national spectrum resource available, as opportunity cost[9] and marginal value foregone[10] are negligible or may be considered insignificant.

4.1.1 Methodology (Spectrum Usage Rights and Valuation)

Regarding the assignment mechanisms considered under the command and control approach to spectrum management, licensee rights tend to be limited to a predetermined purpose of the use or

[7] "Assignment mechanism" refers to the combination of legal, technical and pricing parameters conferred to a spectrum licence holder or authorised user of the national spectrum resource.
[8] "Total economic value" refers to the sum of private use value and external value.
[9] "Opportunity cost" refers to the value that would have been generated from the next best alternative forgone.
[10] "Marginal value forgone (MVF) is the unit by which opportunity cost is measured.

fixed rights of use, frequency band(s), geographic scope and/or transmission power and extract minimal economic value or resource rent through the recovery of administrative cost only.

It has been observed globally that the command and control approach to spectrum management brings sustained technical advantages. Where well-designed allocative bands have been established, the approach facilitates the supply of diverse services with high service reliability for most users and with minimum interference (NTIA, Brookings 2011). The command and control approach, thus, remains the spectrum management approach of choice for national security purposes (NTIA, Brookings 2011).

4.1.2 Benefits and Applications

In an environment of high spectrum demand, dynamic spectrum access and market-based assignment mechanisms may be used to reduce spectrum idling and increase efficiency in the use of the national resource, even in the case of public interest assignments (DCMS Barwise, Cave 2015). This adaptation refers to a public sector body that is assigned spectrum through the command and control approach but is permitted to release unused spectrum (at least for a reasonable period) to another spectrum access seeker and retain the proceeds or opportunity cost savings for so doing. In this arrangement, a public sector body, for example, national defense, is given an incentive to economise on its spectrum usage and thereby reduce spectrum idling and increase its resource utilisation efficiency[11].

The Authority currently employs strict command and control approaches to spectrum management through the allocation of frequency bands to particular end users. Specifically, the Authority has committed the provision of spectrum and assignment of exclusive fixed usage rights to licensees using an administrative cost recovery methodology, for the following uses:

i. National security, law enforcement, public health and safety, and emergency services.
ii. Public radio communications services relating to universality requirements.
iii. Aeronautical radio communications services

[11] In 2012, the USA became one of the first countries to permit surplus public safety spectrum to be sold to other users. The enabling legislation allowed spectrum allocated to public safety to be used to generate revenue when not in use.

iv. Amateur radio operations

4.2 Property Rights (Flexible Rights of Use)

In the property rights approach to spectrum management, exclusive property rights to specific frequencies and/or geographies are assigned to the primary licence holder. Primary licence holders may trade licences in a secondary market, except with those who would cause interferences[12] and, therefore, have broad discretion or flexibility about how they use and share their frequency.

4.2.1 Methodology

In this method, the property rights of specific spectrum bands are administered through market-based auctions, cost-benefit analysis and/or administrative pricing. The primary holder may then determine the spectrum allocated and is motivated to reallocate surplus spectrum or unused frequency bands through secondary trading[13] or spectrum management and/or administrative mechanisms[14], depending on the degree of control held by the licensee.

The advantages of the property rights approach are derived from its ability to reduce idle bands and increase efficiency in the allocation of spectrum to higher social value services and thereby promoting welfare maximisation. Specifically, a profit-driven primary licence holder may assign idle spectrum to access seekers willing to pay the highest price for the resource, through sale or lease. Additionally, due to the reduction in administrative bureaucracy, spectrum and its dependent service markets are expected to respond more efficiently to changes in demand and technology.

The primary disadvantages of the property rights approach involve “anti-commons” or hold up, the potential for interference and high transaction costs. Particularly, strategic, rent-seeking behaviour by the primary licence holder has been noted to prevent spectrum access by potential

[12] Interference is, however, controlled by technical rules that govern transmitters’ specifications and power limits, which may be set by the regulator.
[13] Secondary trading refers to scenarios where by the primary licence holder makes surplus spectrum available to other (secondary) access seekers at a price.
[14] This may include alienation of some users and leasing to other users.

competitors (ITU 2004). Additionally, transaction costs relating to the negotiation of spectrum access by a large number of owners and seekers have been prohibitive.

4.2.2 Benefits and Applications

To reduce externalities[15] in this approach, absolute use priority of the primary licence holder and strict interference regulatory constraints[16] must be maintained.

Furthermore, to reduce the drawbacks of the anti-commons, the "ownership with easement" model, which incorporates the use of new sharing technologies within the property rights market model, has been developed. Particularly, in the ownership with easement model, the exclusive property rights of the primary licence holder are subject to easement, such that unlicensed non-interfering users cannot be excluded from using the spectrum "owned" by the primary holder. The inclusion of an acceptable rate of return can provide additional incentive for the adoption of this augmentation to the property rights approach, however, this may also increase regulatory involvement in an approach designed to be more market-based.

Historically, the Authority did not issue exclusive property rights to spectrum licence holders of any frequency band. Rather, spectrum licences issued by the Authority largely permitted only fixed rights of use to the licensee. Therefore, the potential for spectrum trading and/or spectrum sharing was not provided for within the Authority's regulations.

4.3 Open Access

The open access approach to spectrum management permits spectrum access to all potential users. In this approach, property rights may or may not be granted to access seekers and the price for spectrum access may be determined by the market or set administratively by the regulator.

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[15] "Externalities" refers to the occurrence of congestion or overconsumption of the resource and interference in the provision of services using said resource.
[16] Regulatory constraints include, inter alia, power level or field intensity, geographic area and authorised operation time.

4.3.1 Methodology

The open access mechanism has several known iterations or implementation approaches, one being where a single variable access fee is determined via electronically supplied demand and supply information services and where operational rules are determined by the regulator. This approach is referred to as the managed commons or modern open access.

Other iterations of the open access approach include the standard commons method and market-based methods. In the former method, the government protects the boundaries of spectrum usage by limiting the group of end users who, in turn, have responsibility for spectrum uses, setting standards and dealing with interference. This method confers some degree of joint ownership but excludes property rights and secondary markets.

4.3.2 Benefits and Applications

The advantages of the open access approach include low barriers to entry, low lead times from innovation to market and increased service innovation as a result. The primary drawbacks of the open access or unlicensed approach include congestion and/or interference, also termed "the tragedy of the commons"[17]. These drawbacks hold the potential to significantly outweigh the notable gains of the open access approach when demand for spectrum is high.

To minimise interference and congestion, regulatory oversight, which may take the form of sharing rules, common technical standards and protocols, and resource control, may be adopted to retain some economic efficiency. However, as regulatory controls set in, the adaptation of the open access regime is noted to approach the command and control regime and so too its level of allocation inefficiency.

The Authority currently provides for open authorisation for designated bands of the spectrum, which may be used by persons for specific radio communications services upholding specific technical and operational parameters, in the form of a class licence.

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[17] This refers to a situation where open access and excessive demand for rival resources lead to the depletion or extreme scarcity of the resource.

5 Principles for Spectrum Management

The radio spectrum is a finite and vital resource that needs to be managed carefully, appropriately, efficiently and effectively, in the public interest, if its potential is to be realised. It is a vital input into an ever-widening range of new and innovative services.

Respectable spectrum management principles inform stakeholders about the decision-making approach that SMAs will take in the management of the radio spectrum. They are intended to guide the management of the radiofrequency spectrum in accordance with existing legislative responsibilities and policy settings.

The adopted spectrum management principles, which are consistent with the principles of good regulatory practice, include to:

i. allocate spectrum to the highest value use, to ensure that the maximum benefits to society are realised.
ii. enable and encourage spectrum to move to its highest value use.
iii. use a light-handed approach to achieve policy objectives.
iv. promote both certainty and flexibility, to the extent possible.
v. balance the cost of interference against the benefits gained from greater spectrum utilisation.
vi. harmonise spectrum use with international and regional allocations and standards.

5.1 Allocate Spectrum to the Highest Value Use

The Authority's decision-making processes are conducted in accordance with legislative requirements and are guided by the objectives of the Act. Specific sections of the Act cover, inter alia, radio frequency planning, licensing (including spectrum, apparatus and class licensing), reallocation, technical standards, interference and dispute resolution.

In keeping with the objectives of the Act, the public benefit will be maximised where the spectrum is allocated to the highest value use, i.e., the use that maximises the value derived from the spectrum by licensees, consumers and the wider community.

Section 3(c)(ii) of the Act states, "the objects of the Act are to establish conditions for promoting universal access to telecommunications services for all persons in Trinidad and Tobago, to the extent that is reasonably practicable to provide such access". In assessing the highest value use of the radio spectrum, the Authority shall consider this objective, the community benefits derived from the use of the spectrum and all other applicable requirements.

Spectrum Management Framework Policy Statement

1. *Spectrum will be allocated to the highest value use, to ensure that maximum benefits to society are realised.*

5.2 Enable and Encourage Spectrum to Move to its Highest Value Use

The overall benefits to the public derived from the use of the radio spectrum can be maximised by allowing the spectrum to move to the highest value use as quickly and as easily as possible following its initial allocation. This requires a flexible regulatory system that enables licensees to adapt spectrum access and usage to both market requirements and technology advances.

The Authority shall promote mechanisms that enable and encourage spectrum licensees to move spectrum to its highest value use with minimum regulatory burden.

Allowing spectrum to move to its highest value use quickly and easily will ensure that associated benefits are realised, without the delay and costs of regulatory intervention (ACMA, 2009).

Spectrum Management Framework Policy Statement

2. *Mechanisms will be put in place to enable and encourage spectrum to move to its highest value use.*

5.3 Use of a Light-Handed Approach to Achieving Policy Objectives

Minimising the total cost of spectrum management requires a focus on regulatory effectiveness, taking into account developments in technology and conditions in affected markets. Under good regulatory practice, all benefits and costs of regulations, including compliance costs, are thoroughly assessed.

The light-handed approach reduces regulatory burdens and allows greater freedom for spectrum licensees to optimise their use of the spectrum. The Authority shall seek to operate as efficiently as possible to minimise the total cost of spectrum management.

> ***Spectrum Management Framework Policy Statement***
>
> 3. *The least cost and least restrictive approach shall be used to achieve spectrum management goals and objectives.*

5.4 Promote Both Certainty and Flexibility, to the Extent Possible

Licences issued by SMAs need to be flexible, to facilitate the third-party use of a licensee's spectrum. This flexibility requirement may at times conflict with the desire of some licensees for certainty, particularly in relation to interference management. A stable and predictable regulatory arrangement and sufficient certainty about spectrum occupancy are also essential in order for licensees to be confident about investing in equipment and services. This maximises the public benefits from spectrum use by reducing the risk of market failures arising from uncertainty and risk aversion.

The Authority will therefore promote both certainty and flexibility. If there is any conflict between these two objectives, the Authority will seek an outcome that provides the greatest net benefits for industry, consumers and the wider community.

Spectrum Management Framework Policy Statement

4. *To the extent possible, the Authority will promote both certainty and flexibility.*

5.5 Balance the Cost of Interference Against the Benefits of Greater Spectrum Utilisation

There is no RF environment or operation with a complete absence of potentially interfering signals. As the use of the spectrum for commercial, industrial, government and scientific purposes continues to increase, the number of potentially interfering sources will also increase. Interference can be caused by other valid users of the spectrum, improperly functioning consumer and commercial equipment, and improper or disallowed use of the spectrum.

Interference mitigation techniques are a limited but critical element in efforts aimed at extracting scientific value from an increasingly difficult RF environment. The Authority will weigh the cost of interference against the benefits of greater spectrum utilisation, to ensure the most efficient result that maximises total welfare.

Spectrum Management Framework Policy Statement

5. *The risk and cost of interference will be balanced against the benefits gained from greater spectrum utilisation.*

5.6 Harmonise Spectrum Use with International and Regional Allocations and Standards

Spectrum harmonisation is a desirable goal of SMAs, as it increases economies of scale for equipment and simplifies assignment procedures. As the global marketplace demands enhanced mobility of communications technologies, harmonised spectrum bands and improved technical interoperability among diverse systems play an increasingly important role in the international communications arena.

The Authority will harmonise spectrum use with international and regional allocations and standards as far as practical to reap benefits in terms of access and economies of scale. For example, the IMT spectrum is allocated for the provision of broadband wireless access (BWA) services, in keeping with the Region 2 *Table of Frequency Allocations*.

Spectrum Management Framework Policy Statement

6. *Spectrum use will be harmonised, as far as practical, with international and regional allocations and standards, to generate additional benefits in terms of access and economies of scale.*

6 The Revised Spectrum Management Regime

At the time policies were put in place to support the traditional spectrum authorisation models outlined in section 2, SMAs were bound by the limitations of early technologies. Technologies have since advanced significantly but the existing spectrum structure remains. SMAs must proceed carefully in order to make more effective use of the spectrum and ensure that legacy devices retain their functionality.

The technologies outlined in section 3 are changing the way SMAs need to manage the radio spectrum. Technologies such as SDR and IMT-2020 cannot exist legally without changes to spectrum policy. The changes necessary to make use of new technologies with the least amount of disturbance to existing devices and licensees include developing coexistence models, creating new unlicensed spectrum, clearing underused spectrum and allowing multipurpose radios.

The following are the key areas of this spectrum management framework:

i. Spectrum planning
ii. Spectrum authorisation:
   a. frequency assignment and licensing
   b. mechanism for the granting of licences
iii. Spectrum monitoring and enforcement

6.1 Spectrum Planning

Spectrum planning is the process of setting spectrum management goals for the future and establishing the steps to achieve those goals. The planning process precedes the efficient and effective conduct of any activity, be it governmental or business.

According to the ITU-R Handbook on National Spectrum Management, the purpose of any planning effort is to organise and focus thoughts and actions for the efficient and effective achievement of directed or agreed goals and objectives. This effort is important for any country (and especially important for developing countries) wanting to initiate or improve a national spectrum management process.

Planning activities are classified by time (short term, long term and strategic) and the areas covered (spectrum use and spectrum management systems). Short-term plans are implemented within three to five years and long-term plans consider issues that need resolutions or systems to be implemented within 5 to 10 years.

In comparison, strategic planning involves the identification of several key issues that require concentrated spectrum management attention, to create solutions that need more than 10 years to be implemented (ITU-R, 2019).

The Authority's spectrum planning and policy-making process shall ensure that an adequate amount of spectrum is provided over the short and long term for public service organisations to fulfil their missions, for public correspondence, for private business telecommunications, and for broadcasting. Spectrum usage for research, scientific uses and amateur radio activities shall also be considered.

6.1.1 Spectrum to Support National Socioeconomic Development Objectives

The management of the radio spectrum plays a major role in increasing a country's social and economic well-being, by maximising the use of the spectrum for wireless applications. It is important to note that the economic benefit in this sense must be viewed in a broad context rather than that of merely increasing revenues from licensing.

The output of the spectrum planning effort is the allocation of frequency bands to the various radio services for specific uses. Where there are competing interests for use of the spectrum, the Authority shall determine the use that would best serve public and government interest, including how to share the spectrum.

Under its NICT Plan, GORTT has launched several programmes aimed at developing the information and communications technology (ICT) sector. These initiatives support the National

Development Strategy 2016–2030, Vision 2030, which outlines the country's aspiration to attain "first world nation status" by 2030.

The goals for spectrum management to advance GoRTT's socioeconomic development vision include the following (Zaballos and Foditsch, 2015):

i. Efficient use of spectrum (e.g., avoidance of spectrum hoarding).
ii. Rapid introduction of new technologies (e.g., the introduction of more efficient wireless technologies that utilise a smaller amount of spectrum and provide improved service).
iii. Protection of public service and social welfare (e.g., use of spectrum for public purposes).
iv. Minimisation of interference and solution for coexistence issues (e.g., authorisation of devices that coexist without interference).
v. Generation of revenue (e.g., revenue from auctions used to balance national accounts)
vi. Promotion of universal access (e.g., ensuring that underserved areas have access to broadband service).

Spectrum Management Framework Policy Statement

7. *The radio frequency spectrum, as a scarce national resource, shall be used for the benefit of the public and to facilitate the Government of Trinidad and Tobago's public policy and socioeconomic objectives.*

6.1.2 Spectrum for National Security, Law Enforcement and Emergency Services

The use of spectrum to provide services for national security and protection of the sovereignty of Trinidad and Tobago shall receive high priority in the allocation of resources. Spectrum for the provision of telecommunications services for law enforcement, the safety of life and property, and emergency services shall also be accommodated.

The Authority will work closely with the organisations responsible for providing these services to ensure that a sufficient amount of radio spectrum is made available to fully satisfy their requirements and that such spectrum is used in the most efficient manner.

Government users shall be charged an economic (opportunity cost) rate for the spectrum, which is reimbursed by the central government as part of the overall funding for the services concerned. Users that reduce spectrum use shall be allowed to keep some or all of the money reimbursed. This provides an incentive for them to make more efficient use of the spectrum in order to reduce their fees, potentially freeing up some spectrum for other uses.

The Authority shall ensure that the spectrum granted to government users is efficiently and effectively utilised.

Spectrum Management Framework Policy Statement

8. *Radio frequency spectrum shall be provided for radiocommunications services for national security, law enforcement, public health and safety, and emergency services, on a priority basis, and such spectrum shall be used efficiently and effectively.*

6.1.3 Spectrum to Facilitate Public Telecommunications (Radiocommunications) Services

With the proclamation of the Act and the opening of the market to competition, there is likely to be a heavy demand for spectrum for the provision of public telecommunications networks and services.

Increased competition will fuel demand for "modern" public telecommunications services and the Authority will need to respond to the greater need for spectrum resources for the provision of these services.

Spectrum Management Framework Policy Statement

9. *Radio frequency spectrum shall be provided for public telecommunications services, using a market-based approach to ensure an equitable return for use of the spectrum resources.*

6.1.4 Spectrum for Universal Service

Under the Act, provision was made for the establishment of a Universal Service Fund (USF) that is used to assist in the development of the telecommunications infrastructure and the provision of services to underserved and geographically remote areas in Trinidad and Tobago, to bridge the access divide and boost digital inclusion. The USF is funded by certain concessionaires and licensees, e.g., telecommunications networks and service providers.

One of the measures now used to determine the level of penetration of telecommunications services and the overall ability of citizens to access and use these services is the ICT Development Index (IDI). The IDI is a composite index launched by ITU to measure the development of ICTs within and among various countries[18]. In 2017, Trinidad and Tobago's IDI was 6.04 and the country was ranked 68th internationally by ITU[19]. In 2021, the Authority embarked on a national digital inclusion survey to collect data to gauge the development of ICTs at the national and community levels. As mentioned previously, several access technologies, mostly wireless, which rely on the availability of spectrum, are currently being deployed in various countries across the globe. The Authority will allocate spectrum for the provision of wireless access services, to facilitate the penetration of telecommunications networks and services in Trinidad and Tobago, which ultimately will enhance the growth of the IDI.

Spectrum Management Framework Policy Statements

10. *Radio frequency spectrum shall be provided for public radiocommunications services, to assist in the provision of universal service.*

11. *Consideration may also be given to developing fee formulae that provide direct incentives for rolling out telecommunications networks and services and broadcasting services in underserved areas.*

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[18] IDI Conceptual Framework: https://www.itu.int/en/ITU-D/Statistics/Pages/publications/mis/methodology.aspx#:~:text=The%20ICT%20Development%20Index%20(IDI)%2C%20which%20has%20been%20published,between%20countries%20and%20over%20time

[19] ITU IDI rankings (2017): https://www.itu.int/net4/ITU-D/idi/2017/

6.1.5 Spectrum for Commercial Radiocommunications Services

With the rapid and sometimes disruptive advancements in the telecommunications sector, there is increasing reliance on telecommunications in meeting private and commercial business needs.

Commercial telecommunications applications have flourished with the liberalisation of the telecommunications sector. An important consideration is the relative economic attractiveness of, and demand for, different parts of the spectrum. Whilst the main cellular mobile and broadcasting bands are likely to be highly sought after, the bands mainly used for private mobile radio are likely to be underutilised and substantially lower fees would be justified. Similarly, if congestion arises in the existing bands for fixed links (below 6 GHz), higher frequency bands could be made available at lower fees to encourage their use.

It would also be appropriate to apply lower fees for fixed links at sites that are not heavily used. Fees charged for spectrum access should reflect the opportunity cost where there is current or potential excess demand for spectrum (i.e., reflect the cost of denying access to spectrum for other users).

Spectrum Management Framework Policy Statement

12. *Radiofrequency spectrum shall be provided for commercial radiocommunications services using an appropriate administrative costing methodology or market-based approach, to ensure an economical value for use of the spectrum resources.*

6.1.6 Spectrum to Provide Aeronautical Radiocommunications Services

Radiocommunications facilities to enable the work of air traffic controllers, air-to-ground communications and ancillary services are critical to the safety and efficiency of air transportation.

Currently, the allocation of spectrum within agreed bands is co-ordinated with the International Civil Aviation Organization (ICAO), which plays a major role in the international and regional coordination of the use of the allocated frequencies.

The aeronautical spectrum is generally allocated internationally for the exclusive use of the service and, given the safety-critical nature of the service, cannot be shared by other users. The Authority's role in regard to these services is essential to ensuring that the spectrum is protected in accordance with ITU and ICAO regulations and that effective enforcement action is taken in the case of any interference or other infringement arising.

Spectrum Management Framework Policy Statements

13. *Radio frequency spectrum shall be provided for aeronautical radiocommunications services, using an administrative cost recovery methodology.*

14. *The Authority shall recognise all international and regional radio frequency spectrum allocated to aeronautical services.*

6.1.7 Spectrum for Maritime Radiocommunications Services

Maritime radiocommunications services are required for a variety of purposes including:

i. Global Maritime Safety and Distress System (GMDSS) and Safety of Life at Sea (SOLAS)
ii. Radio navigation
iii. Weather warnings
iv. Commercial use
v. Leisure
vi. Coast station operations
vii. Port operations

A range of frequency bands, including MF, HF, VHF and UHF, and satellite bands are used to provide the above maritime services.

The maritime spectrum is generally allocated internationally for the exclusive use for maritime communication and, given the safety-critical nature of the service, the spectrum cannot be shared by other users. The Authority's role with respect to maritime services is essentially to ensure that the spectrum is protected in accordance with ITU and International Maritime Organization (IMO) regulations and to take effective enforcement action in the case of any interference or other infringement arising.

Spectrum Management Framework Policy Statements

15. Radio frequency spectrum shall be provided for maritime radiocommunications services, using an administrative cost recovery methodology.

16. The Authority shall recognise all international and regional radio frequency spectrum allocated to maritime services.

6.1.8 Spectrum for Amateur Radio and Other Experimental Purposes

Internationally, amateur radio operators have been allocated radio spectrum in various frequency bands to undertake non-commercial radiocommunications activities including experimental work. Many of the allocations are on a secondary basis and may be shared with other users.

The benefits of amateur radio include fostering technical radio skills that may be of subsequent value to the commercial or state sectors, as well as a potential emergency response role. The spectrum shall be made available to radio amateurs consistent with international practice.

Trinidad and Tobago, a Member State of Inter-American Telecommunication Commission (CITEL), became a party to the Inter-American Convention on an International Amateur Radio Permit (IARP Convention) by accession on August 16, 2001. The Authority will adhere to the articles of the IARP Convention and any subsequent revisions or amendments to which Trinidad and Tobago is a party.

The Authority recognises IARPs issued by the other Member States in accordance with the IARP Convention. Visiting amateur radio operators who hold a valid IARP and wish to operate their equipment during their stay in Trinidad and Tobago will be permitted to do so, subject to procedures defined by the Authority in the *Framework for the Authorisation of Amateur Radio Services*.

> ***Spectrum Management Framework Policy Statements***
>
> 17. *Radio frequency spectrum will be provided for amateur radio operations, using an administrative cost recovery methodology.*
>
> 18. *The Authority shall adhere to the articles of the IARP Convention and any revisions or amendments to which Trinidad and Tobago is a party .*

6.1.9 Spectrum for Private Non-commercial Radiocommunications Services

The use of radiocommunications equipment is part of everyday life – from the ubiquitous mobile telephone and the home cordless telephone to the car alarm system. Spectrum resources will need to be made available to facilitate this widespread use of radio technology. Generally, these radio devices operate at relatively low power levels and use the shared spectrum.

The Authority has developed a Class Licensing Regime to allow for the use of low power, low interference potential and mass-market consumer devices which operate within specific technical and operational parameters.

The class licensing process is a simplified authorisation process that imposes minimal administrative and financial burdens on the Authority and users of devices deemed to be class licensed. A class licence will authorise users of such devices to operate in designated spectrum band(s) on a shared basis.

> ***Spectrum Management Framework Policy Statement***
>
> 19. *Radio frequency spectrum shall be made available for private non-commercial radiocommunications services, in accordance with the Authority's Class Licensing Regime.*

6.1.10 Spectrum for Emerging Radiocommunications Services

There are significant developments taking place in the global marketplace with respect to the establishment of new standards and technologies to enable the delivery of wideband telecommunications and broadcasting services via wireless access/delivery systems. In many cases, the provision of these standards and technologies is being fostered by regulatory bodies through a "soft" regulatory regime that facilitates a less costly and easier deployment of systems.

It is anticipated that such systems will greatly assist in the development of the national telecommunications infrastructure and will contribute to the ready access of telecommunications services, thereby contributing to the overall improvement of the country's IDI.

> ***Spectrum Management Framework Policy Statement***
>
> 20. *Radio frequency spectrum shall be made available for enhancing the delivery of emerging radiocommunications services within an enabling spectrum licensing framework.*

6.2 Spectrum Authorisation

One of the main purposes of managing the spectrum is to increase the social gains from its use while avoiding interference between different users. How this is achieved has changed in recent years, as countries transition from more constrained models to more market-based ones. Instead of a one-size-fits-all solution, most countries are currently implementing a mix of policies that will ensure more efficient use of the spectrum.

The technologies outlined in section 3 show great promise in how to make more effective use of the spectrum. These technologies can only be implemented if current regulatory models support or allow their use. SMAs, engineers and economists must understand the implications of technologies and how regulatory regimes will have to adapt if new and emerging technologies are going to succeed.

In recent years, the authorisation toolbox used by SMAs has been enriched by the addition of licensing schemes that allow various arrangements and degrees of shared use of the spectrum resources. The Authorised Shared Access/Licensed Shared Access (ASA/LSA) is an example of a framework that is currently being discussed at international forums. It proposes a sharing scheme in which a dedicated spectrum should be assigned by either the incumbent user or by the licensee, in any given place at any given time.

The emergence of these new licensing schemes that promote the various forms and degrees of organised sharing of the spectrum resources has gradually reduced the uncertainty between the traditional polarised approaches of exclusive licensing versus licence exemption.

A critical decision for the Authority and other Region 2 administrations is balancing the trade-offs between the different spectrum authorisation approaches. As a light-touch regulator, the Authority's preference is to adopt a mixed or flexible approach, allowing market forces to prevail to ensure the continued development of wireless communications services and applications.

6.2.1 Frequency Assignment and Licensing

A key to increasing the overall efficiency of spectrum utilisation is through better sharing, enabled by continued international collaboration and innovation in the management of the radio spectrum. The mixed or hybrid assignment framework offers a modernized approach for the management of the spectrum and conveys a new trend in which different frameworks are merged.

In applying the mixed or hybrid model, also known as the flexible approach, the Authority shall use market mechanisms for spectrum assignment, accord freedom in the choice of technologies and services, and separate universal service obligations from licence terms.

The Authority is of the view that the spectrum should be free of technology and usage constraints as far as possible. Policy constraints shall only be used where they can be justified. However, although some flexibility will be allowed, that flexibility shall be measured to ensure that national policy objectives and international obligations are still maintained. As a result, the Authority intends to adopt licensing practices that are based on a market-oriented system (flexible approach), supported by institutional best practices, such as:

i. Setting up an efficient spectrum management system – achieving streamlined and efficient spectrum management on both the short-term and long-term basis. This involves allocating, allotting and assigning spectrum licences in an economical and efficient manner, relying on market forces, economic incentives and technical innovations

ii. Ensuring transparency of the spectrum management operations – promoting transparent, non-discriminatory, economically efficient and effective spectrum management policies, that provide regulatory certainty.

iii. Adhering to the principle of technological neutrality and flexible spectrum use – promoting wireless innovation by creating conditions for the development of new services, reducing investment risks and stimulating competition among different technologies, including facilitating new competitors' entry into the market.

iv. Managing the availability and use of spectrum – facilitating the timely introduction of new applications and technology, while protecting existing services from harmful interference; ensuring the most efficient use of radio spectrum.

v. Harmonising regional and global spectrum standards – aligning domestic spectrum policies with internationally recommended standards, to achieve faster take-up of new bands and economies of scale.

vi. Promoting affordable and fair access to the spectrum – reducing financial barriers for new entrants into the wireless market and guiding the development of wireless technologies, especially in less developed areas.

vii. Ensuring that all wireless players have equitable and fair access to spectrum resources.

viii. Coordinating shared spectrum use – the key to increasing the efficiency of overall spectrum utilisation is through better sharing, enabled by emerging technologies that promote spectrum sharing, continued international collaboration and innovation in spectrum management.

ix. Monitoring and controlling spectrum use – monitoring, market supervision and enforcement are becoming increasingly integrated fields of operation. Most countries have some monitoring facilities at or near their headquarters as well as a set of regional stations spread throughout the country.

Under the mixed or flexible approach, licensing is currently the mainstream spectrum management approach for mobile broadband, providing the certainty of a dedicated spectrum to support over 8.1 billion connections and almost 5 billion unique subscribers (ITU 2017).

A licence may be granted to an operator at a particular location or for a defined geographical area(s) (niche, major or national), authorising the operation of a station(s) in this/these location(s) or area(s). The licensee secures rights for the transmission of signals and the protection of their reception from interference for a specified period.

All licences are technology-neutral. Frequency coordination enables efficient use of the spectrum between several licensees. It also enables spectrum sharing between different licensed services (e.g., point-to-point links and earth stations).

Figure 3 depicts the hierarchical view of the new spectrum access licensing approach adopted by the Authority, allowing for a degree of organised sharing and the efficient management of the radio spectrum resources. Figure 4 summarises the current authorisation regime and new authorisation regime.

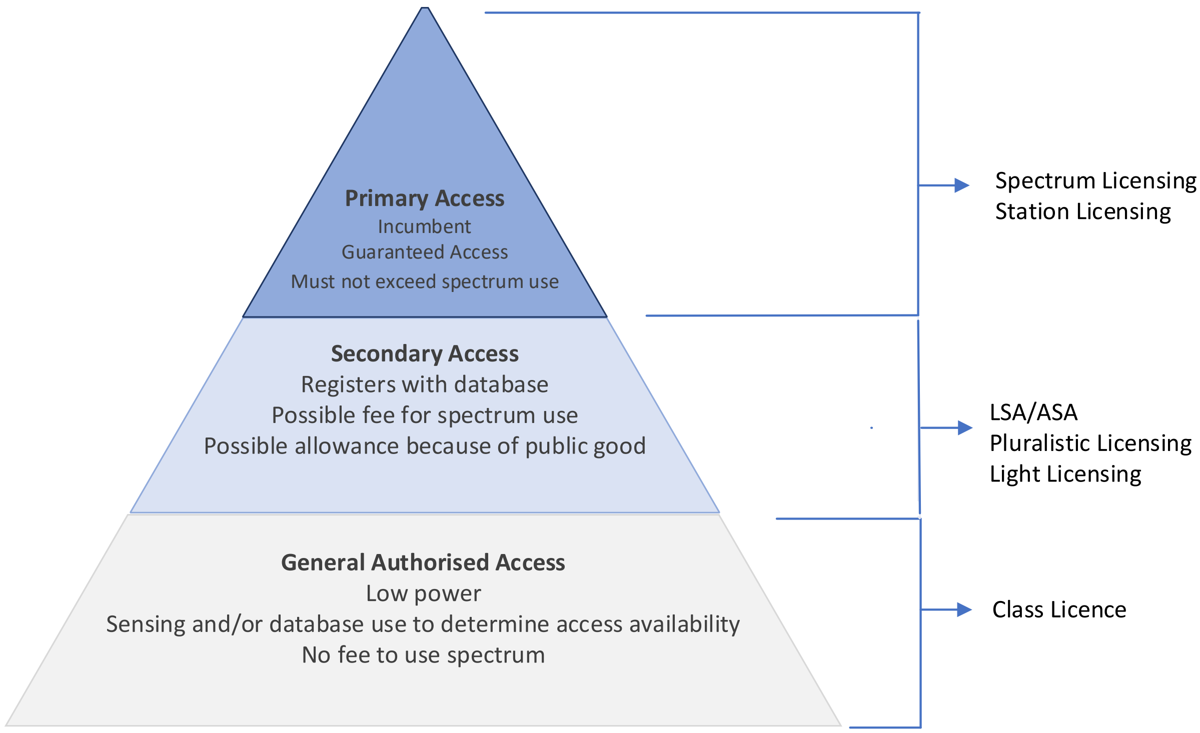

Figure 3: Hierarchical view of the new authorisation approach (Source – US PCAST report 2012)

Spectrum Management Framework Policy Statement

21. The Authority shall employ the following types of licences for the use of spectrum, in accordance with section 36(1) of the Act

i. Primary Access Licence:
- *a. Spectrum*
- *b. Station*

ii. Secondary Access Licences:
- *a. Licensed Shared Access (LSA) or Authorised Shared Access (ASA)*
- *b. Pluralistic*
- *c. Light*

iii. General Authorised Access Licence:
- *a. Licence-exempt (Class Licence)*

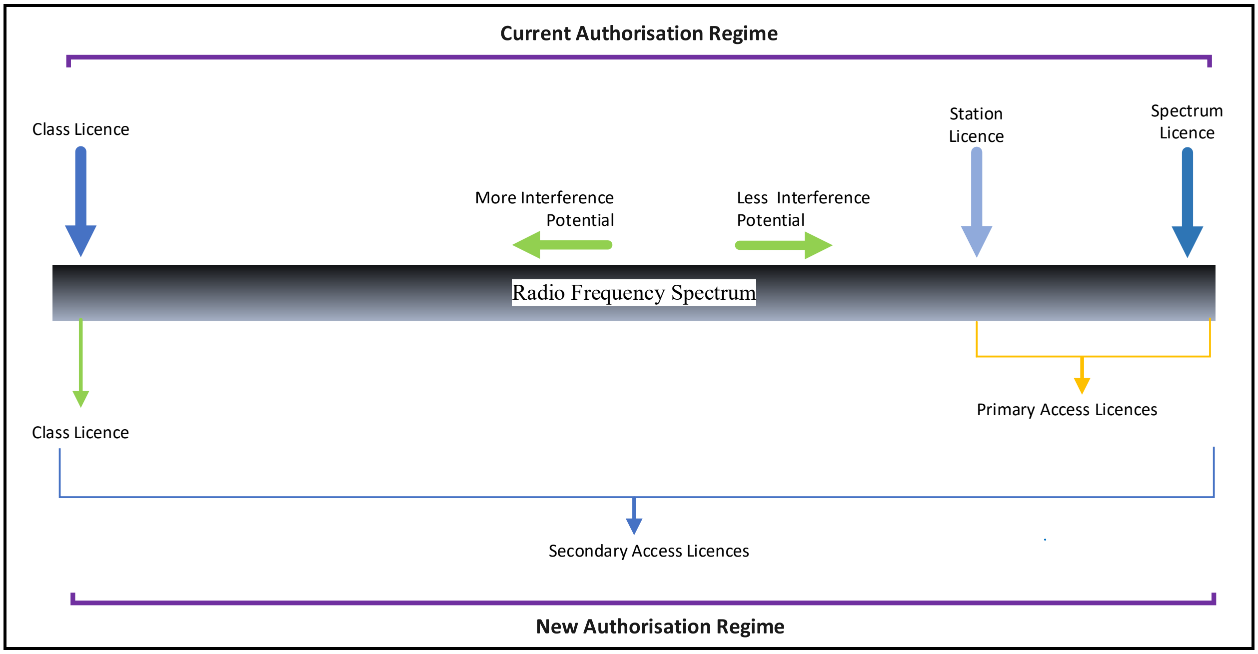

Figure 4: Current authorisation regime vs new authorisation regime

6.2.1.1 Primary Access Licences

6.2.1.1.1 Spectrum Licence

Spectrum licensing, also known as exclusive licensing, is a common model used by most countries in Region 2 in the assignment of spectrum. Under certain minimal conditions, countries like Canada and the United States issue spectrum licences to authorise the use of a specific frequency/frequencies or a frequency block(s) within a defined geographic area(s). Once authorised, licensees are permitted to establish and modify their radiocommunications networks while adhering to the conditions of the spectrum licence.

Exclusive frequency assignments under a spectrum licence should not be interpreted as a reason to preclude other productive uses of spectrum capacity in areas or at times where the primary use is dormant or where underutilised capacity can be shared. The assignment of the spectrum on a secondary exclusive basis shall be accommodated where practical.

The spectrum licence was created to allow licensees or, in some cases, persons authorised by a licensee, to operate radiocommunications devices within a specified frequency band (and/or time and/or geographic area, as required).

The rights and obligations associated with a spectrum licence granted to mobile network operators (MNOs) are included in the concession granted to MNOs by the Authority (e.g., coverage obligations).

The established regulatory environment in Trinidad and Tobago provides the long-term predictability for spectrum licensees and helps incentivise the large investment necessary for network rollout. This is important to enable mobile broadband coverage in rural areas where the business case for service provision can be challenging due to sparse populations.

Additionally, spectrum licences allow for better assurance of interference protection, provide certainty to operators in terms of guaranteed access to spectrum, and enable higher power output, all of which help improve coverage and also incentivise network investment.

Spectrum Management Framework Policy Statements

22. *Authority shall utilise a primary access licence type (spectrum licence) to authorise the exclusive assignment of spectrum for the operation of radiocommunications systems within a specified frequency band under specific conditions on a technology-neutral basis, i.e., no restrictions will be placed on the type of technology used.*

23. *Spectrum licences shall be used to authorise the offering of public or closed user group telecommunications or broadcasting services*

24. *exclusive assignment under a spectrum licence shall mean the right to use the spectrum without precluding other productive uses of the spectrum, in areas or at times where the primary use is dormant, or where underutilised capacity can be shared.*

6.2.1.1.2 Station Licence

A station licence applies to a radiocommunications service that requires the use of a specific location, technical standard, equipment and/or frequencies to achieve the purpose of the radiocommunications service or to facilitate coexistence with other radiocommunications services.

A station licence authorises the licensee to operate the station(s) specified in the licence in accordance with the Act, regulations and the conditions of the licence. A station licence may be one of the following:

i. an assigned frequency licence (i.e., frequency is allocated to users)
ii. a non-assigned frequency licence (i.e., frequencies are shared with other users, no frequency allocated to users).

A radiocommunications service operating under a station licence cannot be changed or modified with respect to any of the particulars mentioned in the licence, including the radiocommunications equipment, the operating radio frequencies, and the location where the station is installed.

Spectrum Management Framework Policy Statements

25. *The Authority shall utilise a primary access licence type (station licence) for the exclusive assignment of spectrum to authorise the use of one or more specific radio stations in accordance with specific conditions.*

26. *A station licence shall apply where the radiocommunications service requires the use of a specific location, technical standard, equipment and/or frequencies within a frequency band in order to achieve the purpose of the radiocommunications service or to facilitate coexistence with other radiocommunications services.*

6.2.1.2 Secondary Access Licences

Figure 5 highlights the secondary access licence types that allow for a degree of organised sharing and the efficient management of the radio spectrum resources.

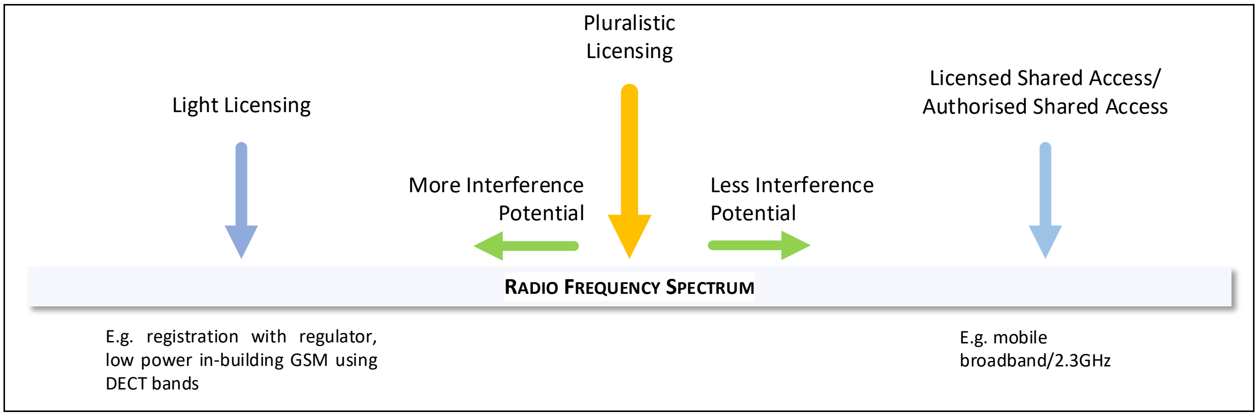

Figure 5: Secondary access licences

6.2.1.2.1 Licensed Shared Access (LSA) Licence

Licensed Shared Access (LSA,) also known as Authorised Shared Access (ASA), is defined as "a regulatory approach aiming to facilitate the introduction of radiocommunication systems operated by a limited number of licensees under an individual licensing regime in a frequency band already assigned or expected to be assigned to one or more incumbent users. Under the Licensed Shared Access (LSA) approach, the additional users are authorised to use the spectrum (or part of the spectrum) in accordance with sharing rules included in their rights of use of spectrum, thereby allowing all the authorised users, including incumbents, to provide a certain Quality of Service (QoS)" (EC 2013).

LSA allows for the shared use of the spectrum using cognitive radio techniques (i.e., geolocation combined with spectrum databases). Under a specific regulatory framework, the non-mobile incumbent could allow a mobile operator non-interfering use of part of its assigned spectrum, pursuant to a commercial agreement with the incumbent, and subject to the terms defined by the relevant government authority.

In Trinidad and Tobago, a spectrum licence (exclusive licence) lasts for 10 years and applies to a frequency block on a national basis. An example of such licensed use is the 2.5 GHz spectrum for the provision of BWA services. Under the LSA concept, existing BWA spectrum user(s) ("the incumbent(s)") would share spectrum with one or several MNOs licensed as LSA users ("LSA licensee(s)"), in accordance with a set of pre-defined conditions. These conditions may be static (e.g., specific exclusion zone or time allowed for operation) or dynamic (e.g., geographic/time sharing, on-demand authorisation by LSA licensees, or on-demand restrictions imposed by incumbents).

A key benefit for MNOs is that the LSA approach enables them to have faster access to a new spectrum without having to wait for difficult, costly and lengthy re-farming policies, thus allowing much less conflicting scenarios (ANFR 2012).

LSA aims to ensure a certain level of guarantee in terms of spectrum access and protection against harmful interference for both the incumbent(s) and LSA licensees. Incumbent(s) and LSA licensees each have exclusive access to the spectrum at a given location at a given time.

Spectrum Management Framework Policy Statements

27. *The Authority shall adopt the LSA type of licensing.*
28. *LSA licences shall be issued for the frequency bands that qualify, to facilitate the introduction of new users while maintaining incumbent services in the bands.*
29. *Minimum technical standards and conditions shall be established before the implementation of the LSA licence.*
30. *The Authority shall determine which frequency bands to apply the LSA licensing type to, from time to time.*

6.2.1.2.2 Pluralistic Licence

In line with the emerging technologies outlined in section 3, pluralistic licensing is the latest emerging licensing concept for flexible spectrum management, under which interference is viewed as a tradeable characteristic of the spectrum.

With pluralistic licensing, licences are awarded under the assumption that opportunistic secondary spectrum access will be allowed, and that interference may be caused to the primary spectrum holder based on defined parameters and rules that are known to the primary at the point of obtaining the licence.

Benefits of pluralistic licensing include:

i. encouraging a more robust or better designed primary system that can cope with an increased degree/risk of interference.

ii. allowing opportunistic spectrum use while providing any level of protection desired by the primary users.

iii. incentivising the primary to make more efficient use of spectrum, and to make unused spectrum available, i.e., it greatly improves spectrum usage efficiency and fairness.

iv. possible pricing mechanisms for secondary systems (e.g., at the certification stage) that might also lead to the better design of secondary systems, such as incorporating sensing for secondary awareness (i.e., better secondary coexistence).

v. highly flexible, depending on the case-by-case deployment context (e.g., intended primary service).

vi. highly scalable to progressive deployment in more spectrum bands.

Pluralistic licensing is a good, adaptable balance between exclusive use and licence-exempt access. Primary interference and licence fees are based on primary/secondary services (Holland, Oliver, et. al. 2012).

Spectrum Management Framework Policy Statements

31. *The Authority shall adopt the pluralistic licensing types to incentivise primary users to make more efficient use of the spectrum.*

32. *Pluralistic licences shall be issued for the frequency bands that qualify.*

33. *The relevant technical conditions shall be established before the implementation of the pluralistic licence.*

34. *The Authority shall determine which frequency bands to apply the pluralistic licensing to, from time to time.*

6.2.1.2.3 Light Licence

Light licensing refers to a regulatory framework that combines licence-exempt use and protection of users of the spectrum. With this approach, interference is typically mediated by technical solutions rather than by the local administrator. In a light licensing framework, a user is required to obtain a non-exclusive licence to operate in a particular frequency band.

Light licensed offers another layer of security when compared to unlicensed. In a light licensed approach, the licensee pays a comparatively smaller fee for a non-exclusive license. Benefits of the light licensed approach include:

i. reduced regulatory/administrative burden on the operator.
ii. comparatively low licence fee as the licence is not exclusive.
iii. fast rollout.
iv. some moderate guarantees against interference.

Spectrum Management Framework Policy Statements

35. *The Authority shall adopt the light licence type to award non-exclusive licences which are either free or have only a nominal fee attached to them.*

36. *Light licences shall be issued for the frequency bands that qualify.*

37. *The relevant technical conditions shall be established before the implementation of the light licence type.*

38. *The Authority shall determine which frequency bands to apply the light licensing to, from time to time.*

6.2.1.3 General Authorised Access

6.2.1.3.1 Class Licence

“Class licensing spectrum” refers to the spectrum in which access is permitted on the basis of a general licence. In some jurisdictions, class licensed frequency bands may also be referred to as "unlicensed or license-exempt" bands. The class licensed bands are inherently based on spectrum sharing among the various class licence users.

Under a class licence regime, no individual authorisation or coordination is required and no fee is payable for using the spectrum.

Access to the spectrum under a class licence is regulated solely by adherence to pre-defined regulatory parameters. These regulatory parameters are defined to ensure the protection of radio services (vertical sharing) and also to ensure equitable access between class licence radio devices (horizontal sharing).

Short-range devices (SRD) commonly fall in the class licence category. Effective access to spectrum by SRDs relies heavily on the principle of "frequency re-use" and is enabled by the low-power operation, cluttered environment, and spectrum access mechanisms such as duty cycle limitation. Administrations have a responsibility to ensure sustainable access to SRD bands, and the impact of a change in spectrum regulations has to be duly assessed prior to decision making.

At present, in several countries, mobile network operators utilise Wi-Fi offload of the downlink data over the class licensed spectrum in the 2.4 GHz ISM band to improve network operations and user experience, and are laying the groundwork for supplemental downlink in segments of the 5 GHz band (ITU WDTC Resolution 9, 2017).

Spectrum Management Framework Policy Statements

39. *The Authority shall maintain its class licence regime for the licensing of short-range radiocommunications devices.*

40. *The class licence shall set out the requirements regarding the permitted radiofrequency emissions and the permitted maximum power of those emissions.*

6.2.2 Mechanisms for the Granting of Licences

The radio spectrum is essential to modern communications. Different spectrum licensing mechanisms are required to deal with the distinct needs of individual radio users and the time period in which a frequency band may be open for licensing (ITU-R 2015).

The licensing mechanism adopted by the Authority for the allocation of the spectrum is based on several factors, such as the potential number of applicants, the number of licences to be granted based on spectrum availability, the type of service linked to the use of the spectrum, universal service requirements and the economic value of the resource.

The Authority has retained the use of both "auctions" and "comparative evaluation" (beauty contests) as the main licensing mechanisms for awarding operating licences.

Spectrum Management Framework Policy Statements

41. *Where the spectrum is scarce (i.e., demand is greater than supply), the Authority shall utilise competitive licensing mechanisms, such as auctions and/or beauty contests, as the main tools for awarding licences.*

42. *Where no scarcity in the spectrum is foreseen, or scarcity can be managed by another mechanism (e.g., spectrum pricing and releasing more spectrum), the first come, first served (FCFS) licensing approach is a simple and administratively straightforward method of individual licence-based assignment that shall be maintained.*

6.3 Spectrum Monitoring

A key component in effective spectrum management is the capability to monitor the use of spectrum resources and to ensure that users comply with the particular technical and operational parameters included in their licences.

Spectrum monitoring supports the overall spectrum management process in general, including frequency assignment and spectrum planning functions, by the practical measurements of the channel and band usage taken during the monitoring process, so that channel availability statistics may be derived and the effectiveness of spectrum use can be assessed (ITU-R Handbook on National Spectrum Management).

The Authority's spectrum monitoring activities fall under two categories: responsive and scheduled.

6.3.1 Responsive Monitoring Activities

Responsive monitoring is unplanned or ad hoc and is based either on internal or external triggers from the Authority's processes, or requests from the Authority's committees and departments. Responsive monitoring consists of the following activities:

i. Interference complaints. In order to accurately determine the location of interference, the Authority's spectrum monitoring system comprises both fixed and mobile units. It has the capability of performing interference analysis for all potential system(s) as well as monitoring to detect cases of interference among existing systems. Responsive monitoring to investigate interference complaints may span several weeks, consisting of one or more types of spectrum monitoring activities, depending on the complexity of the complaint.

   Additionally, in accordance with its objective to manage the national spectrum resource and act to deter or eliminate any harmful interference, the Authority maintains oversight of all licensed users' sites of operation. This oversight includes reviewing the maintenance of all radio-transmitting equipment facilities.

ii. Consumer technical complaints. These responsive monitoring activities, like those undertaken to investigate interference complaints, are focused on the collection of data to investigate complaints, submitted by the public, about the quality of service (QoS) and coverage received from public fixed wireless and mobile telecommunications and broadcasting services that use spectrum.

6.3.2 Scheduled Monitoring Activities

Schedules monitoring activities are planned and take the form of spectrum audits and proactive spectrum monitoring exercises. These activities take considerable time and resources and are critical, both from an operational and planning perspective. Schedule monitoring consists of the following activities:

i. Spectrum planning and management. Scheduled monitoring is used to determine the level of occupancy of the various frequency bands and the availability of spectrum to potential users, and informs the Authority's spectrum planning process.

ii. Licensing. Prior to the assignment of frequencies in the granting of licences, monitoring is conducted to ensure that the frequencies to be assigned to a new system will not create any interference to existing users and that the new system is not subjected to interference from existing users. Scheduled monitoring also provides data that verify spectrum utilisation for expired and surrendered licences.

iii. Compliance with technical parameters. It is mandatory that licensees adhere to the terms and conditions of their licences. The Authority's scheduled monitoring activities are critical in the detection of non-compliance with respect to technical parameters, e.g., power levels and frequency drift.

One area of particular concern is the level of RF activity, i.e., electromagnetic radiation in the vicinity of radio transmitting equipment which should, at all times, conform to the limits established by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) vis-à-vis exposure to the public.

iv. Spectrum audits to identify the unauthorised use of spectrum. The unauthorised use of spectrum poses interference problems for existing users and translates to a loss of revenue for the Authority. Detection of such unauthorised use is of paramount importance. Scheduled monitoring is used to gather information to determine the unauthorised use of the spectrum.

Spectrum Management Framework Policy Statements

43. *The Authority shall perform both responsive and scheduled monitoring activities, in accordance with its objective to manage the national spectrum resource, and act to deter or eliminate any harmful interference.*

44. *The Authority shall ensure that its "real-time" computerised spectrum monitoring and management system is effectively managing the use of the radio frequency spectrum resources in Trinidad and Tobago.*

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