TANZANIA COMMUNICATIONS REGULATORY AUTHORITY

SPECTRUM MANAGEMENT STRATEGY: 2024/2025-2034/2035

First Version

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SPECTRUM MANAGEMENT STRATEGY: 2024/2025-2034/2035

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List of abbreviations

DRM	Digital Radio Mondiale
eMBB	Enhanced Mobile Broadband
FWA	Fixed Wireless Access
HF	High Frequency
HAPS	High Altitude Platform Systems
HIBS	HAPS as IMT Base Station
IFAT	International Frequency Allocation Table
IMT	International Mobile Telecommunication
ISM	Industrial, Scientific, and Medical
ITU	International Telecommunication Union
LEO	Low Earth Orbit
mMTC	Massive Machine Type Communication
NFAP	National Frequency Allocations Plan
RR	Radio Regulations
TCRA	Tanzania Communications Regulatory Authority
T-DAB	Terrestrial Digital Audio Broadcasting
UHF	Ultra High Frequency
uRLLC	Ultra Reliable Low Latency Communication
VHF	Very High Frequency
WRC	World Radiocommunication Conference

Executive Summary

The Spectrum Management Strategic for the United Republic of Tanzania offers a comprehensive framework to guide the effective management of radio frequency spectrum over the next decade. The plan's strategies aim to ensure spectrum is optimally allocated, used, to support emerging technologies while protecting existing service, and ensure equitable access for all stakeholders.

Beginning with an overview of Tanzania's existing spectrum management framework, the plan highlights key policies, legislation and regulations, governing spectrum allocation and usage.

Central to the strategy are the objectives of spectrum management within Tanzania, emphasizing the importance of efficient utilization and equitable distribution of this critical resource. Five strategic objectives are outlined to guide spectrum management efforts, each accompanied by implementation strategies aimed at achieving measurable outcomes.

A comprehensive analysis of the spectrum landscape in Tanzania outlines current spectrum usage across various services and sectors, while also forecasting increased demand due to evolving technological advancements requiring high data capacity.

To ensure the plan's effectiveness, a robust monitoring and evaluation framework is proposed. This framework will track progress, assess the impact of implemented strategies, and facilitate ongoing adjustments to optimize spectrum management practices.

In conclusion, the Spectrum Management Strategy for Tanzania provides a roadmap for optimizing spectrum utilization, fostering innovation, and supporting socio-economic development. Through the implementation of proposed strategies and continuous monitoring, Tanzania can position itself as a leader in spectrum management, unlocking the full potential of this critical resource for the benefit of its citizens and stakeholders.

1. Introduction

1.1 Background information

The radio frequency spectrum is the portion of electromagnetic waves lying between 9 kHz to 3000 GHz, allocated to different Radiocommunication services such as broadcasting, mobile and satellite in line to the Radio Regulations (RR) of the International Telecommunications Union (ITU). The radio frequency spectrum is a finite and valuable resource.

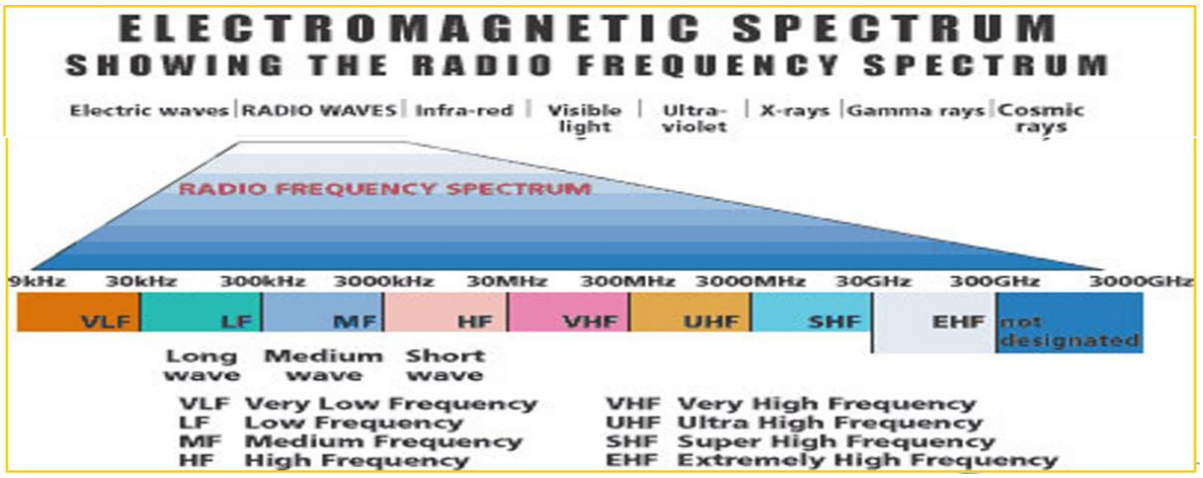

Figure 1: Radio Frequency Spectrum in the Electromagnetic Spectrum
https://www.lbagroup.com/blog/why-is-the-us-strip-mining-radio-spectrum/

Everyone in the United Republic of Tanzania: people, businesses and public organizations uses or relies on a range of wireless services and technologies on a daily basis. Some of the most prevalent consumer uses of spectrum include browsing the internet at home or on using a mobile network and/or a Wi-Fi; making a phone call or sending a text message using a mobile network; watching television or listening to the radio; using Bluetooth to connect a wide range of personal and home devices; accessing navigation services in a smartphone or in a car etc.

Spectrum management is the process of regulating the allocation, assignment, and use of radio frequency spectrum to ensure efficient and effective utilization of this finite resource. It involves establishing policies, legislation, regulations, guidelines and procedures for spectrum allocation, licensing, and coordination to prevent interference and promote fair and equitable access to spectrum resources. Spectrum management aims to balance the competing demands for spectrum among different users, including government agencies, commercial operators, broadcasters, and other stakeholders, while

maximizing spectrum utilization and fostering innovation in wireless technologies and services.

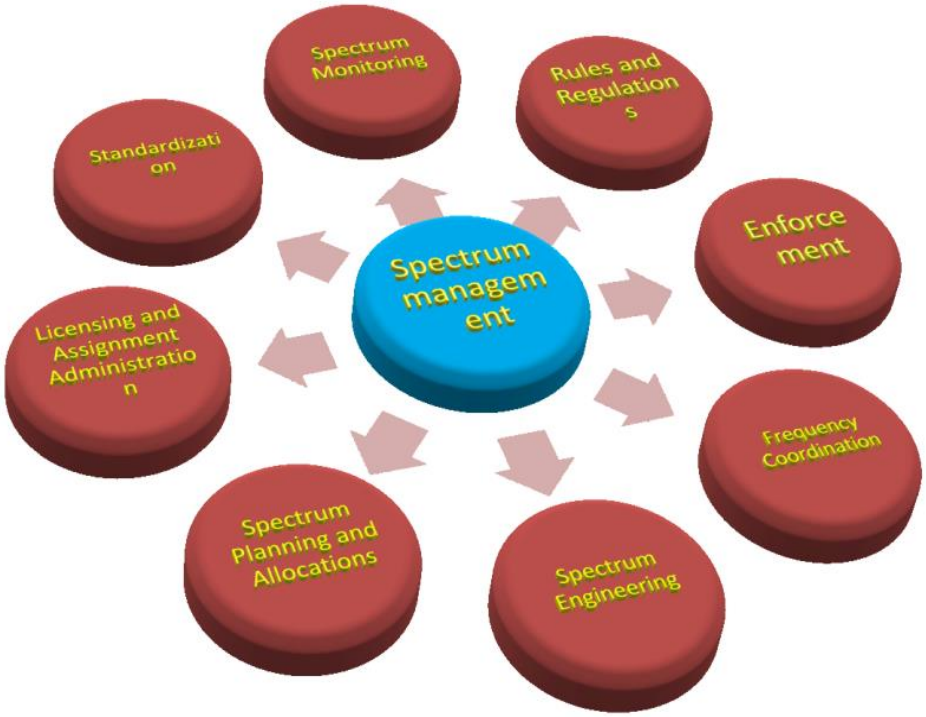

Figure 2 : Spectrum Management Activities
https://www.itu.int/en/ITU-R/seminars/rrs/2016-Asia-Pacific/Intro/Spectrum%20Management.pdf

1.2 Spectrum Management Process

Radio frequency spectrum management involves three key activities which are spectrum planning and allocation, spectrum licensing and assignment and spectrum monitoring and enforcement.

1.2.1 Spectrum planning and allocation

Spectrum planning and allocation starts at the international level coordinated by the International Telecommunication Union (ITU). The following are series of activities done under spectrum planning and allocation from the international level to national level:

1.2.1.1 The World Radiocommunication Conferences (WRCs) convened by the International Telecommunication Union (ITU) review, and, if necessary, revise the ITU Radio Regulations, the international treaty governing the use of the radio-frequency spectrum and the geostationary-satellite and non-geostationary-satellite orbits. It sets the framework for spectrum allocation globally.

1.2.1.2 The World Radiocommunication Conferences (WRCs) convened by the International Telecommunication Union (ITU) review, and, if necessary, revise the ITU Radio Regulations, the international treaty governing the use of the radio-frequency spectrum and the geostationary-satellite and non-geostationary-satellite orbits. It sets the framework for spectrum allocation globally.

1.2.1.3 After every WRC, the ITU prepares the International Frequency Allocation Table (IFAT), which contains a comprehensive allocation of frequency bands for various services and applications across the three ITU regions. This table is outlined in Article 5 of the ITU Radio Regulations and serves as a reference for national regulatory authorities.

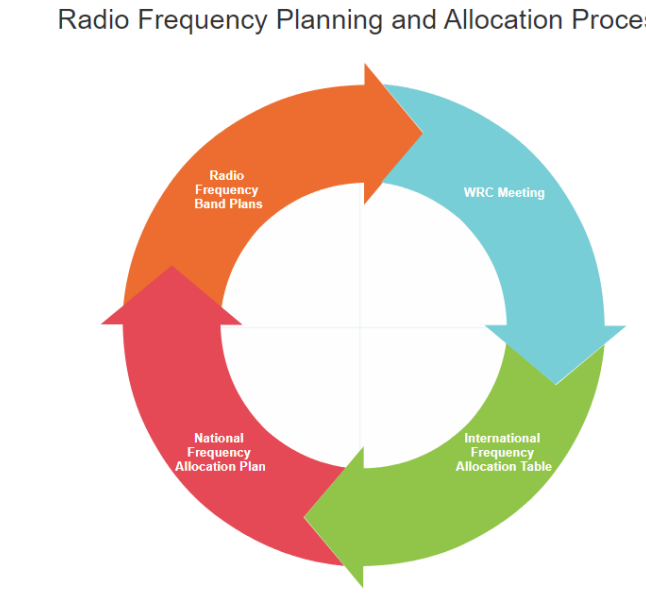

Figure 3: Radio Frequency Planning and Allocation Process

1.2.1.4 The Tanzania Communications Regulatory Authority (TCRA), prepare National Frequency Allocation Plan (NFAP) based on the allocations specified in the IFAT. NFAPs consider the specific needs of the country, current infrastructure, and future requirements for communication networks and services. The NFAP is periodically updated to reflect changes in technology, usage patterns, and regulatory frameworks.

1.2.1.5 Fourth, TCRA develop radio frequency band plans tailored to specific services and applications based on NFAP. These plans allocate portions of the spectrum to particular uses, such as mobile telecommunications, broadcasting, aviation, and emergency services. Band plans ensure efficient spectrum utilization, minimize interference between different services, and promote the orderly development of wireless communications.

1.2.2 Spectrum licensing and assignment

Spectrum licensing and assignment is a regulatory process of assigning specific frequency channel (s) to service providers so that they can provide a desirable service. Spectrum licensing and assignment, overseen by the Tanzania Communications Regulatory Authority (TCRA), involves three primary methods.

1. **The administrative method**, also known as "first come, first served," is utilized when spectrum availability exceeds demand and no competitive pressures exist. Under this approach, specific channels are allocated to service providers in the order they apply.

2. **The market-based method:** This is employed when demand surpasses available spectrum, in this case competitive auctions are conducted. Interested parties bid for the right to access specific frequencies, ensuring allocation to those who value them most and can utilize them efficiently. This method encourages optimal spectrum utilization, commonly applied to valuable bands like those for mobile telecommunications.

3. **The commons or licence exempt:** This approach treats spectrum as a shared resource, accessible to all users without exclusive licensing. Users are expected to coordinate to prevent interference and promote efficient usage. Typically deployed in unlicensed bands, such as the ISM (Industrial, Scientific, and Medical) bands, this method fosters innovation and experimentation by removing access barriers.

1.2.3 Spectrum monitoring and enforcement.

Spectrum monitoring is crucial for effective spectrum management. TCRA conducts spectrum monitoring to fulfill important functions such as;

Firstly, spectrum monitoring serves as the guardian of assigned radio frequency spectrum, ensuring full utilization without interference. By actively monitoring the spectrum, TCRA can identify any instances of unauthorized or illegal use, swiftly taking action to mitigate interference and enforce compliance with regulations.

Additionally, spectrum monitoring enables assess spectrum utilization across different frequency bands and geographical areas. By analyzing usage patterns and demand trends, the authority gains valuable insights into how spectrum resources are being utilized, allowing for informed decision-making in spectrum planning and allocation processes.

Moreover, spectrum monitoring provides essential feedback for improving spectrum planning and assignment processes. By identifying areas of congestion, underutilization, or emerging trends for adjusting strategies and policies to better meet the evolving needs of stakeholders and ensure efficient spectrum management.

The spectrum monitoring is done through the use of equipment that adheres to international standards, ensuring accuracy, reliability, and compatibility with global best practices. By employing state-of-the-art monitoring equipment and techniques, TCRA can effectively fulfill its role as the "eyes and ears" of the spectrum management process, safeguarding the integrity of the radio frequency spectrum and promoting the orderly development of wireless communications.

1.3 Importance of spectrum management

Spectrum management is critical for supporting the growing demand for wireless connectivity and enabling the deployment of emerging technologies such as 5G, Internet of Things (IoT), and smart devices. This process is essential for mitigating spectrum congestion, preventing harmful interference between wireless systems, and promoting equitable access to spectrum resources, thus facilitating the deployment of wireless technologies and services that drive economic growth, innovation, and societal development. The process requires collaboration and coordination among regulators, industry stakeholders, and international organizations to harmonize spectrum allocation and ensure interoperability of wireless systems across borders.

By facilitating the efficient use of spectrum resources and promoting spectrum harmonization and coordination at national and international levels, spectrum management contributes to advancing global connectivity, bridging the digital divide, and unlocking the full potential of wireless communications in the digital age.

1.4 Tanzania Spectrum Management Vision

Quality of Life of Tanzanians enhanced through efficient use of spectrum

2. Radio Frequency Spectrum Management Framework in the United Republic of Tanzania

The radio frequency spectrum management process in the United Republic of Tanzania is guided by the National ICT Policy 2016, the Electronic and Postal Communication Act 2022, Electronic and Postal Communication (Licensing) Regulations 2022 and the Electronic and Postal Communications (Radio Communication and Frequency Spectrum) (Amendment) Regulations 2022.

2.1 National ICT Policy of 2016

One of the objectives of the National ICT Policy 2016 is to strengthen management and promote efficiency in spectrum allocation and utilization that guarantees availability and competition in both urban and rural areas. To achieve this policy objective, the Government of the United Republic of Tanzania promised to: -

i. Ensure availability of spectrum for various uses and allocation that favours public interest; promotes innovation, research and development; strengthens competition and attracts foreign direct investment;
ii. Ensure allocation and assignment of commercial spectrum resources that is transparent, competitive, does not confer permanent ownership to users and that sees to it that the allocated resources are used efficiently for sustainable provision of affordable and quality ICT services;
iii. Strengthen national capacity of management of spectrum and enhance contribution to regional and international spectrum planning and harmonization in conformity with international standards;
iv. Ensure substantial amount of spectrum including digital dividend is dedicated to the government for bridging the digital divide that is necessary for e-service delivery specifically for rural areas.

2.2 Legislation

The legislation that guide the Spectrum Management in Tanzania is Tanzania Communications Regulatory Authority Act 2003. This act established the Tanzania Communications Regulatory Authority (TCRA) with among other functions, is to manage radio frequency spectrum in the United Republic of Tanzania. In doing its operation the TCRA is guided by the Electronic and Postal Communication Act 2022, the Act that grants the TCRA powers to assign, modify, renew and cancel licenses and sets out details of how these powers can be used.

2.3 Regulations

Regulations that govern the spectrum management process are made under the Electronic and Postal Communication Act 2022. These are Electronic and Postal Communication (Licensing) Regulations 2022 and the Electronic and Postal Communications (Radio Communication and Frequency Spectrum) (Amendment) Regulations 2022.

3. Landscape of radio frequency spectrum allocation and assignment in Tanzania

3.1 Overview of existing spectrum allocation

The TCRA through the NFAP has indicated allocation of radio frequencies to different radiocommunication services. As much as the NFAP is enriched, does not necessary mean all allocated frequency in the NFAP are opened up for assignment to operators of radiocommunication services but rather it gives overall allocation of frequencies which is the guide for TCRA doing the assignment when the frequencies are opened up. This section provides an overview of the current spectrum assignment and allocation in Tanzania, highlighting the frequency bands allocated for various services such as broadcasting, mobile telecommunications, aviation, and others.

3.1.1 Mobile Communication Services

Tanzania has strategically allocated spectrum across the low –frequency bands, mid-frequency bands and higher-frequency bands in order to bolster mobile communication services. The low-frequency bands like the 700 MHz, 800 MHz, and 900 MHz excel in providing broad coverage and penetrating indoor areas, especially in rural regions. Meanwhile, mid-frequency bands such as the 1800 MHz and 2100 MHz bolster coverage

and capacity in urban settings. Additionally, higher-frequency bands like the 2300 MHz, 2600 MHz, and 3500 MHz offer added capacity for densely populated urban areas and data-heavy applications. Notably, the 3500 MHz band is earmarked specifically for 5G deployment, facilitating high-speed data transmission and supporting cutting-edge technologies. Collectively, a significant portion of spectrum, totaling 920 MHz, has been assigned to meet the burgeoning demand for mobile services. These spectrums are assigned through market-based approach.

Due to this, Tanzania's telecommunications sector has experienced remarkable expansion, evident in the steadily rising mobile penetration rates over the years. With 2G, 3G, and 4G covering approximately 98%, 88%, and 80% of the country' population respectively, mobile connectivity has become ubiquitous across the country. More recently, the launch of 5G networks has begun, achieving a population coverage of around 13%. These networks promise even higher data rates, lower latency, and increased network capacity, setting the stage for transformative digital experiences. Spectrum allocation plays a pivotal role in facilitating this growth by enabling mobile operators to extend coverage, enhance network quality, and introduce innovative services such as high-speed mobile internet and mobile banking.

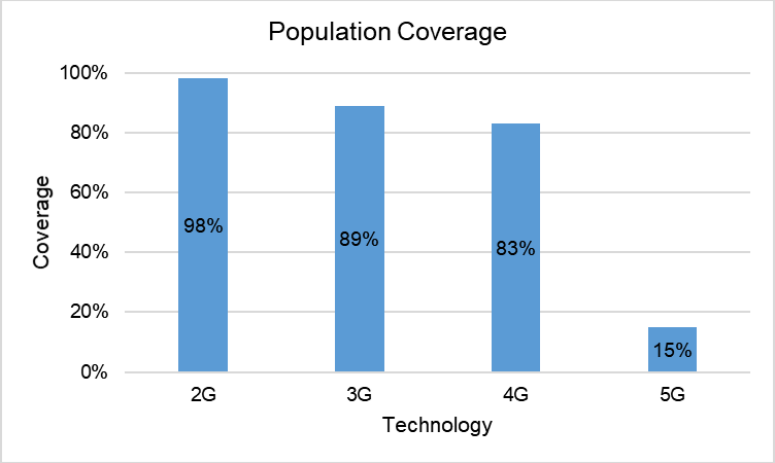

Figure4: Mobile network population coverage per technology
(https://www.tcra.go.tz/uploads/text-editor/files/Communication%20Statistics%20report%20for%20end%20of%20June%202024_EN_1721315046.pdf)

Tanzania adopted a Converged Licensing Framework that supports technology and service neutral, allowing operators to leverage spectrum repurposing for the adoption of more spectral-efficient technologies. For instance, the widely-used 900 MHz and 1800 MHz bands, initially designated for 2G services, have been repurposed for the deployment

of 3G and 4G technologies, maximizing spectrum utilization and ensuring optimal service delivery.

By allocating spectrum resources strategically, TCRA ensures that mobile operators have the necessary bandwidth to deliver ultra-fast connectivity and support the evolving needs of consumers and businesses. This proactive approach not only fosters continued growth and innovation in the telecommunications sector but also contributes to Tanzania's broader socio-economic development goals by promoting digital inclusion and fostering a thriving digital economy.

3.1.2 Broadcasting

Broadcasting remains an essential source of information and entertainment for Tanzanians, with both public and private broadcasters playing crucial roles in serving diverse audiences nationwide. The allocation of spectrum is vital for broadcasting services, ensuring sufficient bandwidth for terrestrial television and radio transmissions. In Tanzania, terrestrial broadcasting services utilize allocated spectrum bands, including the television band (470-694 MHz) and FM radio band (87.5-108 MHz), which were previously assigned on a first-come, first-served basis until 2023. However, since 2023, the allocation of frequency channels within the FM band has shifted to a competitive tendering process, except for community radio broadcasting. The allocated spectrum has facilitated widespread access to radio and television programming across the country. Tanzania boasts a considerable number of radio stations and terrestrial television multiplex operators, offering a diverse range of content to the population. Satellite broadcasting services, such as Direct to Home, utilize spectrum assigned through ITU-coordinated processes.

Plans are underway to introduce digital sound broadcasting in Tanzania, with designated frequency bands (174-230 MHz and 525-1605 kHz) earmarked for this purpose. T-DAB and DRM has been adopted. By embracing these digital sound broadcasting standards, Tanzania aims to enhance the quality of broadcasting services while making more efficient use of available spectrum resources.

Both terrestrial and satellite broadcasting services contribute to the country's broadcasting landscape. This multifaceted approach underscores Tanzania's commitment to evolving

its broadcasting infrastructure to meet the evolving needs and expectations of its citizens in the digital age.

3.1.3 Point-to-Point Microwave Links

In Tanzania, where the deployment of optic fiber infrastructure remains at a relatively low pace, microwave links have remained as essential components of the communication network. These serve as vital conduits for point-to-point communication, facilitating high-capacity connectivity crucial for backhaul networks, interconnecting base stations, and linking remote sites to the core network infrastructure. Currently, a significant number of sites, totaling 8,281, are connected using microwave links, surpassing the 5,305 sites connected via fiber optic cables.

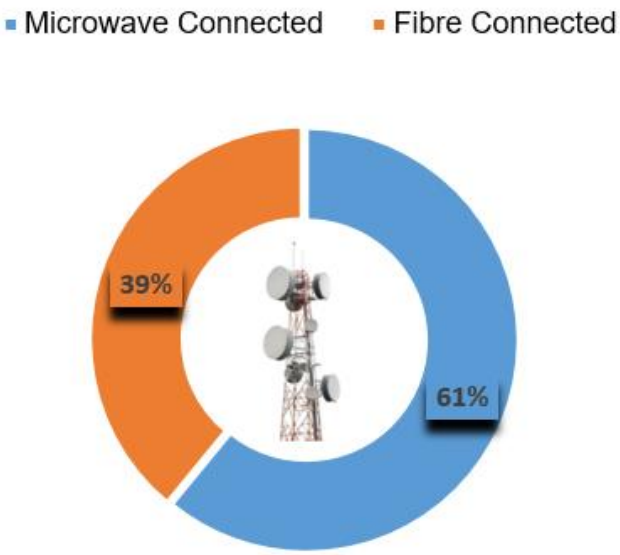

Figure 5 : Mobile Communication sites backhauls (TCRA)

Microwave links in Tanzania operate across various frequency bands, including 6GHz (both lower and upper), 7GHz, 8GHz, 11GHz, 13GHz, 15GHz, 18GHz, 23GHz, and 26GHz. While optic fiber remains a preferred choice for its high bandwidth and reliability, microwave links play a critical role in bridging connectivity gaps, especially in areas where fiber deployment is challenging or cost-prohibitive. As Tanzania continues to expand its telecommunications network and improve connectivity, a balanced approach that leverages both optic fiber and microwave technologies will be essential to meet the growing demands for high-speed data transmission and communication services across the country. These spectrums are assigned administratively.

3.1.4 Wi-Fi Services

Wi-Fi hotspots are deployed in various public spaces, including cafes, hotels, airports, and shopping malls, to provide wireless internet access to users with Wi-Fi-enabled devices. These hotspots utilize unlicensed spectrum in the 2.4 GHz and 5 GHz bands allocated for Wi-Fi and other short-range wireless technologies. One significant benefit of Wi-Fi is their ability to serve as traffic offload for mobile broadband networks. By diverting data traffic to Wi-Fi networks in high-traffic areas such as airports, shopping malls, and urban centers, wireless broadband services help alleviate congestion on mobile networks, leading to improved overall performance and user experience.

3.1.5 Fixed Wireless Access

Fixed Wireless Access (FWA) utilizing licensed spectrum is crucial for expanding high-speed internet connectivity, especially in regions where building fiber last-mile connections is challenging. With exclusive access to designated frequency bands, FWA providers ensure reliable service, high quality, and extensive network coverage, which are essential for fostering digital inclusion. Tanzania's plan to open up the E-Band for FWA highlights the importance of leveraging this technology to rapidly deploy broadband network infrastructure, thus narrowing the digital divide and promoting inclusivity. Overall, FWA plays a pivotal role in complementing traditional wired infrastructure, advancing internet access, and contributing to socioeconomic development and digital inclusion worldwide.

3.1.6 Railways communication services

Railway communication services rely extensively on wireless technologies to ensure the safe and efficient operation of trains and associated infrastructure. Wireless communication plays a pivotal role in facilitating real-time communication among trains, trackside equipment, and control centers. This communication enables crucial functions such as train tracking, route management, speed control, and signaling, thereby ensuring the safe and punctual movement of trains throughout the railway network.

Tanzania has allocated various frequency bands for railway communication services. These bands typically include segments of the radio spectrum designated for fixed and mobile services (in HF, VHF and UHF), as well as specialized bands reserved for railway-

specific applications such GSM-R (876 - 880 MHz / 921 - 925 MHz) and 874.4 - 880 MHz / 919.4 - 925 MHz, and 1900 - 1910 MHz

3.1.7 Aviation and Maritime Communications

Tanzania's diverse geography, boasting the Indian Ocean and renowned lakes like Victoria, Tanganyika, and Nyasa, underscores the importance of maritime activities. Simultaneously, the nation's aviation sector is rapidly expanding, driven by its strategic location, positioning it as a future hub for airlines connecting various destinations.

To support these critical sectors, robust communication services are imperative for ensuring safety and operational efficiency. Exclusive spectrum is allocated for both maritime and aviation communications to, facilitating secure and seamless transportation across sea and sky. This allocation supports vital services such as air traffic control, navigation assistance, and distress signaling, crucial for safeguarding maritime and aviation operations.

3.1.8 Meteorological services

Meteorological services heavily depend on wireless communications for collecting, transmitting, and disseminating data crucial for weather forecasting, monitoring, and research. This data encompasses a wide range of atmospheric parameters, including temperature, humidity, air pressure, wind speed, precipitation, and more. Through wireless transmission, this data is efficiently relayed to central processing centers for analysis and interpretation. The data are indispensable for providing timely and accurate weather information to sectors such as agriculture, aviation, maritime, disaster management, and public safety.

3.1.9 Business radio (Radio Call)

Business radio or sometimes refer to Private Mobile Radio (PMR) provides wireless communications for a wide variety of professional users from a range of sectors including mining, utilities, facilities management and construction. Business radio devices access bands in the VHF and UHF range. In Tanzania most of the business radio users are operating in the VHF and HF bands, while the demand for using a UHF band is increasing.

3.1.10 Public Safety and Emergency Services

Reliable communication is critical for public safety and emergency response operations, where lives may depend on timely and effective coordination. Spectrum allocation for public safety communications involves prioritizing dedicated spectrum bands for emergency services and ensuring interoperability among different agencies and jurisdictions.

3.2 Spectrum Needs and Allocation to Emerging Technologies

As we review the current landscape of spectrum utilization in Tanzania, it's essential to recognize that technological advancements are continuously shaping the future of wireless communication. While we currently deploy various technologies that rely on spectrum, it's crucial to anticipate and prepare for emerging technologies that will demand additional spectrum resources. By understanding these future developments, we can proactively plan spectrum management strategies to accommodate evolving needs and ensure efficient spectrum utilization across the country. This part explores upcoming technologies and services that may require spectrum allocation in the future, such as 5G, Internet of Things (IoT), and smart cities infrastructure.

3.2.1 5G and beyond

5G and beyond represent the next generation of wireless technology, offering faster speeds, lower latency, and greater capacity compared to previous generations. 5G networks are designed to support three use case scenarios which are enhanced mobile broadband (eMBB), massive machine-type communications (mMTC), and ultra-reliable low-latency communications (uRLLC). Beyond 5G, advancements such as 6G are already being explored, aiming to further improve connectivity and enable new use cases, such as AI and Communication; ubiquitous connectivity and integrated sensing and communications.

As these technologies evolve, they will require additional spectrum allocations to meet the growing demand for high-speed data transmission and support innovative applications that drive economic growth and digital transformation. There's a pressing need to allocate spectrum in higher frequency bands (millimeter-wave frequencies) to accommodate the escalating demand.

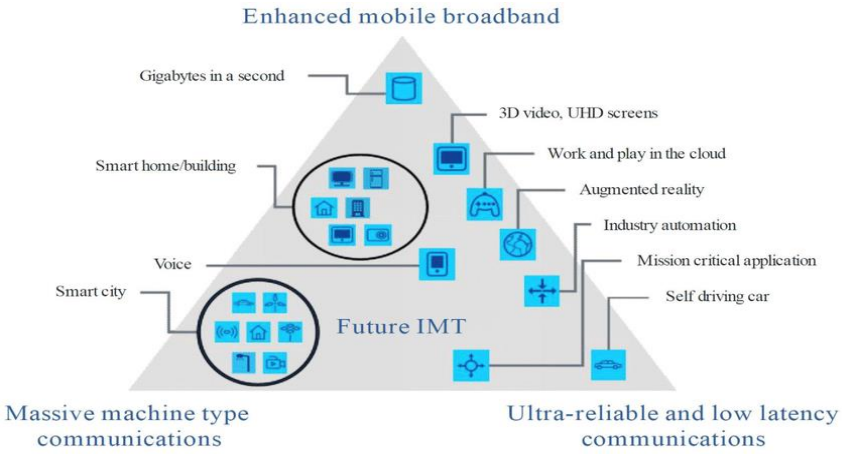

Figure 6 : 5G Use case scenarios
https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2083-0-201509-I!!PDF-E.pdf

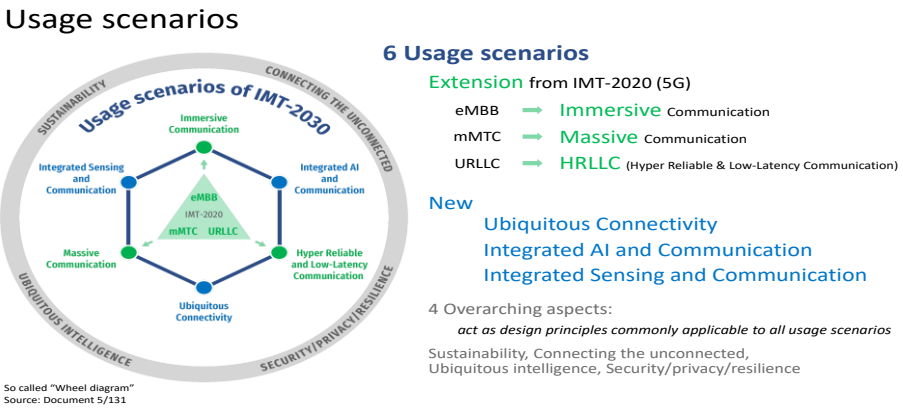

Figure 7 : 6G Use case scenarios
https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2160-0-202311-I%21%21PDF-E.pdf

3.2.2 Internet of Things

The Internet of Things (IoT) represents another frontier in wireless communication, with billions of interconnected devices expected to come online in the coming years. These IoT devices, ranging from smart sensors to connected appliances, relies on wireless connectivity to exchange data and facilitate automation and remote monitoring. IoT is a building block of “smart everything”. The concept of "smart everything" envisions a future where virtually every aspect of our lives is enhanced by IoT technology, leading to greater convenience, efficiency, and sustainability. Whether it's smart cities, smart factories, smart grip, smart meter or smart agriculture etc., IoT serves as the underlying infrastructure that enables the seamless integration of digital and physical environments, driving innovation and shaping the future of society. Number of IoT technology such as LoRaWAN e.t.c operates in licence exempt and others such as NB-IoT, LTE-M etc. operates in licence bands. To accommodate the massive scale of IoT deployments to

enable seamless connectivity and unlock the full potential of IoT technologies require proper spectrum planning.

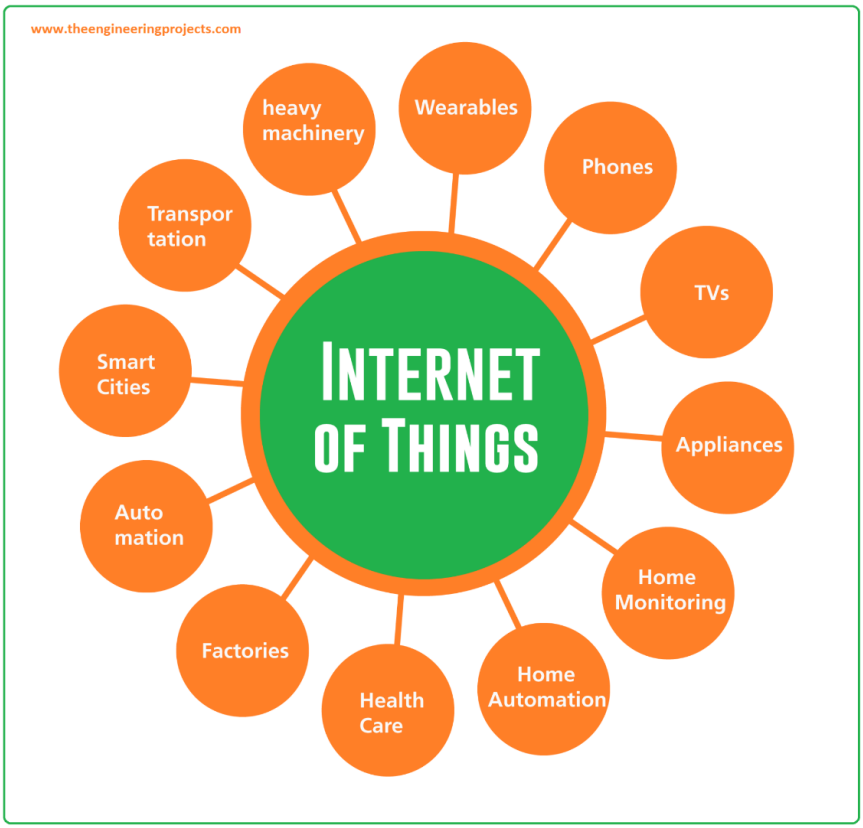

Figure 8: IoT in different applications
https://www.theengineeringprojects.com/2021/03/what-is-iot-internet-of-things-definition-meaning-devices-applications.html

3.2.3 5G Broadcast

5G broadcast is another innovative technology poised to transform the way multimedia content is delivered to mobile devices and other endpoints. Unlike traditional unicast streaming, which requires individual data streams for each user, 5G broadcast enables simultaneous delivery of content to multiple users within a specific geographical area. This approach optimizes spectrum usage and network efficiency, particularly for popular live events, emergency alerts, and immersive media experiences. 5G broadcast relies on dedicated broadcast spectrum bands and multicast transmission techniques to deliver high-quality video, audio, and other content to a large audience with minimal latency and congestion. As 5G networks continue to evolve, broadcast capabilities will play a vital role in enhancing the user experience and enabling new services and applications.

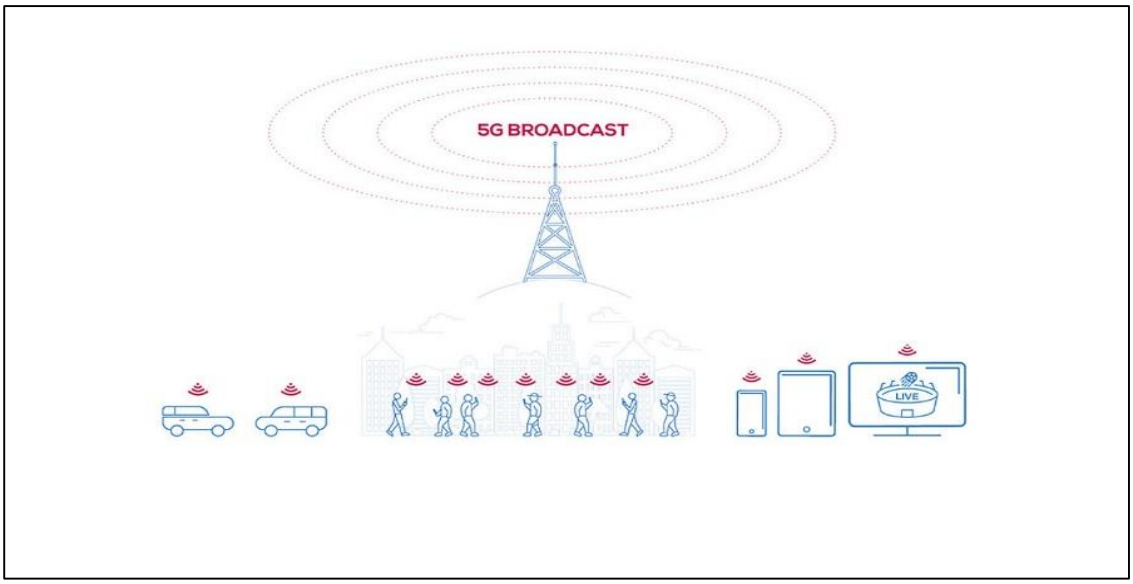

Figure 9 : 5G Broadcasting
https://www.ors.at/en/5g-broadcast/advantages/

3.2.4 Wi-Fi Six and beyond

Advancements in Wi-Fi technology, such as Wi-Fi 6 and beyond, will continue to drive the demand for spectrum in both residential and commercial environments. Private networks, catering to specific industries and applications, will also require dedicated spectrum allocations to support critical communications and mission-critical services. TCRA will strive to ensure equitable access to spectrum by all technologies.

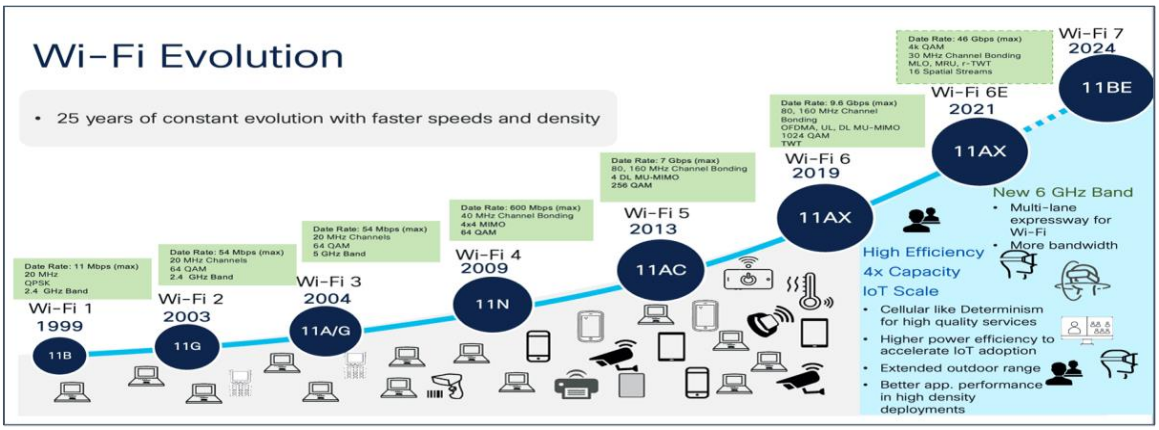

Figure 10 : Wi-Fi Evolution
https://outshift.cisco.com/blog/onward-and-upward-with-wi-fi-7

3.2.5 Satellite Mega constellations

The growing deployment of satellite mega constellations in the Low Earth Orbit (LEO) for broadband internet connectivity poses both challenges and opportunities for spectrum management. Challenges include potential spectrum congestion, interference mitigation

complexities, coordination among numerous satellite operators, licensing issues and space sustainability issues. However, these constellations also offer opportunities such as expanded coverage to underserved areas, innovation in spectrum use, global connectivity fostering communication and data exchange worldwide, and diverse applications enhancing quality of life and economic growth. Effective spectrum management practices, international cooperation, and technological innovations will be crucial in addressing these challenges and maximizing the potential benefits of satellite mega constellations for broadband internet connectivity.

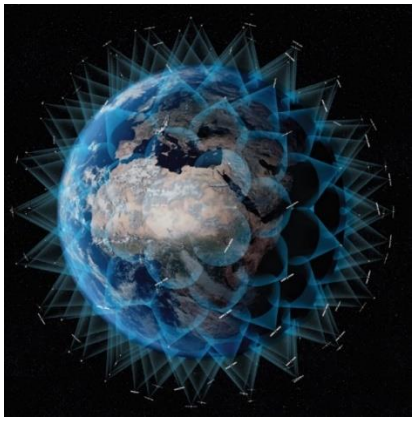

Figure 11 : Satellite Mega Constellations in the low earth orbit
https://www.esa.int/ESA_Multimedia/Images/2019/11/Mega-constellation_coverage

3.2.6 Private Networks

Private networks tailored to industry verticals are a growing trend in wireless communications, offering organizations dedicated and customized connectivity solutions to meet their specific operational needs. These private networks serve a wide range of industries, including manufacturing, utilities, transportation, healthcare, and logistics, providing enhanced reliability, security, and control over wireless communication infrastructure.

Each industry vertical has its unique spectrum requirements for private network deployments. Some organizations may utilize license-exempt spectrum bands, such as the Industrial, Scientific, and Medical (ISM) bands, while others may require licensed spectrum allocations to ensure interference-free operation and reliable connectivity, especially in critical applications.

As private networks become more prevalent across industry verticals, TCRA will use effective spectrum management strategies to address the diverse spectrum needs of different sectors while maximizing spectrum utilization efficiency.

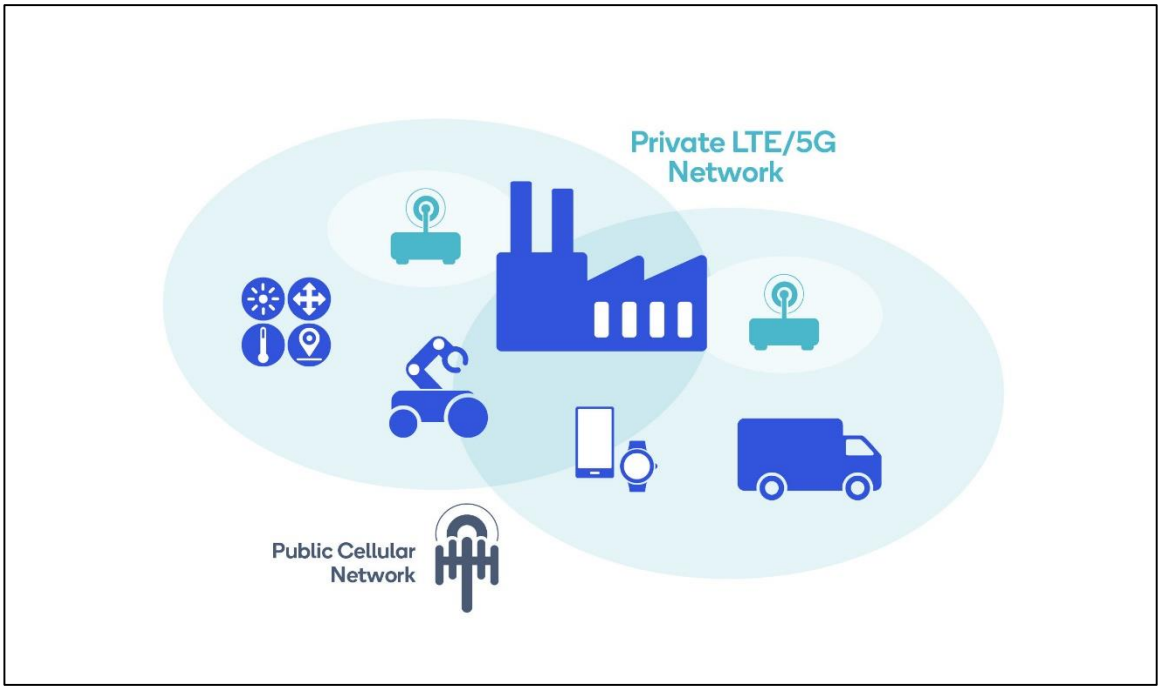

Figure 12 : Private Networks of Industrial Verticals
https://moniem-tech.com/questions/what-is-the-difference-between-private-networks-and-network-slicing/

3.2.7 Radio Astronomy and Scientific Research

Radio astronomy, a branch of astronomy focused on studying celestial objects and phenomena using radio waves emitted or reflected by them, offers unique insights into the universe's mysteries, including pulsars, quasars, galaxies, and cosmic microwave background radiation. While Tanzania has had limited involvement in this field historically, there's a growing interest among Tanzanians to participate in radio astronomy and scientific research, even to the extent of installing telescopes for observation within Tanzania.

The recent emergence of satellite mega constellations and the increasing number of space debris pose significant challenges for radio astronomers globally. These constellations, comprising hundreds or thousands of small satellites, emit signals that can interfere with radio astronomy observations. The sheer number of satellites and their signals obstruct observations and contribute to the escalating problem of space debris, endangering both astronomical research and space missions' safety.

Tanzania's promising involvement in radio astronomy highlights the need to protect radio astronomy bands from interference. Spectrum protection measures are crucial to mitigate

the impact of terrestrial and satellite communications on radio astronomy observations. Collaborating with international research institutions allows Tanzania to tap into expertise and resources, developing effective strategies to preserve radio astronomy bands while addressing the challenges posed by satellite mega constellations.

Figure 13 : Radio Astronomy Observation Centre
https://public.nrao.edu/gallery/vla-background-1/

3.2.8 Convergence of space and terrestrial services

This part explore the emerging trend of integrating space-based and terrestrial services to create seamless and ubiquitous connectivity solutions. This part highlight some technologies such as High Altitude Platform Stations (HAPS), HAPS for IMT Base Station (HIBS), and satellite-to-device communications to extend coverage and enhance connectivity beyond traditional terrestrial networks.

3.2.8.1 HAPS

High Altitude Platform Stations (HAPS) are aerial platforms stationed in the Earth's stratosphere, typically at altitudes ranging from 17 to 22 kilometers. They serve as stationary or semi-stationary platforms equipped with communication antennas and relay equipment to provide various services, including telecommunications, remote sensing, and environmental monitoring

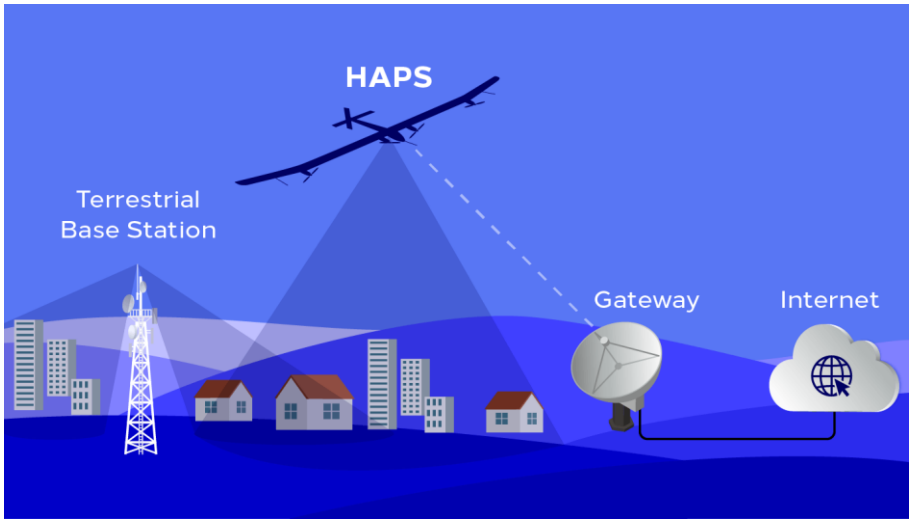

Figure 14 : High Altitude Platform Systems (HAPS) complementing terrestrial coverage
https://www.cst.gov.sa/en/ntn/Pages/air-borne.aspx

3.2.8.2 HIBS

In the convergence between space and terrestrial services, High Altitude Platform Stations (HAPS) play a crucial role including the deployment of International Mobile Telecommunications (IMT) base stations (HIBS). By installing IMT base stations in the HAPS provide wide-area coverage, bridging gaps in terrestrial network coverage and ensuring connectivity for mobile users in rural or isolated regions. HIBS will use same spectrum assigned for terrestrials IMT. This bring the challenges of interference. TCRA will develop proper regulatory frameworks for spectrum sharing and coordination between HIBS and terrestrial services.

3.2.8.3 Satellite to devices

Satellite direct-to-device services (including IMT devices) represent an emerging technology that delivers multimedia content and broadband connectivity directly to end-user devices, bypassing traditional terrestrial networks. Direct-to-services enable users to access high-speed internet, video streaming, and other data-intensive applications using their existing mobile devices, without requiring any modifications. This approach leverages satellite communication to provide ubiquitous coverage, reaching remote and underserved areas where terrestrial infrastructure is limited or unavailable. As this technology evolves, it will require dedicated spectrum allocations or sharing and coordination with existing service to support its growing demand and ensure interference-free operation.

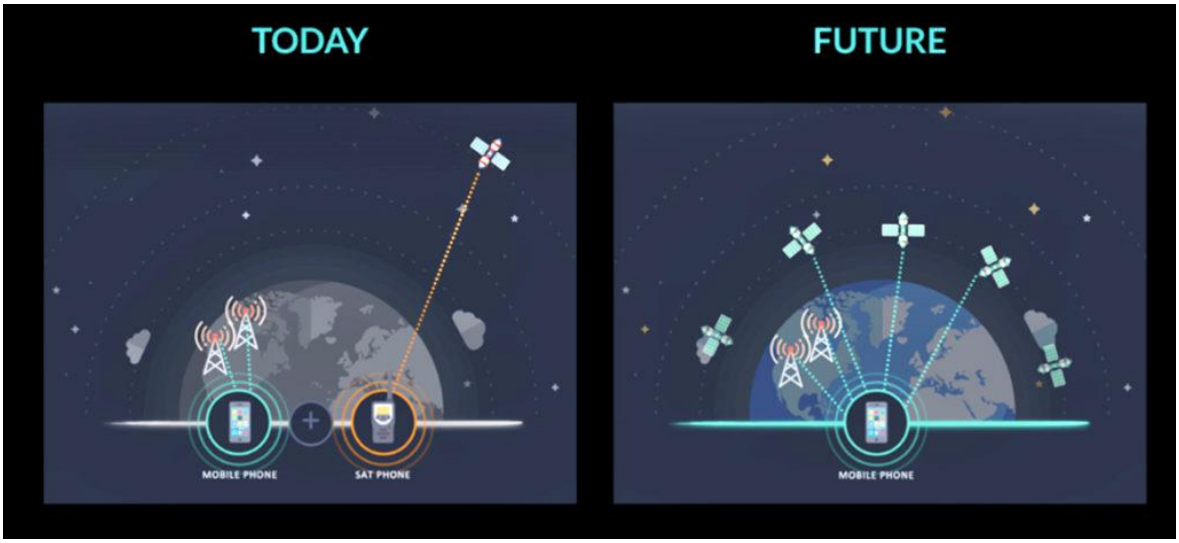

Figure 15 : Space and Terrestrial Services Convergence
https://wirelessnation.co.nz/blog/the-future-of-100-mobile-coverage-explained/

4. Tanzania Spectrum Management Strategies

Spectrum Management Strategy is a document that represents a commitment to coordinate, optimize, and safeguard the utilization of the radio frequency spectrum. It serves as a guiding framework for governments, regulatory bodies, and industry stakeholders to effectively manage this finite resource in a manner that promotes efficient spectrum utilization, fosters innovation, and ensures equitable access for all users. Through transparent planning, assignment, and robust regulatory measures, this strategy pledges to unlock the full potential of the spectrum, driving socio-economic growth and enhancing the quality of wireless communication services.

This strategy aims to ensure that radio frequency spectrum resources is allocated and assigned in a manner that encourages competition, supports technological advancements, and addresses the diverse needs of all stakeholders. By continuously monitoring and adapting to evolving needs and technologies, this strategy vows to uphold the integrity and efficiency of the spectrum ecosystem, delivering on the promise of a more connected and prosperous future

TCRA Spectrum management strategies are built upon several fundamental principles aimed at ensuring efficient and equitable utilization of the radio frequency spectrum. The first is predictability which is essential, providing stakeholders with clear guidelines and processes for spectrum allocation, licensing, and usage. Predictability fosters certainty and confidence among spectrum users, enabling them to plan and invest in their wireless infrastructure effectively. Flexibility is another key principle, allowing for adaptive

responses to changing technological landscapes and spectrum demands. TCRA spectrum management strategy is designed to accommodate emerging technologies and innovative use cases, ensuring that spectrum remains relevant and responsive to evolving needs.

Another principle is efficient use of spectrum. This is a core objective of spectrum management strategies, aiming to maximize the utilization of available spectrum resources while minimizing interference and inefficiencies. This involves implementing spectrum sharing mechanisms, dynamic spectrum access policies, and spectrum re-farming initiatives to optimize spectrum usage across different bands and services. Moreover, priority is often given to those with superior spectrum rights in cases where band sharing occurs, ensuring that incumbent users are adequately protected while facilitating access for new entrants and innovative applications.

Furthermore, global harmonization is another principle used to develop this strategy. It plays a crucial role in spectrum management strategies, promoting economies of scale and interoperability across national borders. Harmonized spectrum allocations and technical standards enable manufacturers to develop standardized equipment and devices, facilitating economies of scale and reducing costs for consumers. By aligning spectrum policies and regulations with international frameworks and agreements, we can leverage global cooperation and coordination to unlock the full potential of wireless communications, fostering innovation, investment, and socio-economic development on a global scale.

5. Objectives of the Spectrum Management Strategy

The spectrum management strategy comprises five (5) specific objectives, each crafted to ensure the efficient allocation and utilization of radio frequency spectrum, while adhering to fundamental principles such as predictability, flexibility, and global harmonization. Each objective is supported by corresponding strategies designed to achieve its respective goal. The objectives are outlined below: -

Objective 1	**To ensure radio frequency spectrum is efficiently and effectively utilized**
Objective 2	Promote equitable access to radio frequency spectrum by all technology and services

Objective 3	To ensure adequate amount of spectrum is allocated to meet the need of current and emerging wireless technologies and services
Objective 4	To ensure radio frequency spectrum support research and innovation initiative aimed at developing new technologies
Objective 5	Ensuring radio frequency spectrum support the advancement of the Fourth Industrial Revolution

Figure 16 : Spectrum Management Strategy Objectives

6. Implementation Strategies of the Objectives of Spectrum Management Strategy

6.1 Objective 1: To ensure radio frequency spectrum is efficiently and effectively utilized

Ensuring the efficient and effective use of assigned radio frequency spectrum is paramount for maximizing its benefits and making the most of the same. Efficient utilization means each assigned radio frequency band is used in a way that maximizes its capacity, minimizing any waste or underutilization while minimizing interference between different services or users within the spectrum, allowing for seamless and reliable communication. Effective utilization means that the assigned frequencies are used to provide services that meet the needs of consumers, businesses, and public services and also to support the development of new and emerging technologies, fostering innovation across in the country.

Strategies

TCRA will use the following strategies to ensure efficient and effective use of radio frequency spectrum: -

i. Conduct regular radio frequency spectrum audits to assess usage of assigned spectrum.
ii. Maintain a comprehensive inventory of assigned radio frequencies, license holders, and usage patterns.
iii. Promotion of cognitive and software-defined networking radio to enable dynamic access to spectrum
iv. Review of radio frequency spectrum fees
v. Establishment/regular review of spectrum sharing guidelines to promote sharing among multiple operators or services.
vi. Implement systems that will help in promptly identification or reporting of interference cases.

vii. Collaborate with neighboring countries for cross-border spectrum management.

viii. Modernizing the spectrum workforce to keep up with technological advancements, meet the growing demand for spectrum access

6.2 Objective 2: Promote equitable access to radio frequency spectrum by all technology and services

Equitable access to radio frequency spectrum by all technology and services refers to ensuring that various stakeholders, including established operators, new entrants, innovators, and underserved communities, have fair and equal opportunities to access and utilize spectrum resources for their respective needs. It is essential for fostering innovation, competition, and inclusivity in the telecommunications sector.

Strategies

TCRA will use the following strategies to ensure equitable access to radio frequency spectrum: -

i. Establish a transparent spectrum allocation and assignment framework providing clear guidelines and criteria to ensure fairness and non-discriminatory assignment of spectrum licenses in various radio frequency spectrum bands

ii. Inclusive stakeholder engagement in development of policy, legislation, regulation and guidelines related to spectrum management

6.3 Objective 3: To ensure adequate amount of spectrum is allocated to meet the need of current and emerging wireless technologies and services

Ensuring an adequate amount of spectrum is allocated to accommodate current and future emerging technologies is a fundamental pillar of fostering innovation, meeting escalating demand for wireless services, and ensuring technological progress for driving innovation and meeting the growing demand for wireless services.

Strategies

TCRA will use the following strategies to ensure adequate amount of spectrum is allocated to meet the need of current and emerging wireless technologies and services: -

i. Conduct a thorough analysis of current and projected spectrum demand across various industries and services, considering trends in technology adoption, data consumption, and emerging applications
ii. Implementing flexible spectrum management frameworks that allow reallocation of spectrum resources based on changing demand and technology evolution
iii. Conducting regular assessments of technological trends and their spectrum requirement. This will to develop a forward-thinking spectrum planning framework that anticipates the future needs of emerging wireless technologies.

6.4 Objective 4: To ensure radio frequency spectrum support research and innovation initiative aimed at developing new technologies and applications

Strategies

TCRA will use the following strategies to ensure radio frequency spectrum support research and innovation initiative aimed at developing new technologies: -

i. Implement experimental licensing frameworks that allow researchers and innovator to obtain temporary licenses for spectrum use in controlled environments for them to conduct experiments and validate new concepts

ii. Actively engage with the research community through workshops, seminars, and conferences to exchange ideas, identify emerging trends, and align spectrum policies with the needs of the research community

6.5 Objective 5: Ensuring radio frequency spectrum contributes to the advancement of the Fourth Industrial Revolution and Verticals

The Fourth Industrial Revolution is characterized by the integration of digital technologies into various industries, leading to transformative changes in sectors such as manufacturing, healthcare, transportation, and agriculture etc. Radio Frequency Spectrum is a critical enabler for many of these technologies and applications, facilitating wireless connectivity, data transmission, and communication between devices and systems.

Strategies

TCRA will use the following strategies to ensure radio frequency spectrum contributes to advancement of 4th Industrial Revolution: -

i. Reserve radio frequency spectrum for verticals or specific industries to facilitate the deployment and adoption of wireless technologies tailored to the unique needs and requirements of those sectors.

ii. Allocating radio frequency spectrum for the Internet of Things (IoT) applications and devices and other emerging technologies.

7. Strategy Implementation Monitoring and Evaluation

Objective 1: To ensure radio frequency spectrum is efficiently and effectively utilized within next ten years					
S/N	**Strategies**	**Indicators**	**Frequency**	**Baseline**	**Target**
1.	Conduct regular radio frequency spectrum audits to assess usage of assigned spectrum.	Spectrum utilization rate	Yearly	90%	100%
2.	Maintain a comprehensive inventory of assigned radio frequencies, license holders, and usage patterns.	Accurate information/data on radio frequency spectrum holdings	Yearly	0	1
3.	Promotion of cognitive and software-defined networking radio to enable dynamic access to spectrum	Number of operators practicing dynamic spectrum access	Yearly	1	3
4.	Review of radio frequency spectrum fees	Number of reviews	Twice in ten years	0	2
5.	Establishment, and regular review of spectrum sharing guidelines to promote sharing among multiple operators or services.	Increased number of operators sharing spectrum	Yearly	0	2
6.	Implement systems that will help in promptly identification or reporting of interference cases.	Number of interferences cases reported/identified and addressed			
7.	Collaborate with neighboring countries for cross-border spectrum management.	Reduced number of cross border interference incidence	Yearly	10	0
8.	Modernizing the spectrum workforce to keep up with technological advancements, meet the growing demand for spectrum access	Number of spectrum management trainings attended	Yearly	0	3
Objective 2: Promote equitable access to radio frequency spectrum by all technology and services within next ten years					
S/N	**Strategies**	**Indicators**	**Frequency**	**Baseline**	**Target**
1.	Establish a transparent spectrum allocation and assignment framework providing clear guidelines and criteria to ensure fairness and non-discriminatory assignment of spectrum licenses in various radio frequency spectrum bands	Spectrum sharing initiatives	Yearly	0	2
2.	Inclusive stakeholder engagement in development of policy, legislation, regulation and guidelines related to spectrum management	Number of key stakeholder's engagement conducted in the development of policy, Legislations, Regulations, Guidelines relating to spectrum management	Yearly	90%	100%

Objective 3: To ensure adequate amount of spectrum is allocated to meet the need of current and emerging wireless technologies and services within next ten years					
S/N	**Strategies**	**Indicators**	**Frequency**	**Baseline**	**Target**
1.	Conduct a thorough analysis of current and projected spectrum demand across various industries and services, considering trends in technology adoption, data consumption, and emerging applications	Spectrum demand vs. availability studies	Yearly	3	8
2.	Implementing flexible spectrum management frameworks that allow reallocation of spectrum resources based on changing demand and technology evolution	Number of spectrum bands re-farmed/repurposed	Yearly	4	8
3.	Conducting regular assessments of technological trends and their spectrum requirement. This will to develop a forward-thinking spectrum planning framework that anticipates the future needs of emerging wireless technologies.	Allocated spectrum bands for emerging technologies	Yearly	0	1
Objective 4: To ensure radio frequency spectrum support research and innovation initiative aimed at developing new technologies within next ten years					
S/N	**Strategies**	**Indicators**	**Frequency**	**Baseline**	**Target**
1.	Implement experimental licensing frameworks that allow researchers and innovator to obtain temporary licenses for spectrum use in controlled environments for them to conduct experiments and validate new concepts	% of Authorized temporary radio frequency spectrum request for innovations	Yearly	90%	100%
2.	Actively engage with the research community through workshops, seminars, and conferences to exchange ideas, identify emerging trends, and align spectrum policies with the needs of the research community	Number of workshop/seminars conducted with research community on spectrum	Yearly	0	10
Objective 5: Ensuring radio frequency spectrum support the advancement of the Fourth Industrial Revolution within next ten years					
S/N	**Strategies**	**Indicators**	**Frequency**	**Baseline**	**Target**
1.	Reserve radio frequency spectrum for verticals or specific industries to facilitate the deployment and adoption of wireless technologies tailored to the unique needs and requirements of those sectors.	Spectrum bands allocated for verticals	Yearly	0	1
2.	Allocating radio frequency spectrum for the Internet of Things (IoT) applications and devices and other emerging technologies.	Amount of radio frequency spectrum bands allocated for IoT	Yearly	2	4

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