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IMPROVING SPECTRUM MANAGEMENT IN NIGERIA WITH RESPECT TO THE BEST PRACTICES IN THE WORLD

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Abstract— **Radio Frequency Spectrum is a scarce resource that cannot be consumed, added to or produced. The RF Spectrum supports a wide range of business, personal, industrial, scientific, medical research and cultural activities, both public and private. Communications are foremost among those activities and, together with radio services, are increasingly important to the economic and social development of Nigeria. This paper reviews World Best Spectrum Management Policies and uses knowledge based on research findings on recent trends in Spectrum Management to propose ways to reduce or entirely remove Nigeria's Spectrum Management Challenges.**

Index Terms: Radio Frequency Spectrum, Spectrum Management, SM World Best Practices

I. INTRODUCTION

Demand for wireless broadband has soared due to technological innovations such as 3G and 4G mobile services and the rapid expansion of wireless internet services. [1]. As a result of this, many new and emerging radio services and technologies are competing to have access to the spectrum.

The electromagnetic spectrum is a unique natural resource shared by various types of services which is free from depletion but subject to congestion through use. If left unplanned, spectrum congestion can lead to harmful interference and hinder users from getting the best these services have to offer [2].

Spectrum management is the process of regulating the use of radio frequencies to promote efficient use and gain a net social benefit [3].

The term *radio spectrum* typically refers to the full frequency range from 3KHz to 300 GHz that may be used for wireless communication. Increasing demand for services such as mobile telephones and many others has required changes in the philosophy of spectrum management.

II. SPECTRUM MANAGEMENT IN NIGERIA

Radio frequency spectrum is one of Nigeria's key natural resources of great economic value as a result of its direct application in telecommunications, broadcasting, military operations, and scientific research in addition to a range of other socioeconomic activities such as social services, law enforcement, education, healthcare, transportation, etc. As a result, many industries depend heavily on the efficient utilization of radio frequency spectrum [4].

These crucial factors therefore, make it mandatory for the government to develop comprehensive and clear-cut policies that will ensure that spectrum resource is optimally utilized for the overall benefit of the nation.

A. Spectrum Regulatory Authorities in Nigeria

Described below is a summary of Spectrum Regulatory authorities in Nigeria.

1. **National Frequency Management Council (NFMC):** Located within the Ministry of Information and Communications, it is the apex body for Spectrum Management and the primary sponsor of and influence on the government's frequency spectrum policies and legislation. The NFMC is responsible for the planning, coordination and bulk trans-sectorial allocation of radio spectrum to the National Communications Commission, the National Broadcasting Commission and the Ministry. The NFMC is the focal coordinator of all frequency spectrum activities. It is chaired by the minister of Information and Communications and consists of high-level representatives of other ministries.
2. **The Nigerian Communications Commission (NCC):** The regulator of the telecommunications industry with wide discretionary powers to plan, manage, assign and monitor the use of spectrum by commercial users of telecommunications services. The commission develops and publishes radio frequency regulations and standards for the industry. The NCC appears to be playing a central role in the development of frequency spectrum policies as the de facto manager of the NFMC.

As an agency of Government, the NCC is charged with the responsibility to develop and adopt policies in accordance with the following policy objectives that will ensure that this scarce resource is well managed in its area of responsibility [4].

3. **National Broadcasting Commission (NBC)**: Charged with regulating the broadcast industry, setting broadcast standards and upholding equity and fairness in broadcasting. It assigns the broadcast frequencies it receives from the NFMC to private and public radio and TV stations.
4. **Ministry of Information and Communications (MoIC)**: Through the Department of Spectrum Management, the MoIC is responsible for the formulation and monitoring of communications polices, International treaties and national representation in International organizations. With the establishment and

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increased legislative empowerment of both the NCC and NBC, the MoIC's functions have gradually been limited to the management and assignment of frequencies to government and non-commercial users, including the Military, Security services, diplomatic missions, volunteer organizations and non-profit groups. The Ministry is the secretariat of the NFMC and acts as the custodian of all frequencies in Nigeria [5].

III. NCC Frequency Management Policy Objectives

- To control and encourage the use of spectrum as an instrument for developing telecommunication (being) which is an essential infrastructure for stimulating the economic growth and social development of the nation.
- To promote competition in the assignment of frequency in order to ensure innovative and efficient use of the radio spectrum (as a scarce resource).
- To achieve optimum pricing of spectrum in order to discourage wastage or speculative acquisition of the scarce resource.
- To generate moderate revenue for government.
- To ensure equitable and fair allocation of spectrum to benefit the maximum number of users.

IV. Spectrum Management World Best Practices

Represented below are a set of Modern Best Spectrum Management World Best Practices.

a. **Transparency of Spectrum Management Operations**: Spectrum Management Polices should be aimed at Promoting transparent, non-discriminatory, economically efficient and effective spectrum management policies, that provide regulatory certainty.

This is achieved in the following ways:

– Carrying out public consultations on SM policies and procedures:

• before changing national frequency allocation plans; and

• Before making SM decisions likely to affect service providers.

– Publication on the regulator's website:

• forecasts of spectrum usage and allocation needs

• frequency allocation plans

• frequency register that gives an overview of assigned spectrum rights, vacant spectrum, and license-free spectrum, taking into account any need for confidentiality and public security

– Clearly defining and publishing, on the regulator's website and in a gazette:

• radio frequency spectrum users' rights and obligations

• licensing and authorization rules and procedures

b. Technology Neutrality

This aims at Maximizing innovation, creating conditions for the development of new services, reduce investment risks and stimulate competition among different technologies.

This is achieved by;

– Adopting decisions that are technologically neutral and which allow for evolution of new radio applications

– Giving industry the freedom and flexibility to deploy their choice of technologies and decide on the most appropriate technology in their commercial interest

– Ensuring that similar applications offered by different radio-communication services (e.g. fixed and mobile) are not subject to disparate regulatory treatment

– Ensuring that bands are not allocated for the exclusive use of particular services and that spectrum allocations are free of technology and service constraints, *as far as possible*

c. Flexible spectrum use policies

– Countries should Introduce policies leading to flexible spectrum use so as to promote innovation and allow for the evolution of services and technologies, facilitate entry into market of new competitors

– Minimizing barriers to entry and providing incentives for small market players by allowing them to begin operations on a small scale at very low cost, without onerous rollout conditions, to enable them gain experience and test market demand for various services

– Adopting lighter regulations in rural areas, such as flexible regulation of power levels, the use of specialized antennas, the use of simple authorizations, lower spectrum fees

– Recognizing that in markets where spectrum scarcity is an issue, the introduction of spectrum trading can in some cases foster innovation and free-up spectrum for new applications

– Finding right balance of licence-exempt and licensed spectrum, balancing the desire to foster innovation with the need to control congestion and interference. One measure that could be envisaged is, for example, to allow small operators to start operations using licence-exempt spectrum, and then move to licensed spectrum when the business case is proved

d. Timely availability of spectrum

This factor should facilitate timely introduction of appropriate new applications and technology, while protecting existing services from harmful interference.

– Ensuring that operators have as wide a choice as possible of the spectrum they may access, and releasing spectrum to the market as soon as possible

– When appropriate, provide a mechanism to allow compensation for systems that must re-deploy for new spectrum needs (re-farming funds)

– Where spectrum is scarce, promote spectrum sharing, including using interference mitigation techniques and economic incentives, to the extent practicable

– Make all available spectrum bands for offer, subject to overall national strategic spectrum master-plans, in order that prices are not pushed up due to restrictive supply and limited amount of spectrum made available

– Special research or pilot testing authorisations could be issued to promote the development of innovative wireless technologies

– Consider creating incentives scheme to promote efficient co-existence/sharing of bands by governmental & non-governmental users

e. International harmonisation

Spectrum Management Policies should align domestic spectrum policies with internationally recommended policies, in order to achieve faster take-up of new bands and economies of scale.

This is achieved by

– Adopting harmonised frequency plans defined by ITU-R and regional bodies in order to facilitate the implementation of competition

– Working in collaboration with regional and other international colleagues to develop coordinated regulatory practices

– Removing any regulatory barriers to free circulation and global roaming of mobile terminals, SRDs and similar radio-communication equipment

– Using internationally recommended data formats and data elements for exchange of data and coordination purposes

– Utilizing regional and international standards whenever possible, and where appropriate, reflecting them in national standards

– Relying to the extent possible on industry standards including those that are included in ITU Recommendations in lieu of national regulations

f. Efficient SM Organization

To achieve efficient SM on both short-term and long-term basis, allocate spectrum in an economic and efficient manner, and by relying on market forces, economic incentives and technical innovations

– Speedy processing of frequency applications, smooth running of SM process

– Computer-assisted frequency assignment: technical database, interference calculation models, digital terrain information

– Computer-assisted frequency coordination: compatible with ITU tools such as BR-IFIC and common data exchange with neighbouring countries

– Computer-assisted spectrum monitoring: spectrum monitoring databases, plans for regular monitoring and inspection

– Computer-assisted licensing: administrative database integrated with frequency assignment, licence records, billing and fee collection

– Active participation in ITU forums and regional organizations

g. Affordability of spectrum access

This would be achieved by reducing financial barriers and promoting development of wireless technologies

– Apply reasonable spectrum fees for wireless technologies to foster the provision of innovative services at affordable prices, and minimize costs that may become barriers to entry for new operators

– Assist the economic viability of wireless technologies in rural and under-served areas through targeted application of reduced costs of access to spectrum

– Auctions and tender processes can also be managed to meet these goals

h. Ensuring level playing field

Ensure that all wireless players have equitable and fair access to spectrum resources

– Assure open and fair competition in the marketplaces for equipment and services, and constantly work on removing any identified barriers that arise to open and fair competition

– Remove any regulatory barriers to free circulation and global roaming of mobile terminals, SRDs and similar radio-communication equipment

– Remove any preferential treatment of domestic technologies/operators, allow free play for global communications technologies, such as satellite communications

– To prevent spectrum hoarding, especially by incumbents, regulators can set a limit on the maximum amount of spectrum that each operator can obtain [6].

V. Need for Efficient Spectrum Management in Nigeria

There has been a dire need for efficient Management in Nigeria and the world at large because of the following;

i. Mobile Broadband growth across regions of the world: There has been an exponential rise in the rate of increase of Broadband Subscriptions around the world. This is shown in Figure 1 below.

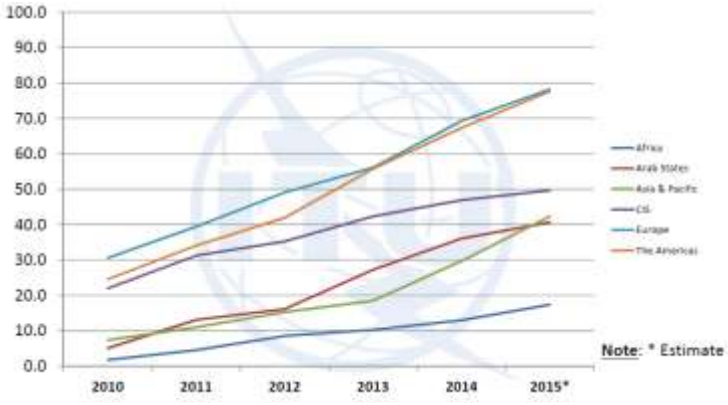

Figure 1: Active Mobile Broadband Subscriptions per 100 inhabitants 2010-2015 [7] .As a result of these, there has been an increased demand of spectrum which is a limited resource that is becoming increasingly scarce due to the fact that many new and emerging radio services and technologies are competing to have access to the spectrum.

ii. **Demand of Content –Internet Traffic Explosion**

Internet Traffic Explosion around the world has also been a strong factor that is straining the efficient management of spectrum.

According to the *Cisco Visual Networking Index*, Africa (and the Middle East) will be the fastest growing region in terms of internet traffic in the next four years with the expectation being a growth equivalent to 527 times the volume of the entire internet in this region in 2005. The report by Cisco forecasts internet growth from 2015 through to 2020, when Africa is expected to reach this predicted volume.

Based on the study, Africa and the Middle East will see an increase of 71% in mobile data and internet traffic in the same period, from the 294 Petabytes per month in 2015 to 4, 314 Petabytes by 2020, with the global increase in mobile data and internet traffic going from 3,685 Petabytes per month in 2015 to 30,564 by 2020.

Furthermore, it appears that video services and content will continue to be the leader compared to all other types of applications. Internet video will increase to a whopping 79% of global internet traffic by 2020, increasing from its 63% in 2015. This will see the monthly video usage increasing to 3-trillion internet video minutes per month. In the category of video, HD and Ultra HD video will see an increase from 53% in 2015 to 82% by 2020, of all the internet video traffic. On the business side, there is an increase expected of approximately 2.3 times the amount in 2015, increasing from 10,149 Petabytes per month in 2015 to 23,383 by 2020 and business mobile data increasing from 658 Petabytes per month to 4,484 in the same period, worldwide. Africa and the Middle East see business internet traffic growing from 678 Petabytes per month in 2015 to 1,758 Petabytes per month by 2020 across mobile and fixed internet devices.

Across the board, the growth of mobile and fixed internet is expected to increase in most geographical areas by between 20% and 80% with Africa and the Middle East with the biggest growth during this period [8].

VI. Ways of Improving Nigeria's Spectrum Management

Improving Nigeria's Spectrum Management would first and foremost involve aligning the policies/objectives of the Regulatory Bodies to align with those described by World's Best Practices of SM Management.

Furthermore, Nigeria would need to exploit newer Spectrum Management Technologies that are in use in other parts of the World. Exploiting technology to its fullest will require some changes in the way spectrum is managed. Unless proper attention is given to optimizing the use of spectrum—balanced with political, legal, and regulatory consideration—change is unlikely to occur in the foreseeable future. Political interests will continue to encourage the seizing of federal allocations.

New communications technologies are providing opportunities to obtain more services and capacity from spectrum. These technologies improve spectrum use and management in five general ways:

1. Information efficient technologies improve spectrum use by optimizing the quantity of information that is sent. The goal of information efficient technologies is to reduce the quantity of bits that must be used to represent information.

2. Spectrum efficient technologies try to reduce the quantity of spectrum needed to send bits at a specified rate.

3. Digital signal processing technologies change the way signals are processed in transmitters and receivers. They enable new ways to modulate and detect signals and make transceivers more flexible. Radio capabilities can be defined in software. DSP has done for communications transceivers what microprocessors did for the adding machine. In addition to being able to perform the adding function, computers can do a whole lot more through software. Similarly, software-defined radios will enable transceivers to do a whole lot more, many of the capabilities may not as yet have been discovered. At the very least, they enable transceivers to be continuously upgraded to employ the most spectrum efficient technologies.

4. Spatial reuse technologies attempt to increase the number of users that may use the same spectrum simultaneously. It achieves this goal by either reducing the spatial footprint over which transmissions can be heard, or by using diversity to enable multiple transmitters to use the same spectrum in the same space at the same time.

5. Dynamic spectrum management enables the management of spectrum in real time. These systems first identify what spectrum is available and then assign it to users for the best benefit. These systems may be directed as to what spectrum they might use or may search for available spectrum and then use it on an opportunistic basis.

None of these technologies is the clear winner in providing the best use of spectrum. Choosing any particular metric to measure efficient use of spectrum will prefer one technology over another. Military users of spectrum seek not only the most efficient way to send bits but also the most reliable way. Metrics that seek spectrum efficiency, i.e.,

bits/seconds/hertz, may favor technologies that are not sufficiently reliable.

VII. Conclusion/Recommendation

At the hub of Nigeria's success at efficiently managing its Spectrum, The spectrum management authorities must key into exploiting new technologies in the following ways

1. **Better Regulation of Commercial Cellular and Mobile Broadband Services**: The center of gravity of the telecommunications sector in developing countries like Nigeria is profoundly becoming wireless instead of fixed. This implies that the availability of spectrum is key to telecommunications development over the next decade [9]. In almost every part of the world, wireless data traffic is expected to increase, even double by some estimates, year over year for the next five years, developing broadband will then depend on spectrum availability. Improvement of Nigeria's efficiency of its Spectrum management will begin with knowing how spectrum is being used and by whom. This could be achieved through spectrum audits and spectrum demand and supply studies widh cover all spectrum users, especially government users, this would lead to steps which can result in new allocations and adjustments between users.
2. **Improving Terrestrial Broadcast Services**: Implementing the following trends would reduce Spectrum use in Nigeria thereby freeing up space on the Spectrum Table:
   a. ***Switch from Analogue to Digital TV Broadcasting***: Nigeria's Spectrum Management would be improved largely if she succeeds at switching over from Analogue to Digital Television Broadcasting. This move which had failed twice, in 2012 and 2015 has been billed to have a new deadline by June 2017. This move would drastically cut down bandwidth usage and free up bandwidth space because Digital TV requires less energy to ensure the same coverage as for analogue while decreasing overall costs of transmission. [10].
   b. ***Further Planning of Single Frequency Networks (SFN)***: SFN's are Networks in which distributed emission is implemented whereby the required coverage is provided through the use of multiple transmitters operating on the same frequency and carrying the same programs. In an SFN, many receiving locations within the coverage area will be served by more than one transmitter. This introduces a certain level of redundancy to signal reception thereby improving the service availability. This field strength variation can be reduced by the presence of several transmitters, located at different bearings as seen from the receiver, since when one source is shadowed, others may be easily receivable. This aspect of SFN gives rise to "Network gain" [11].
   c. ***Adoption of APT 700 MHz band plan***: The Asia-Pacific Telecommunity (APT) band plan is a type of segmentation of the 698-806 MHz band (usually referred to as the 700 MHz band) formalized by the APT in 2008-2010 [12] and specially configured for the deployment of mobile broadband technologies (e.g. most notably Long Term Evolution, LTE). This segmentation exists in two variants, FDD and TDD, that have been standardized by the 3rd Generation Partnership Project (3GPP) [13]. The APT band plan has been designed to enable the most efficient use of available spectrum. Therefore, this plan divides the band into contiguous blocks of frequencies that are as large as possible taking account the need to avoid interference with services in other frequency bands. The adoption of this plan would ensure the availability of more band for mobile users.
   d. ***Use of more Spectral Efficient Technologies***: In digital wireless networks, the system spectral efficiency or area spectral efficiency is typically measured in (bit/s)/Hz per unit area, in (bit/s)/Hz per cell, or in (bit/s)/Hz per site [14]. It is a measure of the quantity of users that can be simultaneously supported by a limited radio frequency bandwidth in a defined geographic area [15]. Spectral Efficiency can be improved by one or a combination of the following technologies;
      i. **Single User Transmission Technique:** This Concept is hinged on MIMO technique. It can therefore be addressed as the Single User MIMO (SU-MIMO). SU-MIMO considers data being transmitted from a single user to another individual user. When SU-MIMO is employed using an algorithm such as Space-Time Block Coding (STBC), performance improvement is greatly achieved [16]. STBC techniques can achieve huge performance gains in multipath fading wireless links by using multiple antennas along with appropriate signalling and receiver techniques to offer a powerful tool for improving wireless performance. [17].
      ii. **Multiple Access Schemes:** alternatively referred to as Channel Access Method allows several terminals connected to the same multi-point transmission medium to transmit over it and to share its capacity [15]. This scheme is based on a multiplexing method that allows several data streams or signals to share the same communication channel or physical medium. Some fundamentals types of this scheme include, FDMA, TDMA, CDMA, SDMA, PDMA. The implementation of a combination of these schemes would significantly enhance spectral efficiency.
      iii. **Implementation of Dynamic Radio Resource Management**: Radio Resource Management (RRM) is the system level management of co-channel interference, radio resources, and other radio transmission characteristics in wireless communication systems [15][18]. RRM involves strategies and algorithms for controlling parameters such as transmit power, user allocation, beamforming, data rates, handover criteria, modulation scheme, error coding scheme, etc. The objective is to utilize the limited radio-frequency spectrum resources and radio network infrastructure as efficiently as posssible. Dynamic RRM schemes adaptively adjust the radio network parameters to the traffic load, user positions, user mobility, quality of service requirements, base station density, etc. Dynamic RRM schemes are considered in the design of wireless systems, in view to minimize expensive manual cell planning and

achieve "tighter" frequency reuse patterns, resulting in Wikipedia, 2016).

iv. **Use of TV White Spaces**: In telecommunications, white spaces refer to frequencies allocated to a broadcasting service but not used locally [19]. This frequency allocation process creates a band plan, which for technical reasons assigns white space between used radio bands or channels to avoid interference. These white spaces are assigned for technical uses to spatially separate immediately adjacent channels to prevent destructive interference between both channels. There are also unused radio spectrum which has either never been used, or has become free as a result of technical changes. Various proposals, including IEEE 802.11af, IEEE802.22 and those from the White Spaces coalition, have advocated using white space left by the termination of analog TV to provide wireless broadband internet access. Devices intended to use these available channels are called "White Space Devices" (WSD). These devices are designed to detect the presence of existing but unused areas of airwaves, such as those reserved for analog television and utilize these unused airwaves to transmit signals for internet connectivity. Such technology is predicted to improve the availability of broadband internet and Wi-Fi in rural areas. [20].

v. If some or all of the aforementioned proposals are sponsored and carried out by the Nigerian government, Nigeria would be a world power at managing spectrum and giving out the best service to mobile users.

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