An Overview of Multi-Operator Global Systems for Mobile Communications Base Stations in the Context of Nigerian Telecommunication Sector

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***Abstract*—The number of users of the Global System of Mobile Telecommunications (GSM) in the world is growing at an exponential rate; with more than 146 million users in Nigeria alone. There is a continuous need to install GSM supporting infrastructure to take care of increasing users in terms of service delivery. As at December 2013, the number of base transceiver stations (BTS) was 28,289; whereas by projection Nigeria needs additional 33,000 BTSs by 2018. However, there are serious technical challenges militating rapid installation of base stations, such as environmental congestion, high capital expenditure (CAPEX), multiple regulations and taxation, anti- competitive practices among a number of operators. In order to address these challenges, infrastructure sharing has been proposed, and adopted by some GSM operators. This paper presents an overview of GSM infrastructure sharing.**

***Index Terms*—Active sharing, GSM, Infrastructure sharing, Mobile network operator, Passive sharing.**

I. INTRODUCTION

The information presented in this paper is a part of a Master's degree thesis [1] and conference proceedings [2]. Global System for Mobile Communications, originally Groupe Spécial Mobile (GSM), is a system designed and developed by the European Telecommunications Standards Institute (ETSI) in order to establish protocols and specifications for the second generation (2G) digital cellular networks utilized by mobile telephones [3]. The GSM system, which in its original form described a digital, circuit switched network optimized for full duplex voice telephony, is a replacement for the first generation (1G) analogue cellular networks. Additionally, it was further enhanced and improved over time to include data communications, initially by circuit switch transport, subsequently, packet data transport via General Packet Radio Services (GPRS) and Enhanced Data rates for GSM Evolution (EDGE) or EGPRS [3]. Moreover, further improvements came when the third Generation Partnership Project (3GPP) developed the third generation (3G) Universal Mobile Telecommunications System (UMTS) standards followed by fourth generation (4G) LTE Advanced standards. Other aspects of the historical progress of GSM technology are reported in [3]-[7].

Meanwhile, functions of some active and passive components of GSM base station such as transceiver (TRx), power amplifiers (PA), combiners, duplexers, antennas, alarm extension system, control function, base-band receiver (BBxx), signal DSP, main distribution board, rectifier and Environmental Monitoring Unit (EMU) are discussed in [8]. Other components discussed are DC ventilation system, air conditioner, generators, BTS cabinet, transmission. According to [9], GSM system is defined as radio communications systems that work properly only if each component part operates within precise limits. Mobile base stations must transmit enough power, with sufficient fidelity to maintain an acceptable QoS, without causing interference to others operators. Moreover, some factors responsible for interference were identified, such as spectrum due to modulation and wideband noise, spectrum due to switching, and transmitter and receiver band spurious. The need to watch out for BTS receiver sensitivity was also highlighted [9]. Therefore, [1], sensitivity parameter was carefully analyzed in the evaluation of the performance of mobile base stations.

II. TECHNICAL ISSUES WITH GSM OPERATIONS

A. Overview of Latest Development of Standard in Human Exposure to Electromagnetic Fields

Electromagnetic radiations are produced by GSM base station antennas, the allowable levels of radiations are regulated by a country's regulatory body. Such bodies following the guidelines and standards recommended by International Commission on Non-Ionizing Radiation Protection (ICNIRP) and Institute of Electrical and Electronics Engineers (IEEE). Radiations are grouped into two, namely ionizing radiations and non-ionizing radiations [10]-[12]. Electromagnetic spectrum, showing types of radiations is shown in Fig. 1.

Manuscript published July 31, 2016.

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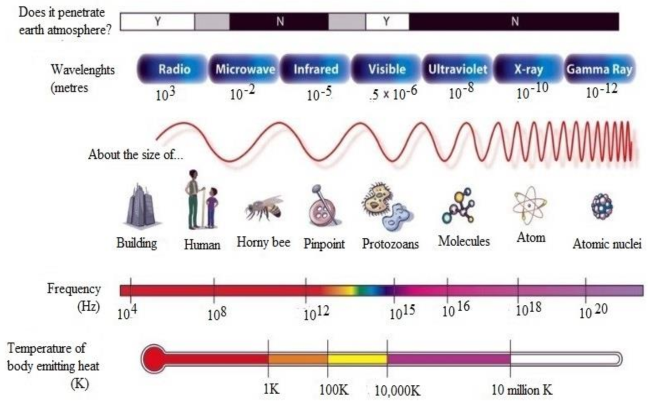

Fig. 1: Ionizing and non-ionizing radiation [13]

Ionizing radiations have sufficient energy to cause alteration in atomic structure, thereby causing genetic damages to human or other living tissues, while non-ionizing radiations, have relatively lower energy and can only raise the body temperature and their frequencies < 1THz [10].

The research to determine the effects of electromagnetic waves on human are inconclusive, since the sample size and duration of study are limited. Hence, we cannot generalize based on the results thus far; researches are ongoing [14], [15].

B. Electric Fields Intensity Measurements and Signal Strength

In order to monitor the amount of radiation, researchers are interested in the variations in the values of electric field intensity, (**E**). According to ICNIRP for the GSM frequency band the electric field strength limit is 60 v/m. The measured electric field strength for both GSM-900 and GSM-1800 are < 1% of ICNIRP [16]. Moreover, it was further mentioned in [16] that the maximum electric field strength from base station is < 0.4V/m for the GSM 900 Base station and < 0.6v/m for Personal Communication System (PCS) or GSM 1800 base station [16]. Therefore, in BTS using both the GSM 900 and GSM 1800, the amount of electric field strength is about 1v/m. The maximum Specific Absorption Ratio (SAR) values in W/kg are based on ICNIRP guidelines, American National Standard Institute (ANSI) and IEEE standard [17]. For ICNIRP, the safety limit is 1.6W/kg but 0.08W/kg inside an elevator [16]. Discussion of occupational exposure due to RF radiation leakage inside the base station cabin, when working on the BTS Radios and TX cables during active radio communication was presented in [18]. It was found out that the maximum instantaneous electric field strength obtained were 3.72 v/m and 16.56 v/m for GSM 1800 and GSM 900 radio, respectively, while the value for TX cables was 11.29 V/m. The field study also obtained the average values of electric field strength from all 30 BTS cabins studied as 1.18±1.07 V/m from the GSM 1800 radios, 2.33±3.82 V/m from GSM 900 radios and 1.77±2.20 V/m from the TX cables. Thus, the results obtained in [18] are higher than those obtained in [16]. One reason for this difference is that, the later focused on the electric field strength inside the BTS cabin, whereas the former carried out measurements outside the BTS cabin. These results help in specifying and choosing the electric field strength for the performance evaluation of the multi-operator mobile cellular base station.

Factors affecting quality of GSM signal strength include multipath reflection, propagation terrain, free space loss, vegetation, buildings, and so on. These were identified in [19]. The received signal strength also depends on the power delivered to the transmitting antenna, the gain of the antenna, antenna geometry and frequency of transmission [20]-[22].

C. Cell Design Principles

Major aspects considered in cellular network design, including such factors as radio propagation, frequency regulation and planning, transmission planning, antenna design, switching exchange, software design, and Teletraffic were discussed in [23]. It did not consider designing a multi-operator base station. The modulation schemes employed in GSM and EDGE networks include Gaussian Minimum Shift Keying (GMSK) and 8-PSK (Phase Shift Keying) deployed in Enhanced Data Rate for GSM Evolution (EDGE) [24], [25]. It was pointed out in [24], that 8-PSK, although, it has increased bandwidth efficiency, has more sensitivity to noise in comparison with GMSK.

D. System Expansion Techniques

Cellular system expansion techniques presented in [23] include addition of new channels, frequency borrowing, cell pattern variation, cell splitting and antenna sectorization. Others include system performance degradation, and channel allocation algorithm. The merits and demerits of each technique were also highlighted. Umbrella cell approach for system expansion, especially in urban areas with frequent network congestion was discussed in [26].

III. WHY GSM INFRASTRUCTURE SHARING?

As pointed out in [5], challenges militating against the rapid deployment of GSM in Nigeria include: Poor public power supply, poor security, as GSM infrastructure is sometimes vandalized, this is further supported by the study reported in [17]. Other sources of impedance highlighted in [5] are high import duty on telecom equipment, which is in the region of 30-70%, anti-competitive practices such as formation of cartel among big operators, scarce resources needed by operators to expand operations, and high operational costs, which is also mentioned in [12].

In order to mitigate these challenges, GSM infrastructure sharing is proposed and sometimes implemented.

Sharing of GSM Base-Stations will assist to minimize the undesirable proliferation of Base Stations. Notably, proliferation of base stations has its attendant negative visual and environmental impacts, which usually results in agitations by environmental Activists or right groups that could be damaging to the image of the network operators [18].

Furthermore, infrastructure sharing among GSM operators can reduce site acquisition time for new entrants. In addition, it enhances expansion into hitherto unprofitable areas by reducing capital expenditure (CAPEX) and operating expenditure (OPEX) requirements [30],[31]. Meanwhile, [30] proposed a model for estimating savings on CAPEX. More so, the airspace becomes less congested by

GSM towers when operators share GSM infrastructure. Another consequence of the proliferation of radio base stations is that it usually leads to property devaluation, due to a composite of health and environment degradation concerns [19],[20]. A more in-depth presentation of GSM infrastructure sharing was given in [2]. The rollout of mobile networks demand large capital outlay, necessitating higher billing of subscribers and consequently dissuading operators from researching and developing novel technology or products in emerging markets like Nigeria. Other deficiencies resulting from high cost of setting up the GSM network are highlighted in [27]. Meanwhile, technology migration, such as the launching of third generation (3G) and 3.5G wireless technologies on top of 2G networks, and the introduction of '4G' technologies including LTE, is becoming increasingly swift and complex [28]. In order to address this reality, operators are adopting various approaches, with network sharing emerging as a far radical stratagem to significantly, and continuously minimize network expenditure. According to [29], as of 2012 about 60% of mobile network towers were shared by two or more mobile network operators in India. The case in Nigeria is not different. However, as noted in [30] mobile infrastructure sharing could also stimulate the migration to novel technologies and the deployment of mobile broadband. This is necessary because mobile broadband is a veritable means of making broadband services accessible to more persons and organizations. It was further highlighted in [30] that eventually, mobile network sharing can play a crucial role in increasing access to information and communication technologies. This can create and promote economic growth. It can also enable nations to meet the objectives established by the World Summit on the Information Society (WSIS) and the Millennium Development Goals of the United Nations.

A. Categories of Telecommunication Infrastructure Sharing Schemes

Various forms of infrastructure sharing can be implemented, ranging from basic unbundling and national roaming, to advanced forms like collocation, and spectrum sharing [30]. Spectrum sharing is often considered an active infrastructure sharing. Another form of infrastructure sharing discussed in the available literature are Mobile Virtual Network Operator (MNVO) [7],[31]. Telecommunication tower leasing to more one network operator by licensed co-locator vendors such as Helios Tower Nigeria Ltd, HIS, MTI and Swap Technology is yet another form of infrastructure sharing [32]. The GSM infrastructure is divided into the following:

Active infrastructure consist of the electronics such as microwave radio equipment, switches, antennas, transceivers for signal processing-both BTS and Gateways, fiber optic network and backbone, transmission and all other electronic systems and components of the mobile network [7].

Passive infrastructure comprises the non-electronic infrastructure, including though, not limited to towers, shelters, air conditioning equipment, generator set, battery banks, electrical supply, technical premises, and easement and pylons, which account for nearly 60 percent of network roll out cost [7]. See Table I below for the categorization.

B. Passive Infrastructure Sharing

Passive infrastructure sharing is described as [7]: the sharing of the non-electronic infrastructure at the cell site. It is also known as site sharing, and in this form of sharing, operators agree to share available infrastructure such as site space, buildings and easements, towers and masts, power supply and transmission equipment.

This type of GSM infrastructure sharing is recommended for urban and sub-urban area with limited availability of land, expensive sites such as underground subway tunnels and rural areas with high transmission and power costs [7]. A case where six (6) mobile network operators comprising of four (4) GSM and two (2) CDMA operators shared the passive resources of a single tower in India was presented in [29], [33].

C. Active Infrastructure Sharing

Active infrastructure sharing is also called Network sharing. Here the operators share common networks, both circuit-switched and packet-oriented domains. In this scheme, operators typically share the Radio Base Station (RBS), Radio Network Controller (RNC), MSC/VLR, and the serving GPRS support node (SGSN) [7]. Fiber optic backbones and international gateways can also be shared. Examples of such fiber optic network include the South Africa Trans-Atlantic-West Africa Submarine Cables (SAT-3/WASC) – a cable stretching from South Africa to Portugal and Spain with landings in many western and southern African countries, Main One and Glo-1 [34]. MTN Nigeria has massively provided a fiber-optics super highway covering more than 8,900 kilometers across the country. This is complemented by international network of fiber optics cable like Glo -1 submarine cable, which is 9,800 km long and the 7,000 km long Main One cable. In addition, the SAT-3/WASC delivered to Nigeria by MTN has a length of 14, 530 km and a bandwidth of 5.12 Tb [35]. Moreover, the authors in [40, 41] proposed the concept of intra-cell roaming-based infrastructure sharing. In the scheme, Mobile Network Operators (MNOs) can switch off their base stations and roam their traffic to active base stations of other cooperative MNOs in the same cell with energy efficiency as the main aim.

IV. Guidelines and Specifications for Towers Installation and GSM Operators Collocation in Nigeria

Guidelines and specifications have been given by the Nigerian Communications Commission (NCC) for the installation of GSM tower in [36]. Moreover, in the guidelines, the maximum allowed tower height is fixed at 150m. Note that passive GSM infrastructure sharing is recommended in [36]. Furthermore, collocation procedure or workflow was highlighted in [7]. Fig. 2 shows an example of a mobiles cell site. Whereas, Fig. 3 shows a 3-operator mobile base station. However, the risks and rewards of aspect of infrastructure sharing were highlighted in [37]-[39].

Fig. 2: Mobile Base Station [29]

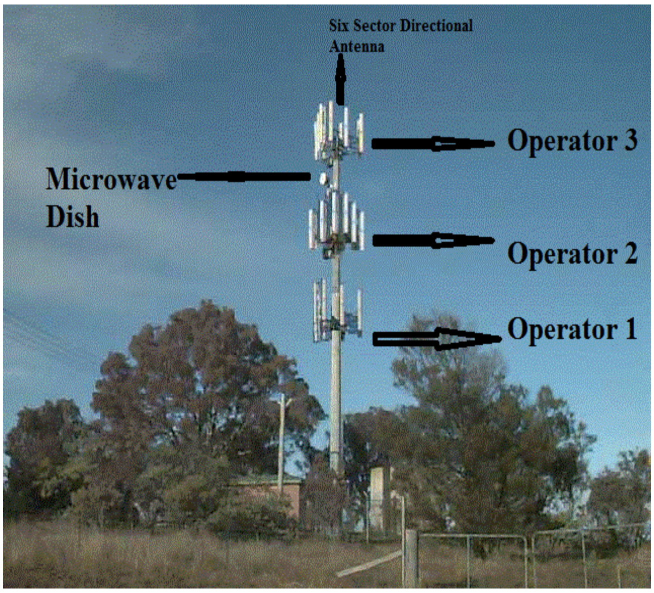

Fig. 3: A Three – Operator Mobile Base Station [40]

V. Some Parameters Affecting Infrastructure Sharing

A. Interference

Radio Frequency (RF) interference is one of the most critical issues in the design and operation of mobile communication systems [41]. The causes, which include intermodulation, frequency leakages, and spurious emission and appropriate mitigation techniques, were also presented in [31],[42].

The mitigation techniques include frequency separation, spatial separation and antenna tilting. Yet another mitigation technique involves the use of improved performance filters. According to [43], if the number of interfering cells in the first tier is σ_1, then the co-channel interference ratio, $\frac{C}{I_c}$ is given by

$$\frac{C}{I_c} = \frac{C}{\sum_{\sigma=1}^{\sigma_1} I_\sigma} \qquad (1)$$

For a hexagonal cell network, σ_1 = 6, cell radius is *R*, distance between two cells, *D* and a balanced system, (1) becomes

$$\frac{C}{I_c} = \frac{R^{-\varepsilon}}{\sum_{\sigma=1}^{\sigma_1} D_\sigma^{-\varepsilon}} = \frac{1}{\sum_{\sigma=1}^{\sigma_1} \left(\frac{D_\sigma}{R}\right)^{-\varepsilon}} \qquad (2)$$

where ε = propagation path loss exponent, which is dependent on the terrain and the operating frequency. Its typical value is around 2 - 4. By system specification $\frac{C}{I_c} \geq 18dB$ [24].

B. Sensitivity and Sensitivity Degradation

It was discussed in [44] that degradation of the links, which falls near or lower than the sensitivity of the BTS (around -110dBm) or that of the mobile (around -104dBm) is unacceptable. At this level of degradation, the number of call drop increases [45].

Degradation of sensitivity results from the transfer of power from the transmitter to the receiver due to coupling effects. It should not exceed 3dB [42].

The sensitivity of a system depends on the following three (3) fundamental factors: ambient noise power (NP), carrier-to-noise ratio (C/N), Noise figure (NF). Network operators have no influence on the first two of these: ambient noise power is a measure of the noise in nature and therefore fixed for the specific carrier bandwidth; carrier to noise ratio, a function of BTS design, is a measure of the relative strength between the received signal and the noise floor [46]. To improve sensitivity, NF is the target parameter. The effects of system sensitivity degradation and the relationship between noise figure degradation and sensitivity degradation were also discussed in [45],[46].

C. Wind Loading

A critical parameter considered in infrastructure sharing is the tower wind loading capability. It was asserted in [36] that the main loading on the tower is the wind loading, and wind loading analysis and tower survivability were done in [47]. As noted in [48] the antenna area accounts for 30% of the total tower area. Table II shows estimated wind loading values at various tower heights for a wind speed of 40m/s. Wind direction and variations of wind speed were however, not considered.

D. Antenna Isolation

Antenna isolation, also called antenna coupling loss or antenna decoupling is defined as the loss between two antenna ports. This usually occurs when two antennas are collocated on the same mast or in close proximity to each other, leading to the existence of an interferer-victim system. Notable parameters affecting antenna isolation are highlighted as follows [49]: the separation distance between the antennas, antenna gain, frequency of transmission, antenna polarization, the radiation pattern of the antennas, the main beam relationship of the antennas, and conducting properties of the tower on which the antenna is mounted.

VI. Conclusion

From the review of the available literatures, it is observed that there are descriptions and recommendation of passive infrastructure sharing and associated parameters. The review highlighted the benefits of infrastructure sharing, hindrances, and examples of countries actively promoting collocation. However, there is no work on performance evaluation of a multi-operator GSM base station, which is the focus of this project work [1]. Deliberate effort should be made to overcome some of the major deterrents discouraging some operators in Africa from sharing infrastructure with other operators, which includes; utilization of different supplier in the value chains, utilization of Inferior equipment and monopolistic Behaviour among well-established operators. These effort should include formulation of specific policies and regulations that will address the above mentioned challenges.

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