Design Considerations for Different Segments of UHF Wireless Network in Cross River State, Nigeria.

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***Abstract*— This design project outlines the procedure and considerations of designing a wireless network for a low-population state, Cross River State, in Nigeria. Considerations were given on the state capital, comprising the largest metropolitan area in the state. Surrounding sections of Calabar that made up the high population density (sub-urban) areas were also considered. These include traffic on the high way and the rural communities; covering a distance of 300km. Traffic capacity, path losses, and signal quality were examined and re-designed using known parameters in order to achieve optimal network for subscribers along the trajectory of the state. The study, attempts to use the minimum equipment possible to improve delivery of quality service, while still taking aggressive population growth into account. The conclusion drawn from this design indicated the hardware units required to cover the investigated area. From the design, 358 units of Base Transceiver Stations (BTSs) were determined; while 23 units of Base Switching Centers (BSCs), and 3 units of Main Switching Centers (MSCs) were required. The cell area, transmission cell radius and other hardware items for the urban, sub-urban and rural areas were presented.**

***Keywords*— DTMF decoder, PIC Microcontroller, programmable electronic controller, signal strength levels, UHF signal**

1. Introduction

Wireless networks have penetrated about a billion subscribers around the world through different hardware segments. The first generation services concentrated on voice, and later innovative progress was made to accommodate modem-based low-rate data services. These services were progressively anchored on circuit-switching technology using the traditional traffic theory.

These innovative trends in telecommunications heralded the cellular mobile networks during the last decade of the twentieth century. Based on the access mode, connectivity through mobile communications was less pragmatic, and demand for these services became higher. As this demand increased, need for higher bandwidths and different multimedia services for the end users increased. More value added services were introduced: the *Internet Protocol* (IP), the *World Wide Web* (WWW), and the popularization of electronic mail (e-mail) communication on the Internet [1]. The integration of wireless cellular networks and the Internet became achievable through the realization of the 3G standardization. However, the systematic development of telecommunications technology through the innovative strides of different segments such as: the introduction of automatic telephone exchange, the digitalization of telecommunication systems and the integration of circuit-switching connection and packet-based connectionless Internet, have been largely sustained and benefited by the developed economy. The technological revolution has not created the necessary impact in developing economies, like Nigeria. For example: [10], analyzed Internet penetration in Africa as 10.7 per cent as against more than 70 per cent in the USA. He further indicated that this penetration level is also visible in the rural areas, unlike the developing countries. To a large extend, Nigeria lacks the penetration of the wired local telecommunication networks, internet protocol (IP) technology and it's transparency to rural and suburban areas; thereby denying the rural dwellers the options to different traffic types.

However, the low-cost switching equipment, roaming capacity and short roll out period for wire-less networks made it very attractive to operators and customers. This is at variance with the cost of operation for wire-line network and the difficulties operators encounter to deploy their network nodes in rural communities due to obscurity in terrain. Modern telecommunications out-fits are therefore anchored on centralized switching and signaling equipment; while deploying Base stations as wireless access points. Further technological break-through in mobile networks introduces wide spectrum and high data rates as well as variety of circuit-switched and packet-based services [12]. It provides IP connectivity, in addition to circuit switching. Future generation mobile systems are expected to include heterogeneous access technologies, as well as end-to-end IP connectivity [4,11].

1.1 Objectives of the Study

The diversity of traffic services and access technologies in the mist of unpredictable population growth and undefined terrain call for modification of design specifications to suit peculiar environment, and create new possibilities of improved traffic performance for the benefit of the operators and subscribers. On the other hand, it raises new traffic and design issues. The study, therefore, attempts to review these new traffic and design issues by re-designing an implementable wireless infrastructure suitable for this terrain. The design coverage spans through the urban city, Calabar, to sub-urban and rural areas in Cross River State of

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Nigeria. It is aimed at using existing parameters to review and re-design a cost effective wire-less network tailored for that location.
The capital city, Calabar, is located in the southern part of the Niger Delta region of Nigeria, and surrounded by suburbs housing rural and sub-rural communities. The state links other sub-urban locations at the central and northern axes with a stretch of more than 300Km. The focus of the design is to ensure signal coverage in the state capital, the sub-urban communities and the rural communities along the 300Km-stretch, as well as seamless coverage between the populated areas and the low density areas.
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2. DESIGN CONSIDERATIONS.

2.1 Population Projection:

The projection on population is an estimate bordering on population mobility. Using the projected population of about 6 million people, and assuming a growth rate of 5 per cent per year, and taking into account the operator's rollout period of 6 years, the following relationship in equation 1 may be used to estimate the population after 6 years [13, 14].

$$P_{proj} = P_{present}\{(1+g)^n\} \quad (1)$$

$$P_{proj-suburban} = 6\times10^6\{(1+0.05)^6\} = 8.04\times10^6 = 8.04e6$$

Similarly, using the given parameter for the suburban area in Eq. 1, the population projection is:

$$P_{proj-suburban} = 4\times10^6\{(1+0.05)^6\} = 5.36\times10^6 = 5.36e6$$

It is assumed that the rural areas have very scanty population and may not attract the interest of the service provider. Consideration is therefore focused on the people who use the highway. The design for the rural area will therefore not be based on population and traffic, rather signal strength, and how far the repeaters can be apart. .

2.2 Traffic and Voice Channels:

Urban area:

Let the total traffic in Erlangs for the urban population be given as shown below using the Eq. 2 and Eq.3 of [5,9]:

$$E_{total} = P_{urban}\cdot MarketShare\cdot MarketPenetration\cdot BHCrate\cdot Holdingtime \quad (2)$$

$$E_{total-urban} = 8.04e6\cdot0.25\cdot0.20\cdot1\cdot\frac{100}{3600} = 11167.5Erlangs \quad (3)$$

Thus, the traffic in Erlangs per subscriber is:

$$\frac{11167.5}{8.04e6\cdot0.25\cdot0.20} = 0.02778\frac{Erlang}{subscriber}(urban)$$

The traffic density can also be calculated as below using Eq. 2 of [3]:

$$TrafficDensity = \frac{E\cdot P\cdot MarketShare\cdot MarketPenetration}{Area}$$

$$TrafficDensity_{urban} = \frac{0.02778\cdot8.04e6\cdot0.25\cdot0.20}{\pi\cdot60^2} = 0.987\frac{Erlangs}{km^2}$$

The number of voice channels is also calculated using Eq. 4 of [6]:

$$NumberRFChannels = \frac{One-wayBW}{ChannelsSpacing} - 1 \quad (4)$$

For a GSM network, the channel spacing is 200 kHz. Therefore, using the given information in Appendix **A** and Eq. 4 is

$$NumberRFChannels_{urban} = \frac{12MHz}{200kHz} - 1 = 59$$

The number of voice channels required is determined from Eq. 5 [5]:

$$VoiceChannel = NumberRFChannels\cdot\left(\frac{slots}{N\cdot sector}\right) \quad (5)$$

For this design, a 3-sector cell is assigned for urban and sub-urban areas [2]. This is based on previous design problems encountered and other studies consulted that recommended this as the most efficient, and a good trade-off for Signal to noise ratio (SNR) versus other traffic considerations. The choice for this parameter was further evaluated in the noise section of this design. The rural area, however, will use simple Omni-directional antennas due to expected low traffic of the area.
In a GSM system, the number of time slots is 8, and in this case, the reuse factor N for the urban and suburban is 4. A reuse factor of 3 is used in the rural area.

$$VoiceChannel_{urban} = 59\cdot\left(\frac{8}{4\cdot3}\right) = 39.33 \approx 39$$

With 39 voice channels, a 1 per cent **GoS** and using the Erlang-B table, the traffic per sector in the urban environment is 28.13 Erlangs [1].

Suburban area:

$$E_{total-suburban} = 5.36e6\cdot0.25\cdot0.20\cdot0.5\cdot\frac{120}{3600} = 4466.67Erlangs \quad (6)$$

$$\frac{4466.67}{5.36e6\cdot0.25\cdot0.20} = 0.01667\frac{Erlangs}{subscriber}(suburban)$$

$$TrafficDensity_{suburban} = \frac{0.01667\cdot5.36e6\cdot0.25\cdot0.20}{\pi\cdot240^2} = 0.0247\frac{Erlangs}{km^2} \quad (7)$$

$$NumberRFChannels_{suburban} = \frac{6MHz}{200kHz} - 1 = 29$$

A 3-sector antenna is also assumed for the suburban area since it is very similar to the urban cell area and demand is estimated to be close.

$$VoiceChannel_{suburban} = 29\cdot\left(\frac{8}{4\cdot3}\right) = 19.33 \approx 19$$

Rural Area:

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In the rural area, an Omni-directional antenna is assumed because the cell organization will be different. From Eq. 4:

$$NumberRFChannels_{rural} = \frac{6MHz}{200kHz} - 1 = 29$$

$$VoiceChannel_{rural} = 29 \cdot \left(\frac{8}{4 \cdot 1}\right) = 58$$

Again using the Erlangs-B table with 1 per cent GoS, and 58 voice channels, the traffic per sector [1] is 45.132 Erlangs.

2.3 Cell Area.

Urban Area:

The cell area based on the traffic requirement can be found using Eq.8 of [5]:

$$CellArea = \frac{TrafficperSector \cdot 3}{TraffricDensity} \quad (8)$$

$$CellArea_{urban} = \frac{28.13\frac{Erlangs}{Sector} \cdot 3Sector}{0.987\frac{Erlangs}{km^2}} = 85.5km^2$$

The cell radius can be found using the relationship for the area of a hexagon Eq. 9 of [5]:

$$CellRadius = \sqrt{\frac{CellArea}{2.6}} \quad (9)$$

$$CellArea_{urban} = \sqrt{\frac{85.5km^2}{2.6}} = 5.73km^2$$

Suburban Area:

Again, it is assumed that a BSC serves only one kind of environment. The calculations follow those of the urban area. Using Eq.10 of [5, 9].

$$BTSs/BSC_{sururban} = \frac{1500Erlangs}{11.23 \cdot 3} \approx 45$$

(10)

$$NumberOfBSCs_{suburban} = \frac{161}{45} \approx 4$$

$$MSC_{cap}E_{suburban} = \frac{500e3 \cdot 120}{3600} = 16666.7$$

$$NumberOfMSCs_{suburban} = \frac{1129.72 \cdot 0.0247 \cdot 161}{16666.7} \approx 1$$

Rural Area:

$$BTSs/BSC_{sururban} = \frac{1500Erlangs}{45.132} \approx 34$$

Finally, the rural area only requires one BTS and one BSC due to low traffic.

2.4 HLRs Required:

It is assumed that a HLR can support multiple BSCs. The given capacity of a HLR is 400,000 customers. The number of subscribers in each environment is found using Eq.11 of [5,9]: and Eq.12 below gives:

$$Subscribers = \frac{NumberOfCells \cdot TrafficDensity \cdot CellArea}{E/Subsciber} \quad (11)$$

$$Subscribers_{urban} = \frac{133 \cdot 0.987 \cdot 85.5}{0.02778} = 404020$$

$$Subscribers_{urban} = \frac{161 \cdot 0.0247 \cdot 1129.72}{0.01667} = 269500$$

$$P_{r\,min-90\%} = SNR_{90\%} + Noise - 10log\left(1 - 10^{\frac{SNR_{90\%}-SIR}{10}}\right)dB \quad (12)$$

$SNR_{90\%}$ refers to the percentage areas required to have a signal-to-noise of 12 dB. SIR refers to the signal-to-interference ratio. SIR is found for a 3-sector antenna using Eq.13 of [2]:

$$SIR_{3-sec} = 10log\left(\frac{1}{q^{-\gamma}+(q+0.7)^{-\gamma}}\right) \quad (13)$$

Here γ is the slope of the path-loss curve, given for the urban environment as 3.8, and q is calculated from Eq.14.

$$q = \sqrt{3N} = \sqrt{12} = 3.464 \quad (14)$$

Therefore, the signal-to-interference-ratio can be calculated from Eq. 15:

$$SIR_{3-sec-urban} = 10log\left(\frac{1}{3.464^{-3.8}+(3.464+0.7)^{-3.8}}\right) = 18.75\ dB \quad (15)$$

Thus, the minimum received power for 90 per cent coverage at a SNR of 12dB and 95 per cent at a SNR of 5dB can be found using Eq.16 [13,14]::

$$P_{r\,min-90\%-urban} = 12dB + -142.97dB - 10log\left(1 - 10^{\frac{12-18.75}{10}}\right)dB = -129.94dB \quad (16)$$

$$P_{r\,min-95\%-urban} = 5dB + -142.97 - 10log\left(1 - 10^{\frac{5-18.75}{10}}\right)dB = -137.78dB$$

The actual radius for 90 per cent and 95 per cent coverage is found in Eq.17 of [2, 8]:

$$radius = \sqrt{\frac{CellArea \cdot \%area}{\pi}} \quad (17)$$

$$radius_{urban-90\%} = \sqrt{\frac{85.5km^2 \cdot 0.90}{\pi}} = 4.95km$$

$$radius_{urban-95\%} = \sqrt{\frac{85.5km^2 \cdot 0.95}{\pi}} = 5.08km$$

This information may then be compared against the maximum distance that a mobile station can be from a BTS using the maximum power of the terminal (1W) as follows

$$d_{max-\%} = \left(10^{\frac{I_o+G_{ms}+G_{bts}-L_{rm}+P_{max}-P_{r\,min-\%}}{10}}\right)^{\frac{1}{\gamma}} \quad (18)$$

Using the given information and the previously calculated information for urban environment, thus:

$I_{o-urban} = -100\frac{db}{km}$; $G_{ms} = 0dBi$; $G_{bts} = 12dBi$; $L_{rm} = 2dB$; $P_{max} = IW = 0dB$ $P_{r\,min-90\%-urban} = -129.94dB$; $P_{r\,min-95\%-urban} = -137.78dBi$ And $\gamma_{urban} = 3.8$

$$d_{max-90\%-urban} = \left(10^{\frac{-100+0+12-2+0+129.94}{10}}\right)^{\frac{1}{3.8}} = 11.25km > radius_{urban-90\%} = 4.95km$$

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$d_{max-95\%-urban} = \left(10^{\frac{-100+0+12-2+0+137.78}{10}}\right)^{\frac{1}{3.8}} = 18.09km > radius_{urban-95\%} = 5.08km$

Since d_{max} is greater than the radii calculated to satisfy the SNR requirements, there is enough signal power using the traffic calculated cell size in the urban environment.

Suburban Area:
Using the path loss exponent given for the suburban environment and the same value for *q* (3 sector antenna and reuse factor of 4), the SIR and minimum received power is determined.

$SIR_{3-sec-suburban} = 10log\left(\frac{1}{3.464^{-4}+(3.464+0.7)^{-4}}\right) = 19.88\ dB$

$P_{r\,min-90\%-suburban} = 12dB + -142.97dB - 10log\left(1-10^{\frac{12-19.88}{10}}\right)dB = -130.20dB$

$P_{r\,min-95\%-suburban} = 5dB + -142.97 - 10log\left(1-10^{\frac{5-19.88}{10}}\right)dB = -137.83dB$

The radii for 90 per cent and 95 per cent coverage are found using the cell area earlier calculated in conjunction with other traffic considerations.

$radius_{suburban-90\%} = \sqrt{\frac{1363.97km^2\cdot 0.90}{\pi}} = 19.77km$

$radius_{suburban-95\%} = \sqrt{\frac{1363.97km^2\cdot 0.95}{\pi}} = 20.31km$

The maximum distance may now be calculated using [2]:
$I_{o-suburban} = -90\frac{db}{km}$; $G_{ms} = 0dBi$; $G_{bts} = 12dBi$; $L_{rm} = 2dB$; $P_{max} = IW = 0dB$; $P_{r\,min-90\%-suburban} = -130.20dB$; $P_{r\,min-95\%-suburban} = -137.83dBi$; $\gamma_{suburban} = 4$

$d_{max-90\%-suburban} = \left(10^{\frac{-90+0+12-2+0+130.20}{10}}\right)^{\frac{1}{4}} = 17.99km < radius_{suburban-90\%} = 19.77km$

$d_{max-95\%-suburban} = \left(10^{\frac{-90+0+12-2+0+137.83}{10}}\right)^{\frac{1}{4}} = 27.91km > radius_{suburban-95\%} = 20.31km$

From these analyses, it is found that the maximum distance allowed to satisfy the SNR criteria is actually smaller than the maximum radius calculated using the traffic considerations. Although the specification for 95 per cent signal coverage is met, the 90 per cent coverage for SNR specification is not met. Therefore, the cell area in the suburbans will have to be reduced from the previously calculated value to a new area using d_{max}.

$CellRadius_{ sururban} = \sqrt{\frac{17.99^2\cdot\frac{\pi}{0.90}}{2.6}} = 20.85km$

Then the cell area may be found:
$CellArea_{suburban} = 2.6\cdot 20.85^2 = 1129.72km^2$

Rural Area:
The cell size for the rural area can now be calculated since the size only depends on power and noise considerations, not traffic. We determine first the SIR. The values given for this area are 3.2 for a path loss and a frequency reuse factor of 3. An Omni-directional antenna is assumed since the cell organization along the highway is different. For an Omni-directional antenna, the SIR can also be found using the following relation [3]:

$SIR_{omni} = 10log\left\{\frac{1}{(2N+1)^{-\gamma}+(2N-1)^{-\gamma}}\right\}$

$SIR_{omni-rural} = 10log\left(\frac{1}{(2\cdot 3)^{-3.2}+(2\cdot 3-1)^{-3.2}}\right) = 21.09\ dB$

$P_{r\,min-90\%-rural} = 12dB + -142.97dB - 10log\left(1-10^{\frac{12-21.09}{10}}\right)dB = -130.40dB$

$P_{r\,min-95\%-rural} = 5dB + -142.97 - 10log\left(1-10^{\frac{5-21.09}{10}}\right)dB = -137.86dB$

The maximum distance may now be calculated as in [3,11]:
$I_{o-rural} = -100\frac{db}{km}$; $G_{ms} = 0dBi$; $G_{bts} = 12dBi$; $L_{rm} = 2dB$; $P_{max} = IW = 0dB$; $P_{r\,min-90\%-rural} = -130.40dB$; $P_{r\,min-95\%-rural} = -137.86dBi$; $\gamma_{urban} = 3.2$

$d_{max-90\%-rural} = \left(10^{\frac{-100+0+12-2+0+130.40}{10}}\right)^{\frac{1}{3.2}} = 18.3km$

$d_{max-95\%-rural} = \left(10^{\frac{-100+0+12-2+0+137.86}{10}}\right)^{\frac{1}{3.2}} = 31.3km$

The cell radius and area for the rural area can be found:

$CellRadius_{rural} = \sqrt{\frac{18.3^2\cdot\frac{\pi}{0.90}}{2.6}} = 11.4km$

$CellArea_{rural} = 2.6\cdot 11.4^2 = 337.9km^2$

2.5 Number of Cells:

Urban Area:
The number of cells required in a given area can be easily found using the geographic area and the cell area [3].

$NumberOfCells = \frac{Area}{CellArea}$

$NumberOfCells_{urban} = \frac{\pi\cdot(60km)^2}{85.5km^2} \approx 133$

Suburban Area:

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$$NumberOfCells_{suburban} = \frac{\pi\cdot(240km)^2}{1129.72km^2} \approx 161$$

Rural Area:
The number of cells required to cover a linear stretch of highway is found using [10]:

$$NumberOfCells_{highway} = \frac{Length}{2\cdot CellArea_{highway}}$$

$$NumberOfCells_{rural} = \frac{600km}{2\cdot 11.4km} \approx 27$$

2.6 Equipment Required:

Urban Area:
It is assumed that a BSC serves only one type of environment. The number of BTSs per BSC is found using the capacity of a BSC in the given parameters and dividing by the total number of Erlangs for a given site for the specific environment [9,12], therefore

$$BTSs/_{BSC} = \frac{BSCCapacity}{Traffic/_{sector}\cdot sector}$$

$$BTSs/_{BSC_{urban}} = \frac{1500Erlangs}{28.13\cdot 3} \approx 18$$

The number of BSCs may then be found using [9]:

$$NumberOfBSCs = \frac{NumberOfCells}{BTSs/_{BSC}}$$

$$NumberOfBSCs_{urban} = \frac{133}{18} \approx 8$$

Now the number of MSCs required in any part of the environment may be found using the maximum traffic. Again it is assumed that a MSC serves only one type of environment [12].

$$MSC_{cap}E = \frac{MSC_{cap}\cdot Holdingtime}{sec/_{hr}}$$

The number of MSCs are determine as:

$$NumberOfMSCs = \frac{CellArea\cdot TrafficDensity\cdot NumberOfCell}{MSC_{cap}E}$$

Thus, for the urban environment:

$$MSC_{cap}E_{urban} = \frac{500e3\cdot 100}{3600} = 13888.9$$

$$NumberOfMSCs_{urban} = \frac{85.5\cdot 0.987\cdot 133}{13888.9} \approx 1$$

Suburban Area:

$$CellArea_{suburban} = \frac{11.23\frac{Erlangs}{Sector}\cdot 3Sector}{0.0247\frac{Erlangs}{km^2}} = 1363.97km^2$$

$$CellRadius_{suburban} = \sqrt{\frac{1363.97km^2}{2.6}} = 22.90km^2$$

Rural Area:
Since capacity issues do not stress repeaters sited in the rural area, the only design consideration is signal strength and noise. Therefore, the cell area is not derived from traffic calculations.

2.6 Cell Size Based on Noise Considerations:

In this section, the maximum distance that a mobile station can be from the BTS is calculated. In addition, a new cell radius is derived based on the maximum transmitted power in a given environment. The radius derived by this method must be larger than the radius derived from the traffic calculations [13]. Alternatively, a new cell topography is designed with special configured antennae.
Using the maximum system temperature in the given parameters, Boltzman's constant (1.38e-23), the noise value (8dB), and the channel spacing (200 kHz for GSM), the thermal noise can be calculated using Eq. 20. [9]:

$$Noise = 10log\left(kT\cdot ChannelBW\cdot 10^{\frac{N_f}{10}}\right)$$

$$10log\left(1.38e-23\cdot 290\cdot 200e3\cdot 10^{\frac{8}{10}}\right) = -142.97dB$$

Urban Area:
Using the above derived thermal noise, the minimum received power required to satisfy the criteria for 90 per cent and 95 per cent coverage as given above can be derived using the following relationship:
In other to calculate the subscribers for the rural area, the traffic density must be derived. The number of Erlangs per subscriber must also be assumed to be 0.02 [3], therefore

$$TrafficDensity_{rural} = \frac{45.132}{337.9} = 0.1336\frac{Erlangs}{km^2}$$

$$Subscribers_{rural} = \frac{27\cdot 0.1336\cdot 337.9}{0.20} = 60629$$

The number of HLRs required can now be found:

$$NumberOfHLRs = \frac{404020+269500+60929}{400000} \approx 2$$

3. CONCLUSION:

The study addressed issues relating to design specifications for a seamless wire-less signal coverage. This was done **in accordance with the International specifications for wir**eless networks under UHF range. Convergence of wire-line and wire-less signal was deployed at the transmission and access pots respectively. Under this scenario, the transmission links was designed for carriage through wire-line network, while the subscribers' access nodes were wire-less. These traffic classification, manages the current problem on mobility and location management of respective subscribers under very difficult locations. Through these mechanisms, high level quality of service can be achieved. In addition, the study aligned with the vision for the future: where mobile networks are predicted to be all-IP networks for all; irrespective of location.

Based on the design-analyses carried out by the study, Table 1 presents the specific wire-less hardware for access distribution and the quantities required for the location under investigation.

Table 1: Wire-less hardware and access distribution quantities required.

	Urban	Suburban	Rural	Total
BTS(units)	144	180	34	358
BSC(units)	18	4	1	23
MSC(units)	1	1	1	3
Cells (units)	133	161	27	321
Cell Area(km^2)	85.5	1129.72	337.9	1553.12
HLR (units)				2

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Appendix **A: Design parameters**

- BTS antenna gain: 12 dBi
- MS antenna gain: 0 dBi
- Receive Cable Connector loss: 2 dB
- Noise figure: 8 dB
- Grade of service: 1%
- Maximum system temperature: 290 Kelvin
- Percentage of mobile call origination: 60%
- No. of VLR within MSC area: 1
- Frequency reuse factor: 4 (urban and Suburban area); 3 (highway)
- Population growth rate per year: 5%
- Roll out time in years: 6
- Your company's market share: 25%
- Maximum power of terminal: 1W
- % Area to have SNR = 12 dB: 90
- % Area to have SNR = 5dB: 95

Urban Area

- Present population: 6×10^6
- Market population: 20%
- One-way bandwidth: 12 MHz
- Average call holding: 100 seconds
- Average BHC rate: 1.0 call/subscriber
- Average handover per call: 1
- One-km intercept: -100 dB/km
- Path-loss exponent: 3.8

Suburban Area

- Present population: 4×10^6
- Market penetration: 20%
- One-way bandwidth: 12 MHz
- Average call holding: 120 seconds
- Average BHC rate: 0.5 call/subscriber
- Average handover per call: 1
- One-km intercept: -90 dB/km
- Path-loss exponent: 4

Rural Area

- One-way bandwidth: 6 MHz
- Average call holding: 150 seconds
- Average BHC rate: 0.25 call/subscriber
- One-km intercept: -100 dB/km
- Path-loss exponent: 3.2

Equipment

	$Max. Capacity$	$Max. Connections$
• MSC	500 K BHC	12 BSCs
• BSC	1500 E	100 BTSs
• HLR		400 K customers

Source: [11, 12]

REFERENCES

[1] Bria, A. (2001). 4th Generation Wireless Infrastructures: Scenarios and Research Challenges," *IEEE Personal Communications*, Vol. 8, No. 6.

[2] Campbell, A. T., et al., (2002). "Comparison of IP Micro-Mobility Protocols," *IEEE Wireless Communications*, February.

[3] Campbell, A. T., et al., (2000). "Design, Implementation and Evaluation of Cellular IP," *IEEE Personal Communications*, Special Issue on IP-based Mobile Telecommunications Networks, June/July.

[4] Guo, Y., and H. Chaskar, (2002) "Class-Based Quality of Service over Air Interface in 4G Mobile Networks," *IEEE Communications Magazine*, Vol. 40, No. 3, March.

[5] Kanter, T. (2001) "An Open Service Architecture for Adaptive Personal Mobile Communication," *IEEE Personal Communications*, Vol. 8, No. 6, December.

[6] Liew, J., et al., (2000). *3G Wireless in the US: cdmaOne to cdma2000*, Harvard University, Massachusetts Institute of Technology, Tufts University, May 8.

[7] Lindgren, A., A. Almquist, and O. Schelen (2001). "Evaluation of Quality of Service Schemes for IEEE 802.11 Wireless LANs," *IEEE Conference on Local Computer Networks (LCN 2001)*, November.

[8] Lu, S., T. Nandagopal, and V. Bharghavan (1998). "A Wireless Fair Service Algorithm for Packet Cellular Networks," *ACM Mobicom'98*, Dallas, TX, October 1998.

[9] Mehrotra, A.(1994). *Cellular Radio Analog and Digital Systems*, Norwood, MA: Artech House, http://www.gsmworld.com.

[10] Perkins, C., (1996). *IP Mobility Support*, RFC 2002, proposed standard, IETF Mobile IP working group, October.

[11] Rappaport, T. S.(1996). *Wireless Communications: Principles and Practice*, Englewood Cliffs, NJ: Prentice Hall.

[12] Redl, S. M., M. K. Weber, and M. W. Oliphant (1995). *An Introduction to GSM*, Norwood, MA: Artech House.

[13] D. E. Bassey., R. C. Okoro., & B. E. Okon (2016). Modelling of a Radio Wave Transmission of Building Located around Niger Delta Urban Microcell using "Ray Tracing Techniques". International Journal of Science and Research (IJSR), ijsr.net 5(2), 337-346.

[14] D. E. Bassey., Aniefiok O. Akpan., & E. Udoeno (2016). UHF Wave Propagation Losses Beyond 40 Percent Fresnel Zone Radius in South-South, Nigeria. International Journal of Science and Research (IJSR), ijsr.net 5(2), 470-475.

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