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Radio Network Planning For GSM900 in A Rural Environment

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Abstract: Radio network planning is perhaps the most important part of the GSM system design process owing to its proximity to mobile users. This study present, a basic approach to radio network planning that provides effective solution in terms of coverage and quality. The objective of this study, which is coverage-driven is to find the minimum number of sites required providing sufficient coverage for a locality comprising of 4 cities and 38 villages and a vast part of the area covered with vegetations and hilly terrains. The intent of this research is to achieve optimum quality of service delivery of GSM radio network to the rural environment sited for this study. A total of 15 numbers of cells was designed to serve an area of about 365 km^2 with an estimated subscriber's size of about 20,000 people.

Key words: GSM network, radio network planning, base transceiver station, grade of service, traffic channel

INTRODUCTION

The Global System for Mobile communications (GSM) began its commercial operation in Nigeria in August 2001. As at now, >3 GSM technology-driven operators have been licensed to operate in the Country. The intent of this technology was to expand the country's teledensity.

The GSM technology is spreading gradually from the urban, to suburban and the rural regions of the country.

However, not all areas within the rural environments are connected to the GSM service area. For the case of Etsako West Local Government Area taken as case study for this report and a GSM operator taken as a reference network, we found out that only 7 functional Base Transceiver Stations (BTS) exist in that locality. This had hampered communication network within and outside the area.

The need to look at what the actual radio network structure would have been if implement is paramount. For this reason, we presented this study. It will be a guide to young engineers interested in radio network planning.

The GSM network is basically built around the radio network and the transmission network. The radio network is the part of the network that includes the Base Transceiver Station (BTS), the interface between them and the Mobile Station (MS). The base station has a radio connection with the mobile user and should be capable of communicating with the mobile station within a certain range while, maintaining good coverage and call quality. In order words the radio network should be capable of providing sufficient coverage and capacity.

In radio network, link budget calculation, coverage, capacity planning and spectrum efficiency and parameter planning are different stages involved in the planning process (Mishra, 2004; Vijay and Joseph, 1996). However, this study is focused on the coverage aspect of radio network planning with particular interest in cell determination.

The main aim of radio network planning is to provide an effective solution for radio network in terms of coverage, capacity and quality. The planning process varies from region to region depending on the dominating factor, which could be capacity or coverage (Mishra, 2004; Tomas, 2006; Lempiamen and Manninen, 2001; Hawkins, 2002).

The process of radio network planning starts with collection of input parameters such as the network requirements of coverage, capacity and quality. These inputs are then used to make the theoretical coverage and capacity plans. This process is known as the pre-planning process. In the pre-planning process, the radio planner notes the capacity-driven areas and the coverage-driven areas as considerations. The objective of the coverage driven factor is to find, the minimum number of sites required to provide sufficient coverage. Capacity involves accommodating the increased number of subscriber and traffic profile. It also involves increasing the number of sites, which result in a more efficient frequency usage and minimum interference (Mishra, 2004; Tomas, 2006; Lempiamen and Manninen, 2001; Hawkins, 2002).

MATERIALS AND METHODS

In this study, we discussed the study area for the survey and mapped out the radio network that will be suitable for good coverage.

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Background study of coverage-driven network planning: The research is focused on developing a planx structure/model for GSM network in a rural environment. Etsako west local government area was taken as a case study and will be referred to as location A. Concept such as frequency re-uses and interference and locations of BTS were not considered in this study. We also took an existing GSM operator in location A as a reference network for our model planning.

Location A comprises of about 4 towns and 38 villages. The landscape is predominantly hilly, rocky and mountainous with steep and sloppy terrains. There are also vegetations in non-habitable places. The region is bounded by an area of about 365 km^2 with a population of over 50,000 people as at 2008.

The existing GSM network in location: A had their base stations built on the following specifications; a Grade of Service (GOS), 48 number of available Traffic Channel, traffic of 28 mErlangs per subscriber and an average holding time of 100 sec $call^{-1}$. This existing GSM operator has till date 7 functional BTS in location A. The poor quality of GSM service provided in the environment is still a problem and the people yearn for better quality and coverage.

In developing a basic GSM radio network structure/model for this area, we estimated a subscriber size of 20,000. This estimation excluded children below the age of 12 years and the aged above 85 years.

We assumed an average holding time of 100 sec $call^{-1}$ and a 2% grade of service was used for our model. We also carried out an optimization process with different numbers of TCH allocated, a 1 and 5% grade of service. This was to enable us determine the suitability of our model for the particular environment under consideration over the other choices of GOS with the same number of available TCH. This will also determine the effectiveness of the proposed network structure for the location A. The tables created from this optimization process will enable us determine the number of base stations and the estimated number of subscribers/cell required to maintain a good radio coverage and quality of service in the area (Mishra, 2004). This may reduce the problems associated with poor call quality.

RESULTS AND DISCUSSION

Theoretical analysis of the network plan/model: With an average holding time of 100 sec, traffic of 28 mErlangs per subscriber and 48 number of available Traffic Channels (TCH) deployed, the total traffic per cell recommended from Erlang B table is 38.39 Erlang at a 2% grade of service.

The traffic per subscriber was deduced from the expression (Vijay and Joseph, 1996);

$$\text{Traffic/subscriber (A)} = \frac{n \times T}{3600} \text{ (Erlangs)} \quad (1)$$

where:

A = Offered traffic from one or more users in the system

T = Average call time in seconds

n = Number of calls h^{-1}

Since, the total traffic per cell carried by the available number of TCH from Erlang B table is 38.39 Erl at 2% GOS, we calculated for the number of subscribers/cell, as with the expressions in Eq. 2 and 3 (Vijay and Joseph, 1996).

$$\text{Estimated number of subscriber/cell} = \frac{\text{Total traffic/cell}}{\text{Traffic/subscriber}} = \frac{38.39}{28 \times 10^{-3}} = 1371 \quad (2)$$

Subscribers/cell

$$\text{Total No. cells} = \frac{\text{Estimated number of subscribers/area}}{\text{Estimated number of subscribers/cell}} = \frac{20000}{1371} = 14.587 \approx 15 \text{ cells} \quad (3)$$

We assumed a hexagonal shape to model the cells, the area and radius of the cell with the expressions in Eq. 4 and 5, respectively (Vijay and Joseph, 1996).

$$\text{Hexagonal area/cell} = \frac{\text{Total coverage area}}{\text{Number of cells}} = \frac{365000}{15} = 24.33 \text{km}^2 \text{ cells}^{-1} \quad (4)$$

$$\text{Hexagonal radius/cell} = (\text{area of cell}/2.6)^{1/2} = 3.17 \text{km} \quad (5)$$

System optimization with different values for GOS was carried out, on the chosen design specifications as in study, thus, a spreadsheet shown in Table 1-3 created.

Table 1: System parameters with 2% grade of service

Total area (km^2)	Estimated no. subscriber	No. available TCH	Total traffic/cell	Traffic/ subscriber (mE)	No. subscribers/cell	No. cells	Areas of cell (km^2)	Radius of cell (km)
a	b	c	d = erlang B	e	f = d/e	g = b/f	h = a/g	i = √ (h/2.6)
365	20.000	12	6.61	28	236	85	4	1
365	20.000	24	16.63	28	594	34	11	2
365	20.000	48	38.39	28	1371	15	25	3
365	20.000	72	61.04	28	2180	9	40	4

Table 2: System parameters with 1% grade of service

Total area (km^2)	Estimated no. subscriber	No. available TCH	Total traffic/cell	Traffic/ subscriber (mE)	No. subscribers/cell	No. cells	Areas of cell (km^2)	Radius of cell (km)
a	b	c	d = erlang B	e	f = d/e	g = b/f	h = a/g	i = √ (h/2.6)
365	20.000	12	6	28	210	95	4	1
365	20.000	24	15	28	546	37	10	2
365	20.000	48	36	28	1290	16	24	3
365	20.000	72	58	28	2070	10	38	4

Table 3: System parameters with 5% grade of service

Total area (km^2)	Estimated no. subscriber	No. available TCH	Total traffic/cell	Traffic/ subscriber (mE)	No. subscribers/cell	No. cells	Areas of cell (km^2)	Radius of cell (km)
a	b	c	d = erlang B	e	f = d/e	g = b/f	h = a/g	i = √ (h/2.6)
365	20.000	12	8	28	284	70	5	1
365	20.000	24	19	28	680	29	12	2
365	20.000	48	43	28	1519	13	28	3
365	20.000	72	67	28	2382	8	43	4

Table 4: Functional table at 2% GOS

f (x)	Area of cell	No. cells	No. subscribers/cell	Available traffic channels	Total traffic/cell
1.00	1.70	72.80	103.90	8.40	2.91
1.30	5.36	65.39	302.17	14.52	8.46
1.60	9.02	57.98	500.44	20.64	14.01
1.90	12.68	50.57	698.71	26.76	19.56
2.20	16.34	43.16	896.98	32.88	25.12
2.50	20.00	35.75	1095.25	39.00	30.67
2.80	23.66	28.34	1293.52	45.12	36.22
3.10	27.32	20.93	1491.79	51.24	41.77
3.40	30.98	13.52	1690.06	57.36	47.32
3.70	34.64	6.11	1888.33	63.48	52.87
4.00	38.30	-1.30	2086.60	69.60	58.43

Data analysis: The following data in Table 1-3 were analyzed. Table 1-3 show the relationship between the designed cell radius and the network functions/ determinant; the required number of cells, number of subscriber/cell, available Traffic Channel, total traffic per cell.

Taking the cell radius as a function of 'x' i.e., f (x) and the value x ranges from 1-4 km, the values of the network functions/determinants corresponding to f (x) within 95% confidence level as obtained from Table 4-6.

We also opted for determining the effectiveness of the radio network structure with different values (1 and 5%) of grade of service, as presented in Table 1-3.

With 2% GOS, 48 available number of TCH, average holding time of 100 sec and 28 mErlangs per subscriber, we obtained 15 numbers of cells, which can give optimum radio coverage over a radius of 3 km and 1371 subscribers/cell, if all other network parameters for the design and deployment of the BTS is put in place. For 1% GOS and 48 available number of TCH, we obtained 16 numbers of cells, which can cover a radius of 3 km and 1290 subscribers/cell. For 5% GOS and 48 available number of TCH, we obtained 13 numbers of cells, which can cover a radius of 3 km and 1590 subscribers/cell. With the same cell radius, the number of cells required as illustrated in Table 1-3, increases with a decrease in the percentage of GOS used. Recommended by NCC is a 2% grade of service, which means for location A, with 48 available number of TCH, 15 cells (BTS) is required for the estimated 20,000 mobile subscribers.

We analyzed the information in Table 1-3 and the numerical results as a function of the cell radius f (x) in kilometer (km) is shown in Table 4-6. In order words, the information in Table 1-3 are well interpreted in Table 4-6. From these Table 1-6, we can deduced that the smaller the radius of the cell, the fewer the number of subscribers/cell and the more cells sites (BTS) the radio planner will require to implement a good network. From Table 4-6, we observed that irrespective of the GOS used for the design, beyond 2.8 km of cell radius, good coverage should not

Table 5: Functional table at 1% GOS

f (x)	Area of cell	No. cells	No. subscribers/cell	Available traffic channels	Total traffic/cell
1.00	1.60	80.90	80.40	8.40	2.20
1.30	5.08	72.62	270.12	14.52	7.51
1.60	8.56	64.34	459.84	20.64	12.82
1.90	12.04	56.06	649.56	26.76	18.13
2.20	15.52	47.78	839.28	32.88	23.44
2.50	19.00	39.50	1029.00	39.00	28.75
2.80	22.48	31.22	1218.72	45.12	34.06
3.10	25.96	22.94	1408.44	51.24	39.37
3.40	29.44	14.66	1598.16	57.36	44.68
3.70	32.92	6.38	1787.88	63.48	49.99
4.00	36.40	-1.90	1977.60	69.60	55.30

Table 6: Functional table at 6% GOS

f (x)	Area of cell	No. cells	No. subscribers/cell	Available traffic channels	Total traffic/cell
1.00	2.50	60.30	146.30	8.40	4.10
1.30	6.40	54.24	360.29	14.52	10.13
1.60	10.30	48.18	574.28	20.64	16.16
1.90	14.20	42.12	788.27	26.76	22.19
2.20	18.10	36.06	1002.26	32.88	28.22
2.50	22.00	30.00	1216.25	39.00	34.25
2.80	25.90	23.94	1430.24	45.12	40.28
3.10	29.80	17.88	1644.23	51.24	46.31
3.40	33.70	11.82	1858.22	57.36	52.34
3.70	37.60	5.76	2072.21	63.48	58.37
4.00	41.50	-0.30	2286.20	69.60	64.40

be expected for the available 48 number of TCH used. If the number of subscribers/cell increases the number of TCH available must increase as well to avoid problems of network congestion, frequent call drops and other associated traffic problems (Vijay and Joseph, 1996).

CONCLUSION

In this study, we design a GSM radio network for 900MHz that will service 20,000 mobile subscribers in location A. With an average holding time of 100 sec, traffic of 28 mErlangs per subscriber and 48 number of available Traffic CHannels (TCH) deployed, the total traffic per cell recommended from Erlang B table was 38.39 Erlang at a 2% grade of service. Using this information, a total of 15 cells was designed for the region under consideration. This number of cell sites obtained from this study should be the minimum number of BTS required for good coverage in location A. Although in practice, only seven BTS of the GSM operator used as a reference network, existed in location A at the period of this report. Perhaps, this may have contributed to the hikes in the disappointing scenario encountered by mobile users trying to establish or receive a call.

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