OPTIMIZING GLOBAL SYSTEM FOR MOBILE COMMUNICATION NETWORK DESIGN VIA MINIMUM SPANNING TREE

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ABSRACT: *This paper explores the technique of minimum spanning tree (MST) to optimize the design of Global System for Mobile (GSM) communication network. The coverage area is Yola North and Yola South Local Government Areas in Adamawa State, Nigeria. The estimated subscriber capacity is 200,000. Area view from satellite images in space using Google earth and Arc GIS software provided part of the site survey data. Base Station (BS) selection was based on population density of any given area. Follow-up physical visit to selected locations was undertaken to augment the information from Google earth and Arc Map. The coverage of each site and the corresponding antenna height were determined from the survey data. The technique of MST was deployed in the analysis of the site survey data. The outcome showed a reduction from 80 possible network links to only 28 links. The MST outcome also provided alternative links that could guarantee service during critical repair works.*

KEYWORDS: Global System for Mobile Communication, Minimum Spanning Tree, Network, Quality of Service.

INTRODUCTION

The challenge for GSM network wireless operators is to balance coverage, capacity, call quality, data services and cost in order to gain maximum revenue from their networks. The focus of this paper is to design a GSM access network using minimum spanning tree methodology to optimize the network links, reduce cost of network operations and construction, enhance better coverage and quality of service, provide a scalable network for future optimization, meet subscribers need and maximize investors' revenue.

As the number of GSM subscribers in Nigeria increased to 94,531,980 in March 2012, the demand for good quality of service (QoS) also increased. The Nigerian Communications Commission (NCC) issued out the threshold level on the key performance indicators (KPI) for ascertaining QoS of all the GSM networks in the country [1]. The KPI on which the GSM networks were tested include: call set-up success rates (CSSR), call drop rates (CDR), call completion success rates (CCSR), handover success rates (HOSR), traffic channel congestion rate (TCHR).

The GSM coverage in Yola North and Yola South Local Government Areas of Adamawa State, Nigeria with total subscriber estimate of 200,000 has posed great concern to subscribers especially as it affects coverage and QoS. For an improved design, second generation (2G), third generation (3G) and WiMAX technologies will be used in the design of the Base Stations to resolve coverage and quality issues.

RELATED WORKS

[2] examined the impact of radio frequency identification detection in cellular network. They observed that researchers have paid less attention to the erratic failure of radios situated in base stations. They emphasized the need for service operators to adopt quick response strategy to improve their Quality of Service which will ultimately improve their revenues.
[3] in their paper acknowledged the continuous increase in both the cellular mobile phone users and service providers with the attendant need for coverage globally. According to the paper, despite the advances in technology, issues like poor cell coverage, air interface interference and area specific network traffic have not abated. They therefore canvassed the need for monitoring the service providers against the identified issues. They introduced "My Operator Coverage (MOC) system that is using Internet of Things (IoT) concepts and tools" to help with the monitoring.

[4] noted that non-availability of base transceiver station (BTS) coverage arises most often when BTS is too far from the location of the mobile station (MS) or the BTS is down.
According to [5] spanning tree protocol (STP) provides a means to prevent loops by blocking links in an Ethernet network. Blocked links can be brought into service if active links fail. Other works that considered spanning tree as a means of optimizing communication networks include [8], [9] and [10].

METHODOLOGY

The use of area view in Google Earth Map was adopted in this paper to determine low and high densely populated areas of the research area.
MODELS
The following models were used:

i. Cost – 231 Hata Model
ii. Link budget
iii. Minimum Spanning Tree

The Cost-231 Hata Model is used to predict path loss of mobile systems not more than 10km between the transmitter and the receiver [6]. The propagation loss formula is given by

$$L_b = 46.3+33.9\log f - 13.82\log h - a(hm) + (44.9 - 6.55\log h_b)\log d + Cm \quad (1)$$

The Link Budget utilizes standard propagation model and corrects the model according to the practical environment. Link budget can only predict the coverage of BTS roughly, the coverage status of the practical system requires field test.

Minimum spanning tree deals with linking nodes of a network, directly or indirectly, using the shortest total length of connecting branches.

The network design was realized using

- Site Survey data
- NCC Standards

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- Google Earth and Arc GIS
- Graphvis 2.27
- POM-QM Version

Site Survey Tools.

- Digital camera
- GPS satellite receiver
- Compass
- Ruler/tape
- Laptop
- Binocular
- A vehicle

RESULTS/FINDINGS

Site Survey

Site survey is fundamental to GSM network design. It defines the needed parameters for network planning, determines the structure of future network and the quality of the network operations. Using a pictorial area survey, site distribution on Google map was based on the following:

- Existing power station and possible interference
- Population distribution and local custom
- City structure and town distribution
- Main streets and traffic flow
- Highlands, lowlands and rivers.
- Long term development trend

Site Selection

Sites were selected based on the following survey conditions.

- Best fit locations are chosen. Offsets not more than ¼ of the coverage radius are used.
- Collocation is considered if coverage, non-interference and traffic balance meets network specification to reduce construction and operational cost.
- Search ring with candidate cells are noted.
- Sites along the border are avoided.
- Signal reflection and dispersion are avoided as much as possible.
- High power radio transmission stations, radar stations and other interference sources are avoided.
- Safe environment, busy road and availability of power supply are preferred positions.
- Sites are located away from the river and dense trees to avert fast fading of received signals.
- Heights of building and trees are used to define antenna height for better coverage.

Table 1 presents the data collected from the site survey indicating the exact site locations as nodes and the network links as connecting nodes.

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Table 1: Site Survey Result.

S/N	NODES	SITE CODE	CONNECTING NODES	DISTANCE (m)	LONGITUDE (UTM)	LATITUDE (UTM)	ELEVATION (m)	ESTIMATED ACCURACY
1	1	ADA001	STARTING NODE	0	220984	1025696	211	11.3
2	2	ADA002	2,1	1922.867	219991	1027344	206	9
3			2,15	1180.692				
4	3	ADA003	3,8	1188.315	218789	1022284	180	14.3
5			3,7	994.63				
6	4	ADA004	4,1	3845.491	216596	1027548	170	11.2
7			4,17	985.375				
8			4,16	1623.869				
9			4,5	1211.366				
10			4,2	2528.555				
11			4,21	938.438				
12	5	ADA005	5,2	1409.543	218602	1027628	168	17.3
13			5,21	2005.548				
14			5,17	1341.087				
15	6	ADA006	6,3	1290.543	216723	1022893	200	12.3
16			6,7	2078.382				
17	7	ADA007	7,1	3648.703	219794	1022242	177	13.4
18			7,11	2340.031				
19			7,12	1629.747				
20	8	ADA008	8,7	1874.114	218298	1023385	201	11.1
21			8,11	2752.639				
22	9	ADA009	9,1	2257.246	218736	1025478	195	15.4
23			9,10	1245.922				
23			9,11	2487.849				
24			9,16	876.908				
25	10	ADA010	10,1	1391.547	219845	1024906	206	14.8
26			10,11	1204.74				
27	11	ADA011	11,1	1388.662	220882	1024297	201	18.1
28			11,13	1322.541				
29	12	ADA012	12,10	2008.128	221036	1023308	193	15.3
30			12,11	1020.982				
31			12,13	1486.483				
32	13	ADA013			222214	1024196	221	13.5
33	14	ADA014	14,1	886.184	221479	1026456	193	18.4
34			14,13	2365.486				
35			14,15	603.196				
36	15	ADA015	15,1	1227.561	221107	1026928	174	14.5
37	16	ADA016	16,1	2232.165	218845	1026355	191	16.4
38			16,11	2892.414				
39	17	ADA017	17,10	2372.436	218017	1026407	178	12.9
40			17,9	1186.414				
41			17,16	849.929				
42	18	ADA018	18,1	5084.581	215898	1025698	175	12.8
43			18,9	2843.52				
44			18,11	5179.977				
45	19	ADA019	19,8	1659.54	217889	1021353	180	11.9
46			19,9	3285.988				
47			19,11	4401.061				
48	20	ADA020	20,18	947.451	216852	1025643	182	13.6

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49			20,11	4272.24				
50			20,9	1896.093				
51	21	ADA021	21,1	4769.91	215518	1027130	167	16.9
52			21,16	2544.209				
53			21,2	3394.44				
54	22	ADA022	22,23	1398.828	222443	1016929	168	18.8
55			22,27	2724.611				
56			22,11	7598.076				
57	23	ADA023	23,11	6826.864	223475	1017966	201	9.8
58			23,1	8123.233				
59	24	ADA024	24,11	7113.581	224866	1018386	190	10.7
60			24,23	1450.666				
61	25	ADA025	25,23	2523.64	225088	1016707	205	14.5
62			25,24	1700.99				
63			25,22	2046.418				
64			25,28	1592.492				
65	26	ADA026	26,23	2117.878	225573	1019879	167	9.3
66			26,24	717.389				
67			26,25	1592.492				
68			26,28	2845.95				
69	27	ADA027	27,11	5007.239	221729	1019314	162	14.9
70			27,23	2525.237				
71			27,7	3297.196				
72			27,28	1993.493				
73	28	ADA028	28,23	2503.075	223264	1019879	167	9.8
74			28,11	5008.357				
75			28,12	4008.417				
76			28,7	3313.083				
77	29	ADA029	29,23	754.941	223061	1018591	185	11.5
78			29,28	1336.921				
79			29,27	1855.315				
80			29,11	6132.241				

The following conditions were adopted in collating data in the table 1:

- No connecting node was repeated.
- Connecting nodes with no line of site were excluded.
- Maximum Base Station Capacity was used across all nodes in 2G, 3G and WiMAX.
- IP technology was used to define capacity with each base station allotted a minimum of 40Mb.

Minimum spanning tree methodology was used to analyze the data. The results of the analysis are shown in figures 1 and 2. Figure 1 is the MST of the network coverage of Yola North and South local government areas. The network links were optimized with nodes having the shortest distances.

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Figure1: Network Diagram with the Minimum Spanning Tree shown in Red.

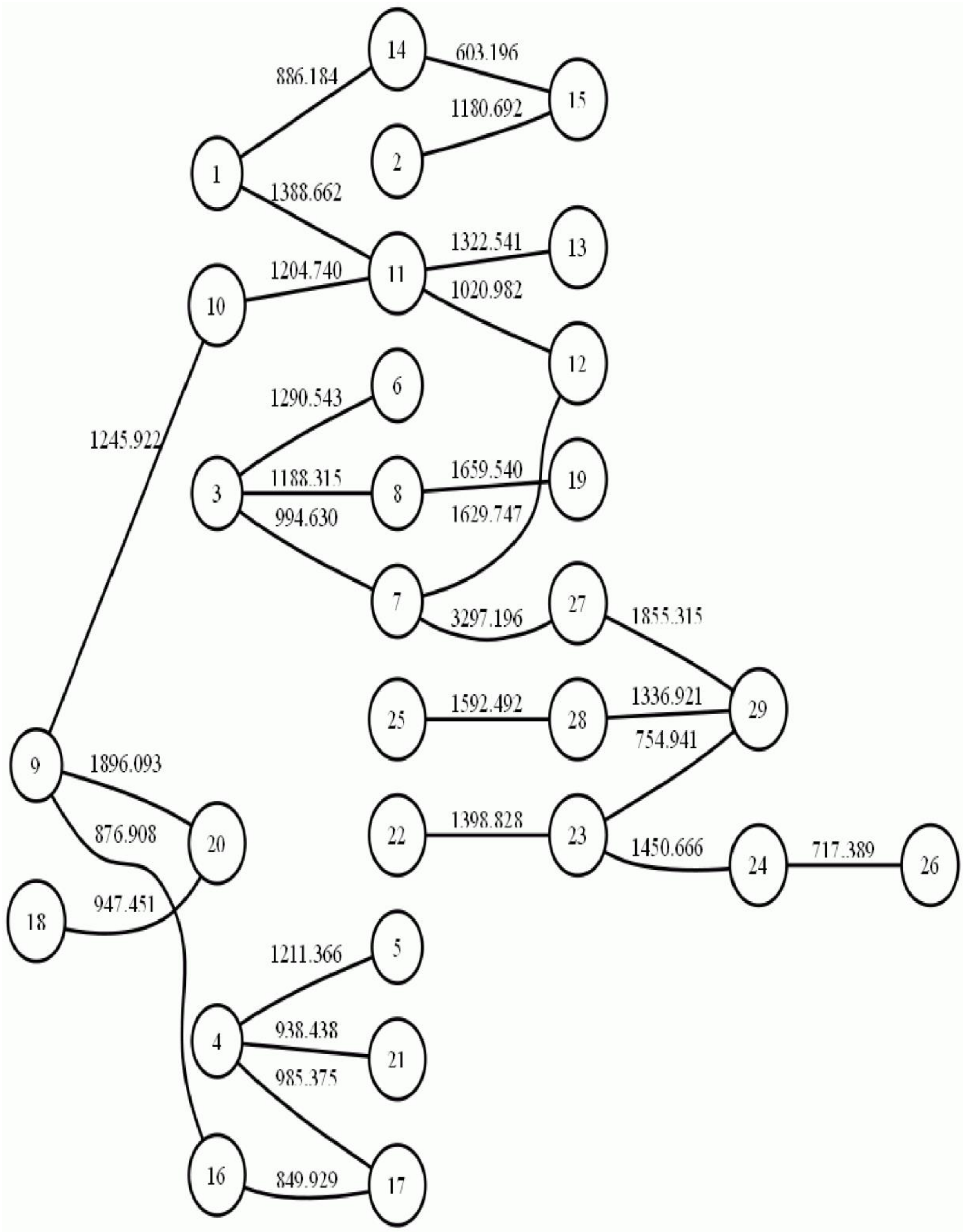

Figure 2: Minimum Spanning Tree Diagram for the Study Area Showing Optimized Links.

DISCUSSION

Figure 1 shows 29 nodes with 80 possible network links and 28 shortest possible links highlighted in red. Figure 2 shows 29 nodes and 28 links with the shortest possible distances

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for interconnection between nodes. The nodes represent GSM base stations while the links are radio frequency transmission paths.

Three (3) types of base stations are evident from Fig. 2.

- Terminal sites: Nodes with only one network link. Ten terminal sites, namely, nodes 2, 5, 6, 13, 18, 19, 21, 22, 25 and 26 are identified.
- Hub sites: Nodes with more than one network link emanating from it. Eighteen hub sites were identified with twelve having two links (nodes 1, 8, 10, 12, 14, 15, 16, 17, 20, 24, 27 and 28), and six hub sites having three links (nodes 3, 4, 7, 9, 23 and 29).
- Backbone sites: Nodes with very high importance and capacity capable of sustaining several other links. Only node 1 is in this category.

Figure 1 shows the network design extracted from Table 1. 80 network links were identified from the survey report however it was optimized to 28 network links by the minimum spanning tree approach. The links are shown in red lines. The 2G and 3G networks are accommodated in all the sites. Frequencies that travel short distances reducing the risk of interference and increasing the possibility of frequency reuse on the transmission links are best fit for this condition.

The quality of survey report is key to the success of figure 2. Based on Google Earth and ArcGIS in Figs 3, 4 and 5 the areas with dense population, schools, institutions and commercial activities were discovered. Customer density and possible population drift around the city are predicted based on activities that were encountered during the practical survey. The prediction however, ensured adequate scalability across the two local governments. Hence the antenna heights were carefully chosen to overcome obstacles and allow scalable down tilt in ensuring coverage of the research area.

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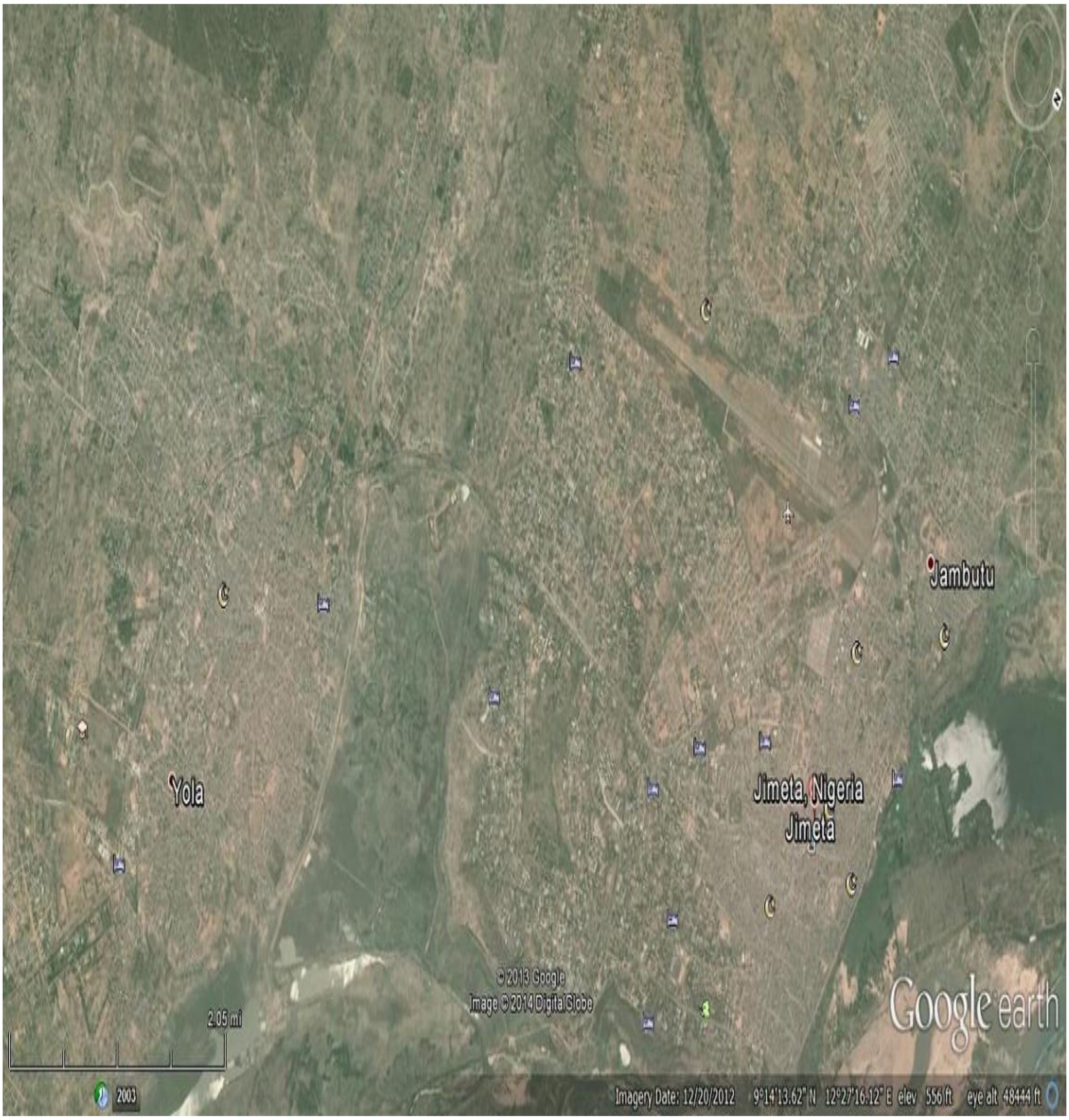

Figure 3: Map of Yola North and South

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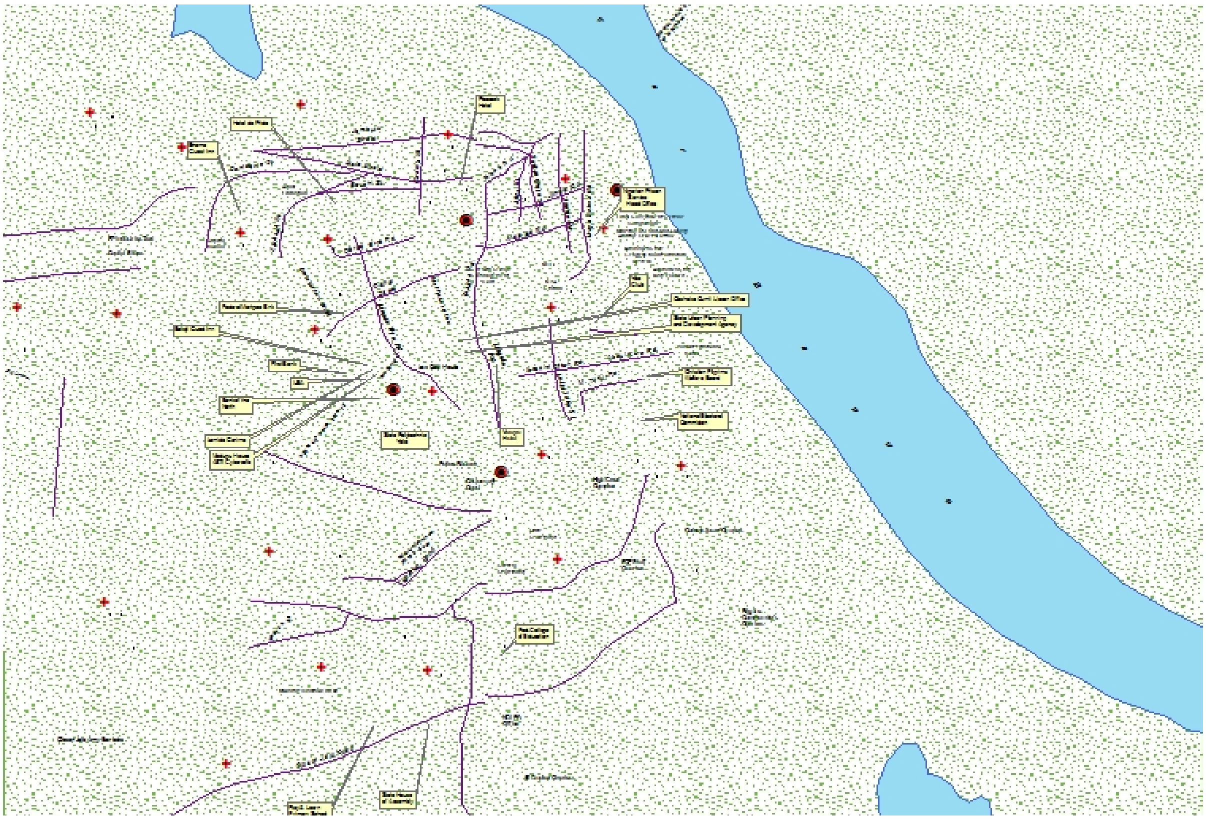

Figure 4: Map of Yola North with all Nodes (Masts) shown as Red Dots

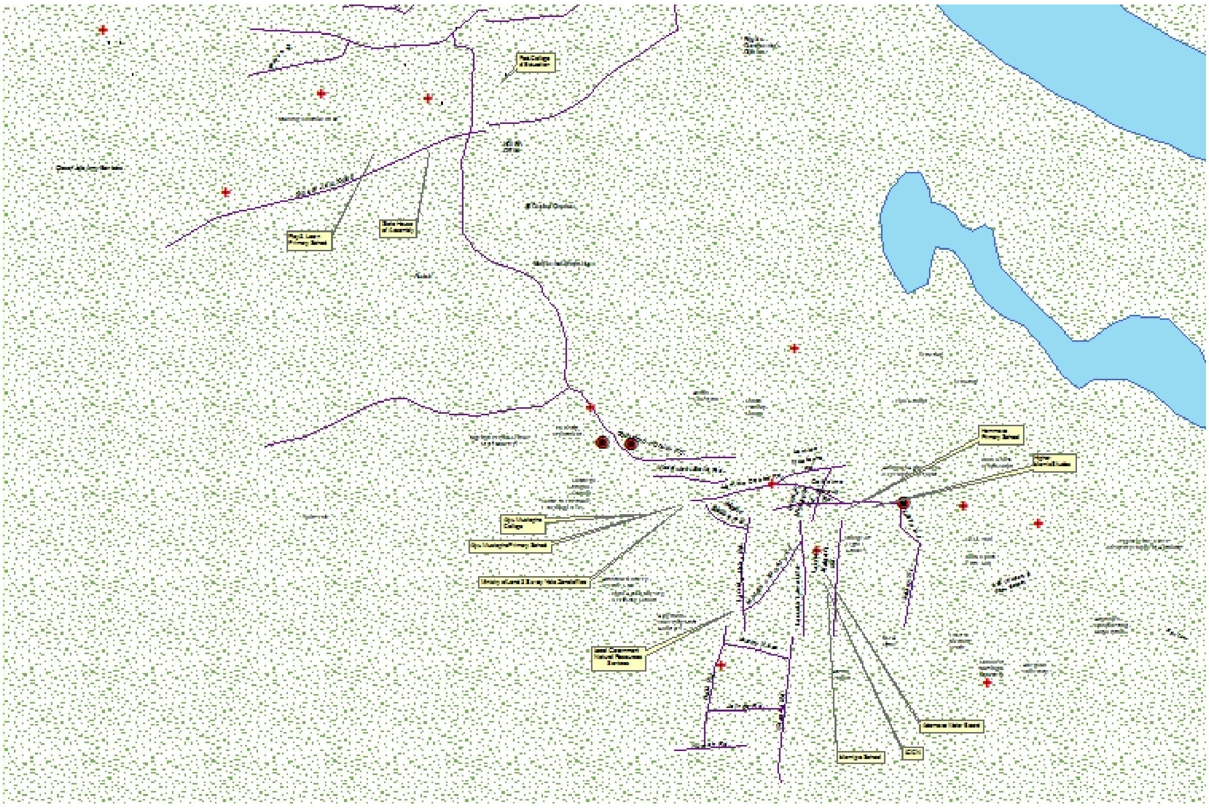

Figure 5: Map of Yola South with all Nodes (Masts) shown as Red Dots

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IMPLICATION TO RESEARCH AND PRACTICE

[7] noted that "antenna height is the basis for GSM coverage area. Hence, if antenna height is increased, path loss is lessened". An increase in the BTS transmit power results to higher receive power by the mobile. The short distances achieved allow the BTS to work at a reduced power (saving energy) and equipment life span.

The cost implication is that equipment and material for link construction will grossly reduce at the nodes. WIMAX, 900 MHz, 1800 MHz and 2100 MHz are used for coverage and quality of service. Their efficiency is improved by the shorter distance the signal travels as such subscribers will have access to higher capacity at the node. This will effectively support the packet switching in the IP based technology used. Note that the proposed IP based packet switching technology is compactable with existing GSM mobiles. The closeness of one node to another improves the quality of coverage and service to subscribers.

Figure 1 also shows that there are other possibilities if the preferred path encounters a problem. This will be handy to keep subscribers on the network when the use of mobile mast is required or maintenance affecting huge subscriber base is encountered especially in the course of de-rigging a tower. Time saving in such maintenance practice is advantageous to both the subscribers and the operators. Time saving is also achieved from packet transmission from one node to the other resulting in a better quality of service.

The research was able to identify areas of high customer patronage during the field survey and assigned more sites accordingly. This strategic site distribution will make it possible to reduce the number of 3G sites to same figure as the 2G and still meet customer requirements. WiMAX and 2G Edge throughput can be maximized to complement 3G across the network. This however will be scalable on the design when area of demand shifts within the research area.

CONCLUSION

The paper has shown MST as an effective method of optimizing GSM network design. This research has shown that MST can provide one of the cost effective ways of network deployment and maintenance due to its ability to identify shortest links between nodes (masts). In addition, possible alternative links are automatically generated which can be harnessed when critical repair works are to be carried out without disrupting services to consumers. The reduction in the number of nodes (masts) paves the way for the deployment of advanced IP technology at the nodes which ultimately enhances capacity and quality of service. The operators will also enjoy increase in profit because of good QoS.

FUTURE RESEARCH

The integration of the computation of coverage, line of sight, quality of service and capacity into the minimum spanning tree software to enhance a more robust network design should be explored.

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