ANALYSIS OF CAPACITY LIMITATION IN NIGERIAN GSM NETWORKS AND THE EFFECTS ON SERVICE PROVIDERS AND SUBSCRIBERS

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ABSTRACT

The performance of GSM network is measured in terms of KPIs (Key Performance Indicators) based on statistics generated from the network. The most important of these performance indicators from the operators' perspective are BER (bit error rate), the FER (frame error rate) and the DCR (dropped call rate).
The Dropped Call Rate (DCR) is a measure of the calls dropped in a network as it gives a quick overview of network quality and revenues lost. This makes it one of the most important parameters in network optimization. At the frame level in the NMS (Network Management System), the DCR is measured against the Slow Associated Control Channel (SACCH) frame. If the SACCH frame is not received, then it is considered to be dropped calls.
For this work data was acquired form the Network Management System of various GSM operators in Nigeria (e.g. MTN, Celtel, Globacom etc.). The acquired data was analyzed to statistically illustrate the extent of revenue that is lost as a result of dropped calls and the consequent impact on the customers/subscribers.

Keywords: GSM, KPIs, BER, FER, DCR, SACCH etc

INTRODUCTION

Quality degradation in a GSM network can be due to many factors such as capacity limitation, interference, unfavorable propagation conditions, blocking and etc.
Without adequate capacity, users will not be able to enter the network even though there might be suitable coverage in the area. Therefore providing the correct capacity in the correct location at the correct time is essential to maximize revenue generation, ensure high utilization of installed network infrastructure and provide seamless service for subscribers' satisfaction. However, capacity, both in terms of bandwidth and hardware will always be limited in a practical communication system and the primary method that is employed in arresting capacity limitation is called Handover. This involves relaying of the excess traffic to a less congested neighboring cell and it is only efficient if there is a major population drift from such cell to the congested cell.

Theoretical Analysis of Capacity Limitation in Nigerian GSM Networks

Due to the limited bandwidth that is available to GSM operators, heavy traffic is usually generated during special events at some cell sites (e.g. religious camps, stadia, markets etc) and the traffic sometimes exceeds the bandwidth capacity of the assigned base station.

Based on this, a high dropped calls which results in huge lost of revenue by the operators and erratic service provision to the customers is regularly experienced.
The bandwidth allotted to GSM operators in Nigeria is as shown below.

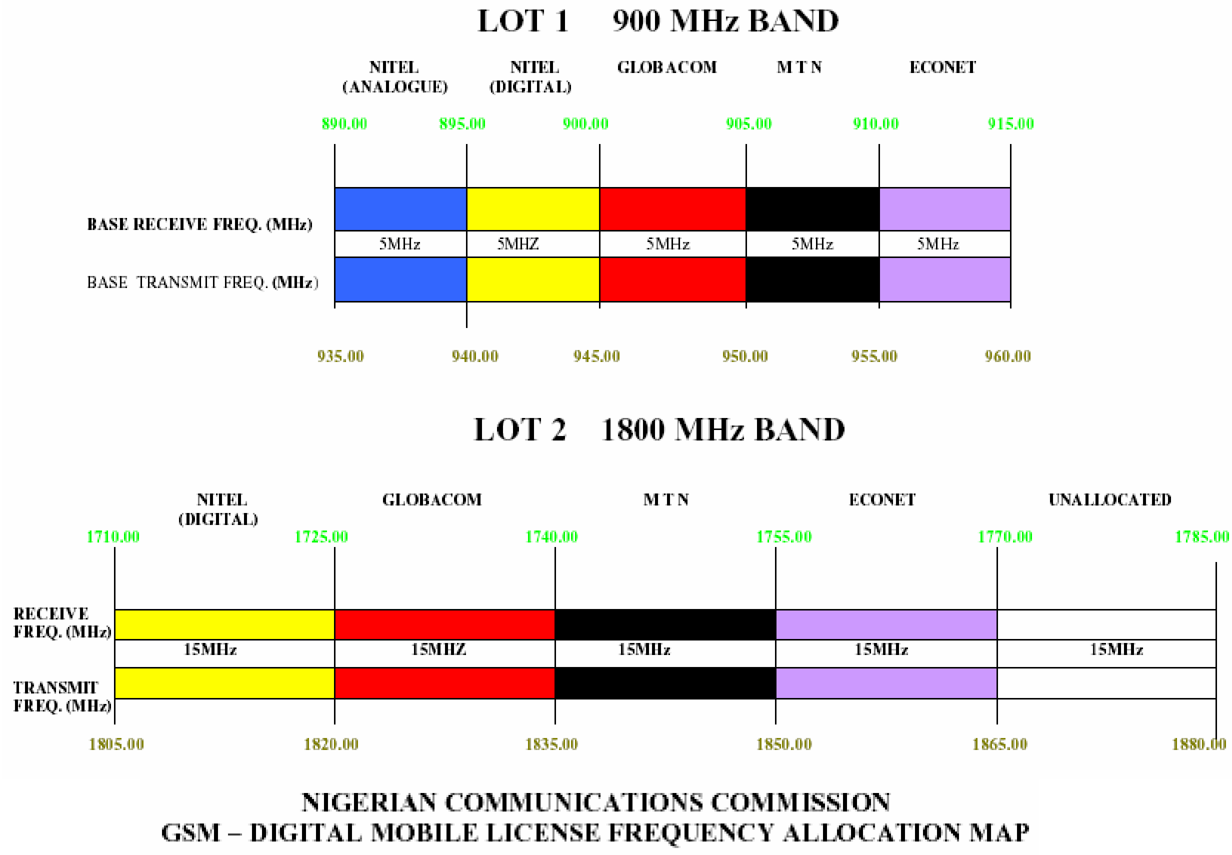

Fig 1.0 (NCC Website)

In MTN network for instance, Canaan Land is served by site T325. This has 2 cells i.e. one 900 band cell (325A) and one 1800 band cell (325 DA).

325A (the 900 band cell on Canaan land) has; - 6 Transceivers (TRX) - 42 Traffic Channels (TCh - for both Voice and Data) - 5 Stand Alone Dedicated Control Channels (SDCCh - for call setup, sms and location update) – 1 Broadcast Control Channel (BCCh - for broadcast by BTS to show network attachment)

While 325DA (the 1800 band cell) has; - 6 Transceivers (TRX) - 45 TCh - 2 SDCCh - 1 BCCh

Similarly, Redemption Camp is served by site T71. This has 6 cells i.e. three 900 band cells (71A, 71B and 71C) and three 1800 band cells (71DA, 71DB and 71DC).

71A has - 4TRX - 29 TCh - 2 SDCCh - 1 BCCh

71B has - 4 TRX - 27 TCh - 4 SDCCh - 1 BCCh

71C has - 4 TRX - 27 TCh - 4 SDCCh - 1 BCCh

71DA has - 6 TRX - 45 TCh - 2 SDCCh - 1 BCCh

71DB has - 6 TRX - 45 TCh - 2 SDCCh - 1 BCCh

71DC has - 6 TRX - 45 TCh - 2 SDCCh - 1 BCCh

The maximum number of users varies according to the size of the cell i.e. number of configured Traffic Channels. MTN for instance uses a 2% grade of service (GoS) and Erlang is the unit of traffic used in telecommunications, which is measured as the total traffic volume of a cell in 1hr.

i.e. Erlang = no of calls x duration/60mins (1hr) ---------------(1)

From the above information, it is expected that 325A (the 900 band cell on Canaan land) with 42 TCh should have an Erlang of 32.84 at peak period, using a GoS of 2% from Erlang B Table. Hence, the number of calls or callers/users can be calculated from the formula above which gives us 394 users assuming an average of 5mins call duration.

Also, 325DA (the 1800 band cell on Canaan land) with 45 TCh has an Erlang of 35.61 at peak period. The maximum number of callers in this cell, assuming an average of 5 mins call duration is 427 callers/users.

Therefore, the total maximum number of users on Canaan land during peak periods assuming call duration of 5 mins is:

394 + 427 = 821 callers/users. --------------------- (2) [3, 4, 8, 11]

It should be noted that any caller beyond the maximum value calculated above for each base station is automatically dropped. Using the formula in equation 1.0 above, Celtel cell parameters at some designated cell sites are shown in Table 1.0 below.

SITES	CELLS	SECTOR	No of TCh	FR Traffic (Erlang)	HR Traffic (Erlang)	NO OF FR USER	NO OF HR USER
CANNAN LAND	LG414D1	1	46	36.53	54.795	1461	2191.8
	LG414D2	2	46	36.53	54.795	1461	2191.8
	LG414D3	3	46	36.53	54.795	1461	2191.8
	LG414G1	1	14	8.2002	12.3003	328	492.012
	LG414G2	2	14	8.2002	12.3003	328	492.012
	LG414G3	3	14	8.2002	12.3003	328	492.012
REDEMPTION CAMP	LI048D1	1	14	8.2002	12.3003	328	492.012
	LI048D2	2	14	8.2002	12.3003	328	492.012

	LI048D3	3	14	8.2002	12.3003	328	492.012
	LI048G1	1	14	8.2002	12.3003	328	492.012
	LI048G2	2	14	8.2002	12.3003	328	492.012
	LI048G3	3	13	7.402	11.103	296	444.12
ABEOKUTA STADIUM	ABY01D1	1	14	8.2002	12.3003	328	492.012
	ABY01D2	2	14	8.2002	12.3003	328	492.012
	ABY01D3	3	14	8.2002	12.3003	328	492.012
	ABY01G1	1	13	7.402	11.103	296	444.12
	ABY01G2	2	13	7.402	11.103	296	444.12
	ABY01G3	3	13	7.402	11.103	296	444.12
NATIONAL STADIUM	LG725D1	1	30	21.93	32.895	877	1315.8
	LG725D2	2	30	21.93	32.895	877	1315.8
	LG725D3	3	30	21.93	32.895	877	1315.8
	LG128D1	1	45	35.62	53.43	1425	2137.2
	LG128D2	2	46	36.53	54.795	1461	2191.8
	LG128D3	3	30	21.93	32.895	877	1315.8
	LG128G1	1	14	8.2002	12.3003	328	492.012
	LG128G2	2	13	7.402	11.103	296	444.12
	LG128G3	3	14	8.2002	12.3003	328	492.012

Table 1.0: Celtel Cell Parameters for Some Sites

(Source: Celtel Sites Documentation)

Statistics of Dropped Calls/Network Congestion on Canaan land Cell Site

The following empirical data (Table 2.0) from Celtel Network Management System (NMS) for weekly call statistics at **Celtel** cells on Canaan Land further illustrates the traffic congestion problem when a cell is overpopulated.

Sector OBJECTID	DATE	HO	DROPS	DROP_CALL_RATE
Sector 5	11/14/2005	0	16	2.48

Sector 1	11/14/2005	0	57	9.74
Sector 3	11/14/2005	0	75	10.37
Sector 2	11/14/2005	0	24	5.37
Sector 6	11/14/2005	0	20	3.21
Sector 4	11/14/2005	0	22	2.84
Sector 2	11/21/2005	0	129	2.45
Sector 1	11/21/2005	0	269	2.96
Sector 5	11/21/2005	0	32	1.25
Sector 3	11/21/2005	0	233	3.7
Sector 6	11/21/2005	0	58	1.14
Sector 4	11/21/2005	0	52	1.28
Sector 5	11/28/2005	0	163	1.02
Sector 1	11/28/2005	0	1428	2.35
Sector 4	11/28/2005	0	207	0.87
Sector 3	11/28/2005	0	2120	2.9
Sector 6	11/28/2005	0	263	1.11
Sector 2	11/28/2005	0	1304	2.82
Sector 3	**12/5/2005**	**0**	**1993**	**1.56**
Sector 4	**12/5/2005**	**0**	**2099**	**0.78**
Sector 6	**12/5/2005**	**0**	**303**	**0.8**
Sector 1	**12/5/2005**	**0**	**3825**	**1.23**
Sector 5	**12/5/2005**	**0**	**1110**	**0.6**
Sector 2	**12/5/2005**	**0**	**2492**	**1.15**
Sector 1	12/12/2005	0	1184	2.1
Sector 3	12/12/2005	0	1914	2.41
Sector 2	12/12/2005	0	785	2.32
Sector 6	12/12/2005	0	132	1.14
Sector 5	12/12/2005	0	72	1.25
Sector 4	12/12/2005	0	113	1.02
Sector 6	12/19/2005	0	168	1.21
Sector 5	12/19/2005	0	98	1.81
Sector 2	12/19/2005	0	1095	2.43

Sector 3	12/19/2005	0	2613	2.53
Sector 4	12/19/2005	0	92	0.68
Sector 1	12/19/2005	0	1601	2.24
Sector 4	12/26/2005	0	124	1.13

Table 2.0: Celtel NMS call statistics from 14/11/2005 to 30/01/2006

(Source: Celtel Network Management System)

It can be seen on the table that on the first day of Shiloh 2005 i.e. (5/12/2005), there was a consistent high dropped calls in all the sectors. This is due to the sudden surge of population on Canaan land for the annual Shiloh event.

For further illustration, figure 4.0 below shows the tabulated weekly dropped calls at Canaan land in December 2005 by MTN network on a bar chart. Peak dropped calls were experienced during Shiloh week as earlier predicted.

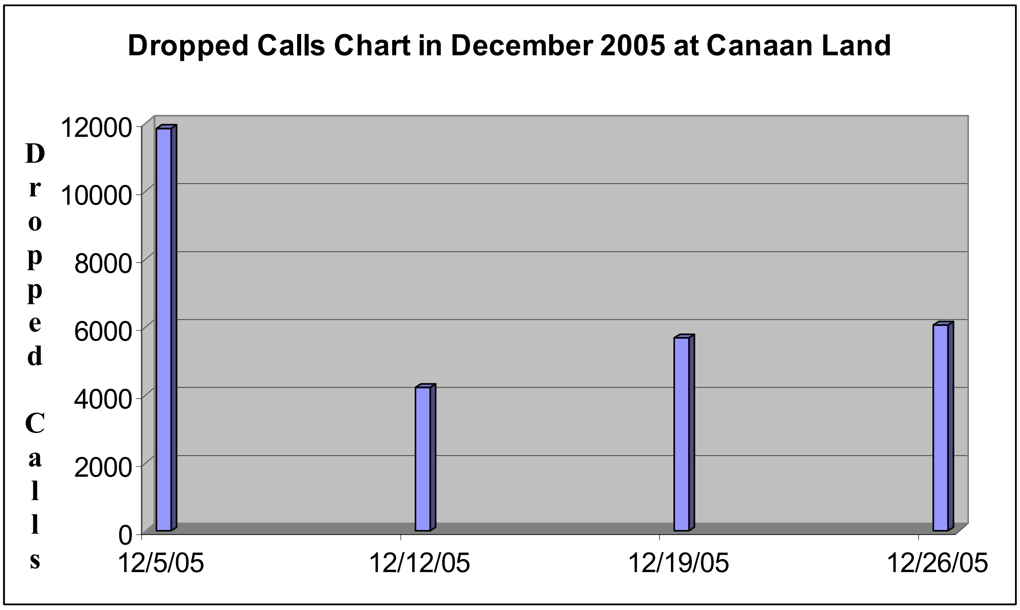

Fig 2.0 Dropped calls at Canaan Land in December 2005 (MTN Network)

Logically, the lost of revenue incurred by cellular operators is in direct proportion to the dropped calls over a given period.

Mitigation of GSM Network Capacity Limitation

To increase capacity given a limited bandwidth, **Frequency Re - use** is implemented by radio frequency engineers. In Nigeria for instance, Frequency Re - use is a way of planning the re -use of the frequencies assigned to every operator by NCC (Nigerian Communications Commission). For example the maximum available frequencies on 1800 band in Nigeria must be shared amongst MTN, Celtel, Globacom and M-Tel, hence the need for re -use. The pattern employed by MTN is 4 X 3 i.e. re -use frequencies after every 4 sites with 3 cells each. Meanwhile, in this scheme, there is no consideration to cater for traffic congestion due to overpopulation.

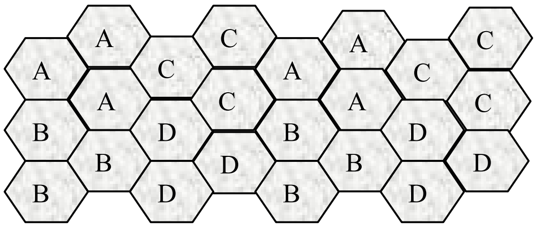

Fig 2.0 MTN (Nigeria) 4 X 3 Frequency Reuse Pattern.

To increase capacity in some cellular networks where the base station capacity is limited by the number of transceivers, **a 'bunch' concept consisting of a central unit (CU) and remote antenna units (RAUs) was proposed for UMTS**.

A typical bunched cellular network is shown in fig 3.0 below.

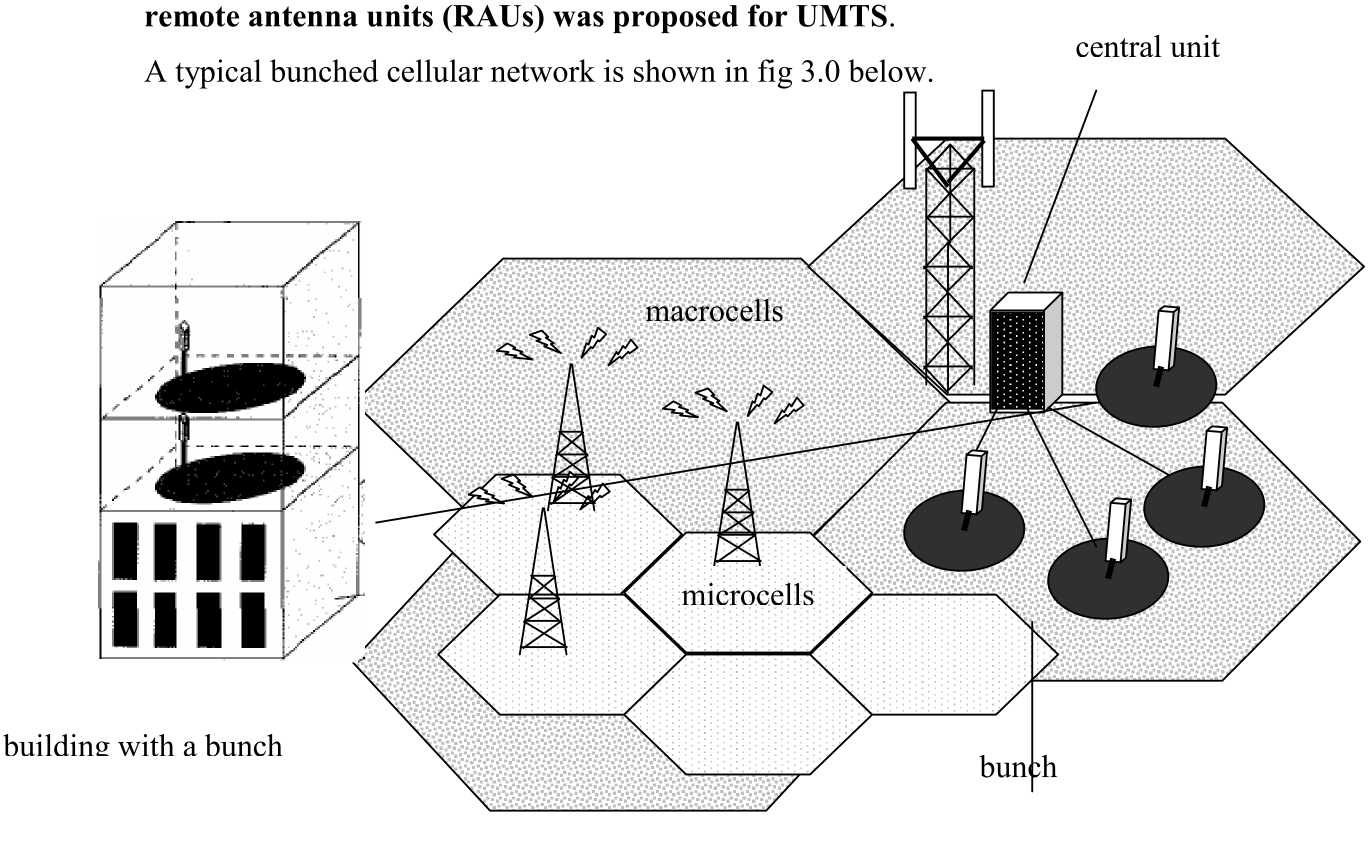

Fig 3.0 A Scenario of mixed cell structure with Bunched Network

The bunch concept involves a Central Unit (CU) that controls a set of remote antennas or base stations. The Central Units deal with all decisions on channel allocation, service request and handover. The concept can be viewed simply as a very advanced base station with a number of small antennas for remote sensing. The central unit will therefore have complete control over all the traffic in its coverage area and will be able to maximize the resource utilization for the current traffic. This provides opportunities for uplink diversity and avoids intercell handovers in its coverage area. [1, 11, 13, 15, 17, 22].

Intelligent Relaying (IR) is another technique used by cellular telecommunication operators to minimize the amount of planning and the number of base stations required in a cellular network and to improve cell capacity. A network employing intelligent relaying includes mobiles that are capable of passing data directly to other mobiles, rather than directly to a base station, as for a conventional cellular network [1].

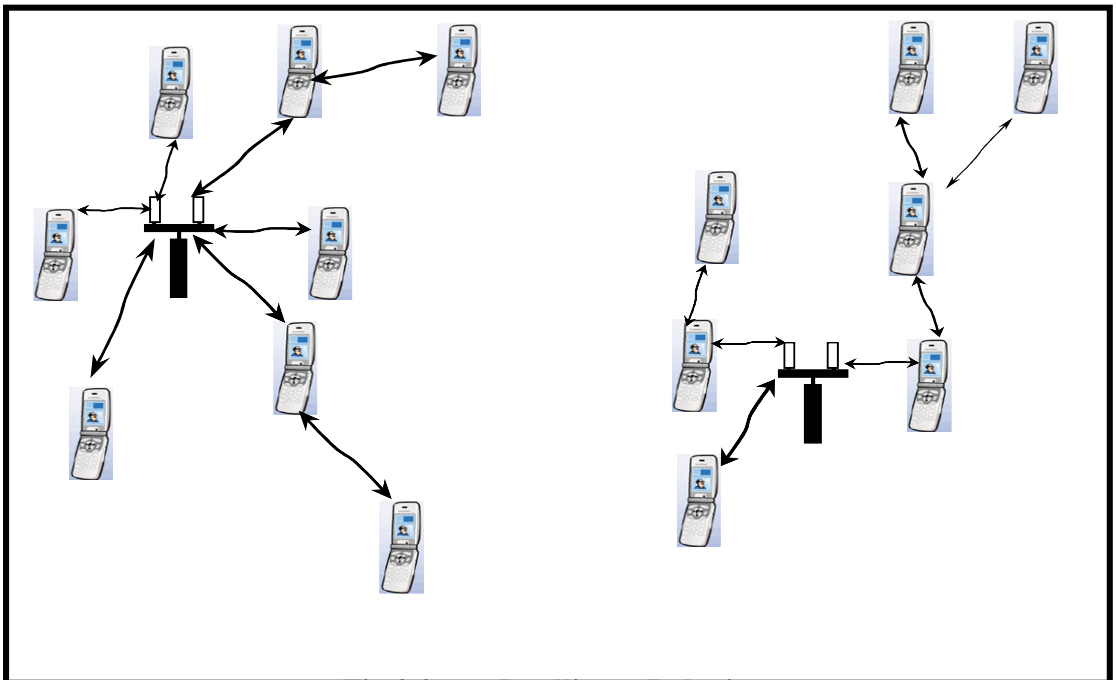

Fig 3.0 Intelligent Relaying

In IR, mobile terminals are permitted to receive and retransmit data on behalf of other users. A cellular network that implements IR is shown in fig 3.0 above which shows how the route between mobile and base station can be broken down into shorter mobile-mobile hops and how IR nodes can act as forwarding nodes for a number of mobiles.
To plan a network incorporating IR for capacity enhancement, each mobile is considered as a "virtual cell", acting as a base station at its center. The coverage area of the virtual cell varies with respect to factors like; change in the transmit power of the mobile, mobility of the user and the number of other mobiles in the vicinity that are available to relay data. Where IR is implemented as a network option, the virtual cells can be considered as an overlay to a conventional cell structure.[1, 7, 8, 16]
Several other approaches such as **dynamic cell sizing** and **radio resource management** are employed to mitigate capacity limitation in a GSM Network and any or combinations of these approaches could be implemented as appropriate.

Conclusion and Recommendation

This paper has analyzed the problem of network congestion due to capacity limitations which usually results in reduction of quality of service (QOS) in cellular communications system. Since QOS is an essential performance criterion, cost effective solutions to minimize the problem and boost the network performance have been explored.
However to further mitigate this capacity limitation problem, we are currently working on a Software radio based approach, to design and simulate a capacity enhancement Nomadic Base Transceiver Station Sub-System (NBTSS).

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