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Improving Service Accessibility (CSSR) In GSM Network using an Intelligent Agent-Based Approach

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Abstract: - The ability to access cellular network serves as the basis of any Key Performance Indicator to be measured. Accessing it allows subscribers to other features or value-added services rendered by the telecommunications operator. The inability to access telecommunication services continues to plunge the performance of the Global System for Mobile Communication network in Nigeria. Most often, when subscribers are denied access, it reduces the overall Call Success Rate (CSR). To this end, network samples were collected during drive test in Enugu State Nigeria, and GSM parameters that prompt blocked calls were extracted from the log-files using TEMS Discovery. The various causes of blocked calls that are software related and their respective solutions were embedded in an Artificial Intelligent system using a Case-Based Reasoning approach to avoid such blocked calls. The log-file was run with the AI system; the result shows that the system accessibility was improved by 5.23%.

Keywords: - GSM, Network Accessibility, Network Quality, Artificial Intelligence, Case-Based Reasoning, Blocked call.

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1. Introduction

In telecommunication, the three (3) major Key Performance Indicators (KPI) used to assess the network performance are the network availability, accessibility, and retainability. These KPIs give the operators a clear performance rating from the subscriber's point of view. This paper focuses on improving GSM network accessibility which is interpreted as reducing blocked calls in the GSM network. A blocked call is said to have occurred when an attempted call by a subscriber is denied legal access to the network services even within the supposed coverage of the operator and meeting their terms. The factors that lead to these access denials are classified as either software or hardware-related. The rate of network accessibility is measured by the call setup success rate which is a fraction of successful call setups to the number of call attempts. It is measured in percentage. The sum of successful call setups and blocked calls is the total number of attempted calls. The threshold for blocked call rate (BCR) in telecommunication is $\leq 2\%$. Global System for Mobile Communication (GSM), network operators, have consistently worked towards reducing BCR which is the bases of this paper.

2. Related work

In today's world, communication technology plays a vital role. It has become an important tool for sharing information in personal lives or/ in organizations for the transfer of data. Among the existing cellular networks, Global System for Mobile

(GSM) communications is the most popular cellular communication system all around the world [1, 2]. GSM network usually called 'cellular network' (as the whole coverage area is divided into different cells and sectors) is comprised of a Mobile Station (MS) which is connected to the Base Transceiver Station (BTS) via the air interface. In addition to other hardware, BTS contains the equipment called Transceiver (TRX), which is responsible for the transmission and reception of several radio frequency (RF) signals to/from the end user [3]. This system was developed over time to include data communications by packet data transport via General Packet Radio Services (GPRS) and Enhanced Data Rates for GSM Evolution (EDGE). Further improvements were made when the 3GPP developed third-generation (3G) UMTS standard followed by fourth generation (4G) LTE advanced standard [4]. In recent years, a great deal of attention has been paid to the planning, evaluation, and optimisation of mobile cellular networks [5, 6].

Several authors have presented some findings that addressed the evaluation and optimisation of operational GSM networks. The network performance evaluation is based on four major KPIs, i.e., call setup success rate, call drop rate, handover success rate, and traffic congestion.

These factors affect the quality of service of a mobile network. [7] It is correct to look at Quality of Service (QoS) mainly from the customer's point of view, that is, QoS as judged by the user. There are standard metrics of QoS to the user. These metrics are the coverage, accessibility, and the audio quality. [8] In coverage, the strength of the signal is measured using test equipment, and this can be used to estimate the size of the cell. Accessibility is about determining the ability of the network to handle successful calls from mobile-to-fixed networks and mobile-to-mobile networks. The audio quality considers monitoring a successful call for a period for the clarity of the communication channel. [8]

A successful call set-up consists of two procedures. The first one is the Immediate Assignment (IA) procedure which is used to create signaling connection between the Mobile Station (MS) and the network, and the second one is Assignment Procedure (AP)which is used to occupy a radio resource (speech channel) [9]. In air interface, logical channels are divided into two categories: a- Traffic Channels and b- Control Channels. The Control Channels are further classified as: "Broadcast," "Common," and "Dedicated" control channels. The aim of this paper is to present and propose solutions for handling GSM network access problems to reduce blocked call rate using an intelligent agent.

3. Research Procedure

The study focuses on improving the rate of accessibility in the GSM network thereby reducing BCR using an AI system with a CBR approach. The network is studied to understand the core causes of low network accessibility performance (Network Characterization), solutions are proffered to the observed causes, which is then embedded in an AI system that solves GSM network accessibility problems from defined and generated GSM network cases.

3.1 Network Characterization

An experimental technique called drive test was used to characterize the network using the experimental setup shown in Fig 3.1. The experimental setup uses a Testing Equipment for Mobile System (TEMS) software license V13.0 install on the laptop, a TEMS mobile phone, a GPS and a power inverter. Voice calls were made for 120secs on the MTNN network by the mobile phone. The test covered the Enugu metropolis in Enugu State, Nigeria. This technique was adopted to evaluate in real time, the number of successful call setups against the number of call attempt of the network under study during the research timeframe. The call flow shows the number of calls initiated, blocked calls and calls setup which are of interest in this paper.

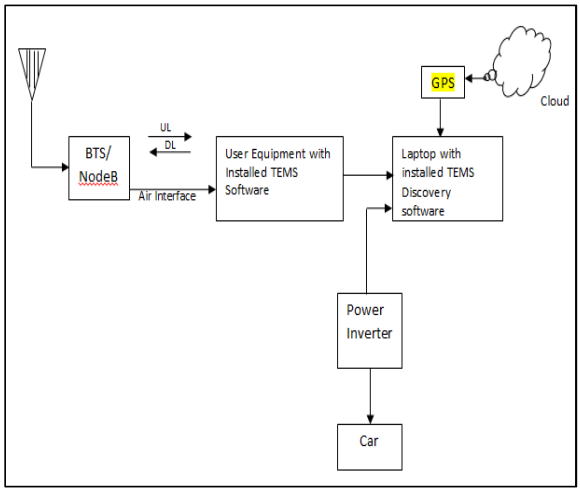

Figure 1: ***Drive Test Experimental Setup***

Network accessibility KPI is calculated as follows:

Let N_{SCS} = Number of successful call setup

And T_{CA} = Total number of call attempts

$$CSSR(\%) = \frac{100(N_{SCS})}{T_{CA}} \quad \text{.....(1.0)}$$

$$BCR(\%) = 1 - \text{CSSR}(\%) \quad \text{. .....(1.2)}$$

3.1.1 Network Characterization Parameter

During network characterization (drive test), various GSM parameters that prompts a blocked call were monitored and studied. These parameters were restricted to block calls that are software related. The poor output of these CSSR parameters affects the accessibility performance of the network.

Global System for Mobile Communication (GSM) Call Setup Success Rate (CSSR) Key Performance Indicator (KPI) parameters considered are:

- *GSM Mobile Station Transmitter (Tx) Power*

When a call is to be initiated, the Mobile Station (MS) communicates with Base Transceiver Station (BTS), its transmitting power is controlled by the network via power command. The GSM MS transmit power controls or manages and tries to reduce the transmit power thereby reducing a possible uplink interference that may arise between the Mobile Station (MS) and neighboring cells where there's frequency reuse.

- *GSM FER*

The GSM Frame Error Rate (FER) measures the rate of successful radio resource transfer between the BTS and MS using layer 3 messages. The response could either be Acknowledge (ACK) or Not Acknowledged (NACK). When the test set does not receive the RR frame in acknowledgment, it retransmits the Layer 2 message. The test set counts the number of times it resends Layer 2 messages.

- *Rx Signal Strength Ratio*

The Rx signal strength is a threshold that defines the minimum receive level of an MS for accessing the BTS. The MS is denied Stand Alone Dedicated Control Channel (SDCCH) access when its value for Rx signal strength ratio is below the set accessibility threshold. It is the ratio of the transmitted to the received power.

- *GSM C/I*

The GSM carrier-to-interference ratio shows the level of broadcast control channel interference between two neighboring cells making it difficult for the MS to camp on any of the cells during call initiation process.

Table 1. shows a sample network characterization output from TEMS Discovery.

Table 1: Abridged network characterization result

Time	Date	Latitude	Longitude	Call Initiation	Call Attempt	MS Tx Power (dBm)	FER Sub (%)	Strength Ratio in dB (S/N1)	GSM C/I	Blocked Call
17:20:17	02/07/2017	6.4667	7.4595	Call Initiation						
17:20:17					Call Attempt					
17:20:17	02/07/2017	6.4667	7.4595			33	100	5	22	
17:20:18	02/07/2017	6.4667	7.4594			35	100	10	22	
17:20:18	02/07/2017	6.4668	7.4593			35	100	13	23	
17:20:18	02/07/2017	6.4669	7.4592							Blocked Call
17:54:51	02/07/2017	6.4667	7.4595	Call Initiation						
17:54:51					Call Attempt					
17:54:51	02/07/2017	6.4755	7.5062			15	4.4	-23	22	
17:54:51	02/07/2017	6.4756	7.5064			15	4.4	-24.9	22	
17:54:51	02/07/2017	6.4761	7.5077							Blocked Call
08:30:10	02/07/2017	6.4667	7.4595	Call Initiation						
09:30:10					Call Attempt					
08:30:10	02/08/2017	6.3863	7.4998			18	3.8	10	19	
08:30:10	02/08/2017	6.3862	7.4997			18	3.8	10	19	
08:30:10	02/08/2017	6.3860	7.4995			18	3.8	10	18	
08:30:10	02/08/2017	6.3859	7.4994							Blocked Call

3.1.2 Network Characterization Result

Using formulas 1.1 and 1.2 above, Table 2: shows the call statistics that defined network accessibility.

Table 2: Call statistics from network characterization

Network Characterization Result	Value
Call Initiation	308
Call Attempt	305
Call Setup	287
CSSR	94.1
Total Blocked Call	18
Software Related Blocked Call (SRBC)	10
Software Related Blocked Call Rate (SRBCR)	55.56%

3.2 Research Target

In this paper, the target is improving network service accessibility concerning call setup success rate in GSM using a Case-Based Reasoning intelligent agent. From Table 3.2 above, the current network service is not meeting the needs of the subscribers. The overall accessibility rate is less than 95%, and with the steady rise in the number of GSM network subscribers, the accessibility rate will drop with time if solutions to resolve these GSM network accessibility issues are not implemented. This paper aims to reduce the blocked calls that are software related (10) which is more than 50% of the blocked calls experienced during network characterization.

3.3 Network Upgrade

To achieve this, Case Base Reasoning (CBR) technique is used by an Artificial Intelligent (AI) system for solving network accessibility issues thereby upgrading the network. AI systems are modeled to manage the specified task as they can take decisions within to match designed expectations by using the knowledge programmed or embedded into the system and from the knowledge they learned overtime from numerical problems. The level of intelligence of the system is tested in the learning phase as it learns from both successful and unsuccessful cases where the solution is implemented. Also, the response time slightly depends on the learning phase as the system would be able to recall a solution that exactly or very-nearly matches the network case/scenario at hand.

3.3.1 Case-Based Reasoning (CBR)

The AI system designed for network upgrade uses the Case Base Reasoning (CBR) approach to match various network cases or scenarios that lead to blocked calls on the GSM network. From a library of solutions in the AI system, a solution that solves the network snag is implemented using a defined reasoning algorithm. Case-Based Reasoning is a method that proffers solution to a new problem by analyzing previously solved problems. Figure 2: gives a summary of the case matching process of the AI system.

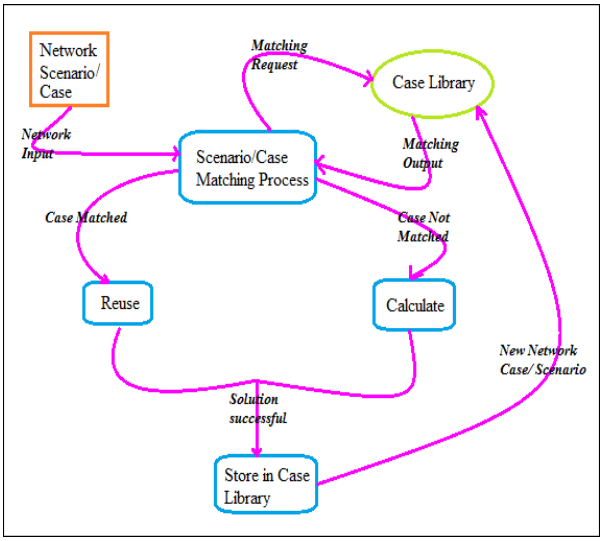

Fig 2: AI system case matching process

The entire CBR process as a whole is divided into two (2): (a) calculation partition (case generation, case reuse, case revision and case retainment) and (b) reuse partition (case retrieval). [10]

- *Calculation*

One of the features of CBR is that, unlike ANNs, it does not need extensive training before being used. A library can be generated in advance from test data ("case generation"), but the maintenance functions that allow new cases to be added also permit a library to be built from scratch. These maintenance functions require an evaluation function to determine how good a case is. Building the case library is the function of a field expert (telecommunication engineer). If the output of the previous case can be used for a new situation that is termed "case reuse"; if it can be reused with some form of modification the term is "case revision." The process of adding the case to be reused in some form to the library, with the appropriate indexing, is "case retainment."

- *Reuse*

The CBR process starts when there is a new problem or new case happening. The first step is case retrieval, which uses the pre-defined events to find the best-match to solved case(s) from the case library. The solution from the retrieved case(s) will be reused. However, the solution might need to be modified to fit the new situation as the new situation will rarely match the old one exactly: this step is called 'revising.' Once the new solution is proposed, the next step is to test it with the real environment. The result is either success or failure. If the solution fails, a monitoring process will analyze the failure, repair the working solution and test again. If the solution succeeds, this new solution will be indexed and retained in the case library to use for future problem-solving. [12]

Table 3. (a) and (b) shows network blocked call cases and corresponding solutions that can be retrieved from the case library.

Table 3(a): Blocked call cases

Blocked Call				
OSS KPIs				
Parameters/ Network Cases	GSM MS Tx Power >=20	GSM FER <= 5%	Rx Signal Strength Ratio > 0	GSM C/I >=13
Case 1	T	F	T	T
Case 2	F	T	F	T
Case 3	F	T	T	T
Case 4	F	T	F	F

Table 3(b): Causes and solutions to various blocked call cases

Case Causes	Case Solutions	Solution Code
Access Grant Channel (AGCH) overload at the BTS	*Assign calls to idle channels in the OSS*	***S1***
Random Access Channel (RACH) Collisions	*Adjust cell reselection criteria in the OSS*	***S2***
Poor uplink (UL) Quality	*Increase TRXs in the Operational Support System (OSS)*	***S3***
BTS Receiver issues	*Configure more idle channels as valid RACH in the OSS*	***S4***

Case retrieval is the use of the library to find the best solution to a particular set of circumstances and to intelligently match almost similar undefined cases to a pre-defined solution which is the core or bases of the research. The library is designed such that the set of input conditions is suitably indexed and the retrieval process finds the "best" match for the current input values. A parallel search method that searches the whole library at the same time, leading to the matching and retrieving processes happening in one step will be implemented.

3.3.2 Network Upgrade Procedure

Figure 3: illustrates the structure/flowchart of the AI system used for the upgrade with the overall CBR system (search case library) incorporated. The MS is first locked to the GSM network before the AI system requests for network accessibility parameters discussed in section 3.1.1. If any of the parameters falls short of its threshold, there's a likelihood of a blocked call occurring. If the CBR engine identifies a case that may produce a blocked call, it does matching to determine the best solution to the network snag, and the performance is then evaluated.

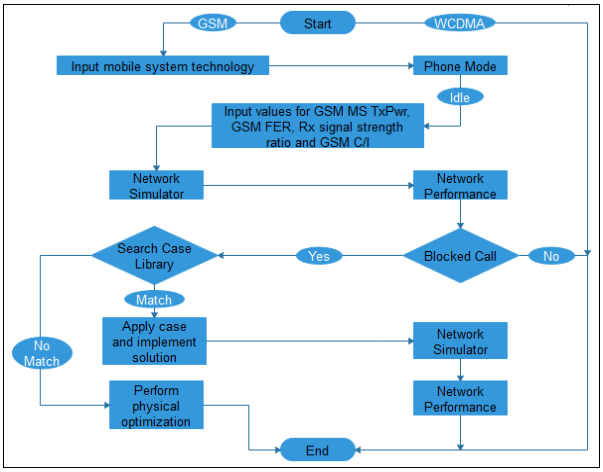

Fig 3: Artificial Intelligent system flowchart

The Base Station Subsystem (BSS) performs various functions including managing radio channels and uplink signal measurement. Hence, network accessibility can be improved from this area. The designed AI system is embedded as part of the software to be loaded in the Base Transceiver Station (BTS) as shown in Figure. 4.

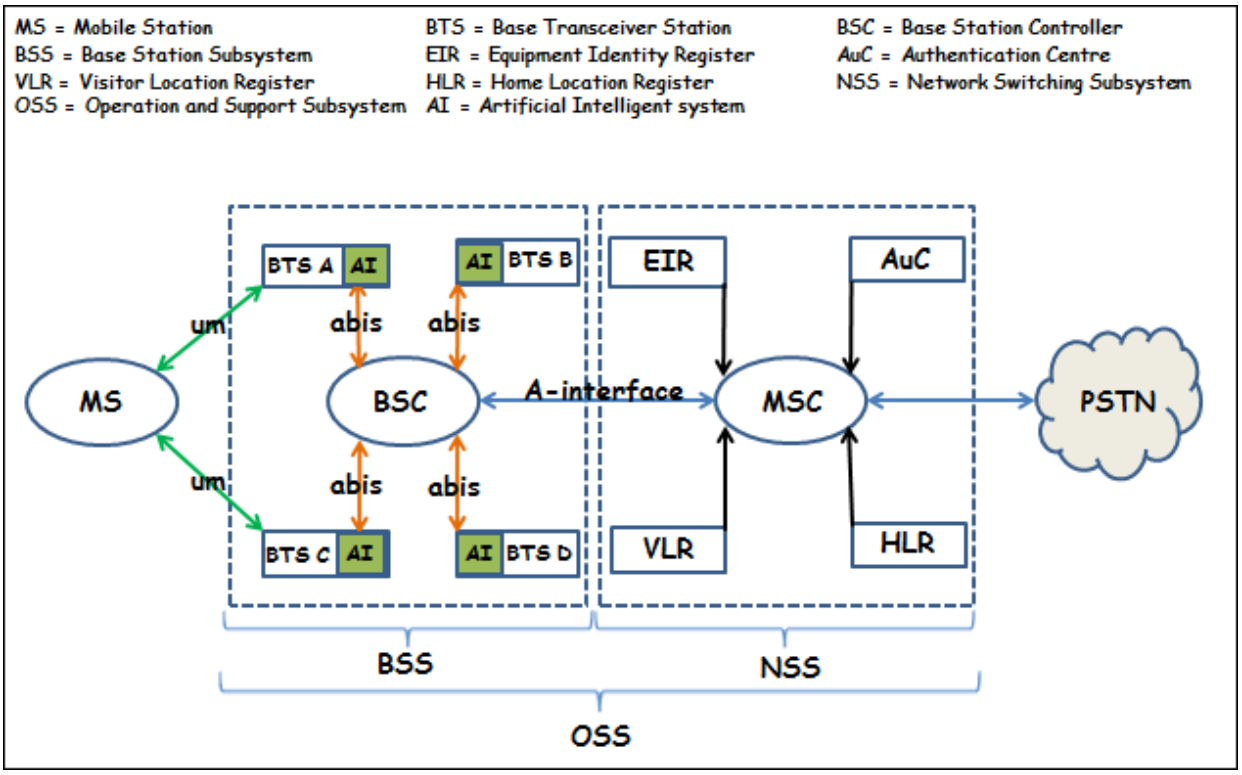

Fig. 4: Review network architectural design

4. Results and Analysis

The AI system manages defined and generated or studied cases with the purpose of improving the overall system performance. The efficiency of the AI system depends on the case library volume and quick response time.

4.1 Case Matching Process for GSM blocked Call

GSM network parameters are collected in milliseconds (ms) as shown in Table 1 and inputted to the AI system. If a blocked call is anticipated due to a failing parameter, the case matching process of the CBR then compares the parameter with the pre-defined scenarios/cases for a blocked call stored in the case library. The CBR model will then be used to find the best solution for the situation. As the Mobile Station (MS) encounters more blocked calls that are undefined to the system, the CBR model tries to retrieve a base-match solved the case from the case library. If a matching solution can be found, the solution will then be proposed to apply in the system; if a near match is found then that will be used, but the performance of the system based on the proposed solution will be monitored, and if necessary the case will be revised.

An aspect of improving Quality of Service (QoS) in GSM cellular network goes beyond network availability by the network operators but prompt access when necessary. Table 4. Shows the blocked calls observed from the pre-defined cases during the test.

Table 4: Blocked call events from drive test.

Cases	Case Status	Accessibility Results		
		Blocked Calls from Cases	Total Blocked Call	% Blocked Call from Cases
A	Pre-defined Cases	4	18	22.22
B		4	18	22.22
C		2	18	22.22
D		0	18	0

4.2 System Performance for Pre-defined Cases

Four cases coded as A, B, C, and D were tested and given the best solution for resolving each case. These solutions are stored in the case library. The CBR compares and retrieves a case and the solution from the case library.

The various network cases or scenarios that precede a blocked call are 25.49% of the entire tested route. Most of the blocked calls experienced in the area were captured in the pre-defined cases, and as such 55.56% of the blocked calls during the drive test was avoided.

MS Power and signal interference are major contributors to poor GSM network accessibility as both had 80% of the total blocked calls that are software related.

4.3 System Performance for Generated Cases

The potency of any AI system designed to perform CBR is its ability to study defined cases, draw some relationship between defined and undefined cases and proffer solution to undefined cases using pre-defined solutions. In testing the system performance in managing cases that have not been saved in the case library, a rule-based algorithm was developed consisting of a simple set of rules based on the studies done while generating the case library and also from the solutions of all existing cases. Figure 5: shows both the pre-defined cases (A, B, C, and D) and the generated cases (AB, AC, AD, BC, BD and CD). More cases can still be generated by the system.

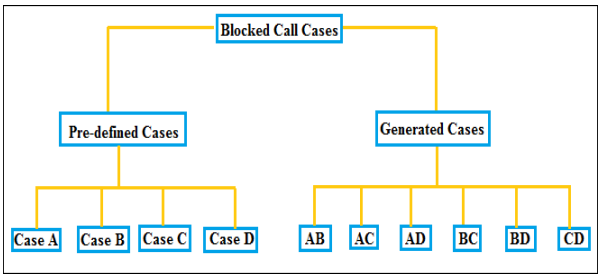

Figure 5. Pre-defined and generated cases

4.2.1 Rule-Based Algorithm for Generating Cases

As shown in Figure 2, if the case matching process is not successful (case not matched), the AI system will generate or calculate a solution which is controlled by a simple set of rules that is developed as part of the CBR model. The set of rules that matches input variables are given below:

Table 5: Set of rules for matching variables.

T	x	T	=	T
T	x	F	=	F
F	x	T	=	F
F	x	F	=	F

Figure 6 shows the algorithm that implements the set of rules in table 5. The algorithm starts from the calculation point of the CBR case matching process in Figure 2

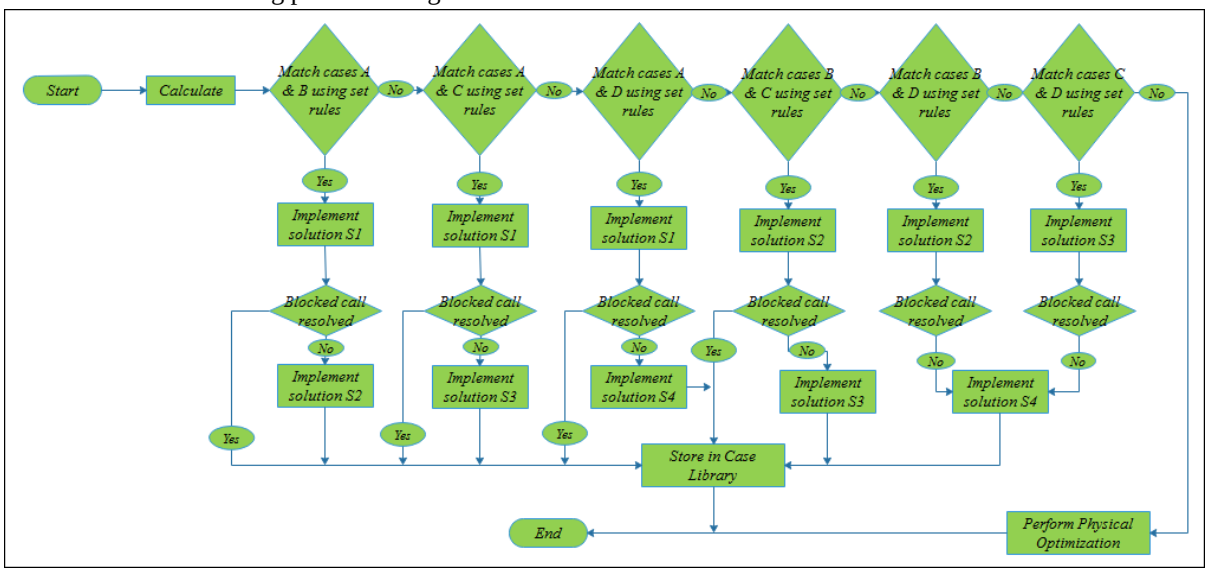

Fig. 6. Rule-Based Algorithm

Table 6: shows the output of the network upgrade.

Generated Cases	OSS KPIs				*Upgrade Results*		
	GSM MS TxPwr >=20	GSM FER <=5%	Rx Signal Strength Ratio >0	GSM C/I >=13	Blocked Calls from Cases	Total Blocked Call	% Blocked Call from Cases
AB	F	F	F	T	1	8	0.125
AC	F	F	T	T	1	8	0.125
AD	F	F	F	F	1	8	0.125
BC	F	T	F	T	1	8	0.125
BD	F	T	F	F	1	8	0.125
CD	F	T	F	F	0	8	0.000

The AI system reduced the number of blocked calls from 18 to 3. Table 7 and Figure 7: compare the network performance from the characterization, defined network cases and the learned or generated cases by the AI system.

Table 7: Compares the Network Performance

SYSTEM STATES	Call Attempts	Call Set-ups	Blocked Calls	CSSR	BCR
Network Characterization (NC)	305	287	18	94.1	5.9
AI Network Cases Performance (AI NCP)	305	297	8	97.38	2.62
AI Generated Network Cases Performance (AI GNCP)	305	303	3	99.02	0.98

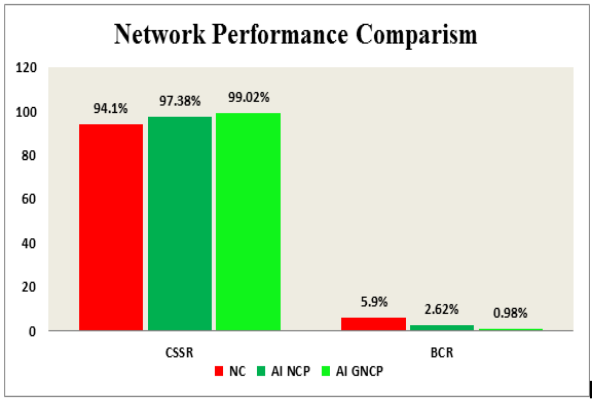

Fig. 7. Network Performance

5. Conclusion

In a cellular network, GSM is the oldest technology in Nigeria. Inability to access the GSM network will be unacceptable hence, the motivation for this paper. The research highlighted the importance of using CBR to manage and improve the efficiency of an Artificial Intelligent system that reduces the blocked calls in a GSM network. The outcome also showed that the system could generate additional cases using the set rules for matching variables and resolves them successfully. The result shows a gradual and steady improvement on the network accessibility performance from the characterization (94.1%) to the defined network cases (97.38%) and to the learned or generated cases (99.02%) by the AI system which meets the telecommunications accessibility threshold. With the network accessibility improved by 5.23%, the network will accommodate more subscribers. Network retainability can be considered in the future study.

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