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Original Research Article

An Intelligent Agent-Based Approach for Call Block Reduction in Wideband Code Division Multiple Access Network

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Abstract

In this article, an Intelligent Decision System (IDS) is proposed for reducing block call rate in Wideband Code Division Multiple Access (WCDMA). Firstly, the network environment was characterized and parameters that impact on network accessibility studied. From the characterization result, the software related causes of block calls were studied and grouped into cases. We further developed an IDS model that links the various network states and generate an output under a transfer function. The IDS uses cases from previous experience to predict and resolve the network snags that led to block calls. Also, the system performance was validated by comparing the data obtained from real life network with that of simulation and the result shows a great improvement on the system. The novel aspect of our research are the development of a model linking all the network parameters and developing an intelligent decision system that reduces block call in a WCDMA network.
Keywords: Intelligent Decision System, Case-Based Reasoning, Network accessibility, WCDMA, blocked call, transfer function.

INTRODUCTION

Wideband Code Division Multiple Access is the bedrock for the Third Generation mobile network. It is an accepted wireless mobile access platform with a very robust system capacity; because of it is underlying principles of allowing multiple users to occupy the same radio channel at the same time. The multiple users use the same allocation, but they are identified by different unique codes. This innovative mobile access platform has spurred a high-speed service, high bit data rate, fast power control, spectrum efficiency, enhanced system flexibility and lower cost [1]. However, with all these attributes, end users of the services provided by the network operators using this technology still find it difficult to access the network. This is more common in the third world country that are not moving with the trend of the recent network evolution, as majority of the populace is still operating within second-generation network. Even with the network in place, maintaining a good quality of service is a major challenge as several times, even within the network coverage area, the mobile users do not have access to the network as calls are blocked when initiated or sometimes terminated while a call is ongoing. These events lead to reduced network accessibility (block calls) which degrades the Quality of Service (QoS). Quality of Service (QoS) is the overall outcome of the service performance, measured in terms of speed, accuracy, accessibility, and reliability [2]. The massive increase in telecommunication equipment and technological evolvement have tremendously affected network accessibility and performance. These have posed difficult challenges for radio resource management [3], and it may worsen if not addressed. It was predicted that by the year 2020, that traffic from wireless and cellular devices will account for above 70 percent of the total Internet Protocol (IP) traffic [4]. Cellular network quality is affected by several factors [5], as the quality of service is judged from the subscribers' perspective. To enhance network accessibility rate, a Non-Blocking Orthogonal Variable Spreading Factor Code was proposed to improve call blocking probability in UMTS [6]. The implementation of this code increased the system capacity by allowing more new calls into the channel. Kumar [7] proposed reducing call blocking probability in 3g using Time Multiplexing NOVSF code aimed at reallocating code cost and allowing more new calls. Also, call blocking can be reduced using Auxiliary Station in search mode [8], Combined Guard Channel Prioritization Scheme [9, 10], and Handover Prioritization Scheme [11]. Call Admission Control Scheme (CAC) also plays a very vital role in network accessibility because of its role in accepting new calls and reducing interference [12, 13]. Therefore, CAC design has to be in such a way as to ensure that quality of service is guaranteed, by prioritizing new initiated calls and handoff of already established calls to address network accessibility problem [14]. Proposed a fuzzy based admission control scheme to overcome measurement and traffic error which it was viewed as part of the causes of poor network accessibility, but the measurement and traffic errors are not the only causes of blocked calls. Eli-Chukwu [15] proposed enhancing network accessibility in GSM network using an intelligent agent-based approach, where causes of poor network were considered as cases and solution were proffered and the intelligent system learned the proffered solution using case-based reasoning, the result of their work showed that about 5.23% of software related network accessibility parameters that affected the network were resolved.

This article proposes enhancing network accessibility using an intelligent decision system. Firstly, the radio environment was characterized to understand how network parameters affect the radio environment in a real-life setting. The rest of the articles is organized as follows: the method section gives a brief description of the approach used in performing the study, the system design section concentrates on the development of the model and the case matching process. The simulation section describes how the simulation was done and then the result is provided and finally the conclusion section.

METHOD

The aim of this work is to enhance network accessibility in Wide Code Division Multiple Access from an agent-based perspective. To achieve this, the following procedures were adopted: data collection, system design, and system simulation. To collect data for the research, drive test was performed across the metropolises of Enugu State, Nigeria to test the live network using the Testing Equipment for Mobile Systems (TEMS) Discovery. The drive test was performed once weekly for 12 weeks (June 2-August 18, 2018). The User Equipment (UE) was locked on WCDMA, and voice calls were made for 120secs (short calls) in each call session during the cluster drive test. The short calls were to reveal the blocked call rate of the network. The parameters that led to blocked calls were extracted from TEMS discovery logfiles and studied for the purpose of developing a model that will link all the network parameters that led to call block, hence optimizing the system.

System Design

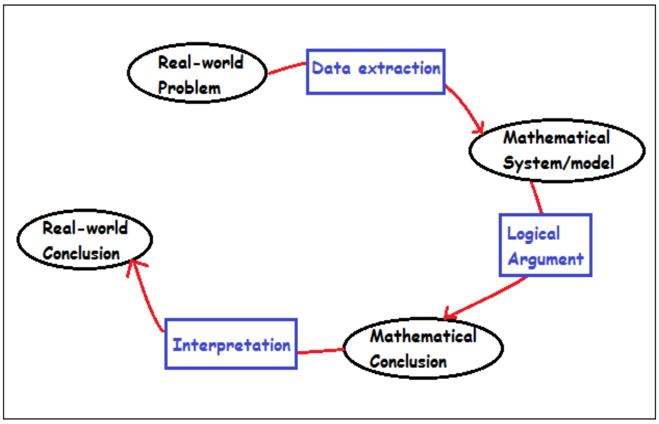


Fig-1: Model development Sequence

This model was developed from real world problem from the behaviour of radio parameters as tabulated in Table-1. Using mathematical tools, the real-world problem is translated into a mathematical problem, which mimics the real-world problem. A solution to the mathematical problem is obtained, which is interpreted in the language of real-world problem to make predictions about the real world. The system shown in Figure-2 has n-inputs $\left\{v_1^{(t)}, \dots v_n^{(t)}\right\}$ and n-output variables $\left\{y_1^{(t)}, \dots y_n^{(t)}\right\}$. If the system is state-defined, knowledge of its state variables $\left\{u_1^{(t)}, \dots u_n^{(t)}\right\}$ at some initial time *t*, and the inputs $\left\{v_1^{(t)}, \dots v_n^{(t)}\right\}$ for *t* ≥ 0 is sufficient to determine all future behaviour of the system. The state variables are defined internally by the system which completely characterize the system state at any time *t*, and from which any output variables $y_i^{(t)}$ may be computed.

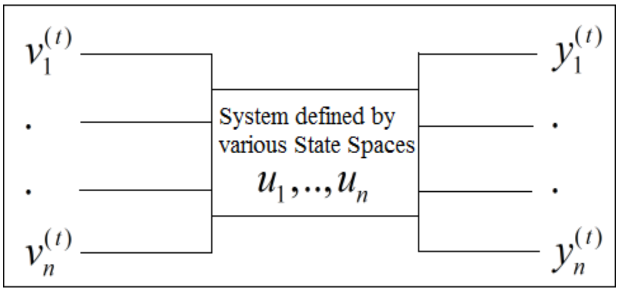


Fig-2: System Model

The State Equations

The state equations are grouped into the input and output equations respectively.

Input Equation

The time derivative of each state variable is expressed in terms of the state variables $\{u_1^{(t)}, \dots u_n^{(t)}\}$ and the system inputs $\{v_1^{(t)}, \dots v_n^{(t)}\}$. The state equations are:

$$\frac{du_1}{dt} = f_1(u, v, t)$$

$$\frac{du_n}{dt} = f_n(u, v, t) \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

For a Linear Time, Invariant (LTI) system of order n, and with n-inputs, the function becomes a set of n-coupled first-order linear differential equations with constant coefficients.

$$\frac{du_1}{dt} = \alpha_{11}u_1 + .. + \alpha_{1n}u_n + \beta_{11}v_1 + .. + \beta_{1n}v_n$$

$$\frac{du_n}{dt} = \alpha_{n1}u_1 + .. + \alpha_{nn}u_n + \beta_{n1}v_1 + .. + \beta_{nn}v_n \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where the coefficients α_{ij} and β_{ij} are constants that describe the system.

$$\frac{du}{dt} = \alpha u + \beta v \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

where the state vector $U_i's$ a column vector, the input vector $V_i's$ a column vector of length n, $\alpha_i's$ an n× n-square matrix of the constant coefficients α_{ij} and $\beta_i's$ an n× n matrix of the coefficients β_{ij} that weight the inputs.

Output Equation

$$y_1^{(t)} = \tau_{11}u_1 + .. + \tau_{1n}u_n + \pi_{11}v_1 + .. + \pi_{1n}v_n$$

$$y_n^{(t)} = \tau_{n1}u_1 + .. + \tau_{nn}u_n + \pi_{n1}v_1 + .. + \pi_{nn}v_n \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where the τ_i and π_i are constants.

It is also expressed in matrix form as:

$$\begin{matrix} y_1 \\ . \\ y_n \end{matrix} = \begin{bmatrix} \tau_{11} & \cdots & \tau_{1n} \\ \vdots & \ddots & \vdots \\ \tau_{n1} & \cdots & \tau_{nn} \end{bmatrix} \begin{matrix} u_1 \\ . \\ u_n \end{matrix} + \begin{bmatrix} \pi_{11} & \cdots & \pi_{1n} \\ \vdots & \ddots & \vdots \\ \pi_{n1} & \cdots & \pi_{nn} \end{bmatrix} \begin{matrix} v_1 \\ . \\ v_n \end{matrix}$$

The output equations y:

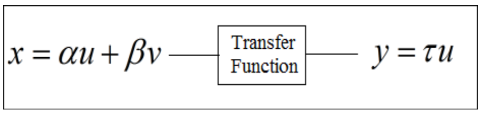
$$y = \tau u + \pi v \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where **y** is a column vector of the output variables $y_i^{(t)}$, τ_i's an n×n matrix of the constant coefficients τ_{ij} that weight the state variables, and π_i's an n×n matrix of the constant coefficients π_i that weight the system inputs.

$$\boldsymbol{y} = \boldsymbol{\tau u} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

The task of modelling the system is to derive the elements of the matrices, and to write the system model in the form

$$x = \alpha u + \beta v$$
$$\boldsymbol{y} = \boldsymbol{\tau u}$$



From the cluster drive test analysis, the causes of blocked calls were recorded and its recommended solution proffered for each network scenarios captured in Table-1(a). The model parameters for the simulation were also tabulated in Table-1(b). These tabulated causes and solutions proffered were used to model an expert system to monitor the signal behaviors and intelligently avoided blocked calls.

Table-1(a): Causes and Solutions to Various WCDMA Blocked Call Cases

Cases	Causes	Solutions
Case 1	Unequal load distribution	Reassign traffic to second carrier
Case 2	No suitable cell	Set low values for QqualMin, QrxlevMin and UE Max Transmission Pwr
Case 3	Missing neighbour configuration	Give a 2-way neighbour definition between AS1 and best DN
Case 4	Signal attenuation	Perform cell reselection to camp on cell with better Rx and Tx power
Case 5	UL Radio Sync failure	Adjust cell individual offset value to a negative value
Case 6	DL Radio Sync failure	Increase Cbackoff value or increase the Initial DL SIR target

Table-1(b): Model Parameters

Network Cases	RSCP ≥ -95 (V1)	PREACH PREAMBLE COUNT ≥ 15 (V2)	Missing Neighbour ≥ 95% (V3)	RRC Con. SR ≥ 98% (V4)	No Call Setup ≥ 2% (V5)	Pathloss ≥ 80 (V6)	Network State Space
Case 1	F	F	T	T	T	T	U1
Case 2	T	F	F	F	F	F	U2
Case 3	T	T	F	T	T	T	U3
Case 4	T	T	T	T	T	F	U4
Case 5	T	T	T	T	F	T	U5
Case 6	T	T	T	F	T	T	U6

The α_{ij}-matrix are parameters that describes the state spaces shown in Table-1(b). There are expressed as proportion.

T = True Conditions

F = Failed Conditions

$$P_{True\ Cond} = \frac{N_{True\ Cond}}{N_{Ntwk\ Entry}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (7)$$

$$P_{Failed\ Cond} = 1 - P_{True\ Cond} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (8)$$

Where,

$P_{True\ Cond}$ = Proportion of true condition

$P_{Failed\ Cond}$ = Proportion of failed condition

$N_{True\ Cond}$ = Number of true conditions

$N_{Ntwk\ Entry}$ = Number of Network Entry

Case Matching Process Flow

Network parameters are collected as shown in Table1 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 UE encounters more, blocked calls that are undefined to the system, the CBR model retrieves a base-match solved 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. 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 volume of the case library and quick response time.

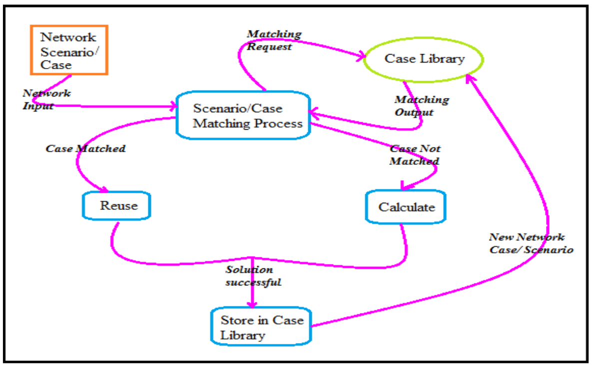


Fig-3: IDS case matching process [15]

Simulation Model

The process of monitoring the network accessibility parameters is done periodically at different time interval $\{t_1, t_2, t_3, t_4, \ldots t_n\}$ and sent to the system decision box where the Artificial Intelligent Case-Based Reasoning (AI/CBR) agent is embedded. The parameters combine to get a system state and their respective solutions at any given time as shown in Table-1(a, and b). During cellular network operations, before a blocked call is reported by the system, there must be at least two (2) consecutive system states (U_1-U_n) that depict a blocked call before the event itself, as shown in Table-1(b). Such that at any given time $\{t_\alpha\}$, if a parameter in the reported state of the network falls below the acceptable threshold, the intelligent decision system compares the system state with pre-defined network states as shown in figure 4. The IDS quickly finds and retrieves the best solution for the system state from pre-defined solutions in the case library before time $\{t_{\alpha+1}$ or $t_{\alpha+2}\}$. If the system state reported by the User Equipment has not been pre-defined to the system, a rule-based algorithm is used to compute a matching state and solution for the system by combining pre-defined cases. Solutions that resolved computed rule-based algorithm cases are stored in the case library with their corresponding cases. If there's no matching case after using the rule-based algorithm, the system recommends a physical optimization to the affected cell.

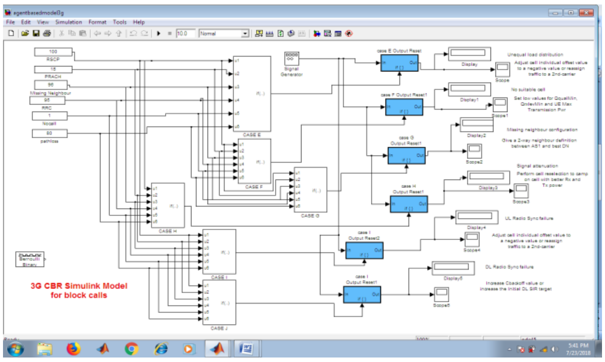


Fig-4: 3G Simulink Model for Block Calls

RESULTS AND ANALYSIS

This section presents the empirical and simulation results and compare the empirical result with that of the simulation to obtain the percentage improvement of the system. In the empirical result as presented in table 2, data was collected through a cluster drive test as explained in section II (Method). The data from the real-life measurement were extracted and was used for modelling the system design in section III. In the system design, the $\{v_1, \dots, v_n\}$ depicts the network parameters that defines a 3g network environment that lead to block calls as presented in table 1(b). For example, to establish a call successfully without call blockage, the Received Signal Code Power (RSCP), PREACH PREAMBLE Count, missing neighbour, RRC Con. SR, call setup and path-loss must be within the acceptable threshold. If not, call accessibility will not be successful. So, we defined these parameters $\{v_1, \dots, v_n\}$ as the input variables and $\{U_1, \dots, U_n\}$as the system state. The system state shows the states of the input variables when block call occurred or when call is established. For example, if the RSCP is at FALSE (F) state which means it is below the acceptable threshold of ≥-100, and other variables are at the TRUE (T) state (within the acceptable threshold), block call will occur at that particular time (t) as detailed in table 1(b). It is at this stage, that the causes of software related causes of blocked call that was recorded during the experiment was noted and solutions were matched for different cases presented during simulation (table 1(b). Table 2 shows the result obtained from the cluster drive test. It shows the total call attempt during each drive and the number of block call that occurred. From the computed result, only week 5 and 9 was within the International Telecommunication Union (ITU-T) block call rate benchmark of ≤2% (Rec. ITU-T E 811 (03/2017 P.9) [16]. The rest of the call events were above the set benchmark.

Table-2: Network Characterization result

Block call events	Call Attempt	Block Calls	Block Call Rate (%)
Week 1	292	8	2.74
Week 2	280	7	2.44
Week 3	299	18	7.17
Week 4	240	16	6.45
Week 5	224	1	0.45
Week 6	272	12	3.22
Week 7	283	14	4.93
Week 8	256	7	2.73
Week 9	216	4	1.85
Week 10	211	21	9.95

Table-3 shows the simulation result. During simulation, different network cases were used in the system modelling. Each case has its solution embedded in the case library of the IDS which is trained over time. If a block call is anticipated due to a failing parameter, the case matching process of the IDS compares the attributes of the failing parameter with the attributes of the embedded solution in the case library, and if it matches, it quickly takes an intelligent decision that will stop the call from blocking. The new resolved solution will be stored in the case library for reuse. As the user equipment encounters more problems that are undefined to the system, the IDS retrieves a matching case in the case library using the rule based algorithm embedded in the system to predict the solution for the network snag. The call log after simulation shows a very high system improvement as the same volume of generated calls made; it was only in the 4th trial that the block rate was above the set benchmark. The rest of the trials were within the benchmark.

Table-3: Simulation Results

Generated Calls	Call Attempt	Block Calls	Block Call Rate (%)
Trial 1	292	3	1.02%
Trail 2	280	2	0.71
Trial 3	299	6	2.01
Trail 4	240	5	2.08
Trail 5	224	1	0.44
Trial 6	272	5	1.84
Trail 7	283	5	1.77
Trial 8	256	4	1.56
Trial 9	216	2	0.93
Trail 10	211	1	0.44

In Table-4 and Figure-5 we compare the Radio environment performance of the measured network with that of the simulated result. From the network value, the RSCP and EcNo/ average simulation performance was 77.982% and 64.462% respectively which has more than 80% of the result fall below the 90% good radio environment threshold. These were majorly affected by various forms of interference due to pilot pollution, high path-loss, huge traffic, measurement errors and poor scrambling code planning. The software related causes of the poor Radio environment was reduced during simulation which led to the improvement in the performance as the RSCP and the EcNo/ of the simulated result was above the 90% of the acceptable radio environment performance as shown in Table-4 and Figure-5.

Table-4: Radio Environment Performance

Generated Calls/Events	Pre-Simulation Result		Simulation Result	
	RSCP (%)≥-95dBm	EcNo /(%) ≥11	RSCP (%)≥-95dBm	EcNo /(%) ≥11
Trial 1	82.98	62.06	95.43	86.89
Trail 2	81.3	62.4	93.9	87.36
Trial 3	79.7	65.29	91.66	89.4
Trail 4	82	67.79	83.3	69.9
Trail 5	79.64	67.42	91.59	84.39
Trial 6	57.02	52.56	95.57	83.58
Trail 7	82.59	67.5	94.98	84.5
Trial 8	77.49	67.38	89.11	82.34
Trial 9	75.02	66.43	96.28	83
Trail 10	82.08	65.79	94.39	89.11

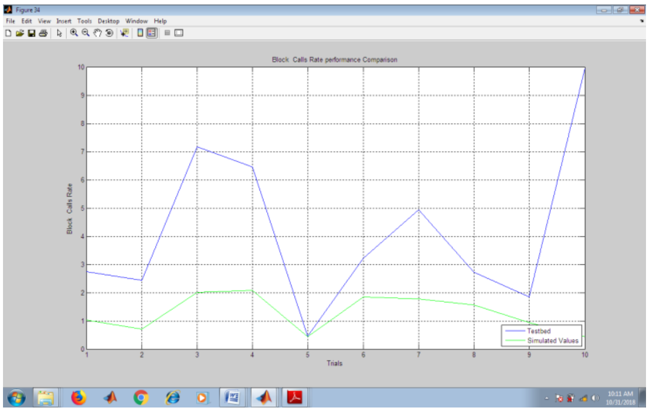


Fig-5: Block Call Rate Performance Comparison

CONCLUSION

The WCDMA radio environment has been characterized and Intelligent Decision System developed. During network characterization, the causes of software related block calls were identified. We observed that for a call to be blocked whether during initiation or handoff, the network parameters must be at a particular system space state. These system states were studied and the cause of network failure in each state filtered. From the study, an intelligent decision system that learns using (CBR) is modelled to improve WCDMA network accessibility. Implementing the proposed system will reduce software related causes of block calls significantly and improve the WCDMA QoS which is the fulcrum of customer retention. This research is very important more especially in the underdeveloped countries where there is connectivity gap. Majority of the rural dwellers are not covered and the small covered areas are still camped under 2G and 3G network saddled with its limitations. With the implementation of the IDS in the network management, quality of service will be enhanced tremendously while waiting for the deployment of the future network in the area served with WCDMA networks. Future research may embrace study on enhancing network reliability and retainability in 3G and LTE network.

Availability of data and materials: Not applicable.

Competing interests

The authors declare that they have no competing interests.

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