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Development of an Adaptive Hybrid Algorithm for Congestion Control and Bandwidth Utilization in a Mobile Network

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ABSTRACT: This research work developed an adaptive algorithm that hybridizes call admission control, bandwidth degradation and load balancing congestion control techniques to improve bandwidth utilization and minimize congestion in mobile network. The developed hybrid algorithm is implemented using NetBeans IDE 6.9.1 platform to obtain performance metrics of blocking probability of new calls and dropping probability of handover calls. The simulation results obtained from the model recorded the New Call Blocking Probability (NCBP) of 0.003 and Handover Call Droppping Probability (HCDP) of 0.001. The developed model's NCBP was better than the ITU-T benchmark standard of 0.01 and matched that of the HCDP of 0.001. Also, real life results from measured data of Etisalat mobile network and simulated data results of the developed model were validated using statistical Welch's T-Test. The probability levels (p-values) of 0.034 for NCBP and 0.001 for HCDP obtained from T-Test, which are less than 0.05 imply that NCBP and HCDP reject the null hypothesis. Hence, there is significant difference between the developed hybrid model and existing model from Etisalat mobile network at 95% confidence level, which also indicates that the developed model has better performance.

KEYWORDS: Adaptive Algorithm; Call Admission Control; Bandwidth degradation; Load Balancing; Bandwidth Optimization; Blocking Probability; Dropping Probability

I. INTRODUCTION

Congestion occurs when the demand for resources exceeds the available capacity, resulting in queuing in the network [1]. In GSM networks, congestion is caused by inadequate radio channels and infrastructure, traffic build up during peak periods and at hot spots on the network, inadequate dimensioning of the network, particularly the switching system, End-to-End System connections, as well as marketing strategies and pricing schemes [1], [2], [3], [4]. These factors overload the channel with packets (calls) thereby leading to a high number of loss calls due to block and drop calls. In order to address this problem, control mechanisms have been developed to reduce congestion related loss calls by minimizing the spread and duration of congestion [5]. In order to address congestion issue in a GSM network, most researchers have proposed and worked on several congestion control schemes, some of which are reviewed in this work.

II. RELATED WORKS

[6] worked on a scheme that combined admission control with bandwidth adaptation to enhance the QoS provisioning. The technique blocked a new call if the number of ongoing calls was greater than or equal to a stated threshold value or there was no bandwidth available in the given cell to accommodate a new call. However, bandwidth was not adaptive to outgoing calls and this made the adjustment to these calls or at the completion of an ongoing call impossible. Also, [7] combined bandwidth reallocation policy with adaptive call control. The significant difference between their work and that of [6] was that the bandwidths of all outgoing calls were adjusted on arrival of any incoming call or at the completion of an ongoing call. The work [7] was only focused on adaptive call control technique. [8] improved the work of [7] by developing a combined scheme that used load balancing strategy to aid an efficient adaptive call admission control scheme. The combined algorithm was implemented on Java platform using real life Call Data Record (CDR). The results obtained by [8] showed better performance when compared with CAC scheme used. The limitation

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of [8]'s work was that it lacked the analytical model to back the design of the algorithm used. These reviewed works considered the congestion control mechanisms based on call admission control, bandwidth degradation, load balancing or any combination of the two techniques. They had high values of NCBP and HCDP congestion parameters and were unable to achieve the NCBP and HCDP minimum values of 0.01 and 0.001 recommended by ITU-T. However, this proposed hybrid model considers all the three control performance metrics to reduce loss calls and improve the quality of service of a GSM network.

III. KEY PERFORMANCE INDICATORS (KPIs)

The most valuable KPIs in this paper which serve as tools in achieving the implementation of the hybrid algorithm measure for congestion control in a GSM network are itemized hereunder.

3.1 Drop-Call Probability

This can be defined as the probability that an accepted call is first terminated before it completes the service. Drop-call probability is given by [9] as:

$$P(Y= n)= \frac{(V_d t)^n}{n!} e^{V_d t}, n \geq 0 \quad (1)$$

where,
t = call duration
Y = random variable that counts the number of drops
n = *the* confirmed calls dropped
V_d= drop-call rate and can be expressed as [10]:

$$V_d = \frac{NDC}{NCA} \quad (2)$$

where,
NDC = Number of Dropped Calls
NCA = Number of Call Attempts
This is a Poisson probability function with a discrete variable which accounts for the number of dropped calls.

3.2 New Call Blocking Probability (NCBP)

The NCBP is the probability that a new call will be blocked or rejected [11], [12].This probability can be expressed mathematically as:

$$NCBP = \frac{NBC}{TNCA} \times 100\% \quad (3)$$

where,
NBC = Number of blocked Calls
$TNCA$= Total Number of Call Attempts

3.3 Handover Call Dropping Probability (HCDP)

The HCDP is the probability that a handover call is dropped or rejected. It measures service continuity during handover [11], [12].The HCDP can be expressed as:

$$HCDP = \frac{NDC}{TNHCA} \times 100\% \quad (4)$$

where,
NDC = Number of Dropped Calls
$TNHC$ =Total Number of Handover Calls attempts

IV. MODEL DEVELOPMENT METHODOLOGY

The hybrid scheme is the joint scheme which consists of call admission, bandwidth degradation, and load balancing control mechanisms jointly designed to improve bandwidth utilization and quality of service of the network. The designed methodology was carried out using the combined algorithms in Figure 1 and activities of the flowchart of the hybrid model represented in Figure 2. Simulation was used to obtain the results and the results of the developed model were validated against raw data from Etisalat mobile network, Abuja using Welch's T-Test.

The developed hybrid algorithm was implemented using Java (NetBeans IDE) programming environment. A Compaq Laptop Computer System (Presario CQ56) with system properties (processor of AMD V160 2.40GHz, RAM

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of 2.00GB, of 32bits, window 7) was used. The simulation of the developed hybrid model was carried out for an average of twenty four hours.

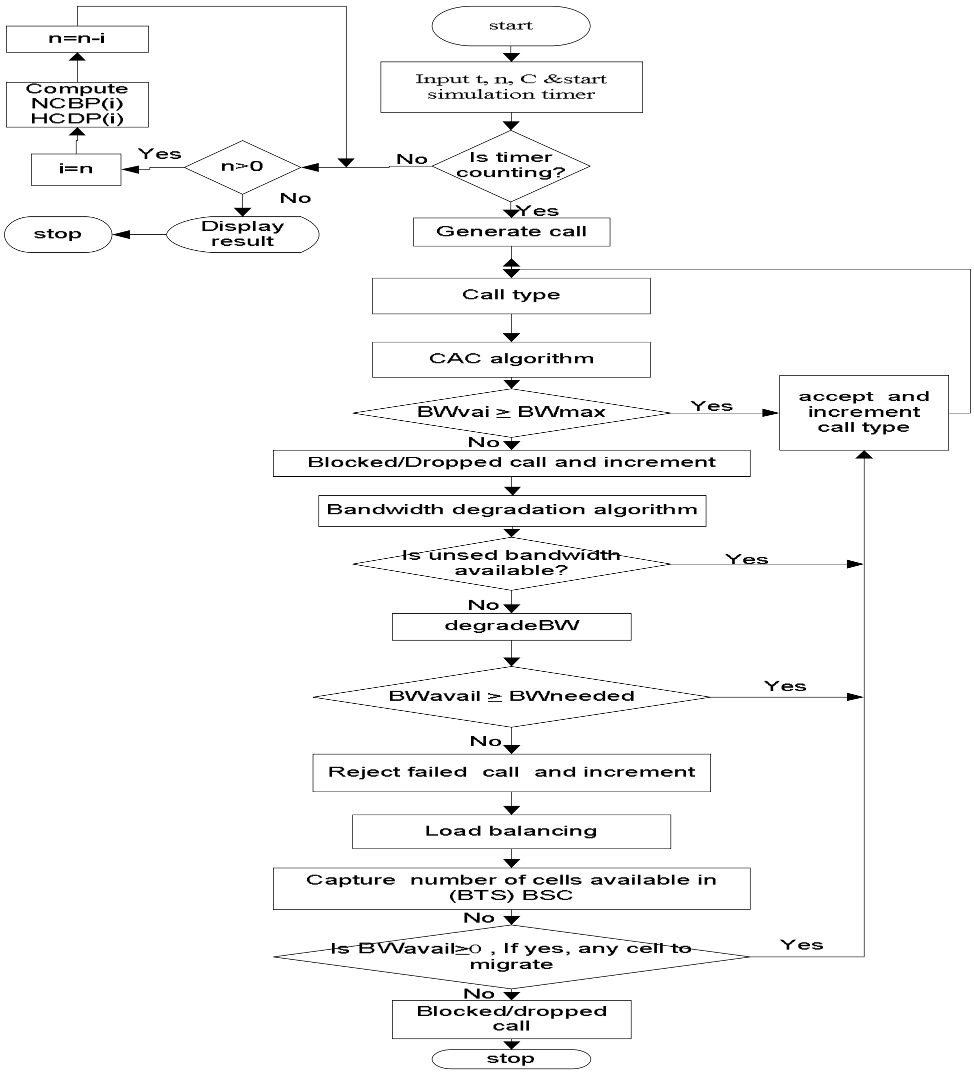

Figure 2: Flow Chart of Developed Hybrid Scheme [12]

V. RESULTS AND DISCUSSIONS

Here, discussions are centered on simulation and raw data results obtained, which were evaluated to establish the authenticity and improvement made by the developed model.

5.1 Simulation Results

The simulation results obtained from the developed algorithm on performance metrics of NCBP and HCDP were computed as presented in Table 1.

5.2 Results of Measured Data

The call traffic data was obtained from Etisalat mobile network Abuja, Nigeria. This data covers a period of two months from May to June, 2014. The raw data was obtained from seven traffic GSM cells with high number of call congestion selected among three BTSs in two BSCs coverage area. These cells were KAD0707, KAD2248, KAD2332,

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KAD2433, KAD2466_2, KAD2466_1 and KAD2466_3, which were represented as Cells 1, 2, 3, 4, 5, 6 and 7 to correspond with the simulated joint scheme cells**.** The average call parameters of measured data were computed for each traffic cell to obtain the NCBP and HCDP values as shown in Table 2. These results were used to test the validity of developed model by using statistical Welch's T-Test and the standard ITU benchmark.

Table 1: Simulation Results

Cell Number	Average number of new call attempts	Average number of blocked calls	Average NCBP Value	Average number of handover attempts	Average number of dropped calls	Average HCDP Value
1	4316	11	0.002548	2927	2	0.0006828
2	3052	18	0.005877	2608	3	0.0011503
3	3484	6	0.001722	2296	4	0.0017422
4	4656	23	0.004940	3276	9	0.0027473
5	3208	8	0.002494	2212	2	0.0009042
6	2981	12	0.004025	2875	0	0.0000000
7	4288	4	0.000932	2432	3	0.0012335

Table 2: Measured Data Results

Cell Number	Average number of new call attempts	Average number of blocked calls	Average NCBP Value	Average number of handover attempts	Average number of dropped calls	Average HCDP Value
1	20881	259	0.0124036	10282	73	0.0070998
2	27947	216	0.0077289	4174	28	0.0067082
3	968	48	0.0495868	6846	57	0.0083260
4	27697	107	0.0038632	6373	49	0.0076887
5	6303	213	0.0337934	6686	18	0.0026922
6	15859	68	0.0042878	9829	73	0.0074270
7	12985	215	0.0204082	7173	34	0.0047399

5.3 Validation of Results

Validation was carried out by comparing the developed model results with Nigerian Communication Commission (NCC) and ITU-T standards, as well as comparing them with measured data obtained from Etisalat mobile network using Welch's t-test.

5.4 Model Validation Using NCC and ITU-T Standards

The NCBP and HCDP results of the Developed Hybrid Scheme (DHS) model which were 0.003and 0.001were compared with that of the NCC and ITU benchmarks for GSM network quality of service as illustrated in Table 3.

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Table 3: Developed Model versus NCC and ITU-T

S/N	KPI	DHS	NCC	ITU
1	NCBP	0.003220	<0.02	<0.01%
2	HCDP	0.001209	<0.02	<0.001%

From the results in Table 3, the NCBP value of 0.003 and HCDP of 0.001 for the developed hybrid model met the NCC benchmark of less than 0.02. Also, the developed model results met ITU-T benchmark of 0.01 for NCBP and 0.001 for HCDP. Hence, the developed hybrid scheme algorithm for call admission, bandwidth degradation and load balancing control mechanisms showed better performance in terms of both blocking and dropping probabilities.

5.5 Model Validation using Welch's T-Test

The results of the Measured Data (MD) and Simulated Data (SD) performance metrics of NCBP and HCDP were inserted and run using IBM SPSS statistics 20 software tools. The t-test results of the NCBP and HCDP metrics obtained were extracted as shown in Table 4 and Table 5, respectively.

5.5.1 NCBP T-Test Results

The results of the independent-sample t-test for NCBP between MD and SD are shown in Table 4.

Table 4: Results of T-Test on NCBP

NCBP	N	Mean	SD	t-value	P
MD	7	0.01887	0.01719	2.396	0.034
SD	7	0.00322	0.00178		

From the result of Table 4, t-value (k=12) = 2.396, P = 0.034.Since P is less than α (0.05), therefore, the null hypothesis is rejected, which means that there is significant difference between the developed model and existing model [13].This indicates that the developed hybrid model is of better performance when compared with the existing model used by Etisalat mobile network.

5.5.2 HCDP T-Test Results

Similarly, the results of the independent-sample t-test for HCDP between MD and SD are shown in Table 5.

Table 5: Results of T-Test on HCDP

HCDP	N	Mean	SD	t-value	*P*
MD	7	0.00638	0.00198	6.338	0.001
SR	7	0.00121	0.00865		

From the result of Table 5, t-value (k=12) = 6.338, *P* = 0.001. Since *P* is less than α (0.05), therefore, the null hypothesis is rejected, which means there is significant difference between the developed model and existing model [13]. This shows that hybrid model performs better when compared with existing model used by Etisalat mobile network.

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VI. CONCLUSION AND FURTHER WORK

The algorithm was developed and implemented on a NetBeans IDE 6.9.1. Based on the simulation results of 0.003 for NCBP and 0.001 for HCDP, the developed hybrid model achieved better performance and good quality of service for a GSM mobile network. This work can be improved by using a heterogeneous network to ascertain the metrics values of NCBP and HCDP.

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