RESEARCH ARTICLE OPEN ACCESS

Evaluation of CSSR with Direct TCH Assignment in Cellular Networks

Paula Aninyie* and K. Diawuo**
*Department of Computer Science, University for Development Studies, Navrongo, Ghana
**Department of Computer Engineering, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

Abstract
Global System for Mobile communication (GSM) operators make use of Key Performance Indicators (KPIs) to appreciate the network performance and evaluate the Quality of Service (QoS) regarding end user perceived quality. KPIs are therefore becoming increasingly important in the context of network rollouts as well as within mature network optimization cycles. The performance of the mobile network is measured based on several counters describing the most important events over a measurement period. The KPIs are derived with the help of these counters using different formulations. Call Setup Success Rate (CSSR) is one of the most important KPIs used by all mobile operators. In Ouagadougou, Burkina-Faso, most of the active workers and remote area farmers rely largely on mobile communication services; the GPRS as data services remain highly competitive with GSM voice services.

This paper presents a comparative evaluation of theoretically estimated CSSR to measured CSSR data on a real network with regard to GPRS services. The measured data was obtained from the Nokia Siemens Network (NSN) statistical tool. The results obtained showed significant improvements in areas where sharp drops in CSSR values were recorded for the measured CSSR. Significantly high R square values of close to 1 representing a high predictive ability from the regression analysis of the estimated CSSR were also recorded. It was concluded that the implementation of the CSSR formulation be extended to CSSR measurements to ensure increased subscriber satisfaction.

Keywords – Call Setup Success Rate, GPRS, GSM, Key Performance Indicators, Subscriber satisfaction.

I. INTRODUCTION

Mobile telephony has become one of the fastest growing and most demanding telecommunications applications. It represents a continuously increasing percentage of all new telephone subscriptions around the world. In developing countries such as Ghana, and Burkina-Faso; it has assumed a dominant position in the telecommunications market and become the main driver of economic growth [1].

New services for mobile phones like email, web browsing, audio and video streaming demands a lot from the underlying network. If the network does not deliver what these services demand, the performance and the user satisfaction will be unsatisfactory. In light of meeting user's satisfaction, many Key Performance Indicators (KPI) for different services as well as on different network layers are defined. Identifying these will make it easier to optimize the network and its applications. Therefore, it is useful for companies who specialize in cellular network optimization or even service providers to have the ability to measure the performance of the network for the purpose of optimizing the network usage and enhancing customer satisfaction [2].

This paper investigates the performance optimization of a GPRS system using Call Setup Success Rate (CSSR) with data obtained from a network statistical tool.

The rest of the paper is organized as follows: in section 2 related works are presented; the model used in evaluating the CSSR is presented in section 3;

sections 4, 5 and 6 are devoted to the methodology, results and discussion, and conclusion respectively.

II. RELATED WORK

Measurements and trials were carried out with performance evaluations of GSM and GPRS as presented in [3]. Their study revealed that limitations existed in the GSM system with regards to accommodating extreme offered traffic. Also, the GSM system could not predict the rapidly increased traffic in many cases and it could definitely not adapt even by reconfiguring system parameters. In their opinion, GSM was not yet optimized and GPRS, on the other hand was still immature and several issues needed to be considered.

Orstad and Reizer [2], performed practical end-to-end performance tests in cellular networks using an end-to-end test agent, TWSE2E. Their objective was to identify what affects end user performance. Special attention was given to the high latency of the wireless links and the delay introduced with the radio access bearer establishment. They concluded that the 3G cellular network Universal Mobile Telecommunications System (UMTS) outperformed Enhanced Data rates for GPRS Evolution (EDGE) with respect to commonly used services like HTTP/WEB and File Transfer Protocol (FTP). It was also discovered that while Transmission Control Protocol (TCP) throughput was good when transferring large files over FTP, the latency of the wireless link made the HTTP performance bad compared to potential TCP throughput.

Adolfsson [4], by simulation identified possible problems when running TCP in a GPRS environment. Some of these problems he noted were mostly caused by the Temporary Block Flows (TBF) which are setup between the Mobile Station (MS) and the Base Station Controller (BSC) whenever data should be sent. The buffers and the slow link between mobile station and base station may cause other problems which are not fatal but may decrease TCP performance or make TCP less able to respond to loss of data. TCP features that are especially important for good performance were also identified. These features he noted mostly dealt with fast recovery from data loss and how to avoid data loss because of small buffers in the GPRS system. He further suggested some improvements to TCP performance such as responding to medium access requests from the MS quickly, using Explicit Congestion Notification (ECN) to avoid unnecessary drops from the Packet Control Unit (PCU) or Serving GPRS Support Node (SGSN) queue, implementing new standards for delayed TBF release which would improve connection setup and maybe improve the acknowledgement clustering situation.

In [5], an approximation method is used for evaluating the GPRS performance of single-slot service in the variable radio resource. Voice services are independent of GPRS and because GPRS is mainly designed to transmit intermittent and burst data, the service time of GPRS is rather smaller than that of voice services. As an approximation, the decomposition technique was used to analyze the GPRS performance. The essence of this technique was to use the voice services probability distribution to describe the interaction of voice services to GPRS. Thus, the GPRS performance in the dynamically variable resource was obtained by combining this distribution with the performance in a fixed resource. By the comparison of numerical results and simulated results, it was shown that the method could be used for evaluating GPRS performance when the average service time of circuit switched services is much longer than that of GPRS. The simulations showed that the interruption probability of GPRS calls due to releasing its channel to the demand of circuit switched services depended on the average message size more strongly than on the traffic load. The multi-slot services caused higher blocking probability and longer delay to the network than the single-slot service. These effects they observed could be reduced by implementing a GPRS resource allocation scheme with flexible multi-slot services. In this scheme, when the available network resource cannot provide a call with its required transmission rate, the network negotiates with the user (GPRS call or circuit switched service) and agrees on a transmission rate which the network can provide.

Meanwhile, Kollár [6] gave a definition of a real Call Setup Success Rate (CSSR) and the possibility of its implementation using current GSM technologies. It was concluded that more complex formulation which utilized the Immediate Assignment Success rate, Traffic Channel (TCH) Assignment Success Rate and Standalone Dedicated Control Channel (SDCCH) Success rate must be used for measuring CSSR. He further stated that this formulation was the best approach despite a higher effort on the processor part of the equipment where the CSSR is to be calculated. He noted that the formulation did not cover the case when the Direct TCH Assignment feature is enabled.

III. MODEL

A. *Call Setup Success Rate (CSSR)*

This measures successful TCH assignments of total number of TCH assignment attempts:

$$CSSR = (1 - SDCCH\_Congestion\_Rate) * TCH\_Assignment\_Success\_Rate \quad (1)$$

$$CSSR = \left(1 - \frac{SDCCH_{Overflows}}{SDCCH_{Call_{Attempts}}}\right) * \left(1 - TCH_{Congestion_{Rate}}\right) * (1 - TCH\_Assignment\_failureRate) * 100\% \quad (2)$$

Therefore, (1):

$$CSSR = (1 - SDCCH\_Congestion\_Rate) * TCH\_Assignment\_Success\_Rate$$

can also be written as;

$$CSSR = \frac{NumTCHAssig}{NumCH\_ReqSpeech} \quad (3)$$

where *NumTCHAssig* represents the number of successfully assigned TCH (number of *ASSIGNMENT Complete* messages) and *NumCH_ReqSpeech* represents the number of *CHANNEL REQUEST* messages but related only to request for a mobile originated (MO) or mobile terminated (MT) call. The other procedures, which can be completed with an SDCCH like SMS – MT, SMS – MO, location updating etc. are not counted because they do not represent the request for the speech call. The practical implementation of (3) is problematic because up to now it is not possible to distinguish between the requests for the speech call and other calls [6].

One possibility of solving this problem is using the simplified formula given in equation 4:

$$CSSR^* = \frac{NumTCHAssig}{NumCH\_Req} \quad (4)$$

where *NumCH_Req* represents total number of *CHANNEL REQUEST* messages and *NumTCHAssig* represents the number of TCH assignments (number of *ASSIGNMENT Complete* messages). Given that:

$$NumCH\_Req = NumCH\_ReqSpeech + NumCH\_ReqNonSpeech \quad (5)$$

where *NumCH_ReqNonSpeech* is the number of *CHANNEL REQUEST* messages not used for MT or MO speech call. Then (4) can be modified to give equation 6:

$$CSSR^* = \frac{NumTCHAssig}{NumCH\_ReqSpeec\ h + NumCH\_ReqNonSpeec\ h} \quad (6)$$

Under the condition that $\frac{NumCH\_ReqNonSpeec\ h}{NumCH\_ReqSpeec\ h} \leq 20\%$ (6) can be modified using binomial series as follows:

$$CSSR^* \approx \frac{NumTCHAssig}{NumCH\_ReqSpeec\ h}\left(1 - \frac{NumCH\_ReqNonSpeec\ h}{NumCH\_ReqSpeec\ h}\right) \quad (7)$$

The absolute error in measurement of Call Setup Success Rate using (4) is then evaluated as given in equation 8:

$$\Delta = CSSR^* - CSSR = \frac{NumTCHAssig}{NumCH\_ReqSpeec\ h}\left(1 - NumCH\_ReqNonSpeechNumCH\_ReqSpeech - NumTCHAssigNumCH\_Req == - CSSR * \frac{NumCH\_ReqNonSpeec\ h}{NumCH\_ReqSpeec\ h}\right. \quad (8)$$

In the case that *NumCH_ReqNonSpeech* is equal to zero, (4) provides exactly the call setup success rate. However, in practice the ratio; $\frac{NumCH\_ReqNonSpeec\ h}{NumCH\_ReqSpeec\ h}$ is within the ranges of tenths of percent which can lead to a big systematic error. Therefore, the mobile operators break away from the use of (4). In principle (4) can be used for the calculation of call setup success rate only in regions where the $\frac{NumCH\_ReqNonSpeec\ h}{NumCH\_ReqSpeec\ h} \leq 1\%$

The second possibility is to replace the denominator (*NumCH_ReqSpeech*) in (3) with *NumTCHAttempt* where *NumTCHAttempt* represents the number of *ASSIGNMENT REQUEST* messages. But in this case the result of the calculation will be TCH Assignment Success rate which is something different from Call Setup Success Rate [6]. Even some of the operators have separate KPIs for Call Setup Success Rate and TCH Assignment Success Rate.

The best approach promises the indirect calculation of *NumCH_ReqSpeech* according to the model given in Fig.1.

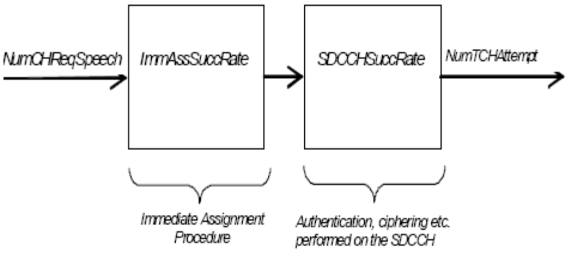

Figure1: Model for calculation of *NumCH_ReqSpeech* [6]

From Fig.1, *ImmAssSuccRate* represents Immediate Assignment Success Rate given by the relationship:

$$ImmAssSuccRate = \frac{NumEstInd}{NumCH\_Req} \quad (9)$$

where *NumEstInd* represents the number of *ESTABLISH INDICATION* messages. In other words, the Immediate Assignment Success Rate represents the total number of requests for channels that were successful during the immediate assignment procedure.

SDCCHSuccRate represents *SDCCH* Success Rate and is given by:

$$SDCCHSuccRate = 1 - SDCCH\_Drop\_Rate \quad (10)$$

where *SDCCH_Drop_Rate* is *SDCCH* Drop rate and provides the total number of SDCCH dropped during the procedures (authentication, ciphering etc.) performed on SDCCH.

From the model in Fig.1,

$$NumTCHAttempt = ImmAssSuccRate * SDCCHSuccRate * NumCH\_ReqSpeech \quad (11)$$

NumCH_ReqSpeech in (11) can be written as:

$$NumCH\_ReqSpeech = \frac{NumTCHAttempt}{ImmAssSuccRate \ * SDCCHSuccRate} \quad (12)$$

Substituting (12) into (3) gives;

$$CSSR = \frac{NumTCHAssig}{NumTCHAttempt} * ImmAssSuccRate * SDCCHSuccRate \quad (13)$$

which can be rewritten as given in equation 14;

$$CSSR = TCHAssSuccRate * ImmAssSuccRate * SDCCHSuccRate \quad (14)$$

(14) is currently the best approach used in measuring the Call Setup Success Rate (CSSR). A disadvantage could be higher effort on BSC or the equipment where the CSSR is to be calculated as three KPIs (or six partial measurements) are used. It provides exactly the CSSR in the case where Direct TCH Assignment feature is disabled [6].

IV. METHODOLOGY

The study was aimed at presenting an insight into network performance evaluation of a

GSM/GPRS cellular network by conducting some measurements. One of the most important KPIs used by all mobile operators is the CSSR. The work carried out a comparative analysis of the measured CSSR to that estimated using a CSSR formulation where the direct TCH Assignment feature is disabled.

B. Data Collection

The performance measurements were conducted on ONATELs GSM/GPRS cellular network using a Nokia Siemens Network Statistics tool to define top level KPIs which describe the success/failure rates of the most important events such as service blocking, service dropping and handovers at the Base Transceiver Station (BTS) level.

C. Sample size and data processing

The data collection was over a four week period and categorized into the following observation time intervals [7]:

- Hour: Hourly statistics give a detailed picture of the network performance and are useful to help spot temporary problems and identify trends.
- Peak or busy Hour: Peak hour statistics are of great significance because they correspond to the time of heavy utilization of network resources. In a way, they provide the “worst-case” scenario.
- Day: Daily statistics are introduced to provide a way of averaging temporary fluctuations of hourly data. Problems can be identified and corrective actions triggered with more confidence.

The aggregative KPI ability that evaluates network accessibility and service retainabilty as perceived by the end user is the Call Setup Success Rate. This consists of three main voice call KPIs [6]:

- Successful Immediate assignment procedure (the result is occupation of SDCCH or FACCH in case of Direct TCH assignment)
- Successful authentication and ciphering on SDCCH or FACCH (these procedures can be excluded in case of Direct TCH assignment)
- Successful TCH assignment

V. RESULTS AND DISCUSSION

In this section results that came up through the comparison of operational data to that estimated using the CSSR formulation as given in (14) is presented:

$CSSR = TCHAssSuccRate * ImmAssSuccRate * SDCCHSuccRate$ The logical channels that are primarily used in today’s mainly, voice traffic in cellular networks are the TCH and SDCCH often referred to as “signalling channels”. Though many other channels exist, these two (especially the SDCCH) are the most important resources where the system relies on in order to accommodate the subscribers needs [8]. A new call cannot be initiated if SDCCH channels are not available and the same happens when SDCCHs are available but all TCHs are blocked. Thus one can say that blocking of these channels is a main performance indicator for an operational GSM/GPRS cellular network that may lead to severe bottlenecks if the phenomenon persists.

The SDCCH and TCH Success Rates KPIs provide an understanding of when and where congestion appears since these channels are the most vulnerable and directly affects the quality of service offered to the subscribers.

In Tables 1 to 3, and figs. 2 to 4, the regression analysis and graphical representations of the measured and estimated CSSR for the various observation time intervals are shown respectively.

D. Presentation of Results

Table 1
Regression Analysis of Hourly CSSR Observations
HOURLY SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.999856442
R Square	0.999712905
Adjusted R Square	0.999712612
Standard Error	0.066270816
Observations	2943

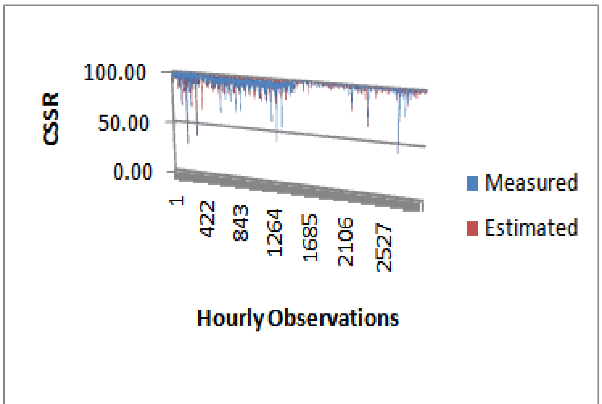

Figure 2: Hourly Plot of Measured and Estimated CSSR

Table 2
Regression Analysis of Busy_Hour CSSR Observations
BUSY HOUR SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.999787297
R Square	0.999574639
Adjusted R Square	0.999563916
Standard Error	0.070670991
Observations	123

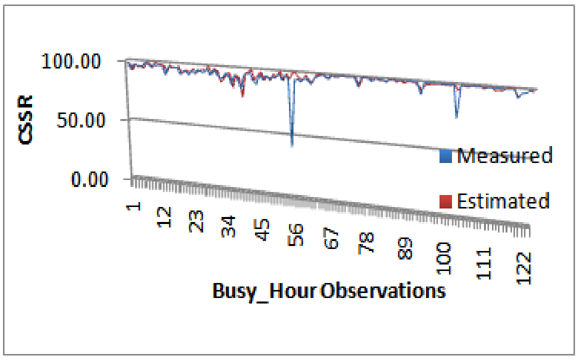

Figure 3: Busy_Hour Plot of Measured and Estimated CSSR

Table 3
Regression Analysis of Daily CSSR Observations
DAILY SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.999921407
R Square	0.999842819
Adjusted R Square	0.999838857
Standard Error	0.037401178
Observations	123

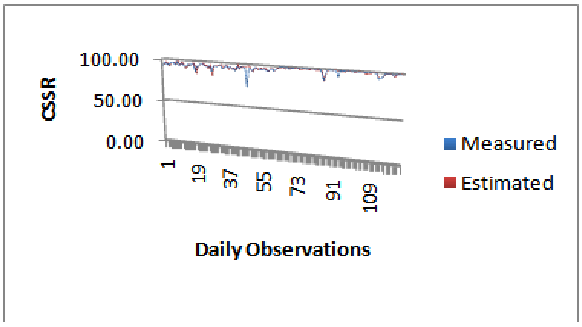

Figure 4: Daily Plot of Measured and Estimated CSSR

VI. CONCLUSION

Operator competency in managing performance and optimizing QoS is not easily taught, it is developed, rather, mainly through trial and error [7]. It is important for mobile network operators to ensure stability and efficiency to deliver a consistent, reliable and high-quality end user (subscriber) satisfaction. For network operators the end user perceived QoS is one of the major forces behind subscriber growth. Thus, it is very important for operators to align their KPI definitions according to what quality and performance means to the subscriber [9]-[10].

The CSSR is one of the most important KPIs used by all mobile operators. However, there is no standard measurement possible for this parameter [6].

In this study, a CSSR formulation for analyzing GSM network performance in the case where the direct TCH Assignment feature is disabled as presented in [6] was evaluated. Significantly, high R square values of close to 1 were recorded from the regression analysis. This means that knowing the regressors or independent variables (IMM_ ASSGN_ Success Rate, SDCCH Success Rate and TCH Assignment Success Rate) helps predict the dependent variable (in this case estimated CSSR) very well. It also means that close to 100% of the estimated CSSR around its mean is explained by the regressors. This indeed points to the fact that the CSSR formulation is efficient.

REFERENCES

[1] O.K. Darkwa. "*Mobile Telephone Markets in Ghana: Status and Outlook*", 4th International CICT Conference, Technical University of Denmark, Copenhagen, 29th – 30th Nov. 2007.

[2] B. M. Orstad and E. Reizer, *End-to-end key performance indicators in cellular networks*, MICT thesis, Agder University College, Norway, May 2006.

[3] S. Kyriazakos, N. Papaoulakis, D. Nikitopoulos, E. Gkroustiotis, C. Kechagias, C. Karambalis and G. Karetsos, "*A Comprehensive Study and Performance Evaluation of Operational GSM and GPRS Systems under Varying Traffic Conditions*", IST Mobile Wireless Telecommunications Summit, 2002, Thessaloniki, Greece

[4] K. Adolfsson, *TCP performance in an EGPRS system*, M. Eng. thesis, Linköpings University, Sweden, June 2003.

[5] S. Ni and S. –G. Häggman. (2002) "*GPRS performance estimation in GSM circuit switched services and GPRS shared resource systems*," in *Proc. IEEE WCNC'99*, vol. 3, pp. 1417–1421.

[6] M. Kollár, "*Evaluation of Real Call Set up Success Rate in GSM*," *Acta Electrotechnia et Informatica*, *vol.8*, pp. 53-56, Feb.2008.

[7] M. Pipikakis, "*Evaluating and Improving the Quality of Service of Second-Generation Cellular Systems*," *Bechtel Telecommunications Technical Journal*, *vol. 2*, pp. 1-8, Sept. 2004.

[8] M. Rahnema., "*Overview of the GSM System and Protocol Architecture*," *IEEE Communications Magazine , vol. 31*, pp. 92-100, April 1993.

[9] S. Raina, "*Optimization and Performance measurement of GSM/GPRS networks*", Telemanagement World Conference, Las Vegas, 29th -31st Oct. 2002.

[10] (2011). The Triangulum website. [Online] Available: www.**triangulum**-telecom.com/src/**Performance**_Improvement_**Solution**.pdf