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Traffic Congestion Analysis in Mobile Macrocells

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***Abstract*—Traffic congestion during busy hour (BH) deteriorates the overall performance of cellular network and may become unmanageable unless effective and efficient methods of congestion control are developed through real live traffic data measurement and analysis. In this work, real live traffic data from integrated GSM/GPRS network is used for traffic congestion analysis. The analysis was carried out on 10 congesting cells using network management system (NMS) statistics data that span three years period. Correlation test was used to show that TCH congestion depend only on call setup success rate (CSSR) and BH traffic at cell level. An average correlation coefficient value of 0.9 was observed between TCH congestion and CSSR while 0.6 was observed between TCH congestion and BH traffic. The correlation test is important when selecting input for congestion prediction modeling.**

Keywords-traffic congestion; GSM; GPRS; macrocells

I. INTRODUCTION

All over the world, cellular network operators are faced with the challenges of improving the quality of service (QoS) while increasing capacity and rolling out new services. This has resulted in many congested networks and consequently degradation of QoS due to inadequate provision of the needed resources or underutilisation of the available resources.

To cope with subscriber demands and meet Regulator standards, cellular network providers dimension network elements on continuous based using network management system (NMS) statistics, drive test trailing and customer feedbacks.

However, Nigerian Communication Commission (NCC) quarterly audit reports of GSM network performance had consistently shown that the operators have not been able to meet the set standards [1] due to network congestion [2]. If there is no hardware fault, network congestion usually occurs due to insufficient number of radio channels in access network elements [3].

This work used busy hour traffic data of access network from a live network to analyse traffic congestion in some macrocells of GSM/GPRS network. The busy hour of a network is the time when the network processes the highest traffic in a day and it is used to measure network performance, determine the robustness of a network and its dimension [4]. To measure the network performance, the pattern of busy hour traffic is considered for congestion evaluation [5] using key performance indicators (KPIs).

These KPIs are defined for different interfaces and network elements of GSM/GPRS. To cater for subscriber demand, radio frequency (RF) optimization teams use the KPIs to generate quality of service (QoS) reports to ensure minimal congestion over all the interfaces and network elements in order to avoid QoS degradation by maintaining the KPIs under pre-defined threshold [6].

Network congestion leads to poor QoS which affect grade of service (GoS) of the network, particularly during the busy hour of the day [7]. In a loss system, the GoS describes that proportion of calls that are lost due to congestion in the busy hour and can be measured using equation (1):

$$\text{GoS} = \frac{Number\_of\_lost\_calls}{Number\_of\_offered\_calls} \qquad (1)$$

While a whole range of services of GSM technology are in use in Nigeria, it is obvious that the network performance in terms of QoS are degrading which proved that GSM network is either over utilized or under dimensioned. Hence the need for this analysis to identify the cells that are responsible for congestion during busy hour by statistically analyzing traffic data of a live network in order to establish the presence or absence of congestion.

II. LITERATURE REVIEW

Traffic analysis is important for evaluating the performance of existing networks and network optimization. The events that occur in BTS trigger different counters in the BSC and MSC memory that are used for performance monitoring and network evaluation. Various KPIs that are used to measure network performances are derived with the help of these counters using different formulations [7]. In practice, the performance can be monitored at different sections of the network [8] and in this work the network performance is evaluated at cell levels in terms of resource allocation and resource utilization.

Some of the early works on GSM network elements performance were done mostly on access part of the network particularly at BTS level. For example, [9] proposed a traffic model for mobile network, using Markov chain to determine call blocking and handoff failure probabilities when no queuing of new or handover calls is performed while [10] modeled the effect of user mobility on the performance of mobile networks using office hours traffic data. Location updates were analyzed to evaluate the probability of call dropping when handover is needed. Likewise, [11] analyzed seventy eight traffic channels and showed that a single dedicated channel is enough for good QoS. [12] investigated GSM/GPRS system performance using dedicated number of GPRS channels and some idle periods between voice calls for GPRS data packet transfers. Reservation of more channels brings handover failure and dropped call probability to very small values but lack of ordinary channels produces a larger new calls blocking probability.

The work of [13] presented the results of study of DCS1800 Um-interface using daily traffic measurement data. The performance indicators used are Traffic, CSSR, handover success rate (HOSR), standalone dedicated control channel (SDCCH) and traffic channel (TCH) congestion. The analysis shows the limitations of the system to accommodate extreme offered traffic without adding more resources. A model combining simulations for paging, signaling and traffic channels was developed by [14] to investigate the optimal dimensioning of a finite physical resource allocated across multiple logical channels with multiple traffic types.

Reference [15] evaluated the performance of GSM1900 Um-interface of two different vendors using daily measurement data for one week. The performance indicators used are peak hour traffic; CSSR; Handover Failure; congestion on control channels (SDCCH blocking rate); congestion on traffic channels (TCH blocking Rate); drop on traffic channels; drop on control channels; cells with TCH congestion rate exceeding 2% and TCH Mean Holding Time.

In another work, [3] analyzed traffic data from a trunked radio network operated by Ecomm in UK using OPNET model. The findings indicated that traditional Erlang models for voice traffic may not be suitable for evaluating the performance of trunked radio networks. In a related work, [16] formulated a dynamic channel allocation model using Markov chain technique as an improvement on [17]. There is one problem common to all these works at BTS level, exclusive handover channels were employed for easy compliance of QoS standards for ongoing calls and handover failure reduction. However, the disadvantage is that new calls blocking increase as a result of the reduction of available ordinary channels. The solution should have been that resources should be added to maintain GoS of the network as put forward by [18] and supported by the work of [13].

III. METHODOLOGY

The setup for data collection in GSM/GPRS network comprises of base station subsystem (BSS) and network subsystem (NSS) connected to standalone system called NMS as shown in Figure 1.

NMS is the functional entity from which the service provider monitors and controls the entire network. The data used in this work was extracted from the NMS with the help of Ericsson Business intelligent (BI) tools installed on the standalone computer and exported to Microsoft Excel environment.

The network is composed of 742 cells, 262 BTSs. Measurements were taken from November, 2012 to September, 2014. Correlation test was used to choose only KPIs that have significant effect on TCH congestion during busy hour.

Correlation coefficient is defined as a number or function indicating the degree of correlation between two variables like X and Y. In this work, the variables are busy hour traffic and CSSR, HOSR, DCR, SDCCH and TCH Congestions as KPIs to measure the network performance. Equation (2) defines correlation coefficient as:

$$Correl(X,Y) = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})^2 \sum(y-\bar{y})^2}} \quad (2)$$

Microsoft excel statistical tools was used for the correlation analysis.

IV. BTS DAILY BUSY HOUR TRAFFIC ANALYSIS

The busy hour traffic data showed that 154 cells experienced congestion out of 742 cells during the period under investigation. In the cell KPIs analysis, 10 worst congesting cells were chosen for BH TCH congestion analysis [19].The ten most congested cells is shown in Table 1, Table 2 presents the maximum and average daily BH traffic of the ten most congested cells over the period.

V. BTS TCH CONGESTION CORRELATION TEST ANALYSIS

Using the BTS KPIs and BH traffic, the correlation test showed that the ten worst cells behaved differently in terms of KPIs that have strong correlation with TCH congestion during busy hour which implied that they must be investigated differently based on their correlation results. However, we selected 4 cells to know which KPI has strong correlation with TCH congestion at cell level. The result of the test for the four cells is summarised in Table 3.

Table 3 shows that BH TCH congestion has strong correlation with CSSR and busy hour traffic for the four cells.

Given the result of the correlation test, the maximum daily BH traffic carried by the ten cells and it impact on CSSR and TCH congestion is shown in Figure 2 and Figure 3.

From Figure 2 and 3, most of the cells CSSR and TCH CONG degraded when they carried maximum traffic while Cell 396B, 393C and 301C suffered worst KPIs degradation.

The behaviour of the ten worst cells when they experienced worst TCH CONG and the effect on other KPIs during the period is shown in Figure 4 to 6.

All the cells CSSR degraded and their ability to carry traffic is limited when they experienced worst TCH CONG while Cell 496B, 430C, 396B and 038B recorded worst KPIs degradation. This shows that traffic channel of these cells are not properly dimensioned.

VI. CONCLUSION

The analysis of traffic channels in an network existing showed that TCH congestion beyond the acceptable 2% threshold for traffic channel (TCH) occurred in 154 cells out of 742 cells investigated.

The busy hour TCH congestion analysis showed that the congestion depends on CSSR and BH traffic. The CSSR and BH traffic has an average correlation coefficient of 0.9 and 0.6 respectively for the cells. The strong correlation showed that the knowledge of CSSR and busy traffic can be used to predict TCH congestion which is crucial for cellular network optimization and resource management.

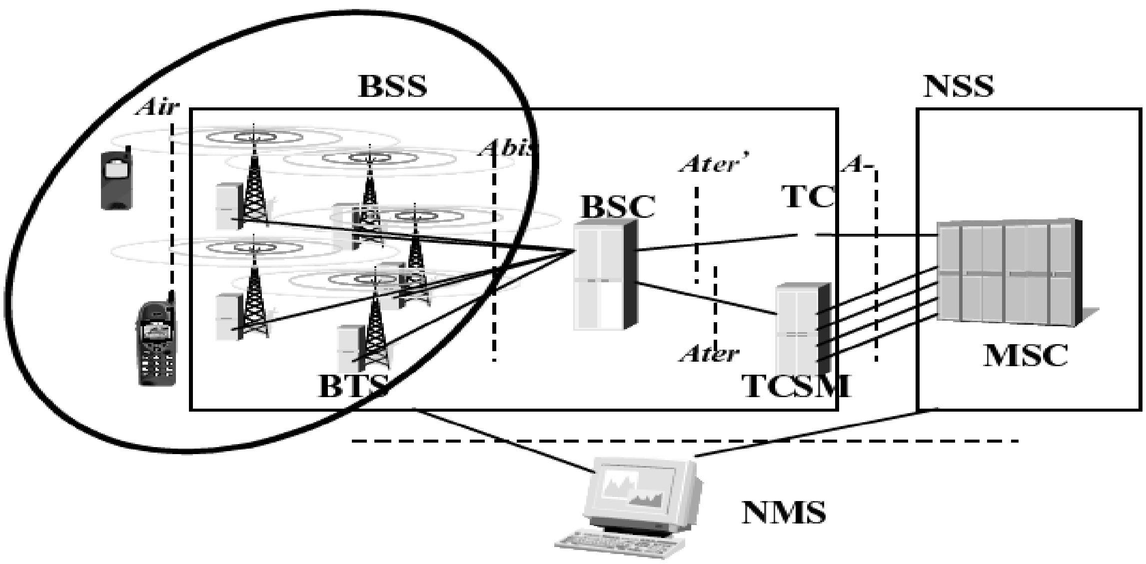

Figure 1. System for collecting traffic data

TABLE I. TEN WORST CONGESTING CELLS

Dates	Cell Ids									
	FC0396B	**FC0301C**	**FC0362C**	**FC0385B**	**FC0393C**	**FC0430C**	**FC0494B**	**FC0496B**	**FC0038B**	**FC0725C**
Jan-13	3.98	60.18	80.01	2.14	4.35	78.95	46.04	69.59	3.7	-
Feb-13	14.44	46.81	23.86	27.91	13.83	24.64	19.92	-	14.67	-
Mar-13	50.87	3.96	62.71	-	-	-	-	20.4	2.41	44.16
Apr-13	20.78	30.47	50.41	32.12	19.74	24.28	55.9	-	7.53	-
Jun-13	15.31	48.24	59.02	9.39	21.63	28.87	33.77	10.23	2.39	-
Jul-13	10.02	53.61	69.77	4.11	14.72	13.31	17.12	7.65	-	30.85
Aug-13	7.15	37.83	67.51	2.17	18.28	18.13	16.78	3.19	-	38.36
Sep-13	10.18	33.95	65.27	-	19.57	5.26	14.01	1.86	-	16.22
Oct-13	9.99	52.04	61.52	3.1	21.07	12.43	21.69	6.05	16.97	2.76
Nov-13	13.8	58.28	63.61	3.03	11.34	3.68	36.6	4.32	-	-
Dec-13	3.42	74.94	84.54	13.31	18.45	9.28	31.63	32.65	-	-
Feb-14	16.65	71.21	80.59	14.57	9.69	82.61	54.85	83.13	17.22	19.15

TABLE II. DAILY BH TRAFFIC (ERLANG) FOR THE TEN WORST CELLS

Cell	Max Traffic	Average Traffic
FC0725C	25.6	15.01
FC0496B	43.93	18.11
FC0494B	21.68	13.61
FC0430C	64.03	37.9
FC0396B	21.59	12.75
FC0393C	19.82	13.85
FC0385B	47.65	13.08
FC0362C	27.66	15.77
FC0301C	34.99	17.12
FC0038B	54.41	21.72

TABLE III. SUMMARY OF TCH CONGESTION CORRELATION TEST

TCH Correlation					
Cell	CSSR	DCR	HOSR	SDCCH CONG	Traffic
FC0725C	0.9	0.2	0.1	0.4	0.5
FC0393C	1.0	0.1	0.4	0.1	0.6
FC0362C	0.9	0.7	0.1	0.0	0.7
FC0301C	0.7	0.6	0.1	0.4	0.6
Average	0.9	0.4	0.2	0.2	0.6

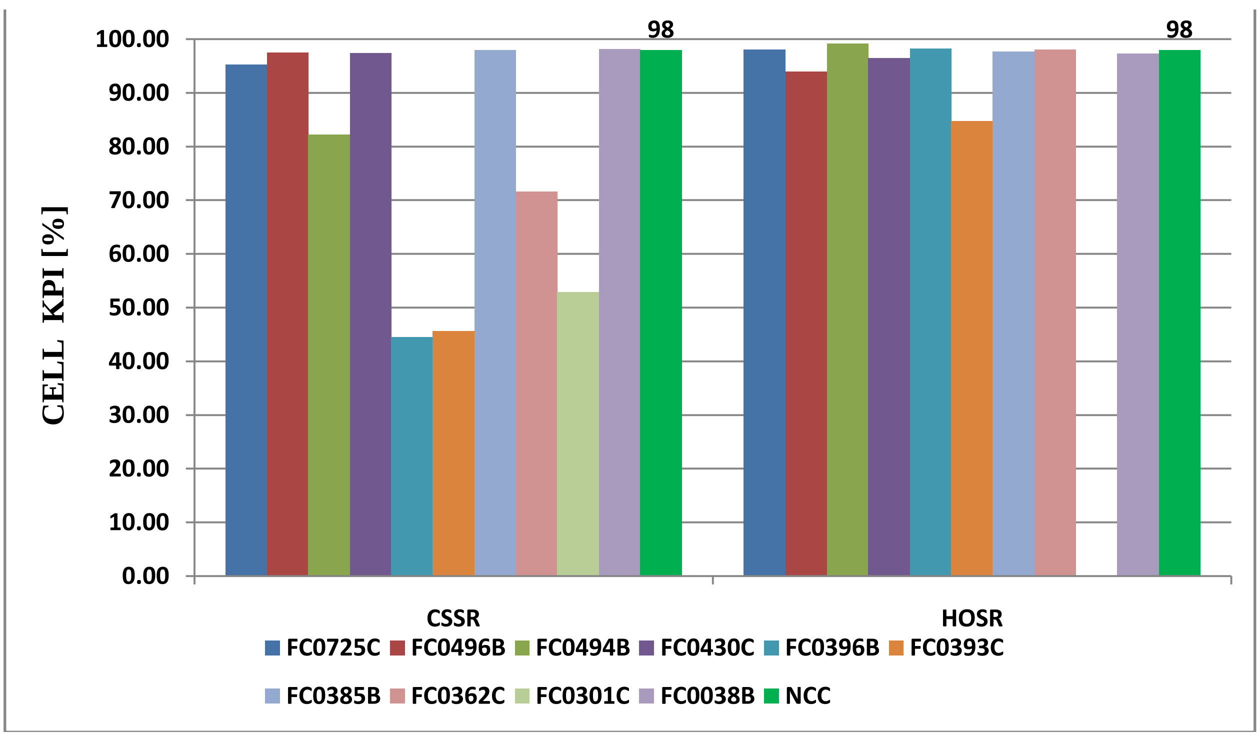

Figure 2. CSSR and HOSR for ten worst Cells during Max. Traffic

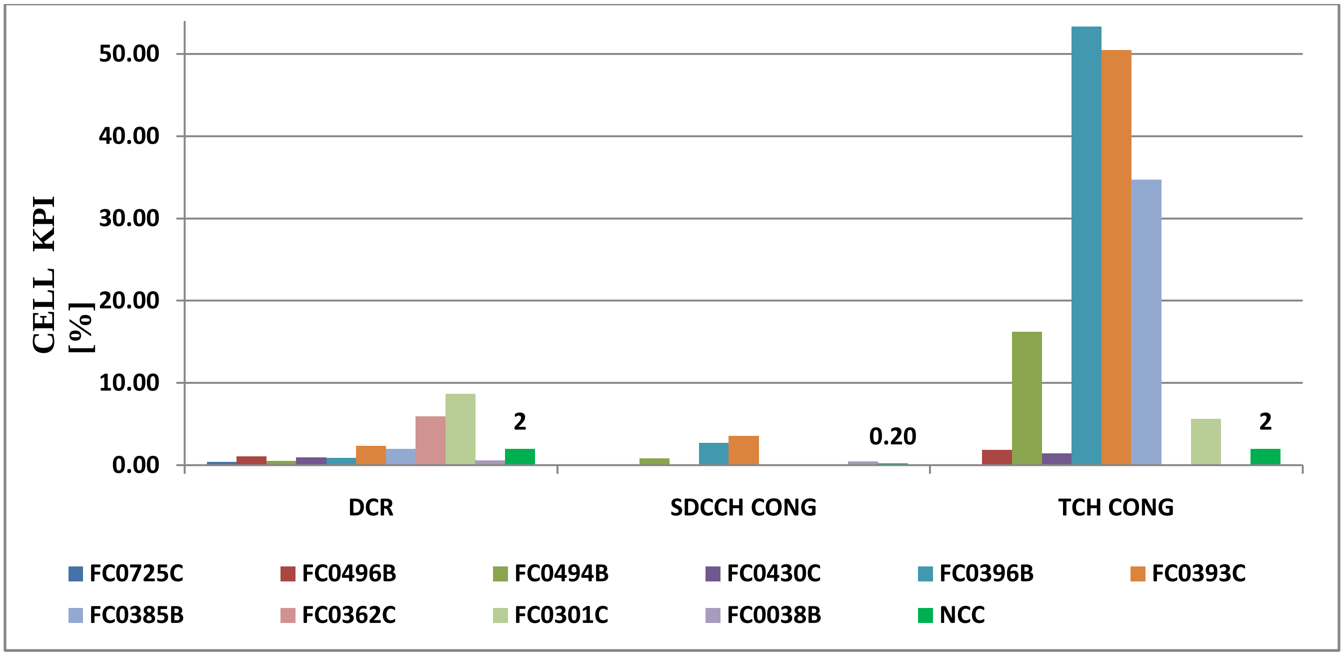

Figure 3. DCR, SDCCH CONG and TCH CONG for ten worst Cells during Max. Traffic

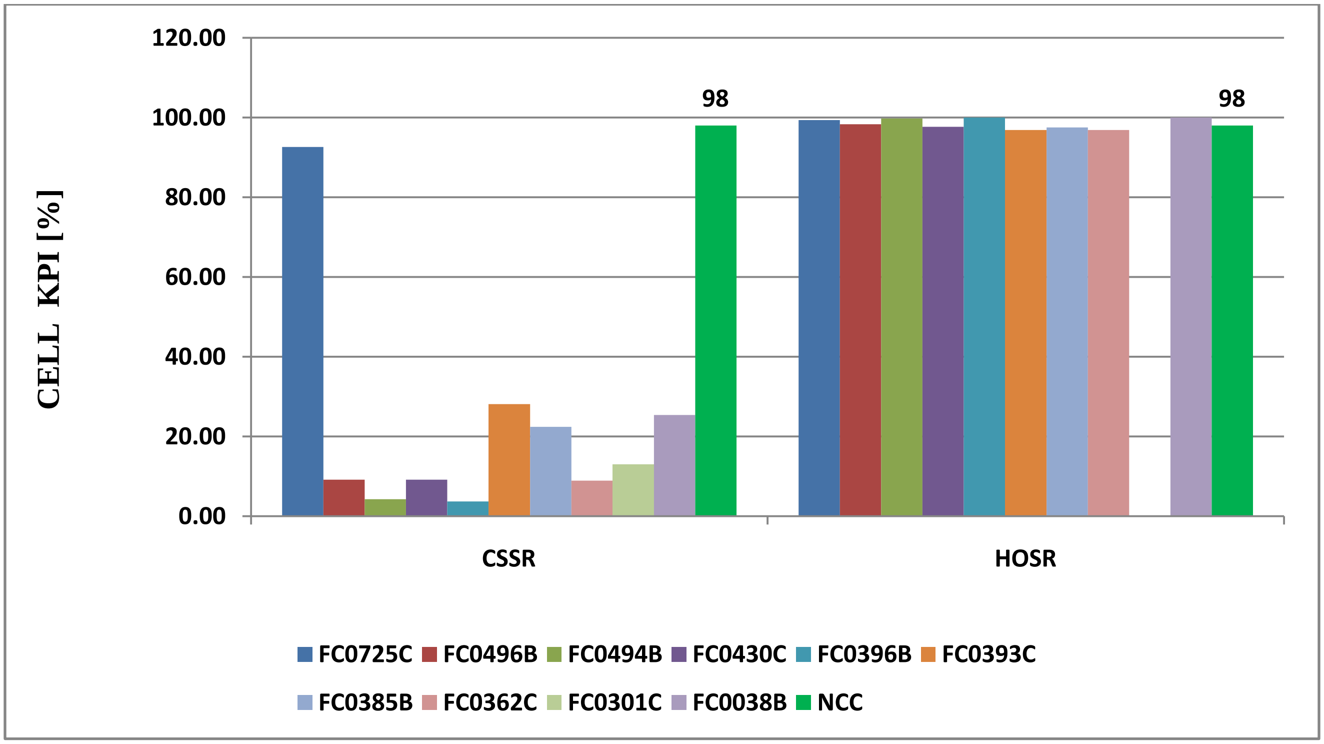

Figure 4. CSSR and HOSR for the Cells during Worst TCH CONG

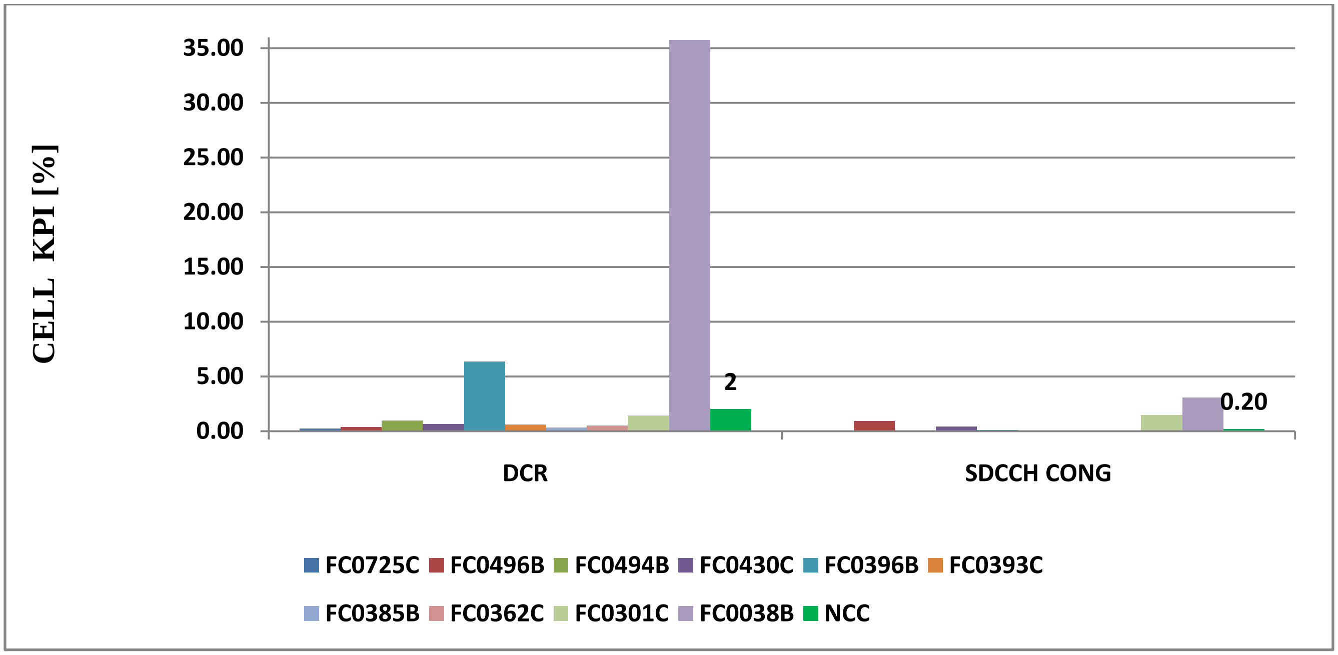

Figure 5. DCR and SDCCH CONG for the Cells during Worst TCH

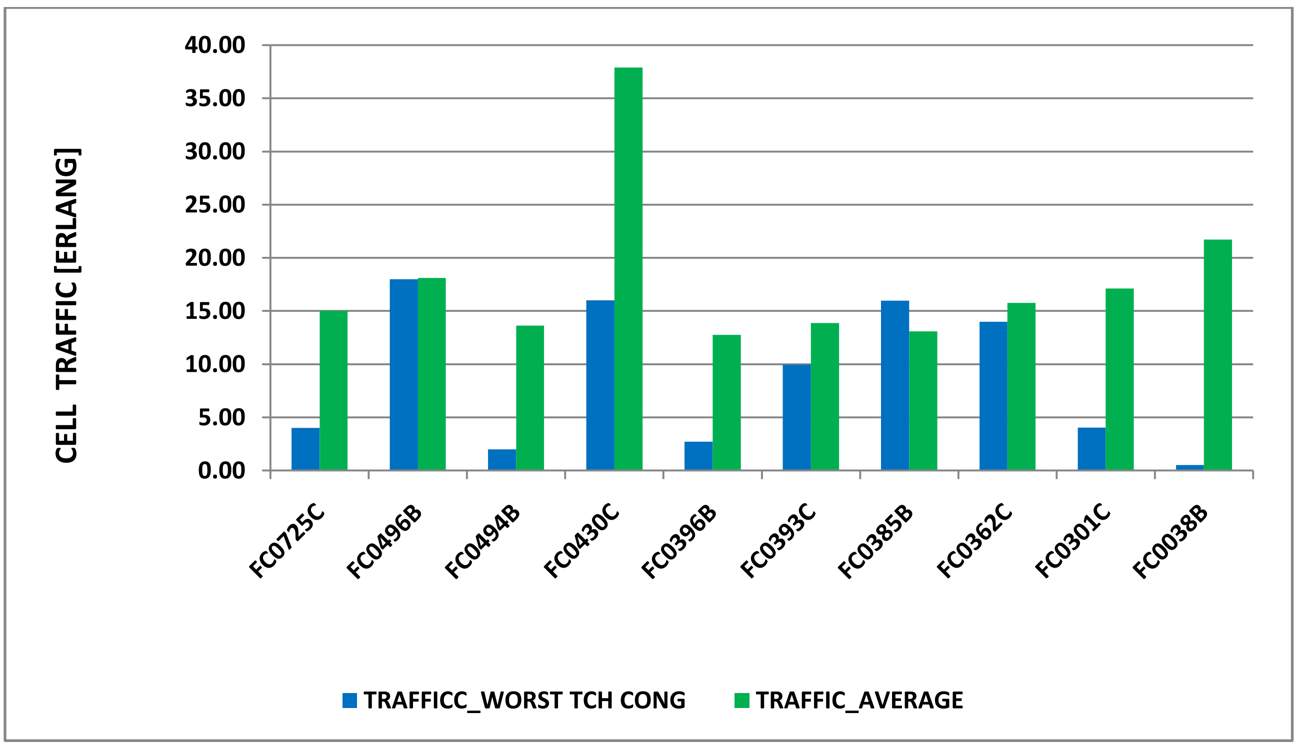

Figure 6. Traffic Average and Traffic Carried by the Cell worst TCH CONG

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