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Evaluation of the quality of service of a cellular network using the network statistics

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Abstract
One of the major concerns of cellular network service providers and their subscribers/customers is its performance which is mostly measured and determined by the Quality of Service (QoS). The assessment of these services from cellular network service providers' point of view is mainly based on some Key Performance Indicators (KPIs). This research exploits and evaluates the major Key Performance Indicators to analyze the quality of service of an operational cellular network service provider that cover the Redeemed Christian Church of God (RCCG) at Redemption Camp, Lagos-Ibadan Expressway, Lagos State, Nigeria using the network statistics. The results from this research show that the Key Performance Indicators fall short from the recommended values by the Nigerian Communications Commission (NCC) especially during traffic intensity. Hence, the quality of service still requires an inflexible advancement and improvement as a panacea to truncate further degradation in service delivery to optimize and ensure better quality of service for the subscribers.

Keywords: KPIs, QoS, network provider, network statistics, subscribers

1. Introduction
After more than a decade of mobile phone operation in Nigeria, the network have witnessed improvement in terms of better coverage and availability but the QoS generally is still not being satisfactory, especially during major events when there is mobility of people [1].
Cellular network performance and QoS evaluation are the most important steps for mobile operator as the revenue and customer satisfaction is directly related to network quality and performance [2]. Network quality is therefore a key parameter in the race for subscribers and this can only be achieved where the network is sufficiently optimized to meet the grade of services expected by its customers/subscribers. Mobile network system is not fully optimized in some part of the world and this is a motivation to trigger new research topics in optimization and performance evaluation due to the rapidly increased number of mobile subscribers [3].
The advantage of using the network statistics of an operational mobile network to measure its performance is the originality it presents in terms of the failed operations of the network itself. From the metric of the KPIs under this research, such operations involve Traffic Channels (TCH) availability, unavailable resources on the signalling channel, missing neighbour relations, faulty time slots, call set up failures, etc. In order to meet the defined KPIs and obtain better QoS for the network, the number of failing operations within the network must be minimized [4].

2. Performance Monitoring
There are three methods commonly used to monitor mobile network performance; Drive Tests, Customer Complaints and Network Statistics.
The drive test method, as embarked by NCC in 2005 to measure QoS of the cellular networks in Nigeria, is one of the mechanisms for performance evaluation. Apart from network performance assessment, it can also be used for the identification of network problem areas, validation of effects of optimization changes and analysis of the root cause of problems in an operational network. But really, the only activities for which drive testing is well suited for is problem root cause analysis and competitive bench marking. Drive test is very expensive and time consuming.
Customer complaints are the most commonly used method since the customer is always ready to give an input whether valid or not. Though performance evaluation by this method is easily achievable, it is not the best option because the customer experience can be emotional and subjective.
The third commonly used method to evaluate network performance is by the network data itself (Network Statistics). The network service providers install on their networks a Network Management System (NMS) with an online database that is responsible for the collection of everything that happens on its network, in a raw data form. In order to measure network performance and offer better QoS for customer satisfaction and retention, this data is analysed and evaluated to spot events, trends, problems areas and KPIs. The availability of a detailed report on these trends and data aggregation allows for a faster and more accurate analysis and resolutions of customer complaints towards an efficient network with good QoS.
By nature these reports show problem areas of the network in raw data form, seriously guarded by the network service providers. This has been one of the major problem that previous researchers face in the adoption of network statistics method for performance analysis and evaluations. This underscores why research in the area (Network Statistics Method), though most reliable compared to others, has not been very robust relative to the other two, earlier mentioned.

We were able to obtain a solution that provides full visibility of the network data of an operational mobile network provider by which this research was undertaken. It is one of the best performance monitoring and evaluation techniques [2, 5].

3. Cellular Network Performance

The operation of a cellular network can be interpreted to consist of a sequence of events. From network operations point of view, certain events are closely associated with bad performance, lack of resources or failures. The entire network event such as call drops, call initiation, traffic channel assignment, traffic channel release, traffic channel demand and many more are reported to the Base Station Controller (BSC) by the Base Transceiver Station (BTS). Therefore, different counters are being triggered against different events. An event either increases or decreases a specific counter value. The counters are computed by the BSC over a measurement period (typically one hour) and stored in the Network Management System. But this data is in the raw form and does not depict any meaningful information until it is interpreted using some formulation in the form of KPIs. Hence evaluation criteria use counters and KPIs to depict network QoS as a whole. These KPIs when taken together, forms the overall QoS report for the entire network in terms of service accessibility, retainability and connection quality [6].

3.1 Service Accessibility

This is the ease with which the service is obtained within a specified threshold and derivable when requested by the user. For instance, a short message service (SMS) sent by subscriber "X" to subscriber "Y" switched ON and within the service area is set at five seconds by the regulatory authority, NCC in 2009. If the message is not delivered after five seconds as bench marked by the regulator, the service is therefore, inaccessible. The target for SMS success rate as set by the NCC is 100%. Accessibility is therefore the number of successful calls set up per the total number of calls access to the network.

The most common KPIs connected to accessibility are as listed below:

i) Paging success rate (PSR)

The paging success rate measures the percentage of paging attempts that have been answered, either as a result of the first or the second repeated page.

$$PSR = \frac{Number\ of\ Paging\ Responses}{Number\ of\ Attempt} \quad (1)$$

Possible reasons for poor Paging Performance could be traceable to:

Paging congestion in MSC, Paging congestion in BSC, Paging congestion in Base Transceiver Station (BTS), Poor paging strategy, Poor parameter setting, Poor coverage, High interference

The NCC set this KPI at 95% of attempts for the busy hour.

ii) SDCCH Access Success Rate

SDCCH access success rate is a percentage of all SDCCH accesses received in the BSC.

Possible reasons for poor SDCCH Access Performance could be; Too High Timing Advance (MHT), Access Burst from another Co-channel, Co-BSIC Cell, Congestion, False Accesses due to High Noise Floor, Unknown Access Cause Code. The busy hour SDCCH congestion as set by the NCC to be measured both at the BSC and cell level is 2%.

iii) SDCCH Drop Rate

The SDCCH Drop Rate statistics compares the total number of RF losses (while using an SDCCH), as a percentage of the total number of call attempts for SDCCH channels. This statistics is intended to give an indication of how good the cell/system is at preserving calls.

$$SDCCHDropRate = \frac{Number\ of\ SDCCHDrops}{Number\ of\ SDCCHSeisures} \quad (2)$$

Possible reasons for SDCCH RF Loss include: Low Signal Strength on Downlink or Uplink, Poor Quality on Downlink or Uplink, Too High Timing Advance, Congestion on TCH. The set target for this KPI is below 1.2%.

iv) Call Setup Success Rate (CSSR)

The QoS of a network can also be ascertained by the user experience in establishing a call. It can be very frustrating for the subscriber to a network that after repeated dialing, especially in an emergent situation, he cannot get his call through to the call party. The Call Setup Success Rate gives the fraction of attempts to establish a call which results in a successful connection to the dialed number. It is the ease by which a call is connected after a dial and measures successful TCH assignments over the total number of TCH assignment attempts. This KPI can be calculated using the following expression:

$$CSSR = (1 - SDCCH\ Congestion\ Rate) \times TCH\ Assignment\ Success\ Rate \quad (3)$$

The following are some of the reasons which account for a low call setup success rate in a cell: Radio interface congestion, Effects of Interference and fading, Poor coverage, Faulty hardware units, Increase in radio traffic in inbound network, Limitations in access network transmission path.

Low CSSR can be improved by taking the following corrective actions; Upgrade and enhancement of radio resources, Expansion of the transport media to accommodate hardware upgrades such as addition of more TRXs (Transceivers) to the congested cell, Reduction of mean time to repair (MTTR) where faults occur, to ensure resource availability. The target for this KPI as set by the NCC is 98%.

v) TCH Congestion Rate

The TCH Congestion Rate statistics provides the percentage of attempts to allocate a TCH for call setups that were blocked in a cell.

$$\frac{No\ of\ TCH\ Blocks\ (Excluding\ HO)}{No\ of\ TCH\ Attempts} \text{TCH Congestion Rate} = (4)$$

Possible reasons for call setup block include; Increasing Traffic Demand, Bad Dimensioning, HW Fault & Installation

Fault, High Antenna Position, High Mean Holding Time (MHT), Low Handover Activity, Congestion in Surrounding Cells.
The set target for this KPI by NCC is below 2%.

3.2 Service Retainability

Service retainability refers to the ability of the provided service, once it has been obtained to continue unhindered for the requested duration. It is a measure of the probability that a call, once it has been connected, will not be disengaged or terminated until there is a sign off by the parties involved. Retainability can thus be given as:

$$\text{Retainability} = \frac{TotalCallsCompleted}{TotalSuccessfulCallsSetup} \quad (5)$$

The KPIs connected to service retainability are listed below:

i) Call Drop Rate (CDR)

This KPI gives the rate of calls not completed successfully. This is expressed as:

$$\text{CDR} = \frac{NumberofTCHDropsafterAssignment}{TotalNumberofTCHAssignment} \quad (6)$$

Possible reasons for TCH Drop Call Rate are; Low Signal Strength on Downlink or Uplink, Lack of Best Server, Congestion in neighboring cells, Battery Flaw, Poor Quality on Downlink or Uplink, Too High Timing Advance, Antenna problems, Low BTS Output Power, Missing Neighboring Cell Definitions, Unsuccessful Outgoing Handover, Unsuccessful Incoming Handover
The busy hour drop rate as set by NCC is below 2%.

ii) Handover Success Rate (HOSR)

The handover success rate shows the percentage of successful handovers of all handover attempts. A handover attempt is when a handover command is sent to the mobile station. Poor handover success rate arises as a result of the following factors: Congestion, Link Connection or HW Failure, Bad Antenna Installation, Incorrect Handover Relations, Incorrect Locating Parameter Setting, Bad Radio Coverage, High Interference, Co-channel or Adjacent channel interference. The busy hour Handover Success Rate set by NCC at all hours = 99%.

3.3 Service Availability

Availability is defined as the percentage of time that the basic physical channels are available for use. The path used to carry information between a mobile station and the base transceiver stations is known as the physical channel. It is embedded in the air interface between the BTS and MS. The different information carried on the physical channels is classified as logical channels. The logical channels are divided into two categories; the control channels and the traffic channels. The percentage traffic channels (PTTCH) available in a cell defines the availability of the cell. Thus for a BTS that is made up of three cells, the sum total of the PTTCH for all three cells makes up the availability of the BTS. The BTSs in the network must be available for that network to be accessible.
The retainability of the network is also a function of PTTCH availability because we cannot retain what cannot be accessed. Network availability is therefore a pedestal by which the QoS of an operational network are measured. It is affected by faulty base station equipment, bad transmission links or wrong configuration parameters defined at the BSC and network power outage. The target for this KPI as set by the NCC is 99%.
With the benchmark or KPIs defined by NCC as a baseline, juxtaposed with the data from an operating cellular network service provider, a comparison was made using several parametric indices of network assessment, enumerated above to analyze the performance of the network by cell clusters where there is mobility of people for an event and when the event is not holding in the area.

4. Methodology

The research was undertaken using a comparative process where the network statistics of an operational cellular service provider was investigated under the following metrics; Call Setup Success Rate (CSSR), Percentage Drop Call Rate (PDROP), Handover Success Rate (HOSR), Percentage TCH Congestion Rate (PCONG) and Percentage of unsuccessful Control Channel Setup (PCTRLFAIL) which shows the control channels that could not be setup or dropped, as an effect of Stand-alone Dedicated Control Channel congestion (SDCCH). These counters were taken together for QoS evaluations relative to the sites/cells covering the area while the event was taking place. The results were compared with the data obtained when there was no event but few numbers of persons in the same area.
Typically, since the important KPIs for QoS evaluation describe the success/failure rates of the metrics outlined above and all of them are affected by PTTCH availability, this metric was also included in the analysis.
By using the network statistics, which gives a more accurate picture of the events in the network in raw data [7], the metrics were investigated relative to the benchmark defined by NCC, for the period when there was heavy mobility of people within the area (during the church programmes). This was done for the period while the event was taking place and when there was no event within the area specified.
The areas selected for this investigation was the Redeemed Christian Church of God (RCCG) at Redemption Camp, Lagos-Ibadan Expressway, Lagos, Nigeria during the Holy Ghost Congress of the Redeemed Christian Church of God (RCCG) between 12th to 19th of December 2016. The BTSs covering these areas were critically examined at cell levels to estimate any change or pattern of behaviour when there is less concentration of human traffic and when there is mobility of crowd.

5. Presentation of Results

The network data of the operational cellular service provider understudy for the BTSs covering the Redemption Camp of the Redeemed Christian Church of God, just before, during and immediately after its Holy Ghost Congress of December 2016 was used for this research.

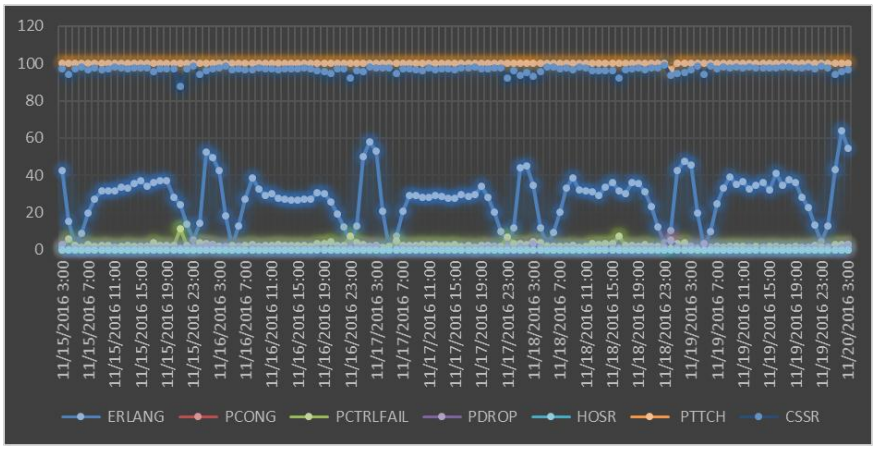

Fig 1: Graphical representation of results for stats before the Holy Ghost Congress of December, 2016 (Cell A).

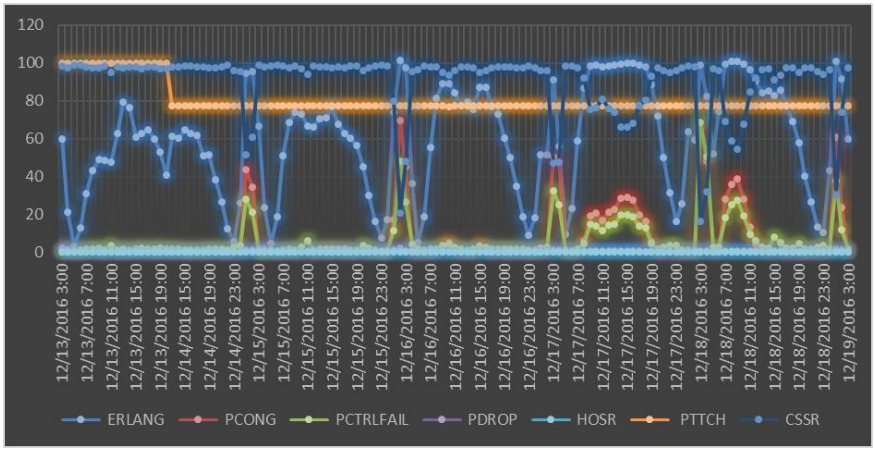

Fig 2: Graphical representation of results for stats during the Holy Ghost Congress of Dec, 2016 (Cell A).

Fig 3: Graphical representation of results for stats after the Holy Ghost Congress of December, 2016 (Cell A).

Figure1 is when there was no programme at the Camp hence, fewer numbers of persons. Figure2 shows the pattern of events while the Church was holding its Holy Ghost Congress and there was mobility of crowd into the Camp for the programme and Figure3 shows a return to normalcy two days after the programme, when the crowd had gone.

Though, there was a drop in PTTCH of cell A during the Congress from 100% to 77.7%, it was the same PTTCH value that was obtainable after the Congress yet, figures 2 and 3 does not look the same. There is a marked difference in all the counters or KPIs investigated and the only variance is just the departure of the crowd after the Congress. With the kind of results during the Congress, the QoS obtained in such a scenario obviously is poor, which correlates network quality and performance in an area with mobility of people.

Similarly, in figures 4, 5 and 6 are for cell B of the same BTS taken at different time periods.

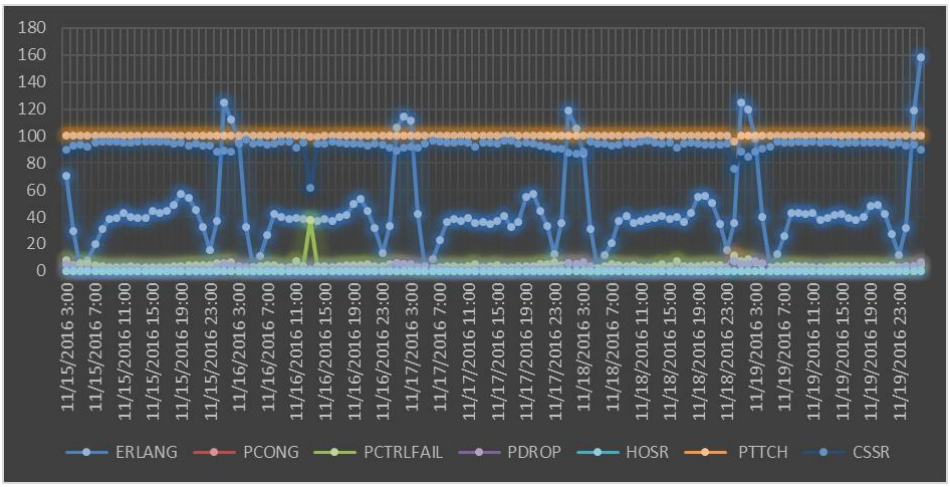

Fig 4: Graphical representation of results for stats before the Holy Ghost Congress of December, 2016 (Cell B).

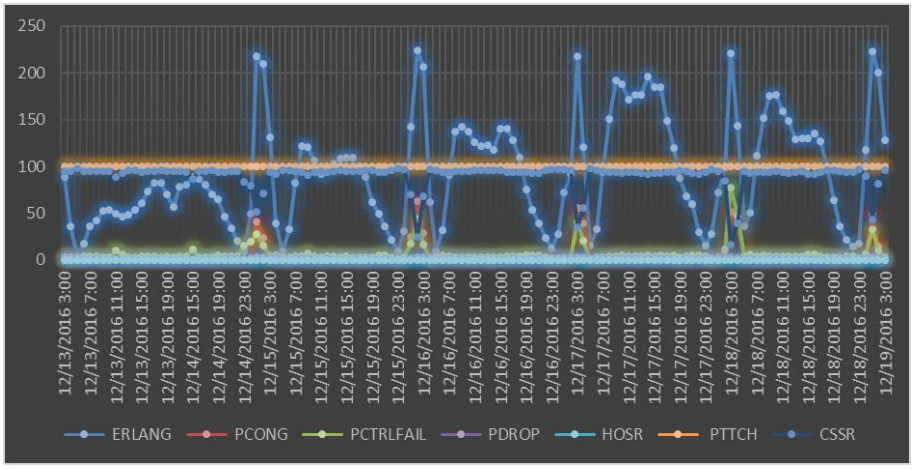

Fig 5: Graphical representation of results for stats during the Holy Ghost Congress of December, 2016 (Cell B).

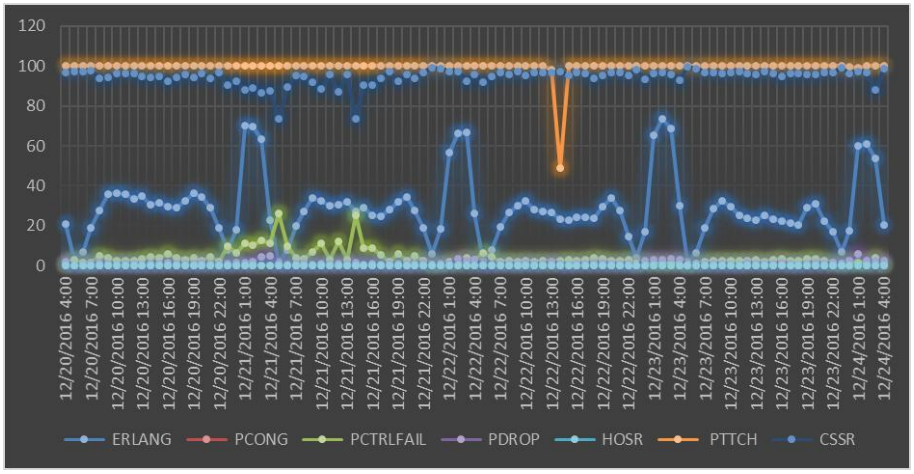

Fig 6: Graphical representation of results for stats after the Holy Ghost Congress of December, 2016 (Cell B).

It is observed in the graph of figure5 that within 0100hrs to 0400hrs from 14/12/2016 till 17/12/2016 when the daily programme of the Church was ending, the percentage TCH congestion on the cell was exceptionally high and the CSSR dropped below an acceptable limit at such instance. The interpretation is that as the main programme for each day ended, people were rushing to make calls and this resulted in high level congestion on the TCH but this is not the case in figures 4 and 6 when there was no crowd at the Redemption Camp.

Concomitantly, in figures 7, 8 and 9 are for one cell (sector C of the same BTS) taken at different time periods.

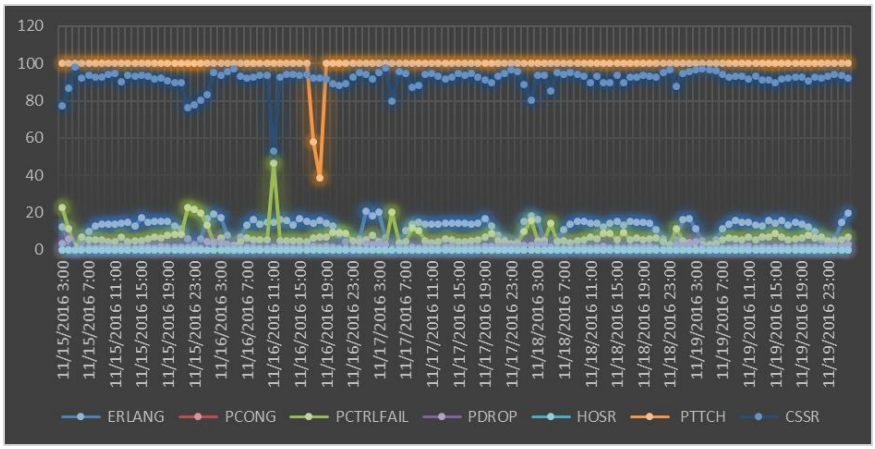

Fig 7: Graphical representation of results for stats before the Holy Ghost Congress of December, 2016 (Cell C).

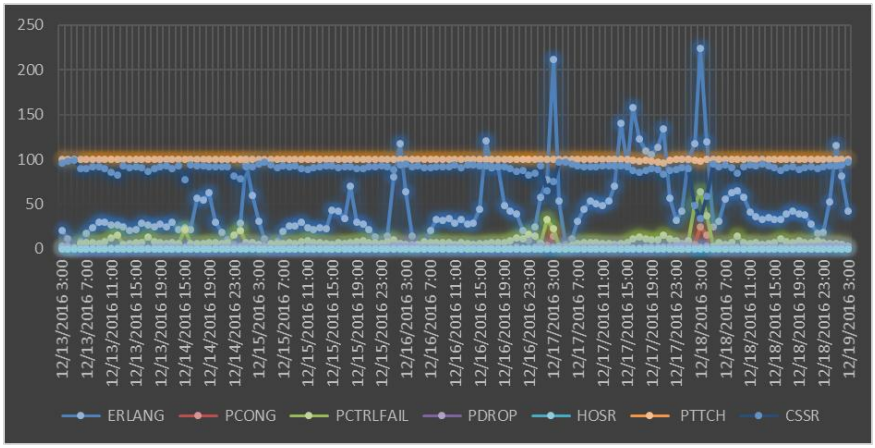

Fig 8: Graphical representation of results for stats during the Holy Ghost Congress of December, 2016 (Cell C).

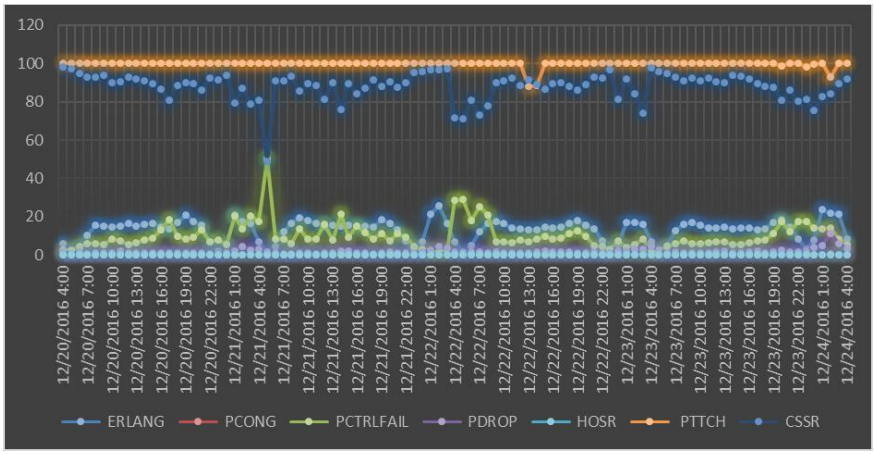

Fig 9: Graphical representation of results for stats after the Holy Ghost Congress of December, 2016 (Cell C).

Just as in cell A and cell B previously considered, it was during the Congress (Figure8) that we observe a marked difference on the counters. In this case, the ERLANG, PCONG and PCTRLFAIL shoots up while the CSSR drops abysmally between 0200hrs and 0400hrs of the last two days of the programme and this is not the case in figure 7 and 9, showing the effect of human traffic on the QoS by the cellular network provider.

As illustrated in the data analysis above, the network statistics of the operational cellular network under study was pooled under a measurement period of one hour for all hours of operation. The results were analysed through a comparative process by comparing the data obtained from the sample area under a normal day occurrence and during events (where there is mobility of crowd) with the KPI targets as benchmarked by NCC. The summary of the results are shown below:

Table 1: Coverage at RCCG, Redemption Camp Lagos

KPIs	NCC (%)	Normal Day Occurrence (%)	Statistics During Events (%)
PCONG	≤ 2.00%	0.83	26.52
PCTRLFAIL	≤ 1.20%	1.87	32.97
PDROP	≤ 2.00%	1.79	1.87
HOSR	≥ 99.00%	63.60	40.50
CSSR	≥ 98.00%	98.20	42.79
PTTCH	≥ 98.50%	100.00	88.73

The results show that for a normal day occurrence that is, without any event attracting mobility of a crowd, the KPIs were close to the benchmark defined by NCC. However, the situation was not the same during major events with the mobility of people within the area. The percentage TCH congestion increases sharply within the period of events while the CSSR reduces. The percentage of unsuccessful control channel setup, which shows the control channels that could not be set up or dropped, increases within the period to show that there was high level congestion within the area as the available network elements servicing the area was not enough to meet up with the demand for signalling channels within the period. Overall, the accessibility to the network within the period reduces drastically and this explains why subscribers in that area might not readily get a call through with their mobile stations.

6. Conclusion and Recommendations

The mobility of people within an area at any given time affects the QoS of a cellular mobile network. Therefore, network quality and performance within an area can be improved by a proactive optimization of the network and provision of contingencies like the deployment of mobile BTSs to accommodate crowd especially during major events that attracts the mobility of people.

Cellular mobile network is not fully optimized yet in developing countries. Poor handover success rates, low call setup success rate, frequent call drops etc, which affects the QoS in an operational cellular network are pointers of an optimization head room.

We therefore, make the following recommendations based on the findings of this research as feasible strategies to remedy the problems associated with poor QoS:

- The various cellular network service providers must ensure a robust optimization of its network for better service delivery to its subscribers.
- The optimization models for cellular network should be proactive and not reactive. For instance, before any major event in an area, the respective cellular network providers should deploy an I-site or a mobile BTS accordingly.
- Finally, there should be a synergy and collaboration between the cellular network service providers and the NCC on how best to improve cellular networks to ensure optimized and better QoS.

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