PILOT CASE-STUDY OF GSMNETWORK LOAD MEASUREMENT IN IKEJA - NIGERIA.

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Abstract— **Managing customer complaints quickly is critical in a heterogeneous business environment. Network analysis can determine the cause(s) of any call drop rate, or call routing problems. It further ensures that quick identification of routes that may result to non-compliance with standard service agreement are arrested. In essence, quality of service deterioration is reduced. In this vein, a pilot case - study of mobile load measurements was carried out in Lagos -Nigeria. The study recorded a relatively good grade of service with an average call set up rate of 85.29 per cent, while the average call drop rate was 1.05 per cent. Also, an average call completion rate of 89.9 per cent was recorded, and 94.6 per cent success in hand-over ratio. From the comparative ITU's bench mark used, these values showed remarkable performance of the operator. However, exceptions were recorded in Route 7 and Route 8. The destination calls along these routes may be under hard handover; which may be due to the influence of the radio resource management algorithm, among others.**

***Keywords*—GSM, Load Measurements, Call Set-up Rate, Call Drop-rate, Hand-over Ratio.**

1. INTRODUCTION

Telecommunications signal is a detectable transmitted energy used to convey information. It is a time dependent variation of characteristics of a physical phenomenon, with a real-time growth intensity usually referred as traffic. Traffic in Global System for Mobile communication (GSM) is a measure of the amount of voice, data or video messages carried in a circuit during a given period of time. It is the traffic intensity carried by a circuit or network in Erlang [3].

Traffic measurements lead to the analysis of routes occupancy and other traffic key indicators. The evaluation of these parameters guides the determination of grade of service offered by the operators. Besides, it assists the maintenance, operation and planning units in network route dimensioning. Timely analysis of these key indicators also assists the operator in tackling traffic bottlenecks before they alter network performance and customer satisfaction. In practice, it is usually difficult to estimate traffic route fluctuations on a network without reference to traffic data. Operators may not have a clear idea of what applications the customers may wish to run and the implication of traffic volume this application may generate. As shown in Table 1, traffic volume or pattern vary significantly during the business days and may also have strong seasonal fluctuation. Network operators can adjust swiftly to such changing patterns if they have real time analysis of traffic flow on these routes.

Loss of communication services for short periods may be very serious in a competitive environment. In such circumstances, redundant routes will be required. In addition, network management software that will automatically reconfigure routing patterns to ensure that the end user is shielded from the effect of equipment or route failure can be implemented through analyzed traffic data.

Since the inception of the first launch of GSM communications network by ECONET in 2001, other operators rolled out their services in quick succession. The growth became so rapid that in less than 13 years of operation, the subscriber base rose to more than 110 million and Nigerian telecommunication landscape was described as the fastest growing cellular market in the world.

However, this tremendous growth occurred amidst subscriber complaints; thereby, making it necessary for the evaluation of performance indices in line with international standards. Real time evaluation of traffic parameters, through the analysis of key network indicators becomes imperative. There are four ways to set fault information [5,6]:

i. Fault complaints from user or customer centre.
ii. Traffic statistic index analysis
iii. Output of alarm system
iv. Abnormality discovered in routine maintenance of patrol inspection.
v. Using auxiliary instruments such as test mobile station, signal analyzer, bit error rate analyzer to take traffic measurements.

Accordingly, measurements were carried out from a major interconnect centre and data collected for the six months period were used to analyze average values for the following performance indicators: traffic carried for the ten routes in Ikeja Interconnect centre, call set –up success rate, call drop rate, call completion success rate and hand over success rate. Average values shown in Table 1 for these parameters were compared with ITU and NCC stipulated standards for GSM operators. Through these comparative analyses, the grade of service offered by the operator was determined.

2. MATERIALS AND METHOD

Standard traffic theory is based on the assumption that during the busy hour, the traffic process is in statistical equilibrium with only random fluctuations, no systematic

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variation, and that successive days in a measurement period are compatible. This led to the dimensioning and capacity of each route based on measurements in a particular period called the busy hour. To determine the busy hour, traffic lead values are measured over intervals of one hour throughout the day, and the highest value measured per each hour is stored. The recorded data is transferred to daily files. This trend is revolutionized by the development of high speed computers which can accept and process very large amounts of data very quickly. As a result, there are proliferation of specially designed traffic measuring devices for use in modern digital switches,

Traffic intensity, measured in Erlang, represents the proportion of time in an hour that a circuit or channel is occupied, while traffic load is determined from the number of calls intensity (λ_o) and the mean holding time (μ) [4].

Traffic can be characterized as:

i. Offered traffic, being the total traffic available in a particular route (channels available),
ii. Carried traffic, being the actual traffic carried and
iii. Loss traffic.

Traffic offered = Traffic carried + traffic lost

Offered traffic (A) can also be denoted as:

$$A = \lambda \times \mu \quad (1)$$

Where λ = number of calls intensity and
μ = mean holding time.

The volume of calls processed or traffic carried by a network can be influenced by various factors such as the RF path loss, spectrum efficiency, bandwidth per channel and the cluster size.

In practice, the coverage area of a mobile phone is irregular because of the radiation patterns, which is under the influence of certain variables: the base station antennas, buildings, trees, mountains, and equipment features. If antenna diversity is employed in the radio system at the mobile station, then the higher signal level would be selected using filtering techniques. At least two filtering methods are possible [4]: window averaging and leaky – bucket integration. For window averaging, the mobile station (MS) maintains a number proportional to the average of the current measurements, and the last W_{-1} measurements, where W is the window size. To actualize this method, the MS performs the following procedure for each new measurement [4]:

$$S_K = S_{K-1} + M_K - M_K - W \quad (2)$$

Where S_K refers to the sum of the window at time k, and M_K, the measurement made at time k.

For leaky – bucket integration, the MS implements a discrete, digital one pole low-pass filter:

$$S_K = aS_{K-1} + M_K \quad (3)$$

Where a<1 is a constant called "forgetting factor."

Another core factor is the signal path loss. Path loss is a measure of the average RF attenuation suffered by a transmitted signal when it arrives at the receiver [7]. This is defined by Pι (dB) = 10log (4)

Where P_t is the transmitted power

P_r is the received power

Under free space scenario, the power reaching the receiving antenna, separated by a distance d from the transmitting antenna is given by the equation:

$$Pr = \frac{(d)P_t G_t \lambda_2}{(4\Pi)^2 d^2 L} (5)$$

Where G_t and G_r are the gains of the transmitting and receiving antenna, L is the system loss factor, and d is the wave length in meters.

Spectrum Efficiency (S_E) refers to the traffic that can be handled within a certain bandwidth in a particular area.

S_E = Total bandwidth (B_T) X Area (A) 6

Also;

B_T = Bandwidth per channel (B) X Number of channel per cell (N) X Cluster size (C)

BT = B x N x C (6)

The carrier bandwidth for both GSM 900 and GSM 1800 is 200KHz. Duplex Distance for GSM 900 is 45 MHz, Bandwidth is 25 MHz. [1]

The data obtained from the operation and maintenance terminal of the telecommunication network such as number of complete calls, number of call attempts, service time(call duration), and drop calls, shall be used to compute key performance indicators(KPIs) of these networks. The key performance indicators (KPIs) are [5]:

- Call set up success rate(CSSR)
- Call drop rate (CDR)
- Call completion success rate (CCSR)
- Handover success rate (HSR)
- Traffic channel congestion rate (TCH).

These key performance indicators (KPIs) which shall be used to evaluation the quality of service (QoS) of this network are defined as follows:

- Call Set Up Success Rate (CSSR)

This indicator measures the rate at which calls are established or set up. The higher the value of CSSR, the easier it is to set up a call. For instance, the CSSR of 60 per cent means that out of every 100 call attempts, only 60 were successful, while 40 were unsuccessful. The indicator is calculated using the expression:

$$CSSR = \frac{Number\ of\ unblocked\ call\ attempts}{Total\ number\ of\ call\ attempts} x\ 100 \quad (7)$$

- Call Drop Rate (CDR)

This indicator measures the network ability to retain all established traffic A value of 5 per cent of CDR means that, out of every 100 set up calls, 8 will drop before any of the calling parties terminates the call. The indicator is calculated using the expression:

$$CDR = \frac{Number\ of\ drop\ calls}{Total\ number\ of\ call\ attempts} x\ 100\% \quad (8)$$

- Call Completion (Success) Rate (CCSR)

This indicator can be derived either from network statistics or from drive test statistics. The indicator takes into account the fact that all network failures are either drop calls or unsuccessful call set ups. It is a good parameter for evaluating the network accessibility and retain ability under the perception of the subscriber. The indicator is derived using the expression:

$$CCSR = \frac{Total\ number\ of\ completed\ calls}{Total\ number\ of\ call\ attempts} x\ 100\% \quad (9)$$

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The indicator measures the success of handovers. The value is expected to be very minimal, as minimal value improves CDR.

- Traffic Channel Congestion Rate (TCHC)

This congestion is the first level of congestion experienced by the subscriber. It measures the relative ease by which the subscriber accesses the services of the network or seizes a traffic channel to set up call after signaling seizure has been successful.

Cellular Traffic

Traffic in mobile communication can be explained as the amount of data, voice call or both over a circuit or channel, during a given period of time. The traffic unit is a measure of traffic intensity. The international unit of traffic intensity is the Erlang. It represents the proportion of time in an hour that a circuit or channel is occupied.

1 Erlang = 1call hour = 3,600 call seconds.

Spectrum Efficiency (SE) is defined as the traffic that can be handled within a certain bandwidth and area.

$$S_E = \frac{Trafficload \;\; or \; traffic \;\; intensity \;\; in \; Erlang}{Total \;\; bandwidt \; h \; (BT) \; X \; Area \; (A)} \quad (10)$$

BT = Bandwidth per channel (B) x Number of channels per cell (N) x Cluster size (C).

BT = B x N x C

$$S_E = \frac{Traffic \;\; intensity \;\; in \; Erlang}{B \;\; x \, N \; x \; C \; x \; A} \quad (11)$$

$$S_E = \frac{Erlang}{Mh_z \; x \; km^2} \quad (12)$$

3. MATERIALS AND METHODS

Three methods are usually employed to monitor and evaluate quality of service parameters. These are Network Statistics, Drive Test, and Subscribers' complaints [1]. The method employed by this study was monitoring, evaluating and analyzing network statistics of a core GSM operator; through their interconnect node in Lagos for a period of six months (October, 2010 to March, 2011). Data were generated through a computerized interconnect route-terminal. The data obtained was used to analyze the performance parameters for various routes in this mega city, Lagos (Nigeria). Route performance indicators appraised were [2]:

Call Completion Rate (CCR)
Call Drop Rate (CDR)
Call Set Up Success Rate (CSSR)
Handover Success Rate (HSR)
Grade Of Service (GOS)

Observation of subscribers' behaviour was carried out using the command: "ENTER DNOBS" to generate data records for each incoming and outgoing traffic. It provides information about how subscriber traffic is distributed over the various traffic routes and supplies values relating to subscriber behavior. Thses data were generated for successful calls and seizures without dialing, and for seizures with incomplete dialing.

Post – processed data were used to determine the following information records:

- The Subscriber behavior
- Service usage and other needed parameters.

The subscriber data were recorded and edited by writing into the cyclic file (IA.ICNB) on the hard disk of the coordinating processor. The data records were binary – formatted.

Thereafter, a comparative analysis was carried out using threshold levels set by the telecommunications regulating bodies: the Nigeria's Telecommunication Commission (NCC) and the International Telecommunication Union (ITU).

4. RESULTS AND DISCUSSION.

Table 1 is the average values of Daily Traffic Intensity in Erlang collated during the BHCA from October 2010 to March 2011 (IKEJA MSC), for Ikeja main switching centre, while Table 2 represents the analysis of the average KPIs per route for the six months period. Both tables covered.

Traffic Intensity = Number of call (per hour) X Average calls duration (secs)/360. [5]

Table 1: Average Values of Daily Traffic Intensity in Erlang during the BHCA. October 2010 - March 2011 (IKEJA MSC)

ROUTES	OCT	NOV	DEC	JAN	FEB	MAR	AVG VALUE
1	90.5	78.6	95.7	68.5	67.9	67.2	78.1
2	89.7	73.4	90.6	59.7	72.1	68.1	75.6
3	91.4	85.1	93.4	55.3	63.1	59.8	74.7
4	89.3	82.7	92.1	60.7	63.5	60.2	74.8
5	85.4	61.3	87.6	66.1	79.2	65.4	74.2
6	93.2	68.6	89.2	65.4	53.4	71.3	73.5
7	56.4	86.2	63.4	59.3	63.7	62.7	65.3
8	68.4	71.3	61.3	68.2	63.7	58.9	65.3
9	97.1	60.7	93.4	68.1	72.5	62.1	75.6
10	96.7	61.4	96.2	72.3	68.9	63.5	76.5

Table 2: Average KPIs per Route for Six Months

Routes	Call set up success rate (CSSR) %	Call Drop Rate (CDR) %	Call completion success Rate (CCSR) %	Hand Over Success Rate %
1	76.56	0.30	92.94	92.9
2	96.42	0.62	92.84	96.4
3	98.06	0.68	94.62	96.7
4	97.04	0.57	95.14	96.8
5	97.18	0.90	93.42	95.6
6	95.58	0.98	91.61	98.6
7	53.20	3.10	51.40	87.3
8	61.70	2.34	57.80	88.6
9	94.78	0.32	95.40	96.4
10	88.72	0.64	94.02	96.6

Monitoring radio load is an important precondition to ensure a stable equipment running and reliable quality of service (QoS). These include: admission control, congestion control and load control. As shown in Table 1, average values of traffic intensity did not indicate very high traffic variations except for the month of October and December. These two

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Peak Hour	It is that hour during the day in which traffic intensity is at its peak	-	-	-

months recorded higher traffic rates which can be attributed to the celebrity mood of the country (Independence celebration and Christmas/ New Year seasons). However, some routes also indicated very poor traffic intensity such as 55.3 Erlang, 53.4 Erlang, 58.9Erlang, etc. These were indications of equipment faults that resulted to blocked calls, poor quality communication, constant interruption of services, and long term high load of cells. These abnormal key performance indicators were mostly observed in routes 7 and 8 as shown in Figure 2 below. The implication of this may result to customers resorting to network substitution.

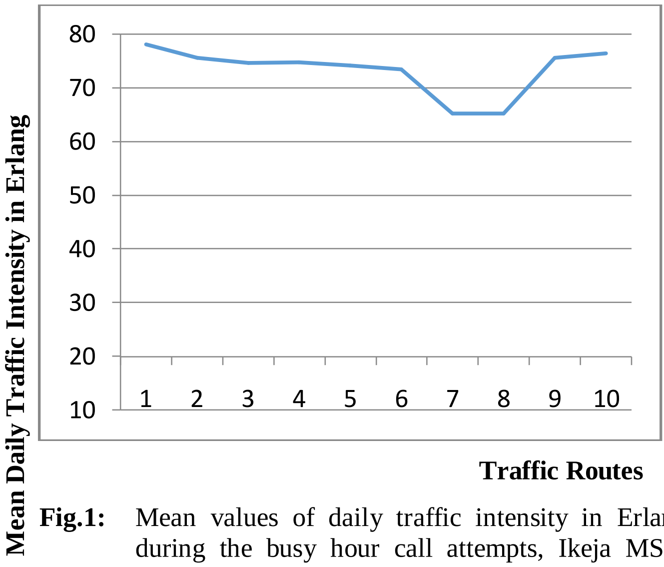

Fig.1: Mean values of daily traffic intensity in Erlang during the busy hour call attempts, Ikeja MSC. October, 2010 – March, 2011.

Table 3:ITU/NCC KPIs/BENCHMARKS

Key Performance Indicators KPIs	Definitions	Equations	Benchmarks ITU	Benchmarks NCC
Call Set up Success Rate (CSSR)	A measure of calls or signals successfully established	Unblocked call attempts x 100% / Total attempted calls	90%	≥ 98%
Call Drop Rate (CDR)	Measure of ability to retain all calls or signals established or connected.	Number of drop calls x 100% / Total number of calls attempts	2%	≤2%
Call Completion Success Rate (CCSR)	The ratio of successful completed calls to the total number of attempted calls.	Total number of completed call x 100% / Total number of call attempted	90%	≥ 96%
Hand over success rate	A measure of call handover commands successfully carried by the network		90%	≥ 98%

Figure 1 is the mean values of daily traffic intensity in Erlang analyzed during the busy hour, while Table 3 is a tabular presentation of key performance indicators' bench – marks for mobile telephony. These KPIs were stipulated by the International Telecommunications Union (ITU), the world's telecommunications regulatory body and Nigeria Communications Commission (NCC); the regulatory body of Nigeria, where this investigation was carried out. The recommended standard value for each performance indicator is clearly indicated in the table. These values serve as comparative bench marks from where network performance appraisal for this investigation was based.

Figure 2, is a graphical presentation of data extracted from mean values of traffic set-up success rate of the routes covered by this investigation.

Fig.2: Call Set Up Success Rate (%) Versus Traffic Routes

From figure 2, call set-up success rate indicated the following: Routes 1, 2, 3, 4, 5, 6, 9, and 10 recorded very high traffic success rates ranging from 88.7 per cent to 97.2 per cent. As observed from Table 2 on traffic intensity, Routes 7 and 8 showed poor call set-up success rates of 53.2 percent and 61.7 percent respectively.

Figure 3 shows the observed mean daily values of call drop rates per route.

ISSN: 2278 – 7798

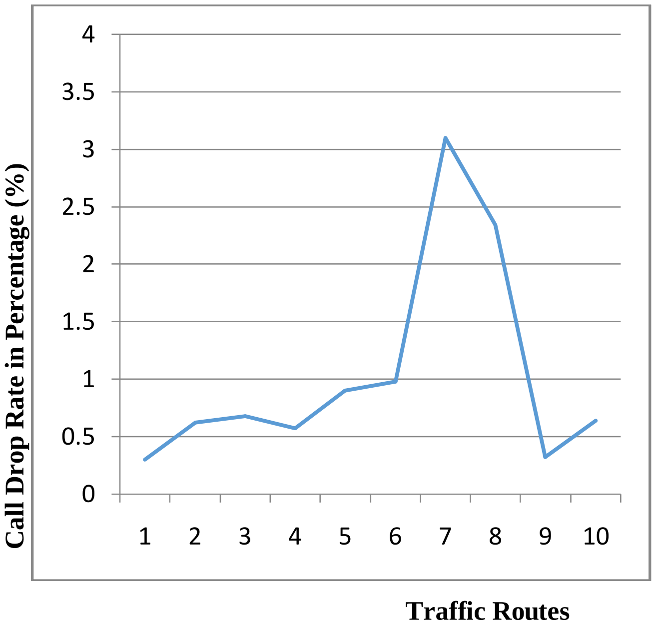

Fig 3: Mean daily value of call drop rates versus traffic routes

Indication from the graph, shows that routes 1, 2, 3, 4, 5, 6, 9 and 10 measured below the benchmark of the international and national regulators. (compare Table 3 and Fig.3). Exceptions were noted in routes 7 and 8 where the OMC recorded 3.1% and 2.3% respectively.

Figure 4 is the mean values of Call Completion Success Rate versus Traffic routes.

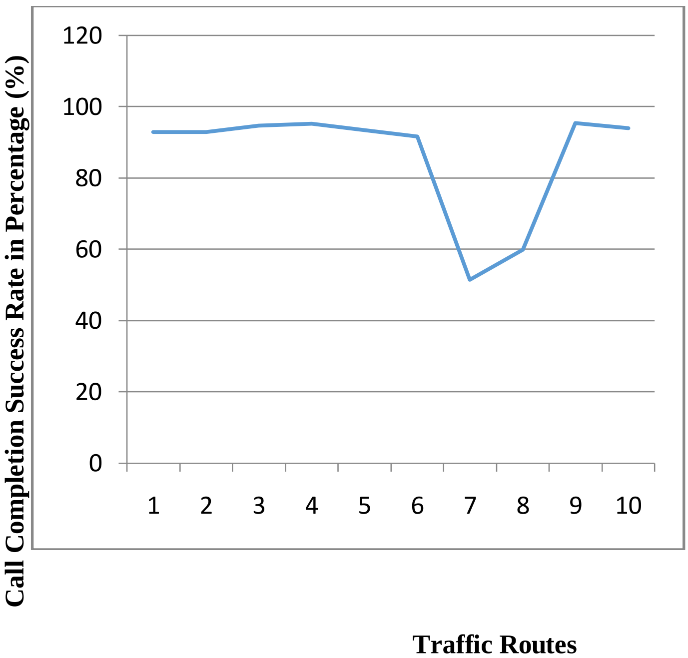

Fig.4: Mean value of Call Completion Success Rate versus Traffic Routes.

From the analysis, routes 1, 2, 3, 4, 5, 6, 9 and 10, recorded values that were below the national regulatory benchmarks, though within ITU's specification. However, the source of worry was routes 7 and 8 where the OMC recorded 51.4 per cent and 57.8 per cent respectively.

Figure 5 is the mean values of Handover Success Rate in Percentage versus Traffic Routes

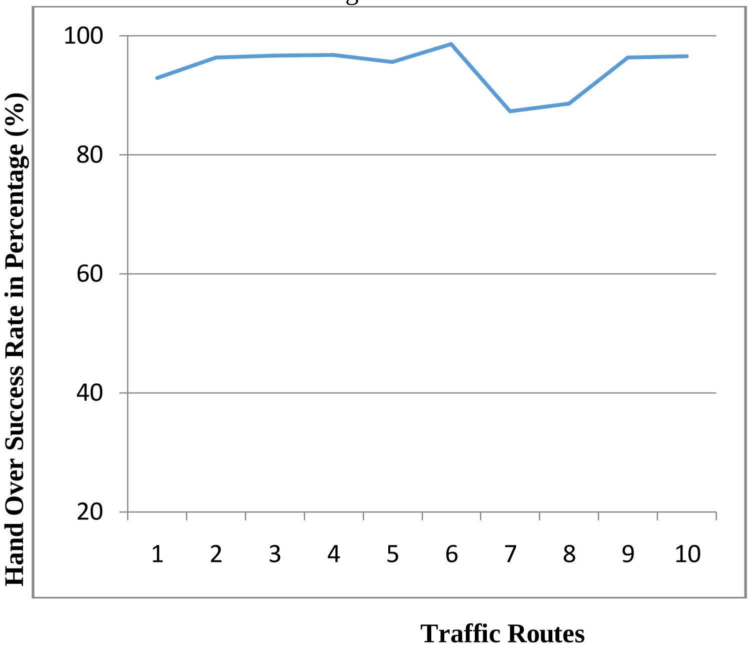

Fig. 5: Mean values of Handover Success Rate (in Percentage) versus Traffic Routes

Results as tabulated in Figure. 5, recorded good handover success rates for routes 1, 2, 3, 4, 5, 9, and 10. These routes indicated success rate above ITU's specifications; though below the national standard. Route 6, posted a remarkable value of 98.6 per cent. Route 7 and route 8 were again very poor in handing over from one cell to another.

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4.0 DISCUSSION AND CONCLUSION

The aim of this study is to carry out a pilot case-study of a core mobile operator in Nigeria, using one centralized network node (main switching centre), to evaluate the network load features.

Accordingly, data record by the Operation and Maintenance Centre (OMC) of the Mobile Switching Center (MSC) for selected routes (routes 1 to 10) were analyzed as reflected in Table 1, Table 2 and Figures 1 to 5. From these analyses, the traffic spectrum of the network node was determined as indicated. Grade of service is a measure of the total number of calls lost divided by the total number of offered calls.

The Grade of service offered by the routes under investigation was relatively good. The average call set up rate was 85.92 per cent, the average call drop rate was 01.05 per cent, the average call completion success rate was 85.9 per cent, while the hand over success rate recorded 94.6 per cent. These values, when compared with the international/national bench-marks, showed remarkable performance. However, Route 7 and Route 8 indicated poor traffic flow features. The reasons for these poor performance indicators may be caused by any of the following:

- The geographical location, such as shadow of high building, corners along the routes.
- Incorrect interpretation of information about user subscription, such as the maximum rate of uplink and downlink link; or the assumed bit rate may be smaller than the operational settings, thereby causing a delay in call set-up.
- Wrong configuration of parameters
- Improper connecting cables, abnormal optical interface
- Lower rate than the data throughput line, caused by many users of Bluetooth technology.
- Imbalance load between cells,
- Serious interference with adjacent cells.

The operator and regulator may troubleshoot the affected routes by checking the load and traffic flow in order to restore the above mentioned bottle-necks accordingly.

This pilot case-study can also be extended to locations/operators with high customer service-dissatisfactions/complaints.In addition, periodic measurements should be taken on these routes in order to observe changes in the quality of active set, radio quality of the adjacent cells. These shall aid the network operator that they meet the triggering conditions of handover. The destination cells on these routes may be under hard handover, and not handover fault, due to restrictions under the influence of the radio resource management algorithm. This problem occurs when the radio links established in these adjacent cells cannot synchronize with the radio links in the active sets, nor conduct soft handover.

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