HANDOVER ANALYSIS

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Abstract

Mobility is the most important feature of a wireless cellular communication system. Usually, Continuous service is achieved by supporting handoff (or handover) from one cell to another. Handoff is the process of changing the channel (frequency, time slot, spreading code, or combination of them) associated with the current connection while a call is in Progress. It is often initiated either by crossing a cell boundary or by a deterioration in quality of the signal in the current channel. All the events being occurred over air interface are triggering different counters in the Base Station Controller(BSC). All GSM operators use Key Performance Indicators (KPIs) to judge their network performance and evaluate the Quality of Service (QoS) regarding end user perspective. In this paper, a well established real GSM handover analysis evaluation is presented. It has been focused to analyze the live network performance; irrespective of the discussions and modeling available in the literature. Different issues, findings, trials and improvements have been summarized and observations/recommendations have been listed to correlate the practical aspects of handover, which increase the QoS of an operational cellular network.

Index terms *MS, TRX, BTS, BSC, MSC, OMCR, CSSR,CDR, HSR, TCH, KPI and QoS.*

1. INTRODUCTION

GSM network usually called as 'cellular network' (as the whole coverage area is divided into different cells and sectors) is comprised of a mobile Station (MS) which is connected to the Base Transceiver Station (BTS) via air interface. In addition to other hardware, BTS contains the equipment called Transceiver (TRX), which is responsible for the transmission and reception of several radio frequency(RF) signals to/from the end user.BTS is then connected to the base station controller(BSC) via abis interface. BSC usually handles radio resource management and handovers of the calls from oneBTS (or cell/sector) to the other BTS (or cell/sector)equipped in it. BSC is then connected to Mobile Switching Centre (MSC).Before GSM network installation, RF network planning(RNP) teams plan the BTS sites to cover a certain specific area keeping

in view the terrain and population. Moreover, marketing teams also help RNP teams to predict population and user traffic estimation in the days to come. RNP teams visit the areas to be covered and prepare technical site survey reports (TSSR). RNP teams use specific enterprise tools such as MapInfo, ASSETT etc to plan the sites having different frequency and miscellaneous parameter allocations. Once the sites are planned, the next phase is to acquire the required land called site acquisition phase. After site acquisition, engineering teams install BTS sites. RNP teams also testify the planned sites with some test parameters and frequencies to verify their planned parameters and link budgets etc such as signal level, signal quality, speech quality, path balance, path loss, call connectivity and so on.To cater the subscriber demand, RF optimization teams ensure minimum blocking/congestion over air interface in order to provide better QoS to guarantee significant network performance. RF Optimization teams used to analyze performance stats and evaluate QoS offered by the existing network. Since the deployment of GSM network, it has been observed practically that there are many phenomena and issues which have been neglected in literature/available text but they severely influence the network performance.

2. EVALUATION CRITERIA

GSM network performance and QoS evaluation are the most important steps for the mobile operators as the revenue and customer satisfaction is directly related to network performance and quality. Radio frequency network optimization (RNO) teams play a very significant and vital role in optimizing an operational network to meet the ever increasing demands from the end users.

Usually the following tasks are assigned to RNO teams:

1) To improve the existing network coverage and capacity.
2) To improve the offered service quality for fulfillment of customer demands.
3) To maintain the KPIs under pre-defined threshold.
4) To sustain the QoS criteria being imposed by country's regulatory authority.
5) To standardize and benchmark the network performance with that of competitor's network to

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attract more customers; keeping a balance between cost and quality.
6) To effectively reuse the available bandwidth and frequency carriers in order to avoid internal   interference and service degradation.

3. PERFORMANCE EVALUATION

GSM Network service providers analyze the network performance and evaluate service quality indicators. These indicators can be used for the following mentioned purposes:
1) To identify and locate BSS (hardware) occasional faults to ensure physical resource availability.
2) To help RF tuning teams to analyze the radio situation, detect radio network problems in one or more BTS and finally devise a way to optimize the network and adopt corrective actions like new frequency allocations, antenna tilt adjustment, and parameter modification in OMCR database etc.
3) To monitor system behavior and variance in terms of traffic load, congestion, successful attempts etc.
4) To predict the upcoming traffic evolution and network expansions as per increasing number of mobile users.
5) To benchmark network with another competitor's network to attract more users at the cost of better quality.

4.PERFORMANCE EVALUATION FLOW

Usually the network performance and indicators are badly affected due to wrong site integrations especially in terms of definition and parameter point of view. Following are the requirements of optimization team in terms of network operation:

1) Frequency allocation Plan
2) Broadcast control channel (BCCH) Plan
3) Neighboring cells Plan
4) Interference (C/I, C/A) values
5) Best Server Plots
6) Site Audit Reports

In order to be capable to measure the network performance, the patterns of a normal day should be considered, while for performance evaluation congestion situations should also be analyzed. Following KPIs aremore important for GSM radio network optimization & benchmarking to achieve remarkable QoS:

1) CSSR (Call Set up Success Rate).
2) CDR (Call Drop Rate).
3) HSR (Handover Success Rate).
4) TCH (Traffic Channel) Congestion Rate.
5) RX Level.
6) RX Quality.

CALL ORIGINATION PROCEDURE

Call origination process has been briefly mentioned here from counters perspective.

Step1: Channel Request or demand sent to BTS by MS in order to set up a call. BTS then forwards the request to BSC.A counter activates in BSC upon receiving channel request from MS in a cell/BTS.

Step2: BSC sends the channel activation command to MS through BTS. Another counter activates here in order to count the channel allocation in a cell/BTS.

Step3: After the channel allocation, call initiates after necessary authentication from core/MSC end. Once the call connected, another counter starts in order to count the abnormal call drop or failures (due to BSS or radio link problems).

KPI ASSESSMENT & QOS ESTIMATION

In order to understand how the behavior of traffic channels(TCH) and control channels (SDCCH) affects the network's performance; one has to analyze TCH and SDCCH blocking when congestion in the network increases . The above mentioned KPIs are frequently used in performancejudgment and QoS estimation of the network.

1.CALL SET-UP SUCCESS RATE (CSSR)

Indicator CSSR
Definition Rate of call attempts until TCH successfulassignment.
Formula Number of successful seizure of SD channel by Total number of requests for seizure of SD channel.
Result $=[(CT01+CT02)/CT03]*100$
ConditionApplied
Where counter CT01 counts SD channels successfully seized for Call termination &CT02 counts SD channels successfully seized for Call origination.CT03 counts SD seizure requests. Where SD (usually called SDCCH stands for Stand-alonededicated control channel) and TCH stands for Traffic channel. A number of issues are related for its degradation as addressed below.
a) Issues Observed:
CSSR might be affected and degraded due to following issues:
1) Due to radio interface congestion.
2) Due to lack of radio resources allocation (for instance:SDCCH).
3) Increase in radio traffic in inbound network.
4) Faulty BSS Hardware.
5) Access network Transmission limitations (For instance :abis expansion restrictions)
b) Analysis & Findings:

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Following methods are used to diagnose CSSR degradations as well as improvements:

1) Radio link Congestion statistics monitored using radio counter measurement.
2) Drive Test Reports.
3) Customer complaints related to block calls have been reviewed.

c)Improvement Methodologies:

Following measures significantly improve the CSSR in live network:

1) Radio Resources enhancement (Parameter modification/changes in BSS/OMCR) such as half rate, traffic load sharing and direct retry parameters implementation.
2) Transmission media Expansion to enhance hardware additions (such as TRX).
3) Faulty Hardware Replacement (such as TRX) in order to ensure the resources availability in live network

2.CALL DROP RATE (CDR)

Indicator CDR
Definition Rate of calls not completed successfully.
Formula Number of TCH drops after assignment by Total number of TCH assignments.
Result =[(CT04+CT05)/CT06]*100
Condition Applied
Where CT04 counts TCH drops due to radiointerface problems & CT05 counts TCH drops due to BSS problems. CT06 countsnumbers of TCH successfullyseized/assigned.A number of issues are associated to its degradation asdemonstrated below.

a)Issues Observed:

CDR might be affected due to following issues:

1) Interference (either external or internal) being observedover air interface. Internal interference corresponds toin-band (900/1800 MHz) while external interferencecorresponds to other wireless (usually military)networks.
2) Coverage limitation is also one of the factors, whichincrease CDR values.
3) Hardware faults (such as BTS transceiver) can also beincorporated in an increasing CDR, which is a part ofBSS failures.
4) Missing adjacencies (definition in BSS/OMCR) is alsoan important factor in CDR values increment.

b)Analysis & Findings:

Following methods are used to diagnose the rise in CDR values:

1) Radio uplink statistics monitored using radio counter measurement in order to confirm any uplink interference.
2) Path Balance stats which depict average of 'ERP-RX Power' (where 'ERP' stands for effective radiated power over downlink and 'RX' stands for receive power over uplink) also divert attention towards faulty Transceivers hardware.
3) Customer complaints related to block calls would have been reviewed.

4) Interference band / Spectrum scanners are also useful in finding and tracing the contaminated frequency carriers resulting in increasing CDR.
5) Drive Test Reports.

c)Improvement Methodologies:

Following are some methods in order to improve the CDR value up to certain pre-Defined baseline:

1) Faulty Hardware Replacement in order to ensure the resources availability in live network.
2) Frequency plans review and model tuning in order to ensure the clean band carriers for serving cells. For instance; band conversion is done from 900 to 1800MHZ in order to cater uplink interference. Some times concentric cells (multi band cell having GSM & DCS(transceivers) solution is also devised.
3) New site integration is also suggested in order to improve indoor and outdoor coverage, which is usually termed as "Grid Enhancement".
4) Sometimes RF repeaters are also used in order to amplify the radio signal to extend coverage area.
5) Existing coverage optimization might be done usingphysical optimization techniques.
6) Parameter tuning can also be done to improve call sustainability. This is done using OMCR terminal. For Instance Power control parameters. Decrease emittedpower when signal receive level and quality (measuredby peer entity) are better than a given value and viceversa.
7) Frequency hopping technique is also incorporated tominimize the effect of interference.
8) Change of antenna orientation (azimuth/tilt) i.e.,increase the down tilt of interferer cell antenna.

3.HANDOVER SUCCESS RATE (HSR)

Indicator HSR
Definition Rate of successful handovers (intracell +intracell).
Formula No of successful [intercell + intracell] HA1 by Total number of handover requests.
Result =[(CT07+CT08)/(CT09+CT10)] *100
Condition Applied
Where CT07 counts no. of incomingsuccessful handovers & CT08 counts no. ofoutgoing successful handovers. CT09 countsno. of outgoing HO requests while CT10counts no. of incoming HO requests.A number of issues are related for its degradation asillustrated below:

a)Issues Observed:

HSR might be affected and degraded due to following issues:

1) Interference (either external or internal) being observed over air interface, which might affect on going call switching in case of handover.
1) HA stands for Handover Attempts
2) Missing adjacencies can also result in HSR degradation.
3) Hardware faults (such as BTS transceiver) can also beincorporated as a decreasing HSR, which is a part ofBSS failures.

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4) Location area code (LAC) boundaries wrongly planned and/or defined (where Location area represents a cluster of cells).

5) Coverage limitation is also one of the factors, which decrease HSR values.

b)Analysis & Findings:
Following methods are used to diagnose HSR degradations as well as improvements:

1) Radio Congestion statistics monitored using radio counter measurement in order to confirm congestion occurrence in a particular cell or area.

2) Neighboring plans reviewed and adjacencies audits being done.

3) Drive Test reports reviewed.

c)Improvement Methodologies:
Following methods are employed in order to improve the HSR in live network:

1) Interference free band i.e., Spectrum analysis might be done to ensure it.

2) Adjacencies audits must be done in order to improve HSR.

3) Coverage improvement is also a vital factor of HSR enhancement.

4) BSS Resources addition (such as TRX) is also a factor for HSR improvement.

5) Parameter modification in OMCR such as Handover margin, traffic handover, power budget parameters to assist better cell handovers.

4.TCH CONGESTION RATE (TCHCR)

Indicator TCH Congestion
Definition Rate of blocked calls due to resource unavailability
Formula Number of calls blocked due to resource unavailable by Total number of requests.
Result $=(CT11 / CT12)*100$
Condition Applied
Where CT11 counts number of assignmentfailures when no TCH available while CT12 counts number of normal assignment requestsfor TCH establishment.A number of issues are related for its degradation, whichwould be addressed here.

a)Issues Observed:
TCH (traffic channel) congestion might arise due tofollowing issues:

1) TRX Hardware faults can also be incorporated as an increasing factor in TCH congestion.

2) Increasing number of subscribers and/or traffic in a certain area also causes congestion.

3) Lesser capacity sites (mainly due to the media issue or hardware resource unavailability) also cause congestion problems.

b)Analysis & Findings:
Following methods are used to diagnose TCH congestion as well as improvements:

1) Radio Congestion statistics monitored using radio counter measurement in order to confirm congestion occurrence in a particular cell or area.

2) Customer complaints can also reveal the issue.

3) Drive Test reports reviewed.

4) WCR (Worst Cell Ratio) and CSSR (Call Set up Success Rate) KPIs also depict the TCH congestion problem.

5) Future subscriber density and growth is also a factor for the judgment of upcoming congestion.

c)Improvement Methodologies:
Following measures are used to minimize the TCHcongestion in live network:

1) BSS Resources addition and expansion (including transceivers and transmission media) are important factors for TCH congestion improvement.

2) Faulty hardware maintenance or replacement can also minimize TCH congestion.

3) Deployment of moving/portable BTS (commonly called COW BTS) can be used as a better solution to improve congestion in case of foreseeable special events such as sports events, important meetings, festivals and exhibitions etc.

5. RX LEVEL:

a)Issues Observed:
Low RX level might arise due to following issues:
1)Antenna orientation and tilt
2)High VSWR value
3)Tx power
b)Improvement Methodologies:
Following measures are used to minimize the RX Level problems in live network:
1)Physical check of orientation and tilt
2)Check RF connectors and RF cables
3)Check the DRX power and connector

6.RX QUALITY:

a) Issues Observed:
Low RX Quality might arise due to following issues:
1)Interference
2)Low Rx level
3)H/O failure
4)Assignment failure ratio
5)Hardware problem
b)Improvement Methodologies:
Following measures are used to minimize the RX Quality problems in live network:
1)Define proper neighbors
2)Check DRX power and connectors
3)Check BCCH and MAIO frequency
4)Reduction of antenna height, orientation and tilt

5)Check the neighbor list and definition
6)Check the neighbor parameters
7)Check DRX and check VSWR and RF cable connectivity
8)Check DRX hardware

CONCLUSION & RECOMMENDATIONS:

The paper describes simple procedure for cellular network performance estimation. In this paper, it has been analytically proved that we can optimize an existing cellular network using different methodologies and fine parameter tuning to offer remarkable QoS to the endusers. Moreover, the issues discussed here are quite helpful for the analysis and performance evaluation of different cellular networks. Optimization teams use QoS reports in order to detect bad service quality areas. These reports also help to plan operators to enhance coverage, improve quality and increase capacity in the days to come. A mobile operator can also set its own QoS targets based on the KPIs in order to ensure end user satisfaction. QoS reports based on different KPIs are duly beneficial for Management team to compare network performance with the competitor's one (called benchmarking) and to plan network evolution and strategy.

Moreover, it is hereby strongly recommended that all mobile operators must ensure a better QoS up to certain threshold and baselines in order to satisfy official regulatory bodies who penalize operators in case of customer complaints regarding service quality. Hence, during radio network planning, it is suggested to all mobile operators that they must divert attention towards better network dimensioning & topology, allocated band scanning, traffic prediction & modeling, network operational expense (OPEX), and network parameter settings to avoid subsequent issues during optimization phase. Secondly, end users require stringent QoS, which compels cellular operators to optimize network performance to meet revenue and commercial targets as well.

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