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Handover and Call Drop Optimization Techniques

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Abstract *— Optimization initiatives typically involve leveraging advanced technologies and enhancing existing network systems to improve Quality of Service (QoS). These efforts may include eliminating redundant data, implementing data compression, enhancing application delivery, and applying traffic shaping techniques to reduce packet loss. This article aims to support on-site engineers in addressing handover and call drop issues. Handover-related challenges continue to pose significant problems for telecommunications providers in The Gambia and globally. Although researchers have made considerable progress in the field of wireless communications, many issues remain unresolved. Handover is closely associated with call drops, as handover failures often result in dropped calls. Therefore, addressing handover-related call drops is a key component of optimizing handover success rates. This paper outlines methods for evaluating network handover and call drop performance, as well as testing and troubleshooting techniques.*

***Keywords*— Handover, call drop, optimization, QoS.**

I. INTRODUCTION

1.1 As GSM technology continues to evolve with remarkable advancements particularly in data-driven technologies like LTE and 5G. The need to establish effective and seamless interfaces between these newer generations and legacy systems such as the Global System for Mobile Communications (GSM) and Universal Mobile Telecommunications System (UMTS), which primarily support voice services, becomes increasingly critical to ensure uninterrupted service continuity [4].

1.2 One of the key features of 3G networks is their integration with 2G networks. The current deployment of Circuit-Switched (CS) networks enables interoperability and flexibility in managing handovers, thus supporting continuous service delivery.

1.3 Wireless Local Area Network (WLAN) coverage, on the other hand, provides additional support in areas with low signal strength [1]. When a User Equipment (UE) initiates a call in one UMTS Terrestrial Radio Access Network (UTRAN) Registration Area (URA) and moves into another URA particularly in a handover region. The UE measures and compares the signal strength from newly detected cells through Inter-Radio Access Technology (IRAT) reselection processes. It then attempts a successful handover, provided the serving cell has defined neighbor relations with the strongest measured cell and that the required signal quality thresholds-such as minimum Energy per Chip over Interference (Ec/Io) and Received Signal Code Power (RSCP)-are satisfied [6]. If this handover attempt fails, it can result in a call drop.

1.4 This document aims to assist on-site engineers in addressing handover and call drop issues by outlining optimization methodologies, performance evaluation techniques, and effective testing and troubleshooting methods.

This paper is organized as follows:

Section I provides a brief introduction to the concepts of handover and call drops, highlighting their close relationship.

Section II presents a flowchart that outlines the necessary steps for detecting, evaluating, analyzing, and addressing handover and call drop issues.

Section III discusses the design and implementation of the Drive Test (DT) procedures and optimization systems.

Section IV focuses on network optimization strategies for improving handover success rates and reducing call drops, including a detailed description of the network operation flow. It also analyzes common problems encountered during network optimization.

Section V concludes the paper, acknowledgement and provides references.

II. DRIVE TEST (CALL QUALITY TEST) OPTIMIZATION FLOW

Drive Test and Call Quality Test are essential tools for network evaluation and optimization. The Key Performance Indicators (KPIs) derived from Drive Tests and Call Quality Tests serve as benchmarks for verifying network performance. Overall, Drive Testing enables the assessment of network coverage, identification of cells with missing neighbors, and detection of cross-cell coverage issues.

Hard Handover (HHO) and Inter-Radio Access Technology (IRAT) handovers are particularly useful for resolving coverage issues in special scenarios where Call Quality Testing is also appropriate. In this section, we briefly describe the optimization flow of Drive Testing and Call Quality Testing, specifically in the context of Soft Handover (SHO), Hard Handover (HHO), and IRAT handovers.

While incorrect or missing configuration data can lead to various types of handover failures, IRAT handover failures often involve more complex factors—such as challenging radio conditions, mismatches between network technologies, and ping-pong reselection behavior. Special attention should be given to configuration parameters at the Radio Network Controller (RNC) level, including the Mobile Country Code (MCC), Mobile Network Code (MNC), Location Area Code (LAC), and Base Station Color Code (BCC), among others.

However, handover failures are rarely caused by configuration mismatches alone, as such issues typically trigger alarms visible on network monitoring tools. Consequently, this section focuses on Soft Handover (SHO) optimization, where certain failures may not be reflected in monitoring systems and must instead be identified through on-site Drive Test data collection.

The flowchart depicting the proposed Soft Handover Drive Test detection and analysis process is shown in **Figure 2.1** below. The sequence of events is explained as follows:

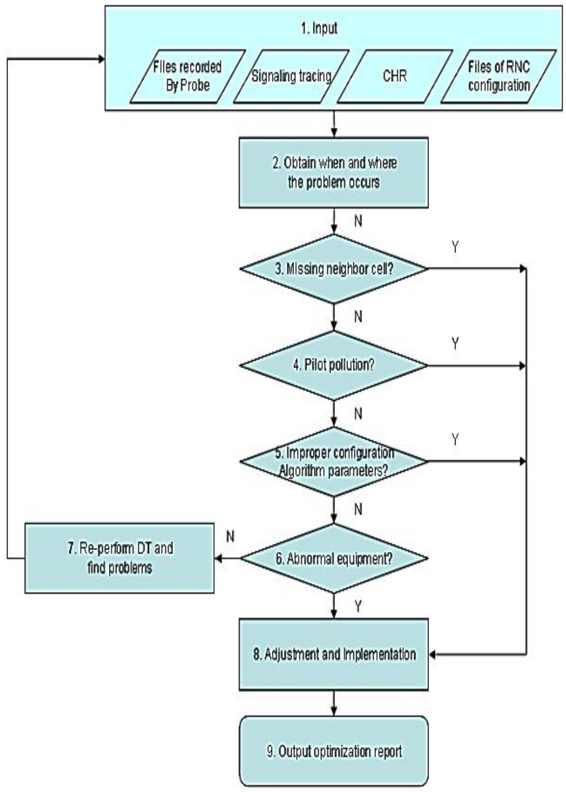

Fig.2.1 SHO DT data analysis flow

2.1 Inputting Analysis Data:

During the detection and evaluation of handover and call drop problems, a drive test is essential for understanding UE behavior in connected and idle modes by collecting data, correlating signaling traces, and retrieving Radio Network Controller (RNC), Call History Records (CHR) and RNC MML scripts. While testing, a Soft-Handover (SHO), related call drop may occur, or the SHO itself may fail. Each such occurrence must be logged, with the precise location and timestamp recorded for subsequent analysis.

2.2 Missing Neighbor Cell:

During the initial stages of optimization, a common assumption is that call drops are often caused by missing neighbor relations. To confirm the presence of inter/intra-frequency missing neighbor cells, the following methods should be employed:

- ✓ **Check the active set Ec/Io recorded by the UE before the call drop and the Best Server Ec/Io recorded by the scanner**.
  Determine whether the Best Server's scrambling code recorded by the scanner is included in the inter/intra-frequency neighbor cell list from the measurement control message before the call drop. A missing inter/intra-frequency neighbor cell is likely if **all** the following conditions are met:
  - The Ec/Io recorded by UE is poor.
  - The Best Server's Ec/Io is strong (good).
  - The scrambling code of the Best Server is not present in the intra-frequency neighbor cell list.
- ✓ **Observe UE reconnection behavior after the call drop**
  - If the UE reconnects immediately after the call drop and camps on a cell with a different scrambling code than the one at the time of the drop, then a missing neighbor cell is suspected between the cells.
  - Confirm this by reviewing the most recent inter/intra-frequency measurement control message before the drop (trace back through signaling messages). Then check whether the scrambling code of the post-reconnection cell was included in the neighbor cell list of that measurement control message.

Neighboring relations between cells are crucial for ensuring the continuous delivery of services within a network. While missing neighbor cells can lead to call drops, redundant neighbor cells can also negatively impact network performance. They increase the signaling overhead and the UE's intra/inter-frequency measurement load. If this issue becomes severe, it may prevent essential neighboring cells from being properly listed, thereby compromising handover success and overall service quality.

2.3 Pilot Pollution:

Another factor contributing to call drops and handover failures is **pilot pollution**. Pilot pollution typically occurs in areas where multiple strong pilot signals are present, but none is strong enough to serve reliably as the primary pilot. This results in interference and confusion for the UE during cell selection or handover processes.

To define rules for identifying pilot pollution, confirm the following criteria

- ✓ **Definition of strong pilot:** A pilot (CPICH) is considered *strong* if its (RSCP) is above a predefined absolute threshold:
  $CPICH\_RSCP > Th_{RSCP\_Absolute}$
  This threshold determines whether a signal is strong enough to be considered useful.
- ✓ **Definition of "excessive":** the number of strong pilots at a location is evaluated. If the number exceeds a defined limit (Th_N) it's considered excessive**:**
  $CPICH\_Number > Th_N$
- ✓ **Definition of "No best server strong enough"**: This is where your image fits. It refers to a **lack of a clearly dominant pilot**, even though many are strong. It uses the difference between the RSCP of the strongest pilot and that of the $(Th_N + 1)^{th}$ strongest pilot:
  $$(CPICH\_RSCP_{1st} - CPICH\_RSCP_{(Th_N+1)th}) < Th_{RSCP\_Relative}$$

Following the descriptions, pilot pollution exists if the following conditions are met:

- ✓ The number of pilots satisfying $CPICH\_RSCP > Th_{RSCP\_Absolute}$ is more than Th_N.
- ✓ $(CPICH\_RSCP_{1st} - CPICH\_RSCP_{(Th_N+1)th}) < Th_{RSCP\_Relative}$

Set $Th_{RSCP\_Absolute} = -95\ dBm$, $Th_N = 3$, and $Th_{RSCP\_Relative} = 5\ dB$, the judgement standards for pilot pollution are:

- The number of pilots satisfying ***CPICH_RSCP > - 95dBm*** is greater than 3.
- ***($CPICH\_RSCP_{1st}$ – $CPICH\_RSCP_{4th}$) < 5dBm***

2.4 Improper Configuration of SHO Algorithm Parameters:

To address call drops and handover failures, two major problems must be resolved by fine-tuning the Soft Handover (SHO) algorithm parameters:

✓ **Delay handover**

In CS (Circuit Switched) services, the User Equipment (UE) may fail to receive the *Active Set Update* command due to timing issues. After the UE reports a measurement message, the Ec/Io of the original cell may drop sharply. By the time the Radio Network Controller (RNC) sends the *Active Set Update* message, the UE may have already powered off its transmitter due to synchronization loss, preventing it from receiving the update.

In PS (Packet Switched) services, the UE may either fail to receive the *Active Set Update* message or perform a Traffic Radio Bearer (TRB) reset prematurely before the handover is completed.

Common scenarios leading to delayed handover include:

- **Turnng corner effect**: The Ec/Io of the serving cell drops sharply, while that of the target cell increases rapidly resulting in a temporarily high measurement value.
- **Needlepoint effect**: The Ec/Io of the original cell drops and momentarily recovers, while the Ec/Io of the target cell spikes for a brief period.

In both cases, the UE typically sends Event 1a and 1c measurement reports before the call drop. The RNC receives these events and issues an *Active Set Update* message, which the UE fails to process due to timing or synchronization issues.

✓ **Ping-pong Handover**

Ping-pong handovers occur when the UE repeatedly switches between two or more cells within a short time. This instability can be caused by two main conditions:

- **Frequent Best Server Changes:** The best server alternates quickly between multiple cells. Each cell may appear as the best server for only a short duration, despite having a strong RSCP.
- **Multiple Cells with Similar RSCP and Poor Ec/Io:** Several cells exist with nearly equal RSCP values, but all have poor Ec/Io, meaning no clearly dominant serving cell exists. As a result, the UE cannot identify a reliable primary pilot.

Signaling Analysis:

When one of the cells is deleted from the active set, the UE immediately reports Event 1a again. The rapid transitions prevent the UE from receiving the *Active Set Update* command in time, leading to a failed handover or potential call drop.

2.5 Abnormal Equipment:

Failures or abnormal functionalities can always be troubleshot by starting with the alarm console for abnormal alarms. Meanwhile, the trace messages should be analyzed to locate the SHO problem by checking the failure message.

2.6 Reperforming Drive Test and Locating Problems:

If the problem is not caused by any of the previously identified issues, perform the Drive Test (DT) again and collect DT data along with supplementary data from problem analysis.

After confirming the cause of the problem, adjust the network using the following appropriate methods:

- **For handover problems caused by pilot pollution:** Adjust the engineering parameters of the antenna so that a best server forms around the antenna. Also, adjust the engineering parameters of other antennas to weaken their signals and reduce the number of pilots. If these measures fail, construct a new site to cover the area (if conditions permit) or combine the two cells as one if the interference originates from two sectors of the same NodeB.
- **For abnormal equipment:** Consult the customer service engineer regarding abnormal equipment and the transport layer on the alarm console. If alarms are present on

the alarm console, cooperate with customer service engineers.

- **For call drops caused by delayed handover:** Adjust antennas to expand the handover areas, set the handover parameters for the 1a event, or increase the Cell Individual Offset (CIO) to enable handover to occur earlier.
- **For needle effect or turning corner effect:** Setting the CIO to 5 dB is recommended, but this may increase the handover ratio.
- **For call drops caused by Ping-pong handover:** Adjust the antenna to form a best server or reduce Ping-pong handovers by setting the handover parameters of the 1B event, including the 1B event threshold, 1B hysteresis, and 1B delay trigger time.

III. HARDWARE, DESIGN AND IMPLELEMTATION OF DRIVE TEST USING GENEX

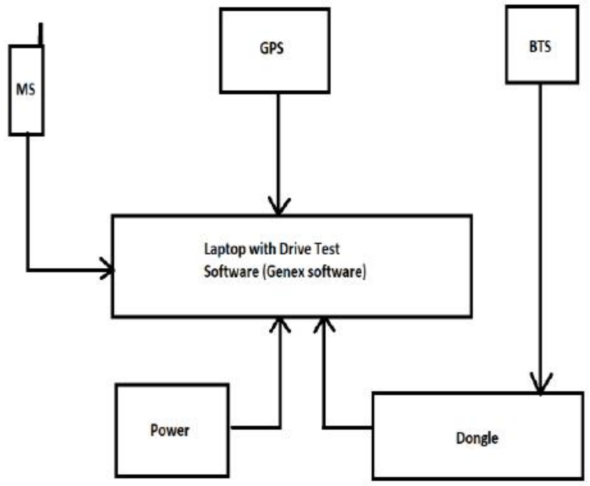

Fig.3.1 Drive Test System

To conduct a successful drive test, the drive test engineer must ensure that the engineering parameters are up to date to have accurate records of UE events during the test. These parameters include antenna azimuths, heights, mechanical and electrical tilting, frequency bands on site, and more. The data collected helps identify and analyze the causes of call drops, handover failures, and other network issues.

The basic Genex drive test tool consist of the following components:

- A laptop with drive test software and GPS connection capability, data cables and multi-connector port.
- A GPS tracker,
- A Drive test mobile phone (e.g. Huawei MT7-L09)
- An inverter or an AC/DC Power source

3.1 Laptop:

A Genex software is installed on the laptop as a tool to collect and visualize data during the drive test. It records the route taken and stores the data for later analysis using another software called "Genex Assistant"

3.2 GPS Tool:

GPS tracker monitors the movements of the drive test vehicle on a map to ensure the target route is fully covered.

3.3 Drive Test mobile phone:

One of the most important tools is the mobile station (MS), as the drive test aims to understand its behavior in both idle and connected modes. The tool captures the events the MS experiences during the test, such as attempted calls, successful and unsuccessful calls, handover success rates, and call drop rates. It also measures threshold settings (coverage, offset, etc.) to minimize unnecessary handovers.

3.4 The Inverter:

The inverter used is a DC-to-AC inverter. Its purpose is to keep the laptop charged during the drive test, preventing interruptions or data loss caused by the laptop shutting down if its battery is completely discharged before the drive test is completed.

IV. NETWORK OPTIMIZATION OF CALL DROP RATE AND HANDOVER

Call drops are typically related to the signaling flow leading up to the drop. These drops can also be observed during drive test analysis using tools like Genex Assistant, as illustrated in Figure 4.1

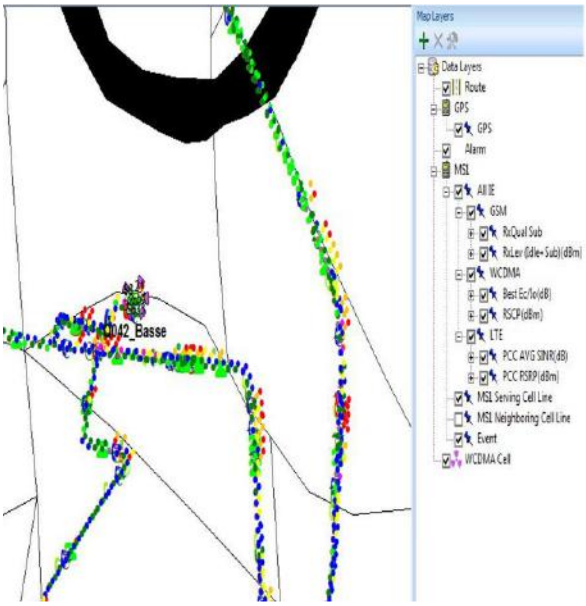

Fig.4.1 Short Call drive test to determine handover and call drop

4.1 Analysis

Check the pilot test data from both the UE and the scanner at the call drop points. Then, examine the scrambling codes recorded by the UE's active set and the scanner prior to the call drop. In the analysis, we observed that the measurement results from the UE active set and the scanner are inconsistent - the scanner detected a scrambling code that does not exist in the UE's active set.

This discrepancy may be caused by a missing neighbor cell configuration or delayed handover, as the scrambling code is not even present in the UE's monitor set, as shown in Figure 4.2 below.

If only the UE recorded information during the test, without scanner data, then call drops due to a missing neighbor cell can be investigated using the following methods:

- ✓ **Confirm the scrambling codes** of all cells in the active set, as well as those in the monitor set measured by the UE before the call drop.
- ✓ **Compare the scrambling code** of the cell that the UE camps on after reselection (i.e., after the call drop) with the scrambling codes in the UE's active set and monitor set before the call drop. If the post-drop scrambling code is not found in either the active or monitor sets before the drop, then the call drop is likely due to a missing neighbor cell.
- ✓ **Check the neighbor cell list** to verify whether the target neighbor is correctly configured. This is essential for resolving call drops caused by missing neighbor cell configurations at the site.

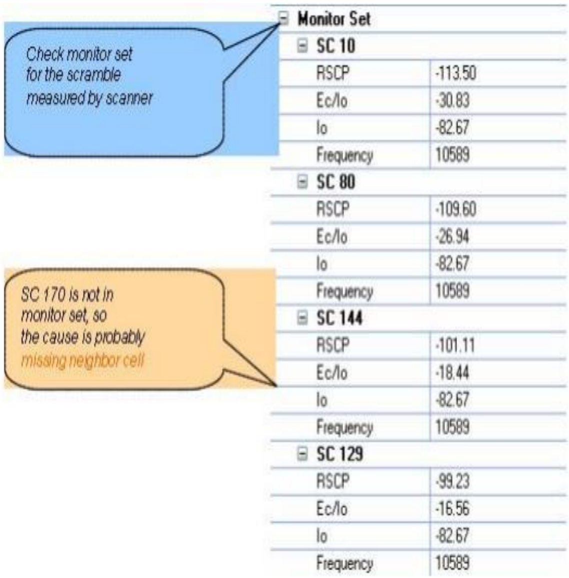

Fig.4.2 Analysis of short Call drive test to determine handover and call drop

4.2 Solution:

When a call drop is caused by a missing neighbor cell, the missing neighbor should be added to the neighbor cell list. This is because the RNC (Radio Network Controller) updates the measurement control information based on the best cell, which is determined through intra-frequency measurement reports specifically, those triggered by the 1D event before the measurement control is sent.

In the post-drive test analysis, after adding the missing neighbor cells, another call drop was observed. However, this time the drop was not due to a Radio Frequency (RF) issue. The scrambling codes of all cells in the active set and the monitor set, measured by the UE both before and after the call drop, were confirmed to be valid neighbor cells, as shown in Figure 4.3

Fig.4.3 Post drive test result

V. CONCLUSIONS

In this paper, we have demonstrated that handover is closely related to call drops. The call drop minimization techniques employed here effectively reduce the number of call drops and improve handover performance in mobile cellular networks, proving to be both efficient and reliable.

However, these techniques should not be considered exhaustive, as call drops and handover failures can also result from various other issues such as transmission failures, faulty channels, and more. For a network optimization engineer, conducting a drive test remains essential to accurately identify the root causes of call drops or handover degradation.

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