Understanding Mobile Terminated Call Failures

80-W2357-1, Rev A

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1 Summary

Have you ever missed a call on your mobile device even though you were in an area with sufficient network coverage? Failed mobile terminated calls (MTC) often lead to customer complaints because a subscriber's device appears to have sufficient signal strength, yet they have problems receiving incoming calls.

This paper explains how a MTC is typically established and outlines a process for collecting and analyzing data to better understand why these calls can sometimes fail. Results from collecting data on a commercial network implementation are presented and explained in detail.

Wireless network operators can use the methods described in this paper to guide them through the process of collecting and analyzing data around MTC failures, ultimately helping them to improve quality of service for their subscribers.

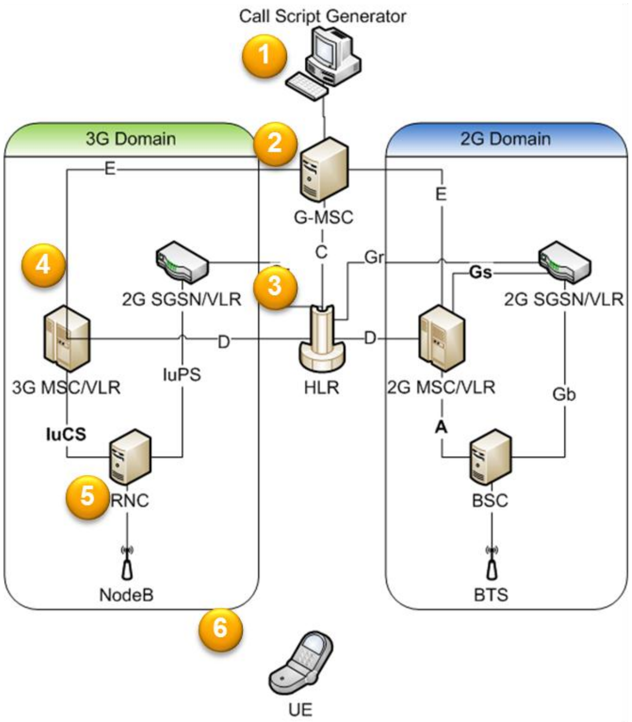
The results from our study show that failed calls were predominantly connected with IRAT reselection; however the process described in this paper has been designed with the flexibility to assess a wide variety of factors that can cause call deliver failure.

Although our scenario focuses on UMTS and GSM/GPRS cellular networks, the concept is also applicable to LTE network technology.

2 Mobile Terminated Call (MTC) Delivery

Figure 2-1 shows the routing procedure for a MTC, or incoming voice call. The call is first routed to the G-MSC which in turn queries the HLR to determine the subscriber's registered location area (LA). Once the LA is established, the call is routed to the corresponding MSC which generates a paging message.

In the majority of the active networks, a repetition strategy is implemented in the MSC and/or RNC/ BSC if there is no response to the initial paging. This gives the called party an extended opportunity to answer the second page so the call can be established.



1. Voice Call generated
2. Call arrives at G-MSC for routing
3. HLR query to identify LA / MSC
4. MSC sends paging to LA
5. UE responds on one Cell
   - RRC establishment if needed
   - Paging response
6. Call establishment

Figure 2-1 Simplified[1] MTC Procedure

Possible reasons a MTC call will fail:

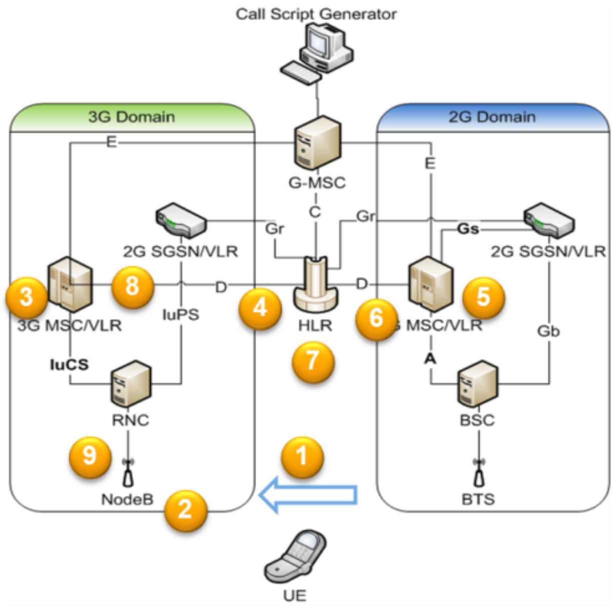
- Paging not routed correctly
- Paging not delivered to air interface
- Paging not received correctly over the air (misdetection probability)
- Failure to respond to paging (radio related)
- Failure to establish call

2.1 Location Area Update

In 3GPP network structure, paging and relocation procedures can occur at the same time. When this happens, the subscriber cannot be reached because the call is routed to the area they just left. Paging repetitions don't fully address this limitation.

[1] Only includes voice delivery calls (CS domain) and assumes the called party's device is registered and idle on the network so its location area (LA) can be determined.

Figure 2-2 shows an example of a location area update procedure. Variations, such as combined LAU/ RAU, can generate different “flavors” of the procedure, but the steps will essentially remain the same.



1. UE moves to new LA
2. Establishes RB connection
3. Sends LAU Request to MSC/VLR
   - Indication of old LA
4. New VLR send LAU req to HLR
5. HLR requests to delete UE in old VLR
6. Old VLR confirms deletion to HLR
7. HLR updates own database
8. HLR confirms update to new VLR
9. MSC/VLR sends LAU Accept
10. RB connection release

For Routing Area Update (PS) the procedure is equivalent involving SGSN

Figure 2-2. Simplified Location Area Update Procedure

In the majority of current implementations, incoming calls querying the HLR between steps 1 and 8 are expected to fail. This is not a network design flaw, but rather a limitation with most implementations that can partially be addressed. Failures typically occur when device and network information are out of sync during the location area update.

Operators can modify their network parameters to reduce the number of MTC failures using data derived from evaluating paging performance. The remainder of this paper describes how this data can be collected and analyzed to expose potential optimization opportunities.

3 Identifying Potential Network Optimizations

3.1 Capturing Data

To properly assess MTC failure causes it is crucial to capture data from both the network and user equipment (UE) and correlate it with precise time synchronization, within a millisecond. In our study, GPS was used to synchronize UE logging, and network time protocol (NTP) was used in network elements. Information was analyzed in the order it was collected so that success or failure could be determined at each step. When a step failed, additional logging data was used to identify the specific type of failure and identify areas for improvement.

Figure 3-1 shows the interfaces and devices used for time synchronized logging circled in red. To minimize the logging effort, only the signaling messages were captured. During further analysis, signaling was filtered to include only the key messages necessary to describe MTC setup progress.

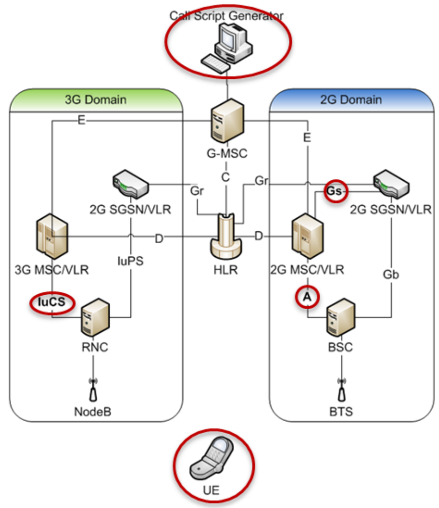


Figure 3-1 Synchronized Logging Sources

All circled interfaces and devices (Iu-cs, Gs and A) are involved in paging, call setup (also MTC) and location area updates (LAU). Therefore, a single signaling message (e.g. paging) can be captured across all interfaces on the network side and ultimately traced on the device. Because the various devices trace signaling differently, the resulting data must be harmonized to allow for a unified analysis.

The following RRC messages are used:

- Paging
- RRC Connection Setup
- Location Update Request
- Location Update Accept
- CONNECT

To optimize traces on user equipment, logs are collected on a test route that includes as many IRAT boundaries as possible. This increases the number of usable samples per test.

This process doesn't capture paging messages delivered over the radio interface, as this is technically challenging on a commercial network. However, systematic failures can be eliminated by ensuring there are successful cases. Also, the performance counter for *Dropped Paging Messages* indicates the source of MTC failures and can be used to identify opportunities for performance improvement.

3.2 Collecting Data

Only failure scenarios are being analyzed, so it is important to have a rough estimation of failure probability when performing test and analysis. Our study assumed a failure scenario of 1.5% MTC, correlating with IRAT (or more general LA) boundaries.

Keep in mind that the accuracy of the analysis will improve as the sample size increases. To maximize the number of calls collected while minimizing test time, 4 test devices were used in parallel during our study. To avoid collisions and maximize interaction with the IRAT/LA boundary, a script was used to create a 22 second offset between devices. Call duration was approximately 60 seconds, long enough to successfully establish a call or encounter failure. Calls were spaced 30 seconds apart to give the phone and network time to recover from an error condition before making subsequent calls. The resulting call pattern can be seen in Figure 3-2.

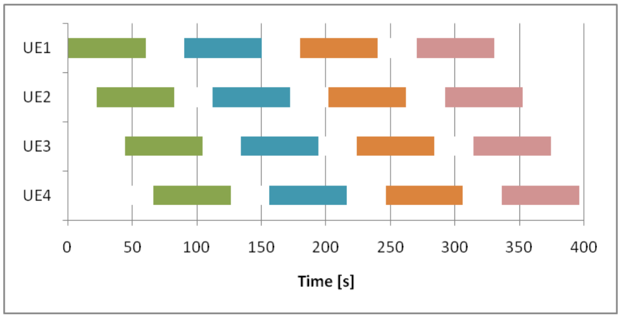


Figure 3-2. Call Generation Pattern

With these parameters, an estimated 160 calls per hour were captured on the 4 parallel terminals, resulting in a failure rate of 2.4%. Testing was conducted for 6 hours a day for 2 days, capturing an estimated 1,478 calls, including 50 expected failures.

During execution, the 4th terminal was used to capture idle mode behavior and parameters. This provided the opportunity to assess pure paging performance in a UMTS environment, another important factor for a complete analysis. Though not detailed in this paper, failure data collected from the idle device was used to assess cell quality by exposing areas where RF design was insufficient for paging delivery.

3.3 Interpreting Data

A total of 1,478 MTC were attempted, resulting in 50 MTC (3.4%) failures. An additional 85 (5.8%) calls relied on paging repetition to establish a call successfully, increasing overall calls affected to 9.1%. The network was configured with a single paging repetition (with IMSI) from the MSC in the same LAC after 2 seconds. Paging repetition from the RNC was not used. UMTS and GSM were configured with different LACs.

Figure 3-3 shows failure scenarios broken-out by category. Each category has been further broken-down in sub-categories that correspond to the information provided in Table 3-1.

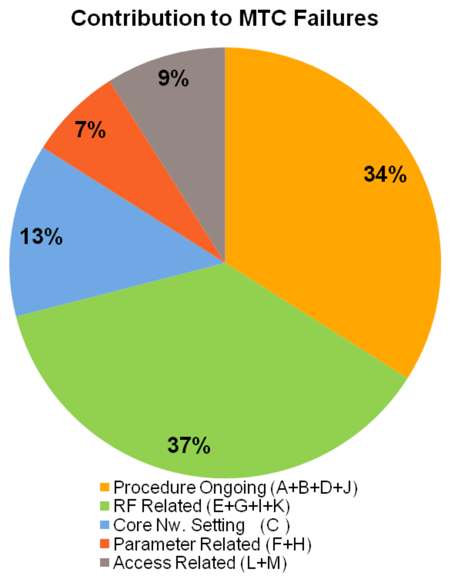


Figure 3-3. Contributing Factors for MTC Failures

	Failure Cause		Call OK	Call Failed	
			1st Page	1st Page	2nd Page
A	IRAT Reselection Ongoing	W2G	0	6	5
B		G2W	1*	**12**	2
C	No HLR re-query		-	-	13
D	LU ongoing on W		5	0	1
E	Poor RF	While on W	**30**	10	8
F		After G2W	0	1	2
G		While on G	10	2	2
H		After W2G	0	2	2
I	Missed Paging	While on W	**23**	6	3
J		After G2W	0	4	4
K		While on G	**14**	3	3
L	RRC Fails	At PRACH	1	2	2
M		At Setup	1	2	3
Total			*85*	*50*	*50*

W = WCDMA
G = GSM

Table 3-1. Detailed Causes and Occurrences

The "Call OK" column includes paging failures where repeated paging was able to establish the call. The "Call Failed" columns include cases when paging failed (first and repetition) and a call could not be established.

Each category and sub category includes failure details, a root cause analysis and recommendations for addressing individual facets of MTC failures. Improving MTC failures sometimes requires a tradeoff in performance. The analysis generates the data necessary to determine which tradeoff makes the most sense for achieving optimal performance.

Figure 4 shows the break-down of factors contributing to the failed the paging procedure. While the root causes are the same, the pie chart indicates the relative weight of these factors.

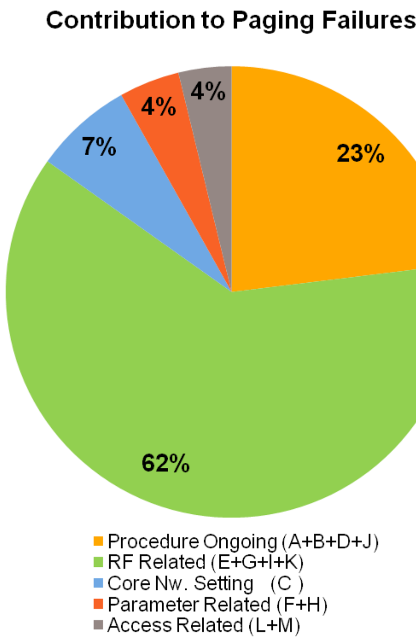


Figure 3-4. Contributions to Paging Failures

Reviewing the inter-arrival times and the paging repetition timer can help to estimate which paging was actually answered by the terminal. When combined with data on general paging performance, these statistics can help to identify potential adjustments for improving paging performance at the network coverage border (at cell boundary).

4 Conclusion

Operators can improve the mobile experience for their subscribers by reducing the number of missed incoming calls in areas with sufficient network coverage. The test and analysis methods defined in this paper will help network engineers to better understand failure scenarios and their root causes so they can adjust network parameters accordingly.

The methods are flexible enough to be used across various network technologies and do not require extensive measurements for assessing and improving mobile terminated call failures. To maintain optimal MTC performance, the assessment should be repeated periodically.

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Appendix A Glossary

GPRS	General Packet Radio Service
GSM	Global System for Mobile Communications
IRAT	Inter Radio Access Technologies
LA	Location Area
LAU	Location Area Update Procedure
MTC	Mobile Terminated Call
RAT	Radio Access Technologies
QPST	Qualcomm Product Support Tool
UE	User Equipment
UMTS	Universal Mobile Telecommunications System

Appendix B References

Number	Organization	Title
31.102	3GPP	3rd Generation Partnership Project; Technical Specification Group Core Network and Terminals; Characteristics of the Universal Subscriber Identity Module (USIM) application
24.008	3GPP	3rd Generation Partnership Project; Technical Specification Group Core Network and Terminals; Mobile radio interface Layer 3 specification; Core network protocols; Stage 3