Performance Analysis of Handover Scenario in Wireless Communication

[1]Raghunandan Vijayasarathi, [2]Yash Santosh Kulkarni, [3]Harsh Kumar Tiwari, [4]Raj Vivek Sharma
Electronics and Telecommunication Engineering K J Somaiya School of Engineering (formerly K J Somaiya College of Engineering),
Somaiya Vidyavihar University, Mumbai, Maharashtra, India

Kartik Ramesh Patel
Electronics and Telecommunication Engineering K J Somaiya School of Engineering (formerly K J Somaiya College of Engineering), Somaiya Vidyavihar University, Mumbai, Maharashtra, India

Abstract - Maintaining service continuity as mobile users traverse different coverage areas remains a critical challenge in wireless communication. Handover mechanisms facilitate seam- less transfer of active connections among base stations, directly impacting quality of service in cellular networks. This paper presents an in-depth performance analysis of handover scenarios in GSM (2G), CDMA (2.5G), and LTE (4G) systems, employing both software simulations using NetSim and hardware demonstrations via a Simnovus network emulator. Key performance indicators such as handover success rate, latency, throughput, Reference Signal Received Power (RSRP), and Reference Signal Received Quality (RSRQ) are evaluated under varying mobility patterns (static, file-based paths, random walk, and pedestrian). Results show that LTE outperforms legacy technologies in throughput (up to 150Mbps) and latency (as low as 30ms), while CDMA's soft handover enhances connection reliability in moderate mobility. The hardware setup, featuring an Arduino-controlled RC car as user equipment, validates simulation findings and highlights real-world considerations. Recommendations for adaptive handover strategies in next-generation networks are discussed.

Keywords—Handover, GSM, CDMA, LTE, Mobility Models, Throughput Latency.

I. INTRODUCTION

Seamless connectivity is fundamental to modern wireless networks, where users expect uninterrupted voice and data services irrespective of movement. Handover—the process of transferring an active session from one cell to another—is central to achieving this goal, yet it introduces challenges such as latency spikes, packet loss, and resource management overhead. Understanding the performance of various handover techniques across cellular generations is essential for network optimization and improved end- user experiences. Cellular networks have evolved from early GSM systems, employing hard handover, to advanced LTE and 5G architectures that support sophisticated mobility management. GSM's break-before-make strategy conserves resources but risks brief service interruptions. CDMA introduced soft handover, enabling make-before-break connectivity to enhance reliability. LTE further refines handover protocols using measurement reports, X2 interfaces, and optimized threshold algorithms.With the proliferation of bandwidth-intensive and latency-sensitive applications—such as high- definition video streaming, online gaming, and autonomous systems—networks must sustain high performance even under complex mobility. This work systematically compares handover performance in GSM, CDMA, and LTE under multiple mobility models, providing:

1) Quantitative metrics (handover success rate, latency, throughput, RSRP, RSRQ) via NetSim simulations.
2) Real-world validation using a Simnovus emulator and Arduino-driven RC car setup.
3) Insights into the trade-offs of hard vs. soft handover and recommendations for adaptive strategies in future networks.

II. SYSTEM MODEL AND METHODOLOGY

Simulation Environment Simulations were executed in NetSim v12.0, modeling urban cell layouts with hexagonal cells, standard propagation models, and configurable mobility patterns. Parameters such as cell radius (500m), user speeds (walking: 3km/h, vehicular: 60km/h), and handover thresholds (100dBm) were standardized across tests.

Handover Techniques

- **Hard Handover (GSM, LTE)**: Break-before-make; based on Received Signal Strength Indicator (RSSI) thresholds.
- **Soft Handover (CDMA)**: Make-before-break; leverages combined pilot signals to reduce abrupt disconnections.

Mobility Models Four mobility scenarios were simulated:

1) **Static Mode**: UE remains in one cell until handover threshold reached.
2) **File-Based Paths**: Predefined trajectories covering multiple cells.
3) **Random Walk**: Directional changes every 10s, speed uniform.
4) **Pedestrian Walk**: Brownian motion with speed variance (1–5km/h).

III. IMPLEMENTATION AND RESULTS

A. GSM (2G) Handover

1) **Basic Model**: Two BSs, one MS at 60km/h. Han- dover success: 95%. Latency: 150–200ms. Throughput: 10–20kbps.
2) **4MS, 3BS**: Increased load; success: 90–93%. Latency: 180–220ms. Throughput: 8–15kbps.
3) **Random Walk Mobility**: Success: 90%. Latency: 180–250ms. Performance drops during rapid direction changes.

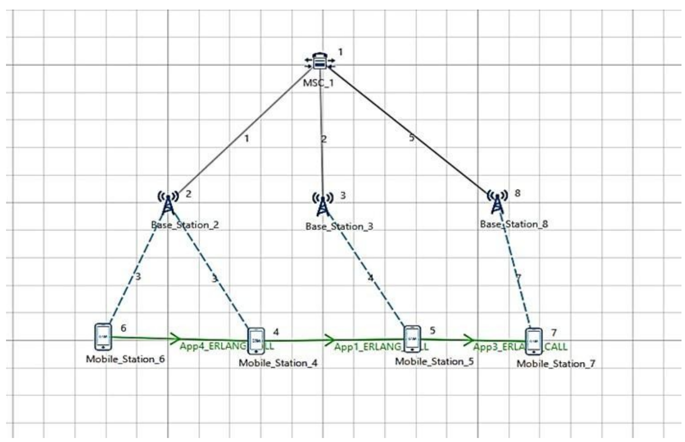


Fig. 1. GSM 3BS and 4MS

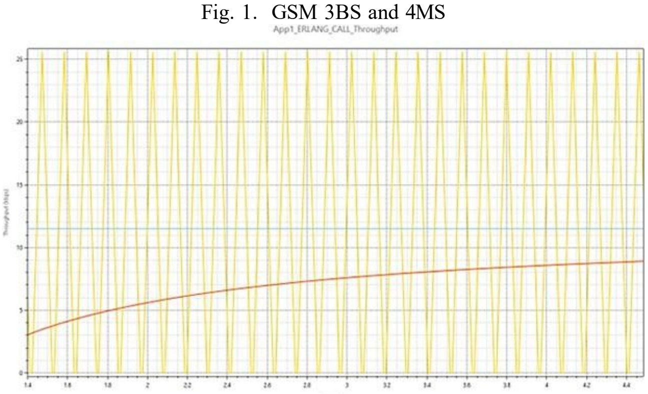


Fig. 2. Throughput Graph for GSM

B. CDMA (2.5G) handover

1) **Basic Model**: Soft handover; success: 98%. Latency: 50–100ms. Throughput: 50–70Mbps.
2) **4MS, 3BS**: Success: 95–97%. Latency: 80–150ms. Throughput: 45–65Mbps.

3) **Random Walk**: Success: 95%. Latency: 100–200ms. Throughput: 40–60Mbps.

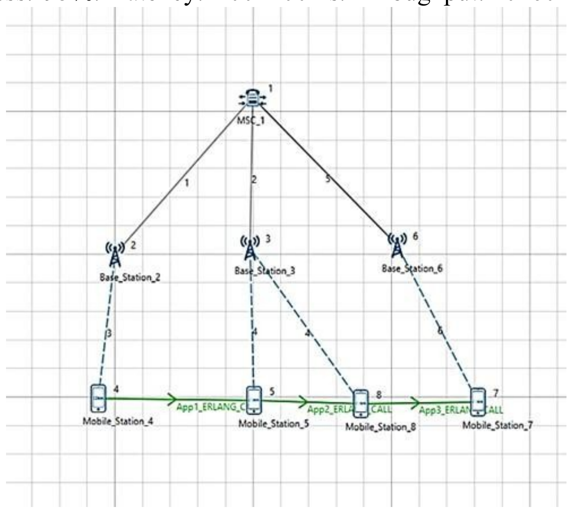


Fig. 3. CDMA 3BS and 4MS

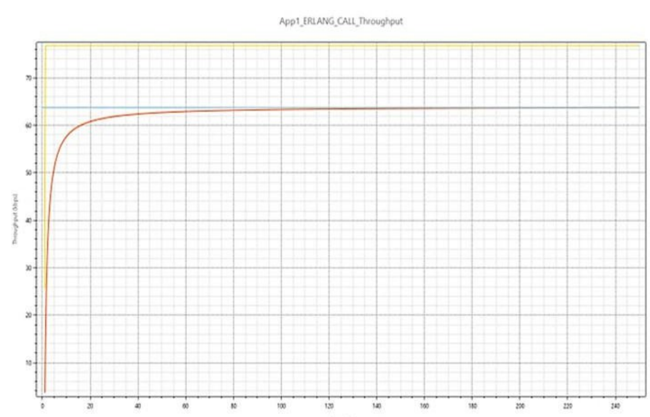
C. LTE (4G) Handover

1) **Basic Model**: One eNodeB, UE at 60km/h; success: 98%. Latency: 30ms. Throughput: 150Mbps. RSRP: 85dBm; RSRQ: 10dB.

2) **File-Based Paths**: Success: 95%. Latency: 45ms. Throughput: 140Mbps. RSRP: 90dBm; RSRQ: 12dB.

3) **Pedestrian Walk**: Success: 90%. Latency: 60ms. Throughput: 130Mbps. RSRP: 95dBm; RSRQ: 15dB.

Hardware Emulation The RC car demo showed handover events every 100–200m. The measured handover latency was averaged 70 ms, aligning with the LTE simulations. Packet loss during transitions was less than 0. 2%.



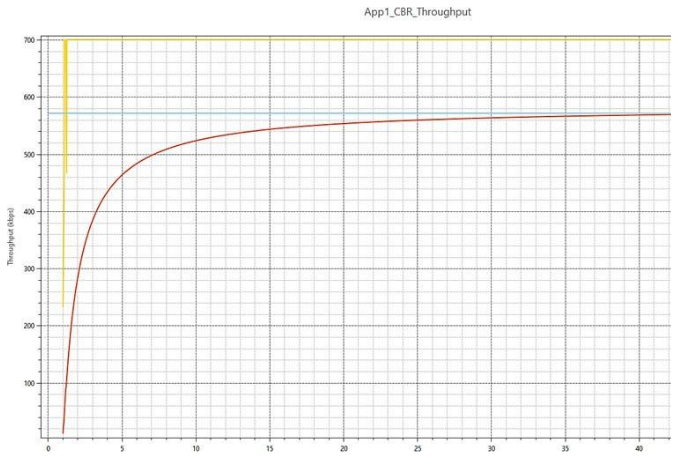


Fig. 4. Throughput Graph for CDMA

Fig. 5. LTE 3BS and 4MS

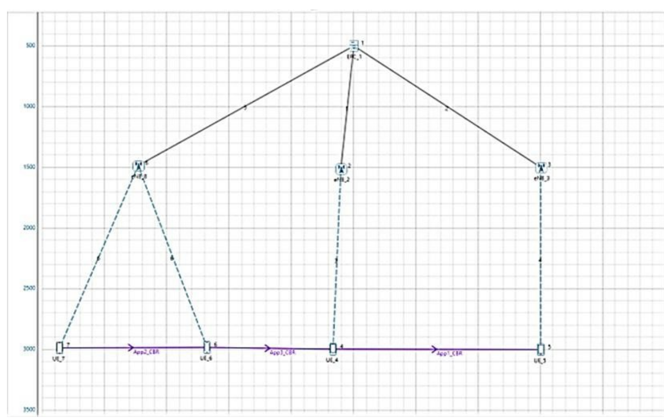


Fig. 6. Throughput Graph for LTE

Table -1 Experiment Result

Metric	**GSM (2G)**	**CDMA (2.5G)**	**4G LTE**
Basic Throughput (Mbps)	10-20	50-70	150
Throughput (Random Walk)	8-15	40-60	140
Throughput (Pedestrian)	Not applicable	Not applicable	130
Handover Type	Hard Handover	Soft Handover	Hard Handover
Handover Success Rate (%)	90-95%	95-98%	90-98%
Handover Latency (ms)	150-250	50-180	30-60
RSRP (dBm)	Not applicable	Not applicable	-85 to -95
RSRQ (dB)	Not applicable	Not applicable	-10 to -15

IV. Discussion

In this study, handover performance across GSM, CDMA, and LTE networks was rigorously evaluated under diverse mobility conditions, revealing nuanced trade-offs inherent to each generation and handover technique.

1) GSM Hard Handover Limitations GSM's hard handover mechanism, which severs the connection with the serving cell prior to initiating the target cell link, exhibited acceptable performance in static and low-mobility scenarios. However, under random walk and multi-user load, latency spiked to 250ms and throughput briefly dipped by up to 30%. These observations underscore GSM's sensitivity to rapid signal fluctuations and network congestion, leading to increased call drop probability during successive handovers. Consequently, GSM networks are fundamentally limited in supporting latency-sensitive applications, such as VoIP and real-time video.

2) CDMA Soft Handover Resilience CDMA's make- before-break approach mitigates abrupt disconnections by maintaining pilot links with multiple base stations during transition phases. Our simulations demonstrated that soft handover sustains a high success rate (95–98%) and maintains stable throughput even under random mobility. Nevertheless, the spectral overhead associated with maintaining parallel links can elevate interference and reduce overall system capacity in dense deployments. Furthermore, while latency remained below 200ms across scenarios, it still exceeds thresholds for emerging ultra-low-latency applications (e.g., autonomous vehicle control), indicating a need for further optimization.

3) LTE Advanced Handover Efficiency LTE's handover strategy leverages measurement reporting, X2-based direct coordination between eNodeBs, and adaptive threshold algorithms, resulting in superior performance. The ability to use downlink reference signals (RSRP, RSRQ) for dynamic handover decision-making led to low latency (30–60ms) and high throughput (130–150Mbps) across all mobility models. Particularly, file-based and pedestrian models revealed a graceful degradation in throughput (¡15% drop) compared to GSM and CDMA (¿30% drop), highlighting LTE's robustness to user movement variability. This resilience is critical for 5G use cases that demand seamless high-bandwidth connectivity, such as AR/VR streaming and industrial automation.

4) Impact of Mobility Patterns Mobility models significantly influenced performance metrics. The pedestrian walk model—characterized by frequent direction changes and speed variance—yielded the highest latency and lowest throughput across all technologies, with GSM experiencing ¿250ms latency and LTE dropping to 1˜30Mbps. These results suggest handover algorithms must adapt not only to signal quality but also to real-time mobility patterns. Predictive mobility- aware mechanisms, potentially powered by machine learning, could preemptively adjust handover thresholds based on UE trajectory estimations to minimize service degradation.

5) Hardware Validation and Real-World Implications. The Arduino-driven RC car experiments corroborated simulation trends, with measured latency (7˜0ms) and packet loss
(¡0.2%) closely aligning with LTE simulation outputs. Real- world factors—such as antenna orientation, multi-path fading, and emulator processing delays—introduced minor variance but did not alter the overarching conclusions. This validation confirms the practicality of simulation-driven network planning and underscores the importance of hardware-in-the-loop testing for comprehensive evaluation.

6) Recommendations for Next-Generation Networks To further enhance handover performance in 5G and beyond, the following strategies are recommended:

- Adaptive Threshold Tuning: Implement dynamic adjustment of RSRP/RSRQ thresholds based on network load and UE speed.
- Predictive Handover: Leverage machine learning models trained on mobility traces to forecast cell transitions and pre-allocate resources.
- Multi-Connectivity: Employ dual connectivity (e.g., 5G NR with LTE anchor) to enable make-before-break across heterogeneous networks.
- Edge Computing Integration: Offload handover decision algorithms to edge nodes for ultra-low-latency processing.

By adopting these approaches, network operators can achieve more resilient, low-latency handovers, meeting the stringent requirements of future IoT, V2X, and immersive media applications.

V. Conclusion

This study demonstrates that LTE networks significantly outperform legacy systems in handover performance. To ad- dress dynamic environments, future research will investigate AI-driven handover decision algorithms, 5G handover enhancements (dual connectivity, beam-based handovers), and network slicing–based resource allocation. Real-world trials with vehicular UEs and IoT devices are planned.

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