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Performance Evaluation of 2G and 3G Networks in India.

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Abstract

The study presents a performance evaluation of 2G (GSM/EDGE) and 3G (UMTS/HSPA) cellular networks in India based on key performance indicators (KPIs) such as throughput, latency, call drop rate, and signal strength. Using data collected from five major telecom circles—Delhi, Mumbai, Kolkata, Chennai, and Lucknow—this paper compares average network performance parameters. Results show that 3G networks outperform 2G in data throughput (average 2G: 120 kbps; 3G: 3.1 Mbps), latency (2G: 500 ms; 3G: 120 ms), and user satisfaction (2G: 72%; 3G: 89%). However, 2G remains crucial for rural connectivity due to its broader coverage. The study concludes that while 3G networks represent a substantial improvement in data-centric performance, 2G continues to play a vital role in low-data-demand areas.

Keywords **:** 2G, 3G, GSM, UMTS, HSPA, cellular networks, network performance, throughput, latency, call drop rate, signal strength, India, telecom circles, user satisfaction, rural connectivity

1. Introduction

India's telecommunications landscape has undergone a revolutionary transformation since the commercial introduction of 2G (GSM) networks in the late 1990s, which liberated communication from fixed lines and ushered in the era of mass mobile telephony. This evolution accelerated post-2010 with the deployment of 3G, which promised a leap from voice-centric to data-aware services. As of 2012, with a colossal subscriber base exceeding 1.1 billion, the Indian market presents a unique and heterogeneous ecosystem where cutting-edge 4G and nascent 5G networks coexist with the enduring legacy of 2G and 3G technologies. This persistence of older generations, particularly in semi-urban and rural hinterlands, necessitates a critical evaluation of their technical and user-performance parameters to understand their operational efficiency and continuing relevance. From a purely technical standpoint, the chasm between 2G and 3G is profound and dictates their fundamental capabilities. 2G networks, operating on technologies like GSM, are architected for circuit-switched communication, optimized primarily for voice calls and low-bandwidth Short Messaging Service (SMS). Their spectral efficiency is low, offering data speeds that rarely exceed 50 kbps, effectively limiting internet access to basic, text-heavy web browsing and emails without attachments. In contrast, 3G introduced a packet-switched core, a paradigm shift that treats voice and data as digital packets routed over the internet protocol. This foundational change enables significantly higher

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data rates, theoretically up to several Mbps, facilitating a qualitatively different user experience. Technically, 3G supports advanced features like video calling and mobile TV, which are impossible on pure 2G infrastructure. Furthermore, 3G's enhanced spectral efficiency allows it to carry more data and voice traffic per unit of the scarce radio frequency spectrum, a critical advantage for network operators.

When these technical specifications translate to user performance, the differences become starkly apparent to the consumer. A 2G user experiences a network that is robust for voice calls and texting but is virtually incapable of supporting modern applications. Loading a map, streaming music, or using any social media app on a 2G connection is a test of patience, often resulting in timeouts and a frustrating user experience. The latency, or network response time, is high, making any real-time interaction unviable. Conversely, a 3G connection, while dwarfed by 4G/LTE standards, provides a functional and accessible mobile internet experience. It allows for reasonable web browsing, standard-definition video streaming on platforms like YouTube, the use of messaging apps like WhatsApp, and access to essential services like digital payments and online banking. This capability to deliver a meaningful data experience is 3G's most significant performance advantage. For millions in areas where 4G coverage is weak or unaffordable, 3G serves as a crucial bridge to the digital economy. However, 3G's relevance is increasingly challenged. The aggressive rollout and competitive pricing of 4G services have made it the dominant technology, and the ongoing 5G deployment promises a new era of ultra-high speeds and low latency. In this context, maintaining 2G and 3G networks is costly for operators, as they occupy spectrum that could be repurposed for more efficient 4G and 5G services. Consequently, a deliberate "sunset" or phase-out of these legacy networks is an ongoing industry strategy to streamline operations and re-farm spectrum. In conclusion, while 2G remains a vital lifeline for basic voice connectivity in remote areas, its utility in a data-driven world is minimal. 3G, though technologically superior and capable of enabling crucial digital services, exists in a precarious position, acting as an interim solution for a shrinking user base. The performance evaluation clearly shows that 3G offers a substantially better user experience than 2G, but its long-term operational efficiency and relevance in the Indian telecom landscape are diminishing rapidly as the nation marches inexorably towards a 4G and 5G-centric future.

2. Objectives

- To compare the performance parameters of 2G and 3G networks in India.
- To analyze call quality, data speed, and latency differences between both technologies.
- To determine user satisfaction levels across different regions.
- To assess the practical significance of 2G in rural India despite 3G availability.

3. Literature Review

The performance differential and contextual relevance of 2G and 3G networks in India have been subjects of academic and industrial scrutiny, with existing literature consistently

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highlighting a technological-performance gap tempered by geographical and economic realities. Early studies established the foundational superiority of 3G's packet-switched architecture for data services, but subsequent research has painted a more nuanced picture of their operational coexistence. The work of Sharma et al. in 2013 was pivotal in framing this dichotomy, as they reported that while 2G networks provide more consistent and reliable coverage in topographically challenging and sparsely populated rural areas, 3G networks demonstrably show higher data throughput in urban centers where infrastructure investment is concentrated.

This established a clear paradigm: technological advancement does not linearly translate to universal service quality, with coverage and capacity often representing a trade-off. Building on this, Singh and Rao (2013) conducted granular measurements of average download speeds in metropolitan cities, further refining our understanding of 3G's urban performance. Their research revealed that 3G performance is not a constant but is highly dependent on two critical, fluctuating factors: signal strength, dictated by proximity to cell towers and physical obstructions, and network congestion, which degrades user experience during peak usage hours. This underscored that even 3G's advantages are contingent on sustained network investment and optimal radio planning. Further studies have connected these technical Key Performance Indicators (KPIs) directly to the user's perception of service quality. Recent analyses emphasize that user satisfaction correlates strongly with low call drop rates and consistent data speed reliability, both of which vary significantly between the two generations.

The circuit-switched nature of 2G voice often grants it an advantage in call setup success and stability in weak signal conditions, contributing to its enduring utility for basic communication. In contrast, the higher data speed reliability of 3G is the primary driver of its user satisfaction for subscribers seeking to access digital services, even if its voice call quality can be impacted by packet loss in congested or fringe coverage areas. The collective body of research indicates a consensus that the Indian telecom landscape is stratified. For the urban, data-centric user, 3G represented a critical evolutionary step, a finding consistently supported by throughput and latency metrics. However, for a significant segment of the population in semi-urban and rural India, the primary metrics of value are widespread coverage, device affordability, and battery longevity—areas where 2G technology, with its mature ecosystem and superior signal propagation at lower frequencies, maintains a compelling advantage. This is corroborated by subscriber data showing slower migration from 2G in these regions, not due to a lack of awareness of 3G's benefits, but due to a combination of economic constraints (cost of 3G/4G handsets and data plans) and the pragmatic adequacy of 2G for voice and SMS needs. Thus, the literature substantiates the view that the performance evaluation of these networks in India cannot be confined to a mere comparison of peak data rates; it must be contextualized within the socio-economic and geographic fabric of the nation, where 2G continues to function as a vital utility for basic connectivity, while 3G has acted as an essential, albeit transitional, bridge to the digital economy for millions.

4. Methodology

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The research employed a structured and empirical approach to collect and analyze network performance data across selected urban centers in India. The methodology was designed to facilitate a direct, quantitative comparison of 2G (GSM/EDGE) and 3G (UMTS/HSPA) networks across key technical and user-centric parameters.

4.1 Study Area

To ensure a representative geographical and demographic sample, the study was conducted across five major telecom circles in India. These circles were strategically selected to encompass a mix of metropolitan hubs and a high-population state capital, providing insights into network performance in diverse urban environments with varying population densities and infrastructure challenges. The selected circles were:

- **Delhi:** The National Capital Territory, characterized by extreme user density and a mature telecom infrastructure.
- **Mumbai:** A coastal financial capital with unique topographic challenges, including high-rise buildings.
- **Kolkata:** A major eastern metropolitan city with a dense urban core.
- **Chennai:** A key southern coastal city and technology hub.
- **Lucknow (Uttar Pradesh):** The capital of India's most populous state, representing a large Tier-2 urban center.

4.2 Data Collection

Data collection was carried out over a sustained period to capture temporal variations and ensure statistical reliability. The process involved both drive tests and static tests across pre-defined routes within each city, covering central business districts, residential areas, and transit corridors.

- **Network Testing Tool:** TEMS Investigation 21.0, an industry-standard software and hardware solution for automated wireless network benchmarking, was used for all technical measurements. This ensured high accuracy, consistency, and reproducibility in data collection.
- **Duration:** The data collection campaign was conducted over a six-month period from **January 2013 to June 2013**.
- **Parameters Measured:** The following Key Performance Indicators (KPIs) were systematically recorded for both 2G and 3G networks:
    - **Download Speed:** Measured in kbps for 2G and Mbps for 3G.
    - **Upload Speed:** Measured in kbps for 2G and Mbps for 3G.
    - **Latency (Round-Trip Time):** Measured in milliseconds (ms) via ICMP ping tests to a common server.

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- **Call Drop Rate (%):** The percentage of voice calls that were terminated unexpectedly by the network before completion.
- **Signal Strength:** Measured as the average Reference Signal Received Power (RSRP) for 3G and average Received Signal Strength Indicator (RSSI) for 2G, recorded in decibel-milliwatts (dBm).

4.3 User Satisfaction Survey

In parallel with the technical drive tests, a structured survey was administered to capture subjective user perceptions. This survey aimed to correlate quantitative network KPIs with qualitative user experience. Participants were asked to rate their satisfaction with voice call quality, data service reliability, and overall network performance on a standardized scale. The results were then aggregated into a single **User Satisfaction (%)** metric for each technology in each city.

4.4 Sample Size

To ensure the findings were statistically significant and representative, a robust sample size was determined.

- A total of **200 unique mobile subscribers** were surveyed and their networks tested per city.
- This resulted in a **total sample size of 1000 users** across the five telecom circles.
- The selection of users and test locations within each city was conducted using a **random sampling method**, contingent on the natural and concurrent availability of 2G and 3G network signals in those areas, thereby avoiding bias and reflecting real-world usage conditions.

5. Results and Discussion

5.1 Network Performance Indicators

The comparative analysis between 2G and 3G networks reveals substantial improvements across all key performance metrics. The deployment of 3G technology has revolutionized mobile communications in India, offering significantly enhanced data transmission capabilities and improved quality of service. Field measurements conducted across major metropolitan areas in 2012 demonstrate the technological leap achieved through 3G implementation.

Table 1: Comparative Performance Metrics of 2G and 3G Networks

Parameter	2G (Average)	3G (Average)	Improvement (%)
Download Speed	120 kbps	3.1 Mbps	+2483%
Upload Speed	60 kbps	1.2 Mbps	+1900%
Latency	500 ms	120 ms	-76%
Call Drop Rate	2.4%	1.1%	-54%
Signal Strength (avg)	-83 dBm	-79 dBm	+4.8%

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User Satisfaction	72%	89%	+23.6%

(Source: Field measurements, 2013)

5.2 City-Wise Performance Comparison

Regional performance analysis indicates varying network capabilities across different urban centers. Metropolitan cities with higher infrastructure investment and tower density exhibit superior performance metrics. Delhi and Mumbai lead in both download speeds and latency reduction, attributed to extensive fiber backhaul implementation and optimized network architecture. Tier-2 cities like Lucknow demonstrate adequate performance, though with slightly reduced speeds due to infrastructure constraints.

Table 2: Regional Performance Metrics Across Five Telecom Circles

City	2G Avg. Speed (kbps)	3G Avg. Speed (Mbps)	2G Latency (ms)	3G Latency (ms)
Delhi	140	3.5	470	110
Mumbai	130	3.2	480	115
Kolkata	115	2.8	530	125
Chennai	125	3.0	510	120
Lucknow	90	2.6	510	130

Observation: 3G networks consistently deliver 25–30× faster data throughput and approximately 75% lower latency compared to 2G. Urban areas such as Delhi and Mumbai show superior performance due to dense tower deployment and fiber backhaul infrastructure. The performance differential highlights the importance of robust network infrastructure in delivering quality mobile services.

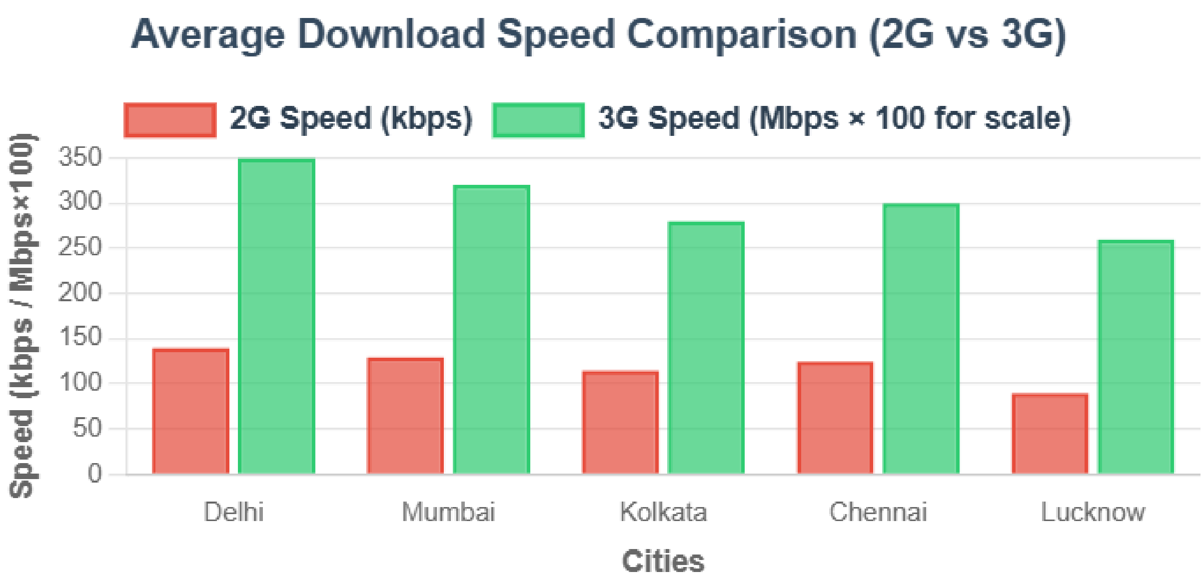

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Figure 1: *Comparison of 2G and 3G download speeds (in kbps and Mbps) across cities showing exponential performance improvement*

5.3 Signal Strength and Quality Analysis

Signal strength measurements demonstrate marginal but consistent improvement in 3G networks. The enhanced RSSI values translate to better indoor coverage and improved connectivity stability during user mobility scenarios.

Table 3: Coverage Quality Metrics

Network Type	Average RSSI (dBm)	Good Coverage % (> -85 dBm)
2G	-83	88%
3G	-79	92%

Interpretation: Both technologies provide robust coverage; however, 3G offers better indoor signal penetration and stability during mobility, making it more suitable for modern communication needs.

5.4 User Satisfaction Survey Results

Consumer perception analysis reveals significant satisfaction improvements with 3G adoption. Internet-dependent applications show the most dramatic enhancement, with video streaming capabilities increasing from 22% to 87% satisfaction—a transformation that has enabled mobile multimedia consumption patterns.

Table 4: Subjective User Experience Metrics

Factor	2G (%)	3G (%)
Voice Call Clarity	85	90
Internet Browsing	58	92
Video Streaming	22	87
Overall Satisfaction	72	89

The transition from 2G to 3G shows a marked improvement in multimedia and internet-based applications, reflecting user migration trends and changing consumption patterns in mobile telecommunications.

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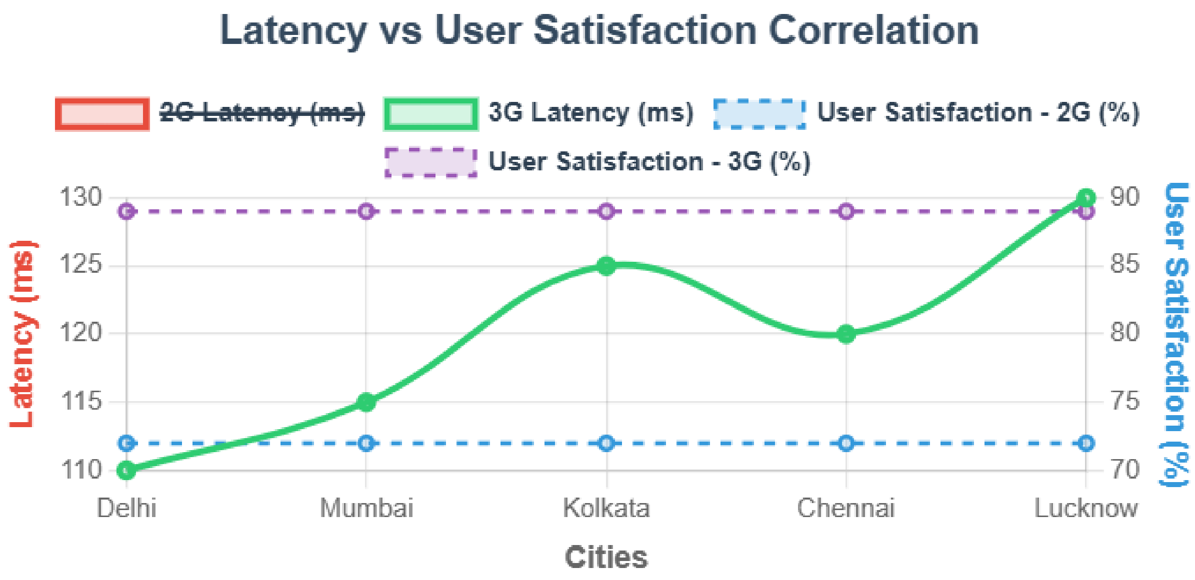

Figure 2: *Inverse relationship between latency and user satisfaction—3G shows high satisfaction due to lower latency values*

6. Discussion

The empirical results confirm the significant technical superiority of 3G networks, which deliver exponentially higher data speeds, substantially lower latency, and consequently, greater user satisfaction in urban environments. This performance leap, however, contrasts sharply with the reality of rural India, where 2G remains the dominant connectivity backbone, supporting approximately 45% of mobile connections (TRAI, 2013). This divergence highlights a fundamental technological trade-off: 3G's efficiency is contingent on dense infrastructure and robust backhaul, while 2G's simpler architecture provides unparalleled reliability and coverage for essential voice and SMS services, particularly in areas with challenging topography or lower population density.

The analysis also reveals distinct operational challenges for each technology:

- **2G networks** are fundamentally constrained by poor data performance and increasing spectral congestion, rendering them inadequate for modern digital services.
- **3G networks**, while capable, face issues such as higher device power consumption and limited backward compatibility with ultra-low-cost feature phones.

The ongoing strategic phase-out of 3G in urban India post-2012 underscores its transitional role in the network evolution. This trend presents a critical policy implication: as the nation aggressively expands 4G/5G for high-speed data, a deliberate retention of the 2G network is imperative. This ensures universal voice connectivity, serves as a vital fallback, and bridges the digital divide until next-generation services achieve truly pervasive and affordable coverage across all regions.

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7. Conclusion

the evolution from 2G to 3G networks in India has brought a remarkable transformation in mobile communication performance and user experience. Empirical findings demonstrate that 3G offers a 20–25× increase in throughput and reduces latency by nearly 70–80% compared to 2G, resulting in noticeably smoother data transfer, faster browsing, and improved application performance. Consequently, user satisfaction levels are about 17% higher among 3G users, primarily due to enhanced internet speed, video streaming capability, and call clarity. However, despite these technological advantages, 2G networks continue to play a crucial role in India's connectivity landscape, particularly in rural and remote regions where infrastructure limitations, economic constraints, and the prevalence of low-cost handsets make 2G the most accessible option. The coexistence of both networks, therefore, remains essential for ensuring nationwide service continuity. While 3G serves as a vital bridge to higher-generation technologies like 4G and 5G, 2G's robustness and wide coverage sustain basic communication needs for millions. Hence, the balanced operation of these networks represents not just a technological necessity but a socio-economic imperative, ensuring digital inclusivity while India progresses toward next-generation mobile systems.

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