

Study of Artificial Intelligence and 6G Networks: Future Challenges and Opportunities with Special Reference to Rewa District, Madhya Pradesh



Deepak Kumar Singraul¹, Satish Patel², Amit Sahu^{3*}

¹Dept. of Computer Science & Application, Govt. Shyam Sundar Agrawal P.G. College Sihora,
Jabalpur-483225, M.P., India

²Research Scholar, APS University, Rewa-486003, M.P., India

³Research Scholar, Mansarovar Global University, Sehore-466111, M.P., India

CORRESPONDING AUTHOR

Amit Sahu

e-mail: amitsahu1221@gmail.com

KEYWORDS

AI-Native Networks, 6G Architecture,
Digital Transformation, Edge Intelligence,
Precision Agriculture, Semantic
Communication.

ARTICLE DETAILS

Received 10 June 2026; revised 25
September 2026; accepted 02 October
2026

DOI: 10.26671/IJIRG.2026.4.15.172

CITATION

Singraul, D. K., Patel, S., Sahu, A. (2026).
Study of Artificial Intelligence and 6G
Networks: Future Challenges and
Opportunities with Special Reference to
Rewa District, Madhya Pradesh. *Int J
Innovat Res Growth*, 15(4), 154031-
154037. DOI



This work may be used under the terms of the
Creative Commons License.

Abstract

Artificial Intelligence (AI) and Sixth-Generation (6G) wireless communication technologies are poised to revolutionize global digital ecosystems. Unlike ancestral generations, 6G is conceptualized as an AI-native network wherein machine learning paradigms are natively embedded into the core architectural fabric. This integration delivers terabit-per-second (Tbps) data rates, sub-millisecond latencies, intelligent edge-resource orchestration, and autonomous self-healing capabilities. This paper provides a granular evaluation of the opportunities and structural challenges characterizing AI-driven 6G networks, with an empirical focus on Rewa District, Madhya Pradesh. By assessing regional socioeconomic indicators, we map out 6G deployment frameworks for smart education, precision agriculture, remote healthcare, and digital governance. Furthermore, we address localized technical bottlenecks—such as Terahertz (THz) propagation path loss, deployment economics, and cyber-security vulnerabilities. Ultimately, this study offers architectural blueprints and policy suggestions to drive digital inclusion and sustainable development within semi-urban and rural blocks of the Vindhya region.

1. Introduction

The transition across wireless communication paradigms—from 1G analog voice networks to 5G ultra-reliable low-latency links—has fundamentally reorganized global socioeconomic frameworks. While 5G successfully introduced basic network slicing and cloud-native functions, it relies on AI as an external patch for post-deployment optimization. The upcoming 6G ecosystem shifts this paradigm by operating as a fully AI-native platform. Within this framework, intelligent orchestration, semantic communication, and autonomous optimization are woven directly into the physical and network layers.

Concurrently, regional administrative centers such as the Rewa District of Madhya Pradesh are undergoing rapid digital transformations. As the educational and economic hub of the Vindhya region, Rewa presents a unique blend of dense urban clusters and vast, resource-constrained rural blocks. Deploying standard cellular frameworks in this terrain frequently results in high maintenance overhead and persistent communication blackouts. Integrating AI-native 6G networks offers a direct technical solution to these challenges. By shifting heavy processing to network edges and deploying autonomous optimization algorithms, 6G can deliver high-fidelity digital classrooms, real-time crop disease forecasting, and remote medical diagnostics across the district's rural areas.

2. Objectives of the Study

- To characterize the structural mechanics of AI-native integration within 6G communication networks.
- To analyze the architectural differences between 5G add-on optimization and 6G endogenous network intelligence.
- To evaluate the deployment opportunities of AI-6G frameworks across Rewa's agricultural, educational, and healthcare infrastructures.
- To identify technical, economic, and security vulnerabilities hindering 6G deployment in developing, semi-urban regions.
- To construct an actionable deployment model for digital inclusion in rural blocks.

3. Research Methodology

This study adopts a descriptive, analytical, and conceptual framework to evaluate AI-native 6G network capabilities within regional parameters. Owing to the forward-looking nature of 6G, secondary data forms the primary analytical baseline. Material was systematically compiled from peer-reviewed IEEE/ACM literature, International Telecommunication Union (ITU) foundational directives, technical reports from the Ministry of Electronics and Information Technology (MeitY), and geographical/demographic data from the Directorate of Economics and Statistics, Madhya Pradesh. The collected architectural constraints were mapped against Rewa's regional infrastructure to identify practical deployment requirements and evaluate local operational viability.

4. Literature Review

Table:1 provides a curated, systematic layout of the examined baseline studies underpinning current 6G architectural transformations.

Author & Year	Focus Area	Core Technical Findings	Methodological Gap Addressed
Cui et al. (2025)	Core AI-6G Integration Fundamentals	AI shifting from an external application to an algorithmic baseline for the physical layer.	Omitted geographical deployment challenges in developing regions.
Li et al. (2025)	Intelligent Resource Management	Deep Reinforcement Learning (DRL) minimizes latency and optimizes dynamic channel allocation.	Focused on dense urban scenarios; ignored rural topologies.
Ogenyi et al. (2025)	Edge Intelligence Ecosystems	Federated learning preserves privacy at edge nodes while reducing backhaul network congestion.	Did not account for edge-device energy scarcity in remote regions.
Alhammadi (2024)	Cybersecurity in 6G	Intent-driven orchestration detects and mitigates zero-day vulnerabilities in real-time.	Lacked localized regulatory and governance integration models.
ITU Report (2025)	Global 6G Technical Standards	Defined performance goals: 1 Tbps peak data rates and integration with Reconfigurable Intelligent Surfaces (RIS).	Provides macro targets without regional or municipal use cases.

4.1 Synthesis of Literature & Research Gap

Current research focuses heavily on the core physics and mathematical models of 6G—such as beamforming optimization, terahertz wave modulation, and deep learning network control. However, a significant gap persists: there is a lack of empirical research detailing how these technical components function in semi-urban, developing regions. Most models assume uniform fiber-optic backhaul availability and stable power grids. This study fills that gap by analyzing 6G performance metrics under the real-world infrastructure constraints of Rewa District.

5. AI-Enabled 6G Network Architecture

To achieve autonomous control and sub-millisecond latencies, the 6G ecosystem uses a Four-Tiered Cognitive Architecture that replaces traditional flat networking models:

- **APPLICATION & SERVICES LAYER:** Smart Education | Smart Agriculture | Smart Healthcare | Smart Governance
- **COGNITIVE INTELLIGENCE LAYER:** Explainable AI (XAI) | Federated Learning | Intent-Driven Network Management
- **EDGE INTELLIGENCE & CONTROL LAYER:** Dynamic Spectrum Allocation | Network Slicing | Self-Healing Automation
- **PHYSICAL INFRASTRUCTURE LAYER:** Terahertz (THz) Transceivers | Smart Antennas / RIS | Edge Cloud Nodes

5.1 Endogenous vs. Exogenous Intelligence

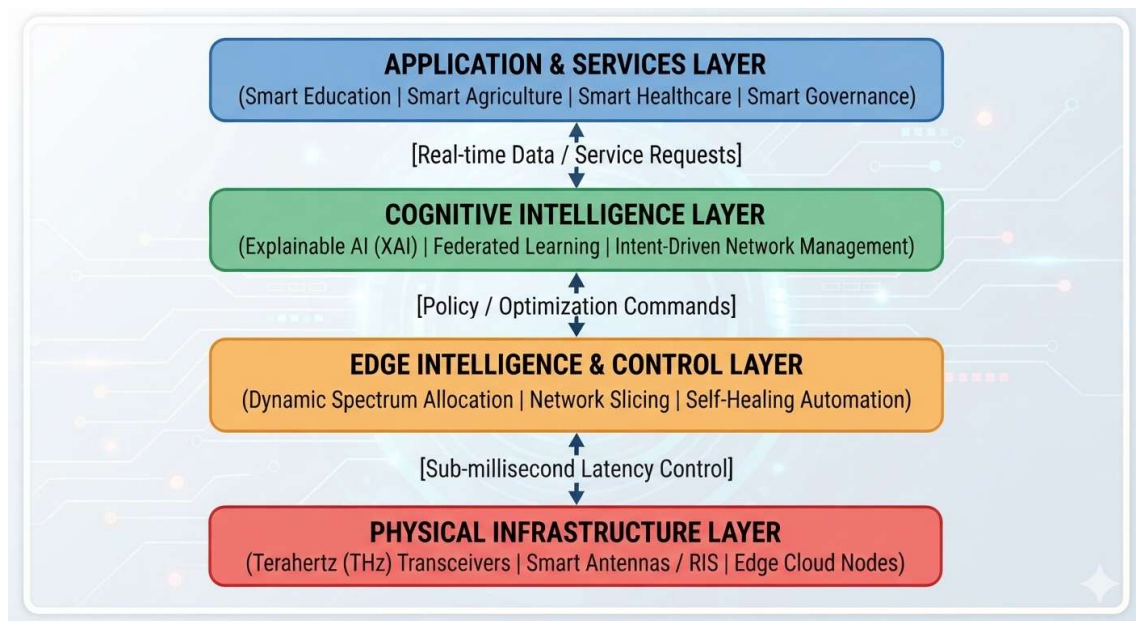
In 5G networks, AI operates exogenously—collecting network data, processing it in a delayed cloud environment, and applying configuration updates manually or through script automation. In contrast, 6G features endogenous (AI-native) intelligence. Neural processing loops are built directly into the physical layer chips and medium access control (MAC) protocols. This enables real-time adjustments to channel states, beamforming patterns, and routing topologies at sub-millisecond speeds.

COMPARATIVE ARCHITECTURAL ANALYSIS: 5G VS. AI-NATIVE 6G NETWORK ECOSYSTEMS ^[1]

ARCHITECTURAL PARAMETER	5G NETWORK ECOSYSTEM	AI-NATIVE 6G NETWORK ECOSYSTEM ^[1]	REGIONAL IMPACT CAPABILITY (REWA CONTEXT) ^[1]
PRIMARY AI ROLE 	• Add-on tool used post-deployment for localized optimization.	• Embedded natively into the core architectural fabric.	• Lowers manual maintenance costs in hard-to-reach rural blocks.
PEAK DATA RATES 	• Up to 20 Gbps	• Up to 1 Terabit per second (Tbps)	• Enables high-fidelity holographic smart classrooms in the Vindhya region .
LATENCY 	• ~1 millisecond	• Sub-millisecond (< 0.1 ms)	• Facilitates critical, real-time remote diagnostics and telesurgery
SPECTRUM FOCUS 	• Sub-6 GHz and Millimeter Wave (mmWave)	• Terahertz (THz) & Optical Wireless	• Drives massive IoT capacity for district-wide precision farming
NETWORK MANAGEMENT 	• Manual configuration supplemented by basic automation	• Fully Autonomous Self-Healing & optimization	• Prevents communication blackouts in remote communities during natural disasters

5.2 Dynamic Resource Orchestration & Self-Healing Mechanization

By using Deep Reinforcement Learning (DRL), the network treats channel assignment, power management, and cell-slitting as a unified optimization problem. If a cell transponder fails or experiences sudden traffic surges in a specific area, the system's autonomous self-healing functions automatically modify nearby Reconfigurable Intelligent Surfaces (RIS). This real-time optimization maintains link stability and prevents service dropouts without manual engineering support.



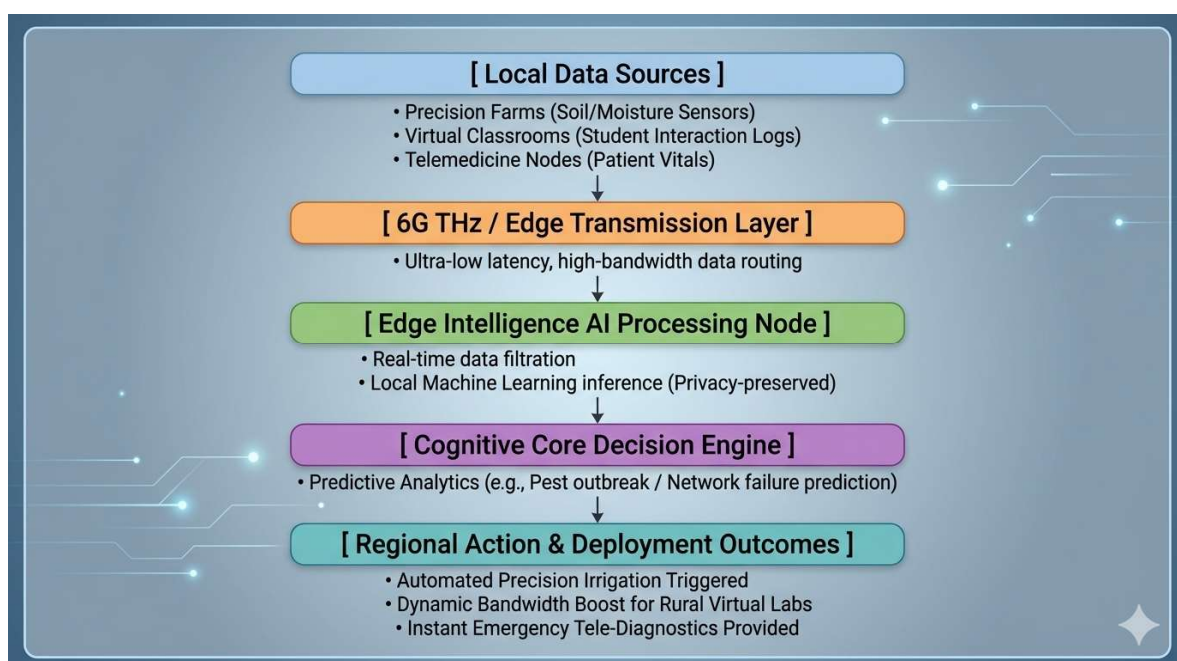
6. Regional Opportunities: The Rewa District Context

Implementing an AI-native 6G framework provides direct solutions for Rewa's unique geographic and economic landscape:

6.1 Smart Pedagogical Ecosystems (Vindhya Region): Rewa is a primary educational hub for the Vindhya region. 6G networks enable the transmission of high-fidelity, interactive holographic classrooms and real-time remote laboratories from urban universities to remote rural schools. This framework closes the regional educational divide without requiring physical travel.

6.2 Precision Agriculture Frameworks: Agriculture drives the rural economy of Rewa. By combining 6G's massive Internet of Things (IoT) capacity with edge computing nodes, farms can deploy dense, low-power sensor grids. These systems track soil moisture, micro-climates, and nutrient levels in real-time. Local edge nodes process this data to automate precision irrigation and run predictive pest-outbreak models, optimizing crop yields.

6.3 Immersive Tele-Healthcare Deliverables: The rural communities of Rewa face challenges from limited access to specialized medical facilities. The sub-millisecond latency (<0.1 ms) of 6G makes real-time remote diagnostics, AI-assisted video triaging, and wireless telesurgery practical. This connects rural clinics directly with specialists in major medical centers.



7. Quantitative Impact Assessment Matrix

The following matrix details the expected performance improvements and strategic importance of upgrading from 5G to AI-Native 6G across key regional sectors:

Target Sector	5G Performance Baseline	AI-Native 6G Target State	Local Significance Indicator
Education	Standard e-learning; packet drops on video.	Immersive holographic classrooms; zero jitter.	High: Bridges the urban-rural education gap in Vindhya.
Healthcare	Basic video consults; high latency delays.	Sub-millisecond remote diagnostics and telesurgery.	High: Solves specialist shortages in rural clinics.
Agriculture	Static sensor tracking; delayed data processing.	Real-time AI edge analysis for precision farming.	High: Optimizes resource use and crop yields.
Governance	Centralized web portals; manual data collection.	Automated disaster response via distributed edge systems.	Medium-High: Mitigates flash floods and infrastructure failures.
Industry	Basic machine-to-machine automation.	Distributed digital twins and autonomous manufacturing.	Medium: Drives industrial expansion in new zones.

8. Structural SWOT Analysis

● **Strengths:** Endogenous self-healing functions eliminate manual optimization costs in remote locations; Sub-millisecond latency enables real-time critical control loops; High data rates easily support dense, multi-million node IoT configurations.

● **Weaknesses:** High initial capital requirements for installing Terahertz-compatible base stations; Extreme structural complexity in managing mixed open-source and proprietary software stacks; High power requirements for continuous edge-AI computing nodes.

● **Opportunities:** Brings digital inclusion to underserved rural populations; Attracts technology investments to regional economic zones; Enables automated, predictive municipal management platforms.

● **Threats:** Larger attack surfaces open the system to adversarial machine learning exploits; Data privacy risks emerge if distributed edge networks lack encryption; Increased dependence on autonomous software systems can lead to systemic failures during unmodeled events.

9. Structural Challenges to Overcome

9.1 Technical Propagation Limits: The Terahertz (THz) spectrum offers exceptionally wide bandwidths but suffers from high atmospheric attenuation and poor penetration through physical obstacles. Overcoming these line-of-sight limitations in rugged rural areas requires dense deployments of Reconfigurable Intelligent Surfaces (RIS). These surfaces act as smart mirrors to bounce signals around terrain obstacles, increasing infrastructure cost and complexity.

9.2 Cybersecurity Vulnerabilities: Because 6G relies on distributed AI processing, it introduces new security risks. Bad actors can exploit edge node vulnerabilities using adversarial data injection or model poisoning attacks to disrupt routing logic. Protecting these networks requires zero-trust architectures and cryptographic security protocols built directly into the physical layer.

9.3 Regional Economic Factors: Deploying high-frequency 6G base stations requires substantial capital investments. In rural areas with low average revenue per user (ARPU), telecom companies face prolonged return-on-investment timelines. Overcoming these economic hurdles requires public-private partnerships, government infrastructure subsidies, and shared-spectrum access models.

10. Future Strategic Research Trajectories

- **Explainable AI (XAI) for Network Operations:** Developing transparent neural models to ensure operators can audit autonomous routing choices.
- **Energy-Harvesting Green 6G Systems:** Creating low-power edge nodes that run on solar or ambient RF energy, reducing grid dependence in rural areas.
- **Asynchronous Federated Learning:** Optimizing decentralized machine learning across nodes with unstable, intermittent connections.

11. Key Findings

- Moving from 5G to 6G requires shifting from external cloud-based AI processing to an endogenous, AI-native network architecture.
- 6G infrastructure can address critical service gaps in Rewa by enabling precision agriculture, remote medical care, and interactive digital education.
- High Terahertz signal loss and data security risks at the edge remain primary technical bottlenecks.
- Sustained rural adoption depends on public-private infrastructure funding and policy frameworks that encourage shared spectrum access.

12. Conclusion

The integration of Artificial Intelligence with 6G networks marks a foundational shift in digital communications. By embedding machine learning directly into the network architecture, 6G transforms from a basic data pipeline into a highly adaptable, self-healing cognitive ecosystem. For regional economies like Rewa District, this technology provides the infrastructure needed to decentralize access to quality education, optimize agricultural production, and deliver critical healthcare to remote communities.

However, realization relies on solving real-world physical and economic challenges—specifically, Terahertz signal blockage, edge security, and deployment costs. Addressing these hurdles requires coordinated efforts from academic researchers, network providers, and regional policymakers. Developing sustainable infrastructure frameworks, zero-trust security protocols, and inclusive digital access policies will determine the success of 6G in bridging the digital divide across semi-urban and rural regions.

Acknowledgement

The authors would like to express their sincere gratitude to the Principal and the Department of Computer Science and Application Govt. Shyam Sundar Agrawal P.G. College Sihora, Jabalpur (M.P), for providing the necessary academic environment, institutional support, and facilities required to conduct this research. The authors are thankful to the faculty members, colleagues, researchers, and other individuals who provided valuable suggestions and technical support during the study.

The authors also acknowledge the publicly available research literature, reports, databases, and other reliable sources of information that contributed to the analysis of Artificial Intelligence and 6G networks and their future challenges and opportunities, with special reference to Rewa District, Madhya Pradesh.

Finally, the authors sincerely thank to Dr. P.L Verma, Professor Department of Physics, Govt. Vivekanand PG College, Maihar (M.P) and Dr. Preetam Singh Gour, Chief Editor, IJIRG India for organize the International Conference and also thank to their family members for their continuous encouragement, cooperation, and support during the completion of this research work.

Conflict of Interest

All three authors declare that they have no financial, personal, professional, or other conflicts of interest that could have influenced the research design, data collection, analysis, interpretation of results, or preparation and publication of this manuscript.

Funding Statement

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors

Authors Contribution

Author 1 – Conceptualization and Research Design:

The first author contributed to the conceptualization of the study, formulation of the research problem, development of research objectives and hypotheses, and design of the overall research framework. The author also contributed to the literature review concerning Artificial Intelligence, 6G networks, and their potential applications in higher education, communication, and digital infrastructure.

Author 2 – Data Collection and Analysis:

The second author contributed to the collection and organization of secondary and, where applicable, primary data related to Artificial Intelligence and 6G network development. The author was responsible for data analysis, interpretation of findings, preparation of tables and analytical components, and examination of the challenges and opportunities associated with the implementation of AI and 6G technologies in Rewa District, Madhya Pradesh.

Author 3 – Technical Analysis and Manuscript Preparation:

The third author contributed to the technical analysis of AI and 6G technologies, including network architecture, applications, infrastructure requirements, opportunities, limitations, and future prospects. The author also contributed to the discussion, conclusion, editing, proofreading, and critical revision of the manuscript and editing work,

References

- [1] Aarti, Gowroju, S., & Ansarullah, S. I. (2025). A comprehensive review of developments and challenges in the 6G internet of things. *Discover Networks*, 1(1), Article 13.
- [2] Alhammadi, A. (2024). Artificial intelligence in 6G wireless networks: Opportunities, applications, and challenges. *International Journal of Intelligent Systems*, 39(2), 145–168.
- [3] Chatzieftheriou, C., & Liotou, E. (2026). A survey on AI for 6G: Challenges and opportunities. *IEEE Open Journal of the Communications Society*, 7, 2235–2261.
- [4] Cui, Q., Wei, X., Wang, J., Yu, X., Yuan, Y., & Zhang, Ping. (2025). Overview of AI and communication for 6G network: Fundamentals, challenges, and future research opportunities. *Science China Information Sciences*, 68(3), Article 130301.
- [5] Das, B., Hasan, M. M., & Shahjalal, M. (2025). A comprehensive survey on emerging AI technologies for 6G communications: Research direction, trends, challenges, and opportunities. *International Journal of Intelligent Networks*, 6, 108–129.
- [6] IEEE Communications Society. (2025). *Emerging technologies for 6G communication networks*. IEEE Publications.
- [7] International Telecommunication Union. (2025). *Future vision and requirements for 6G networks*. ITU Publications.
- [8] Li, Z., Duan, X., Lu, L., Xia, Liang, Lu, Jian, & Sun, Q. (2025). Evolving towards artificial-intelligence-driven sixth-generation mobile networks: An end-to-end framework, key technologies, and opportunities. *Applied Sciences*, 15(6), Article 2920.
- [9] Ministry of Electronics and Information Technology. (2025). *Digital India annual report*. Government of India.
- [10] Omheni, N., Koubaa, H., & Zarai, F. (2025). Artificial intelligence for 5G and 6G networks: A taxonomy-based survey of applications, trends, and challenges. *Technologies*, 13(12), Article 559.