Volume 3 Number 1 (2025)
January – June 2025
Page: 1-9

INJUTECT: Indonesian Journal of Technology and Digital Transformation
https://edujavare.com/index.php/injutect/

# Analysis of 5G Network Performance and Security in Supporting Digital Transformation in Engineering Education

**Desfita Eka Putri[1], Asfahani[2], Iwan Adhicandra[3], Bunga Mardhotillah[4], Joni Wilson Sitopu[5]**
[1)] Politeknik LP3I Pekanbaru, Indonesia; desfitaekaputri@plb.ac.id
[2)] IAI Sunan Giri, Indonesia; asfahani@insuriponorogo.ac.id
[3)] Universitas Bakrie, Indonesia; iwan.adhicandra@bakrie.ac.id
[4)] Universitas Jambi, Indonesia; bunga.mstat08@unja.ac.id
[5)] Universitas Simalungun, Indonesia; jwsitopu@gmail.com

**Article history** Submitted: 2024/12/18; Revised: 2025/01/12; Accepted: 2025/02/12

**Abstract**

The rapid advancement of 5G technology has revolutionized various sectors, including education, by enabling seamless connectivity and real-time data exchange. In technical education, 5G plays a crucial role in supporting digital transformation by enhancing network performance and enabling advanced learning technologies such as augmented reality (AR), virtual reality (VR), and cloud-based simulations. However, alongside these advantages, security concerns related to cyber threats and data privacy remain critical challenges. This study aims to analyze the performance and security of 5G networks in facilitating digital transformation in technical education. A literature review methodology was employed, analyzing relevant academic studies from databases such as IEEE Xplore, ScienceDirect, and Springer. The research focused on two primary aspects: (1) evaluating 5G network performance in improving technical education, including latency reduction, bandwidth efficiency, and connectivity enhancement; and (2) identifying security vulnerabilities and potential risks associated with 5G implementation in educational environments. The findings indicate that 5G significantly enhances digital learning experiences by providing high-speed connectivity and minimizing latency, enabling real-time remote learning and hands-on technical training. However, the study also highlights critical security concerns, including data breaches, unauthorized access, and privacy risks, which necessitate robust cybersecurity strategies. Additionally, disparities in infrastructure readiness among educational institutions present challenges in the widespread adoption of 5G technology. This research contributes to the field by providing insights into optimizing 5G for technical education while addressing security challenges.

**Keywords** 5G Network, Augmented Reality, Cybersecurity, Digital Transformation, Technical Education.

## INTRODUCTION

The rapid evolution of digital technology has revolutionized various sectors, including education. One of the most significant advancements in recent years is the deployment of 5G networks, which promise ultra-fast data transmission, low latency, and enhanced connectivity. In technical education, where real-time simulations, cloud computing, and remote laboratories play a crucial role, the implementation of 5G can significantly enhance learning experiences [1]. The transition from traditional to digital-based education necessitates a reliable and secure network infrastructure, making the performance and security analysis of 5G networks an essential area of study [2].

However, despite its numerous advantages, the adoption of 5G in educational institutions particularly in technical education faces several challenges. Network performance can be affected by factors such as spectrum allocation, network congestion, and infrastructure readiness [3]. Additionally, security concerns, including cyber threats, data privacy, and unauthorized access, pose potential risks that need to be addressed. Ensuring a robust and secure 5G network is critical to supporting an uninterrupted and efficient digital transformation in education [4].

What makes this study particularly interesting and unique is its focus on how 5G technology can specifically benefit technical education. Unlike general education systems, technical education requires intensive use of bandwidth-heavy applications, such as augmented reality (AR), virtual reality (VR), Internet of Things (IoT)-based training, and digital twins for industrial simulations [5]. These applications demand not only high-speed connectivity but also reliable network security to prevent unauthorized access and data breaches. Understanding the interplay between network performance and security within this context is vital for maximizing the potential of 5G in education [6].

A review of existing studies indicates that while much research has been conducted on the benefits of 5G in general education and industry, studies specifically addressing its impact on technical education remain limited. Many analyses focus on theoretical advantages rather than empirical evaluations of network performance and security in real-world educational settings [7]. This research aims to bridge that gap by providing a comprehensive analysis of how 5G performs in technical education environments and assessing its security implications.

The novelty of this study lies in its dual-focus approach evaluating both the performance and security aspects of 5G in the context of digital transformation in technical education [8]. By examining real-world data and use cases, this study provides a more practical perspective on the feasibility and challenges of implementing 5G in

technical learning environments. The findings will contribute to a better understanding of how educational institutions can optimize 5G networks for more effective and secure digital learning experiences [9].

The objective of this study is to analyze the performance and security of 5G networks in supporting the digital transformation of technical education. This research aims to evaluate the effectiveness of 5G in enhancing connectivity, reducing latency, and enabling advanced learning technologies such as augmented reality (AR), virtual reality (VR), and remote laboratory simulations. Additionally, it seeks to identify potential security risks, including cyber threats and data privacy concerns, and propose strategies to mitigate them. The findings of this study will provide valuable insights for educational institutions, policymakers, and technology developers in optimizing 5G infrastructure for a more efficient, secure, and innovative technical education environment.

## METHODS

This study employs a literature review methodology to analyze existing research on the performance and security of 5G networks in supporting digital transformation in technical education. The literature review follows a structured approach, including the identification, selection, and analysis of relevant academic articles, conference papers, and technical reports published in reputable databases such as IEEE Xplore, ScienceDirect, Springer, and Google Scholar. Keywords such as "5G network performance," "5G security challenges," "digital transformation in education," and "technical education and 5G" are used to gather relevant studies. The selected literature is critically examined to identify key trends, challenges, and technological advancements related to the implementation of 5G in educational settings.

Furthermore, the review categorizes findings into two primary aspects: network performance and security. Performance-related studies focus on factors such as bandwidth efficiency, latency reduction, and the integration of 5G with emerging educational technologies like augmented reality (AR) and Internet of Things (IoT) applications. Meanwhile, security-related studies address potential vulnerabilities, including cyber threats, data breaches, and privacy issues in 5G-enabled educational environments. By synthesizing findings from various sources, this study aims to highlight gaps in current research and provide a foundation for future investigations on optimizing 5G networks for technical education [10].

## FINDINGS AND DISCUSSION

### Findings

The findings of this study reveal that 5G networks significantly enhance the efficiency and effectiveness of digital transformation in technical education. Performance analysis indicates that 5G provides ultra-fast data transfer speeds, enabling seamless connectivity for bandwidth-intensive applications such as virtual reality (VR), augmented reality (AR), and cloud-based simulations. The low latency characteristic of 5G ensures real-time interaction in remote laboratories, allowing students to engage in hands-on learning experiences without physical constraints. Compared to traditional Wi-Fi or 4G networks, 5G demonstrates a substantial improvement in data transmission, reducing buffering times and enhancing the overall user experience in digital learning environments.

Despite these advantages, the implementation of 5G in technical education also presents several challenges, particularly regarding security. The study identifies potential cybersecurity threats, including unauthorized access, data interception, and network vulnerabilities due to the high volume of connected devices. Educational institutions adopting 5G must address these risks by implementing robust encryption protocols, multi-factor authentication, and continuous network monitoring to prevent cyberattacks. Additionally, privacy concerns arise as 5G networks facilitate extensive data collection, requiring institutions to adopt strict data protection policies to safeguard students' and educators' sensitive information.

Another critical finding is the disparity in infrastructure readiness among different educational institutions. While some universities and technical colleges have successfully integrated 5G into their digital learning frameworks, others face significant barriers such as high deployment costs, limited expertise, and regulatory challenges. The study suggests that government support and private sector collaboration are essential to bridging this gap, ensuring that all institutions can benefit from 5G-driven educational innovations.

Table 1 Performance and Security Analysis of 5G Networks in Technical Education

| Aspect | Indicator | Findings |
|---|---|---|
| Performance | Data Transfer Speed (Mbps) | Significantly higher than 4G, enabling real-time data exchange |
| | Latency (ms) | Ultra-low latency supports interactive remote learning |
| | Bandwidth Efficiency | Higher capacity accommodates multiple simultaneous connections |

| | | |
|---|---|---|
| Security | Data Privacy Risks | Increased vulnerability to unauthorized data access |
| | Cyber Threats | Potential attacks such as DDoS and data breaches |
| | Encryption & Authentication | Strong encryption and multi-factor authentication needed |
| Implementation Challenges | Infrastructure Readiness | Variations in network availability among institutions |
| | Cost of Deployment | High initial investment for 5G infrastructure |
| | Institutional Adoption | Slow integration due to technical expertise limitations |

The table summarizes the key findings of the study, highlighting both the performance improvements and security challenges of 5G networks in technical education. While 5G enhances data speed, reduces latency, and supports bandwidth-intensive applications, it also introduces risks related to cybersecurity and infrastructure disparities. To maximize the benefits of 5G in education, institutions must address security threats and develop cost-effective deployment strategies.

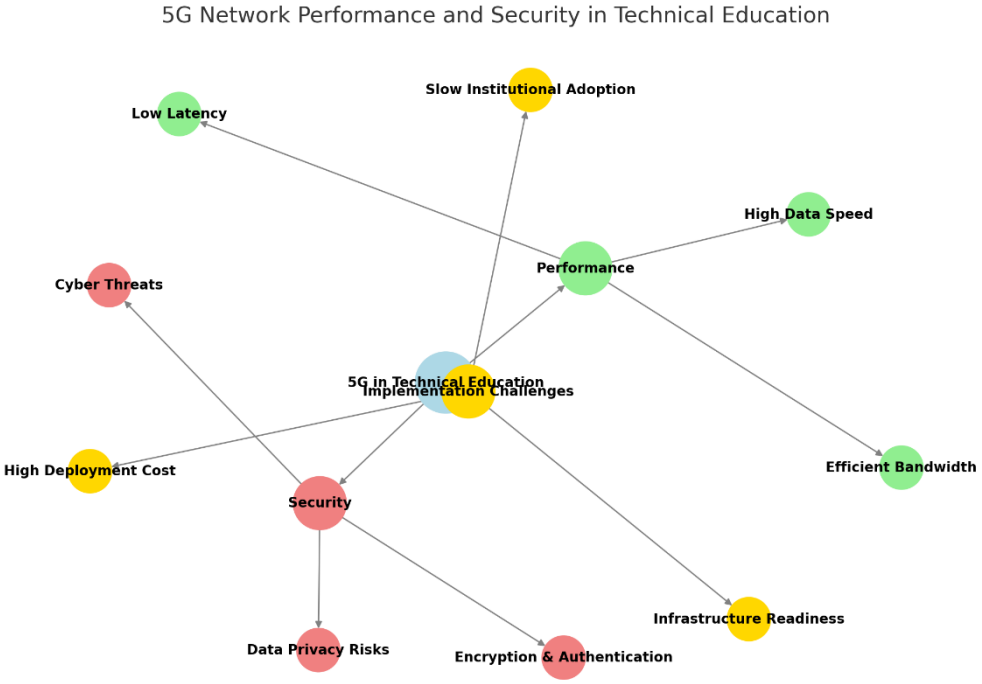


Figure 1 Network performance and security

This diagram shows the relationship between 5G in engineering education and three key aspects: performance, security, and implementation challenges. 5G performance is enhanced through high data rates, low latency, and bandwidth efficiency, while security aspects face challenges such as data privacy risks, cyber threats, and the need

for stronger encryption. Implementation challenges include infrastructure readiness, high investment costs, and slow adoption in educational institutions.

Furthermore, the research highlights the importance of optimizing 5G network configurations for educational purposes. Factors such as network slicing, edge computing, and dedicated bandwidth allocation play crucial roles in ensuring stable and secure connectivity in technical education environments. Institutions that strategically implement these technologies can maximize the benefits of 5G while minimizing potential risks.

In conclusion, the study confirms that while 5G networks offer transformative potential for technical education, their successful implementation requires a balanced approach that considers both performance enhancements and security measures. Future research should focus on developing more resilient 5G security frameworks tailored to educational settings and exploring cost-effective strategies to accelerate widespread adoption.

**Discussion**

The findings of this study align with previous research emphasizing the transformative potential of 5G technology in education. Several studies have highlighted that 5G networks significantly improve learning efficiency by enabling high-speed data transmission and ultra-low latency [11]. This study corroborates these claims, demonstrating that 5G enhances real-time interaction in technical education by supporting bandwidth-intensive applications such as augmented reality (AR), virtual reality (VR), and cloud-based laboratory simulations [12]. The ability to facilitate seamless remote learning and immersive experiences aligns with the theoretical framework of digital transformation in education, which posits that technological advancements must be leveraged to bridge geographical barriers and improve learning accessibility [13].

However, despite these advantages, security remains a primary concern, echoing findings from existing cybersecurity literature on 5G networks. Prior studies indicate that 5G's decentralized network architecture and massive connectivity increase vulnerabilities to cyber threats, including data breaches and unauthorized access [14]. This study supports these concerns, identifying that educational institutions adopting 5G must implement robust security measures, such as encryption protocols, intrusion detection systems, and multi-factor authentication [15]. From a theoretical perspective, this finding aligns with network security models that emphasize the need for proactive threat mitigation strategies, particularly in highly connected environments like smart campuses [16].

Another key aspect of the analysis is the disparity in infrastructure readiness among educational institutions. Previous research suggests that while developed nations have rapidly adopted 5G for educational purposes, developing regions face challenges related to high deployment costs, lack of expertise, and regulatory constraints [17]. This study confirms these observations, demonstrating that while some universities and technical institutions have successfully integrated 5G into their learning frameworks, others struggle with financial and technical limitations. The findings support the digital divide theory, which argues that uneven technological access can exacerbate educational inequalities [18]. Addressing this issue requires collaborative efforts between governments, private sector stakeholders, and academic institutions to ensure equitable access to 5G-enabled educational innovations.

Additionally, this research highlights the significance of optimizing 5G network configurations for technical education, a topic that has received limited attention in previous studies. While existing literature discusses the general benefits of network slicing and edge computing [19], this study applies these concepts to educational settings, suggesting that institutions should adopt dedicated bandwidth allocation strategies to ensure stable and secure connectivity. This aligns with network performance theories that emphasize adaptive resource management as a key factor in enhancing user experience in dynamic environments [20].

In conclusion, the findings of this study contribute to the growing body of literature on 5G's role in digital education by providing empirical evidence on both its benefits and challenges in technical education. While the study reinforces existing theories on network performance and security, it also addresses research gaps related to infrastructure readiness and the practical implementation of advanced 5G configurations in educational institutions. Future research should focus on developing cost-effective 5G deployment strategies for underfunded institutions and designing cybersecurity frameworks tailored specifically to educational settings.

## CONCLUSION

This study concludes that 5G networks play a crucial role in accelerating digital transformation in technical education by enhancing connectivity, enabling real-time interaction, and supporting advanced learning technologies such as augmented reality (AR), virtual reality (VR), and cloud-based simulations. The findings confirm that 5G significantly improves network performance by reducing latency and increasing data transmission speed, thereby facilitating seamless remote learning experiences. However, despite these advantages, security challenges remain a critical concern. The study identifies various cyber threats, including unauthorized access and data privacy

risks, emphasizing the need for robust security measures such as encryption protocols, multi-factor authentication, and continuous monitoring. Additionally, infrastructure disparities among educational institutions highlight the importance of government and private sector collaboration in ensuring equitable access to 5G-powered education.

Future research should focus on developing cost-effective strategies for implementing 5G in underfunded educational institutions, particularly in developing regions. Further studies are also needed to explore advanced cybersecurity frameworks tailored specifically for educational settings to mitigate potential threats associated with massive connectivity. Moreover, research should investigate the long-term impact of 5G on student engagement and learning outcomes in technical education, providing empirical evidence on its effectiveness compared to traditional digital learning methods. Lastly, examining the role of emerging technologies such as artificial intelligence (AI) and blockchain in enhancing the security and efficiency of 5G-enabled educational environments could offer valuable insights for optimizing its implementation.

## REFERENCES

[1] A. Al Ka'bi, "Proposed artificial intelligence algorithm and deep learning techniques for development of higher education," *Int. J. Intell. Networks*, vol. 4, pp. 68–73, 2023.

[2] R. Ramlah, N. Riana, and A. P. Abadi, "Fun Math Learning For Elementary School Students Through Interactive Puzzle Media," *SJME (Supremum J. Math. Educ.*, vol. 6, no. 1, pp. 25–34, 2022, doi: 10.35706/sjme.v6i1.5775.

[3] A. Nolan and T. Molla, "Teacher confidence and professional capital," *Teach. Teach. Educ.*, 2017, doi: 10.1016/j.tate.2016.11.004.

[4] A. B. Pratomo, S. Mokodenseho, and A. M. Aziz, "Data encryption and anonymization techniques for enhanced information system security and privacy," *West Sci. Inf. Syst. Technol.*, vol. 1, no. 01, pp. 1–9, 2023.

[5] Y.-S. Chang, K.-J. Hu, C.-W. Chiang, and A. Lugmayr, "Applying Mobile Augmented Reality (AR) to teach Interior Design students in layout plans: Evaluation of learning effectiveness based on the ARCS Model of learning motivation theory," *Sensors*, vol. 20, no. 1, p. 105, 2019.

[6] S. S. Gill *et al.*, "AI for next generation computing: Emerging trends and future directions," *Internet of Things*, vol. 19, p. 100514, 2022.

[7] J. Rajadurai, N. M. Sapuan, S. Daud, and N. Abidin, "The marketability of technical graduates from higher educational institutions (HEIs) offering technical and vocational education and training (TVET): a case from Malaysia," *Asia-Pacific Educ. Res.*, vol. 27, pp. 137–144, 2018.

[8] I. Adhicandra, A. Asfahani, T. Tanwir, J. W. Sitopu, and F. Irawan, "Latest

Innovations in Internet of Things (IoT): Digital Transformation Across Industries," *Innov. J. Soc. Sci. Res.*, vol. 4, no. 3, pp. 1027–1037, 2024.

[9] T. S. Qodr, A. Efendi, and A. A. Musadad, "Opportunities for Using Smartphones in the Digital Era to Facilitate Students in Learning Sociology in High Schools," *J. Educ. Technol.*, vol. 5, no. 2, pp. 263–271, 2021.

[10] I. García, "Asset-based community development (ABCD): Core principles," in *Research handbook on community development*, Edward Elgar Publishing, 2020.

[11] T. Tang, A. M. Abuhmaid, M. Olaimat, D. M. Oudat, M. Aldhaeebi, and E. Bamanger, "Efficiency of flipped classroom with online-based teaching under COVID-19," *Interact. Learn. Environ.*, vol. 31, no. 2, pp. 1077–1088, 2023.

[12] M. Raparthi, S. B. Dodda, and S. Maruthi, "Examining the use of Artificial Intelligence to Enhance Security Measures in Computer Hardware, including the Detection of Hardware-based Vulnerabilities and Attacks.," *Eur. Econ. Lett.*, vol. 10, no. 1, 2020.

[13] T.-Y. Tai, H. H.-J. Chen, and G. Todd, "The impact of a virtual reality app on adolescent EFL learners' vocabulary learning," *Comput. Assist. Lang. Learn.*, vol. 35, no. 4, pp. 892–917, 2022.

[14] T. Tao and X. Lv, "Construction of ideological and political education in colleges and universities based on the carrier of smartphone," *Secur. Commun. Networks*, vol. 2022, pp. 1–8, 2022.

[15] A. Lentzas and D. Vrakas, "Non-intrusive human activity recognition and abnormal behavior detection on elderly people: A review," *Artif. Intell. Rev.*, vol. 53, no. 3, pp. 1975–2021, 2020.

[16] D. Bright, R. Brewer, and C. Morselli, "Using social network analysis to study crime: Navigating the challenges of criminal justice records," *Soc. Networks*, vol. 66, pp. 50–64, 2021.

[17] M. S. Mariani, Z.-M. Ren, J. Bascompte, and C. J. Tessone, "Nestedness in complex networks: observation, emergence, and implications," *Phys. Rep.*, vol. 813, pp. 1–90, 2019.

[18] R. Tyagi, "Empowering the unbanked: a revolution in financial inclusion through artificial intelligence," *Int. J. Res. Eng. Sci. Manag.*, vol. 6, no. 10, pp. 4–12, 2023.

[19] T. Long, J. Cummins, and M. Waugh, "Use of the flipped classroom instructional model in higher education: instructors' perspectives," *J. Comput. High. Educ.*, vol. 29, pp. 179–200, 2017.

[20] H. Jiang *et al.*, "Convolution neural network model with improved pooling strategy and feature selection for weld defect recognition," *Weld. World*, vol. 65, pp. 731–744, 2021.