IoT-Enhanced Smart Campus Management System

Harsh Sharma, Dharmender, Himanshu, Amit Kumar Sharma

Department of Computer Science and Engineering, Sharda University, Greater Noida, India

harshsh2685@gmail.com, vashisthdharmender8368@gmail.com,

himanshusinghnirwan7418@gmail.com, amit.krsharma123@gmail.com

Abstract

The emergence of smart campus technologies has transformed educational environments by integrating biometrics, the Internet of Things (IoT), Artificial Intelligence (AI), and Machine Learning (ML). This paper reviews key advancements in automatic attendance systems, intelligent learning environments, and campus infrastructure optimization. Biometric approaches such as fingerprint, facial recognition, RFID, and NFC enhance the accuracy of real-time attendance monitoring, reducing proxy incidents and administrative workload. IoT frameworks further enable wireless connectivity, real-time analytics, and cloud-based storage, improving system reliability and responsiveness. Concurrently, AI-driven Learning Management Systems (LMS) and Campus Management Systems (CMS) provide personalized learning recommendations, student performance predictions, and risk assessment models with predictive accuracy exceeding 90%. Based on these insights, an IoT-based Smart Campus Management System is proposed that integrates RFID check-in, AI-powered facial verification, and teacher-in-the-loop supervision for robust, privacy-preserving attendance monitoring. This multi-sensor, human-assisted framework enhances accuracy, scalability, and decision-making, contributing to the development of adaptive, secure, and data-driven smart campus ecosystems for future-ready education.

Keywords: -Smart Campus, IoT, Biometric Attendance, RFID, Face Recognition, AI, Machine Learning, Campus Management System (CMS), Edge Computing

1. INTRODUCTION

The digitisation of educational institutions into smart campuses has accelerated with the development of Biometrics, the Internet of Things (IoT), and Artificial Intelligence (AI). Conventional attendance procedures, such as manually taking roll or using paper registers, waste already precious class time and increase the likelihood of proxy attendance and recording inaccuracies. With the increasing trend toward automated, data-driven decision-making in education, the need for an efficient, secure, and privacy-preserving attendance system is growing as well.

Recently, several studies have focused on biometric data-based attendance systems, such as fingerprint verification, face recognition, RFID, and NFC. (Gupta et al., 2020; Nguyen et al., 2021; Sasirekha et al., 2024) These solutions are more accurate and reduce fraudulent behaviour; however, they are usually not scalable, sensitive to the environment, and concerned with privacy issues. At the same time, the use of AI and ML in Learning Management Systems (LMS), such as personalisation, risk prediction, and monitoring of academic performance, with high predictive accuracy (Shoaib et al., 2024; Nouman et al., 2024; Rahman et al., 2016). IoT-based solutions are not only used to monitor attendance, but also in smart

campuses for energy efficiency, parking and health management, and enhanced security, indicating a day not too far off when everything will be part of an integrated ecosystem. (Li et al., 2024; Sahane et al., 2025; Wang & Sun, 2023)

Based on these advances, this paper designs an IoT-based Smart Campus Management System which includes RFID-based check-in, AI-based facial verification, and teacher-patrolled supervision. It further introduces an initial RFID/NFC step to detect student presence, followed by real-time, edge-based, CV-driven monitoring of student presence. For privacy, raw videos are processed locally and deleted immediately after an analysis to avoid unauthorized storage or access. It also introduces a teacher-in-the-loop to the system, who can override generator-based attendance marking in authorised or special cases, thereby maintaining equity and flexibility.

The multi-sensor approach, if implemented, can overcome the drawbacks of the existing system while offering many benefits, including fast RFID speed, high AI face recognition accuracy, and human intervention. It also delivers respectful data insight for studying academic performance, privacy, management and scalability.

Our work supports the vision of next-generation smart campus environments by automatically embedding attendance management into smart learning platforms and campus infrastructure, delivering an efficient, secure user experience and fulfilling academic requirements.

2. LITERATURE REVIEW

The analysed research publications on smart campus solutions have been classified into four major categories: biometric attendance & access control; RFID/NFC check-in; Internet of Things (IoT) campus services; and AI/ML learning platforms and administrative platforms.

Biometric-based attendance systems are commonly used, including fingerprint-based, face-based, and combined biometric methods, to reduce proxy attendance and human-driven errors. Fingerprint-based methods achieved recognition rates of about 87% to 92% (Gupta et al., 2020; Nguyen et al., 2021), but had disadvantages such as physical contact and sensor failure. Face recognition models built on Raspberry Pi hardware, using algorithms such as Viola-Jones, Eigenfaces, Fisherfaces, and Local Binary Patterns (LBP), achieved up to 95% accuracy on small datasets, demonstrating potential for contactless verification (Sasirekha et al., 2024). However, due to the sensitivity of these machines to different types of illumination, occlusions, and pose variations, it is necessary to incorporate a privacy-preserving design into them.

RFID and NFC-based attendance systems save time (Gupta et al., 2020; Wang & Sun, 2023) through quick entry via card scanning or mobile authentication. Authors have proposed administrative reductions and increased convenience; however, the associated concerns with these systems include the outsourcing of attendance unless a secondary verification (e.g., a vision-based approach or biometric identification) is adopted concurrently.

Smart campus IoT applications are more than just attendance tracking. Other literature focuses on energy regulation employing hierarchical IOT layers architectural for real time monitoring of lighting and air conditioning costing more than 50% in operation savings (Li et al., 2024; Sahane et al., 2025; Nguyen et al., 2021) Other showcased prototypes include Parking management system with Raspberry Pi and cameras, GPS modules and ultrasonic sensors, Health and safety monitoring with vaccination status, temperature check, mask detection and LMS-IoT integration for secured access control to the events.

The above use cases illustrate how flexible IoT technology can make a difference in improving campus management efficiency, as well as the associated challenges of interoperability, data governance, and system expansion.

More and more, schools use AI and machine learning to help students learn and make school work easier. Some AI models can guess how students will do in school with about 90% right. Other tools, like learning recommendation systems and school management platforms, help teachers and principals see student progress quickly.

But there are still problems. No one has tried a system that uses both RFID and face recognition and also lets teachers check if students are really there. We also need ways to keep data private, like using video only on the device and deleting it after checking. Other problems are how to make it work for many students, stop cheating, and send attendance info to school systems.

Our system tries to fix these problems. It uses RFID cards to check in and out, face recognition on the device, and teacher monitoring. This way, the system is fast, correct, and fair.

3. RESEARCH GAPS

Despite significant advancements in smart campus systems, several critical research gaps remain. First, most existing attendance systems rely on a single technology such as RFID, fingerprint scanning, or facial recognition, which can lead to reliability issues and fraudulent attendance logging. Limited work has explored multi-sensor fusion approaches that combine RFID/NFC and AI-driven facial verification to enhance accuracy and minimize false records. (Gupta et al., 2020; Li et al., 2024; Sasirekha et al., 2024) In addition, the position of teachers as monitoring entities in the attendance verification process--which enable manual overrides for legitimate absences--is predominantly ignored.

There is also a significant privacy and ethical gap. Most face recognition systems are based on cloud computing, which lead to the risk of data leak and abuse of biometric information and knowledge. (Li et al., 2024; Nguyen et al., 2021) There is a lack of solutions emphasizing edge processing, on-device computation, and automatic deletion of raw video to ensure compliance with privacy standards.

Additionally, while some studies link learning management systems with performance analytics, few attempt to correlate real-time attendance data with academic outcomes in an integrated framework (Shoaib et al., 2024; Nouman et al., 2024). Finally, most smart campus solutions address isolated functions such as attendance, energy management, or parking, yet fail to deliver a unified, IoT-enabled ecosystem that simultaneously supports operational efficiency, academic analytics, and privacy-aware management.

Gap Area	Description	References
Hybrid Attendance Verification	Most systems use either RFID/NFC or face recognition independently. Few propose a combined multi-modal approach integrating both for higher accuracy	(Gupta et al., 2020; Nguyen et al., 2021; Sasirekha et al., 2024)
Teacher-in-the-Loop Oversight	Existing studies automate attendance fully but lack teacher control to override in case of legitimate absence (e.g., authorized leave).	Sahane et al., 2025; Shoaib et al., 2024
Privacy-Preserving Mechanism	Facial recognition studies process data centrally, raising concerns about data misuse. Edge-based video processing and auto-deletion of raw data remain underexplored	Li, 2022; Li et al., 2024; Wang & Sun, 2023

Scalability & Reliability	Many prototypes are validated on small datasets or limited environments (single classroom or lab). Real-world deployment with thousands of students and devices is rarely addressed	Sahane et al., 2025; Wang & Sun, 2023
Anti-Spoofing & Security	Systems using RFID/NFC remain vulnerable to proxy attendance, while face recognition is sensitive to spoofing (photos, masks). Few works propose combined defenses.	Nguyen et al., 2021; Sasirekha et al., 2024
Unified CMS–LMS Integration	IoT projects cover isolated functions (energy management, parking, access control) but lack a unified framework connecting attendance data with LMS analytics for academic insights	Shoaib et al., 2024; Nouman et al., 2024; Rahman et al., 2016; Carbonaro, 1 C.E.

4. ARCHITECTURE AND MODELS FOR IOT- ENHANCED CAMPUS MANAGEMENT SYSTEM

The IoT-enabled Smart Campus Management System (CMS) introduced in this study is a multi-layer design integrating RFID-based check-in, AI supported facial recognition, teacher supervision, as well as IoT-based service. The system intends to provide accuracy, privacy, fairness and scalability in campus activity management.
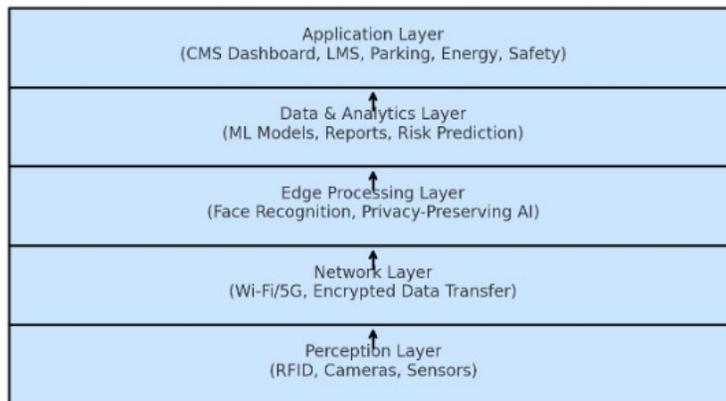

Fig:-1 – Iot enabled Smart Campus Management System Architecture

A. **System Architecture**
The adopted model by the CMS is five-layer IoT model tailored for education institutions:

Perception Layer: Consists of RFID/NFC tags for initial check-in, cameras for edge-based facial recognition, and IoT sensors for room environmental analysis (e.g. energy consumption, occupancy). Raw video data are removed after video processing at the local site in order to protect privacy.
Network Layer: It transfers encrypted attendance and sensor data in real-time via Wi-Fi/5G with lightweight protocols (e.g., MQTT, HTTP).

Edge Processing Layer – Real-time facial verification is performed on Raspberry Pi or edge servers, with raw video stored locally on the device. This ensures low latency and high security (Li, 2022; Wang & Sun, 2023; Sahane et al., 2025)

Application Layer – Provides a CMS dashboard that includes:
- Attendance verification and teacher intervention
- Analysis of student performance
- Facility management
- Physical safety monitoring

B. Function Model Based on Attendance Monitoring

The system uses a **hybrid approach**, combining automation with human oversight:
- **RFID/NFC Check-in** – Students log in quickly using a card or mobile device.
- **AI-powered Facial Verification** – Ensures the student is physically present in class, minimizing proxy attendance.
- **Teacher Oversight** – If a student leaves after the allocated grace period, an alarm is triggered throughout the school. Teachers retain the ability to override records to maintain fairness.

This idea blends automation with human intervention, decreasing wrong positives while lowering administrative workload.

C. Integration with Campus Services

Beyond attendance tracking, the system interfaces with a variety of **Campus Management System (CMS)** applications:
- **LMS (Learning Management System)** – Links attendance records with academics and student performance.
- **Resource Management** – IoT-enabled automation schedules classroom lighting and HVAC systems, optimizing energy usage.
- Smart Parking – Real-time information about available parking space is informed to students via a Raspberry Pi, camera, and GPS module.
- **Safety and Compliance** – Features such as mask detection, record verification, and event access enhance campus safety and ensure compliance.

D. Data Flow Model

The flow of the data consists of the following:

Check-in for student by scanning RFID card.

Camera identifies the owner locally with our facial recognition technology.

If both checks are successful attendance is valid.

Exits beyond threshold raise absence flag.

Teacher validates or overrides status.

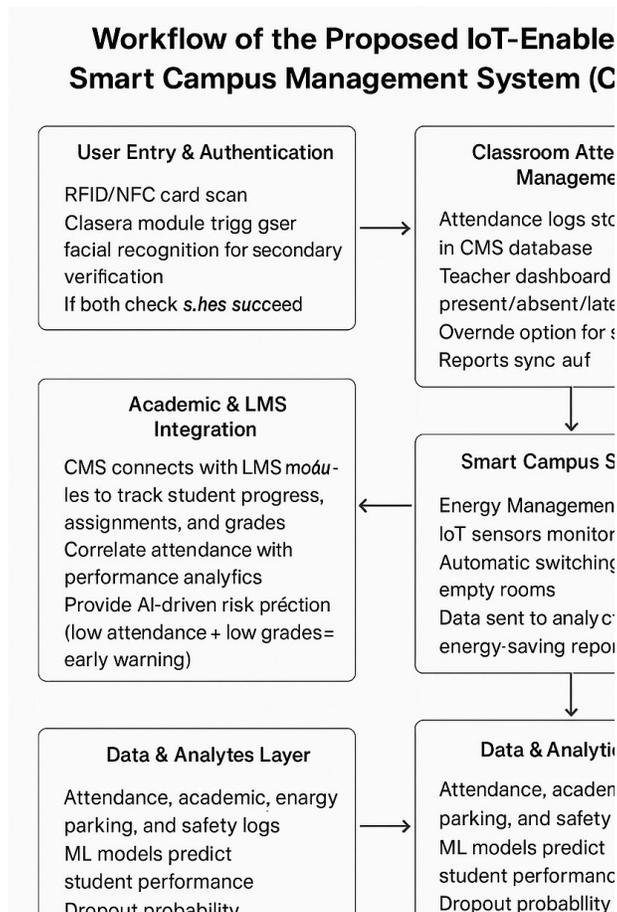Final record written through to CMS database and synched

Fig:-2 Work Flow of Iot Enhanced Campus Management System(CMS)

5. FUTURE DIRECTIONS

The reviewed literature and the proposed system demonstrate major improvements for smart campus management using biometric attendance, RFID/NFC-based authentication, services and analytics with IoT and AI. This subject also leaves some open problems to future investigation and improvement:

Scalability and Real-Time Processing :
Existing systems scale well in small and medium dataset sizes, but have issues for scaling to thousands of students and multiple campus environment. Further research can concentrate on distributed architectures, edge, and cloud integration to guarantee real-time performance that scales without bottlenecks.

Hybrid Attendance Assurance
Although RFID and face recognition perform well independently, spoofing, light changing, and card stealing are still problems. In future systems, the multimodal user authentication (RFID + facial recognition + behavioral biometrics as gait recognition) may apply with.textContent.MATCHING_MODALITIES teacher proofs of the same person.

Privacy-Preserving Mechanisms

There were the fewer studies in biometric and videobased attendance with privacy. It also indicates that any new systems have to include on-device (edge) processing, homomorphic encryption and auto-deletion of raw data in order to comply with privacy regulations and instil user trust.

AI-Driven Academic Insights
Today's AI applications generally predict student risk/performance. Further studies could be conducted on the XAI models which not only predict school success but explain the factors that contribute to this success, actionable from teachers or principals.

Interoperability and Unified Data Frameworks
Current IoT applications for energy, parking and security monitoring all suffer from lack of integration. Next generation systems would be better served by employing standardized protocols and common frameworks so that disparate campus services can be integrated, avoiding redundancy and increasing efficiency.

Energy-Sustainable Campuses
Energy management using IoT computing has exhibited the potential, but restricted to the light devices and air conditioners. Prospective studies can push the boundaries in smart grids, renewable sources of energy and predicted demand-supply coordination for environmentally friendly and cheap campuses.

Inclusive and Accessible Design
Many of the solutions that currently exist do not cater for all user needs for accessibility. Here are a few other ways that designs in the future will need to facilitate inclusivity: Voice-based authentication, assistive IoT devices, and adaptable interfaces for differently abled students and staff.

Comprehensive CMS Ecosystem
Coaches have to be strictly punctual for this phase of the roll. Their participation in matches could be the result of limiting the selection of players for the group, and of any concerns parents have about the range of players. Along with the players' participation.

6. CONCLUSION

The paper presented an IoT-enabled Smart Campus Management System that leverages RFID-based check-in, AI-based facial recognition, and teacher-operated controls to ensure fair and authentic attendance recording. By integrating multimodal authentication with edge privacy-preserving processing, the system addresses standard issues of proxy attendance, environmental prerequisites, and data confidentiality. More than just attendance, the smart campus services integrated into the proposed CMS include energy management, parking guidance, and health and safety monitoring, among others, forming a refined digital ecosystem for today's university.

The review literature showed that, despite the presence of different approaches such as biometric authentication, RFID/NFC attendance, IoT-based services, and artificial intelligence tools for academic prediction, the article stated that all systems are mostly limited in applicability, scalability, and privacy.

Our method closes these gaps by combining several technologies into a hybrid, teacher-in-the-loop architecture that provides a trade-off between automation and human control. Going

forward, the system may be improved by adding scalable cloud–edge integration, explainable AI models for academic insights, interoperability across different campus services and sustainable green-campus solutions. In general, the proposed CMS demonstrates the utilisation of IoT, AI, and intelligent system design, which, when combined, transform higher education management into a more efficient, safe, and student-oriented system.

References

[1] Shoaib, M., Sayed, N., Singh, J., Shafi, J., Khan, S., & Ali, F. (2024). AI student success predictor: Enhancing personalized learning in campus management systems. *Computers in Human Behavior*, *158*, 108301. https://doi.org/10.1016/J.CHB.2024.108301

[2] Sahane, P. *et al.* (2025). Smart Campus Solutions: Leveraging AI-ML Technologies for Integrated Campus Management Platform. In: Iglesias, A., Shin, J., Patel, B., Joshi, A. (eds) Information Systems for Intelligent Systems. ISBM 2024. Lecture Notes in Networks and Systems, vol 1254. Springer, Singapore. https://doi.org/10.1007/978-981-96-1744-9_7

[3] Li, C.H. *et al.* (2024). How to Embed AI Applications of Building Management System in Campus Management. In: Nagar, A.K., Jat, D.S., Mishra, D., Joshi, A. (eds) Intelligent Sustainable Systems. WorldS4 2023. Lecture Notes in Networks and Systems, vol 812. Springer, Singapore. https://doi.org/10.1007/978-981-99-8031-4_35

[4] Gupta, S., Baranwal, A. K., Mishra, S., & Tiwari, P. (2020). Smart campus management with advanced learning management system. *2020 21st National Power Systems Conference, NPSC 2020*. https://doi.org/10.1109/NPSC49263.2020.9331898

[5] Li, C. (2022). Development of Artificial Intelligence Campus and Higher Education Management System Under the Background of Big Data and WSN. *Proceedings of the International Conference on Electronics and Renewable Systems, ICEARS 2022*, 750–753. https://doi.org/10.1109/ICEARS53579.2022.9752451

[6] Wang, Y., & Sun, Y. (2023). Construction of an Artificial Intelligence Student Management Information System Under Big Data Analysis Algorithms. *Proceedings - 2023 2nd International Conference on Artificial Intelligence and Intelligent Information Processing, AIIIP 2023*, 61–65. https://doi.org/10.1109/AIIIP61647.2023.00017

[7] Nguyen, S. T., Le, B. N., & Dao, Q. X. (2021). AI and IoT-powered Smart University Campus: Design of Autonomous Waste Management. *Proceedings - 2021 International Symposium on Electrical and Electronics Engineering, ISEE 2021*, 139–144. https://doi.org/10.1109/ISEE51682.2021.9418672

[8] Sasirekha, V., Ramadevi, R., Presitha Aarthi, M., Malarvizhi, C., Mohankumar, N., & Velmurugan, S. (2024). Intelligent Campus Safety Management using IoT and CNNs for Surveillance, Access, and Emergency Response. *2024 3rd International*

Conference for Innovation in Technology, INOCON 2024. https://doi.org/10.1109/INOCON60754.2024.10512335

[9] Shoaib, M., Sayed, N., Singh, J., Shafi, J., Khan, S., & Ali, F. (2024). AI student success predictor: Enhancing personalized learning in campus management systems. *Computers in Human Behavior*, *158*, 108301. https://doi.org/10.1016/J.CHB.2024.108301

[10] Sharma, V. K. (2025). Cloud Computing & IoT: 5G Focused IoT with Cloud Solutions. International Journal of AI, BigData, Computational and Management Studies, 6(3), 21-25.

[11] Kiy, A., Lucke, U., & Zoerner, D. (2014). An Adaptive Personal Learning Environment Architecture. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, *8350 LNCS*, 60–71 https://doi.org/10.4018/978-1-59140-729-4.CH007

[12] Rahman, S. A., Ahmad, N. R., Ahmad, M., Kamis, Y., & Taib, K. M. (2016). A design of a Personalized Educational Resources Management System. *2015 IEEE 7th International Conference on Engineering Education, ICEED 2015*, 140–144. https://doi.org/10.1109/ICEED.2015.7451508

[13] Nouman, N., Shaikh, Z. A., & Wasi, S. (2024). A Novel Personalized Learning Framework With Interactive e-Mentoring. *IEEE Access*, *12*, 10428–10458. https://doi.org/10.1109/ACCESS.2024.3354167

[14] Mohd, C. K. N. C. K., & Shahbodin, F. (2015). Personalized Learning Environment (PLE) Experience in the Twenty-First Century: Review of the Literature. *Advances in Intelligent Systems and Computing*, *355*, 179–192. https://doi.org/10.1007/978-3-319-17398-6_17

[15] Mohd, C. K. N. C. K., & Shahbodin, F. (2015). Personalized Learning Environment (PLE) Experience in the Twenty-First Century: Review of the Literature. *Advances in Intelligent Systems and Computing*, *355*, 179–192. https://doi.org/10.1007/978-3-319-17398-6_17

[16] S. Gupta, A. K. Baranwal, S. Mishra and P. Tiwari, "Smart Campus Management with Advanced Learning Management System," 2020 21st National Power Systems Conference (NPSC), Gandhinagar, India, 2020, pp. 1-6, doi: 10.1109/NPSC49263.2020.9331898.

[17] Li, C.H. *et al.* (2024). How to Embed AI Applications of Building Management System in Campus Management. In: Nagar, A.K., Jat, D.S., Mishra, D., Joshi, A. (eds) Intelligent Sustainable Systems. WorldS4 2023. Lecture Notes in Networks and Systems, vol 812. Springer, Singapore. https://doi.org/10.1007/978-981-99-8031-4_35

[18] Gusain, Nutan, and Himanshu Sharma. "Communication-efficient federated learning in industrial IoT—a framework for real-time threat detection and secure device

International Conference on Multidisciplinary Perspectives in Advanced Computing and Technology (IMPACT 2026)

G. B. Pant University of Agriculture and Technology, Uttarakhand, India. Jan. 10-11, 2026

coordination." *International Journal on Computational Modelling Applications* 2, no. 2 (2025): 18-29.

[19] Zhang, X., Zheng, B., & Pan, L. (2020). Using virtual reality technology to visualize management of college assets in the internet of things environment. *IEEE Access*, *8*, 157089–157102. https://doi.org/10.1109/ACCESS.2020.3019836

[20] Wakim, P., & Mershad, K. (2018). Using Internet of Things in a Learning Management System for Campus Access Control. *2018 International Conference on Computer and Applications, ICCA 2018*, 46–51. https://doi.org/10.1109/COMAPP.2018.8460302

[21] Shyr, W.-J., Zeng, L.-W., Lin, C.-K., Lin, C.-M., & Hsieh, W.-Y. (2018). Application of an Energy Management System via the Internet of Things on a University Campus. *Eurasia Journal of Mathematics, Science and Technology Education*, *14*(5), 1759–1766. https://doi.org/10.12973/EJMSTE/80790

[22] Zeng, Y., & Boontasorn, N. (2022). Student Management System Based on Intelligent Technology of Internet of Things. *Lecture Notes on Data Engineering and Communications Technologies*, *84*, 866–876. https://doi.org/10.1007/978-981-16-5857-0_110

[23] Sharma, V. K., & Abhilash, K. S. (2025, October). Hierarchical Cloud-IoT Architecture for AI-Powered Intelligent Disaster Response. In 2025 7th International Conference on Innovative Data Communication Technologies and Application (ICIDCA) (pp. 603-610). IEEE.

[24] Sharma, V. K., & Abhilash, K. S. (2025, September). Latency-Aware Edge-Cloud Architecture for 5G IoT Integration. In 2025 6th International Conference on Electronics and Sustainable Communication Systems (ICESC) (pp. 1398-1405). IEEE.