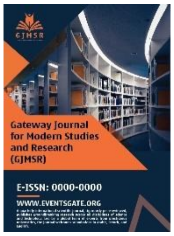
Gateway Journal for Modern Studies and Research (GJMSR), vol.3, no.1, 27 Feb. 2026
DOI: https://doi.org/10.61856/f5wabv17



Scientific Events Gate

GJMSR

Gateway Journal for Modern Studies and Research

https://gjmsr.eventsgate.org/gjmsr/

IoT-Based Smart Transportation System Using Optical Fiber Communication for Enhanced Safety and Efficient Data Transmission

RAWA MUAYAD MAHMOOD

[1] **SCIENTIFIC EVENTS GATE- Malysia**
[2] **WIPNET, Department of Computer and Communication Systems Engineering, Faculty of Engineering, Universiti Putra Malaysia (UPM), Serdang 43400, Selangor, Malaysia**

Received 25/11/2025 - Accepted 15/01/2026 Available online 27/2/2026

Abstract: The rapid growth of urbanization and motorized transportation has resulted in increased traffic congestion, higher accident rates, and significant challenges in ensuring road safety and efficient transportation management. Traditional transportation systems often lack real-time monitoring, intelligent decision-making, and reliable communication infrastructures required to address these challenges. The emergence of the Internet of Things (IoT) has enabled the development of smart transportation systems through real-time data collection, vehicle monitoring, and predictive analytics. However, the effectiveness of such systems is highly dependent on the underlying communication network. This research proposes an IoT-based smart transportation system utilizing optical fiber communication as a high-speed, low-latency, and reliable backbone for data transmission. The proposed system integrates IoT sensors with an optical fiber network to support real-time traffic monitoring, accident prevention mechanisms, and efficient data exchange. The system is designed and evaluated using simulation tools, including OptiSystem and MATLAB, to assess key performance parameters such as bit error rate, signal quality, transmission distance, and system reliability. The simulation results demonstrate that optical fiber communication significantly enhances data transmission performance and system stability, making it a suitable solution for next-generation intelligent transportation systems (Mahmood, 2024).

Keywords: Internet of Things (IoT), Smart Transportation, Optical Fiber Communication.

DOI: https://doi.org/10.61856/f5wabv17

1. Introduction

The continuous evolution of communication technologies has played a fundamental role in enabling modern intelligent systems, particularly those requiring high-speed, reliable, and real-time data transmission. Early communication infrastructures were primarily based on copper transmission media and wireless technologies, which, despite their widespread use, suffer from inherent limitations such as restricted bandwidth, signal attenuation, electromagnetic interference, and limited scalability. To overcome these constraints, optical fiber communication has emerged as a next-generation transmission medium capable of supporting long-distance and high-data-rate communication with minimal signal degradation and enhanced reliability.

In parallel, the rapid expansion of the Internet of Things (IoT) has transformed conventional systems into interconnected, data-driven environments. IoT enables the integration of a large number of sensors, devices, and control units that continuously generate vast volumes of heterogeneous data (S. Madakam, 2015), (D. Giusto, 2015). This massive data generation introduces challenges related to data integration, real-time processing, and communication efficiency, particularly when dealing with unstructured data such as images and video streams (O. Katerna, 2019). Consequently, IoT-based applications require robust communication infrastructures that can provide high bandwidth, low latency, and secure data transmission (L. Atzori,2010), (J. Gubbi, 2013), (M. Chen, 2014), (S. Al-Sarawi et al., 2017).

Transportation systems represent a critical component of economic and social development, as they facilitate the movement of people and goods while reducing operational costs and improving market accessibility. Studies have shown that the development of transportation and communication infrastructure is strongly linked to economic growth and efficiency (O. Katerna, 2019), (L. Figueiredo, 2001). However, rapid urbanization and the increasing number of vehicles have resulted in traffic congestion, higher accident rates, and significant losses in human lives and property. Traditional transportation systems often lack real-time monitoring, intelligent decision-making, and reliable communication capabilities necessary to address these challenges effectively.

Recent research has highlighted the potential of Intelligent Transportation Systems (ITS) that integrate IoT technologies to enhance traffic management, vehicle monitoring, and road safety. IoT-based transportation systems have been proposed to support real-time data collection, accident detection, and predictive safety mechanisms (T. M. Bojan, 2019), (S. Bhattacharya, 2022), (S. Shashank, 2021), (Y. Zhang, 2020), (F. Al-Turjman, 2021), (J. Gubbi, 2013), (F. Bonomi, 2012), (S. Talari et al., 2017), (P. S. Saarika, 2017), (D. C. Rotescu, 2013). While these systems demonstrate promising results, many existing solutions rely heavily on wireless communication technologies, which may suffer from bandwidth limitations, latency, and interference, particularly in dense urban environments and safety-critical applications.

To address these limitations, optical fiber communication offers a highly reliable and high-capacity backbone for IoT-based smart transportation systems. Optical fiber networks provide superior bandwidth, low latency, immunity to electromagnetic interference, and enhanced security, making them suitable for supporting real-time transportation applications (B. Yazar, 2013), (W. Zeng and H. Gao, 2014), (G. Keiser, 2021), (G. P. Agrawal, 2012), (J. M. Senior and M. Y. Jamro, 2009),

DOI: https://doi.org/10.61856/f5wabv17

(C. F. Lam et al., 2010). The integration of IoT sensing technologies with optical fiber communication enables efficient data transmission, improved system stability, and enhanced support for advanced transportation services.

Therefore, this research aims to develop and evaluate an IoT-based smart transportation system that leverages optical fiber communication as a core data transmission infrastructure. The proposed system focuses on real-time monitoring, intelligent data processing, and safety enhancement to improve transportation efficiency and reduce road accidents. Through simulation-based evaluation, this study demonstrates the feasibility and effectiveness of integrating IoT technologies with optical fiber communication to support next-generation intelligent transportation systems suitable for smart city environments.

2. Literature Review

Recent studies have extensively explored the application of the Internet of Things (IoT) in intelligent transportation systems as a key enabler for smart city development. IoT-based transportation solutions have been proposed to improve traffic monitoring, vehicle tracking, and commuter safety through real-time data collection using sensors, GPS, and communication networks (T. M. Bojan, 2014), (S. Shashank et. al., 2021). Several researchers have highlighted the role of IoT in enhancing road safety by analyzing driver behavior, detecting over-speeding, monitoring road conditions, and predicting accidents using data-driven and machine learning approaches (S. Bhattacharya et. al., 2022), (S. Talari et al., 2014), (Y. Zhang et.al., 2020), (F. Al-Turjman, 2021), (J. Gubbi et. al., 2013), (F. Bonomi et. al., 2012), (S. Talari et al., 2017), (D. C. Rotescu et. al., 2023) (Muayad, 2024) (Muayad, 2025). In addition, vehicle-to-everything (V2X) communication has been investigated as a promising technology to support information exchange between vehicles, infrastructure, and pedestrians, contributing to accident reduction and traffic efficiency, particularly in the context of emerging 5G networks (Laha, 2025), (M. T. Kawser et. al., 2019), (K. Abboud et. al., 2016). On the communication side, optical fiber technology has been recognized as a superior transmission medium due to its high bandwidth, low latency, long-distance capability, and resistance to electromagnetic interference (B. Yazar, 2013), (G. P. Agrawal, 2012), (J. M. Senior and M. Y. Jamro, 2009), (C. F. Lam et al., 2010),. Previous research has demonstrated the effectiveness of optical fiber communication in supporting data-intensive applications and large-scale networks, including IoT environments (W. Zeng and H. Gao, 2014), (M. A. Khan and K. Salah, 2018). However, most existing IoT-based transportation studies rely predominantly on wireless communication infrastructures, which may face limitations in reliability, scalability, and latency under dense urban and safety-critical conditions. This highlights the need for integrated approaches that combine IoT technologies with optical fiber communication to provide a robust and high-performance backbone for smart transportation systems.

3. Methodology

This research adopts a simulation-based methodology to design, implement, and evaluate an IoT-based smart transportation system utilizing optical fiber communication as the core transmission infrastructure. The methodology focuses on integrating IoT sensing technologies with a high-speed

DOI: https://doi.org/10.61856/f5wabv17

optical fiber backbone to enable real-time data transmission, traffic monitoring, and safety enhancement. The overall methodological framework consists of system design, communication modeling, simulation setup, performance evaluation, and result analysis.

The proposed system architecture is designed to support reliable and low-latency communication between transportation entities, including vehicles, roadside infrastructure, and control centers. Optical fiber communication is employed as the primary transmission medium to ensure high bandwidth, long-distance connectivity, and immunity to electromagnetic interference. The optical communication network is modeled using OptiSystem software, which allows detailed simulation of optical components and transmission channels. Key elements such as continuous wave (CW) lasers, Mach–Zehnder modulators, wavelength division multiplexing (WDM), optical fibers, erbium-doped fiber amplifiers (EDFA), and photodetectors are configured to emulate realistic communication conditions.

In parallel, IoT components are integrated into the system to represent data acquisition and monitoring functionalities within the transportation environment. Sensors deployed on vehicles and infrastructure are simulated using MATLAB to generate real-time data related to traffic conditions, vehicle movement, and safety parameters. This data is transmitted through the optical fiber network to a centralized processing unit, where it is analyzed to support intelligent transportation operations such as traffic monitoring and accident prevention.

The performance of the proposed system is evaluated through a set of key metrics that reflect communication quality and system reliability. These metrics include Bit Error Rate (BER), signal quality using eye-diagram analysis, input and output optical power levels, and transmission distance. Multiple simulation scenarios are conducted by varying input power levels and fiber transmission distances to assess system behavior under different operating conditions. The results are analyzed to determine the impact of optical fiber communication on data integrity, latency, and overall system efficiency (I. Poole, 2014),(J. G. Proakis and M. Salehi, 2008), (D. R. Smith, 2003).

This methodology enables a comprehensive evaluation of the proposed IoT-based smart transportation system in a controlled simulation environment. By combining optical fiber communication modeling with IoT data generation and analysis, the study validates the feasibility and effectiveness of the proposed approach for supporting reliable, high-performance intelligent transportation systems suitable for future smart city applications (D. C. Montgomery,2012).

4. Results and Discussions

4.1 Effect of Input Power on Eye Diagram Performance

Eye diagram analysis is a fundamental technique for evaluating signal quality and timing performance in optical communication systems. As shown in Figure 1, the eye diagram at low input power levels (−20 dBm) exhibits significant distortion, narrow eye opening, and increased jitter, indicating high noise influence and a greater probability of transmission errors. As the input

DOI: https://doi.org/10.61856/f5wabv17

power increases to moderate levels (0 dBm to 15 dBm), the eye opening becomes clearer and more symmetrical, reflecting improved timing accuracy and reduced inter-symbol interference. At an input power of +20 dBm, the system achieves optimal signal integrity with wide eye openings and minimal distortion, confirming the effectiveness of the optical modulation and transmission process.

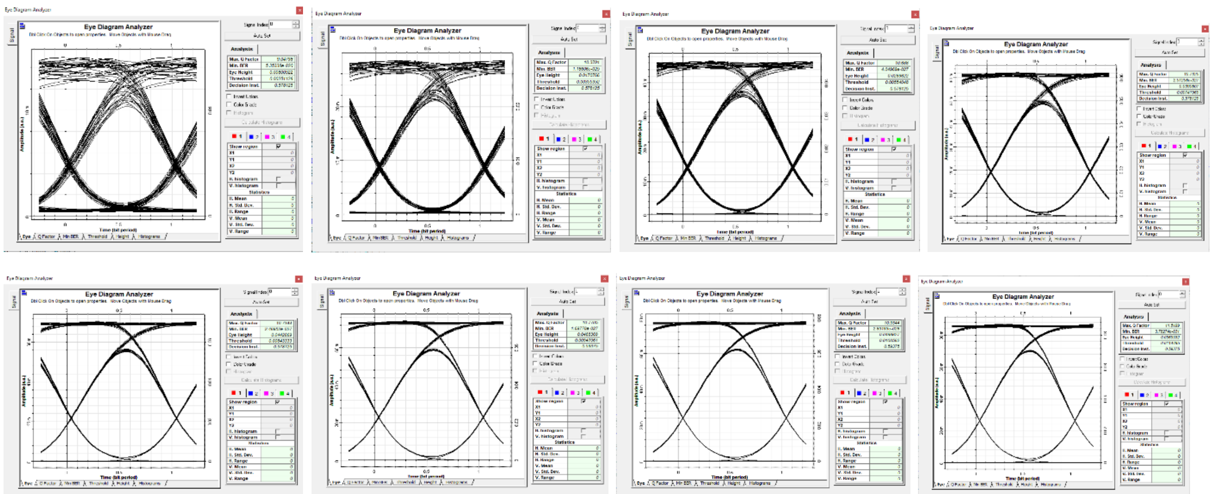


Figure 1. Eye diagrams of the received signal at different input power levels (−20 dBm to +20 dBm).

4.2 Input Power Versus Output Power Characteristics

The relationship between input power and output power is illustrated in Figure 2. A near-linear increase in output power is observed as the input power increases, indicating efficient signal transmission with minimal power loss. This linear behavior confirms the stability of the optical fiber link and the effectiveness of amplification mechanisms used in the system.

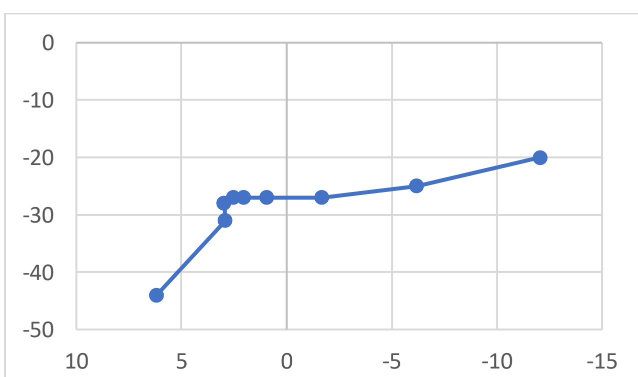


Figure 2. Relationship between input power and output optical power.

Gateway Journal for Modern Studies and Research (GJMSR), vol.3, no.1, 27 Feb. 2026
DOI: https://doi.org/10.61856/f5wabv17

4.3 Bit Error Rate Performance with Respect to Input Power

The Bit Error Rate (BER) performance as a function of input power is presented in Figure 3. The results show that BER decreases exponentially as the input power increases. At low power levels, BER values are relatively high due to signal degradation and noise. However, at higher input power levels (above 2 dBm), BER approaches extremely low values (approximately 10^{-44}), indicating highly reliable and near error-free transmission.

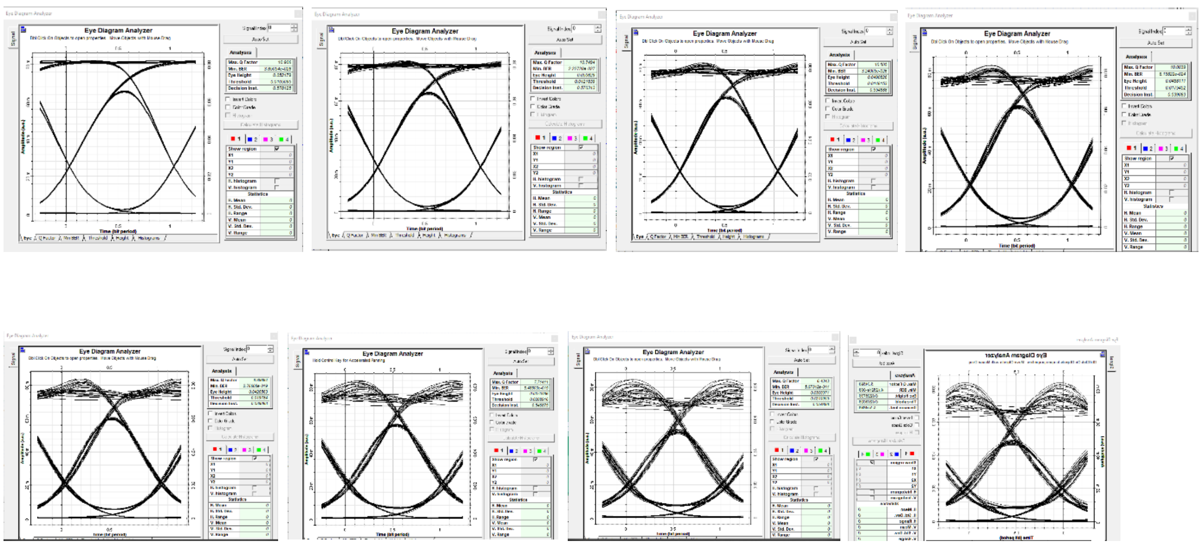


Figure 3. BER performance versus input power.

4.4 Impact of Transmission Distance on Eye Diagram Quality

The effect of transmission distance on signal quality is illustrated in Figure 4. At shorter distances (10–30 km), the eye diagrams remain wide and clearly open, indicating excellent signal quality. As the transmission distance increases beyond 50 km, the eye opening gradually deteriorates due to fiber attenuation and dispersion effects. At distances exceeding 60 km, significant eye closure is observed, highlighting the limitations of long-distance transmission without compensation techniques.

DOI: https://doi.org/10.61856/f5wabv17

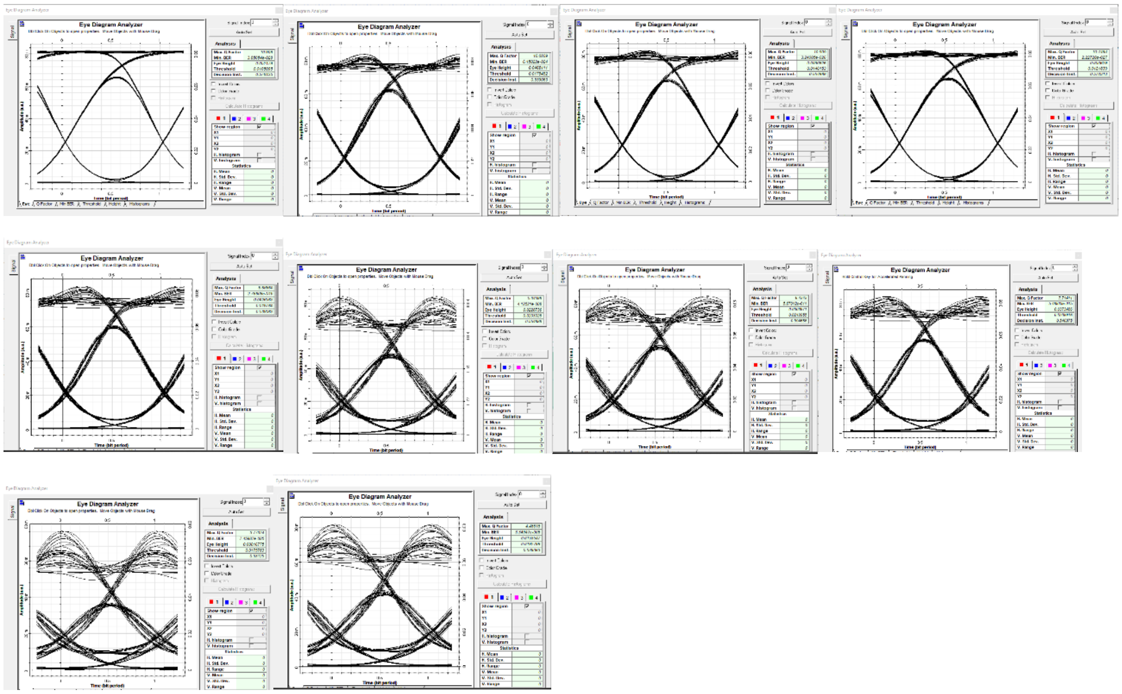


Figure 4. Eye diagrams of the received signal at different optical fiber lengths (10 km to 90 km).

4.5 Distance Versus Bit Error Rate Analysis

The relationship between transmission distance and BER is shown in Figure 5. BER increases progressively with distance due to cumulative attenuation and dispersion effects in the optical fiber. Acceptable BER levels are maintained up to approximately 50 km, supporting the system's suitability for city-scale transportation networks. Beyond 70 km, BER increases significantly, indicating the need for network optimization.

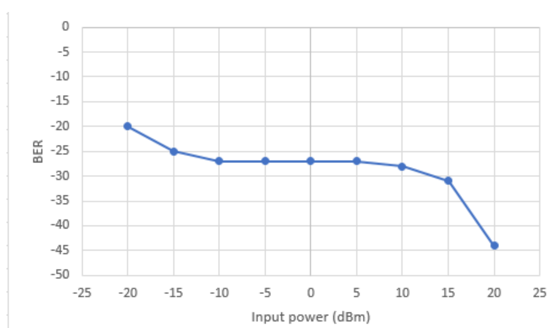


Figure 5. Bit Error Rate (BER) versus transmission distance.

DOI: https://doi.org/10.61856/f5wabv17

4.6 Distance Versus Output Power Behavior

Figure 6 illustrates the variation of output optical power with transmission distance. A consistent decrease in output power is observed as distance increases, which is expected due to inherent fiber losses. These results emphasize the importance of proper amplifier placement and power budget optimization in large-scale optical communication networks.

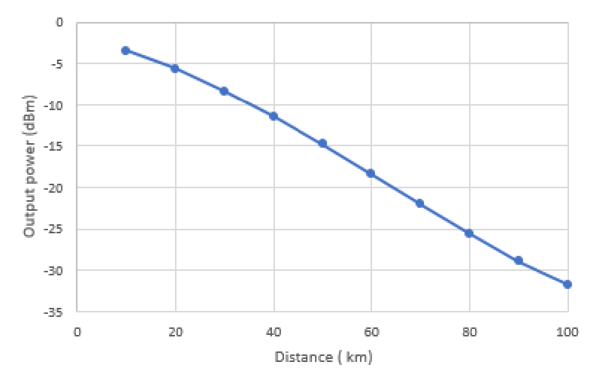


Figure 6. Output optical power versus transmission distance.

5. Conclusion

This study presented the design and performance evaluation of an IoT-based smart transportation system utilizing optical fiber communication as a high-speed and reliable communication backbone. The proposed system aimed to address key challenges in modern transportation networks, including real-time data transmission, system reliability, and road safety enhancement, by integrating IoT sensing technologies with optical fiber infrastructure.

Simulation results obtained using OptiSystem demonstrated that optical fiber communication significantly improves signal quality, transmission reliability, and data integrity for IoT-enabled transportation applications. The analysis of eye diagrams, Bit Error Rate (BER), optical power levels, and transmission distance confirmed that the system achieves excellent performance under adequate input power conditions and moderate transmission distances. In particular, the system exhibited extremely low BER values and clear eye openings at higher input power levels, indicating near error-free data transmission suitable for safety-critical transportation systems.

The impact of transmission distance revealed that the proposed system performs efficiently up to approximately 50 km, making it well-suited for city-wide and metropolitan transportation networks. Beyond this range, performance degradation due to fiber attenuation and dispersion becomes noticeable, highlighting the necessity of employing optimization techniques such as optical amplification or dispersion compensation for extended deployments. These findings provide valuable insights into practical network planning and scalability considerations for smart transportation infrastructures.

Overall, the results confirm that the integration of IoT technologies with optical fiber communication offers a robust, scalable, and high-performance solution for intelligent transportation systems. The proposed approach supports real-time monitoring, efficient data exchange, and enhanced system reliability, contributing to safer and more efficient transportation environments. This study establishes a solid foundation for future research and potential real-world implementation of IoT-based smart transportation systems within smart city frameworks.

References:

Abboud, K., Omar, H., & Zhuang, W. (2016). Interworking of DSRC and cellular network technologies for V2X communications. *IEEE Transactions on Vehicular Technology, 65*(12), 9457–9470. https://scholar.google.com/scholar?hl=en&as_sdt=0%2C5&q=Interworking+of+DSRC+and+cellular+network+technologies+for+V2X+communications&btnG=

Agrawal, G. P. (2012). *Fiber-optic communication systems* (4th ed.). Wiley. https://books.google.iq/books?hl=en&lr=&id=yGQ4n1-r2eQC&oi=fnd&pg=PR15&dq=Fiber-Optic+Communication+Systems&ots=P_D6N4oJon&sig=Mi6w4WW-0RYrgo09iwRRdjFe5zs&redir_esc=y#v=onepage&q=Fiber-Optic%20Communication%20Systems&f=false

Al-Sarawi, S., et al. (2017). Internet of Things (IoT) communication protocols: Review. In *Proceedings of the 8th International Conference on Information Technology (ICIT)*. https://www.researchgate.net/profile/Kamal-Alieyan/publication/320614944_Internet_of_Things_IoT_Communication_Protocols_Review/links/59f06dfeaca272cdc7ca2a64/Internet-of-Things-IoT-Communication-Protocols-Review.pdf

Al-Turjman, F. (2021). Towards smart cities: IoT-enabled intelligent transportation systems. *Computers & Electrical Engineering, 89*, Article 106906. https://link.springer.com/chapter/10.1007/978-3-030-04203-5_13

Atzori, L., Iera, A., & Morabito, G. (2010). Understanding the Internet of Things: Definition, potentials, and societal role. *Computer Networks, 54*(15), 2787–2805. https://doi.org/10.1016/j.adhoc.2016.12.004

Bhattacharya, S., Jha, H., & Nanda, R. P. (2022). Application of IoT and AI in road safety. In *Proceedings of the International Conference on Emerging Technologies*. https://www.researchgate.net/profile/Radhikesh-Nanda/publication/358966023_Application_of_IoT_and_AI_in_Road_Safety/links/62ac5881e1193368baa4b2b7/Application-of-IoT-and-AI-in-Road-Safety.pdf

DOI: https://doi.org/10.61856/f5wabv17

Bojan, T. M., Kumar, U. R., & Bojan, V. M. (2014). An Internet of Things based intelligent transportation system. In *Proceedings of the IEEE International Conference on Vehicular Electronics and Safety (ICVES)* (pp. 174–179). https://d1wqtxts1xzle7.cloudfront.net/96663365/9645-English-IranArze--libre.pdf

Bonomi, F., Milito, R., Zhu, J., & Addepalli, S. (2012). Fog computing and its role in the Internet of Things. In *Proceedings of the ACM MCC Workshop* (pp. 13–16). https://doi.org/10.1145/2342509.2342513

Chen, M., Mao, S., & Liu, Y. (2014). Big data: A survey. *Mobile Networks and Applications, 19*, 171–209. https://link.springer.com/article/10.1007/s11036-013-0489-0

Figueiredo, L., Jesus, I., Machado, J. A. T., Ferreira, J. R., & Martins de Carvalho, J. L. (2001). Towards the development of intelligent transportation systems. In *Proceedings of the IEEE Intelligent Transportation Systems Conference (ITSC)* (pp. 1206–1211). http://www.universelle-automation.de/1984_Columbus.pdf

Giusto, D., Iera, A., Morabito, G., & Atzori, L. (2010). *The Internet of Things*. Springer.

Gubbi, J., Buyya, R., Marusic, S., & Palaniswami, M. (2013). Internet of Things (IoT): A vision, architectural elements, and future directions. *Future Generation Computer Systems, 29*(7), 1645–1660. https://doi.org/10.1016/j.future.2013.01.010

Hecht, J. (2018). *Understanding lasers: An entry-level guide* (4th ed.). Wiley. http://lib.ysu.am/disciplines_bk/ebaf7aa36414bf0eb8a3b9d3b4b01ccb.pdf

Katerna, O. (2019). Intelligent transport system: The problem of definition and formation of classification system. *National Aviation University Journal, 2*, 45–52. https://doi.org/10.35774/econa

Kawser, M. T., Fahad, M. S., Ahmed, S., Sajjad, S. S., & Rafi, H. A. (2019). The perspective of vehicle-to-everything (V2X) communication towards 5G. *IJCSNS International Journal of Computer Science and Network Security, 19*(4), 64–72. https://d1wqtxts1xzle7.cloudfront.net/87872319/20190419-libre.pdf

Keiser, G. (2021). *Optical fiber communications* (5th ed.). McGraw-Hill. https://d1wqtxts1xzle7.cloudfront.net/30421110/optical_fiber_communication-libre.pdf?1390887712=&response-content-disposition=inline%3B+filename%3DMobile_Radio_Communications.pdf&Expires=1773175066&Signature=cOsMx9EPYG6xQirNs1Xs-4D7LLCWS-w0EaRgDfatAicXSZVnA6uLBYCXTAj-guPOclt50Z-4JRNn2C75R4PqJAo4vdGN4BXhc6dwR3eaqJLlnmwOtnKmR2z3RSRNX1xjS3Bnhm-UNJv~tHorIn3fbqeKNOIqV~tXuz0UV9ZMulcnEKjXapgBdr~~Lt68edN7eLg78ppbwVWzWYNfTAOvAkT8FU1BjhcQ0DX2gktmTZaOo8TVVM9qC0EdH8qbtFRPLg

1YxkAxB-YoDcoyxtzelLcpkDzJ4vpocQ7HIBaCz-6r3spltReiEjLqTw6sdQCoJ7urq7PprB7PJneVkWa1aw__&Key-Pair-Id=APKAJLOHF5GGSLRBV4ZA

Khan, M. A., & Salah, K. (2018). IoT security: Review, blockchain solutions, and open challenges. *Future Generation Computer Systems, 82*, 395–411. https://doi.org/10.1016/j.future.2017.11.022

Lam, C. F., et al. (2010). Fiber optic communication technologies: What's needed for datacenter network operations. *IEEE Communications Magazine, 48*(7), 32–39. https://www.audentia-gestion.fr/Recherche-Research-Google/36603.pdf

Madakam, S., Ramaswamy, R., & Tripathi, S. (2015). Internet of Things (IoT): A literature review. *Journal of Computer and Communications, 3*(5), 164–173. https://doi.org/10.4236/jcc.2015.35021

Montgomery, D. C. (2013). *Design and analysis of experiments* (8th ed.). Wiley. https://www.kwcsangli.in/uploads/2--Douglas-C.-Montgomery-Design-and-Analysis-of-Experiments-Wiley-(2012).pdf

Poole, I. (2014). BER bit error rate tutorial and definition. http://www.radio-electronics.com

Proakis, J. G., & Salehi, M. (2008). *Digital communications* (5th ed.). McGraw-Hill.

Rotescu, D. C., Spinu, C. S., & Riza, I. (2023). Risk and security management for accident prevention. *Ovidius University Annals, Economic Sciences Series, 23*(1), 98–105. https://stec.univ-ovidius.ro/html/anale/RO/2023-i1/Section%204/31.pdf

Senior, J. M., & Jamro, M. Y . (2009). *Optical fiber communications: Principles and practice* (3rd ed.). Pearson Education. https://d1wqtxts1xzle7.cloudfront.net/63467509/Optical_Fiber_Communications_John_M._Senior_1_20200529-23039-cnqq4h-libre.pdf?1590787873=&response-content-disposition=inline%3B+filename%3DOptical_Fiber_Communications_Principles.pdf&Expires=1773175196&Signature=AjhFYJxT6nY6Mxlc6IhMSBq4podc8dMbNGnjdzeN7wkTNx3j31UNkq2qVZzmk5ZRrBuHV4DGQdf4VwYinqtxrRmN1CV5~gT1UWFarvB~1YxY8tieSS9k4YSth9ikLLW4oi3omr-0BokHeOqiLNwcv5F5z6M4tzcpqwsxxskpiZePM9ZI-9f~rH6utKEGUPEN9OZTgwHkZBMUgjxpPR5--nC~1JRGmuqsFGhmPr2sQGfiK0gy6lKxdk5P4Kqh-NecziDFFMByX9ZAkxdtl7mGP3ChRMttUNvTkZXRat32ekBEZ1iRJFwfTDTTAPYvAmTb1vh7E546gKwUiu1N0og8OQ__&Key-Pair-Id=APKAJLOHF5GGSLRBV4ZA

DOI: https://doi.org/10.61856/f5wabv17

Shashank, S., Kiran, P., Nischay, D., Kumar, M. V., Vatsala, B. R., & Raj, C. V. (2021). IoT based traffic management system. *International Journal of Scientific Research in Computer Science, Engineering and Information Technology, 7*(4), 184–187. https://doi.org/10.48550/arXiv.2005.07596

Svelto, O. (2010). *Principles of lasers* (5th ed.). Springer. https://uomustansiriyah.edu.iq/media/lectures/6/6_2018_03_27!11_07_39_PM.pdf

Talari, S., et al. (2017). A review of smart cities based on IoT concepts. *Energies, 10*(4), Article 421. https://doi.org/10.3390/en10040421

Wang, Y., Kung, L. A., & Byrd, T. A. (2018). Big data analytics: Understanding its capabilities and potential benefits for healthcare organizations. *Technological Forecasting and Social Change, 126*, 3–13. https://doi.org/10.1016/j.techfore.2015.12.019

Yazar, B. (2013). *Fiber optical network design problems: Case for Turkey* (Master's thesis, Middle East Technical University). https://repository.bilkent.edu.tr/server/api/core/bitstreams/9cce1565-7c89-4868-9b1d-ce73338dda12/content

Zeng, W., & Gao, H. (2014). Optic fiber sensing IoT technology and application research. *Sensors & Transducers, 180*(10), 16–21. https://www.sensorsportal.com/HTML/DIGEST/october_2014/Vol_180/P_2431.pdf

Zhang, Y., Wang, J., & Liu, Y. (2020). IoT-based intelligent traffic management system for smart cities. *IEEE Access, 8*, 192033–192044. https://link.springer.com/article/10.3103/S875669902470078X

Laha, S. R., Al Smadi, K., Habboush, A. K., Pattanayak, B. K., Pattnaik, S., & Mohanty, B. (2025). Smart waste management framework for green cities: Integrating IoT, LoRa, and deep learning for efficient waste classification and management. *Tikrit Journal of Engineering Sciences, 32*(SP1), 1–14. https://doi.org/10.25130/tjes.sp1.2025.1

Mahmood, R. M. (2024). Impact of three different plans on the next generation passive optical networks stage two for downstream transmission. *International Innovations Journal of Applied Science, 1*(SPC). https://doi.org/10.61856/gn8kv980

Muayad, R. (2025). A DWDM-RoF system for the 5G communication networks. *Gateway Journal for Modern Studies and Research (GJMSR), 2*(1). https://doi.org/10.61856/eme16g83

Rawa Muayad. (2024). A comprehensive overview of 6G communication systems and emerging technologies. *Gateway Journal for Modern Studies and Research (GJMSR), 1*(1). https://doi.org/10.61856/tpxv1543