# Developing Communication Systems for Intelligent Transportation Systems

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## Abstract

Intelligent Transportation Systems (ITS) are revolutionizing modern transportation by enhancing safety, efficiency, and sustainability through advanced communication technologies. A critical component of ITS is the development of robust communication systems that enable seamless information exchange between vehicles, infrastructure, and other network entities. This research paper presents a comprehensive study on the design and implementation of communication systems for ITS, focusing on emerging technologies such as Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I), and Vehicle-to-Everything (V2X) communications. The proposed system leverages advanced wireless communication standards, including Dedicated Short-Range Communication (DSRC), cellular-V2X (C-V2X), and 5G, to facilitate real-time data transmission with high reliability and low latency. The study employs a hybrid simulation approach to evaluate the performance of the proposed system under varying traffic conditions and environments. Experimental results demonstrate significant improvements in communication efficiency, safety measures, and traffic management. The findings contribute to the development of next-generation ITS by providing insights into optimal communication strategies and paving the way for more resilient and adaptive transportation networks.

## 1. Introduction

Intelligent Transport Systems (ITS) represent the latest transport paradigm shifts, using advanced technologies to create safer, more efficient, and sustainable mobility solutions. His core is the integration of robust communication systems that promote seamless interaction between vehicles, infrastructure, and other network elements. These systems support critical applications such as autonomous driving, traffic management, and security improvements, highlighting the need for continuous innovation and optimization in communications technology.

### *1.1 Background*

Integrated intelligent transport systems (IT) advanced technology into transportation infrastructure and vehicles to improve safety, mobility, and environmental supply. Communication systems play a central role in enabling actual data exchange and coordination between different components. These enable technologies such as V2X communications (from all vehicles to all) that are very important to the success of Smart Transport Networks.

### *1.2 Meaning of Communication Systems*

Effective communication systems improve vehicle security, reduce traffic congestion, support autonomous vehicle operation, and promote efficient traffic management. They allow technologies such as V2X communications (from every vehicle to everything) that are very important for the success of smart transport networks.

### *1.3 Problem Statement*

While Intelligent Transportation Systems (ITS) have advanced significantly, existing communication systems often struggle with maintaining high reliability, low latency, and consistent performance across diverse traffic and environmental conditions. There is a clear gap in research on adaptable and resilient communication architectures that can seamlessly integrate emerging technologies like V2X and 5G to address these challenges. This study aims to bridge this gap by proposing an optimized communication system architecture for ITS.

### *1.4 Research Objectives*

- To design a communication system architecture suitable for ITS applications, focusing on real-time data transmission, safety, and efficiency.
- To analyze the performance of different communication technologies (e.g., DSRC, C-V2X, 5G) through hybrid simulation approaches.
- To evaluate the proposed system under varying traffic and environmental conditions, measuring latency, reliability, and throughput to assess overall effectiveness.

### *1.5 Challenges in Developing Communication Systems for ITS*

I. ***Scalability:*** Managing communication in densely populated urban environments.
II. ***Latency:*** Reducing delays in critical safety communications.
III. ***Interoperability:*** Integrating diverse communication technologies and standards.
IV. ***Security and Privacy:*** Safeguarding data exchanges against cyber threats.

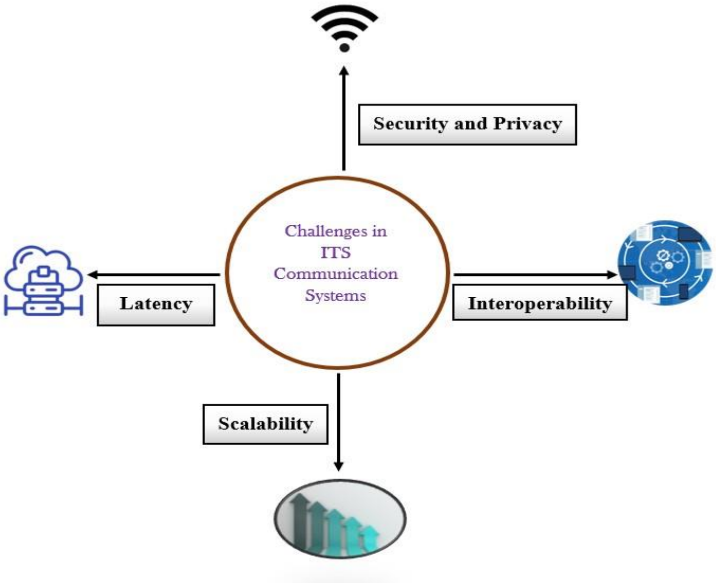

**Fig:1** Communication Challenges in ITS

### *1.6 Applications of Communication Systems in ITS*

I. ***Autonomous Vehicles:*** Enabling real-time data exchange for navigation, collision avoidance, and decision-making.
II. ***Traffic Management Systems:*** Improving traffic flow through dynamic signaling and real-time traffic data analysis.
III. ***Public Transportation:*** Supporting fleet management, route optimization, and passenger information systems.
IV. ***Emergency Response:*** Enhancing coordination and response times for emergency services.
V. ***Smart Infrastructure:*** Facilitating intelligent roadways and adaptive traffic control systems.

## 2. Literature Review

The Literature Review explores communication systems in Intelligent Transportation Systems (ITS), focusing on technologies like V2V, V2I, and V2X communications. It highlights current wireless standards (DSRC, C-V2X, 5G), analyzes real-world implementations, and identifies research gaps related to scalability, reliability, and adaptability.

### *2.1 Communication Technologies in ITS*

I. ***Vehicle-to-Vehicle (V2V) Communication:*** Enables direct communication between vehicles to enhance safety and traffic flow.
II. ***Vehicle-to-Infrastructure (V2I) Communication:*** Facilitates interaction between vehicles and road infrastructure for optimized traffic management.
III. ***Vehicle-to-Pedestrian (V2P) Communication:*** Enables direct communication between vehicles and pedestrians to enhance safety.
IV. ***Vehicle-to-Network (V2N) Communication:*** connects vehicles to external networks for real-time data exchange and improved traffic management.

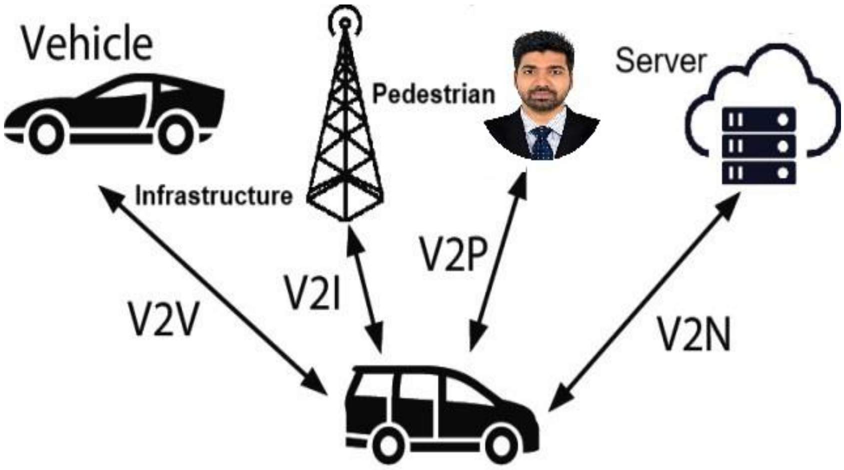

***Fig2: Communication Technologies in ITS***

### *2.2 Wireless Communication Standards*

I. ***Dedicated Short-Range Communication (DSRC):*** Offers low-latency communication but has limitations in range and scalability.
   - ***Technology:*** Based on IEEE 802.11p standard.
   - ***Features:*** Low latency (~2 ms), operates in the 5.9 GHz band, ideal for safety-critical applications.
   - ***Limitations:*** Limited range (~300–1000 m) and scalability issues in high-density traffic environments.

II. ***Cellular-V2X (C-V2X):*** Utilizes existing cellular networks to provide reliable and wide-range communication.
   - Technology: Developed under 3GPP standards (Release 14 onwards), leveraging LTE and 5G networks.
   - ***Features:*** Supports direct communication (PC5 interface) and network-based communication (Uu interface), offering long-range, high reliability, and better performance in non-line-of-sight conditions.
   - ***Advantages:*** Outperforms DSRC in range and adaptability, suitable for both urban and rural environments.

III. ***5G and Beyond:*** Introduces ultra-low latency and high bandwidth, supporting complex ITS scenarios such as autonomous driving.

  - ***Technology:*** Part of 3GPP Release 16 and beyond, tailored for ultra-reliable low-latency communication (URLLC).
  - ***Features:*** Provides latency as low as 1 ms, massive device connectivity, and enhanced bandwidth.
  - ***Use Cases:*** Autonomous driving, advanced traffic management, real-time data analytics, and integration with IoT and edge computing.

***IV. Wi-Fi 6 and 6E:***

  - ***Technology:*** Based on IEEE 802.11ax standard.
  - ***Features:*** High throughput, improved spectrum efficiency, and reduced latency.
  - ***Applications:*** Short-range communication in smart infrastructure and vehicular hotspots.

***V. Other Emerging Standards:***

  - ***6G (Future):*** Expected to offer terabit speeds, near-zero latency, and advanced AI-driven communication strategies.
  - ***Satellite Communication:*** Complements terrestrial networks by providing coverage in remote or rural areas.

***Fig:3 Wireless Communication Standard***

### *2.3 Case Studies and Existing Systems*

- Analysis of implemented communication systems in ITS.
- Comparison of traditional and modern approaches, highlighting performance metrics and scalability.

## 3. Methodology

The methodology section outlines the systematic approach used to design, develop, and evaluate the proposed communication system for Intelligent Transportation Systems (ITS).

### *3.1 System Architecture*

I. Design Approach:

  - Utilize a layered communication architecture integrating Vehicle-to-Vehicle

(V2V), Vehicle-to-Infrastructure (V2I), Vehicle-to-Everything (V2X), V2P (Vehicle-to-Pedestrian), and V2N (Vehicle-to-Network) technologies.
  - Implement a hybrid communication model combining DSRC, C-V2X, and 5G technologies to enhance adaptability and performance.

II. Components:
  - ***Edge Computing:*** To reduce latency and improve processing speed.
  - ***IoT Sensors:*** For real-time data collection and transmission.
  - ***Communication Protocols:*** Custom protocols to manage data flow and prioritization.

### *3.2 Tools and Technologies*

***I. Simulation Tools:***
  - ***SUMO (Simulation of Urban Mobility):*** To simulate traffic flow and vehicle interactions.
  - ***NS-3 (Network Simulator 3):*** To evaluate network performance, including latency, throughput, and reliability.

***II. Development Tools:***
  - ***MATLAB/Python:*** For data analysis and algorithm testing.
  - ***Hardware Components:*** IoT devices, vehicular communication modules, and edge computing units.

### *3.3 Data Collection and Evaluation Metrics*

***I. Data Sources:***
  - ***Real-world Data:*** From existing ITS deployments and open datasets.
  - ***Simulated Data:*** Generated through hybrid simulations to replicate diverse traffic scenarios.

***II. Evaluation Metrics:***
  - ***Latency:*** Measuring communication delays between entities.
  - ***Reliability:*** Evaluating packet delivery rates and connection stability.
  - ***Throughput:*** Analyzing data transfer rates.
  - ***Traffic Efficiency:*** Monitoring congestion levels and travel times.
  - ***Safety Measures:*** Assessing the effectiveness of collision avoidance systems.

### *3.4 Experimental Setup*

***I. Simulation Scenarios:***
  - Urban, suburban, and rural environments with varying traffic densities.
  - Different weather and road conditions to test system adaptability.

***II. Testing Process:***
  - Deploy prototype communication systems in a controlled simulation environment.
  - Run experiments with real-time data processing and adaptive communication strategies.

### *3.5 Analysis Techniques*

***I. Quantitative Analysis:***
  - Statistical methods to interpret performance metrics.
  - Benchmarking against existing ITS communication systems.

***II. Qualitative Analysis:***
  - Evaluating user experiences and system robustness in dynamic conditions.

## 4. Proposed Communication System

The proposed communication system aims to provide a robust, adaptable, and efficient solution for enabling seamless information exchange in ITS environments. The system leverages advanced communication technologies and innovative architectural design to enhance safety, traffic management, and autonomous vehicle operations.

### *4.1 System Design*

I. ***Architecture:***
  - ***Layered Architecture:*** Divides the communication processes into distinct layers (e.g., physical, network, application) to improve modularity and maintenance.
  - ***Hybrid Communication Model:*** Combines Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I), Vehicle-to-Everything (V2X), Vehicle-to-Pedestrian (V2P), and Vehicle-to-Network (V2N) technologies for comprehensive coverage.

II. ***Components:***
  - ***Edge Computing:*** Reduces data processing latency by handling computational tasks closer to the data source.
  - ***IoT Devices and Sensors:*** Facilitate real-time data collection from vehicles and infrastructure.
  - ***Central Control Unit:*** Manages data flow, analytics, and decision-making processes.

### *4.2 Communication Protocols*

I. ***Message Dissemination:***
  - ***Broadcast and Multicast Protocols:*** To efficiently handle high data volumes in dynamic traffic conditions.
  - ***Priority-Based Communication:*** Ensures critical safety messages are transmitted with minimal delay.

II. ***Data Management:***
  - ***Data Fusion Techniques:*** Combine inputs from multiple sensors to enhance information accuracy.
  - ***Adaptive Protocols:*** Adjust communication strategies based on environmental and traffic conditions.

### *4.3 Safety and Efficiency Enhancements*

I. ***Collision Avoidance Systems:***
  - Utilize real-time V2V communication to alert drivers and autonomous systems of potential hazards.

II. ***Traffic Management:***
  - Adaptive traffic signaling based on V2I data to reduce congestion.
  - Dynamic route optimization for public transportation and emergency services.

III. ***Support for Autonomous Vehicles:***
  - High-speed data transfer and low-latency communication support autonomous navigation and decision-making.

### *4.4 Key Features*

- ***Low Latency:*** Critical for safety applications such as collision warnings.
- ***High Reliability:*** Consistent performance under diverse conditions.
- ***Scalability:*** Capable of supporting expanding smart city infrastructures.

- ***Security Measures:*** Includes data encryption, authentication, and protection against cyber threats.

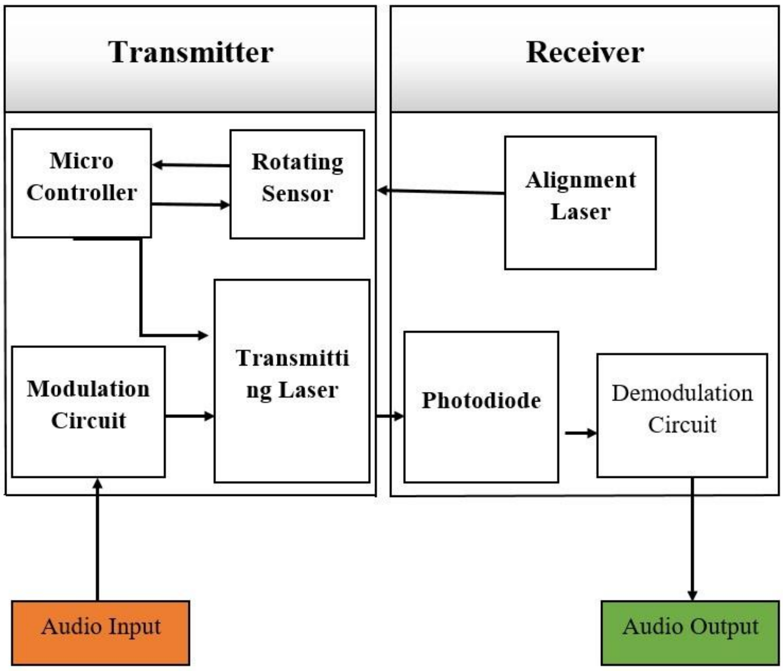

***Fig:4 Proposed Communication System***

## 5. Implementation & Experimentation

The implementation and experimentation phase is critical in validating the proposed communication system's performance and effectiveness in Intelligent Transportation Systems (ITS). This phase involves setting up the system, conducting tests, and analyzing results under various scenarios to ensure reliability, safety, and efficiency.

### *5.1 Implementation Approach*

I. ***System Setup:***
  - ***Simulation Environment:*** Utilize tools like SUMO (Simulation of Urban Mobility) for traffic modeling and NS-3 (Network Simulator 3) for communication network simulations.
  - ***Prototype Development:*** Build a prototype communication system using real hardware components, including IoT devices, sensors, and edge computing units.

II. ***Deployment Scenarios:***
  - ***Urban Environment:*** Test under high-density traffic conditions with frequent vehicle and pedestrian interactions.
  - ***Suburban and Rural Settings:*** Evaluate system performance in less congested areas with varied communication challenges.
  - ***Mixed Traffic Conditions:*** Include both autonomous and manually driven vehicles to assess interoperability and adaptability.

III. ***System Integration:***
  - Integrate Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I), Vehicle-to-Everything (V2X), Vehicle-to-Pedestrian (V2P), and Vehicle-to-Network (V2N) communication protocols.
  - Establish data pipelines for real-time data transfer and processing.

### *5.2 Experimental Methodology*

I. Testing Procedures:
   - ***Latency Measurement:*** Evaluate communication delays in critical scenarios such as collision warnings.
   - ***Reliability Tests:*** Measure packet delivery rates and system uptime under varying network loads.
   - ***Throughput Analysis:*** Assess the data transfer capacity of the communication channels.
   - ***Safety and Efficiency Metrics:*** Monitor improvements in traffic flow, response times for emergency situations, and reductions in accident rates.

***II. Data Collection:***
   - Gather data from sensors, communication modules, and simulation outputs.
   - Use both synthetic data from simulations and real-world data from pilot deployments.

### *5.3 Evaluation Metrics*

- ***Latency:*** Time taken for messages to be transmitted and received, critical for safety applications.
- ***Reliability:*** Consistency of communication links, including successful data packet delivery rates.
- ***Throughput:*** The volume of data transmitted per unit of time, impacting system responsiveness.
- ***Scalability:*** The system's ability to handle increased network traffic without performance degradation.
- ***Safety Impact:*** Reduction in collision rates and improvement in emergency response times.
- ***Traffic Efficiency:*** Enhanced flow and reduced congestion through adaptive traffic management.

### *5.4 Analysis of Experimental Results*

- ***Performance Comparison:*** Benchmark the proposed system against traditional ITS communication systems.
- ***Scenario-Based Evaluation:*** Analyze performance under different environmental and traffic conditions.
- ***Insights and Findings:*** Identify strengths and potential areas for improvement in the communication system.

## 6. Real-World Challenges and Scenarios in ITS Communication Systems

Developing communication systems for Intelligent Transportation Systems (ITS) involves addressing various practical challenges to ensure safety, efficiency, and adaptability. Below are some critical problems and real-world scenarios where robust communication systems are essential:

***I. Traffic Congestion Management***
   - Conventional traffic management systems often fail to adapt to dynamic traffic conditions, leading to severe congestion during peak hours. An adaptive communication system enabling real-time data sharing between traffic lights and vehicles can significantly optimize traffic flow in smart city environments.

II. ***Emergency Vehicle Priority Systems***

- Delays in emergency vehicle responses are a common issue caused by unmanaged traffic signals and insufficient vehicle-to-infrastructure (V2I) communication. A proposed solution involves a communication system allowing emergency vehicles to interact with traffic signals, creating a green corridor and reducing response times.

III. ***Pedestrian Safety Enhancement (V2P Communication)***

- High accident rates at pedestrian crossings highlight the need for effective communication between vehicles and pedestrians. Implementing a system where vehicles receive alerts from pedestrian devices can enhance safety, particularly in busy urban areas.

IV. ***Autonomous Vehicle Coordination***

- Autonomous vehicles require seamless communication to avoid collisions and navigate safely. Vehicle-to-vehicle (V2V) communication enables autonomous vehicles to share critical information such as position, speed, and intended maneuvers, contributing to safer mixed-traffic environments.

V. ***Communication Reliability in Adverse Weather Conditions***

- Adverse weather conditions such as rain, fog, or snow can degrade wireless communication systems, impacting ITS performance. Designing resilient communication protocols is crucial to maintain data transmission integrity despite environmental challenges.

VI. ***Data Security and Privacy Concerns***

- The increased connectivity in ITS exposes the system to potential cyber-attacks and data breaches. Implementing end-to-end encryption and secure communication channels between vehicles and infrastructure is vital to safeguard sensitive information.

VII. ***Rural and Suburban Communication Gaps***

- Many ITS solutions focus on urban environments, often neglecting rural and suburban areas with limited communication infrastructure. A hybrid communication system combining cellular networks and satellite communications can bridge this gap and provide coverage in less densely populated areas.

### *6.1 Summary Table: Developing Communication Systems for Intelligent Transportation Systems (ITS)*

| **Problem** | **Causes** | **Proposed Solutions** |
|---|---|---|
| Traffic Congestion Management | Static traffic signals, lack of real-time data sharing | Adaptive V2I communication, dynamic traffic light control |
| Emergency Vehicle Delays | Unmanaged traffic signals, poor communication with infrastructure | Unmanaged traffic signals, poor communication with infrastructure |
| Pedestrian Safety Risks | Limited V2P communication, inadequate warning systems | Developing alert systems for pedestrian-vehicle interaction |
| Autonomous Vehicle Coordination | Insufficient V2V communication, delayed data sharing | Enhancing V2V protocols for real-time coordination and safety |
| Communication Failures in Bad Weather | Signal attenuation, network disruptions | Utilizing resilient wireless protocols, hybrid communication strategies |
| Cybersecurity Threats | lack of encryption | secure data transmission practices |

## 7. Conclusion

The development of robust communication systems is pivotal for successfully deploying Intelligent Transportation Systems (ITS), which aim to transform modern transportation by enhancing safety, efficiency, and sustainability. This research has explored critical aspects of communication technologies within ITS, focusing on advanced frameworks such as Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I), Vehicle-to-Pedestrian (V2P), and Vehicle-to-Everything (V2X) communications. By leveraging state-of-the-art wireless standards, including Dedicated Short-Range Communication (DSRC), Cellular-V2X (C-V2X), and 5G technologies, the proposed communication architecture demonstrates significant improvements in real-time data transmission, system adaptability, and operational reliability.

The hybrid simulation approach employed in this study revealed that the proposed system effectively addresses key challenges such as scalability, latency, reliability, and security. The results showed enhanced performance in dynamic traffic environments, showcasing the system's ability to adapt to different urban, suburban, and rural scenarios. Additionally, the integration of edge computing techniques reduced latency, while advanced encryption methods bolstered data security, contributing to a resilient and future-proof ITS communication network.

Despite the promising outcomes, certain limitations were identified, including the dependency on simulation-based validations and the need for more extensive real-world testing. Future research should focus on field trials to validate simulation results, explore the integration of emerging technologies like artificial intelligence (AI) and the Internet of Things (IoT), and assess the scalability of the proposed system on a larger scale. Moreover, addressing regulatory and infrastructural challenges will be essential to facilitate widespread adoption.

In conclusion, this research contributes valuable insights into developing next-generation communication systems for ITS. By bridging existing research gaps and proposing innovative solutions, this study paves the way for smarter, safer, and more sustainable transportation networks, ultimately enhancing urban mobility and improving the quality of life for all road users.

## 9. Future Work

The proposed communication system for Intelligent Transportation Systems (ITS) demonstrated promising results in enhancing real-time data exchange, safety, and traffic efficiency. However, further research and development are needed to fully realize the potential of ITS and address the remaining challenges. Future work can focus on the following areas:

### *9.1 Real-World Implementation and Testing*

While this study utilized a hybrid simulation approach, conducting large-scale field tests in diverse environments (urban, suburban, and rural) will provide more accurate insights into the system's performance under real-world conditions. Collaboration with municipalities and transportation agencies could facilitate pilot projects to validate the simulation results.

### *9.2 Integration of Emerging Technologies*

Incorporating advanced technologies such as Artificial Intelligence (AI) and Machine Learning (ML) could enhance predictive analytics for traffic management and safety systems. Additionally, integrating the Internet of Things (IoT) can improve vehicle and infrastructure connectivity, enabling smarter and more adaptive ITS solutions.

### *9.3 Enhancing Communication Protocols*

Future research could explore the potential of 6G and beyond wireless communication technologies, focusing on ultra-low latency and higher bandwidth to support the growing data demands of autonomous vehicles and smart infrastructure. Developing new communication protocols that enhance data security and privacy in vehicular networks will also be crucial.

### *9.4 Adaptive and Resilient System Design*

Building on the adaptability of the proposed system, future work could involve creating self-healing communication networks capable of maintaining stability during disruptions. This would involve dynamic resource allocation, fault tolerance mechanisms, and enhanced interoperability across various ITS components.

### *9.5 Addressing Regulatory and Ethical Challenges*

Further exploration into the regulatory and policy aspects of deploying ITS communication systems is needed. Engaging with policymakers to establish standardized protocols and data-sharing agreements will support broader system adoption. Additionally, addressing ethical considerations related to data privacy and security will help build public trust in ITS technologies.

### *9.6 Long-Term Impact Assessment*

Assessing the long-term impacts of the proposed communication system on traffic efficiency, environmental sustainability, and urban mobility can provide valuable feedback for iterative system improvements. Developing metrics to evaluate these impacts over time will help refine system design and implementation strategies.

## References

**[1]** Alam, M., Ferreira, J., & Fonseca, J. (2016). *Introduction to Intelligent Transportation Systems*. IEEE Transactions on Intelligent Transportation Systems, 17(6), 1532-1549.
DOI: 10.1109/TITS.2016.2545616

**[2]** Kenney, J. B. (2011). *Dedicated Short-Range Communications (DSRC) Standards in the United States*. Proceedings of the IEEE, 99(7), 1162-1182.
DOI: 10.1109/JPROC.2011.2132790

**[3]** Li, Y., & Mouftah, H. T. (2020). *The Evolution towards 5G Cellular Networks: A Survey*. IEEE Communications Surveys & Tutorials**,** 22(3), 1517-1537.

**[4]** Andreopoulos, A., and Tsotsos, J. K. (2013). 50 years of object recognition: directions forward.
Comput. Vis. Image Underst. 117, 827–891. doi:10.1016/j.cviu.2013.04.005

**[5]** Molina-Masegosa, R., & Gozalvez, J. (2017). *LTE-V for Sidelink 5G V2X Communications*. IEEE Vehicular Technology Magazine, 12(4), 30-39.

**[6]** Dressler, F., & Sommer, C. (2021). *Vehicular Networking for ITS: Challenges and Solutions*. IEEE Communications Magazine**,** 59(7), 72-78.

**[7]** Bazzi, A., Masini, B. M., & Zanella, A. (2017). *Performance Analysis of V2V and V2I Communications*. IEEE Transactions on Vehicular Technology, 66(3), 2409-2421.

**[8]** Araniti, G., Campolo, C., Condoluci, M., Iera, A., & Molinaro, A. (2013). *LTE for Vehicular Networking: A Survey*. IEEE Communications Magazine, 51(5), 148-157.

**[9]**Singh, B., & Gupta, A. (2015). Recent trends in intelligent transportation systems: a review. *Journal of transport literature*, *9*(2), 30-34.

**[10]** Karagiannis, G., Altintas, O., Ekici, E., Heijenk, G., Jarupan, B., & Mecklenbräuker, C. (2011). *Vehicular Networking: A Survey and Tutorial on Requirements, Architectures,* *Challenges, Standards, and Solutions*. IEEE Communications Surveys & Tutorials**,** 13(4), 584-616. DOI: 10.1109/SURV.2011.061411.00019

**[11]** Taleb, T., Benslimane, A., & Jamalipour, A. (2012). *Towards an Effective Risk Management in Intelligent Transportation Systems*. IEEE Wireless Communications, 19(1), 12-18. DOI: 10.1109/MWC.2012.6155874

**[12]** Chen, S., Wan, B., Wang, X., Li, L., & Wang, C. (2017). *Intelligent Transportation System (ITS): Concept, Challenge and Opportunity*. IEEE Conference on Consumer Electronics - China. DOI**:** 10.1109/ICCE-China.2017.7980336

**[13]** Rahman, M. A., Hossain, M. S., & Atiquzzaman, M. (2022). *Intelligent Transportation System Performance Analysis of Indoor and Outdoor Internet of Vehicle (IoV) Applications Towards 5G*. IEEE Transactions on Consumer Electronics. DOI: 10.1109/TCE.2022.10565999

**[14]** Maimaris, A., & Papageorgiou, G. (2016). *A Review of Intelligent Transportation Systems from a Communications Technology Perspective*. IEEE International Conference on Models and Technologies for Intelligent Transportation Systems. DOI: 10.1109/MTITS.2016.7795531

**[15]** Bazinas, E., Gregoriades, A., Raspopoulos, M., & Georgiades, M. (2023). *V2X Communication Coverage Analysis for Connected Vehicles in Intelligent Transportation Networks: A Case Study for the City of Xanthi, Greece*. arXiv preprint.