Journal of
Data Acquisition and Processing
ISSN: 1004-9037
https://sjcjycl.cn/
DOI: 10.5281/zenodo.7641924

VEHİCULAR AD-HOC NETWORKS İN INTELLİGENT TRANSPORT SYSTEMS - COMPHREHENSİVE SURVEY

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Abstract: Modern transport systems face many challenges, and Intelligent Transport Systems (ITS) have emerged as a promising solution that aims to increase sustainability, efficiency, and safety. Among the various ITS technologies, Vehicular Ad Hoc Networks (VANETs) are essential for enabling communication and coordination between vehicles, infrastructure, and other elements of the ransportation ecosystem. With a focus on the key ideas, issues, and developments in this area, this urvey paper offers a thorough overview of the integration of VANETs into ITS. It looks at the nderlying ideas behind VANETs, such as network architectures, communication protocols, and ecurity mechanisms. The study looks at the various ways that VANETs are used in ITS, including raffic management, collision avoidance, intelligent routing, and emergency services, by applying arious emerging technologies.This survey provides an analysis of the current security landscape in ntelligent Transportation Systems (ITS) and Vehicular Ad hoc Networks (VANET) with a focus on ntegrating different routing protocols and algorithms. It examines the potential security threats and hallenges faced by ITS and VANET, including attacks on vehicle-to-vehicle and vehicle-to-nfrastructure communications, privacy breaches, and data integrity issues. The survey investigates the role of routing protocols and algorithms in addressing these security concerns and improving verall security in ITS and VANET. It evaluates the strengths and limitations of various protocols, onsidering factors like scalability, adaptability, and resilience to security threats. The survey explores the influence of external factors such as environmental conditions, traffic patterns, and user behavior on the performance of VANET-based ITS. Furthermore, emerging technologies such as edge computing, artificial intelligence, and blockchain are examined in the context of addressing these challenges in enhancing security in ITS and VANET. The findings and recommendations of this survey provide guidance for researchers, practitioners, and policymakers in developing secure ITS and VANET environments.

Keywords- *Intelligent Transport Systems, Vehicular Ad Hoc Networks, VANET, ITS, Communication protocols, Artificial Intelligence, Machine Learning, Deep Learning, Blockchain.*

I. Introduction

Intelligent Transport Systems (ITS) and Vehicular Ad Hoc Networks (VANET) are two interrelated fields that have attained significant attention in recent years. As our cities become more populated and traffic congestion increases, the need for advanced technologies to enhance transportation efficiency, safety, and sustainability becomes increasingly crucial. ITS, coupled with VANET, offers promising solutions to address these challenges by integrating information and communication technologies into the transportation infrastructure. Vehicle ad hoc networks have emerged as a promising and challenging field with numerous potential applications. While research in this area has been ongoing for several decades, widespread practical implementation is still a work in progress [1]. The automotive industry is witnessing the development of nascent models that can communicate with each other and exchange real-time information. This communication paradigm, known as vehicular ad hoc networks (VANET), serves as an integral component of intelligent transportation systems (ITS) [2]. A critical aspect of emerging ITS applications is the concept of vehicle-to-everything (V2X) communication, enabling vehicles to interact with other vehicles, pedestrians, road infrastructure, and the Internet [3]. V2X facilitates the exchange of alerts and warnings among connected vehicles, providing drivers with crucial information about road conditions and potential hazards. In the near future, vehicles will be able to communicate with their surroundings and neighboring vehicles, enabling them to avoid traffic congestion and ensure road safety. Each vehicle node within the V2V network acts as a part of a mesh network, allowing for the transmission, reception, and relaying of messages.

Intelligent transportation systems (ITS) [4] encompass the utilization of information and communication technologies (ICT) within road transportation to enhance and support a wide range of applications.

1.1 Historic Evolution of Intelligent Transport System:

The development of computerised urban traffic signal control systems is where Intelligent Transportation Systems (ITS) got its start. Notably, ITS has evolved significantly because of technologies like SCOOT (Split Cycle Offset Optimisation Technique) and SCATS (Sydney Coordinated Adaptive Traffic System), which were first developed for road networks [5]. These developments have taken place across many continents, including Japan, Europe, and North America, and each has made a unique contribution to the history of ITS.

The Japan's ITS development and history traces the beginnings of urban traffic control research and development to the Tokyo traffic control system, which started in 1967. Beginning in 1971, Japan implemented signal control systems across all urban areas through a series of 5-year plans [6]; by 1985, there were 74 police-operated urban traffic control centres.

The evolution of ITS (Intelligent Transportation Systems) in Europe followed a path resembling that of ITS in Japan [7]. With the ALI system from Bosch/Blaupunkt, which used inductive loops in the roadway to communicate with vehicles, work on vehicle navigation and route guidance in Germany started in the late 1970s.

In comparison to Japan and Europe, the use of computer technology for traffic management on city streets was relatively delayed in North America. Computer control of urban traffic signals didn't take off until the 1980s and 1990s in cities like New York and Los Angeles [8].

In the early 1990s, the field of intelligent transportation systems (ITS) saw significant progress with key events and developments [9]. The world congress on Applications of Transport Telematics and Intelligent Vehicle-Highway Systems held in Paris in 1994 brought together experts from Europe, Japan, and the United States, laying the foundation for future congresses and fostering international collaboration.

Development and application of ITS was also accelerated by the publication of a strategic plan for IVS in the US by ITS America and the funding of a thorough study by the USDOT [10-13]. Raising awareness, fostering interoperability, and setting standards for ITS projects in North America were all made possible by the US National ITS Architecture study.

1.2 Innovations and User Services in ITS

Intelligent transportation systems (ITS) are built on communication, and the development of the Internet and digital cellular phone networks in the late 1990s was instrumental in making the vision of a mobile information society with intelligent transportation infrastructure, cutting-edge vehicle technologies, and real-time dynamic traffic and travel information services a reality [14].

Recent advancements in data transfer rates and communication networks, including the widespread adoption of 4G and 5G networks, coupled with the increased connectivity within vehicles through Electronic Communication Units (ECUs), such as sensors and communication devices connected to the Internet of Things (IoT), have been catalysts for rapid developments in communication protocols, traffic optimization algorithms, and communication technologies [15-16]. These technological advancements have paved the way for various forms of vehicle connectivity, such as Vehicle-to-Vehicle (V2V) communication, Vehicle-to-Infrastructure (V2I) communication, Vehicle-to-Pedestrian (V2P) communication, and the more recent concept of Vehicle-to-Everything (V2X) communication, ultimately leading to the emergence of Intelligent Transportation Systems (ITS) [17]. ITS leverages these solutions to effectively control and manage traffic while utilizing communication technologies to transmit data generated [18] by ECUs to cloud-based servers for processing and analysis, aiming to address urban and road traffic challenges [19].

1.3 Historic Evolution of Vehicular Ad Hoc Networks (VANET)

The concept of VANETs was initially introduced in 2001 under the context of "car-to-car ad-hoc mobile communication and networking" applications [20]. These networks enable the establishment of connections between vehicles, allowing information to be exchanged among them. Vehicular ad hoc networks (VANETs) are wireless networks formed among vehicles [21], applying the principles of mobile ad hoc networks (MANETs) to facilitate vehicle-to-vehicle (V2V) and vehicle-to-roadside (V2R) communication. Initially introduced in 2001, VANETs have become a crucial component of intelligent transportation systems (ITS) [22] and are often referred to as Intelligent Transportation Networks. They play a significant role in enhancing road safety, navigation, and roadside services. VANETs have evolved into the broader concept of the "Internet of Vehicles," where interconnected vehicles form a network for seamless communication. This evolution paves the way for the future development of an "Internet of autonomous vehicles”.

The remaining article is organized as: Section II gives the objectives of this survey Section III gives the literature review on the ITS and VANET; Section IV the research challenges in the relevant field; and Section V gives the conclusion of this article.

II. Objective of the Survey

The purpose of the survey is to evaluate the current state of ITS research, development, and VANET implementation. It entails identifying the current technologies, protocols, and standards used in ITS applications based on VANET.

i) Application Scenarios Evaluation: The survey aims to investigate the different application scenarios and use cases of ITS with VANET. This includes researching how VANET can improve traffic control, raise driving standards, enable effective vehicle communication, and support intelligent transportation systems.

- Traffic Management: By providing real-time traffic data and enabling intelligent traffic control systems, VANET can significantly contribute to the optimization of traffic management systems. Dynamic route planning and traffic signal optimization are made possible by the ability of vehicles outfitted with VANET technology to share data on traffic movement, roadway conditions, and congestion dimensions. This can lead to shorter travel times, better traffic flow, and increase the overall effectiveness of transportation networks.
- Road Safety: Through the implementation of proactive safety applications and real-time hazard alerts, VANET has the potential to significantly increase road safety. Vehicles connected to the VANET can communicate location, speed, and moving data that can be used to anticipate and avert collisions. Additionally, VANET can support automatic rescue braking, coordinated collision avoidance technologies, and intersection management.
- Effective Vehicle Communications: VANET enables effective V2V and V2I (vehicles to infrastructure) interaction among vehicles. Numerous applications, including cooperative adaptive speed control, and intersection coordination, can be supported by this communication. Through cooperative procedures and coordination, smoother traffic flow, lower fuel consumption, and increased operational efficiency of vehicle operations are all made possible by VANET, which enables the exchange of information on speed, acceleration, and position between vehicles.
- Smart Transportation Systems: VANET is a vital component of these systems, which are designed to improve the overall effectiveness, viability, and user experience of transportation networks. Smart transportation systems can take advantage of the enormous amount of data collected from vehicles and infrastructure by integrating VANET with other cutting-edge technologies like IoT (Internet of Things) and cloud computing. This enables predictive maintenance, enables personalised services for users, and supports the operation of autonomous and connected vehicles.

ii) Examining Communication Protocols: The survey's primary focus is on identifying and analyzing the various protocols for communicating used in VANET-based ITS. In order to do this, it is necessary to look into the protocols SAE J2735/SAE J2945, IEEE 1609, and IEEE 802.11p, which specify the network frameworks, data packets, and physical communication norms for Dedicated Short-Range Communication (DSRC).

iii) Evaluation of Performance and Reliability: The survey's objective is to assess the effectiveness and dependability of ITS solutions based on VANET. In order to comprehend the efficiency and constraints of VANET in real-world scenarios, this includes analyzing metrics such as communication latency, throughput, packet loss, network coverage, and scalability.

iv) Finding Research Gaps and Challenges: The survey aims to find Research Gaps and Challenges in ITS Implementation with VANET. This entails looking into issues like network congestion management, security and privacy concerns, scalability problems, integration with existing infrastructure, and the need for standardisation.

v) Providing Insights and Recommendations: In considering the survey's results, the goals include outlining future directions for the creation and implementation of ITS with VANET. This can aid in directing academics, businesspeople, government officials, and other interested parties in advancing their research and maximizing the potential of VANET-based ITS applications.

III. Literature Review

This section presents a comprehensive literature review to explore and analyze the existing body of research and advancements in the field of Intelligent Transport Systems (ITS) with a particular emphasis on Vehicular Ad Hoc Networks (VANETs). ITS encompasses a range of technologies and applications that utilize advanced communication and information systems to enhance the efficiency, safety, and sustainability of transportation systems. VANETs, as a subset of ITS, specifically focus on enabling communication and data exchange among vehicles and infrastructure components in a dynamic ad hoc network.

Qureshi et.al [23] in their article discussed how crucial Intelligent Transportation Systems (ITS) are for addressing traffic issues and enhancing transportation effectiveness. It emphasizes the requirement for information, communication, and computer technology integration in the transportation industry to develop a thorough and effective transportation management system. The Vehicle Infrastructure Integration (VII) program, which enables communication between vehicles and roadside infrastructure, is the main focus in the United States. The paper highlights the international scope of traffic problems and the significance of international technological cooperation. The article also discusses the foundational ITS technologies, such as GPS, DSRC, wireless networks, mobile telephony, roadside camera recognition, and probe vehicles.

Fayaz, Danish [24] in their article, presents the idea of Intelligent Transportation Systems (ITS) is examined, as well as how it might be used in India's transportation engineering. It draws attention to the difficulties caused by population expansion, emigration, and economic growth, all of which have put tremendous strain on transport services and infrastructure. In order to address traffic issues, parking issues, and congestion, the review discusses the need for an effective management system. The importance of ITS in delivering solutions via innovations like GPS, GNSS, and C-ITS is emphasized. The review also mentions the various ITS applications and their beneficial effects on intermodal connections, efficiency, and safety, such as parking guidance and facility management.

Miles, John C, [25] in their research gives a review of the aforementioned material and gives a general overview of Intelligent Transport Systems (ITS) and the various applications that they can be used for. The author also explores how communications, control, and information processing technologies are integrated into the transportation system, to increase convenience, safety, and efficiency. The review highlights the advantages of ITS, including enhanced public transportation systems, real-time travel information, improved traffic management, electronic payment systems, and air quality monitoring. The author also presents ITS applications are divided into various groups, such as Advanced Traffic Management Systems (ATMS), Advanced Traveller Information Systems (ATIS), Advanced Vehicle Control Systems (AVCS), Commercial Vehicle Operations (CVO), Advanced Public Transport Systems (APTS), Electronic Payment Systems (EP), and Security and Safety Systems (SSS) and concludes how these programs help with better navigation, lessening traffic, and effective transportation operations.

Al-Sultan, Saif et.al [26] in the study highlights how VANETs differ from MANETs in terms of their architecture, difficulties, traits, and applications. Architectures of VANET such as On Board Unit (OBU) wave device which is mounted on the vehicle to exchange the data with other roadside units (RSU), also various functions of OBU such as wireless radio access, ad hoc and geographical routing, network congestion control, ensuring reliable message transfer, maintaining data security, and facilitating IP mobility are discussed. The author also presents the communication domains of the VANET such as the In-vehicle domain, Ad-hoc domain, and infrastructure domain. Wireless technologies in the VANET cellular systems, WiMax, GSM, DSRC/WAVE are explored. This study gives researchers important information about the difficulties and uses of VANET.

Zhou, Fan, Qing Yang et.al [27] in an article describe a Bayesian framework for reliable traffic forecasting called Variational Graph Recurrent Attention Neural Networks (VGRAN). Through the Industrial Internet of Things (IIoT), it is intended to increase the productivity and security of transportation networks. In their article and research authors suggest, in order to collect time-varying road sensor readings, VGRAN employs dynamic graph convolution operations. This technique enables it to learn latent variables associated with sensor representation and traffic patterns. This probabilistic method is a flexible generative model because it takes into account the stochastic nature of sensor attributes and temporal traffic correlations.

Vatanian Shanjani et.al [28] Survey presents a comprehensive literature review on the evolution and development of transportation systems, with a specific focus on Vehicular Ad Hoc Networks (VANET) as a component of Intelligent Transportation Systems (ITS). The review explores the main issues, characteristics, and applications of VANET, including inter-vehicle communication, mobility models, consortiums, and protocol classifications. The study provides suggestions for routing protocols, data diffusion, media access control protocols, and security. The article identifies future research areas such as mobility models, protected frequency allocation, road safety, routing protocols, integration with wireless technologies, and data dissemination.

Carianha et al. [29] introduced the CMAX method, which involves utilizing a masking region with encrypted mix-zones, to enhance the confidentiality of vehicle location in mix-zones. The CMAX protocol employs a private encryption key provided by the RSU to encode the direction, position, and speed of the data. Only authorized vehicles that enter the mix-zone are assigned private keys by the RSU. The messages or beacons are then encrypted using these private keys. Within the mix-zone, the sender's private key is used to encrypt the status information. Upon decryption using the respective receiving vehicle's private key, the RSU forwards the messages to neighboring vehicles in proximity to the source vehicle, known as neighbor vehicles. However, it is important to note that the CMAX method is susceptible to security threats such as side-channel attacks and replay attacks.

Manogaran, Gunasekaran et. al [30] in their study propose a multi-variate data fusion (MVDF) technique to enhance data fusion in connected vehicles. The MVDF technique is designed to handle asynchronous and discrete data from the environment and convert it into continuous and delay-less inputs for applications. The fusion process utilizes least square regression learning to identify errors at different time instances. By employing this regression model, the technique distinguishes between indefinite and definite data fusion instances, enabling the identification of errors in advance. The differentiation process takes into account the application's run-time interval, facilitating data fusion within the same or extended time instance and data slots.

Abbasi, Irshad Ahmed et.al. [31] in their study carried out a thorough analysis of position-based routing protocols for vehicle-to-vehicle communication in urban environments. The article begins with a description of the VANET architecture before examining various position-based routing protocols such as GSR (Geographic Source Routing), GPCR (Greedy Perimeter Coordinator Routing), GPSRJ+ (Greedy Perimeter Stateless Routing Junction+), A-STAR (Anchor-based Street and Traffic Aware Routing), GyTAR (Greedy Traffic-Aware Routing), E-GyTAR (Enhanced Greedy Traffic-Aware Routing), TFOR (Traffic Flow Oriented Routing), DGSR (Directional Greedy Source Routing), E-GyTAR-D and going over their operational principles and constraints. A qualitative comparison of these routing protocols is provided, taking into account factors like mobility, traffic density, forwarding method, junction selection mechanism, location requirement, and methods for solving local optimum issues.

The research challenges in Intelligent Transport Systems with Vehicular Ad Hoc Networks

i. **Communication and Networking Challenges:**

- Reliable and Efficient Data Dissemination: VANETs face challenges in achieving reliable and efficient data dissemination due to the highly dynamic nature of vehicular networks. Developing protocols that ensure timely and accurate data delivery is crucial.
- Routing Protocols: Designing robust and scalable routing protocols for VANETs is essential, considering the varying network topologies caused by vehicle mobility. Routing protocols need to adapt to changing network conditions while minimizing latency and maximizing throughput.
- Network Congestion and High Mobility: VANETs experience congestion and high vehicle mobility, which can impact communication performance. Efficient congestion control mechanisms and mobility management techniques need to be developed to maintain network connectivity and stability.
- Quality of Service (QoS) Provisioning: VANETs support various real-time applications and services, such as traffic monitoring and emergency messaging. Ensuring QoS for these applications, including latency, reliability, and bandwidth requirements, is a challenge.

IV. Conclusion

In conclusion, this survey paper highlights the research challenges in Intelligent Transport Systems (ITS) with Vehicular Ad Hoc Networks (VANETs).Integration of VANETs into ITS offers immense potential for improving transportation efficiency and safety. However, several critical challenges need to be addressed. These include communication and networking challenges, security and privacy concerns, data management issues, resource allocation optimization, and system integration complexities. Overcoming these challenges requires interdisciplinary research and the application of artificial intelligence, machine learning, and data analytics techniques.

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