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Review of Key Technologies and Applications in Intelligent Transportation Systems

Hanlou Diao, Wei Shen*

China Design Group Co., Ltd., Nanjing 210001, Jiangsu Province, China

Corresponding author: Wei Shen, 22125759@bjtu.edu.cn

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Abstract: The development of Intelligent Transportation Systems (ITS) is closely intertwined with the growth of every city, serving as a critical component of smart city construction. This paper provides a concise overview of the concept and overall framework of smart transportation. It emphasizes the application of key technologies, including Traffic Element Identification and Perception, data mining, and Smart Transportation System Integration Technology, in the field. Furthermore, the paper elucidates the current practical applications of smart transportation, showcasing its advancements and implementations in real-world scenarios.

Keywords: Smart city; Intelligent transportation; Smart bus; Smart parking

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1. Introduction

Intelligent Transportation integrates advanced Information Technology (IT) such as the Internet of Things (IoT), cloud computing, big data, and mobile internet into traditional intelligent transportation systems to provide real-time traffic data services [1]. In the new era, constructing intelligent transportation systems to achieve smart travel is a crucial aspect of national transportation development. It is a significant initiative in building a powerful transportation nation and an excellent opportunity for intelligent transportation upgrades in the post-pandemic era. The strategic connotation of smart travel includes ensuring transportation safety, achieving convenient travel, promoting green travel, and creating smart travel solutions. Building intelligent transportation systems is a vital measure for achieving sustainable transportation development and upgrading the transportation industry chain. By leveraging these high-tech advancements, the goal is to enhance traffic management, improve safety and efficiency, and ultimately foster a more sustainable and intelligent transportation infrastructure.

2. Overview of intelligent transportation

Intelligent transportation represents an advanced iteration of ITS, integrating sophisticated technologies like the

Internet of Things, cloud computing, big data, and wireless sensing. Its application is projected to significantly increase the capacity of congested roads and overall transportation during peak times while decreasing traffic accident rates by 80 percentage points [2].

Intelligent transportation encompasses various fields, including highways, railways, civil aviation, and waterways. The challenge for intelligent transportation is how to integrate information from multiple platforms and analyze the data to uncover potential traffic patterns, thereby providing better services to road users [3]. In an intelligent transportation network, pedestrians, vehicles, and surrounding infrastructure can all act as sensing terminals, connected to form an urban road network information system. These terminals use technologies such as Radio Frequency Identification (RFID), Global Positioning System (GPS), and infrared sensing for intelligent identification. They are interconnected according to specific protocols and continuously exchange information.

The transition from ITS to intelligent transportation represents a qualitative leap both in theory and application. The framework of intelligent transportation is becoming increasingly clear, as depicted in **Figure 1**. The framework in previous research, enhanced with auxiliary networks, exemplifies intelligent transportation [4]. Vehicles adjust speed dynamically based on environmental feedback and aid drivers in decision-making during unexpected incidents.

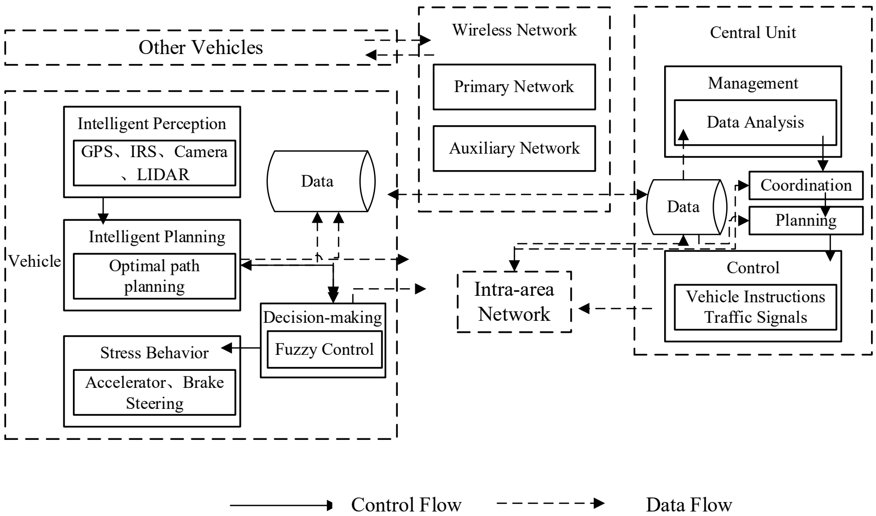


Figure 1. Improved AUTOPIA general framework

3. Key technologies of smart transportation

3.1. Traffic element identification and perception

Intelligent recognition and wireless sensor technology are pivotal for object identification in smart transportation systems. Objects are tagged with unique barcodes, Quick-Response (QR) codes, or RFID tags encoding their characteristics and location, read by intelligent devices for identification and decision-making [5]. Wireless Sensor Networks (WSNs) form a multi-hop, self-organizing network of low-cost micro-sensor nodes within the monitoring area, offering flexibility, cost-effectiveness, and ease of deployment [6]. In smart transportation, sensors are divided into collection and sink nodes. Collection nodes, as embedded systems, gather and process environmental data before transmitting it to other nodes or the sink node. The sink node integrates data from collection nodes and forwards it to the processing center [7]. As the IoT's underlying network, WSNs enhance smart transportation's safety, reliability, and sensitivity. However, sensor node energy consumption and lifespan are crucial, as neglecting them can lead to substantial maintenance costs.

3.2. Data processing

The complexity of smart transportation data, characterized by vastness, diversity, and heterogeneity, spans from basic facility and vehicle data collection to intricate traffic incident detection requiring real-time, accurate processing. Key techniques include Data Fusion, Vitalization, etc.

Data Fusion is a multidisciplinary technique integrating Artificial Intelligence (AI), communication, decision theory, and estimation theory. It processes multi-source information at data, feature, and decision levels [8]. Preprocessing aligns diverse sensor data for consistency, reliability, and accuracy [9]. In intelligent transportation, isolated data handling is inefficient. Data Mining converts noisy data into valuable knowledge [10]. A Statistical Package for the Social Sciences (SPSS) Modeler study analyzed traffic data, revealing flow relations with time, holidays, and weather, confirming mining reliability [11].

Data Vitalization is an innovative technique that animates data via "Vital Cells" capable of storage, mapping, and computation, evolving autonomously with data description changes and adapting to user behavior [12]. In transportation, it promises a data-driven evolution, leveraging Point of Interest (POI), GPS, and passenger flow data to analyze urban traffic and offer services like navigation, location-based alerts, and traffic rerouting [13].

3.3. Smart transportation system integration technology

Currently, smart transportation systems are fragmented across provinces, cities, departments, and scenarios, forming "information islands" due to a lack of data sharing, leading to high costs and unrealized potential. Urgent research on system integration technology, categorized as data and equipment integration, is needed.

Data integration has two application approaches. One is the fusion of data within a single platform system, such as the integrated processing of multiple sensor information from vehicle monitoring modules. The other is the analysis and processing of related data from multiple platforms and sensors across different periods, leveraging fused data to predict traffic information [14].

Equipment integration is necessary for legacy systems to transition to smart transportation without immediate replacement. A unified standard system and management regulations can create a standardized platform integrating government, enterprise, and research resources in the smart transportation industry. Large enterprises can lead industrialization, forming a comprehensive management system [15].

4. Typical applications

Presently, extensive research has been carried out on diverse aspects of smart transportation. From terminal intelligence, there are smart vehicles, intelligent traffic signals, and others. Broadly, smart transportation includes smart buses, taxis, ports, etc. In terms of functionality, it covers license plate recognition, Closed-Circuit Television (CCTV) surveillance, traffic flow control, vehicle dispatch, smart parking, route planning, navigation, and assisted driving systems. This article briefly discusses the current status of smart transportation through several typical applications.

4.1. Smart bus

Public buses, the primary urban transportation mode, offer advantages over private cars in capacity, fuel efficiency, land use, and cost. The Smart Bus System integrates advanced technologies like intelligent recognition, network communication, and Geographic Information System (GIS) for efficient management in dispatching, operations, route planning, and passenger services. This system resembles a mini-IoT for transportation, with in-vehicle sensors, platform equipment, and Integrated Circuit (IC) cards collecting data transmitted to the dispatch center for processing. Real-time information on bus arrivals, surroundings, and passenger flow is then displayed via smart signs and displays [16].

Based on Wuhu's bus system, previous literature proposed a public transportation integration framework using Service-Oriented Architecture (SOA) [17]. It employs the Fisher clustering algorithm to analyze IC card data and passenger flow patterns, introducing a time-segmented adaptive dispatching algorithm tailored to passenger flow fluctuations. Cities like Beijing, Suzhou, and Changzhou have implemented smart bus systems, enhancing residents' travel.

Figure 2 depicts the transport system model adopted in the proposed architecture, leveraging advancements in intelligent systems, communication technologies, and sensors. Dimitrakopoulos introduced the concept of cognitive transport networks, where infrastructure, vehicle, and personal device sensors collect data transmitted via various communication technologies. Advanced data processing, like big data or mining, generates new knowledge to improve public transport.

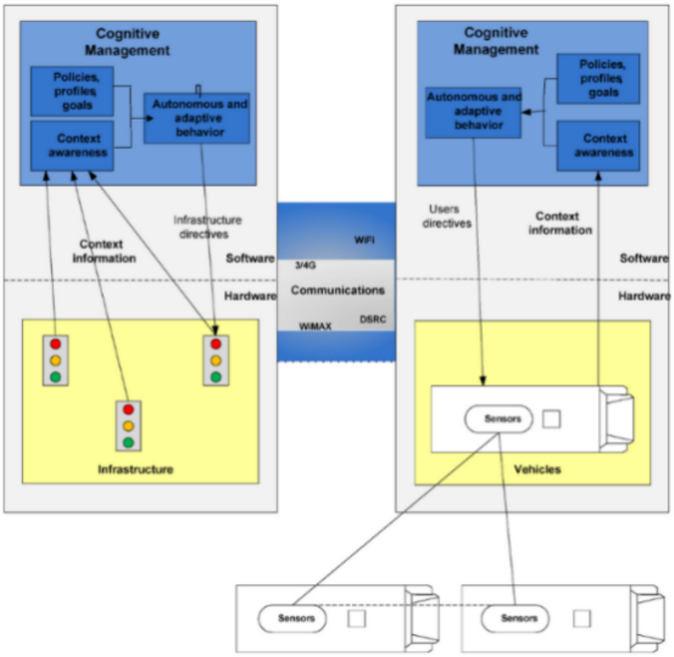
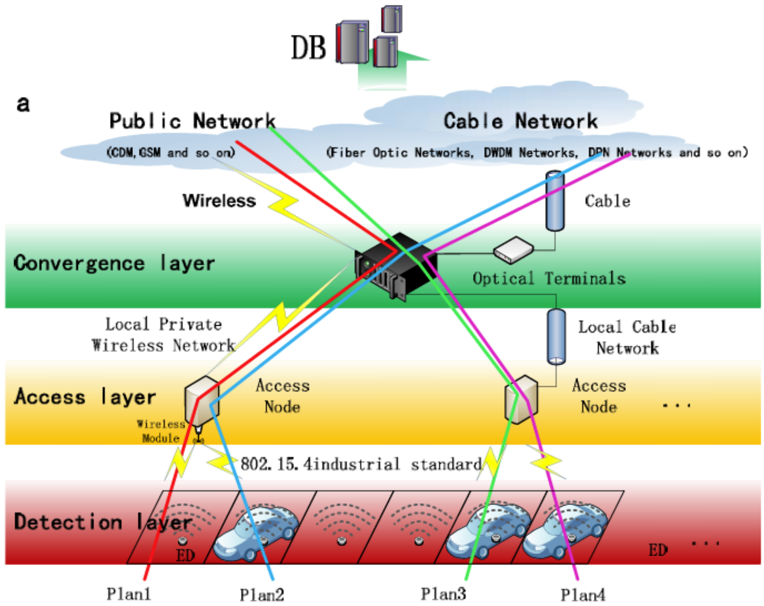


Figure 2. Concept illustration of the cognitive transport network based on the cooperation of all elements of the transport network (infrastructure, vehicles, and users) [18]

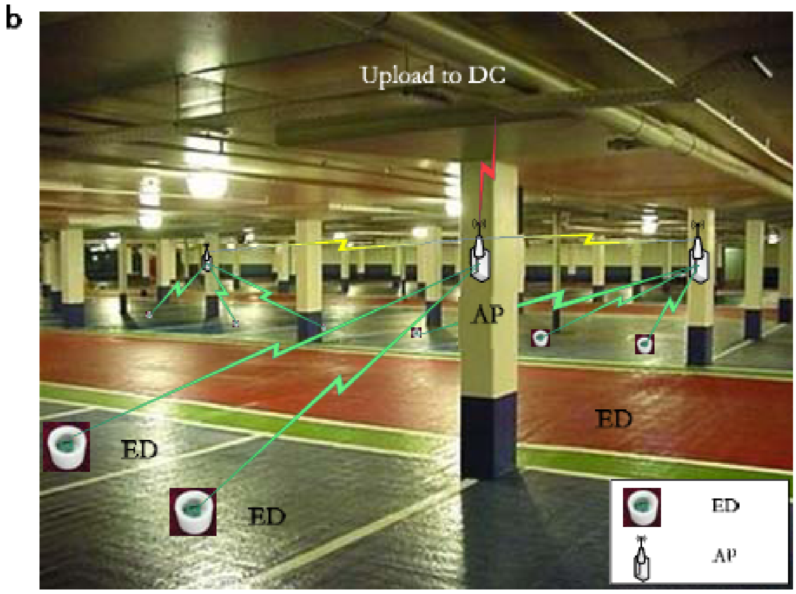
4.2. Smart parking

Magnetic sensor-based parking surveys in intelligent systems, crucial for planning with facility details, utilization rates, and indices are considered. Real-time space availability supports parking management, strategy, and driver needs. Surveillance-enabled surveys update availability, enhancing guidance systems to expedite parking and cut emissions. Magnetic sensors excel in cost, size, weight, power, and installation compared to others. The system uses WSN for data capture, as shown in **Figure 3(a)**.

The frame comprises three layers: detection, access, and convergence, especially for long transmission distances. In the detection layer, data from electronic devices (Electronic Devices (EDs) or sensors) is sent to the access layer via 802.15.4 industrial standard, then to the convergence layer via local wireless or cable networks. Ultimately, data reaches the Data Center (DC) similarly to the access layer path. Four plans exist for data transmission in WSN. In parking lots, a two-layer WSN can detect spaces if data is only uploaded to the local DC (see **Figure 3(b)**, where AP stands for Access Point).



(a) General case: when the transmission distance is far [19]



(b) Special case: when the transmission case is closed [19]

Figure 3. Working frame of WSN

Ali Cloud pioneered smart parking by deploying a payment system in Hangzhou covering over 20,000 spaces across various districts. This system utilizes smart sensors to detect vehicle entry and exit, alerting parking attendants via handheld devices, and enhancing space turnover efficiency [20]. Li proposed an embedded monitoring system with enhanced real-time performance using ZigBee and Advanced RISC Machine (ARM) [21]. Shan from Liaoning Technical University developed a Ultra-High Frequency (UHF) reader paired with passive tags, overcoming RFID range limitations in standard parking lots for broader applications [22].

Indoor parking more often has complex environments, and their equipment is not easy to maintain, making precise indoor positioning and real-time response even more challenging. To address this, Zhang from Jiangxi University of Science and Technology's indoor smart parking management system utilizes Bluetooth for communication and installs guiding lights at intersections within the parking lot to provide reverse guidance for parking spaces.

5. Conclusion

This article commences with an exploration of the concept of intelligent transportation, subsequently delving into the pivotal technologies and evolutionary trajectory shaping this domain. Furthermore, it presents a concise synopsis of the hallmark applications of intelligent transportation. Subsequently, the article delves into the operating principles and showcases exemplary instances of smart buses and smart parking systems. These systems leverage cutting-edge technologies to revolutionize public transportation and parking management, enhancing efficiency, reducing emissions, and enhancing the overall travel experience for commuters.

Disclosure statement

The authors declare no conflict of interest.

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