INTELLIGENT TRANSPORT SYSTEMS: AN INTEGRATED APPROACH FOR SMART CITIES

Akhmatokhunov Bakhtiyor
Andijan State Technical Institute, Senior Lecturer of the Department of Transport Logistics

Annotation. In the context of the growing need for safety, efficiency, and environmental sustainability in the modern transport sector, intelligent transport systems are developing at a rapid pace. These systems play an important role in improving the quality of traffic, effectively managing urban infrastructure, and regulating traffic flow. They include traffic management, autonomous vehicles, real-time systems, and applications developed on the basis of advanced digital technologies. The article also examines the initiatives put forward by car manufacturers - that is, activities to develop and comply with the standards of intelligent transport systems that harmonize the interests of drivers, passengers, and city managers.

Keywords: Intelligent transport systems, real-time monitoring, smart city technologies, sensor networks, traffic flow control, artificial intelligence, IoT.

Annotatsiya. Zamonaviy transport sohasida xavfsizlik, samaradorlik va ekologik barqarorlikka bo'lgan ehtiyoj ortib borayotgan bir sharoitda aqlli transport tizimlari tez sur'atlar bilan rivojlanmoqda. Ushbu tizimlar transport sifatini yaxshilash, shahar infratuzilmasini samarali boshqarish va transport oqimini tartibga solishda muhim rol o'ynaydi. Ular transportni boshqarish, avtonom transport vositalari, Real vaqt tizimlari va ilg'or raqamli texnologiyalar asosida ishlab chiqilgan ilovalarni o'z ichiga oladi. Maqolada, shuningdek, avtomobil ishlab chiqaruvchilari tomonidan ilgari surilgan tashabbuslar - ya'ni haydovchilar, yo'lovchilar va shahar menejerlari manfaatlarini uyg'unlashtiradigan aqlli transport tizimlari standartlarini ishlab chiqish va ularga rioya qilish bo'yicha tadbirlar ko'rib chiqiladi.

Kalit so'zlar: aqlli transport tizimlari, Real vaqtda monitoring, aqlli shahar texnologiyalari, sensorli tarmoqlar, transport oqimini boshqarish, sun'iy intellekt, IoT.

Аннотация. В контексте растущей потребности современного транспортного сектора в безопасности, эффективности и экологической устойчивости быстрыми темпами развиваются интеллектуальные транспортные системы. Эти системы играют важную роль в повышении качества дорожного движения, эффективном управлении городской инфраструктурой и регулировании транспортных потоков. Они включают в себя управление дорожным движением, автономные транспортные средства, системы реального времени и приложения, разработанные на основе

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передовых цифровых технологий. В статье также рассматриваются инициативы, выдвинутые автопроизводителями, то есть мероприятия по разработке и соблюдению стандартов интеллектуальных транспортных систем, которые гармонизируют интересы водителей, пассажиров и сити-менеджеров.

Ключевые слова: Интеллектуальные транспортные системы, мониторинг в режиме реального времени, технологии "умного города", сенсорные сети, управление транспортными потоками, искусственный интеллект, Интернет вещей.

Introduction

Intelligent transport systems (ITT) are developing as technological solutions that have brought about revolutionary changes in the modern transport sector, fundamentally reforming the processes of cargo and passenger transportation. These systems are aimed at significantly increasing the efficiency, security, and environmental sustainability of transport infrastructure by combining advanced information and communication technologies, big data processing, and artificial intelligence algorithms [1].

Intellectual transport systems allow for the widespread introduction of modern technologies in a number of areas of the transport sector, in particular, in the management of traffic flows in urban conditions, increasing the efficiency of vehicle use, optimizing public transport systems, and targeted organization of the movement of special vehicles. It is aimed at reducing traffic congestion, reducing travel time, increasing safety, increasing the efficiency of special vehicles, and reducing the negative impact on the environment using real-time data, large-scale sensor networks, and intelligent algorithms.

Intelligent transport systems are comprehensive, including advanced applications such as intelligent traffic light systems, autonomous vehicles, dynamic route planning, electronic payment systems, and real-time public transport tracking. These technologies will serve not only to improve transport services, but also to increase energy efficiency, reduce emissions, and ensure environmental sustainability in the field of urban planning.

In the process of rapid urban development and increasing demand for transport systems, intelligent transport systems are recognized as the main factor determining the future of mobility. Globally, governments, corporations, and research institutions strive to create and implement intelligent transport system technologies on a large scale to create more intelligent, interconnected, and environmentally friendly transport ecosystems.

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In recent years, the emergence of advanced technologies such as the Internet of Things (IoT) and 5G communication has significantly accelerated the application and rapid development of intelligent transport systems[1]. Intelligent traffic lights (ITL), virtual traffic lights (VTL), automotive Ad-hoc networks (VANET), and mobility prediction technologies are among the most popular directions of intelligent transport systems, aimed at optimizing traffic flow and reducing congestion[2].

Methodology. Intelligent transport systems are the main link in the creation of smart city infrastructure in large cities, where the urbanization process is proceeding at an accelerated pace. Because it helps minimize vehicle downtime, gives priority to emergency special vehicles, reduces travel time in emergency situations, increases traffic efficiency, prevents unexpected collisions, and reduces carbon emissions. Integrating 5G real-time communications into these technologies will further enhance their effectiveness.

Studies have proven that efficient traffic management systems based on intelligent transport systems have the ability to drastically reduce the duration of transport movement by up to 25%, which allows for significant savings in passenger time. By optimizing traffic light timing, intelligent traffic control systems can reduce energy consumption and greenhouse gas emissions by approximately 15-20%. According to the results of a survey conducted in cities [5], intelligent traffic management systems can reduce the number of accidents occurring in metropolitan areas by up to 20%. This is achieved by coordinating traffic flow and improving event management in real time [5].

Vehicle ad-hoc networks (VANETS)

Acceptance of the Internet of Vehicle (IoV) ecosystem for smart cities allows collecting and exchanging information about cars, roads, infrastructure, buildings, etc. VANETS has a very wide range of capabilities, as it is divided into various subcategories that describe how the VANET process works in smart cities. Communication from vehicle to vehicle (V2V) and from vehicle to infrastructure (V2I) are the main functionalities of VANETS. In B2B communication, vehicles directly exchange information with each other to exchange information such as location, speed, and direction. This data is very important for the development of collaborative advanced technological applications that help prevent road traffic accidents and minimize traffic congestion, reducing the travel time of special vehicles [6]. The second main type is (V2I), which allows vehicles to exchange data between traffic lights, sensors, and cameras to improve safety and traffic flow. These types of communication provide drivers with real-time information about road conditions, traffic congestion, and road traffic accidents [6-8].

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From Car to Server (V2S) is a subset of (V2I) that involves data exchange between a vehicle and a remote server and is typically used for real-time traffic tracking and route optimization.

Vehicle-Cloud Technology (V2C) communication establishes communication between a vehicle and cloud-based services by exchanging information about the state of vehicles, road conditions, assembled from vehicle sensors, navigation systems, and other modern equipment. This data is sent to cloud technologies for analysis and subsequently sent back to the vehicle in the form of valuable accurate time data, planning the traffic situation and optimal route [8].

V2N (Vehicle-to-Network) technology provides vehicle connection to external systems via a cellular network, which allows vehicle integration with intelligent traffic lights and traffic control systems. These connections are essential for improving the efficiency of the transport network, as the system allows you to quickly update and distribute traffic, navigation, weather conditions, and other real-time information.

The use of vehicle-pedestrian (V2P) communication at intersections will help us achieve an effective result, which is shown in Figure 2. 3. These images show warning messages that are transmitted in real time to both pedestrians' smartphones and vehicle screens through the mobile network. This communication system works effectively when a vehicle approaches an intersection or intersection and unexpectedly appears on the road and does not notice an approaching vehicle moving at high speed. By providing such timely warning, V2P communication significantly reduces the risk of accidents [6-10].

Intelligent traffic lights.Intelligent traffic lights are essential for intelligent transport systems, as they enhance road safety by managing traffic flow. Intelligent traffic lights are technological devices that allow reducing traffic flow efficiency and traffic congestion using real-time traffic data and complex algorithms. "Intelligent traffic lights (ITLs) operating within intelligent transport systems collect traffic information in real time using equipment such as cameras, radars, and various sensors. These data are analyzed using advanced algorithms, and based on such factors as traffic flow, traffic congestion, and pedestrian movement, an optimal traffic light operating schedule is formed. This approach differs from traditional traffic light systems, which automatically change color phases only within a specified time interval.

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Figure 1. Intelligent traffic lights.

For example, traffic lights can adjust traffic lights' operating times in accordance with real conditions to reduce traffic congestion. This leads to a significant reduction in vehicle downtime, as well as a decrease in harmful gases, especially CO2 emissions. In addition, intelligent traffic lights have the ability to identify cyclists and pedestrians, ensuring the necessary time for their safe passage. This is an important factor in reducing the risk of road accidents [10]."

Additionally, Intelligent traffic lights can control traffic in such a way that emergency special vehicles can pass through without stopping. It detects emergency special vehicles and changes their position to green, thus allowing them to pass quickly. Intelligent traffic lights can also reduce collisions by avoiding red lights. Intelligent traffic lights can reduce the waiting time of vehicles at red lights by optimizing the time of road signs using advanced algorithms.

With the application of 5G and IoT, the order will significantly improve. Since 5G networks have minimal latency, traffic signals can communicate with each other and other connected devices in real time. This allows traffic lights to respond more quickly to changes in traffic patterns and change signals accordingly. For example, a traffic light noticed a traffic jam in a certain direction. In this case, it can change the alarm time so that more cars can pass through. The use of 5G enhances the use of more sophisticated sensors and cameras for real-time recording of road conditions.

Sensors installed on the road surface can detect the presence of cars. To detect the presence and movement of vehicles, these devices use various

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technologies such as inductive rings, radar, or infrared. Cameras can also be installed for recording and devaluing images of the crossing using computer viewing algorithms.

These algorithms can detect the presence of vehicles, highlight their class (e.g., car, truck, bicycle, emergency vehicle), and track their movement. IoT devices, such as GPS-powered cars or mobile phones, can also provide information about the location and movement of vehicles near the junction. All of this data will be collected and analyzed in real time using available feedback based on current traffic conditions.

Virtual traffic lights (VTL) significantly improve intelligent transport systems using a 5G network and road infrastructure (cameras, sensors, and other devices) for vehicle detection and sending virtual signals to the road. This system operates in real time using devices installed on specially equipped vehicles to inform drivers about road conditions.

For example, if there is a correctly moving vehicle at the intersection and there is another vehicle coming at high speed from the left or right, the virtual traffic light identifies this situation and sends a warning message to a special device inside the vehicle about the need to stop. If a slow-moving vehicle is forced to stop, the virtual traffic light system sends a signal to the driver through a special device or to the vehicle's automated control systems. Thus, an automatic braking system will be activated to prevent collisions. Similarly, the system ensures safety when pedestrians cross an intersection.

The virtual traffic light also reduces travel time in emergencies and gives priority to emergency service transport. The use of virtual traffic lights at intersections reduces traffic congestion, improves traffic flow, increases safety, and reduces downtime. Especially in areas with limited street width, where real traffic lights are not installed, virtual traffic lights significantly increase driving safety.

For the effective operation of virtual traffic lights, the role of OBU (vehicle-mounted devices) is important. These devices transmit the speed of the vehicle, road conditions, and other necessary information to the control system and allow communication with other vehicles.

Communication technologies that provide efficient and intelligent transport systems. Smart cities and intelligent transport systems depend primarily on reliable communication technologies. With population growth, cities are facing huge problems such as traffic congestion, energy consumption, and pollution. They are turning to smart technologies to solve these problems by combining various systems and sensors that allow them to collect, analyze, and make decisions in real time. Today, and intelligent transport systems have gained popularity not only

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because they combine various communication technologies to optimize traffic flow, but also because they minimize traffic congestion and improve road safety.

Conclusion.Applying intelligent transport systems in smart city infrastructure to improve mobility, reduce traffic congestion, manage traffic flow, and reduce environmental damage is a solution to many existing problems. Recent technological achievements, such as IoT, V2X communication, and 5G networks, have made it possible to implement innovative solutions such as ITL and VTL. Using real-time communication through 5G networks and various sensor technologies, including AI cameras, RSU and OBU, ITL and VTL systems, can effectively optimize traffic flow and reduce CO2 emissions.

In addition, this article emphasizes the importance of addressing security issues related to the implementation of Intelligent Transport Systems to protect the privacy of public transport. Through the study of specific urban areas, it became known that the integration of intelligent transport systems plays an important role in the development of Sustainable Smart Cities by improving driving experience, road safety, and traffic management in general, as well as reducing CO_2 emissions and harmful pollutants. The active participation of car manufacturers in complying with the standards of Intelligent Transport Systems further emphasizes the mutual benefit of both drivers and urban centers.

In conclusion, the implementation of intelligent transport systems is a transformational approach to building more efficient, sustainable, and resilient urban transport systems, thereby contributing to the creation of a cleaner and healthier environment for future generations.

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