Internet of Things-Based Smart Transportation System for Smart Cities

E. Fantin Irudaya Raj and M. Appadurai

1 Introduction

Many developing countries like India invest a huge amount of money to transform their old existing cities into modern smart cities. A smart transportation system is an integral part of this planning and commissioning. Advancement in the Internet of Things (IoT) and Information and Communication Technology (ICT) plays a crucial role in smart city development. The smart city concept combines ICT and IoT to improve the efficiency of city services while also connecting them to inhabitants. It facilitates communication between officials and the public, as well as civic infrastructure, in order to monitor cities for various objectives. The quality and interactivity of city services are expected to augment with the help of IoT.

These technologies also play a vital role in a modern transportation system. Vehicles with sophisticated accident-prevention systems, such as collision warning systems (CWSs) or lane-keeping assistance (LKA), are now available in the market. The next stage in decreasing road accidents is to plan ahead of time for such cars to minimize collisions while also improving traffic flow. In order to effectively manage traffic problems, vehicle-to-infrastructure (V2I) communications are required.

Self-driving cars or autonomous vehicle is also a part of this modern transportation system. Many researchers are working towards this area in recent times. The Internet of Things (IoT), Information and Communication Technology (ICT), remote sensing, Global Positioning Systems (GPS), and embedded systems all contribute

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to the development of this autonomous vehicle technology. Advancements in these areas make the autonomous vehicle's maneuvering easier and more precise. Electric vehicle adoption and converting the existing gasoline vehicles into electric vehicles also play a crucial role in the future transportation system. The smart cities also needed to plan accordingly and make proper arrangements for vehicle charging and all.

2 Literature Review

The last century saw substantial improvements in the quality of life, particularly in terms of access to services. However, administrators, architects, and urban planners have faced a significant problem due to intensive industry and the rising population in metropolitan regions [1]. Over the last decade, the Internet of Things (IoT) and information and communication technologies (ICT) have had a tremendous impact on how businesses approach innovation and how they originate and exploit opportunities in their daily operations. These were compounded in Smart Cities, where the purpose of the IoT is to leverage ICT to allow value-added services for citizens while also giving enterprises more opportunity to innovate by integrating cutting-edge technology [2]. One facet of the smart city is smart transportation. Transportation has become the second-largest source of carbon emissions due to its low efficiency. It has an impact not only on smart transportation but also on the smart environment. As a result, improving transportation efficiency is critical to smart transportation and smart cities [3]. Although transportation has substantially improved our lives, numerous major challenges remain unsolved, including auto crashes, traffic jams, and vehicle discharge. Intelligent transportation has recently become a hot topic in the Internet of Things (IoT) space, and it is seen as a solution to the challenges mentioned above [4].

Applications have become smarter as the Internet of Things has grown in popularity, and connected gadgets are being used in all areas of modern cities. Machine Learning (ML) approaches are used to improve the intelligence and capabilities of an application as the volume of acquired data is expanding [5]. As the world's population grows, so does the number of vehicles on the road, increasing traffic management issues, particularly for public transportation. Furthermore, the frequency of accidents and other traffic-related problems is increasing. The Intelligent Transportation System (ITS) overcomes most of these problems by merging existing technologies with the fundamental infrastructure [6]. Because of mobile technology and the ubiquity of the cellular network, real-time vehicle tracking for effective transportation management is now conceivable. The Intelligent Public Transportation System eliminates the need to wait for hours for a bus. Smartphones are one of the most enticing alternatives for developing IoT apps due to their omnipresent nature and ever-increasing power at a low cost. A system based on a blend of technologies such as GPS and Android is being investigated here to reassure consumers who utilize public transit [7].

A decentralized data management system for smart and safe transportation is built to tackle the data vulnerability problem, leveraging blockchain and the Internet of Things in a sustainable smart city framework [8]. Electric Vehicles (EVs) are predicted to become widely used in personal, business, and public fleets in urban cities in the future. The popularity of electric vehicles will greatly impact the city's long-term sustainability and economic prosperity [9]. The effective management of hybrid electric vehicles with modern machinery and its effective way to control the machine is also discussed [10–12]. The various electric vehicles can be adopted for smart city environments, and their charging methodologies are also explained [13–15].

Vehicle parking is also another major concern in many smart cities. Because most of today's smart cities were converted from older traditional cities, they may have limited roads that can't handle a huge number of vehicles. As a result, finding a parking spot at the right time and in the right location has become an inevitable requirement for people worldwide. However, finding the right place to park the vehicles may also lead to time wastage and more gasoline consumption. The availability of parking occupancy information in advance plays a critical role in ensuring that motorists have a stress-free trip. It also makes service-profit management easier for parking lot owners. It also aids in the control of pollution in smart cities by lowering traffic congestion by reducing cruising time [16, 17].

Smart transportation design and planning, smart communities, smart cities, smart control systems, and other sectors all use big data analytics. A model for evaluating transportation data utilizing Hadoop and Spark is proposed to handle real-time transportation data. The suggested system is put to the test using transportation data from a variety of reliable sources. The results reveal data processing and real-time distribution to citizens in the shortest time possible [18–20]. Vehicle-to-vehicle communication and Vehicle-to-Infrastructure communication are playing an important role in smart transportation [21, 22]. These techniques are creating the basic foundation for autonomous vehicles for future smart cities.

From the review of the literature, we can understand the importance of IoT-based smart transportation systems. Further, the following sections explain the IoT-based Traffic Management system, vehicle parking system in detail. In addition, the autonomous vehicles for future smart cities in the modern transportation system are also explained in detail.

3 Autonomous Vehicles for Smart Cities

In recent years, the smart city project has been implemented in urban areas to enhance the sophisticated life of the people by adopting advanced technology. The people are interested in utilizing the modern innovations in network connectivity, garbage handling, transportation, traffic management, city monitoring, security, water management, and autonomous vehicles. Especially in the automotive field, the three modern technologies such as electric vehicles, connected vehicles, and autonomous vehicles are revolutionized. The electric vehicle gives the option for a pollution-free environment inside the urban region. The autonomous vehicle provides crash less driving and controls the rash driving of youngsters. The connected vehicle has an internet connection that gets onsite information about the city traffic and navigation details from the cloud storage. These benefits are employed by establishing smart devices throughout the city. However, without these sensors, transducers, and high-speed wireless internet connectivity, these modern innovations can't be utilized by people.

The city traffic can be efficiently controlled with the help of autonomous vehicles by taking dynamic decisions in traffic management from real-time information. For an efficient traffic management system, the smart city project needs base technology such as self-driving technology, vehicle-to-vehicle communication, vehicle-to-infra communication, and smart parking system. These concepts and their needs are briefly discussed in the below sections.

With the implementation of driverless vehicles in smart cities, people get several benefits. Road accidents and transportation costs are entirely reduced. The traffic congestion is efficiently managed. The optimum driving speed inside the city can get implemented. The vacancy in parking spaces is given as on-board information, so the time to search the parking area is reduced. Thus, the fuel economy is improved by reducing unnecessary parking area searches and city traffic, and thus, the greenhouse gas emissions can significantly decrease. On the road, there is a provision that gives priority to emergency vehicles and medical waggons. The autonomous vehicle provides overall public safety in roadways.

3.1 Vehicle-To-Vehicle Communication

Vehicle-to-vehicle communication empowers the automotive to exchange their information among the vehicles. The speed, destination, and navigation are wirelessly broadcasted to the nearby vehicles. The proper software tools are installed in each vehicle to exchange the data without potential threats. The driver is alerted by messages and warning alerts for necessary control over the vehicle movement to avoid accidents. The message transfer is done more than 300 m before to alert drivers regarding the traffic, weather conditions, threats, and general information. With the assistance of vehicle-to-vehicle communication and roadside sensors, road accidents are minimized to enhance road safety. The best sample for this safety method is adaptive cruise control technology [23], in that sensors are utilized to avoid vehicle collisions. An automotive vehicle integrates with an adaptive control device. Therefore, the speed is spontaneously regulated to move at a particular speed. It is implemented with the assistance of vehicle-to-vehicle communication only. As a result, the automotive is efficiently coordinated in a specific region by controlling the speed and applying brakes automatically on demand. The dynamic clustering of autonomous vehicles improves road lane utilization and reduces inner-city traffic

[24]. For this, efficient data analysis techniques are essential. Since the sensor information is not always examined. The required onsite information is only monitored for dynamic analysis.

IoT devices assist in coordinating the several devices to connect with embedded computing tools. The IoT connects with the sensors by wireless network connection. The smart city project utilizing IoT tools has various benefits, such as being user-oriented and better performance. The several sensing elements like alcohol sensor, vibration measuring transducer, accelerometer, and pressure transducer are linked with IoT devices to avoid highway accidents. The device enhances driver safety by getting simultaneous data from the sensor nodes to avoid crashes among vehicles. The standard procedure is followed during the lane change [25] in an autonomous vehicle to avoid a collision. The vehicle is moved to another lane when the required spacing is available. The driverless vehicle must maintain adequate space among the host and surrounding vehicle to avoid a crash.

The heavy freight vehicle consumes a large amount of fuel for its displacement. Fuel saving is a universal requirement due to the increase in fossil fuel prices and Greenhouse gas emissions. The sensors in the vehicle-to-vehicle communication concept give better solutions for fuel-saving [26]. The sensors in the automotive analyze geological data such as wind velocity, road elevation for dynamic decision making. The sensor communicates with the infrastructure to know about city traffic and possible clear routes. The vehicle-to-vehicle communication method gathered the data beyond the eyesight, and acquired information is used for efficient traffic management. The feasible route is identified and communicated with the vehicle handler. Thus, vehicle fuel saving is improved by this concept. Figure 1 illustrates

Fig. 1 Vehicle-to-vehicle communication

the detailing of vehicle-to-vehicle communication.

Sustainable development is the main objective of modern technologies, and the smart city project creates a way for people to live in the available environment in comfort. The balancing of the resources in digital cities is enhanced by the proper handling of all available resources eventually. For example, public transport is viable to all types of people by providing separate expressways. The time delay of the public transport due to city traffic in the highway is eradicated by this special expressway. The daily workers use the public vehicles for their routine trips, and this reduces separate vehicle usage. The smart sensors interact with the vehicles and infrastructure to monitor by analyzing gathered information. The smart city design is capable of handling the more challenging sustainable projects inside congested cities. The supply chain management related to electricity supply, garbage management, material consumption, and wastewater recycling is done with the assistance of smart sensors [27].

3.2 Vehicle to Infra Communication

A smart city utilizes several electronic devices and sensors to gather information from several nodes. The transportation system can communicate with different infrastructures [28] available in the digital city project. The social transformation is happening by the smart city project and fifth-generation network connection. The 5G network implementation [29] depends on the population and economic wealth of the nation. The automobile sector is also moving towards the utilization of higher-end technology. The modern connected vehicles receive and transmit information from their environment. The rescue vehicle or hospital wagon accesses the roadways easier by smart technology from such information. The road traffic is efficiently managed. Traffic congestion, pollution, land utility, energy demand are reduced, and mobility and safety are increased from modern innovations in connected vehicles. The data exchange between vehicles or between vehicles and infrastructure are essential in smart traffic management projects. The location, velocity, and navigation of the vehicle are continuously monitored to prevent accidents. The dynamic routing is done on heavy traffic by the gathered data from the vehicle to infra communication. Figure 2 shows the vehicle to infrastructure communication intangible diagram.

The connected vehicles have in-built sensors capable of analyzing their surroundings without human interference while navigating. Automated vehicles run on the road due to the advancement in network connections and computing technology. Modern communication technologies like 4G and 5G allow driverless vehicles to connect with thousands of network nodes, neighboring cars, and roadside electronic devices.

Fig. 2 Vehicle to infra communication

3.3 Vehicles Platooning

The navigation of vehicles in tightly aligned units on the highway roads is called vehicle platooning. This concept gives several advantages: enhanced traffic management, higher road capacity, crashless driving, better fuel economy, and idle movement. The vehicle handlers get relaxed without driving and do other work. It increased the productivity of the human workforce by doing other tasks on traveling. For the platoon vehicles, continuous information transfer with nearby automotive is supported. Thus, vehicle-to-vehicle communication is very important in vehicle platooning. The joining or relieving of vehicles is done at any time on active platoon movement [30]. The alerting of nearby automotive is made on platoon forming and leaving. This alert assists the vehicle to join or smoothly leave the platoon without disturbing other vehicles. Messages indicating acceleration, navigation, routing, platoon head change, and braking are transmitted to the vehicle to ensure safety of the vehicle.

3.4 Intelligent Transportation System

The sensors, IoT devices, and wireless networks are efficiently used in data exchange on intelligent transportation systems in smart cities. The vehicles have sensors for gathering onsite data. The dynamic information about vehicle location, navigation, and speed is provided by short message type services to the drivers. The on-road movement of automotive is made to the required destinations without human interference. Smartphones connected with vehicle networks give real-time information. The roadside sensor is erected at a uniform distance to gather data about the vehicle movement in that region [31]. Figure 3 shows the conceptual diagram of roadside sensor installation. The IoT devices can develop interconnectivity with the surrounding devices automatically.

The vehicle needs to connect with another vehicle, the roadside acts as the intermediary device among them. The roadside sensor provides an intermediate connection to

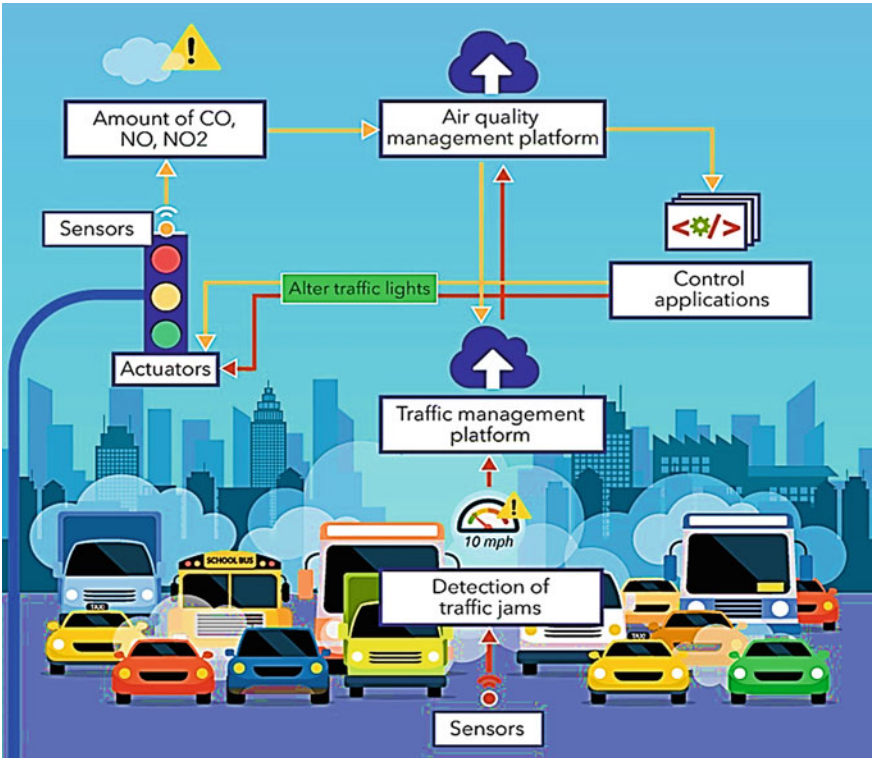

Fig. 3 Roadside sensors

a particular range. The alert having vehicle information is given to the owner on unauthorized access of the automotive. An intelligent transportation system effectively handles city traffic. The first step in the traffic management concept is registering the vehicle data to the roadside sensor. The destination of the vehicle to reach is also given. The roadside sensor in one region is interconnected to the other sensor to gather the traffic details. A first vehicle route is analyzed about the traffic details. If it is feasible, the first route is provided; otherwise, the next route is considered and so on. Thus, the optimum route is given to the vehicle for reducing traffic congestion in urban areas. IoT devices deliver the information with the optimum route via message. Implementing this technology makes it possible to create a traffic-free environment in modern cities. This technique provides the suitable and fastest route for forwarding hospital wagons. The safety, parking space handling is enhanced with the available traffic information [32]. The unnecessary time delay for travel is efficiently controlled, and the traffic problem is reduced.

4 IoT-Based Vehicle Parking System for Smart Cities

Normally, the cities are furnished with tall residential buildings, giant commercial malls, and densely populated vehicles. Each family has at least one vehicle for their transport. The special or collective parking area is developed in the apartments and commercial malls to facilitate their customers. The lift-type shaft type parking slot is also built-in densely populated cities. This considerable investment is opened correctly for the people's benefit. The investment amount gets payback only through proper utilization of resources. Electronic devices such as IoT are installed in each region to gather real-time information for traffic management.

The free parking slop searching is a huge task for the drivers in the inner city traffic. The time and fuel are wasted in searching the parking space. The connected vehicle has a sensor that provides information about the location and navigation details. The parking area is equipped with IoT to load onsite information to the central server. The central server gets data from several network nodes and delivers it as needed. People can use apps on their cell phones to obtain information from the cloud server. Before arriving at a specific location, the vehicle operator can look for available parking spaces. When the moving destination is input into the app on the smartphone, the central server sends numerous pieces of information. The essential details such as city traffic, weather condition, optimum route to move to avoid city traffic, parking slot free space, distance to travel, and the time to reach the destination are available in the smartphone app. The unnecessary searching of the parking area is avoided in this smart parking concept. The pollution and fuel wastage due to severe traffic and parking space examining is controlled. It offers cost-beneficial returns on smart project investments. The automatic movement of the car to the parking slot is depicted in Fig. 4.

Fig. 4 Smart parking

The autonomous vehicle further utilizes the driverless benefits. Only the smartphone app allows you to choose a parking spot. Self-driving technology moves the vehicle to and from the parking area without the need for human interaction. The smart vehicle concept is being developed further. When people travel to work in autonomous vehicles, there is no need for them to drive. They can do their work in the car at the time of traveling. After reaching the destination, the vehicle automatically moves to the parking space. The vehicle service and fuel refilling are also done by providing commands through a smartphone app.

5 Conclusion

The present work discussed IoT-based Smart and intelligent Transportation systems for smart cities. Autonomous vehicles for smart cities and their importance are also getting discussed. The underlying principles like vehicle-to-vehicle communication and vehicle-to-infrastructure communication of autonomous vehicle's technology are also explained. Another important issue in many smart cities is their vehicle parking system. The IoT-based modern system addresses this issue effectively and acts more precise and efficient than a conventional parking system. We conclude that implementing IoT-based smart transportation systems has overcome the daily issues faced by the inhabitants of smart cities because of transportation. As a result, people's lives in smart cities will improve, their productivity and effectiveness in the current environment will increase, and their entire facet will alter.

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