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Integration of Advanced Sensors in Smart Transportation Systems: Enhancing Efficiency and Safety

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Abstract

The article examines how Smart Transportation Systems (STS) might revolutionize transportation, using Nigeria as a case study. It addresses worldwide urban transportation obstacles, such as traffic jams and safety concerns, and presents STS as a workable solution, outlining its main features and advantages. The study explores the classification of sensors in STS, including vehicle-based, traffic control, and supporting technologies, and clarifies how they contribute to traffic management, driving assistance, and safety improvements. The research delves into communication protocols as well, with a focus on wireless sensors and Vehicle Ad- hoc Networks (VANETs), which provide real-time data sharing between cars and infrastructure for enhanced traffic updates, route optimization, and safety precautions. The report highlights Nigeria's efforts and emphasizes the potential advantages of universal adoption, while admitting the limited implementation of STS in poor nations. In order to fully realize the advantages of STS in enhancing urban life and transportation systems, not just in Nigeria but also worldwide, it finishes by highlighting the need for ongoing research, legislative frameworks, and infrastructure investment.

Keywords: Advanced Sensors; Smart Transportation Systems; wireless sensors and Vehicle Ad- hoc Networks (VANETs); traffic jams and safety concerns.

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1. Introduction

For the advantage of the general public, transportation serves as a way of enabling the movement of people, products, and services. It entails making use of vehicles like metro and subways as well as city buses, trolleybuses, trams, passenger trains, ferries, and others [1]. The development of transportation networks has been essential to the economic prosperity of every country. Despite this, there is an uncontrollable increase in both human and vehicular traffic in many urban cities across the world. This has led to environmental problems like traffic jams, delays, rising fuel prices, an increase in carbon emissions, accidents, emergencies, and a decline in the standard of living for society [2;3]. In today's interconnected world, the Smart Transportation System (STS) is essential. The standard for developing next-generation technology is the Smart Transportation System (STS). Qureshi and Abdullah in [4] define a smart transportation system as a unique field that functions across several domains within the transportation system, including operations, policy, control techniques, control infrastructure, and transportation management. The payment that is received from STS deployments varies greatly. The implementation of Smart Transportation Systems (STS) has the potential to significantly mitigate hazards associated with high accident rates, traffic congestion, carbon emissions, and air pollution. Conversely, STS may improve safety and dependability, traffic flow, travel speeds, and passenger satisfaction across all modes. One aspect of developing a smart city is smart transportation. It is used in a variety of technologies that combine data from various sources or applications, including automated plate recognition, traffic signal management systems, and navigation [5]. Additionally, according to authors in [6], a smart transportation system consists of three main parts: the transportation management system, which includes regulatory bodies and traffic rules; the primary transportation infrastructure, which includes cars, buses, and road networks; and, most importantly, the integration of information and communication technology (ICT), which includes the Internet, cellular networks (4G/5G), cloud/edge computing, and the Global Positioning System (GPS). These concepts have one thing in common: they integrate ICT into transportation networks. Technologies like the Internet of Things (IoT) make it possible to combine data from roads, traffic controllers, and cameras with real-time traffic movement information from a variety of transportation media, including cars, buses, boats, trains, and airplanes [5]. Big data is produced by these processes, and analytics and/or machine learning algorithms may be used to mine it for insightful information that can be used to make choices quickly. Services like carpooling, in which users share a single vehicle with others traveling to similar or nearby locations, and mobility as a service, in which various transportation media and services are combined and offered as a "trip package," are made possible by this integration. Along with smart parking, accident detection, vehicle surveillance and tracking, license plate recognition, path planning and routing, proactive infrastructure management, and smart traffic lights [6], ITS also enable intelligent traffic management [7]. Owing to the hectic pace of many cities worldwide, people look for solutions to transportation- related problems. Numerous industrialized nations, like the United States, United Kingdom, Germany, and Singapore, have adopted intelligent transportation systems to enhance speed and convenience of transit inside their borders. However, since most developing nations have not yet completely embraced STS, the notion is not well-formed in these communities. However, a small number of nations—including Nigeria and a few other African nations—have begun to work in this direction, but only in their larger cities. This study, will carry out a systematic review of the state of STS in Nigeria, employing a bibliographical approach to review research publications on the subject matter within the period of the study.

2. Related Studies on Smart Transportation Systems

2.1 Sensors and frameworks of Smart Transportation Systems

This section focuses on and explores the many sensors utilized in the development of smart transportation systems. The sensors and frameworks studied in this study were separated into three categories: enabling technologies, traffic control sensors, and sensors used in vehicles. In addition, smart transportation systems employ a variety of communication protocols.

2.1.1 Sensors used in the Vehicle

The smart technologies included in a vehicle to assist traffic management are the sensors that are used in it. Table 2.1 contains a list of these frameworks, which were also discussed.

2.2.1 Safety Sensors

The goal of the safety sensor applications is to decrease the frequency of transportation-related problems including accidents and injuries while also increasing driver and passenger safety. According to [2], the safety sensors in a car are equipped with cameras that are strategically placed. For example, the cameras behind the rearview mirror may monitor lane markers on the road and identify any lane drifts. Radar, speed, and distance sensors are used by adaptive cruise control applications to adjust speed and maintain a safe following distance from cars ahead. The Electronic Control Unit analyzes the data from the radar unit's long- or short-range scanning of the vehicle's front to ascertain the proximity and time of objects in front of the vehicle. The vehicle performs the preprogrammed remedial actions—such as warning the diver, filling the brake reservoir, or deploying the brakes—in response to the information.

2.2.2 Sensors for Diagnosis

The primary objective of these diagnostic sensors is to provide diagnostic services that facilitate the identification of component problems that may lead to a breakdown [3]. On-Board Diagnostics (OBD), which refers to the in-car system that tracks and reports the vehicle's state, is one kind of diagnostic sensor. Diagnostic Trouble Codes, which may be used to access numerous vehicle metrics including engine and emission data as well as vehicle speed, are made possible via the OBD port and OBD connection. a standardized interface that connects the car's computer system to external electrical equipment. Through engine component performance monitoring, the OBD system is intended to predict failure. An On-Board Diagnostic system is made up of actuators and ECU sensors. To achieve the required performance, the actuators are controlled by the ECU using information from a variety of sensors [8]. Additional diagnostic sensors include fuel level monitors, chemical sensors that assess fluid quality, temperature sensors that assess fluid temperature, and powertrain sensors that assess the condition and performance of the vehicle's mechanical components and engine in real-time.

Table 2.1: Sensors used in the Vehicle

Category of Sensor	Description	Example
Safety	Form the basis of safety systems and focus on recognizing accident hazards and events almost in real- time.	Micro-mechanical oscillators, speed sensors, cameras, radars and laser beams, inertial sensors, ultrasonic sensors, proximity sensors, night vision sensors, haptic.
Diagnostic	Focus on gathering data for providing real-time information about status and performance of the vehicle for detecting any malfunction of the vehicle.	Position sensor, chemical sensors, temperature sensors, gas composition sensors, pressure sensor, airbag sensor.
Traffic	Monitor the traffic conditions in specific zones, gathering data that improves the traffic management.	Cameras, radars, ultrasonic, proximity
Assistance	Responsible for gathering data that provide support for comfort and convenience applications.	Gas composition sensor, humidity sensors, temperature sensors, position sensors, torque sensors, image sensors, rain sensors, fogging prevention sensors, distance sensors.
Environment	Monitor the environment conditions, offering drivers and passengers alert and warning services that are used to enhance their trips.	Pressure sensors, temperature sensors, distance sensors, cameras, weather conditions.
User	Focus on gathering data that support the detection of abnormal health conditions and behavior of the driver that can deteriorate the driver's performance.	Cameras, thermistors, Electrocardiogram (ECG) sensors, Electroencephalogram (EEG). sensors, heart rate sensor.

Source: [2]

2.2.3 Traffic Control Sensors

The management and enforcement of traffic on roads continue to be issues that need attention. Traffic management is the planning, direction, and control of all types of automobiles, bicycles, pedestrians, and stationary and moving traffic. Its objectives are to maintain and, to the extent possible, enhance the surrounding environment on and around traffic infrastructure in addition to guaranteeing the efficient, safe, and effective movement of people and goods. The traffic sensor system facilitates better traffic flow on roads and in cities. There are two categories of applications for surveillance: fixed surveillance systems, which consist of fixed stations with sensors and cameras positioned on the roadways to monitor the condition of the infrastructure. [2] state that the second type, referred to as surveillance-on-the-road, uses built-in cameras and sensors to facilitate surveillance.

According to [9], applications for lane control are often used when there are very high traffic loads due to events, emergency evacuations, or dangerous weather. This application identifies the direction, velocity, and occupancy of vehicles using radar, cameras, and infrared sensors. In unique locations like stadiums or convention centers, special event transportation management systems—a variant of lane management systems—are utilized to control and reduce traffic congestion issues. Lane changes may be made depending on traffic demands using cameras and sensors (such radar and infrared). Group intersection management software are taking the role of traffic light-based junction control systems. In order to manage traffic safety more effectively, this application brings together road users, infrastructure, and traffic control centers. To achieve this, they make use of RFID, cameras, radar, ultrasonic, proximity, and trajectory planning [3]. By helping with space management and distribution, parking management applications (PMA) lessen traffic problems and traveler annoyance related to parking search [10]. Using magnetometers, microwaves, inductive loops, infrared, or RFID technologies, PMAs gather data on parking occupancy and notify cars of spots that are open or possible to park in the vicinity of their zone. The use of traffic control is becoming more and more important. Nonetheless, each of those apps has to work together as a system in order to support the deployment of ITS. We want better traffic management that considers the opinions of all relevant community members and stakeholders.

2.2.4 Assistance System

Systems for practical driving assistance are being developed to increase vehicle convenience and safety. The "Traffic Congestion Assistance System" is one such device that helps drivers during times of traffic jams. In an attempt to address transportation issues including traffic accidents and congestion, new transit systems have been developed recently. One such advancement is the Smart Transportation System, which has a feature called "Safe driving assistance" whose goal is to increase driver convenience and car safety by offering services like hazard alerts, travel environment information, and driving aid. The ultimate goal is to lower the amount of traffic accidents and facilitate driving for automobile owners [11]. Environment Sensor System

In order to guarantee ideal temperature conditions for transportation, the environment sensor system is a device that measures and tracks a variety of environmental data. Modern environmental sensors use cutting-edge technology to gather data in real time on temperature, humidity, and location—all of which have a significant impact on efficient transportation. Usually, these sensors are mounted inside the car.

Temperature monitoring: environmental sensors measure the interior temperature of the car continuously and provide an accurate reading in real time. Humidity monitoring: environmental sensors track the amount of humidity inside the car. Location tracking: environmental sensors often use GPS to track the location of the car. This guarantees real-time tracking of the car's movements and makes sure it remains on the approved path and gets to the destination on schedule. A centralized monitoring system receives the data wirelessly from a motive environmental sensor. Operators may proactively handle any abnormality with the real-time visibility, analytics, and reporting capabilities that this system offers [12].

2.2.5 User Sensor System

Sensors in the user category utilize variables including mental state issues, fatigue, and alcohol use to monitor drivers' performance and behavior, which is essential for enhancing traffic safety and reducing collisions. As per the technical analysis conducted by the American Automobile Association (AAA), in high-income and low-income countries, respectively, drunk driving resulted in 20% and 69% of drivers being fatally injured in traffic accidents, while sleepy driving caused 21% of fatal traffic accidents and 13% of collisions that required hospitalization. 10% of fatalities in 2014 were attributed to distracted driving, according to estimates from the National Highway Traffic Safety Administration (NHTSA). Applications that warn against sleepy driving use cameras to monitor head and eye movements to detect signs of exhaustion. Radar sensors monitor an automobile's motion and detect instances of driving that are not consistent. Other applications might make use of steering angle sensors to detect odd driving behavior. The driver is alerted by an audio indication or vibration. There are now a lot of sensors used in cars. There are two types of road sensors that may be distinguished: intrinsic and non-intrinsic. The classification of these sensors is shown in Table 2.2.

Table 2.2: Road Sensors

Classification	**Sensor**
Intrusive	Pneumatic road tube.
	Inductive Loop Detector (ILD).
	Magnetic sensors.
Non-Intrusive	Video Image Processors (VIP)
	Radar sensors.
	Infrared.
	Ultrasonic.
	RFID (Radio-frequency identification)

Source: [2].

Any intelligent traffic control system must have an efficient and often comprehensive traffic surveillance and monitoring system in place in order to track network conditions. In order to provide the required geographic and critical time coverage, a variety of sensors are positioned in, on, and above the road. Some of the sensors used to regulate traffic conditions on the road are listed in Table 2.2. These sensors as listed above are briefly discussed as follows:

2.2.6 Pneumatic Road Tube

When a car tire passes over a rubber tube, pneumatic road tube sensors cause a burst of air pressure to be sent down the tube. An electrical signal is generated when the pressure pulse shuts an air switch, and this signal is sent to analysis software or a counter. Powered by lead-acid, gel, or other rechargeable batteries, the pneumatic road tube sensor is a portable device. The road tube is often used for research studies, planning, axle count and spacing vehicle categorization, and short-term traffic counts. It is erected perpendicular to the direction of traffic flow. When the counter is used in combination with a vehicle transmission sensor, certain versions collect data to compute vehicle gaps, intersection stop delay, stop sign delay, saturation flow rate, spot seed as a function of vehicle class, and journey duration.

2.2.7 Inductive Loop Detector (ILD)

An inductive loop is an electromagnetic communication or detection device that creates a current in a neighboring wire by use of a moving magnet or an alternating current. Communication signals are sent and received by induction loops, which are also used in vehicle presence indicators and metal detectors to identify metallic objects. Induction loops are often used in contemporary times to help hearing aid users hear better.

2.2.8 Magnetic Sensor

A magnetic sensor is a sensor that produces electric signals based on the strength and fluctuations of a magnetic field. Magnets and the earth's magnetic field are two examples of well-known yet unseen magnetic fields. Research on magnetic sensors that translate imperceptible magnetic fields into electric signals and observable consequences has long been ongoing. Years ago, sensors that used the electromagnetic induction effect were the first. A magnetic sensor, according to [13], is based on detectors that gauge the magnetic field's characteristics nearby. At junctions with traffic signals, they are fixed in the pavement. An electrical sensor detects the disruption of the magnetic field around the detector as a vehicle approaches. It is feasible to determine an object's size and speed of motion based on its noise level. This enables the system to differentiate between different types of vehicles and make the best choices for controlling the traffic lights. Depending on the size of the intersection, the system requires the installation of at least several detectors in order to function correctly [14]. The controller, which analyzes traffic in both directions and cyclically regulates the lamps at several intersections, should receive the data gathered from the detectors.

2.2.10 Video Image Processors (VIP)

The usual components of this sensor are one or more cameras, a computer for picture digitization and analysis, and software for image interpretation and data conversion into traffic flow. Algorithms analyzing groups of visual components inside the video frames with varying gray levels are used to analyze black and white images. One lane may have numerous sections and multiple lanes using traffic flow data provided by a VIP system. VIPs may report on the number, presence, lane occupancy, and speed of cars for each class and lane in addition to classifying vehicles based on length.

2.2.11 Radar Sensor

A radar sensor may be used to detect an object's relative speed as well as its distance, velocity, and motions across large distances. By determining the geometry of the item, this sensor use wireless detecting technologies such as FMCW (Frequency Modulated Continuous Wave) to detect motion. This sort of sensor is not impacted by light or darkness as other types are. The sensor is safe for both humans and animals, and it can detect further distances. There is continuous modulation of the carrier frequency within a narrow spectrum. By comparing frequency, it is possible to ascertain both the object's speed and distance after the signal from the object is reflected back.

2.2.12 Infrared Sensor

An electrical component called an infrared sensor is made to recognize certain radiation wavelengths, including heat. Sensors enable gadgets to identify and react to their surroundings. It operates by identifying infrared waves that are released by the car and penetrate the sensing region of the car that has an infrared sensor [15].

2.2.13 Ultrasonic Sensor

A device that produces or detects ultrasonic radiation is called an ultrasonic sensor. It is an electrical gadget that uses sound waves to estimate distance by gathering the echoes that return. With the ability to measure objects up to 4.5 meters away, this multipurpose instrument can precisely measure both short and long distances without coming into touch with the target object. This makes it indispensable for a variety of applications, including obstacle avoidance systems in robotic or autonomous vehicles. Transceivers, receivers, and transmitters are the three types of ultrasonic sensors. Ultrasound is converted into electrical signals by transmitters, while ultrasound is converted into electrical signals by receivers. Transceivers are capable of both transmitting and receiving ultrasound.

2.2.14 RFID (Radio-frequency identification)

Radio-frequency (RFID) sensors are used for smart parking, vehicle detection to allot space for parking, and automatically recognizing and gathering data from operating automobiles on roadways. Three essential parts make up RFID technology: RFID tags, RFID readers, and middleware logic for ongoing database contact with the back end. RFID technology can be used to improve automated bus tracking, which can be very helpful in providing accurate arrival time estimates and ultimately improve passenger convenience. This technology can address issues that public transportation faces, particularly in urban areas. An Event, Condition, and Action (ECA) architecture is used in a real-time tracking and monitoring system. This works well for efficiently filtering data to eliminate any unnecessary or erroneous information, after which important data may be grouped together. In an attempt to better the tracking system and, ultimately, the public transportation travel experience, the use of gathered data for bus movement prediction is being considered [16].

2.3 Enabling technologies

In this portion of the research, some of the technologies—such as edge/cloud computing, Network Function Virtualization, Software Defined Networking, virtualization, and containerization—that make it possible for smart transportation to be network-sliced from an application perspective are discussed. Additionally, we examine the current network slicing survey efforts and provide an overview of the technologies they cover.

2.3.1 Network Functions Virtualization

Network services that were formerly operated on proprietary hardware, including firewalls and routers, may now be virtualized thanks to a technique called network functions virtualization, or NFV. It is one of the main technologies that makes network slicing possible. The NFV architecture is made up of three main parts: management and orchestration, NFV infrastructure (NFVI), and VNF. The software version of network functions that is used in virtual environments is called VNF. NFVI refers to the NFV infrastructure resources, such as networking, computation, and storage, on which VNFs will be installed. According to [10], MANO is the component in charge of orchestrating VNFs and NFVI, managing deployed services, and managing VNF lifecycles. It also handles NFVI resource management.

2.3.2 Software Defined Networking

SDN separates a network's control plane from its data plane. A logically centralized controller that can directly train the underlying devices in the data plane via an open northbound interface realizes the control plane [17]. With its comprehensive network perspective and ability to determine the best network control and management techniques via data mining and big data analytics, the controller functions as the network's intelligent brain. These tactics can be put into practice because to SDN's programmability. The application layer, control layer, and infrastructure layer are the three essential layers that make up the SDN architecture [18]. Specifically, the application layer houses all network services and applications, such as load balancing and firewalls. at essence, the SDN architecture's controller is located at the control layer. Switches and routers are examples of the physical network equipment that are part of the infrastructure layer. The northbound interface serves as an additional means of communication between the application layer and the control layer in addition to the southbound interface that connects them [19].

2.3.3 Virtualization & Containerization

In virtual environments, a server may host many VNFs using both virtualization and containerization technologies. With virtualization, a single physical server's hardware may support several virtual machines (VMs), each of which has its own operating system, binaries, and libraries [20]. A hypervisor is a piece of software or firmware that sits on top of a server's hardware and is used to construct virtual machines (VMs) and allow them to share the same physical resources of the server while operating side by side. Virtual Machines (VMs) often have many gigabytes in capacity and need several minutes to start. Comparably, containerization enables the simultaneous operation of numerous containers on the hardware of a single physical server (or virtual machine; a container lacks an operating system of its own; instead, all containers share the operating system, binaries, and libraries of the physical server that is hosting them) [21]. As a result, containers are lighter than virtual machines. A container typically takes seconds to start and has a size of gigabytes.

2.3.4 Edge and Cloud Computing

The computational and storage capacity that may be used in different parts of network slicing is provided by edge and cloud computing. For instance, it may assist the SDN controller in computing AI-powered solutions for network slicing management, and it can be used by MANO to calculate NFV management and orchestration methods [22]. Furthermore, it may be used inside a slice to provide processing power for the accommodated service. When compared to cloud computing, edge computing places processing power closer to the point of demand. For applications that are sensitive to delays, this may greatly minimize the transmission time between the computing facilities and the users/applications. Because edge computing operates locally, it may also provide some degree of privacy protection for data processing [23]. Owing to the restricted processing and storage capacity at the network edge, edge computing—also referred to as edge-cloud orchestration—typically works in tandem with cloud computing to accomplish the necessary computational tasks for network slicing.

2.4. Smart Transportation Communication Protocols

A wide range of sensors, actuators, and communication devices, including GPS units, mobile devices, and embedded computers, are becoming more and more common in modern cars. These days, strong communication, sensing, networking, and processing capabilities are installed in vehicles and surrounding roadside units (RSUs), forming a vehicular ad hoc network (VANET). They are able to converse and share data and information with other automobiles. Vehicle-to- vehicle networks and intelligent transit equipment When combined, these technologies—Internet of Things, cloud computing, distributed computing, and communication protocols like WiFi, 4G/5G, and TCP/IP—can help create more sophisticated and effective transportation systems. These technologies are used by vehicles, infrastructure, applications, and the outside world. The following categories cover the protocols for smart transportation communication: Ad-hoc network for vehicles and wireless sensors.

2.4.1 Wireless Sensors

A wireless sensor is an apparatus designed to collect sensory data and identify changes in nearby surroundings. Wireless sensors are made to monitor certain aspects of their physical environment and provide outputs—typically electrical signals—for further processing. Wi-Fi connections are being used more and more in smart cities to link different resources. Wi-Fi networking is usually employed in smart transportation systems to link cars, traffic signals, and lampposts because of its limited bandwidth [24]. Research groups are putting out complementary, low-cost options since roadside electrical equipment necessary to power VANETs is expensive. A complementary option is a Wireless Sensor Network (WSN). Wireless self-organizing sensor network nodes are often powered by low-cost, battery-operated, energy-efficient collecting, processing, and communication technologies [25]. With only two AA batteries, these low-power nodes may often operate for many years, reducing the need for maintenance. Numerous roadside WSNs may be placed strategically to support vehicle communication technology because to their cheap cost and power consumption [26].

2.4.2 Vehicle Ad-Hoc Network (VANET)

A vehicle ad-hoc network (VANET) is an assembly of mobile automobiles that interact with local roadside units (V2I) and with each other over a wireless network. This makes it possible for information to be shared, enhancing passenger comfort and safety. Only direct peer-to-peer communication may be supported by a

VANET, which is a decentralized, dynamic, self- organizing network with constrained capacity and range [27].

Three advancements in route planning using VANET technology were introduced by [28]. First, using two real-time traffic information sources not previously used in conventional GPS applications, a vehicular ad hoc network-based A (VBA) route planning algorithm is suggested to find the route with the shortest trip time or the lowest fuel consumption. The traffic data that has been captured for the section of road that the vehicle has drove is the primary source of traffic information. A wireless network based on IEEE 802.11p is then used to transfer the data between vehicles. Then, another traffic update is provided by Google Maps. Lastly, six different route planning techniques are simulated in a single congested environment via the VANET simulator. On the predicted route, VBA saves a substantial amount of time and fuel as compared to standard route planning algorithms [29].

The following components make up VANET's basic architecture: Both vehicle-mounted communication interfaces and roadside unit infrastructure base stations including distinct On- Board Units communications modules are available. Numerous information, transceiver, and processing devices are housed in the OBU, an integrated module that is attached to the vehicle board. The unmodified composition has communication interfaces to facilitate communication between VANET modules. Both hardware and software components are covered by these interfaces. The types of interfaces that are recognized depend on the way data is transferred between objects [30].

Vehicle to Vehicle (V2V). This form of encounter occurs between two cars. This form of connection is required since there may not always be intermediate base stations along the roadways. As a result, in this style of connection, brief messages are employed to communicate about circumstances.

Vehicle-to-infrastructure (V2I). This sort of infrastructure is designed mainly to alleviate wireless interface congestion. This kind is ideal for coordinating data collecting and transferring data to a management center, followed by traffic control.

Infrastructure to Infrastructure (I2I). RSUs are interconnected. Data may be sent over a variety of communication modes, including wired and wireless. As a result, the data rate in this case may be quite high.

Vehicle to X (V2X). This form of connection is ubiquitous; you may extend it as far as feasible using any interaction interface.

Vehicle to Broadband Cloud (V2B). This form of interface connection allows you to engage with cloud services. Broadband technologies are used in this engagement.

Vehicle to Home (V2H). This form of connection allows interaction with IoT gadgets deployed in the smart home. There are several chances to enhance the spectrum of services, such as car diagnostics without leaving home, data transmission from home to automobiles, and much more.

2.5 Importance of Integrated Smart Transportation Systems

According to [31] and [32], there are several advantages of integrating sensor devices into smart transportation systems. Improved traffic management: One of the benefits of integrating sensors into transportation systems is the ability to enhance traffic management. These sensors give a real-time picture of traffic conditions, allowing authorities to take appropriate measures to reduce traffic issues such as congestion. Enhancing safety: Another key benefit of sensor transportation systems is that they improve safety for both drivers and pedestrians. Sensor technologies can identify possible risks and accidents, giving users with early warnings. For example, smart sensors may notify car users of impending congestion or road maintenance, enabling them to reduce their speed or arrange other routes. Increase efficiency: Smart sensors may help to increase traffic control efficiency. Smart transportation sensors may minimize the amount of time a vehicle spends in traffic or looking for parking by optimising traffic flow. This decrease in time may lead to increased efficiency.

Environmental benefits: A smart transportation system may help to ensure environmental sustainability. Reducing traffic congestion and improving fuel efficiency reduces greenhouse gas emissions. Similarly, smart transportation system technologies such as electronic toll collection and smart parking systems decrease the need for physical infrastructure, resulting in reduced land use and damage of the natural environment.

2.5 Challenges of Smart Transportation System

Despite the necessity of incorporating smart sensors into transportation systems, there are certain challenges in implementing these technologies. High maintenance costs: Installing sensors may be fairly costly. This includes the costs of deploying sensors, cameras, data centers, and other infrastructure. Furthermore, sustaining these technologies may be costly owing to the requirement for frequent system upgrades, replacements, and repairs. These fees may be a considerable financial burden, particularly for towns with limited resources.

Reliability and technical flaws: Like any other digital system, smart sensors are prone to technological errors and failures. The dependability of these systems is strongly dependent on the correct operation of all of their components. A single malfunctioning sensor or a glitch in the data processing facility might result in inaccurate traffic management choices, possibly causing pandemonium on the road.

Privacy problems: The use of cameras and other sensors for data collecting in smart transportation has highlighted privacy concerns. These systems continually watch and record vehicle movement, which may lead to the exploitation of personal data. Ensuring people' privacy while employing smart technology remains a critical concern in the integration of sensors in smart transportation systems.

3. Review of Empirical Studies

The creation of an integrated system that is helpful for timely monitoring and reporting of traffic accidents to road traffic authorities was the main emphasis of [33] study. The method that was produced was set up to use an altered kind of data fusion inside the Internet of Things (IoTs). Both monitoring and prediction techniques are used. The Internet of Things (IoT) uses a vast array of sensors to communicate with other devices, the cloud, and automobiles. To get better information for an enhanced road safety system, sensor data is combined. The linked automobiles make it possible to continuously check the vehicle's fundamental components to guarantee safety. In order to monitor and identify the actual state of the road network, this research employs data fusion of a multi-sensory system that integrates an imager/camera, accelerometer, and carbon monoxide sensors for situation awareness. By employing real-time road monitoring of certain physical factors, such as vehicle speed and CO emissions, this technology will let safe road administrator's better grasp the actual state of the roads. This technology will track and forecast traffic incidents on Nigeria's roadways.

Reference [3] focuses on how intelligent and smart transportation networks may be created by using the sensing and communication capabilities of automobiles and sensing devices in a seamless manner. It was also covered how sensor technology may be integrated with the transportation infrastructure to create a sustainable Intelligent Transportation System (ITS) and how many sensors placed in different ITS components might be advantageous for safety, traffic management, and entertainment applications. The researcher listed some of the obstacles that need to be cleared in order to allow a completely functioning and cooperative ITS ecosystem in the conclusion.

Reference [20] evaluated network slicing management in terms of general use cases and specific Industrial Internet of Things (IIoTs) services, such as smart factories, smart energy, and smart transportation. They also outlined the benefits and drawbacks of the current survey and numerous other works/surveys that have been conducted in relation to a number of key criteria. Furthermore, the writers showcase an architecture designed to handle intelligent network slicing for the Internet of Things, with a particular emphasis on three services: smart manufacturing, smart energy, and smart transportation. They provide a thorough examination of the network slicing architecture, application needs, and related enabling technologies for each service. In addition, the research provided a thorough grasp of network slicing orchestration and management for every service, including edge computing-enabled network slicing, orchestration architecture, AI-assisted administration and operation, dependability, and security. Regarding the intelligent network slicing management architecture that has been demonstrated and how each IIoT service uses it. In conclusion, the study determined the associated major obstacles and unresolved problems that might direct further investigation.

Using Nigeria as a case study, Reference [34] investigated the crucial success elements for smart mobility systems (SM) and evaluated its present application level for the development of smart cities. This research uses a mixed-methods approach (quantitative survey and Delphi). Seven essential success elements for smart mobility were identified by the research. The study's conclusions also showed that the most important elements for the success of smart mobility are the availability of ICT infrastructure, a sustainable, creative, and safe transportation system, local accessibility to transportation infrastructure, and transportation infrastructure (bike, cycling, and pedestrian mobility facilities). Additionally, a strong agreement was reached about each success criteria. The final Delphi result's Mann Whitney test showed that there was no discernible difference between the two expert groups' replies. According to the expert, evaluating the use of the smart mobility success elements showed a pitiful application level. By identifying the SM success elements that need be taken into account to create a sustainable smart mobility system in a city, this research adds to the corpus of knowledge.

An Internet of Things (IoT) application that combines many separate systems into a single whole was presented. The research concludes that these systems accomplish their goals and operate well on their own. The overarching goal of the research was to enhance these separate systems in accordance with the adage "the whole is greater than individual parts." Smart parking, intelligent emergency services, smart health, and hospital administration are all linked into the planned Smart Patient Health Management System (SPHM). This article presents the many parts of the SPHM framework, their interactions, and the underlying technologies that make this system possible. Furthermore, a smart transportation tool named CABIFY for Android was created to support the SPHM in providing prompt and effective healthcare services.

To improve traffic flow in congested cities, Reference [37] investigated the use of smart transportation systems in managing traffic congestion. It has been shown that the migration of individuals to metropolitan regions in pursuit of livelihood opportunities and infrastructure has resulted in a significant growth in the population of such locations. People now have difficulties with mobility as they move about to go about their everyday lives, which has led to traffic congestion. To make it to their daily appointments, many individuals have attempted a variety of traffic-congestion avoidance strategies, one of which is traveling at strange hours, either extremely early in the morning or very late at night. Furthermore, this is by no means a dependable solution to the traffic congestion issue.

In order to ensure efficient vehicle toll operations, Reference [38] investigated the implementation modalities of a microcontroller based monitoring system. The system comprises of a SIM 800L GSM/GPRS Module, two MA40E7R ultrasonic sensor units, and an Arduino Mega 2560 microprocessor unit. Every ultrasonic sensor unit at the toll station sends out ultrasonic pulses into the atmosphere, detecting the waves that are reflected back by moving vehicles. The microcontroller unit implements a protocol vehicle Found when both units detect reflected waves at the same time. The microcontroller's counting sequence is advanced by one step each time this protocol is used. A time stamp and count sequence are stored in the memory slot of the microcontroller for each increment, and the SIM 800L GSM/GPRS module concurrently implements a protocol for sending data online. A dedicated cloud facility was used to archive and monitor data produced by the ground station in real-time throughout the testing process. Through the operational cycle of the system, human bias is completely eliminated and minimum systemic error is guaranteed, resulting in effective monitoring operation.

In order to build smart systems and universal mobile accessibility, advanced technologies such as Intelligent Transportation Systems (ITS) are connected to physical objects via the Internet. [39] examined and explained a complete design and implementation of a typical Internet of Things-Intelligent Transportation System for a smart city context on typical Indian region based on a case study that provide explanation about several hardware and software components associated with the system. According to the report, IoT-based vehicle-to-vehicle communication will usher in a new age of communication that will lead to the development of smart transportation systems. In order to support the development of IoT-ITS, the study focused on the use of multiple regression analysis, multiple discriminant analysis, logistic regression, co-joint analysis, cluster analysis, and other big data analytic approaches.

4. Discussion of findings

Studies provide a comprehensive overview of smart transportation systems and their applications in Nigeria, with a primary emphasis on integrating Internet of Things (IoT) technologies for real- time traffic accident monitoring [40;38]. Through sensor data fusion, incorporating imager/camera, accelerometer, and carbon monoxide sensors, road safety is significantly enhanced by offering a comprehensive understanding of the road network's current state [38; 37]. The studies collectively highlight the importance of establishing intelligent and seamless transportation networks, utilizing the sensing and communication capabilities of vehicles and infrastructure. Challenges in achieving a fully functional Intelligent Transportation System (ITS) ecosystem are acknowledged, emphasizing the need to overcome obstacles for successful implementation. Furthermore, success factors for smart mobility systems are identified, encompassing elements like ICT infrastructure availability, sustainable transportation systems, local accessibility, and facilities for alternative mobility modes [36]. The studies also explore the integration of separate systems into a cohesive Internet of Things (IoT) application, aiming to enhance efficiency in areas like smart parking, intelligent emergency services, and healthcare administration[20; 3; 35]. The study was discovered that assessments of network slicing management for Industrial Internet of Things (IIoTs) services draw attention to particular uses and the advantages and difficulties that go along with them. Along with an assessment of the existing application level in smart cities, success criteria for smart mobility systems are highlighted, such as the availability of ICT infrastructure and sustainable transportation. It is shown how to combine disparate systems into a coherent IoT application, which improves productivity in a number of areas. Research also looks at the use of microcontroller-based monitoring systems for effective toll operations and the use of smart transportation systems for managing traffic congestion.

4.1 Findings on Smart Transports System

Smart transportation systems have revolutionized the way we think about urban mobility. The integration of advanced sensors in these systems has played a crucial role in enhancing efficiency, safety, and overall user experience [41]. By leveraging cutting-edge sensor technology, transportation systems can gather real-time data, monitor traffic flow, and detect potential hazards more effectively than ever before[42]. One of the key benefits of advanced sensors in smart transportation systems is the ability to improve traffic management. With the use of sensors, traffic signals can be optimized in real time to minimize congestion and reduce travel times[43]. This not only improves the efficiency of the transportation network but also has a positive impact on the environment by reducing emissions from idling vehicles.

Furthermore, the integration of sensors can enhance safety by detecting and alerting drivers and pedestrians about potential dangers on the road, such as accidents, obstacles, or adverse weather conditions. This proactive approach to safety not only reduces the risk of accidents but also contributes to the overall peace of mind for commuters [44]. In addition to improving efficiency and safety, advanced sensors also play a pivotal role in enabling autonomous transportation systems. By providing real-time data on road conditions, traffic patterns, and surrounding environments, these sensors are laying the groundwork for the future of autonomous vehicles and smart transportation networks[45].

Smart Sensor Technology System. The rapid advancement of sensor technology has revolutionized the landscape of intelligent transportation systems (ITS), offering unprecedented opportunities to enhance efficiency, safety, and sustainability [46]. The integration of advanced sensors, such as cameras, LiDAR, and radar, has enabled vehicles and transportation infrastructure to gather a wealth of data, providing a comprehensive understanding of the driving environment. The ability of advanced sensors to capture real-time data about the surrounding environment has significantly improved the capabilities of smart transportation systems. By utilizing cameras, LiDAR, and radar, vehicles and transportation infrastructure can not only detect and track objects but also analyze the data to predict potential hazards and optimize traffic flow[47]. Cameras play a crucial role in providing visual information, enabling vehicles to identify road signs, traffic signals, and pedestrians. LiDAR, on the other hand, utilizes laser pulses to create detailed 3D maps of the surroundings, offering precise measurements of distances and shapes. Radar complements these capabilities by detecting objects and obstacles, even in adverse weather conditions [48].. The integration of these advanced sensors has transformed traditional transportation systems into intelligent networks capable of making informed decisions in real time. This enhanced situational awareness and predictive analysis not only improve road safety but also contribute to the overall efficiency and sustainability of transportation systems.

4.2 Limitations of Advanced Sensors in Smart Transportation Systems

4.2.1 Technical Challenges in Integrating Advanced Sensors

The integration of advanced sensors in smart transportation systems poses several technical challenges that need to be addressed. One of the primary challenges is the compatibility and standardization of different sensor technologies[49]. As smart transportation systems incorporate a variety of sensors such as LiDAR, radar, cameras, and infrared sensors, ensuring seamless integration and communication among these heterogeneous devices is crucial[50].

4.2.2 Data Processing and Analysis

Another significant technical challenge in integrating advanced sensors in smart transportation systems is the processing and analysis of the vast amount of data generated[51]. Advanced sensors produce a large volume of real-time data, and effectively processing and analyzing this data is essential for making informed decisions. This requires powerful computing resources and advanced algorithms for real-time data processing and analysis.

4.2.3 Power and Energy Consumption

Power and energy consumption is a critical limitation when integrating advanced sensors in smart transportation systems[52]. Advanced sensors require a continuous power supply to operate effectively, and integrating them into transportation systems may pose challenges in terms of power management and energy consumption. Finding efficient and sustainable power solutions for these sensors is essential to ensure continuous and reliable operation[53].

4.2.4 Environmental Factors and Sensor Reliability

The reliability of advanced sensors in various environmental conditions is a significant limitation in their integration into smart transportation systems. Environmental factors such as extreme weather conditions, pollution, and physical obstructions can impact the performance and reliability of sensors]. Ensuring the durability and reliability of sensors in diverse environmental conditions is crucial for the successful integration of advanced sensors in smart transportation systems.

4.3 Data Processing and Analysis Complexity

Another limitation of integrating advanced sensors in smart transportation systems is the complexity of data processing and analysis. Advanced sensors generate large volumes of data, including real-time traffic patterns, vehicle behavior, and environmental conditions[54]. Handling and analyzing this data in real-time require sophisticated algorithms and powerful computing resources, which can be a significant challenge for transportation infrastructure providers.

4.3.1 Cost and Scalability Concerns

The cost of deploying and maintaining advanced sensor technologies in smart transportation systems is another limiting factor. Integrating a diverse range of sensors throughout transportation networks can be financially burdensome, especially for regions with limited resources[55]. Additionally, ensuring the scalability of sensor deployments to accommodate growing urban populations and evolving transportation demands presents a significant challenge for stakeholders in the smart transportation domain.

4.3.2 Reliability and Maintenance of Sensor Networks

Ensuring the reliability and continuous operation of sensor networks in smart transportation systems is critical for their effectiveness[56]. Advanced sensors are susceptible to environmental factors, vandalism, and technical malfunctions, requiring regular maintenance and robust security measures to uphold the integrity of the transportation infrastructure[58]. As smart transportation systems continue to evolve, addressing these limitations will be essential to maximize the benefits of integrating advanced sensors and realize their full potential in shaping the future of transportation.

5. Conclusion and Recommendation

By evaluating some of the key sensors built into the smart transportation systems, an evaluation of those systems was conducted in this research. The research examined these technologies (sensors) under three main categories: communication protocols, enabling technologies, and sensors utilized in cars and on roads to manage traffic. Additionally, the significance of sensor integration and the difficulties encountered in creating intelligent transportation systems. In cities all around the globe, smart transportation systems rely heavily on sensors and other cutting-edge technology. Their usage makes it possible to develop a variety of applications for traffic management, convenience, and driving assistance. Sensors provide a system for gathering data on the vehicular context, including road conditions, traffic conditions, and vehicle conditions, in order to solve some of the transportation-related difficulties, such as accidents and traffic congestion among other traffic challenges. The full potential of sensor integration to smart transportation systems is shown via the use of analytical and statistical methodologies. In order to improve traffic management and the safety of the transportation systems, this integration is a prospective issue that will enable the development of several next-generation smart applications. Based on the discussions, it's recommended that, there is a need to enhance the integration of Internet of Things (IoT) technologies for real-time traffic accident monitoring through further research and development, focusing on refining sensor data fusion techniques. Addressing challenges associated with establishing a fully functional Intelligent Transportation System (ITS) ecosystem requires collaborative efforts between government bodies, technology developers, and transportation authorities. Prioritizing Information and Communication Technology (ICT) infrastructure development is essential for the success of smart mobility systems, ensuring widespread connectivity and technological support. Advocating for sustainable transportation systems, promoting alternative mobility modes, and investing in eco-friendly infrastructure are crucial for long-term environmental considerations. Encouraging research in integrating disparate systems into cohesive IoT applications can enhance efficiency across various domains, while exploring microcontroller-based monitoring for toll operations can eliminate biases and improve effectiveness. Investigating and implementing smart transportation systems to manage traffic congestion involves utilizing real-time data and intelligent algorithms. Lastly, fostering collaborative research and development between academia, industry, and government bodies is essential to address emerging challenges and drive continuous innovation in the transportation sector.

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