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Research Article

Smart Traffic Management System for Metropolitan Cities of Kingdom Using Cutting Edge Technologies

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The expansion of technology in metropolitan centers draws people to cities, which causes excessive traffic on the roadways during peak hours. This exacerbated the traffic situation, resulting in a delay, a loss of resources, and a waste of time. Like any other metropolitan metropolis, Riyadh, Saudi Arabia, has everyday traffic congestion during business hours. The current traffic management has made many attempts to ease traffic congestion in cities; despite these measures, the problem has not been solved adequately. To handle this road congestion, there is a need to appropriately store the big data collected by traffic sensors and utilize it for efficient traffic management employing cutting-edge technology. This study provides an architecture for a smart traffic management system that uses modern technologies such as the Internet of Things (IoT), cloud computing, 5G, and big data to aid conventional traffic management systems and efficiently handle the stated problem. The proposed technique has the potential to reduce traffic congestion significantly. Our proposed solution encourages mobility by using roadside messaging agents to offer real-time traffic information on traffic congestion and unexpected traffic incidents. Citizens will save time by getting these early warning messages, particularly during peak hours. As part of the suggested method, each signal dashboard gets traffic information. A case study is used in the research to evaluate alternative solutions to traffic congestion. The case study results show that the proposed strategy outperforms the present options.

1. Introduction

In today's fast-paced world, the rapid increase in automobiles on the road continues to be a severe concern in big cities [1]. In Riyadh [2], traffic congestion is becoming more of a worry as the number of cars on the road continues to grow exponentially, surpassing the capacity of existing infrastructure. Furthermore, since the city of Riyadh is growing at a fast pace, the extent of the issue is expanding in parallel with the city's population. It contributes to road traffic congestion [3], becoming more typical with each passing day. Traffic congestion is one of the key causes of rising transportation expenses, primarily due to excessive gasoline and the resulting time delay. In Riyadh, congestion costs have been proved to result in a significant economic loss for the city.

The increasing number of vehicles on the road has necessitated the development of effective traffic management systems. The academic research suggested different technologies for monitoring vehicles and recognizing traffic congestion to improve traffic management [4–6]. Identifying traffic congestion may be accomplished using loop coils and intelligent video cameras (also known as security cameras systems). A massive amount of data, namely, big data or traffic data, is gathered from various sources, including cameras that serve as sensors, police officers responsible for maintenance, service providers, and drivers on the highways themselves. However, cameras have several downsides, such as being affected by weather conditions and having a high installation cost [7]. Therefore, the Kingdom must use the internet and cutting-edge technologies [8, 9], especially in metropolitan areas, to provide residents with more certainty and dependable services than they now have.

Numerous technical advancements in various disciplines, such as hardware size reduction, wireless technology, environmental sensors, and integrated computers, have contributed significantly to the physical world. Example includes, the Internet of Things (IoT) is one of these promising technologies that has significantly contributed to society's advancement. IoT refers to connecting smart things to the internet [10–12], enabling people and machines to interact in real-time. The IoT is gradually becoming one of ICT's most notable development and research topics [13]. The IoT links various devices, systems, and applications to provide consumers with more sophisticated services than traditional machine-to-machine communication [14, 15]. The big data generated through IoT sensors is stored in Cloud for further usage, and 5G technology helps to transmit this big data among multiple entities involved.

The preceding explanation demonstrates how cutting-edge technologies contribute significantly to intelligent traffic management. This study leverages the benefits of advanced technologies, namely, IoT, big data, Cloud computing, and 5G, and presents a smart traffic management architecture for Kingdom metro cities. The proposed approach is a layered approach based on cutting-edge technologies. These layers include (1) the physical layer, which contains the IoT sensors and agent, as depicted in Figure 1 at the roadside. This layer is responsible for sensing, counting, and uploading the available vehicle data to the Cloud using the Wi-Fi controller/5G through the second layer; (2) the network layer is mainly responsible for uploading the data to the Cloud and then syncing that data to the dashboard and an updated Google Map for traffic route awareness; (3) the application layer helps with the specifically designed dashboards in the cars, equipped with the Google Map routes, and smart mobile app-based smartphone application, to assist the drivers with the current traffic situation.

The explicit contribution of the study is mentioned as follows:

(i) Using cutting-edge technologies to provide an appropriate solution for reducing traffic congestion in metropolitan areas

(ii) Monitoring real-time traffic on junctions using magnetic sensors and providing error-free vehicle detection, particularly during peak hours

(iii) Keeping the city residents updated on traffic status and significant traffic incidents using Google Maps

1.1. Background. Before moving toward the existing knowledge in the area under study, this subsection discusses cutting-edge technologies used in the study for a better understanding of the readers.

1.1.1. Internet of Things. The Internet of Things (IoT) is a networked system of interconnected computing devices, mechanical and digital machinery, items, animals, or people with unique identities (UIDs), and the capacity to transmit data without needing human-to-human or human-to-computer contact. It comprises web-enabled smart devices that gather, transmit, and act on environmental data using embedded systems, including CPUs, sensors, and communication hardware.

1.1.2. 5G. Fifth-generation wireless (5G) is the most recent evolution of cellular technology, developed to boost wireless network speeds and responsiveness significantly. Some estimates put the maximum speed of 5G at 20 Gbps, allowing for the transmission of multigigabit data through wireless internet connections. Latency is less than 5 ms, making these speeds ideal for applications that need instantaneous responses. Because of more bandwidth and improved antenna technology, 5G will allow for a dramatic rise in the volume of data sent across wireless networks.

1.1.3. Cloud Computing. Computing resources, such as data storage (cloud storage) and processing power, may be made available on demand in a cloud computing environment without requiring the user to take on any administrative responsibilities. Functions in large clouds are generally decentralized over numerous data centers. To accomplish consistency, cloud computing uses pooled resources and a "pay as you go" pricing model, both of which may assist cut down on upfront costs but can potentially leave consumers unprepared for ongoing service fees.

The remainder of the study is arranged as follows: the second section will discuss relevant traffic management studies; Section 3 will discuss the research methodology; Section 4 will focus on a case study; Section 5 will include the results and a discussion of them. The last presents the conclusion and future work.

2. Related Work

This section covers recent advances in smart transportation research, such as models for traffic analysis, traffic congestion estimates, and the use of roadside units to send messages. The following sections cover some recent developments in the field of traffic management.

The authors of [16] developed a traffic information system based on historical traffic data. This research intends to let drivers choose a different route or change their existing route in the case of a traffic incident. Traffic speed data was collected via video analysis of varying segment routes. Each road length is captured using cameras, which are then processed to get speed information. Using the data, an interface is created to show traffic conditions on an open map with speed restrictions displayed in various colors, which may be used as a reference for developing countries where navigation is unavailable. On the other hand, this technique has some disadvantages, and the most significant is that collecting many videos is difficult and time-consuming. Furthermore, only historical

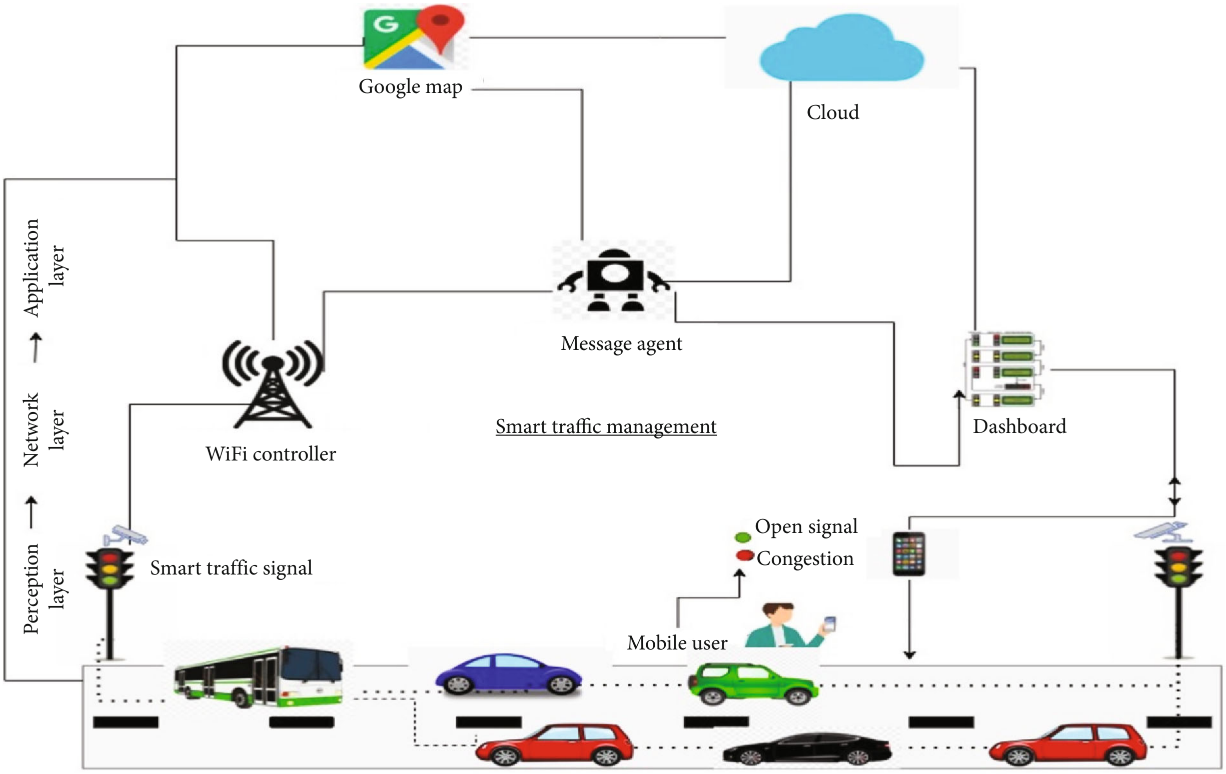

Figure 1: IoT-based architecture of Smart Traffic Management System for metropolitan cities.

data is available, rather than real-time traffic statistics, and it is also restricted to highways.

According to research [17], the first step in traffic management is to identify and assess congestion. Flow, occupancy, and density are the most regularly used road congestion measures, which are often derived from photographs or videos taken by vision-based cameras. The prototype was developed in this study to assess traffic data from public roadways. Web-based applications were used to manage traffic data packets. For dynamic signalized intersection handling based on the traffic density, an IoT-based existing traffic surveillance system has been proposed by [18]. The suggested approach involves a prototype. It includes two components: one for traffic monitoring and another for priority scheduling, along with a set of sensors. IoT devices send the density concentrations of a public roadway to the next signal, and the data is transferred to the server for later use. Ultrasonic sensors were used to identify cars, and the density rates of a public roadway were communicated to another signal by IoT devices. On district roads, the planned prototype is put to the test.

The researchers of the paper [19] presented an ultrasonic controller system model for traffic intersections on significant highways. Aside from traffic signal lights, the system also detects illegal vehicle activity, such as crossing red lights. Another study [11] proposes an IoT-based intelligent traffic framework to control real-time traffic via a centralized and decentralized server. To validate the system, an experiment is carried out on a national highway. Sensors, camera systems, and RFIDs are used at the data gathering layer. The application layer automatically controls the control signal depending on the traffic density, and a daily report is provided via a web application.

In addition to sensors, video monitoring is used to predict traffic congestion intensity and real-time update traffic lights in the study [20]. The proposed paper is based on a case study of a public route. According to study findings, surveillance cameras are both costly and challenging. Another scientific advancement proposed by a study [21] is the internet of linked automobiles, which collects real-time traffic data from local traffic. Based on this data, vehicle monitoring is possible with connected automobiles. Integrating the road units (such as traffic signals) with the vehicular platform ensures that traffic events are reliable. This system was created with highways in mind as this study predicts drivers using smart devices, traffic updates via roadside message units are not included.

The development of the Beijing Olympic region [22] is a great example of how to deal with city traffic. In-vehicle monitors are used to keep track of and deliver traffic information. However, because of new programs and gadgets, system development became much more expensive. Following that, a lot of research was done in this field to figure out how to improve traffic flow. In paper [23], a structure is put in place at decision points to show traffic congestion using three different light colors on electronic boards. The number of cars on this major highway is estimated based on the average speed of the vehicles detected by automotive detection sensors. The authors used image processing techniques to look at real-time traffic footage, and optical flow was used to determine the congestion rate.

One of the key features of “smart cities” is the connected-vehicle infrastructure. All automobiles and other road users’ real-time data is necessary to fully realize the advantages of connected-vehicle technology. Existing connected-vehicle deployments, however, only learn about the connected cars’ current condition in real time, while still being in the dark about the unconnected traffic that shares the roads with them. Finding a method to gather the disconnected road users’ high-resolution real-time status is essential. Because it will be impossible for all automobiles, pedestrians, and bicycles to actively broadcast their real-time status in the near future, improving traffic infrastructures to actively recognize and broadcast each road user’s status is a natural way to bridge the data gap. With the help of roadside LiDAR sensors and DSRC roadside units, the next generation of linked infrastructures introduced in paper [24] may actively detect the high-resolution state of surrounding traffic participants. However, LiDAR has numerous drawbacks, including a hefty price tag and the inability to gauge distances in conditions of severe rain, snow, or fog.

The above discussions show that current studies address the problem of traffic congestion management on different city roads such as district roads, urban areas, and a section of the highway, as well as real-time monitoring and traffic control. However, some of the most cutting-edge technologies, such as IoT and cloud computing, may help to improve traffic monitoring systems in major cities. To leverage the potential benefits of modern cutting-edge technologies in getting context awareness and providing real-time traffic updates [25, 26], this paper proposes an IoT-based architecture to provide mobile users with real-time traffic updates via roadside message agents and Google Maps. This smart traffic management is required in metropolitan areas to avoid congestion, control delays, and comfort end-users daily, especially during peak hours.

3. Proposed Methodology

This section covers in detail our proposed three-tier architecture, which includes different components such as vehicle sensors, roadside message agents, Cloud-based server, Google Map, and user dashboard, as seen in Figure 1. The suggested architecture’s detailed operation is also illustrated using an algorithm and a flow chart in Figure 2. The first layer of the proposed architecture is the physical layer; this layer contains the sensors and actuator/software agents working at the roadside. Sensors are responsible for capturing vehicle images while the actuators count the vehicles and upload the vehicle data to the Cloud using Wi-Fi controller/5G through the second layer. The second layer of the proposed architecture is the network layer which is mainly responsible for uploading the data to the Cloud and then syncing that data to the dashboard and an updated Google Map for traffic route awareness. The third layer is the application layer, which helps with the specifically designed dashboards in the cars, equipped with the Google Map routes and smart mobile app-based smartphone application to assist the drivers with the current traffic situation.

3.1. Working of the Proposed Methodology. In the proposed system, sensors detect the presence of cars on the road, and actuators determine their quantity. This count is compared to the predetermined threshold number to determine the road’s condition. The information collected by sensors and actuators is saved in the Cloud for decision-making purposes. If the number of vehicles on the road is fewer than the threshold figure, the dashboard will display a green signal, indicating that the road is not crowded. If the number of vehicles on the road exceeds the threshold amount, a red indicator will show on the driver’s dashboard to indicate traffic congestion.

Below, we provide the detailed working of the components used in the proposed architecture.

3.2. Magnetic Sensors. Magnetic sensors are a kind of multisensor system that is used to recognize many types of vehicles [27]. As vehicle movement influences the Earth’s magnetic field in the monitored location, this magnetic disturbance may be detected with the help of appropriate magnetic sensor equipment. The HMC-5883L magnetic sensor is extensively employed in traffic monitoring due to its high sensitivity and low cost [28, 29]. Its vehicle identification rate is 99 percent correct. As a result, in our suggested architecture for gathering vehicle data, we employed the HMC-5883L magnetic sensor. The magnetoresistive sensor used by HMC5883L is constructed of nickel-iron (Ni-Fe magnetic film) and is set up in a bridge circuit. Its electrical resistance changes as the magnetic field being applied changes. The earth’s magnetic field interacts with the nickel-iron substance in space in a way that affects its resistance, which in turn causes voltage fluctuations across the bridge. The direction of the magnetic field in space may be determined using this voltage change. Among the characteristics of HMC5883L are: it may be used for inexpensive magnetometry and compassing. Compass heading accuracy is up to 1 to 2 degrees and it contains a 12-bit ADC. Anisotropic Magneto Resistive (AMR) technology from Honeywell is used in it, and it offers accuracy in axis sensitivity and linearity. To interface with microcontrollers, it employs the I2C communication protocol. When an automobile or any other metal object passes over the HMC5883L AMR sensor, which measures the earth’s magnetic field in three directions (x, y, and z), the earth magnetic field is disturbed, and the values of x, y, and z are significantly altered from their initial values. The sensor offers a resolution of up to 5 milli-Gauss and a full-scale range of 8 Gauss.

3.3. Actuators. Actuators are autonomous software agents that have been created as a low-cost option for tackling complicated issues across a wide range of application fields [30, 31]. Actuators in the proposed architecture operate as message agents to improve traffic flow by learning a traffic management policy that determines when to show signal status, which measures the number of cars at a specific signal

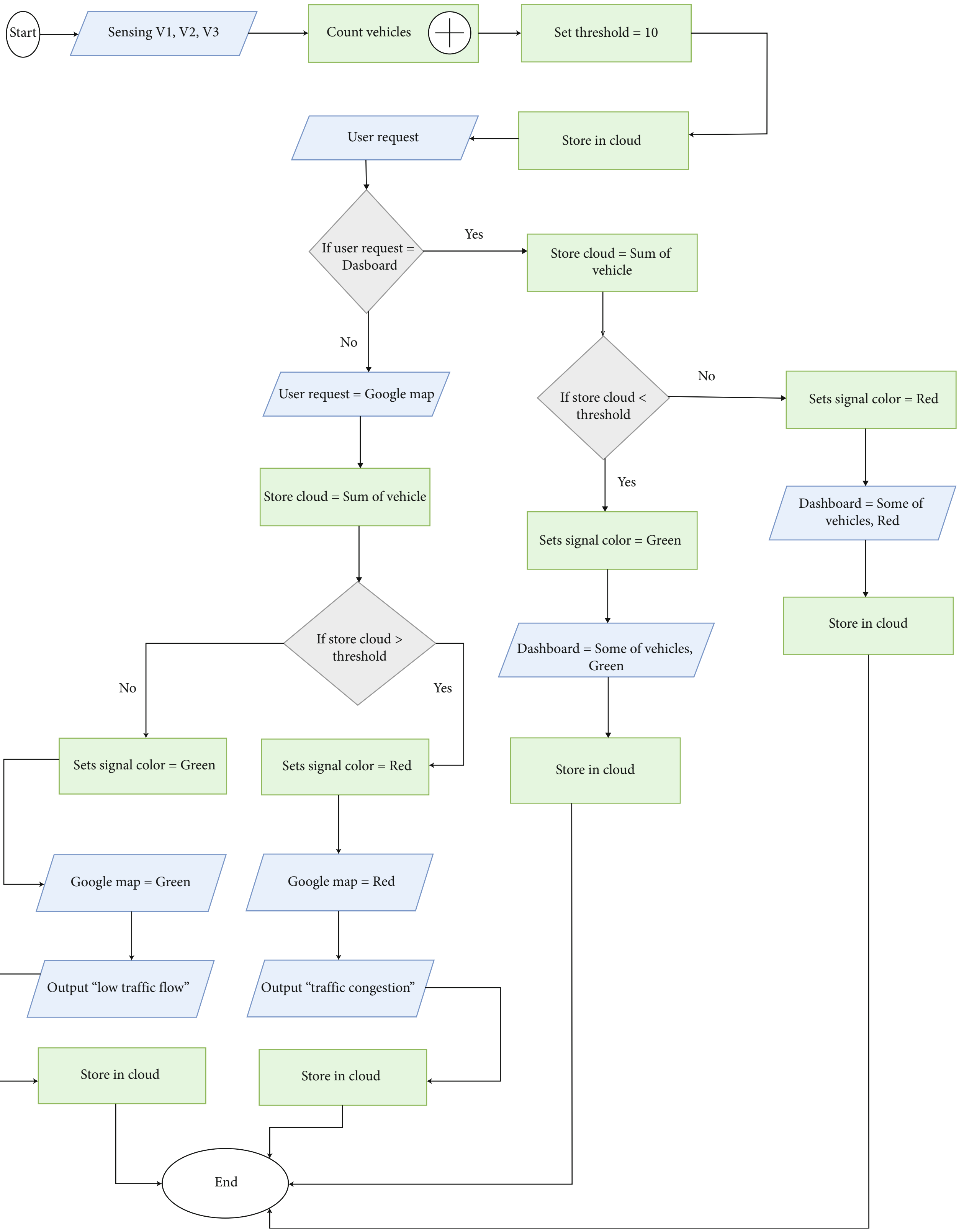

Figure 2: Real-time traffic updates on signal dashboard and Google Map.

[32]. Actuators collect vehicles' information and upload this data to the Cloud using Wi-Fi controller/5G through the network layer.

3.4. Mongo DB Atlas as Cloud Storage. MongoDB Atlas is a multicloud database service that allows you to construct durable and performant global applications on your preferred cloud providers [33]. MongoDB Atlas is used in the proposed architecture to store vehicle information and then sync this information to the dashboard and an updated Google Map for traffic route awareness. We picked MongoDB Atlas due to its robust access control and broad query language.

3.5. LCD Unit. Dashboards are character-type LCD devices that are Wi-Fi enabled [34, 35] and are used to display messages in the proposed design. Vehicles dashboard is equipped with Google Map routes and a smart mobile app-based application to assist the drivers with the current traffic situation.

4. Mathematical Modeling and Evaluation

The proposed approach aims to minimize traffic congestion by providing timely intimation to the drivers on their dashboards using cutting-edge technologies. The objective function in our case is to reduce traffic congestion by optimizing traffic information updates. Table 1 lists down the notations used for mathematical modeling

$$ {}_{o}F = \text{minimize}(\mathbb{C}\mathscr{g})\text{under}\,\mathfrak{I}, \tag{1}$$

where

$$\mathbb{C}\mathscr{g} = \bigcup_{v=1}^{n} f(\mathscr{sv}, \mathscr{cv}, \mathscr{uvc}, \mathscr{sd}, \mathscr{ugm}), \tag{2}$$

where $v = 1$ to n represents the number of vehicles presented on the road.

The $\mathbb{C}\mathscr{g}$ will be minimized $\Leftrightarrow \mathscr{sv} \Cap \mathscr{cv} \Cap \mathscr{uvc} \Cap \mathscr{sd} \Cap \mathscr{ugm} = 1$

All the factors affecting congestion optimization will be true in the normal situation; however, during $\mathfrak{I}$, there is a chance that the absence or lack of any of these factors will affect the $\mathbb{C}\mathscr{g}$ control. To evaluate the effect of individual factors on $\mathbb{C}\mathscr{g}$, we need to consider the partial derivative of Equation (2) w.r.t. mentioned factors as shown in Equations (3)–(7), where $h \longrightarrow 0$ implies that we are interested in extremely tiny values of h those close to 0.

$$\frac{\partial \mathbb{C}\mathscr{g}}{\partial \mathscr{sv}} = \lim_{h \longrightarrow 0} \frac{f(\mathscr{sv} + h, \mathscr{cv}, \mathscr{uvc}, \mathscr{sd}, \mathscr{ugm}) - f(\mathscr{sv}, \mathscr{cv}, \mathscr{uvc}, \mathscr{sd}, \mathscr{ugm})}{h}, \tag{3}$$

$$\frac{\partial \mathbb{C}\mathscr{g}}{\partial \mathscr{cv}} = \lim_{h \longrightarrow 0} \frac{f(\mathscr{sv}, \mathscr{cv} + h, \mathscr{uvc}, \mathscr{sd}, \mathscr{ugm}) - f(\mathscr{sv}, \mathscr{cv}, \mathscr{uvc}, \mathscr{sd}, \mathscr{ugm})}{h}, \tag{4}$$

$$\frac{\partial \mathbb{C}\mathscr{g}}{\partial \mathscr{uvc}} = \lim_{h \longrightarrow 0} \frac{f(\mathscr{sv} + h, \mathscr{cv}, \mathscr{uvc} + h, \mathscr{sd}, \mathscr{ugm}) - f(\mathscr{sv}, \mathscr{cv}, \mathscr{uvc}, \mathscr{sd}, \mathscr{ugm})}{h}, \tag{5}$$

$$\frac{\partial \mathbb{C}\mathscr{g}}{\partial \mathscr{sd}} = \lim_{h \longrightarrow 0} \frac{f(\mathscr{sv} + h, \mathscr{cv}, \mathscr{uvc}, \mathscr{sd} + h, \mathscr{ugm}) - f(\mathscr{sv}, \mathscr{cv}, \mathscr{uvc}, \mathscr{sd}, \mathscr{ugm})}{h}, \tag{6}$$

$$\frac{\partial \mathbb{C}\mathscr{g}}{\partial \mathscr{ugm}} = \lim_{h \longrightarrow 0} \frac{f(\mathscr{sv} + h, \mathscr{cv}, \mathscr{uvc}, \mathscr{sd}, \mathscr{ugm} + h) - f(\mathscr{sv}, \mathscr{cv}, \mathscr{uvc}, \mathscr{sd}, \mathscr{ugm})}{h}, \tag{7}$$

where gradient of $\mathbb{C}\mathscr{g}$ packages all its partial derivatives into a vector as shown in Equation (8)

$$\nabla \mathbb{C}\mathscr{g} = \begin{bmatrix} \dfrac{\partial \mathbb{C}\mathscr{g}}{\partial \mathscr{sv}} \\ \dfrac{\partial \mathbb{C}\mathscr{g}}{\partial \mathscr{cv}} \\ \dfrac{\partial \mathbb{C}\mathscr{g}}{\partial \mathscr{uvc}} \\ \dfrac{\partial \mathbb{C}\mathscr{g}}{\partial \mathscr{sd}} \\ \dfrac{\partial \mathbb{C}\mathscr{g}}{\partial \mathscr{ugm}} \end{bmatrix}. \tag{8}$$

4.1. Case Study. In this section, we will evaluate the proposed methodology using a real-life case study and will discuss the results in detail

A case study of the Smart Traffic Management System is conducted in a metropolitan city of the Kingdom. The steps involved in conducting a case study are:

(1) Capturing images

(2) Counting Vehicles

(3) Updating Traffic dashboard with real-time traffic data

(4) Sending data on user devices through Google Maps

Consider a traffic scenario with heavy traffic during crowding hours and having four entry and exit points, as shown in Figure 3

(a) Empty roads and interconnection on road A

(b) Vehicles are approaching near to intersection on road B

(c) Vehicles are approaching near to intersection on road C

(d) Vehicles are approaching near to intersection on road D

4.2. Case A: Road A with Zero Traffic towards the Junction. Using the suggested architecture, traffic management in the instance (a) of the case study is controlled in such a manner that IoT sensors capture vehicle images. Actuators/message agents count the number of cars approaching the intersection. Actuators are also in charge of storing big data in the Cloud through a Wi-Fi controller/5G. The Actuator/message agent provides the most current vehicle status to the user's dashboard through Cloud and Google Maps. The dashboard provides all vehicle data concerning the concerned intersection, which helps drivers stay informed about traffic conditions. There are specifically designed dashboards in the cars, equipped with the Google Map routes and smart mobile app-based smartphone applications to assist the drivers with the

```
Let $V1 \cdots ..Vn$ are vehicles on the Road.
Begin.
Read $V1 \cdots ..Vn$.
Compute CountVehicle $\Sigma V \longleftarrow V1 + V2 + V3 \cdots ..Vn$
Set Threshold ←10
Initialize User Request ←Dashboard or GoogleMap
//////////////////Traffic Updates on Signal Dashboard////////////
While User Request==Dashboard
Store.Cloud ←Count Vehicle
If (Store.Cloud <Threshold) then
Active Message.Agent
    Set Signal.Colour←Green
    Dashboard ←ΣV,Signal.Colour
    Updat Store.Cloud
else
    Store.Cloud←Heavy traffic
    Set Signal Color ←Red
    Dashboard ←ΣV,Signal.Color
    Goto step userRequest
//////////////////Message Popup on Users Smartphones///////////
    While User Request==GoogleMap
    Store.Cloud ←Count Vehicle
    If (Store.Cloud >Threshold) then
    Active Message.Agent
    Set Signal.Colour←Red
    GoogleMap ←Signal.Color
    Output←Traffic Congestion
    Update Store.Cloud
else
    Store.Cloud←Empty Road
    Set Signal Color ←Green
    GoogleMap ←Signal.Color
    Output←Smooth Passage
    Update Store Cloud
    End.
```

Algorithm 1: Proposed algorithm.

Table 1: Symbols used for mathematical modeling.

Symbols	Used for
$\mathscr{oF}$	Objective function
$\mathbb{C}\mathscr{g}$	Traffic congestion
$\mathfrak{I}$	Peak hours timings
$\mathscr{sv}$	Sensing vehicle/capturing vehicle images
$\mathscr{cv}$	Counting vehicles
$\mathscr{uvc}$	Uploading vehicle data to Cloud
$\mathscr{sd}$	Syncing dashboards
$\mathscr{ugm}$	Update Google Map

current traffic situation. These dashboards display a red or green indicator indicating traffic congestion or a smooth journey. Users get a green light on Google Maps in this situation since there is no traffic on the road and the user has a clear path to go.

4.3. Case B: Vehicles Are Oncoming near to Intersection on Road B. Using the proposed architecture, traffic management in case study instance (b) is regulated in such a way that IoT sensors identify vehicles. Message agents count the total number of vehicles, which is 10 in this case, as indicated in Figure 3, and save this data to the Cloud through Wi-Fi controller/5G. The messaging agent is constantly updating the cloud storage. The Dashboard in the car receives traffic data from Google Maps through Cloud. The updated data comprises traffic statistics on the affected route since the number of vehicles on the road exceeds the threshold value. In this situation, a red signal will display on the user's dashboard, indicating traffic congestion. This early warning message benefits drivers in lowering the driving time and arriving on time.

4.4. Case C: Vehicles Are Oncoming near to Intersection on Road C. Using the proposed architecture, traffic management in case study instance (c) is regulated in such a way that IoT sensors identify cars. Message agents counted four cars and this data is transmitted to the Cloud. Following processing, vehicle data is received on the users' dashboard. In this situation, a green signal will display

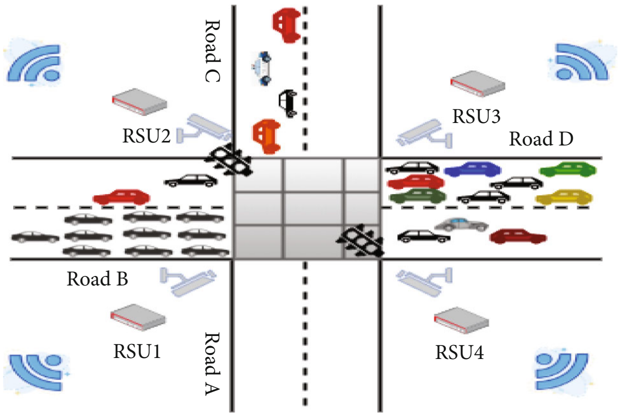

Figure 3: Case study description of road junctions.

on the user's dashboard, indicating that there is little traffic, and the driver will get a delay-free signal.

4.5. Case D: Vehicles Are Approaching near to Intersection on Road D. Using the proposed architecture, traffic management in case study instance (d) is regulated in such a way that IoT sensors identify cars. Message agents counted eight vehicles. In this situation, a red signal will display on the user's dashboard, indicating traffic congestion. This enables drivers to save time and arrive at their destination on time.

5. Results and Discussion

As mentioned in the previous section, a case study was performed to demonstrate the proposed architecture's applicability. This section provides the results of the case study; our results will focus on the following two main functions:

(i) Collection and counting of vehicles

(ii) Broadcast message on dashboard and Google Map

To assess the resulting values for correctness, we established a threshold value against which the obtained values may be compared. Below, we discuss our findings in detail.

5.1. Collection and Counting of Vehicles. Table 2 presents the evaluation of IoT sensors and actuators used to collect and count vehicles in the given case study scenario.

As seen from the data in Table 2 and Figure 4, the total number of vehicles on all four roads at a junction identified by sensors and tallied via the actuator is the same as the total number of cars on all four lanes. This demonstrates that the proposed architecture's vehicle detection and counting approach using IoT sensors and actuators is sufficient in all situations.

Table 2: Vehicle detection and counting using IoT sensors and actuators.

Road	Real vehicle	Detected
A	00	00
B	10	10
C	04	04
D	08	08

5.2. Sync Message on Dashboard and G-Map. In real-time traffic data, Smart Traffic Management System uses cutting-edge technologies to collaborate with road junctions and agents to build signal dashboards, store real-time traffic data, and continuously update data in Cloud storage to save time and provide convenience to users. In this case study, we set the sync timing of communication messages between sensors, message agents, and the Cloud to 3 seconds. This value demonstrates the efficacy of our recommended approach. Figure 5 shows the time consumption of communication messages between sensors, message agents, and the Cloud.

5.2.1. Road A. Sensors detect no vehicles. It takes 0.5 seconds to sense the vehicle, and the message agent takes 1.5 seconds for all processing and sends it to the Cloud. In contrast, all the data is stored and updated in only 02 sec. At the same time, our threshold value is 3 sec.

5.2.2. Road B. Sensors detect ten vehicles. It takes 1.0 seconds to sense the vehicles, and message agent takes 2.0 seconds for all processing and sending to the Cloud. In comparison, all the data is stored and updated in only 03 sec, matching our threshold value.

5.2.3. Road C. Sensors detect 04 vehicles. It takes 0.5 seconds to sense the vehicles, and the message agent takes 1.75 seconds for all processing and sends to the Cloud. At the same time, all the data is stored and updated in only 2.25 sec. Sync message timing is less than our threshold value.

5.2.4. Road D. Sensors detect 08 vehicles. It takes 0.75 seconds to sense the vehicles, and the message agent takes 1.75 seconds for all processing and sends to the Cloud. At the same time, all the data is stored and updated in only 2.75 sec.

This reveals that our proposed system takes less time to transport messages from the sensor to the cloud repository, demonstrating its efficacy.

The proposed architecture is compared with an existing solution by real-time data collection to a cloud repository. Figure 6 represents the calculated timing of messages to reach collected data to the citizens of the Kingdom by broadcasting on the signal dashboard or showing on Google Map by the end user's request from their smartphones.

5.2.5. Road A. Signal dashboard takes 3.5 secs to update the traffic status. In comparison, Google Map takes 4 secs to update the traffic signal status.

5.2.6. Road B. Signal dashboard takes 4.0 secs to update the traffic status. In comparison, Google Map takes 4.5 secs to update the traffic signal status.

5.2.7. Road C. Signal dashboard takes 3.65 secs to update the traffic status. In comparison, Google Map takes 4.25 secs to update the traffic signal status.

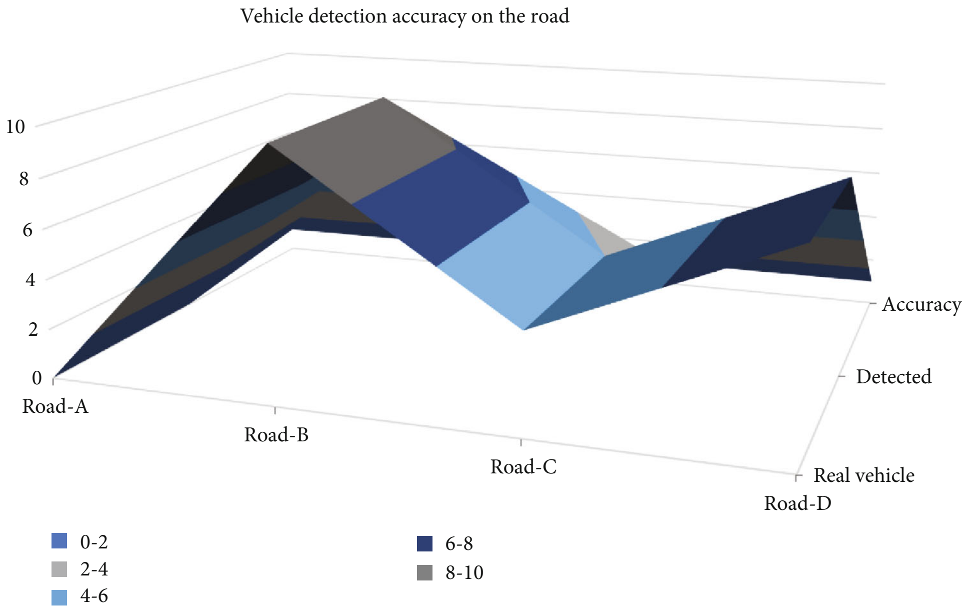

Figure 4: Vehicle detection accuracy on the road.

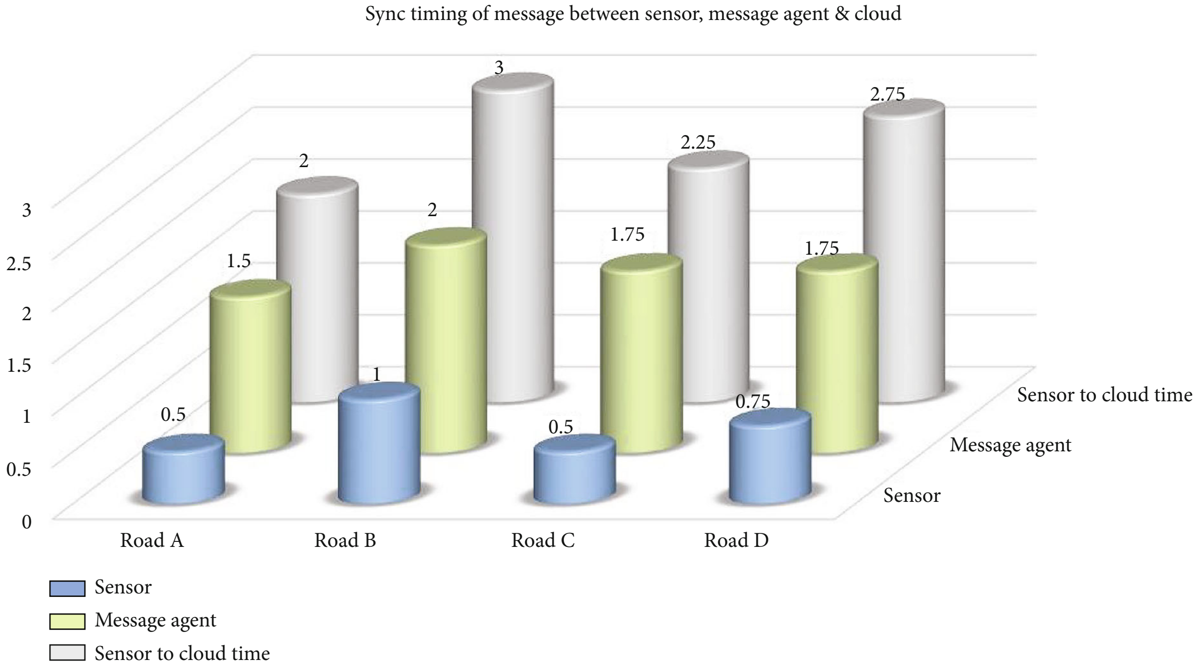

Figure 5: Sync timing of communication messages between sensors, message agents, and Cloud.

5.2.8. Road D. Signal dashboard takes 3.75 secs to update the traffic status. In comparison, Google Map takes 4.0 secs to update the traffic signal status.

Figure 7 represents the sync time between components of the proposed solution, which is further elaborated in Figures. 8 and 9. Real-time traffic information is broadcasted on the signal dashboard and Google Map. Figure 7 shows that message timing between components is directly proportional to the number of vehicles detected on every road junction.

The case study results demonstrated accuracy in vehicle detection with zero error, and timings of various messages sent to the dashboard and Google Map were elaborated. As a result, the proposed architecture can help citizens of the Kingdom save time and fuel by receiving early messages on smartphones, particularly during

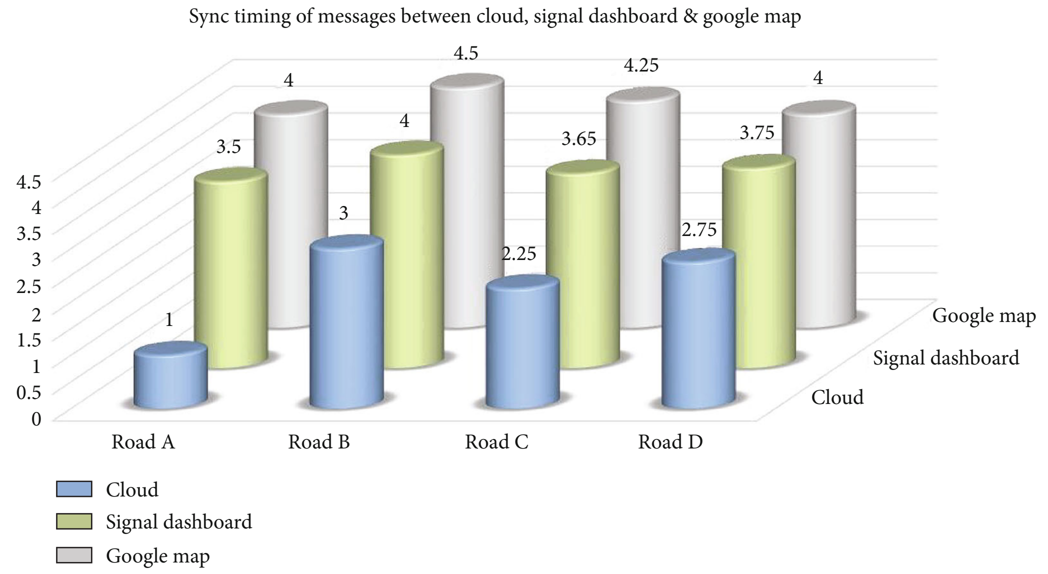

Figure 6: Sync timing communication messages between Cloud, signal dashboard, and Google Map.

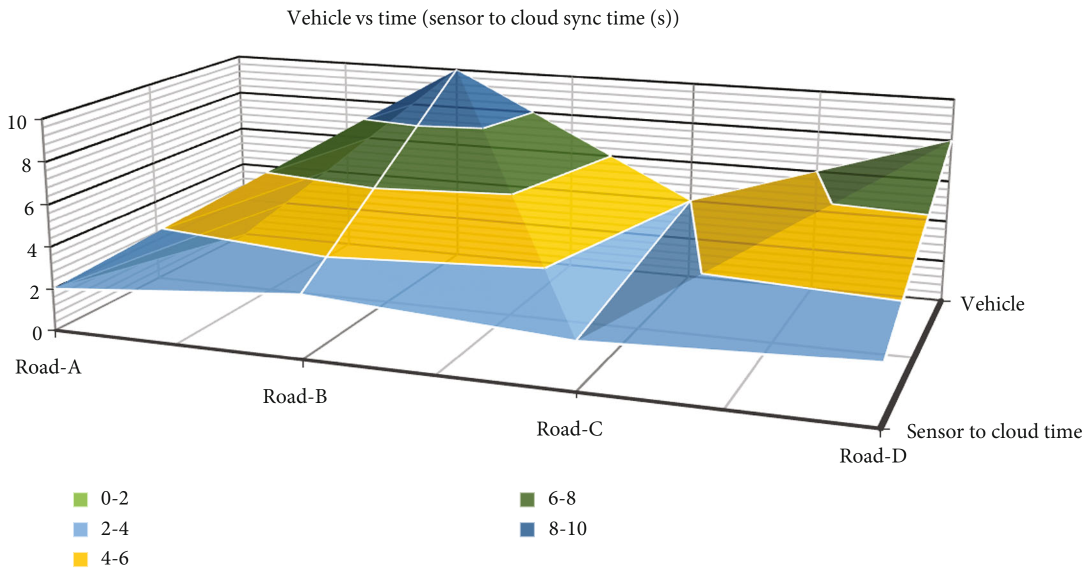

Figure 7: Road vise total sync time (sensor—Google Map) and (sensor—signal dashboard).

crowning hours. These messages will assist with traffic congestion and unusual incidents, and citizens can arrive at their destinations on time.

The above discussion shows that the proposed solution can be implemented in metropolitan cities of the Kingdom to improve citizens' lifestyles. They get updated information on their mobile phones or previous signal dashboard. These alert messages help citizens consume valuable time and reach their targeted area on time.

To evaluate the main objective of the research, Table 3 compares Existing Traffic Management (ETM) with our proposed solution in which we define different parameters such as successfully addressed, partially addressed, and not addressed by assigning symbols as shown below.

Successfully Addressed = ✦✦
Partially addressed = ✦◊
Not Addressed = ◊◊

Three parameters are selected to have a broader look at efficiency and accuracy. These parameters are real-time traffic collection and counting. Real-time traffic updates on the signal dashboard and Google Map, as shown in Table 3.

Because IoT devices are more accurate than traditional cameras, real-time vehicle collection in existing ETM is less accurate than smart traffic management (STM). No dashboard data is built-in to ETM because our proposed solution is provided on each signal. Google Map provides traffic updates, resulting in a more efficient Smart Traffic Management System than ETM. The results show that based on

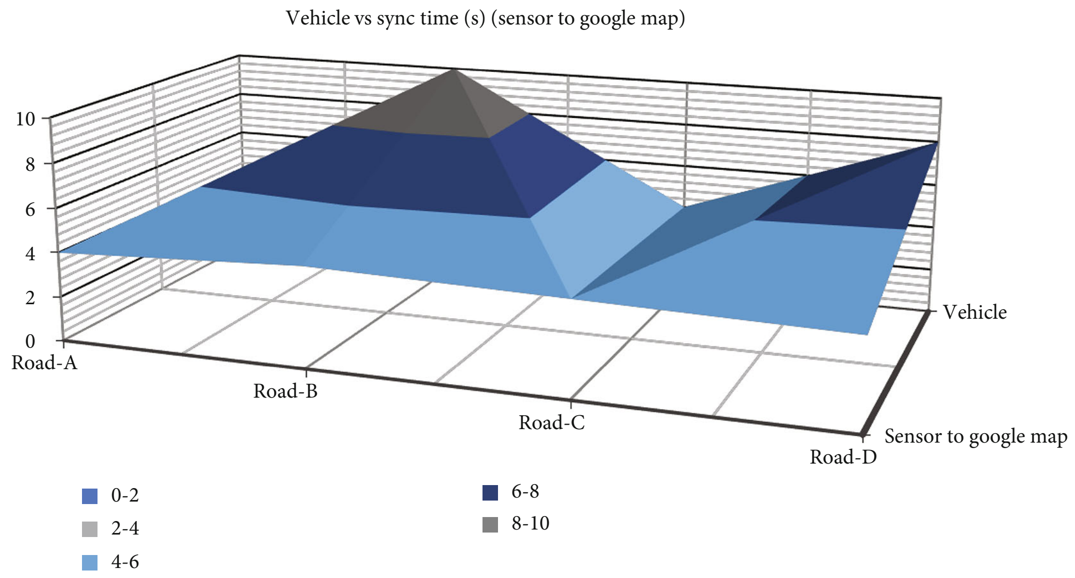

Figure 8: Vehicle vs sync time(s) (sensor to Google Map).

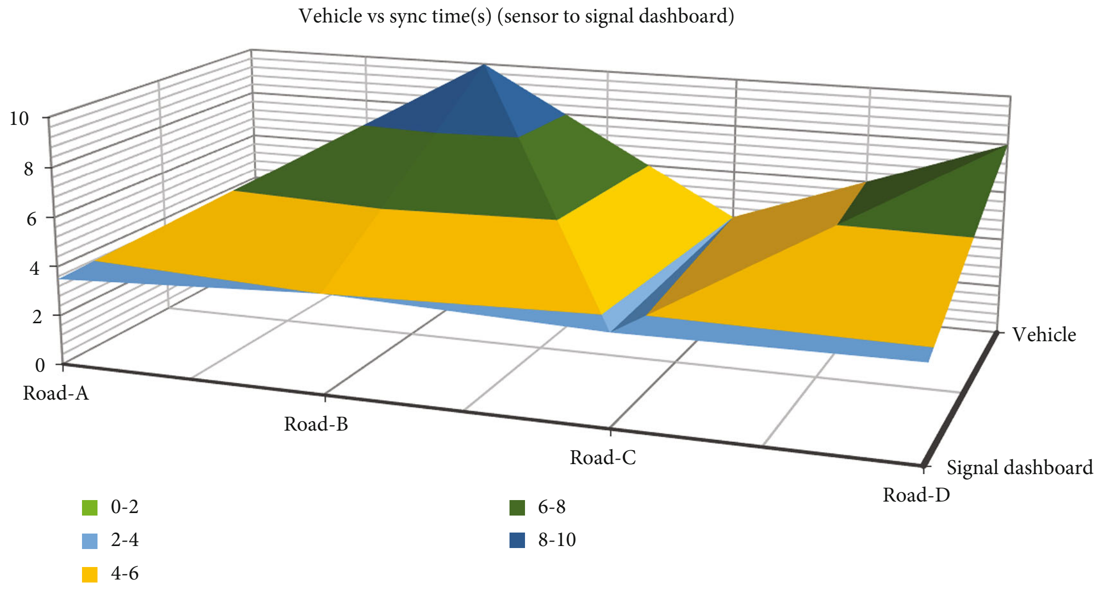

Figure 9: Vehicle vs. sync time(s) (sensor to signal dashboard).

real-time data, our solution can be practically implemented in Kingdom metropolitan cities to ensure congestion control and time consumption.

Table 3 represents the efficiency comparison of our proposed solution. In 2019 and 2020, researchers took a step towards real-time traffic monitoring. It was either partial or ultimately achieved, but real-time traffic updates are missing, a need of today's lifestyle. As the technology grows and citizens' demands are enhanced, there is a need for a Smart Traffic System that provides early alerts for the delay and congestion control. Our Smart Traffic System helps the citizen with time consumption, delay control, and efficiency by providing traffic updates on the signal dashboard and Google Map. This graph summarizes the proposed system is distinct from existing traffic management systems.

6. Conclusion and Future Work

This study proposed an IoT-based architecture with agents collecting and counting vehicles via IoT devices and storing real-time data on clouds via message agents. The messaging agent acts as an actuator in the proposed solution and collaborating in real-time with the environment and cloud storage. Meanwhile, these messages are being broadcasted on the dashboard and Google Map to assist Kingdom citizens in making decisions and saving time on the roads. Wi-Fi-

Table 3: Comparison of the proposed approach with existing studies.

Ref	Year	Real-time monitoring	Real-time traffic updates on the signal dashboard	Real-time traffic updates on Google Map
Proposed system	2022	✦✦	✦✦	✦✦
[17]	2020	✦✦	◊◊	◊◊
[18]	2019	✦◊	◊◊	◊◊
[19]	2020	✦✦	◊◊	◊◊
[20]	2020	✦✦	◊◊	◊◊
[21]	2019	✦◊	◊◊	◊◊
[22]	2020	✦✦	◊◊	◊◊

enabled controllers carry out this process to send a message on time. The case study is carried out to validate the accuracy of the proposed architecture.

In terms of future directions, the proposed system could be enhanced further by taking various features into the version. The first dimension requires recommending an optimum route based on real-time data to drivers. Future research will focus on dynamic traffic signal control functionality and performance in low-light environments or during extreme weather. Communication between roadside display units and traffic lights must be recognized in this case. Another factor to consider is the system's real-time implementation, which includes IoT security features in the communication layer; the architecture must be expanded to a whole end-to-end system with central server communication.

Data Availability

The numerical data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare no conflict of interest.

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