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Research Article

Smart Transportation in Developing Countries: An Internet-of-Things-Based Conceptual Framework for Traffic Control

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In recent years, an exponential increase has been witnessed in the population of the urban area worldwide, causing a significant increase in the use of transportation services. The traditional transportation system in metropolitan cities is overwhelmed, leading to many challenges. The Internet-of-Things- (IoT-) based technology has the potential to optimize transportation services in several ways. This paper highlights the challenges and consequences of an existing transportation system in Peshawar, Pakistan, in response to the rapid growth in population. Apart from the common issues, some areas in Peshawar are highly vulnerable to massive traffic jams. For this purpose, we have proposed an IoT-based framework for busy traffic junctions. The proposed framework considers the route selection problem as a game of two players, where Nash Equilibrium (NE) sets traffic for each route so that no individual can improve its performance by changing its strategy. NE calculates the traffic density from a roadside unit (RSU) collected data, which later detects and avoids traffic congestion by an alternate route selection. The framework in this paper provides a platform for the academia and transport department to convert the existing transportation system to IoT-based intelligent transportation in Peshawar, Pakistan.

1. Introduction

The rapid growth in the world population is causing a gradual decrease in the quality of services within urban areas. According to the United Nations, around 55% of people live in urban areas and are expected to reach 68% by 2050 [1]. The exponential increase in the metropolitan area is due to the migration of people for jobs, education, business, health, and other essential facilities of modern life. This increasing number puts a great burden on the city administration to manage resources more efficiently. The city administration needs to have sustainable solutions to deal with an increasing number of citizens. A smart city is the integration of information with communication technologies to enhance the services and operations of the city to facilitate citizens. Intelligent transport is a vital factor of a smart city where vehicles are connected to a centralized controller or cloud [2]. Public transport is one of the leading services that need to be streamlined to assist citizens. Peshawar city (the capital of Khyber Pakhtunkhwa) in Pakistan is one of the busiest and most congested area linking Afghanistan at North West borders. The population of Peshawar city in 2020 was 2.3 million [3], with an increase of 3.8% from 2019. This number is increasing day by day as people move towards the city for better resources and opportunities. The city administration finds it difficult to provide support to this rapid growth, especially in public transportation. The current status of public transport in the city is highly deplorable. The primary sources of public transport are buses, wagons, and rickshaws, as shown in Figure 1. Peshawar has mainly one trunk road from the central city to the Karkhano market and few diversions to Saddar Bazar and Hayatabad town. The

(a) (b) (c)

Figure 1: Public transport in Peshawar city: (a) buses [4]; (b) wagon [5]; (c) rickshaw [6].

geographic location and existing traffic infrastructure of Peshawar city make it an excellent use-case for this research.

Public safety and a clean environment are essential public transportation factors in developing countries. Road accidents are widespread. It reveals the inadequacy of safety measures in traffic management systems. Some areas are highly vulnerable and often subject to massive traffic jams in Peshawar, Pakistan. Traffic jam in Hasthnagri and Firdaus areas is a routine matter that causes severe problems for students, employees, and patients to reach their destinations on time. This work not only elaborates on the challenges in the current traffic status but also proposes a framework for efficient management of massive traffic zone like Firdaus chowk to minimize the occurrence of severe traffic jams. The proposed traffic jam avoidance framework is an application of Internet-of-Vehicles (IoV) technology [7]. According to the suggested framework, all the participant vehicles must be equipped with GPS, an onboard unit (OBU), and IEEE 802.11p. The route selection problem at the massive congested intersection point is considered as a game of players, i.e., drivers, where Nash Equilibrium (NE) sets traffic for each route so that no individual can improve its performance by changing its strategy [8]. NE calculates the traffic density from a roadside unit (RSU) collected data, which later detects and avoids traffic congestion by an alternate route selection. Our game represents vehicles, available routes, travel time as a player, strategies, and payoff, respectively. In the proposed framework, the intelligent cars act as players to compete with other opponents in an appropriate route selection to receive an optimum payoff in a short traveling time. It estimates the traffic density based on the frequent beacon messages. Additionally, concerning the relevant density of vehicles, it recommends a particular speed based on the space head-ways aiming to avoid the intercollision of ongoing cars. Additionally, it also provides an alternate route to minimize the congestion level.

The rest of the paper is divided into six sections, where Section 2 focuses on the related work. Sections 3 and 4 deal with the potential challenges and consequences of smart transportation on the public, respectively. Section 5 explains the proposed framework, and Section 6 represents the evaluation of the proposed traffic game framework. Finally, Section 7 concludes the paper with recommendations for the future.

2. Relevant Literature

The rapid deployment of IoT-based applications provides a tremendous change in human lives. Some of the IoT applications are intelligent transportation, smart hospital, smart home, smart grid, etc. [9–12]. Different sensors (visual and scalar) are used in smart transportation, and roadside units (RSU) are deployed along the traffic routes [13–16]. Transportation has always been necessary for any country, whether through trains, cars, ships, buses, or airplanes. Public transport facilities like buses are widespread and frequently used in everyday life. On the global scale, around 1.2 million people die due to road accidents every year, and nearly 50 million people get injured [17]. Nowadays, driver fatigue and drowsiness are among the leading causes of road accidents throughout the world. Various sensors are used for this purpose in vehicles to detect drowsiness. Furthermore, different sensors are installed on the roadside connected to the driver's phone or car to detect road surface anomalies to minimize road accidents by alerting the driver. Apart from this, many researchers in the literature have contributed to smart transportation by proposing different techniques [18–20]; a few of them are discussed here.

In smart transportation, route optimization or navigation system is one of the most crucial areas. User mobile data [15] or roadside units on specific locations [21] try to approximate traffic congestion. The congestion of traffic is the primary concern of cities, and the ratio of congestion is increasing day by day due to the increased number of vehicles. Route optimization or navigation is a technique to provide the best path from source to destination in such a way to reduce traffic congestion that will decrease vehicle emissions and traveling time [21].

Smart street light (SSL) is another essential service in smart cities. It ensures a reduction in energy consumption, which detects the condition of traffic to operate accordingly, rather than simply following a predefined schedule. An energy-efficient approach presented in [22] proposed a Raspberry Pi-based automatic light on and off system by using a light sensor to detect the intensity of light and IR sensors to detect bypassing pedestrians or vehicles. A smart lighting system is presented in [23], where different kinds of environmental sensors were used to automatically switch on/off or dim depending on the environment to preserve energy.

Another application of intelligent transportation is smart parking, where various intelligent devices, such as sensors, are used for vehicle detection. For example, the authors in [24, 25] used a scalar sensor (IR sensors or magnetic field) for vehicle detection in a parking area and information sent to a centralized system to increase parking slots and decrease the searching time. Furthermore, a vehicle-to-vehicle (V2V) communication based on an IoT framework using M2M communication is proposed in [26], where vehicles share their GPS position, movements, and speed with the nearest cars and simultaneously upload to a server.

In light of the above literature, this paper highlights the potential challenges of the existing transport in developing countries (i.e., Pakistan). Traffic congestion is at the top of all transport issues. In this paper, we proposed a framework based on the game theory to reduce the intensity of traffic congestion.

3. Challenges: Smart Transportation

The concept of a smart city is adopted in numerous developed countries. Some cities are already declared smart cities, such as Singapore, Seoul, London, and Barcelona. However, the transformation from traditional cities to smart cities is still a big challenge in these countries. One of the challenging and vital aspects of the smart city is smart transportation to contribute positively to the regional economy. Smart transportation in developing countries aims to improve the region's public transport and minimize traffic jams. Some of the challenges in developing countries are highlighted in this section. Peshawar city is considered as a case study.

3.1. Technology Infrastructure. In developing countries, the public transport system in even the major cities is often void of technological advancements. One of the main challenges for adapting smart transportation is the lack of robust supporting infrastructure. Consequently, there is no such public transport system in Peshawar city where drivers can get real-time information about road conditions or accidents. Traffic jams at certain junctions are very often badly affects the citizens' activities. In intelligent transportation, the drivers can be updated on traffic conditions, route suggestions, accidents, and infotainment using various applications.

Three modes of communication can achieve smart transportation, i.e., vehicle-to-vehicle (V2V) communication, vehicle-to-infrastructure (V2I), and connectivity with regional transport authority (RTA). The vehicles with intelligent devices share information with other cars in the neighborhood, while V2I communicates vehicles with the roadside unit (RSU) [27]. All of the RSUs are connected and installed at different points in the city along different routes. Moreover, a pedestrian can also communicate with RSU to get updated information. The collected data is passed to RTA for monitoring purposes and can further plan to avoid traffic jams. For intelligent and sustainable infrastructure, RTA needs to implement these technologies to improve citizens' quality of life to breathe in a clean and safe environment.

3.2. Governance. Governance plays a significant role when it comes to new technology adaptation. Policymakers at the city level need to contribute positively to uplift the region's transport infrastructure and contribute towards the betterment of the overall traffic conditions of a city. In developing countries, unregistered vehicles such as cabs and rickshaws also burden the traffic that needs to be controlled. The government needs to get them to register and streamline public transport to minimize traffic's adverse effects. The government's role is very crucial to uplift the transportation of any region. In developing countries, bus transit and metros need to be started to minimize vehicles on the routes, especially within the city. Due to the rapid growth in the population, the number of cars on the road also increases. RTA needs to think seriously by allocating funds to improve the road and public transport conditions. As a case study, the Peshawar local government has started a bus rapid transit (BRT) project to improve the city's traffic condition and transport facility [28]. Intelligent and sustainable transportation is the need of the day to give improved services to the citizen keeping in view the current resources and future predictions.

3.3. Education. In most developing countries, low-income people use public transport, especially the labor class, as they cannot afford a personal car. In this part of the world, the poverty rate is 31% [29], due to which people are unable to continue their education and start earning to look after their families. It is one of the main reason of unregistered cabs and rickshaw that puts an extra burden on the roads. It is a big challenge for Peshawar to adapt smart transportation as many citizens are not educated. Citizens cannot use the mobile application for updates regarding traffic conditions, infotainment, bus or wagon schedules, online map, etc. The interactive screens are often deployed at bus stops to facilitate citizens. Various parameters are recorded and displayed inside the bus to keep citizens updated. It is also a big challenge for those who are not educated enough to benefit from intelligent transportation.

3.4. Cost. The current condition of public transport is not good because the drivers/owners are not upgrading their vehicles despite the pathetic conditions. Moreover, almost all public transport that moves in Peshawar city is privately owned. The local administration has no funds for the transport chain to facilitate both citizens and drivers. To deploy the government-funded public transport across the city requires a handsome budget to buy well-equipped buses and wagons that run on the main roads while the rest of the vehicles will use other specified tracks. The overall management and control rooms need to be established at different city locations to monitor the traffic condition and avoid traffic jams, especially at peak hours. Technology-assisted buses need to be hired with proper infrastructure deployed that can be connected to each vehicle. A complete setup is required to implement the features offered by intelligent transportation.

4. Consequences of Smart Transportation on General Public

In developed countries, citizens benefit from different transport facilities in the form of public transport, either through full-fledged smart transportation or a rapid transit bus. In this section, the impact of intelligent transportation in developing countries is explored; Peshawar city is considered a case study. Below are the crucial factors that directly impact the general public, whether they use public transport or not.

4.1. Social

4.1.1. Problem. In Peshawar city, the citizens are not satisfied with public transport in its current form, and most of them are reluctant to use it. Most students and low-income people travel on the local buses, and others opt for private transport or cab services. The amount of traffic on the road, comfortability of the buses, the behavior of the drivers, travel time, and making stops at their determination can lead to frustration and tension. It can be on the higher side during summers, severely affecting an individual, whether a student or an ordinary person. Increased traffic means more time on-road, and it becomes even worse at peak times. It is highly recommended that user behavior be adequately analyzed depending on the city to better plan its available resources and forecasts future services [30].

4.1.2. Opportunity. Citizen's satisfaction is essential, and it can be achieved if the government adopts intelligent technologies to facilitate them. Smart transportation can significantly contribute to citizen satisfaction by giving maximum system accessibility, minimizing trip time and affordable fare, and reducing traffic accidents. In an intelligent environment, citizens can track the bus, vacant seat, bus schedule, optimum routes, notification of traffic jams on specific roads, and an accident alert. Moreover, comfortable buses and dedicated routes will minimize the stress and frustration of citizens and spend less time. The less you travel on the local bus, the more you feel good. The government needs to upgrade the public transport of the citizen to give a better and safe life.

4.2. Environmental

4.2.1. Problem. An increase in the number of vehicles on the road increases the emission that severely affects the environment. In Peshawar, public transport, private cars, and cabs are not well maintained, which causes pollution [31]. It is dangerous for health, causing various diseases such as cancer, heart attack, and respiratory problems. If a vehicle spends more time on the road, it will cause more pollution, and according to the World Health Organization (WHO), every year, around 5.5 million people die due to air pollution. Therefore, local administration needs to divert attention towards a clean and healthy environment. Less time on the road means less consumption of fuel resulting in money savings and time.

4.2.2. Opportunity. Adapting an intelligent transportation system can reduce emissions and minimize overall pollution, thus contributing to a clean and healthy environment. In smart transportation, standard buses with routine maintenance can result in less fuel consumption and less emission. Intelligent devices such as environmental sensors are installed at certain places where the number of pollutants in the environment is monitored. Local administration can be reported for taking any precautionary measure or future planning. Suppose people are provided with excellent public transport facilities, in that case, they will minimize their private transport usage, reducing the number of vehicles on the road. Thus, as a result, it will reduce traffic congestion, emission, and even traffic accidents.

4.3. Economic

4.3.1. Problem. Poor public transport compels people to opt for their private conveyance or use a cab service. In Peshawar, if you travel from Hayatabad town to Saddar bazaar in your car, it will take around 20-25 minutes, depends on the traffic condition, and the fuel consumed will be about 200 PKR. However, if you opt for public transport, it takes around 45-55 minutes, costing 15-20 PKR, although it is economical at the cost of time wastage. If you choose cab (taxi) services, it will charge around 300–350 PKR. Public transport seems to be very economical, but it wastes time and adds fatigue and stress. You can opt for rickshaws to the nearby destination in Peshawar city, but it is rarely used on the main trunk's lanes. Due to poor services offered, public transport is decreasing daily, which results in lower drivers' earnings and can contribute to poverty and unemployment. Moreover, people mostly prefer a shared cab to reach the destination on time by giving a bit more fare than public transport [32]. In addition to the above economic factor, it is reported in [16] that air pollution directly impacts our health and wallets. The medical cost is in trillion dollars due to the increase of various diseases caused by pollutant air.

4.3.2. Opportunity. The government needs to focus on the improvement of public transport. Reliable transportation can surely minimize the use of private conveyance and cab services. Using the above example, the passenger can reach the destination in less time. It is good to pay 20-30 PKR instead of paying 300-350 PKR. People will be encouraged to use public transport rather than private transport, resulting in less fuel consumption and saving money and time (dedicated routes). The drivers can be trained and educated regarding traffic rules and regulations. Moreover, they can be compensated in these buses to contribute towards poverty reduction and to society. A clean and healthy environment can undoubtedly minimize the diseases caused by these pollutants as citizens will breathe in a clean environment and reduce medical expenses.

4.4. Public Health Improvement

4.4.1. Problem. The number of vehicles on the road directly impacts the environment due to emissions. The more cars

(a) [18] (b) [19]

Figure 2: Traffic condition in Peshawar city at day time; the more vehicle emits pollutants, the more it badly affects the environment; thus, having negative impact on human health can cause health diseases.

on the road, the more environment will be polluted, as shown in Figure 2. According to a report published in [17], particulate matter (PM2.5) has surpassed in Peshawar the threshold defined by the National Environmental quality standard (NEQS). The NESQS recommends 15 micrograms/cubic meters. According to [17], Peshawar has a minimum of 40 and a maximum of up to 90 PM2.5 levels, alarming that it causes an increase in age-specific deaths and can severely affect the heart and lungs. There are many other reasons for this cause: dust, waste burning, etc. But vehicular emission is a significant factor. In Peshawar, the condition of vehicles used for public transport and even cabs is not maintained. The number of motorcycles is increasing day by day for easy transport. Furthermore, nitrogen dioxide (NO_2) is also on the higher side that weakens the respiratory system causing various problems to respiration. Mostly traffic police wardens and people doing roadside businesses are highly exposed daily for the whole day.

4.4.2. Opportunity. Smart transportation can control the increasing number of vehicles on the road by providing excellent and affordable public transit. Most of the problems, such as traffic congestion, vehicle emission, and accidents, can be minimized to a greater extent. In Peshawar, the current transport system is fragile. The worst condition of the buses and wagon is possible to convert to a well-maintained transport. Minimizing the number of vehicles, especially motorcycles and cabs, will undoubtedly reduce the PM2.5 and NO2 levels to improve public health. Moreover, environmental sensors can be deployed at congested points to check different pollutants and help local administration accordingly.

4.5. Quality of Life

4.5.1. Problem. The quality of life index is crucial for every citizen around the globe. It is considered very seriously in developed countries, whereas in developing countries, it is pretty ignored or the statistics are not satisfactory as per standards. Quality of life index is the aggregate of various parameters such as safety index, health care, cost of living, traffic commute time, pollution, and few others. High pollution adds to poor public health. The traffic police, shopkeepers, and those having their small setup at the roadside are highly exposed. Due to the high traffic and bad condition of public transport, those who cannot afford private transportation or cab are even reluctant to travel. Social gatherings, visiting parks, and tourist spots play a vital role in individual health. Peshawar city is named a city of flowers [33], but it is a polluted city due to increasing pollution and the local administration's poor management.

Figure 3: Traffic intersection point (Firdous Intersection) for the proposed traffic framework.

4.5.2. Opportunity. To improve the quality of life from the perspective of transport, citizens can easily travel to different tourist spots of the city and parks by providing good public transport facilities. They even can visit their relatives at affordable prices. If you need to go to any garden or social point in Peshawar, you might think several times also if you are using your transport. It is of utmost importance for the government to conduct a survey and identify the significance of various cities in terms of quality of life. The government needs to reduce problems as much as possible in every service offered in the town but mainly transportation services. Their roads and transport facilities can easily judge the quality of life in a particular city.

5. Proposed Traffic Jam Avoidance Framework

The existing transportation system in Pakistan has many issues, as discussed in the above sections. The proposed framework is a step towards intelligent transportation, which is based on IoT [34]. It is assumed that all the vehicles are equipped with onboard units (OBUs), a global positioning system (GPS), and IEEE 802.11p [35]. Additionally, a roadside unit (RSU) is embedded inside the traffic signal near the highly vulnerable zone for congestion, i.e., Firdous Intersection Peshawar. The intersection that we considered in the proposed framework for traffic control is shown in Figure 3 (taken from http://www.openstreet.org).

To assess the traffic congestion at the intersection point, every vehicle frequently exchanges beacon messages with other vehicles and RSU. The RSU on intersection point

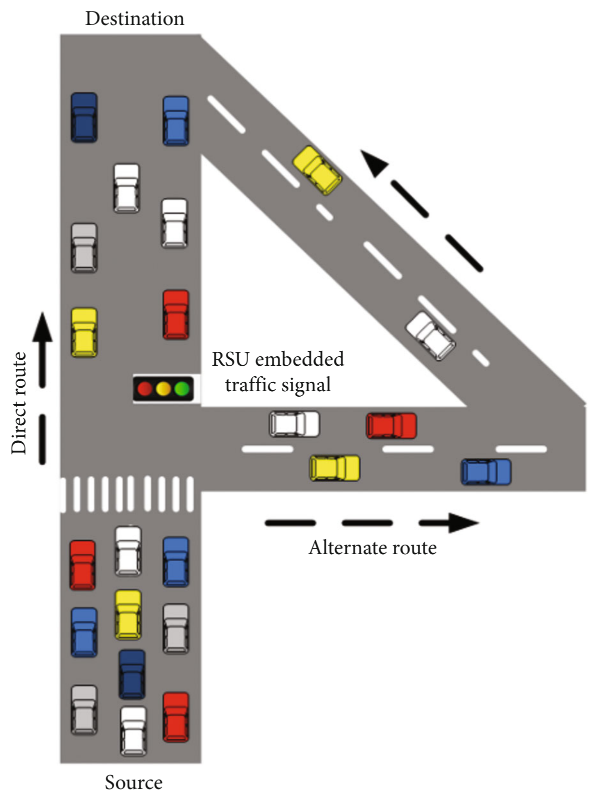

Figure 4: Proposed traffic monitoring and control framework.

estimates the vehicle density, which later uses for traffic jam detection and an alternate route selection. In the frequent beacon messages, every vehicle exchanges necessary information, including vehicle identifier, speed, direction, acceleration, location, lane number, road type, and time with other vehicles and RSU [36]. After receiving the beacon messages, an RSU turns the vehicular network into a directed graph $G(N, E)$, where N and E denote the number of cars and roads linking the junction sites, respectively. RSU creates an adjacency matrix A for a particular road map based on the received beacon messages. The following formula is used to calculate the graphical representation of a vehicular topology:

$$G = \begin{cases} JT & \text{if } \left(J_i, J_j\right) \in E, \\ \infty & \text{otherwise,} \end{cases} \quad (1)$$

where JT refers to the journey time between intersection J_i and J_j. The congestion detection in the proposed framework is considered a noncooperative game, where Nash Equilibrium (NE) [8] sets traffic for each route so that no individual can improve its performance by changing its strategy. From the system model, as shown in Figure 4, it is noticed that we have two strategies, i.e., direct and indirect. If all the vehicles use the same strategy, massive congestion will be transferred to one side of the road. Let us consider the proposed intersection point, i.e., Firdous Chowk, where a driver has two routes to reach the destination, as shown in Figure 4. The driver can go directly or indirectly. It is supposed that each route to destination (represented by I_{len}) has a fixed length and speed limit, i.e., 1 km and 40 km/h, respectively. The maximum number of vehicles NV in a high congestion scenario on each route will be:

$$NV = \left(\frac{I_{\text{len}}}{\text{Avg}_{V\text{len}}}\right) l, \quad (2)$$

where l, $\text{Avg}_{V\text{len}}$, and I_{len} represent the number of lanes, the average length of vehicle (length + minimum gap), and the length of the intersection. In the given scenario, the number of vehicles in severe congestion will be 285 by considering $K = 2$ and $\text{Avg}_{V\text{len}} = 7$ m.

Table 1: Strategy profile of the proposed intersection point.

Player 1/player 2		Player 2	
		D	I
Player 1	D	TT_{1D}, TT_{2D}	TT_{1D}, TT_{2I}
	I	TT_{1I}, TT_{2D}	TT_{1I}, TT_{2I}

Table 2: List of parameters and its description.

Parameter	Description
Road type	Intersection point
No. of lanes	2
Arrival and departure of vehicles	Poisson distribution
Arrival rate	(0-5) veh/min
Departure rate	(0-8) veh/min
Vehicle's length	5 m
Vehicle's speed	60–80 km/h
Vehicle's acceleration	(2, 3) m/s/s
Car transmission range	500 m
RSU's transmission range	1000 m
Simulation time	500 s
No. of RSUs on intersection	1
No. of traffic signals	1
Traffic signal mode	Auto
Proposed game	Nash Equilibrium
Players	Cars passing from south to north
Strategies	Direct and indirect
Performance metrics	Average total waiting time, average travel time, average speed
Propagation model	Two ray-ground

5.1. Traffic Control without Equilibrium. Suppose that 250 cars want to move from source to destination. In the absence of proper route planning, it is possible that all cars take the direct route; then, the total travel time for every car is 370 seconds (6 minutes approx.) calculated

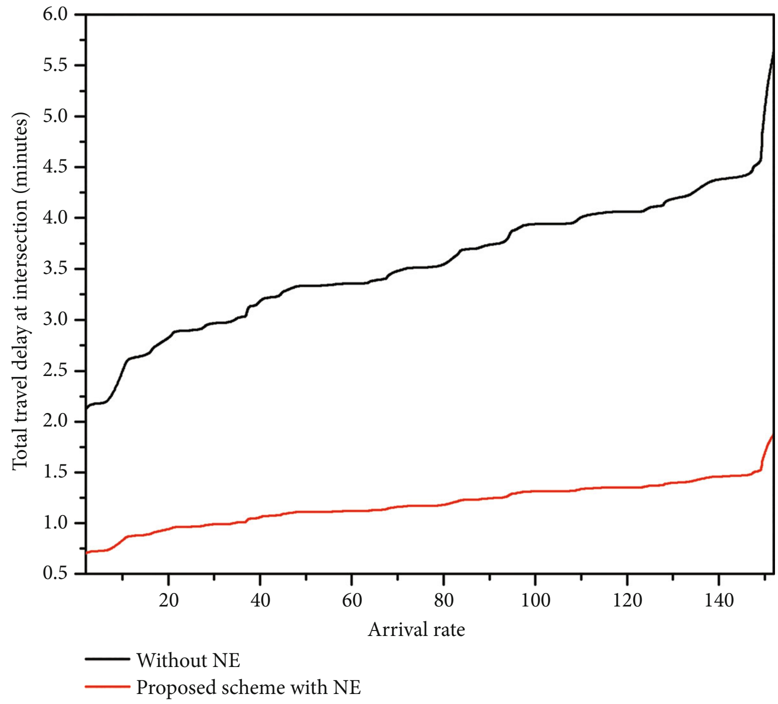

Figure 5: Expected waiting time on road intersection under different arrival rate.

by Equations (3) and (4). The same is true for the indirect route as well.

$$v_i = \left(1 - \frac{d_i}{d_j}\right) v_l, \quad (3)$$

$$TT = \frac{I_{\text{len}}}{v_i}, \quad (4)$$

where v_i, d_i, and v_l represent the current speed, current density, and speed limit, respectively. TT in Equation (4) refers to travel time. Contrarily, if the traffic evenly divides among the two routes, so that each carry 125 cars, then the total travel time on each route is $1000/12.48 = 80$ seconds.

5.2. Traffic Control with Theoretic Game Approach. The traffic control in the above scenario is a game where the opponents/players correspond to the drivers, and their route selection to the destination refers to strategies. In this paper, Nash Equilibrium is used among the opponents to improve traffic flow over the selected strategies, i.e., direct and indirect. In NE, no player/opponent will benefit by changing its current route to the other route. In the above scenario, the payoff to each player in the equilibrium case is optimal, and it degrades in the case of switching the strategy. The game in this paper is limited to two strategies. However, there are no constraints on the number of players. As mentioned earlier, any strategy in which the number of vehicles is not equal to 125 cannot be NE. On the other hand, if both strategies have similar vehicles, i.e., 125, then the given situation will be NE. We used a mixed strategy NE in the proposed framework. The traffic congestion avoidance game is shown in Table 1, where two players, i.e., player 1 and player 2, are fighting to get a good payoff.

The D and I in Table 1 refer to direct and indirect routes, respectively. Let player 1 plays D with probability p and I with probability $(1 - p)$. In addition, player 2 plays D with probability q and I with probability $(1 - q)$. The order pair (TT_{1D}, TT_{2I}) represents the probability that player 1 will select strategy D given that player 2 will select strategy I. From the mixed strategy NE game, the expected payoff of player/agent 1 is a function of player 2 individual strategies' probabilities, i.e., $u_1(D) = f(q, 1 - q)$. If player 1 best responds with a mixed strategy, player 2 must make him indifferent between D and I.

$$\begin{aligned} u_1(D, (q, 1 - q) &= u_1(I, (q, 1 - q)), \\ TT_{1D}q + TT_{1D}(1 - q) &= TT_{1I}q + TT_{1I}(1 - q). \end{aligned} \quad (5)$$

The same procedure can be carried out for player 2 payoff calculation considering player 1 strategy probabilities, i. e., $(p, 1 - p)$. Likewise, player 1 must randomize to indifferent player 2.

$$\begin{aligned} u_2(D,(p, 1 - p) &= u_2(I,(p, 1 - p)), \\ TT_{1D}p + TT_{1D}(1 - p) &= TT_{1I}p + TT_{1I}(1 - p). \end{aligned} \quad (6)$$

Thus, the given game will be mixed strategy NE, if only player 1 plays direct and indirect strategies with probability p and $1 - p$, respectively. Additionally, player 2 plays with q and $1 - q$ probabilities for direct and indirect strategies, respectively.

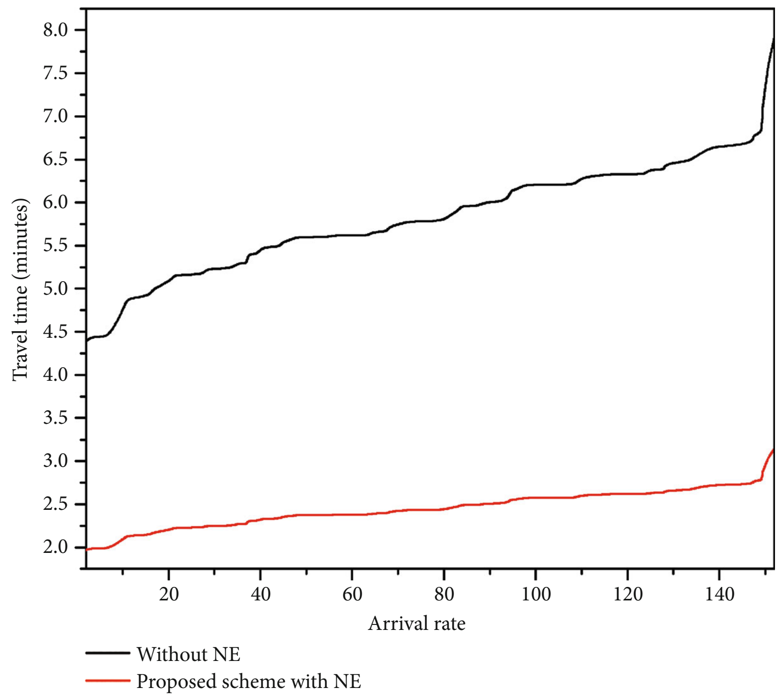

FIGURE 6: Average travel time from source entrance to destination under different arrival rate.

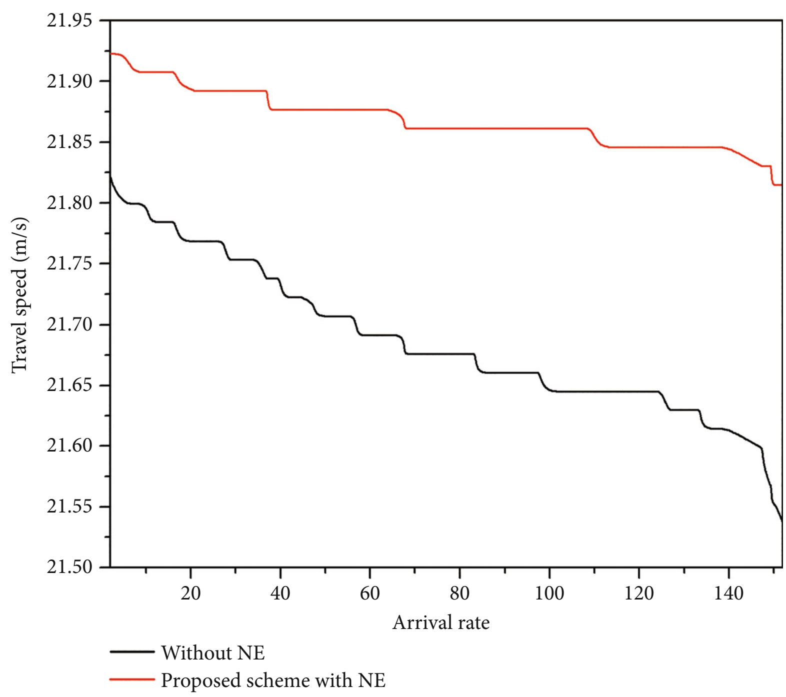

FIGURE 7: Average travelling speed from source entrance to destination under densities of different arrival rate.

6. Assessment of the Proposed Framework

We conducted various experiments to measure the efficacy of our proposed framework. The performance of the suggested framework is compared with a simple queuing model that ignores the equilibrium of vehicle flow in each direction.

6.1. Environment Setup. The proposed framework is checked and evaluated at a congested intersection where alternate paths exist to a specific destination. For this purpose, we used http://OpenStreetMap.org [37] to extract real road traces of a junction point in Peshawar city, Pakistan, as illustrated in Figure 3. The OpenStreetMap gives a complete overview of the road structures. We set the specified junction in the OpenStreetMap address bar and extracted it for traffic assessment. Later, for traffic generation and route planning, a well-known traffic simulator SUMO (Simulator for Urban Mobility), version 0.24.0, is employed [38]. The SUMO traffic traces were used as a data set for our suggested system, which was later imported to MATLAB (R2019b) for further assessment. The parameters and performance metrics that we used in our experiments are given in Table 2.

From Table 2, we have three performance metrics that are measured under various densities due to nonpredictive arrival rates. The definitions of all these metrics are taken from the queuing theory, as discussed in the reference in the context of telecommunication [39].

6.2. Results and Discussion. This section evaluates the proposed traffic model with different densities of vehicles under varying arrival rates at the intersection. Three performance metrics, namely, average total waiting time (the average waiting time of a vehicle at intersection), average travel time (the time taken during travelling), and average speed (average speed of an individual vehicle during travelling), are evaluated with different vehicle arrival rates. The relationship between arrival rate and waiting time at the intersection is depicted in Figure 5.

The line graph illustrates that the arrival rate is precisely related to the delay on the junction. In other words, the higher the arrival rate, the longer the delay at the selected junction point. However, the performance of our suggested traffic model in terms of waiting time is not adversely affected by frequent vehicle arrivals. The efficient use of NE, in which players select an optimal path based on the activities of other players, is the cause for the resilience against the high arrival rate. The effectiveness of NE can also be verified by looking at the results of a typical traffic model (without NE), where frequent arrivals have a substantial impact on the waiting time at intersections (see Figure 5). Now look at the performance in terms of travel time, we can see in Figure 6 that our proposed method outperforms the traditional scheme.

The proposed traffic controller takes 2-2.5 minutes to reach the destination after leaving the intersection at a given speed. Because the proposed framework correctly handles traffic on all possible routes, the number of vehicles on any given road segment is insignificant. As a result, travel time is not affected like other conventional schemes. Again, the traditional method performs worse than the suggested traffic control scheme, with a maximum arrival rate of 7 minutes. Finally, the travel speed is evaluated in relation to various arrival rates at the intersection point. Figure 7 depicts the speed of travel from the source entrance to the destination. It can be shown that the arrival rate is inversely related to speed. As a result, increasing the arrival rate reduces the speed of cars, as shown in Figure 7.

7. Conclusions

Smart transportation is an advancement in the conventional transport system which improves quality of public life by providing optimized services and enhances the sustainability of urban cities. The realization of smart transportation has enormous challenges and consequences. The metropolitan city Peshawar is the capital of Khyber Pakhtunkhwa province in Pakistan, one of the most populated city of the region. The current status of public transport in Peshawar is deplorable.

The transport department faces many challenges to support this rapid growth, especially in public transit. Some routes in Peshawar are highly vulnerable to massive traffic jams, which leads to various issues for students, employees, and patients striving to reach their destination without delays. IoT-based smart transportation is the need of the day to cope with massive traffic jams. It optimally assesses the traffic density, detects congestion, recommends appropriate speed to the drivers under various circumstances, and resolves the congestion by discovering an alternate route to the destination. The proposed framework in this paper not only reduces the travel time to the destination but also reduces fuel consumption and environmental pollution. The proposed framework uses two players' games. In the future, we will consider multiple player games aiming to reflect the highly congested traffic scenario effectively.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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