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An Intelligent Road Traffic Signaling System Based On Vanet

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ABSTRACT

The Road Traffic Data System is a crucial component of the highly developed transportation network of today. By feeding it real-time data from a variety of road sensors and vehicles, a wide area controller can improve traffic flow, trip time, and safety for road users. The VANET architecture provides a reliable foundation on which to construct a cutting-edge signal-control system. A unique VANET related road traffic signalling model is implemented, which has the potential to significantly improve traffic flow, fuel efficiency, and safety for drivers on the road. There is now a functioning VANET because of the utilisation of a decentralised architecture and distributed networking. We introduce a VANET-based Smart Road Traffic Signaling System in the initial section of this study (IRTSS). Preliminary results from a simulation model built on the OPNET framework are shown here. Simulations show that the proposed architecture can successfully manage traffic loads on an 802.11p enabled VANET network.

I. INTRODUCTION

Overcrowding, accidents, and pollution from vehicles and factories have all contributed to a degradation in the quality of life in the world's major cities. Through the use of a sophisticated traffic monitoring system, we can lessen traffic, improve commute times, and cut carbon emissions. Meanwhile, the arrival of next-gen electric vehicles may provide a significant chance to implement automated traffic signalling systems to enhance road safety. An autonomous technique that relies on real-time signalling could take over an electric vehicle's control system, negating the need for the driver's response and decisions in some situations. Use the enforcement of a speed limit in a school zone as a simple example [1]. For example, a controller output may provide efficiency indicators over the VANET, and the car's control unit could use this data to maintain the driving behavior inside the zone's limits. Similarly, a VANET-based signaling system [2] can be used by vehicular networks to impose varied road surfaces in elevated zones or during severe weather. When it comes to road vehicles, a VANET-based framework can analyze the information to optimise signals, cycles, timing, and other process variables based on variables like the number of vehicles on the road, their destinations and routes, the modes of transportation they use, and the times of day when they are another very likely to be in motion. It will enhance traffic flow and fuel economy if people can keep their cars turned off for shorter periods of time.

We present a Vehicle-to-Infrastructure (V2I) oriented road traffic control system which uses a wide-area network (VANET) to collect data on traffic conditions from personal cars and then uses this data to dynamically change the timing of traffic signals. Some high-traffic sections of the city use roadside sensors to predict traffic arrivals using existing road traffic signalling system, albeit these only provide a partial view of the traffic situation overall. Considering the high cost and complexity of integrating such systems into preexisting infrastructure, it would be impossible to implement them in all large cities. We propose a method that employs VANET infrastructure to gather and disseminate regional traffic data to nearby signalling nodes in order to reduce traffic congestion, commute times, and carbon footprints. The main advantages of an IRTSS based on a VANET are that I little in the way of infrastructure is required, so there is no need for road monitors to assess traffic flow, ii) systems can be expanded to accommodate larger populations, and iii) many different options exist for distributing and sharing road traffic data. We show that it is possible to use a VANET-based IRTSS to manage traffic at a single road intersection, and that this architecture can be scaled up to control traffic in a much broader region.

II. LITERATURE SURVEY

One of the main goals of an IRTSS is to keep traffic moving freely and without interruption along a network of roads and intersections. When it comes to adapting to changes in traffic volumes, route topologies, and other time-based events, a having the skills traffic system can act far more swiftly than a conventional road traffic system.

The present generation of IRTSS controls traffic by modifying the light cycle, timing, and sequence. There isn't just one way to assign cars to streets, but several, including some that are time-based and others that use complex algorithms guided by live traffic data. The universally accepted traffic signalling cycle consists of three phases: green, amber, and red. Various signalling stages may be implemented depending on the road configuration and the permissible traffic movements at crossings. The control logic decides how much time should pass between each stage. This, at least, is what the DC Department of Transportation claims.

The actions a traffic controller takes in response to oncoming vehicles at an intersection depend on the specifics of the situation. This class of technologies includes either static and dynamic approaches to managing traffic lights. Isolated intersection management, arterial regulate, and network control are all methods used in traffic management at intersections. The ability to adjust to changing traffic conditions in real time is a crucial aspect of any ITC system, and this is where adaptive signal control comes in. The construction of an adaptive traffic signal system is complicated by the need for real-time detection and estimate of traffic.

Earlier attempts on the testing method of congested traffic in smart transportation systems have typically relied on WSNs, RFIDs, V&I processing, and loop detector [4]. In reference [5], an adaptive approach for using a wireless sensor network to track traffic and identify moving vehicles was described. The intersection control agency (ICA) was given information about the road's conditions, such as the number, speed, and length of vehicles, in order to set the adaptive traffic lights in the most efficient order. We used an open-loop system to measure the system's efficiency. The wireless sensor network collected information on traffic patterns and delivered that information into the traffic simulator. It was suggested (in reference [6]) that RFID tags be affixed to vehicle in order to count the number of automobiles on each road in order to build a smart road traffic signalling system. The traffic and vehicle information will be kept in a dynamic database under the control of a centralised computer system, and will be sorted by VIN (VIN). The computer model can be adjusted to take into consideration variables such as vehicle type, priority of vehicles, time during the day, and more. There was no evaluation of the RFID-based adaptive traffic-signal system's effectiveness in the published work. An RFID-based approach is quite like the current e-tag system, but it requires extensive roadside infrastructure to collect data from vehicles.

A system for adaptive traffic signal management is proposed, with the help of machine learning and the help of reference [7]. Each traffic light's ideal phase has been calculated using a road-user based function, which takes into account the preferences of waiting drivers. Using the proposed strategy, motorists may now choose the route with the least amount of waiting time. If everyone follows the very same route to work, traffic jams could result. A VANET-based Direction Clustering method was developed for this purpose in reference [8]. (DBCV).

. Using a variation on Webster's equation, this model optimises the adaptive signalling phase of vehicle-to-vehicle (V2V) communication. If a significant number of vehicles were to converge at once, the transmission range would be insufficient. The cited publication [2] suggests using a wireless sensor network to recognise real-time traffic data, make decisions in green light sequence, and determine the length of a traffic light. The primary goal of this work was to develop an analysis approach for the required intelligent traffic light phase method, which would cut down the average wait time and the number of pauses along the route. The communications infrastructure design requirements for deploying the approach were not specified in the cited paper.

A radical departure from prior VANET-based work is represented by the proposed IRTSS algorithm. When deployed over a VANET, the IRTSS provides enhanced choices for managing traffic on roads. A potential benefit of an IRTSS is its potential to cut down on pollution and gas consumption by improving traffic flow. A new traffic estimation approach compliant with the 802.11p design has been developed to aid in the implementation of an adaptive signal control system at intersections. Vehicle arrivals from many lanes are tracked, and the scheduling of the intersection's traffic signals is adjusted, thanks to this model's use of the VANET's vehicular (V2I) communications mechanism. An OPNET-centric co-simulation model integrates an adaptive signalling system model, a vehicle mobility model, and a communications system model onto a single control platform to represent real-world scenarios.

III. PROPOSED METHODOLOGY

Short-range communication between mobile nodes and between mobile nodes and roadside infrastructure provider are the primary goals of the Mobile Ad Hoc Network (MANET), a subclass of the broader sophisticated Mobile Ad Hoc Network (VANET). There is a subclass of the MANET that includes the VANET. Typically, vehicles will have On Broad Units (OBU) (IEEE802.11p core units) installed, while stationary communication equipment will be referred to as Road Side Units (RSUs). Wireless local area network (WLAN) standard IEEE802.11p was created to improve WAVE (wireless access in a moving vehicle). For reliable vehicle-to-vehicle and vehicle-to-infrastructure communication, look no farther than this standard, also known as Dedicated ShortRange Communication (DSRC). The DSRC is authorised to use 75 MHz of available band at 5.9 GHz. Both the IEEE 802.11a and IEEE 802.11p standards share similarities in their physical layers. Of course, OFDM (Orthogonal Frequency Division Multiplexing) technique is used in both cases, but the channel width for DSRC applications is now just 10MHz instead of the original 20MHz. Because of the fluid nature of the routing protocol, this choice was made to mitigate the risk of delay propagation. There are seven channels using the 75 MHz of available bandwidth; one is the control channel (CCH), and the other six are utility channels (SCHs). Roadway security

The CCH is employed to send massages, while the SCHs are put to use sending out information about applications. Four distinct data classes are supported by both the CCH and the SCHs, each of which has its own priority according to the normative specifications. In some cases, the maximum allowable data transfer rate may be as high as 27 Mbps. Broadcast data is transmitted using the CCH. Unicast communication over the CCH necessitates the inclusion of the recipient's address within the media access control (MAC) frame. Two service channels can be combined into a single 20MHz channel, increasing the possible data transfer rate to 54Mbps. Downlink and uplink power levels should be kept below 33 dBm for optimal performance.

It is important to note that the distributed coordination function is the backbone of the packet transfer used by the IEEE 802.11 standard (DCF). The carrier sense multiple access collision avoidance (CSMA/CA) technique is used to facilitate the random access method for BSS devices. The DCF can keep the ad hoc network running even if there is no access point or other necessary infrastructure. In order for systems like the intelligent road traffic mechanism to function, the VANET must be able to cope with the constant flow of vehicles (IRTSS). Vehicle speeds typically range from from 40 to 80 kilometres per hour (km/h) in a city's road system. The IRTSS operates within reasonable latency restrictions, making it an excellent choice for city traffic. A car travelling at its utmost speed in a city with a data packet delay of one second can only travel 22.22 metres. That's the farthest you can travel. Consequently, it is not completely out of the question for a VANET-based system to reliably collect traffic data by employing the OBU in each car. In the following paragraphs, we'll go into greater detail about the VANET's performance analysis. One of the most difficult aspects of the IRTSS design is managing the total amount of channel traffic. Therefore, this action is required to preserve QoS. A simple idea was used to create this elaborate system. The RSU is a piece of road infrastructure that, when connected to a communication network, sends out signals and other traffic-related data on its downlink at regular intervals. The on-board unit of a vehicle is able to exchange data with the RSU via an uplink, which includes details like the vehicle's identification number, kind, and destination/route. Through its IEEE802.11p uplink connection, the OBU is accountable for the transmission of data packets. The traffic analysis computer receives data from the RSU and uses it to adjust the settings of the traffic lights. The RSUs in a WAN-based traffic control system are linked via a backhaul so that they may exchange data and coordinate operations.

i) Network interaction

Using a communication architecture like the one shown in Figure 1, the suggested IRTSS could effectively monitor and control a wide area. The system relies on the standard design of the DSRC's V2I communication programme, which is based on a network of RSUs and OBUs linked together via Ethernet. The system depends on this sort of structure to function. Each RSU can communicate with all automobiles that are nearing a junction within a range of 500 metres, thanks to the cell's coverage area. Each RSU has a cell coverage range of 500 metres, allowing all vehicles nearing a junction to talk to the RSU. Based on the traffic data it has received via broadcast packets, the RSU will provide the necessary signalling information. At any road intersection, includes crossroads and T-junctions, RSUs can provide traffic signalling data to OBUs. Any four-way stop can serve as a transmission point for such data. The OBUs built into the car's navigation system will send the driver information, and the driver will have to act on that information.

Each RSU in a wide area signalling method carries information from its neighbours, including the number of projected approaches from other junctions, and uses this information to calculate the extra traffic at each junction. The local RSUs exchange this data with one another. As RSUs are able to regulate the range of each cell's communications, they may anticipate traffic and gather relevant data in advance. When compared to the existing loop-based systems, the proposed concept offers a huge improvement in terms of both sophistication and flexibility.

ii) Method of signal

In the ensuing flow, we see how the RSU and OBU communicate and perform their massage exchanges in accordance with their underlying operational principle. To create the model recommended for use with the IRTSS, we considered not only the mobility of vehicles but also the characteristics of the network itself as it operates. The RSU transmits signalling information based on calculated and observed data on impending traffic flow. As part of the RSU procedure, a one-of-a-kind optimization approach has been implemented to adjust the timespan of the adaptive signaling pathways.

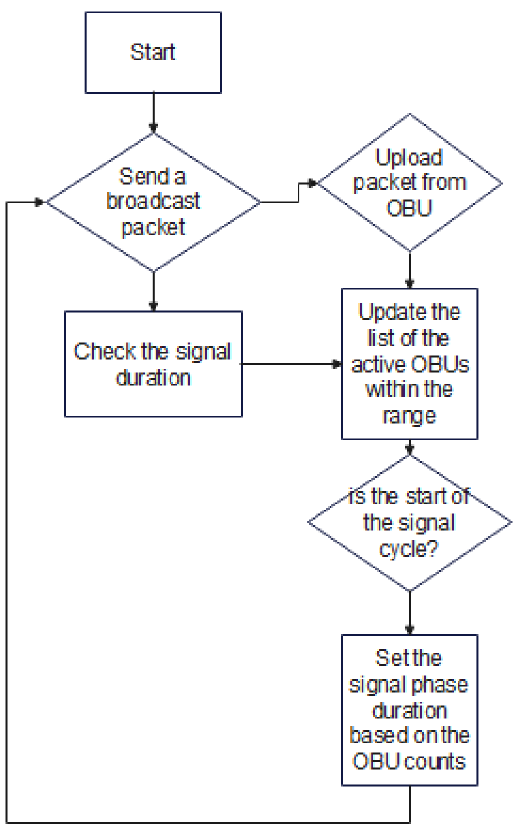

Fig 1: Diagrammatic representation of the method used in the RSU for the adaptive broadcasting of road traffic signals

As soon as an OBU enters the RSU's coverage area and obtains that the very first signal from the RSU, it begins trying to send unicast texts to the RSU that relates to it at a regularity of once each five seconds to keep the RSU apprised of the OBU's exact velocity, position and approximate arrival time at the interplay. Every five seconds, the RSU refreshes the list of running OBUs in the range and transmits the current traffic signal state to all OBUs. The RSU also updates its database of operational OBUs once per second. If an OBU knows how much time is left in the current signal phase and how much time is left before it reaches the intersection, it can predict whether it will be in the GREEN, AMBER, or RED signal stage when it reaches the intersection. This allows the OBUs to respond appropriately, such as by adjusting their speed based on the data or keeping it constant.

The length of time that can be spent properly accelerating and breaking was factored into the construction of the signal cycle. Optimal signal durations in an adaptive IRTSS might be challenging to achieve because of the many factors that must be considered. The rate of vehicle arrival, the density of cars, and the saturation flow are all relevant variables. Our model optimises for the number of vehicles approaching a junction from each of the four directions by adjusting the duration of the signal phase timings. All four possible traffic flow directions—eastbound (EB), westbound (WB), southbound (SB), and northbound (NB)—have been labelled. East Bound (EB), West Bound (WB), South Bound (SB), and North Bound (NB) are all abbreviations for directions (NB). In the following paragraphs, I will describe the process by which this system operates.

There is a two-phase signalling mechanism built into the planned IRTSS. The internal phases of each phase are color-coded green, amber, and red (P1 and P2). The critical lane volume, denoted by Z1, is determined by the RSU based on a combination of eastbound (EB) and westbound (WB) traffic counts. The critical southbound and northbound (SB & NB) lane volume is also measured and denoted by the symbol Z2.

The phase durations of our proposed ITRS are calculated using Eqs. 4 and 5. These equations represent the relationship between the length of the green signal (G1) and the length of the red signal (R1) during phase P1. Similarly, in phase P2, the periods G2 and R2 are color-coded green and red. The saturating headway (s) is the distance between vehicles in a steady-moving platoon, and Lt is the time lost (including the start-up time). When joined to the red time frame, the yellow interval makes up the new red time frame.

$$R_1 = G_1 + Y$$

$$R_2 = G_2 + Y$$

However, if the critical lane capacity disparity is very large, the less critical lane timings value will suffer from long wait times at the intersection due to the model's assumptions. Because the model anticipates increased traffic through the crossing, this occurs. From implementing these equations in the OPNET simulation model, we learn that vehicles in the critical lane with the smaller share have a high average waiting time if the traffic volume of any critical lane reaches 75% of the total traffic flow of all critical lanes. This is because lanes with higher vehicle flow concentration need green lights for longer periods of time before additional automobiles can move through the intersection, while lanes with lower vehicle flow density must wait till the intersection is clear before moving. To solve this problem and make sure that different lanes with varied flow volumes wait the same amount of time on average, a new technique of determining phase duration was implemented. If 75% or more of traffic volume is moving via a critical lane, the revised green time is calculated using the following formulas.

IV. SIMULATION AND RESULTS

The simulation model was executed with various vehicle flow densities coming from a variety of directions, and this was done for both the fixed and the adaptive signal cycle scheme. The number of vehicles that arrived at the intersection where the vehicle flow density was 400 vehicles per hour in the east-west direction and 200 vehicles per hour in the north-south direction .This results shows the average number of vehicles that arrived at the intersection. These statistics on vehicle flow were measured with the help of the OBU RSU architecture, which was detailed in the part before this one. The theoretical traffic volume that we choose to use for the analysis is equivalent to the traffic value that was generated by the simulation.

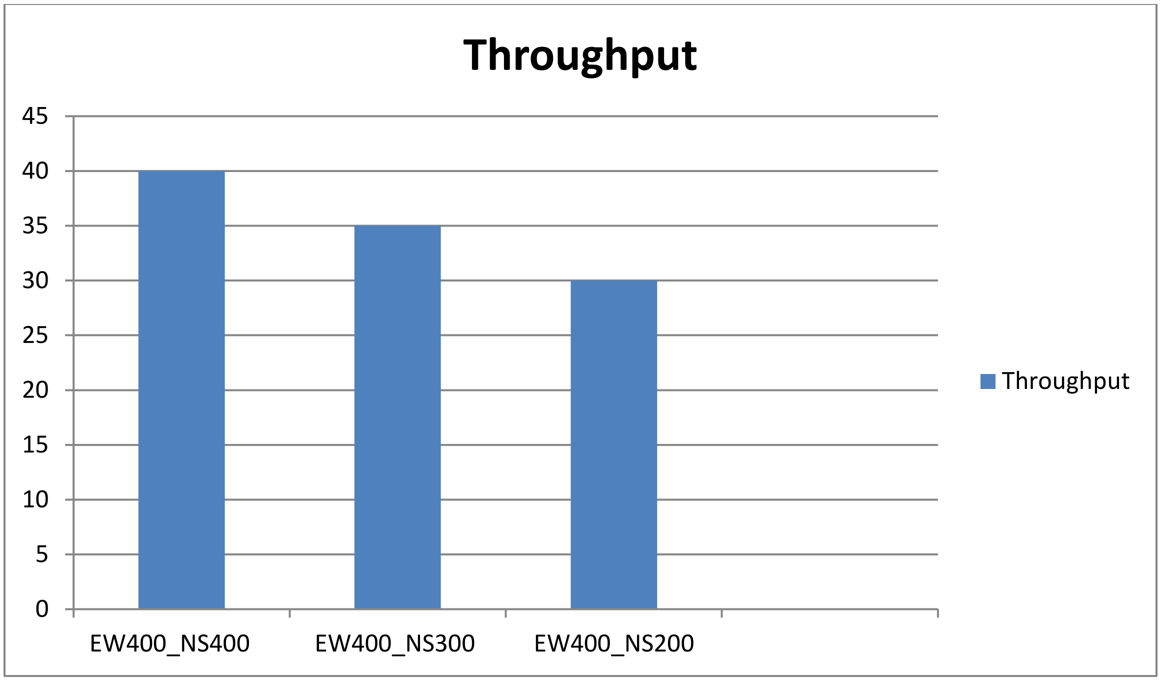

Fig 2: The average throughput of the network for the various vehicle flows

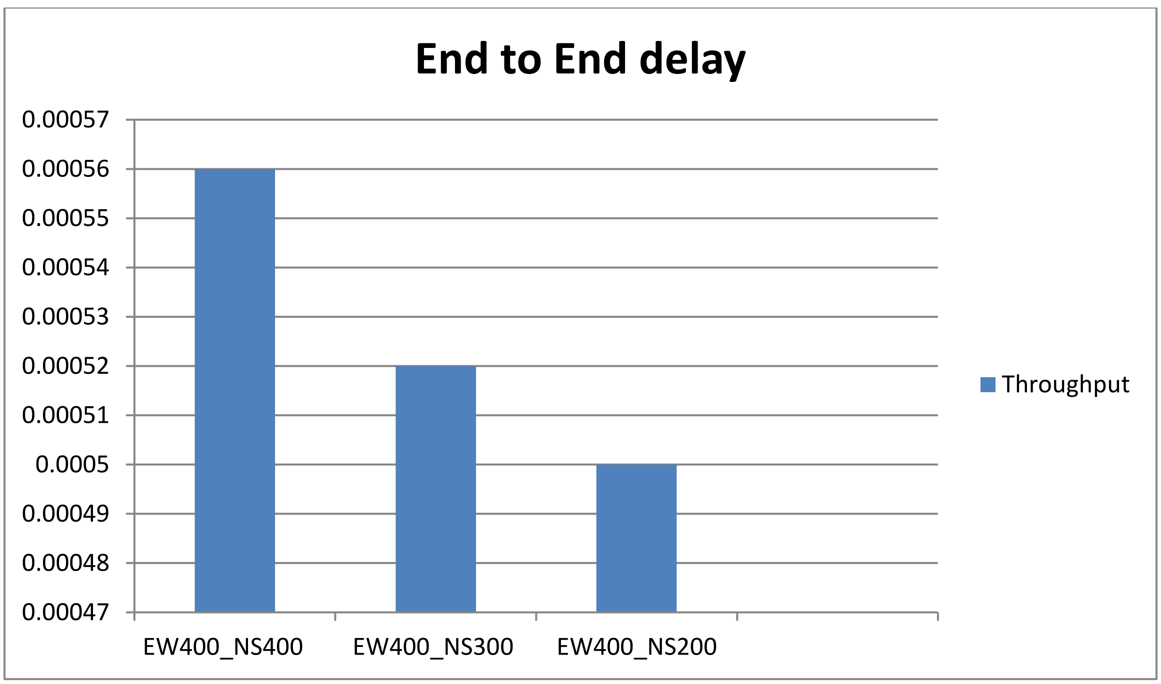

Fig 3: standard deviation of the network throughput for the various vehicle flows

The both fixed as well as the adaptive signal cycles systems were tested in the simulation with a wide range of vehicle flow densities from a number of directions. Amount of traffic that entered an intersection with a north-south flow density of 200 cars per hour and an east-west flow density of 400 vehicles per hour. The average daily traffic volume at the crossroads is depicted here. The preceding section described the OBU RSU design that was used to collect the data on vehicle flow. The simulated traffic volume is equal to the theoretical volume we utilise for the analysis.

Because of the importance of being capable of quantifying the amount of time waiting at a four-roads junction when arguing for the efficacy of a VANET-based IRTSS, we opted to use an adaptive traffic signalling light to measure the amount of time having waited at the intersection. The RSU uses the VANET to collect information about vehicles entering and exiting intersections so that it can predict the flow of traffic and coordinate the timing of the lights. The average time spent at the intersection waiting for traffic to stop. In this analysis, we compare how long cars waited when they followed the adaptive light sequence with how long they waited when they followed the fixed light sequence.

The adaptive algorithm could be biassed in favour of a particular path if it turns out to be the best course of action. No matter the direction of travel, the signalling system must treat all vehicles equally.

Table 1: Index of fairness

Flow density	Fairness Index
EW400 NS200	0.997
EW400 NS300	0.994
EW400 NS400	0.992

Table 1 also includes the measured fairness index values that were derived from the adaptive signalling model for various vehicle flow densities. By comparing wait times across routes of traffic flow and calculating a fairness index, the table reveals that all routes of traffic flow receive very similar service.

After this little break, we'll return to talking about how efficient the VANET is. The average VANET network throughput shown in Figure 2 shows how many vehicles per square mile are needed to sustain the packet exchanges of the RSU and OBU. An area 500 metres in circumference is within the RSU's range of transmission. The OBU is required for reacting to broadcast packets, as was mentioned earlier. The uplink throughput has grown as a result of the growing number of OBUs within transmission range as a consequence of the increasing volume of moving vehicles. It's probable that as uplink traffic volume grows, so does the level of congestion, leading to a longer link delay. Figure 3 displays an example of an average uplink packet delay. The VANET is able to keep the end-to-end delay within a manageable range, which is critical for the provision of traffic data even when vehicle flow densities increase. Due to the shared nature of the uplink and downlink channels, the latency of one or the other can impact the delay of the packets travelling uplink. Since we wanted to limit the amount of time users spent waiting for data, we restricted the amount of traffic flowing down the wire.

V. CONCLUSION

In this piece, we take a look at a fresh new intelligent traffic signalling system built on VANETs. The smart traffic light employs an adaptive signalling plan that helps use of real-time traffic estimation to maximise the efficiency of the signal durations. The traffic light system uses this configuration. The IRTSS was created using a very basic VANET layout as its basis. More work needs to be done on the model before a region-wide traffic management system can be implemented. Each OBU in the broader area traffic management system will be linked to every other OBU through a permanent backbone network. By doing so, traffic data from a wide area may be relayed to all OBUs, leading to a more efficient system for managing traffic flow. And because of the wide area network, OBUs will indeed be able to find out where vehicles are headed. In order to reduce traffic congestion, OBUs could use the destination data to do computations that estimate the load on different highways and, if necessary, power allocation traffic on other roadways. A traffic control technology suitable for such a broad area is now being built by the research team in anticipation of future development.

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