Al-Nahrain Journal for Engineering Sciences **NJES** 28(4)606-614, 2025
http://doi.org/10.29194/NJES.28040606

A Virtual Platform to Solve Baghdad's Traffics Jam Based on IoT

Hanaa S. Basheer

Authors affiliations:
1) Institute of Laser for Postgraduate Studies, University of Baghdad, Baghdad- Iraq.
hana@ilps.uobaghdad.edu.iq

Paper History:

Received: 5th Mar. 2025

Revised: 15th Apr. 2025

Accepted: 12th May 2025

Abstract

In Urban cities, services are supported by intelligent applications and are connected to each other through ad hoc networks. Any service can be operated using a compatible of an Internet of Things (IoT) technology. This study focuses on the transportation service and finding a non-cost solution to solve the crossroads congestion that affected people time and money. The Wireless Sensor Networks (WSNs) that are planted on the roads can help in monitoring the roads situation by collecting their data and send them through wireless communication to a traffic management center. In this work two phases of time are considered for a crowded area. Low-cost components are suggested to solve the congestion at the cross roads without the need for reconstruct the roads. IoT device such as smart phone can be wirelessly connected to the Traffic Management Center (TMC), which can analyze the incoming data from WSN and send back the calculated time to the police officer to control the green light long and overcome the standard time installed for all directions. The main idea is to solve the congestion problem in real time by extending the time long of the green traffic light for the road direction with the highest vehicle density. The suggested algorithm was operated on a dataset of 6 days and for the time phase from 7:00-10:00am.

Keywords: IoT, WSN, TMC, LDR

إنترنت الأشياء والشبكات المخصصة لحل مشكلة الازدحام المروري في المدن الحضرية: دراسة حالة على احد طرق بغداد

هناء سامي بشير

الخلاصة:

في المدن الحضرية، يتم دعم الخدمات بواسطة تطبيقات ذكية وترتبط ببعضها البعض من خلال شبكات مخصصة. يمكن تشغيل أي خدمة باستخدام تقنية إنترنت الأشياء (IoT) المتوافقة. ان هذه الدراسة تركز على خدمة النقل وإيجاد حل غير مكلف لحل ازدحام مفترق الطرق الذي يؤثر على وقت واقتصاد المجتمع. يمكن لشبكات الاستشعار اللاسلكية (WSNs) المزروعة على الطرق أن تساعد في مراقبة حالة الطرق من خلال جمع بياناتها وإرسالها عبر الاتصال اللاسلكي إلى مركز إدارة المرور. في هذا العمل، تم تقسيم الوقت الى مرحلتين زمنيتين لمنطقة مزدحمة. تم اقتراح مكونات منخفضة التكلفة لحل الازدحام عند مفترق الطرق دون الحاجة إلى إعادة بناء الطرق. يمكن توصيل اي جهاز مثل الهواتف الذكية لاسلكيًا بمركز إدارة المرور (TMC) والذي يمكنه تحليل البيانات الواردة من WSNs وإرسال الوقت المحسوب إلى ضابط الشرطة للتحكم في إشارة المرور. الفكرة الرئيسية هي حل مشكلة الازدحام في الوقت الفعلي عن طريق تغيير وقت إشارة المرور الخضراء الخاصة بالاتجاه الاكثر ازدحاما وتخطي كون الاشارة تتغير بنفس الزمن لجميع الاتجاهات. تم اختبار الخوارزمية المقترحة على مجموعة بيانات تم جمعها في ٦ أيام خلال الفترة الزمنية ما بين ٧:٠٠ إلى ١٠:٠٠ صباحاً.

1. Introduction

Internet of Things (IoT) can be defined as connected devices supported by several established technologies to be suitable for wireless communication network. IoT technology is "everything talks with others in an intelligent & automated manner to gain human beneficiary". The IoT consisted of different devices to exchange data between then and between the cloud, so that the websites can dynamically adjust content based on data collected from IoT devices. The IoT can process different applications to analyze a collection of information, make a decision, and send back a solution [1]. IoT is one such technology that enhanced the ITS domain by enabling the seamless

NJES is an **open access Journal** with **ISSN 2521-9154** and **eISSN 2521-9162**

communication of devices and applications in real-time. IoT has the ability to determine the behavior of IoT devices and evaluate them to give the right solutions for the world [2].

The trend these days is to support the devices that are connected through ad hoc network by different types of WSNs to gain (energy-efficient) which known as 'green communication' that helps in making intelligent decisions. These devices are referred to as Green IoT devices. The main goal of the government is to improve the performance of the IoT technologies and ad hoc networks to develop and auto control users' services in the smart cities. One of the important services is the Intelligent Transportation (IT) that aims to improve road safety and allows comfortable travels [3].

IoT traffic management system with the WSN can help in monitoring the roads flow although watching roads 24 hour a day is a hug matter. This leads to thinking of dividing the day time into two phases. The first phase is the rush hours' time when the roads are highly congested and another phase is when the roads flow is normal. IoT technologies and ad hoc network can support a solution immediately for vehicles traffic congestion in large cities.

The smart transportation service is one of several IoT applications that consist of many connecting things such as sensors, cameras, and onboard vehicles' appliances. As mentioned in [4], the interlaced role of technologies and goals needs both smart and digital projects and actions to realize a better city for people. Smart transport and Mobility consist of many components such as; bike schemes, real time bus, timetable information, and electric vehicle car.

WSN along area segments are used to control the traffic flow in roads, obtaining information such as vehicle density, speed, etc. Sensor nodes at road intersections are helpful in making decisions on how to control traffic based on the information provided by the sensor nodes along the road. Sensors are placed before the traffic lights, possibly one per lane, to find out the number of arrivals at the intersection from each road direction. Although sensor nodes can also be placed after the traffic lights and made a comparison with the number of departures [5].

Many techniques were introduced in a comprehensive review [6]. These techniques used image processing and computer vision, video camera for traffic monitoring applications. The applications provide necessary traffic flow information efficiently. The video camera is supplemented by modern technologies including computer graphics, state-of-the-art cameras, high-end computer functions, and automated video analysis for traffic monitoring. Drones' applications were involved for solving transportation engineering problems [7]

A literature focused on finding the best location of the sensors used in vehicular traffic networks. Some of the proposals they mentioned were based on the use of Evolutionary Algorithms (EA) to obtain the optimal sensor locations. The study showed the use of Particle Swarm Optimization (PSO) in WSN to optimize and locate the sensors in specific places to cover, connect and save energy efficiently. This optimization technique is common because of its simplicity, high quality of solutions, fast convergence, and insignificant computational burden. On the other hand, using PSO requires large amounts of memory and that they might not be suitable for real-time applications [8].

Many other works were introduced for the same interest although they either not taking the police officer safety into consideration or they used expensive devices that have to be installed on the area. The authors in [9] thought about using graph coloring based technique to model and control intersection. The green light of the traffic only enabled a lane within a phase in Cross intersection while other lanes were disabled with red lights. Also, whenever a lane is enabled, other lanes can move free on red.

A method was proposed to reduce traffic congestion using roadside units (RSU) and basic safety messages and probe vehicle data to accurately monitor vehicle presence and status. The study aimed to enhance traffic flow and safety within the autonomous driving era [10].

The authors in [11] mentioned in their article that the future of intelligent transportations will depend on the new technologies such as artificial intelligence, machine learning, Internet of Things, and 5 G connectivity. The advantage of these technologies is facilitated the real-time data collection, analysis, and decision-making for maintenance of transportation infrastructure. Moreover, the data generated by IoT sensors, and other IoT devices and applications will affect the behavior, and infrastructure performance. Safety remains the goal, so exchanging real time information of the roads' situation can be with benefit to future IT safety.

One of the new ideas is to use the artificial intelligent AI with the digital maps of an area to optimize traffic signal durations. For this goal, a proposed work used penalty-based traffic signal management algorithm combining jam factor data from HERE maps with a time allocation algorithm. This work claimed that in this way it can decrease the CO2 emissions, journey durations, fuel consumptions intersection queue length, and vehicle waiting times. These improvements enhance the environmental sustainability of urban centers [12]. A measurement for travel performance was studied to show how congestion affect the moderate and linear impact on travel delay. The study in [13] discussed the charging rule for using specific roads where in urban transportation the absence of road congestion pricing has small returns due to highly elastic demand. This study gave an approvement for how successful the Peak-hour pricing may help correct other externalities. IT and IoT traffic management system offer many solutions in daily live; it can remotely monitor and control the overall system. Therefore, IoT technology-based on IT simplifies the daily tasks of humans, supporting the transferring with automobiles to be a safe environment and more secure and provide greater peace of mind in the roads.

This work aims to overcome traffic congestion at the crossroads junctions by reducing long time delay waiting for the traffic light. The main challenge is to find a best traffic signal configuration schedule that maximizes the traffic flow in a network. This issue can be determined by finding an ideal waiting duration for each traffic signal; this can be done by monitoring the crossroads, analyzing traffic history information, and overcoming the limitation of traffic signal components. The scheme is designed to be implemented at the crossroad junctions, where a counter is placed to count the vehicles using a simple but effective, non-cost Light Dependent Resistor (LDR). Moreover, system can be applied without a need for any additional infrastructure.

(LDR) is One of the simplest components, which is a passive electronic component that changes its resistance according to the intensity of light that falls on its surface. LDRs are made of semiconductor materials that have high resistance in the dark and low resistance in the light. LDRs are widely used as light sensors in various applications. Figure 1 shows the symbol that is used to determine LDR, where the two arrows indicate the direction of light falling on it [14].

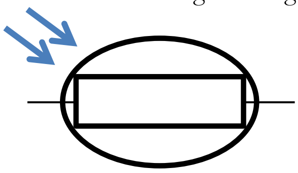

Figure (1): LDR symbol

The rest of the paper is organized as follow. In section 2 many related works that toke Baghdad's roads situation into consideration. Section 3 shows the work motivation and section 4 gives an idea about the objective of the work. The motivation to start this work is illustrated in section 5 and finally section 6 and 7 presents the work suggested algorithm and the work conclusion respectively

2. Previous studies for different areas in Iraq

Many works were considered the crowded roads in urban area of Bagdad the capital of Iraq with different suggested solutions, but none of them take well thought of using the new technologies of IoT to solve road congestions. Since this work is studying Baghdad roads, works with the same interests will be reviewed in this section. Baghdad roads are still not equipped with Road Side Unites (RSUs) devices, meaning that there is no auto connected between the internet and the vehicles. Counting moving vehicles can be done only from the cameras around. The proposed work in [15] based on Smart Traffic Analyzer (STA) software to figure the traffic volume and vehicle movement data that showed by the videotapes. The authors thought of dividing the time into two phases (morning and afternoon) and get data from days with normal situation. Then they suggested changing the road structure with a new design.

The authors in [16] proposed a system with three modules: the intelligent visual monitoring module, intelligent traffic light control module, and the intelligent recommendation module for emergency vehicles. Each module had its own purpose and they work together to improve the flow of vehicles. This work considered al Sader area / Baghdad / Iraq which have many cross roads. In the approach, the congestion and traffic flow were controlled by calculating the score of the highest priority across streets for traffic light control configuration. The proposed control module used Particle Swarm Optimization (PSO) algorithm and the result shows that the optimization ratio was in range of 86% to 91.8%.

The transportation system in Iraq faces major challenges, as it has not adopted a strategy to implement the intelligent transportation system, where its infrastructure has been worn out, and a structural map has not been developed to determine the courses of action of the intelligent transportation system. Add to that the lack of funds needed for such project. Zbar in his poll with the officer in the Baghdad traffic Directorate has figured that there are many problems facing the transport sector in Iraq, some of the unsolved problems are mentioned in the last column (paragraph). [17]

Table 1: problems of transport sector in Iraq and the available of the smart applications [17]

Problems	High	Middle	Low	Paragraph
Crowded Congestion	X			Un solved Problem
Traffic accidents		X		Un solved Problem
Length Of Emergency Response		X		Un solved Problem
Pollution Level	X			Un solved Problem
Smart Applications	**Available**	**Partially Available**	**Not Available**	
Electrical Traffic Movement Management			X	
Situation Management and Control			X	
Transportation Demand Management			X	
Emergency Vehicle Management Devices		X		
Automated Safety Inspection Devices			X	
Electronic Counters			X	
Camera		X		

Another study for the area from Iraq and Baghdad governorate had suggested expanding the use of Global Position Systems (GPS) to organize traffic and track vehicles in government departments. This study aimed to create a main database for transportation field in Baghdad by using GPS and tracking devices to avoid conflicts, and minimized the waste of effort, energy, and money in this field. The technologies Geographic information systems (GIS) and GPS with sensors are important for supporting the collection of roads data and digital maps for the database. Then the study gave a suggested system using the collected data and gave a user the ability of selecting the type of digital maps to be used for tracking, where it can display and track the vehicle's movement in real time and using historical data for more confidence [18].

Time reliability was considered in one of the recent works. The authors considered a part of (Abi Talep) urban street in Baghdad city of Iraq capital starting from (Al- Shaab bridge intersection) to (Al – Nidaa intersection), which have four cross roads. They used average car method with a group of vehicles and volunteers to record the data. This data was collected during peak hours (from 7:00am – 10:00am) for one month and 35 runs for each road intersection to get maximum dependability in estimating the time of travel of these roads' intersections. After analyzing the collected data to see which road is with highest values for travel times, the authors depend on buffer time measure equation which represents the additional time someone should allow above the average travel time to reach his destination. The research found that buffer time index leads to worse reliability conditions therefore authors cannot give ideal solution for time reliability instead of that they gave some simple ideas to reduce the vehicles number such as using public transportation instead of private cars [19].

Many other studies considered different Iraqis' governorates such as solve the road problem of delay in the road network of Hilla City, the study suggested a ring road as a solution to the problem of internal congestion in the city, and another study for transport vehicles in Samawah city that suggested to create an application for public transportation locations awareness. This application based on radio navigation system for user and vehicle communication called global system for mobile communication (GSM) with global positioning system (GPS) to help the application to receive exact information about the location continually [20], [21].

4. Model Description

As knowing the urban cities are the target of everyone seeking for economically benefits. In the last few years, Baghdad the capital of Iraq became the target of every investor either as a company or as a person. Though the population in Baghdad increases and the roads become very crowded due to the high number of vehicles that are used during day life. Beside an observation was made and found that the direction of vehicles flows during morning spatially between 7:00-10:00am is inbounded from surrounding areas to downtown areas, while between 1:00 - 3:00pm is out bounded from downtown areas to surrounding areas. The timer system for traffic lights around Baghdad roads are used almost at each road junction to announce the driver about the waiting time before green light is on. Meaning that the timer system for the traffic lights are not suitable during the two time phases for two ways roads, since one of the sides would be less congestion than the opposite side. When the traffic is out of control in any junction the traffic officer will be visible. His position would be always in the middle of the crowded junction which may make him faced many unsafe situations such as hitting by a vehicle or being under a bad weather. This work shows how the IoT based traffic management system is the best solution for such problem.

This work suggested a scheme based on components that can be set at chosen points near roads cross. The components are with low cost and they are:

- Light dependent resistor (LDR) that detect the presence and absence light intensity falling upon it. LDR can be placed at the right sides of every lane near the junction. LDR that will detect the presence of the coming vehicle.
- A red-light source (RLS) should be placed at the left side of each lane. RLS was suggested since its wavelength is very high, thus its range is also very high.
- A counter to count vehicles must be placed in every direction of the junction based on WSN, this to help in sending vehicles density to the traffic management center (TMC) through the internet.
- A real time counter.
- TMC will permit the traffic officer at a specific time to connect his smartphone or a laptop device to control the traffic light instead of standing in the middle of the junction to direct the movement of the vehicles.

To illustrate the suggested model, figure 2 below can give a clue of the scheme components and working steps. To explain the steps let's take the morning Phase when the time counter is between 7:00-10:00am for example. If the sensors detect a high vehicle density, the counter start counting vehicles and the TMC gives the traffic officer the permission to control traffic lights timer system.

4.1 Case Study:

For the suggested scheme the cross roads of Al-Jadria near University of Baghdad had been considered, since it has the highest road congestion in both time phases that we studied. Figure 3 shows the Google Earth image that illustrated for the chosen junction area. The crosses roads are consisted of four main roads, each road has two-sided vehicles' flow with three lanes both directions as shown in figure 4

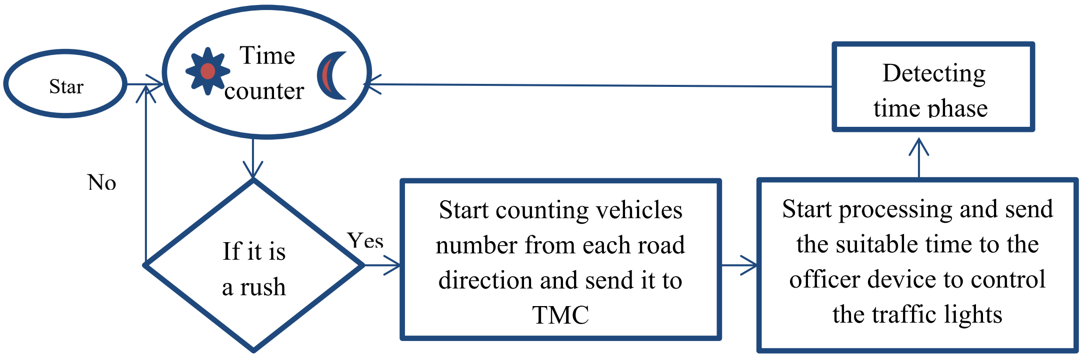

Figure (2): The suggested scheme steps

Figure (3): Al-Jadriyah intersection (Google Earth, © Maxar Technologies).

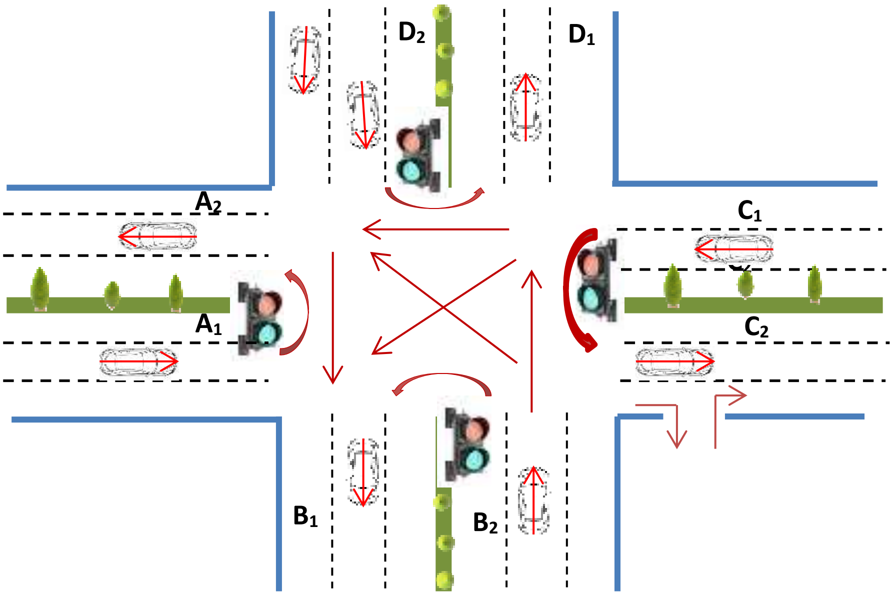

Figure (4): Four cross roads (A_j, B_j, C_j, and D_j), each with two directions (j= 1 and 2) and explained by the red arrows with three lanes.

5. IoT Traffic Light Management Algorithm:

As mentioned before the suggested model is consisted of six main components: the vehicles counter that is based on WSN, LDR, RLS, the timer, and the TMC interface. For more explanation see figure 5, this sketch describes the installation of the components at one of the four roads. Other roads will be equipped in the same way. The WSN installed based on barrier topology by deploying several nodes transversely one per lane of the road to obtain the existing of vehicles that passes a determined sensor in the road. The function of each one of these sensors in every lane is simple since it is just to detect passing vehicle and transfer the collected data to the TMC through internet connecting with one of the available connections such as 4G, or Wi-Fi. The LDR replaced at the right side of each road near the traffic light and far from the sensors' nodes for about 150m. RLS placed at the left side of each road facing LDR directly, so when a vehicle passes RLS, its light switched off, and LDR resistance is high lead to let the transistor in off mode.

The average standard of a vehicle length is between 4.5 and 5m in length based on standardization of vehicles' companies. The distance between two moving vehicles in the same lane direction must be not less than half meter for safety matter. By simple calculation if a road of length 150m and three lanes then vehicles number passing the sensor nodes with speed of 40km/h during congestion are about 80 to 90 vehicles every 13.50s.

When a vehicle passes RLS, the light will be switched off, so LDR resistance is high and the transistor is in off mode and vice versa. The counter then starts to count the number of switching off/on of LDR to send the final number to the TMC.

When the timer refers to one of the time phases (either between 7:00-10:00 am or between 1:00 - 3:00 PM) the collected data from the WSN and the LDR counter must be transfer to the TMC for centralizing data processing every 13.50s plus T_B as transmitting time. This process gathers the data, analyses the traffic parameters and then send it back to the traffic officer's device to give him the control of the traffic light according to the calculating of the suitable traffic light time.

The LDR switch off/on counted data cannot be the same as WSN data, since there is a chance when three vehicles are passed at the same time and made LDR in off-mode.

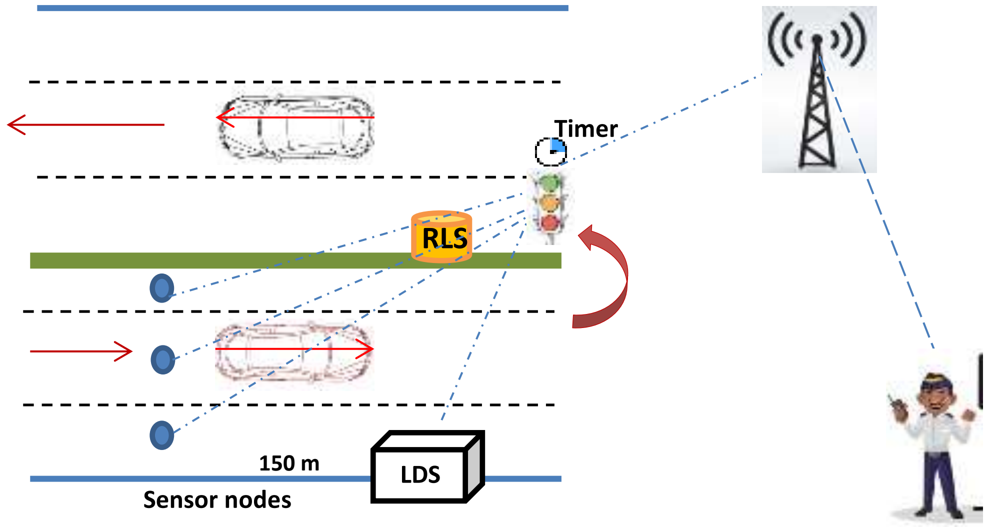

Figure (5): Sample of one of the roads components (road A in figure 4)

The process starts when receiving the collected data from WSN and the switch off/on counter to predict the suitable traffic light duration in seconds. After many trials equation (1) is created to be used for the best predicting duration time D_{Pj} for arranging traffic light.

$$D_{Pj} = \frac{T_E + T_B + 13.50}{S} \times 10 \dots\dots (1)$$

Where T_E is the time the traffic light last before it changes, and since we could not find a standard period, we assumed it is 120s after observing some traffic lights of crossroads in Baghdad. T_B is the prediction time to send data to the TMC. S is the number of LDR switching off/on and it is less than the counter of WSN. The three sensor nodes data of any road j will be combined as N_j using equation (2), where j is either 1 or 2 for (A_j, B_j, C_j, or D_j)

$$N_j = \sum_{i=1}^{3} n_i \dots\dots (2)$$

Where n_i is the data of one of the three sensor nodes (i), and i= 1 to 3 for each direction of the road

At the rush hours which we assumed are between 7:00-10:00am and between 1:00 - 3:00pm, an algorithm is suggested to help the police officer take control of the traffic lights. The direction with the maximum car number have to get the longest green light duration. The maximum car number $MAX = N_j$ is calculated at the TMC, then according to N_j result the roads' traffic lights will get its time duration in descending order. Therefore, calculating a suitable time duration new D_{Pj} for traffic light during congestion is by using equation (3).

$$\text{new } D_{Pj} = 3 \times D_{Pj} + T_E \dots\dots (3)$$

Where D_{Pj} calculated from equation (1). Algorithm 1 will be activated when the global timer refers to one of the rush hours phases. The TMC starts processing continuously when it receives the data. Algorithm 2 starts when road density getting to be high and the cross roads began to be congestion. The idea of using TMC and starting algorithm 2 is to help the police officer in making his decision and take control of the traffic lights using his mobile or a laptop. Though with this IoT technology a safe service can be done to protect the police officer from facing hard situations and bad weather and also it help in solving roads congestion.

Algorithm 1: TMC processing during rush hours (time phase 1 or phase 2)

1: Start
2: For j=1, 1, 8; where j denoted which road data the algorithm processing
3: Calculate N_j from equation (2)

4: If $100 < N_j < 270$ then calculate D_{Pj} from equation (1) where 260 is
(Vehicles per hour)
5: $ND_{Pj} = D_{Pj} + T_E$
6: If $N_j < 100$ then $ND_{Pj} = T_E$
7: Else go to algorithm 2
8: Endif
9: Endif
9: j++
10: End for

Algorithm 2: Calculating the predicted duration time to give control to the police officer

1: Start
2: For j=1, 1, 8
3: calculate all N_j and arrange them in decreasing order starting from $MAX = N_j$
4: End for
5: For j=1, 1, 8
6: Calculate $newD_{pj}$ from equation (3) for each N_j
7: Give the officer device a permission to control traffic light
according to the time calculated
8: End for

5.1 Experimental results

In this section a dataset is prepared according to an observation done by volunteers' team to test the created equations using MATLAB program. The assumption is to consider the road A_1 from figure 4 to be with the maximum vehicles' density. For 6 days we pick evenly spaced sample times from (7:00-10:00am) where the volunteer persons stand on the side of the road and count how many cars travel on that street within a fixed window of time. Then, average and scale those numbers up for one-hour period, noting that for very low traffic streets, we needed to increase the size of each sample window. Table 2 illustrates the estimate dataset of vehicles density during morning time period starting from Monday until the end week holiday which are Friday and Saturday in Iraq to be considered as WSN (Nj). The LDR (S) counting is predicted since it was not possible to use the suggested circuit board which is explained by the block diagram in figure 6. The simulation program shows how the time controller for green light changes according to the vehicles' density using the created equation, where the light will be last longer according to the high vehicles' density as shown in Fig.7

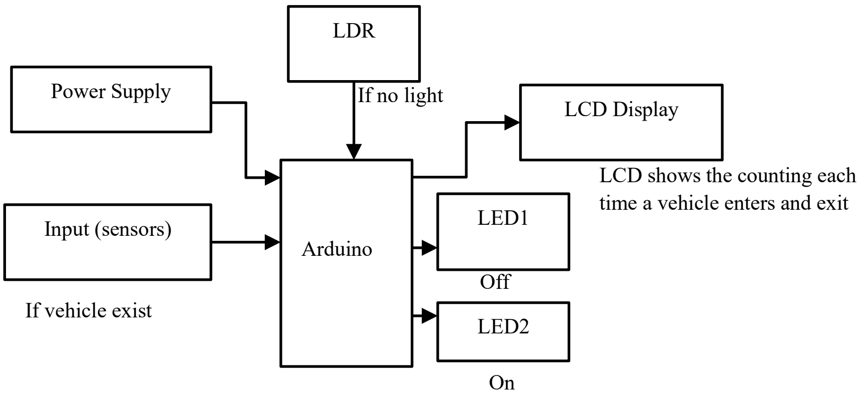

Figure (6): The controller block diagram of how to count vehicles number using LDR

6. Conclusion

The main goal of this work is to solve the traffic jam during rush hours using IoT technology and without the need for road construction. This work can be with benefit for the involve police officers by helping him controlling the traffic jam with his intelligent device and avoiding standing in dangerous point during vehicles congestions or in bad weathers.
The idea of this work is to design a method for controlling traffic lights using available and low-cost components. IoT technology can manage road traffic with the wireless sensor network (WSN) which can help in monitoring the roads flow and collect data. Since monitoring roads 24 hour a day is a hug matter, the suggestion was to take two phases of time with high traffic jam:

- The morning time phase between 7:00 to 10:00 am
- The afternoon time phase between 1:00 to 3:00 pm

The proposed design consists of six components: WSN, LDR with counter, RLS, timer, and a TMC interface. The work algorithm gives the police officer that is on duty a permission from the traffic management center (TMC) to control the traffic light on need. TMC receives the vehicles' number and calculates the Max number of vehicles to arrange roads density in descending order and then send to the officer the best time duration for the green light according to the algorithm result. The created equations are trained on an estimated dataset for one road direction that were observed for 6 days. The results showed how effective the work is in changing the time lasting of green light according to vehicles density. In Future more work must be done with the support of the general traffic directorate to get access to the main road cameras and also enhancing the LCD controller circuit to be used efficiently in real life

Table 2: a dataset with N_j as a vehicles' density and S is the LDR switch off/on for A_1

Date	Morning Hours	N_j	S	ND_{pj} in sec	$newD_{pj}$ in sec
18/12/2023 Monday	7-8	200	170	127.9412	-
	8-9	290	155	-	146.129
	9-10	250	180	127.5	-
19/12/2023 Tuesday	7-8	190	180	127.5	-
	8-9	300	270	-	135
	9-10	270	240	-	136.875
20/12/2023 Wednesday	7-8	190	180	127.5	-
	8-9	310	285	-	134.210
	9-10	275	270	-	135
21/12/2023 Thursday	7-8	190	190	127.1053	-
	8-9	280	260	-	135.577
	9-10	270	265	125.0943	-
22/12/2023 Friday	7-8	60	60	120	-
	8-9	70	69	120	-
	9-10	80	77	120	-
23/12/2023 Saturday	7-8	70	70	120	-
	8-9	80	75	120	-
	9-10	90	86	120	-

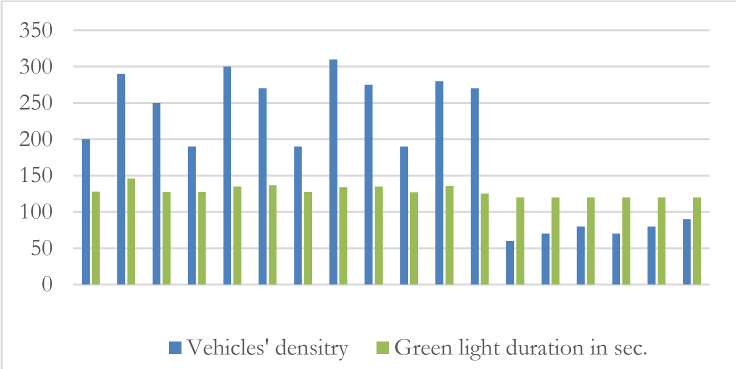

Figure (7): Change green light timing according to the vehicles' density for road A_1 for 6 days during the chosen period of time (7:00-10:00 am)

References

[1] A. S. Ibrahim, A. M. Abbas, A. M. A. Hassan, W. M. Abdel-Rehim, A. Emam, and S. Mohsen, "Design and implementation of a pilot model for IoT Smart Home Networks," IEEE Access, vol. 11, pp. 59701-59728, 2023. https://doi.org/10.1109/ACCESS.2023.3282095

[2] K. S. Khattak and Z. H. Khan, "Evaluation and challenges of IoT simulators for intelligent transportation system applications," Science, Engineering and Technology, vol. 4, no. 1, pp. 94-111, 2024. https://doi.org/10.54327/set2024/v4.i1.107

[3] H. Basheer and M. Itani, "Zero Touch in Fog, IoT, and MANET for Enhanced Smart City Applications: A Survey," Future Cities and Environment, vol. 9, no. 1, pp. 1-19, 2023. https://doi.org/10.5334/fce.166

[4] R. P. Dameri and C. Rosenthal-Sabroux, Eds., Smart City: How to Create Public and Economic Value with High Technology in Urban Space. Springer, 2014. https://doi.org/10.1007/978-3-319-06160-3

[5] F. Losilla, A. J. Garcia-Sanchez, F. Garcia-Sanchez, J. Garcia-Haro, and Z. J. Haas, "A comprehensive approach to WSN-based ITS applications: A survey," Sensors, vol. 11, no. 11, pp. 10220-10265, 2011. https://doi.org/10.3390/s111110220

[6] A. F. Abbas, U. U. Sheikh, F. T. Al-dhief, and M. N. H. Mohd, "A comprehensive review of vehicle detection using computer vision," TELKOMNIKA (Telecommunication Computing Electronics and Control), vol. 19, no. 3, pp. 838-850, Jun. 2021. https://doi.org/10.12928/telkomnika.v19i3.12880

[7] D. Cvitanić, "Drone applications in transportation," in Proc. 5th Int. Conf. Smart and Sustainable Technologies (SpliTech), IEEE, pp. 1-4, Sept. 2020. https://doi.org/10.23919/SpliTech49282.2020.9243807

[8] V. R. Kulkarni and G. K. Venayagamoorthy, "Particle swarm optimization in wireless-sensor networks: A brief survey," IEEE Trans. Syst., Man, Cybern., Part C (Appl. Rev.), vol. 41, no. 2, pp. 262-267, 2010. https://doi.org/10.1109/TSMCC.2010.2054080

[9] B. A. Sanusi, Z. T. Adeyemo, E. O. Omidiora, S. O. Olabiyisi, A. O. Olowoye, M. O. Oyediran, and A. A. Corresponding, "Decongesting traffic at coordinated junctions in a multi-road intersection

using graph coloring based technique," Res. Appl. Web Dev. Design, vol. 3, no. 2, 2020.

[10] S. Lee, J. Oh, M. Kim, M. Lim, K. Yun, H. Yun, C. Kim, and J. Lee, "A study on reducing traffic congestion in the roadside unit for autonomous vehicles using BSM and PVD," World Electric Vehicle Journal, vol. 15, no. 3, p. 117, 2024. https://doi.org/10.3390/wevj15030117

[11] M. Elassy, M. Al-Hattab, M. Takruri, and S. Badawi, "Intelligent transportation systems for sustainable smart cities," Transportation Engineering, p. 100252, 2024. https://doi.org/10.1016/j.treng.2024.100252

[12] K. Sreejith, S. Mathi, and P. Pradeep, "Beyond Sensors: IntelliSignal's Map-Integrated Intelligence in Traffic Flow Optimization," IEEE Access, vol. 12, pp. 39028-39040, Mar. 2024. https://doi.org/10.1109/ACCESS.2024.3375335

[13] G. Kreindler, "Peak-Hour Road Congestion Pricing: Experimental Evidence and Equilibrium Implications," Econometrica, vol. 92, no. 4, pp. 1233-1268, 2024. https://doi.org/10.3982/ECTA18422

[14] Electrical4U, "Light Dependent Resistor: A Comprehensive Guide," 2023 https://www.electrical4u.com/light-dependent-resistor-ldr-working-principle-of-ldr/#google_vignette

[15] H. H. Mohammed and M. Q. Ismail, "Efficiency assessment of a signalized roundabout and a traffic intersection in Baghdad City," Eng., Technol. Appl. Sci. Res., vol. 11, no. 6, pp. 7910-7916, 2021. https://doi.org/10.48084/etasr.4564

[16] E. I. Abdul Kareem and H. K. Hoomod, "Integrated tripartite modules for intelligent traffic light system," Int. J. Electr. Comput. Eng. (IJECE), vol. 12, no. 3, pp. 2971-2985, 2022. https://doi.org/10.11591/ijece.v12i3.pp2971-2985

[17] Z. S. Abood, "Intelligent transportation strategy and its role in improving services and reducing pollution in Baghdad," Res Militaris, vol. 13, no. 2, pp. 6937-6950, 2023.

[18] F. S. Raheem and A. F. Hasan, "Enhancing artificial intelligence in advanced database systems for Baghdad's urban transportation management," Period. Eng. Nat. Sci., vol. 11, no. 3, pp. 217-228, 2023. https://doi.org/10.21533/pen.v11.i3.147

[19] H. A. Mahawi and A. S. Abduljabbar, "Reliability of travel time for Abi Talep urban arterial street in Baghdad City-Iraq," in AIP Conf. Proc., vol. 2793, no. 1, Aug. 2023. https://doi.org/10.1063/5.0163359

[20] A. S. Musllim and A. A. A. Alwash, "Feasibility study for implementing a suggested road to solve the problem of delay in the road network of Hilla City," in IOP Conf. Ser.: Earth Environ. Sci., vol. 1374, no. 1, p. 012043, Aug. 2024. https://doi.org/10.1088/1755-1315/1374/1/012043

[21] D. Z. Khutar, S. M. Abd, and E. L. Kadhem, "Using embedded systems programming to develop an intelligent system for tracking public transport vehicles in Samawah City," Global J. Res. Eng. Comput. Sci., vol. 5, no. 1, 2025.