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Smart Traffic Control Using Internet of Things and Geographical Information System

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Abstract: The concept of integrating information, communication, and some physical devices and being connected to a network to support the city operations and services efficiently is a part of building a smart city. In this research, IoT devices and GIS are utilized to predict the status of roads based on time to avoid traffic congestion. The GIS and IoT sensors are utilized to collect the required data to run the proposed research to control traffic lights. The info of each light is saved in a predefined list and equipped with three lights: red, orange, and green. These colours are used to indicate the status of the road in front of the drivers. The proposed method introduces a novel algorithm to avoid the traffic using GIS and IoT devices to avoid traffic congestion.

Keywords: Smart Road, Internet of Things (IoT), Traffic Congestion, Geographical Information Systems (GIS)

I. INTRODUCTION

Several types of research are conducted to improve and enhance the works behind smart cities. Sharing information, using smart technologies, and increasing the efficiency of operations to improve the quality of life of citizens are the main objectives of building a smart city. A city can be called smart based on incorporating machine learning, automation, and IoT (Internet of Things). Classic examples of a smart city can be a smart parking meter that helps the drivers to find available parking space, a smart traffic system that utilizes the traffic light by skipping the street that has no vehicles, a smart public transportations system that certifies that the public transportation encounters users demand, smart lighting to save energy and others as shown in Figure 1.

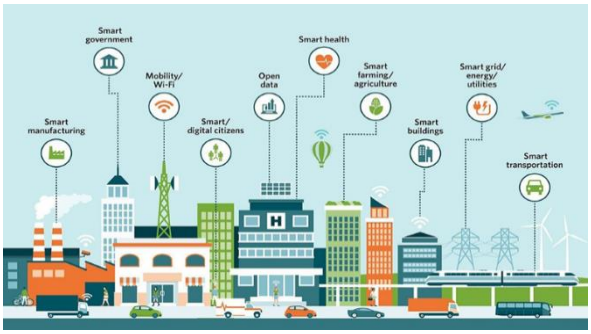

Figure 1 Smart City Components.

Security is also an important aspect of interest when it comes to smart cities. For example, security can be better enforced by enabling a smart border entry system through increasing the reliability and efficiency of border control measures. The work in [1] has introduced a modern biometric system for passports called e-Passports, which automatically authenticates the identity of travellers. Also, the work presented in [2] can be used to recognize the walkers by tracking the human facial expressions from the recorder cameras which later can be used to predict crimes based on a smart approach.

In a smart city, the population tends to avoid spending several hours while waiting in traffics. Local drivers, who know the traffic and road conditions of the alternative roads; follow the road with the best conditions according to their knowledge. This case is not generally applied because some of the drivers come from other cities, countries, or they can simply be local drivers who tend to follow specific roads. Also, the status of the road is variant which means they can be

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blocked, semi-blocked, or being cleared at any time. Hence, the drivers need a guide to help them to avoid traffic by utilizing current tools and energy such as streetlights, policemen, radio channels, or volunteers.

Ordinarily, drivers tend to use special software embedded in portable devices with GPS service to avoid traffic congestions or by keep listening to the radio channels (needs waiting for a list of roads) to be informed about the latest congestion zones. Mobile devices require an internet connection for some applications such as Google Maps. Several drivers may not have these services and require an immediate notification regarding their current locations.

This can be performed by using sensors embedded in streets and traffic lights. The collected data is shared via wireless technology to keep vehicles moving. The drivers keep reporting their locations on their smartphones to inform the city hall. Consequently, this research tends to resolve the problems by investigating the possibilities of reducing the traffic congestions by using the streetlight, gathering the required data about the traffic at each street, and locating the sensors of the proposed method on the streets of the city.

In this research, a solution to the congestion traffic is introduced by utilizing the lights of roads and IoT devices to inform the drivers to avoid the ahead congestion. The importance of this research can be retrieved by showing the added values by integrating the proposed technique with the GPS service, and on how much energy can be saved when applying our novel idea on the lighting roads system of highways. Also, and on its offer to support the decisions of the city hall to build a bridge, underground tube, adding or removing streetlights.

The remaining section and their principal contribution are organized as follows: Section 2 provides an extended literature review of recent research on usages of smart cities, street lighting cities, and traffic congestion of the smart city. Section 3 describes the dataset that is going to be used to conduct the experiments and evaluations. Section 4 presents the adopted approach to creating an efficient system for avoiding traffic congestion zones using machine learning (ML) and IoT devices, and the experiments and evaluations of the proposed approach, and finally, the conclusion and recommendations of the future works are presented in section 5.

II. LITERATURE REVIEW

In general, this section covers the literature review from different sources related smart city technologies. Recently, there have been lots of studies about smart cities by research associations and huge companies. These studies and research purpose to make our cities smarter and efficiently use available resources even with the growth in population size. Today, the street lighting road system of a smart city is a very important issue to solve the traffic jam in the whole world. The recent research is focused on creating a development framework, which can help in the growth and deployment of smart city services. The paper has also presented Agent-Based Modelling (ABM) for simulation of argument data retrieval system, and it has used many tools to test the framework as shown in [3].

In [4], it was shown that Street lighting is one of the main issues of smart transportation for the smart city environment. The paper has shown the main goal of the smart urban environment and the performance of the proposed system is evaluated using OMNET++ network simulation. The research has offered an efficient street lighting system with reduced power consumption in comparison to classical lighting systems. This is able by using a WSN-based street lighting system.

An overview of the concepts of Intelligent Transport Systems (ITS) for smart cities is discussed in [5], the authors proposed a framework for the design of an autonomic transportation system that provides personalized mobility services to its users in a smart city setting. Additionally, it can be a reference for the design of future transportation systems. The framework fulfills the main requirement of providing suitable information about the local decision engines in vehicles and infrastructure interacting with smart city traffic [5], [6]. The introduced work explained the Intelligent Street Lighting (ISL) system as the first method to accomplish the demand for flexible public lighting systems.

ICT-enabled service innovation intelligent transportation system (ITS) is required to provide a better service in a smart city [6]. The research has implemented Eight ICT mechanisms that provided growth of service innovation in the smart city. The extremely growing traffic jam and transport need smart traffic solutions. The research was proposed four core applications to solve the road traffic such as ETC: Electronic Toll Collect, AVI: Parking Infrastructure, EVR: Electronic Vehicle Registration, and ITS: Intelligent Transportation Systems [7]. The project was helped to reduce and control traffic flow in urban-based on cost-effective passive RFID technology, the powerful and dynamic ITS network is to fulfill future smart city requirements and save infrastructure costs [8]. In [9], The main objective of the proposed project “IoT Based Smart Intelligent Lighting System for Smart City “is designing and executing the advanced development in embedded systems for energy saving of streetlights. Today there is a manual system where the streetlights will be switched ON in

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the evening before the sunsets and they are switched OFF the next day morning after there is sufficient light on the outside. But the actual timing for these lights to be switched ON is when there is absolute darkness. With this, the power will be wasted up to some extent.

The project has tackled the problem of electrical power wastage and provided a solution for energy saving. This is achieved by sensing and approaching a vehicle using an IR transmitter and IR Receiver couple. The project was implemented with a smart embedded system that controls the streetlights based on the detection of vehicles or any other obstacles on the street [9]. IoT-based intelligent transportation systems are implemented to support the Smart City vision in the work presented in [10]. The research has presented a real-time traffic monitoring system to tackle the problem of real-time traffic controlling, monitoring, and providing a new way of traffic control by the better utilization of resources. The solution available for the implementation of urban IoTs was analysed in [11]. The discussed technologies in the project are close to being standardized, and industry players are already active in the production of devices [11]. The recent model of a smart city aims to enhance social development [12].

III. METHODOLOGY

Ultra-Sonic sensors are distributed to cover 100 meters before each traffic light of interest which are integrated with a communication network to receive the required data such as the location, status, and date & time. The daily traffic transactions are saved into a remote database that will be useful to apply the neural network to predict the traffics status for each road based on the date and time. Also, the traffic status for each road of interest is extracted from the GMAP service and being sent to the remote database. The collected data was gathered using the connected network, it can be utilized to apply the future decisions such as building bridges, setting up traffic lights, and managing the interval times between the streetlights. Controlling the traffic lights interactively with traffic congestions will be a promising field of research for other researchers. A smart computerized system is required to be implemented to control traffic congestions in real-time using wireless connections, sensors, and microcontrollers.

The roads of cities are going to be labeled with unique expressions (a simple junction map is shown in Figure 2). The data is collected from the Google map and being assigned for each streetlight in the LoR. The structure of the proposed method is shown in Figure 3.

To bring the system to the life, a prototype was created to achieve the main aim of this research. An Arduino controller board was integrated with Internet and GPS services. Also, three LED lights colors were employed with the board as Red, orange, and white. Based on the status of the interesting road which returns from the G-Map service, the light is switched on, and the data is saved in the remote database.

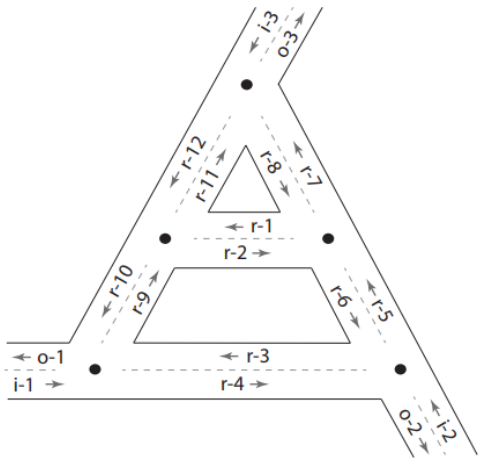

Figure 2: A simple model of the traffic network.

The matrix concentrates on data collections regarding traffic statuses and information analysis within the traffic and transport field. The matrix aims to provide quality traffic advice for the public, private, and business sectors. Traffic surveys include pedestrian counts, speed surveys, parking surveys, intersection counters, and automatic traffic counters

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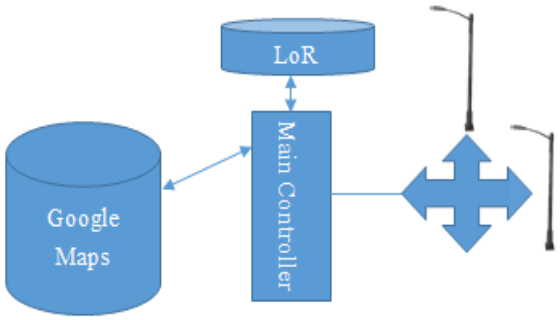

Figure 1: A simple model of the traffic network.

Hence, a prototype of the proposed system using an Arduino controller board integrated with Internet and GPS services was designed to conduct the experiments. This can be called a node which later can be employed on each streetlight of interest. Each node is associated with a specific streetlight. The system is also employed with software to return the status of the traffic on a given road, which is later used to light with a specific suitable color. This is later used to guide the drivers to avoid traffic congestion. This can be applied by employing three colors for each LED light such as red, orange, and white. The red color will denote high congestion, orange color to intermediate congestion, and white for low traffic congestion.

To the best of our knowledge, this is the first work where streetlights are used to provide drivers with information regarding the current state of the traffic. The local drivers are expected to use all possible free streets that are supposed to release the blocked congestion roads.

IV. EXPERIMENTS AND EVALUATION

This is an experiment of traffic road control by exploring a new technique based on utilizing the streetlights on roads. The steps are simple, the prototype of the proposed system was integrated on a local streetlight located in Amman the capital city of Jordan. The number of vehicles that decided to change the main road because of the congestion per hour was considered. It was noted that the drivers who saw the red light have changed their paths as shown in Figure 4. Consequently, the traffic congestion that was on the next roundabout was released. Again, the red light on the streetlight was only for warning and not an official procedure, and its mission differs from the traffic signal. It was noted that out of 50 vehicle drivers, 43 drivers were aware of the alert light signal, while the others were not interested. A total of 43 drivers have decided to take the other paths to avoid traffic congestion. This means that 86% of the vehicles can be released on roads before any expected traffic congestion.

Comparing the performance of the proposed method with the traditional traffic controls is shown in Figure 4. Three criteria were employed: equipping device in each vehicle, obstructing the driver's field of vision, and providing information about the traffic. The comparison was conducted between traffic signals, the general navigation systems (Google Map, TomTom, and Waze), and the proposed method. Clearly, the proposed method has outperformed the former methods in terms of cost and safety as no device is required to be equipped in each vehicle, and thus, no screens to obstruct the driver's vision.

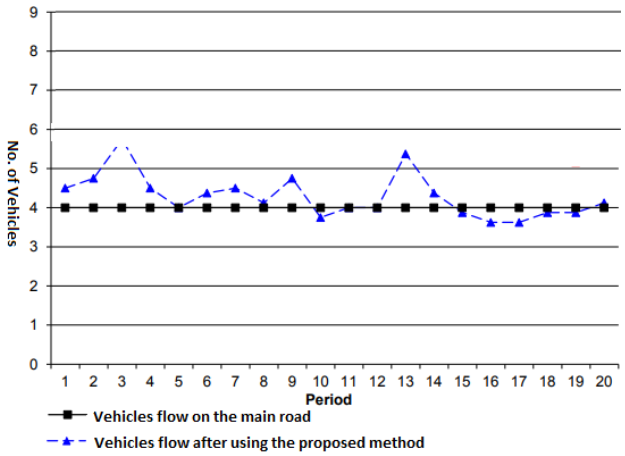

Figure 2: The result of the vehicles flow before and after applying proposed method.

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Table Error! No text of specified style in document.**-1: The evaluation of the proposed method.**

#	Method Name	The equipped device in each vehicle (cost)	Obstruct driver's field of vision	Providing Info about the traffic
1	Traffic Signals	No	No	No
2	Navigators such as GMAP, TomTom, Waze .etc.	Yes	Yes	Yes
3	The Proposed Method	No	No	Yes

V. CONCLUSION

The main aim of this paper is to avoid traffic congestion based on data collected from our prototype located on traffic streetlights. A list of road lights is created to indicate which streetlights are required to be equipped with the three colours. Each streetlight in the list is equipped with three lights red, orange, and white used to indicate the status of the road. The proposed system collects the required data from Google Map to return the status of the traffic on specific roads. The future work can be based on integrating cameras on the streets and building a data retrieval information system to capture the status of the street as in the human vision, in addition to the current proposed research work.

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