A Simulated System for Traffic Signal Management Based on Integrating GIS & WSN Techniques

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Abstract – Traffic signals management systems (TSMS) are traffic systems based on cameras, infrared sensors and satellite systems. Such systems have been lacking the ability of real-time data collection and support. This paper proposes a solution to the traffic signal management problem using combined techniques that combines both GIS information with WSN based techniques. This combination provides appropriate techniques and tools that will enhance the capabilities of traffic jam prevention, early detection, efficient surveillance, efficient spread control, and fast termination of possible hazards. Consequently, this work proposes a new methodology through merging WSN and GIS techniques to produce valuable information for traffic signals management systems purposes.

Keywords – Traffic Signals Management System (TSMS), Geographical Information System (GIS), Wireless Sensors Networks (WSN), Traffic Management.

I. INTRODUCTION

Traffic management is considered the backbone of any Intelligent Transportation Systems (ITS). Appropriate techniques and tools are to be developed to avoid problems associated with traffic, to provide better solution to these problems and to enhance the capabilities of traffic jam prevention, early detection, efficient surveillance, efficient spread control, and fast termination of such hazards [4]. In fact, recent developments in information technology have major effect on the design of traffic management systems. Recently, the advanced technologies application for the transportation infrastructure and for cars has been one of the most vital missions for improving the efficiency and safety of the transportation system known as Intelligent Transportation Systems [9]. The integration of GIS and WSN has been accessible to defeat the traffic management problems during traffic signals management. Traffic signals control is a core part of TSMS. This paper applies both GIS and WSN techniques to enhance the number of vehicles in urban network and limitation of road infrastructure [1].

A. Geographic Information Systems

A visualization map and interactive tool used for representation of a spatial configuration at a specific instant in time, or a spatial Configuration valid for an interval of time [5].

An evolving, that initially referred to geographically managed information with component primarily stored in vector format with associated attributes [10].

GIS is about mapping, spatial indexing, spatial operators, geocoding and routing technology [11]. The Goal of the GIS is to graphically represent studied area in a map form. One property of GIS is that it can display studied items in the form of layers. This is a common method to represent terrain features such as mountains, water and even buildings [9].

GIS techniques is divided into the following rules: (Storage, Analysis, Reporting of data sets and integrating various databases related to the study area) [13].

B. Wireless Sensor Network (WSN)

A network of small sensor nodes (SNs) interconnecting wirelessly. It merges distributed sensing, computation and wireless communication technologies [12].

A huge number of small-power multi-functional sensor nodes, operating in various environments, including (sensing, computation and communication capabilities) [3].

Tiny and cheap devices that communicate wirelessly and sense their surroundings. Each device node consists of sensors, a processor, a memory, a radio, and energy source [8].

A sensor: is a device that translates some physical actions of the environments into an electrical signal. The basic components of sensor unit: (ADC (Analog to Digital Converter), CPU (Central processing unit), power unit and communication unit) [4].

With the rapid developments of sensor technology there are many types of sensors: (Loop detectors, microwave, probe vehicles, cameras and cell phones are adapted to collect data for traffic state estimation).

The typical WSN architecture consists of: Huge number of sensors, wireless gateways and Access Points (APs). AP has huge computing resources, and provides radio signals connected to a power supply network. Generally, the sensor nodes sense environmental conditions, configured with a spatial density and at a sampling rate configured by the application. The access point operates as follows; the access point operates on the data gathered from all sensors within network to provide information, translated into meaningful format and forwarded to traffic controller or another control system. The sensor operates signals using cars detection algorithm; detection events are then generated and forwarded to the access point. After collecting data from these synchronized sensor nodes; the access point can measure the cars counts, occupancy and speed of the monitored traffic flow. Consequently, the
traffic management Centre uses this real-time traffic information for traffic monitoring and signal control [3].

C. Conventional Solutions to Traffic Problems

Due to the increasing number of vehicles in the world, especially in urban areas, existing traffic management systems have become inefficient. This can be clearly seen in our life through existing traffic jam and the growing number of accidents. As conventional solutions to traffic issues have become less and less effective, high-tech solutions have to be sought. The conventional solutions to traffic problems are to: construct new roads (not likely to happen on a large scale), reduce traffic (travel demand management alternative transportation) and increase existing infrastructure capacity (covered in geometric design).

As a result, the integration of GIS and WSN for Traffic Signals management has become a solution to these problems. The role of WSN is to sense the road conditions (max. Speed, road-capacity, average speed, and traffic rate). The role of GIS is to visualize the road state, display ways states, defeat traffic jam, reduce accidents and overcome congestion.

II. PREVIOUS STUDIES

Recent advancement in WSNs and GIS provides new opportunities for better environmental managements in urban cities. In the future, GIS platform will be used in providing important features including: (daily temperature, humidity, weather conditions, and monthly traffic accidents). WSN platform will be used in sensing and actuating nodes will be placed outdoors in urban environments to improve the people’s living conditions as well. For example, this technology could be applied to monitoring and controlling traffic.

(COLLOTTA, Mario et al, 2015) suppose the Traffic light control system is a dynamically managed traffic light cycles and the phases are independent inter sections; Consequently, the system is a combination of Wireless Sensor Network (WSN) for real time traffic monitoring with several fuzzy logic Controllers. Each phase works simultaneously. Therefore, each fuzzy controller addresses vehicles turning movements and dynamically manages both the phase and the green time of traffic lights. The system is characterized by better performance, fault-tolerance, and support for phase-specific management. In conclusion, the system combines the benefits of Wireless Sensor Network (WSN) and fuzzy logic Controllers. However, applying the Neural Network could make the system able to forecast the traffic conditions [6].

(YANG, Inchul; JAYAKRISHNAN, R, 2015) propose a system consists of 2 levels (strategy level and control level). Therefore, supposing optimal states in the strategy level for long time period, the optimal signal timings for a short-term period are measured in the control level that consists of two steps: (queue weight update and signal optimization). Consequently, depending on the ratio of the cumulative green time to the desired green time is the first step to update the queue weights that are used in the optimization to find signal timings for minimum total delay. The proposed schema considers the expected route flows to evade the gaming of the control. Although queue weights, cycles and phase sequences are not explicitly given, this allows the system to adapt dynamic changes of traffic arrivals at intersections [14].

(KAFI, Mohamed Amine, et al, 2013) propose an intelligent transportation system (ITS) based on Wireless sensor networks (WSN) as an effective solution to overcome present traffic jam and incremental number of accidents. Therefore, it enables new range of smart applications including control traffic congestion, monitoring road state, vehicular warning services, and traffic safety and parking management. Finally, WSN helps to avoid the traditional ITS system drawbacks, due to its cheap price and scalable nature [8].

(ABDOOS, Monireh, et al, 2013) suppose traffic control system that applies detectors data to determine the boundary conditions of all incoming and exit links. They developed control system capable of handling many boundary conditions of the recurrent, non-recurrent congestion, transited signal priority and downstream blockage conditions to enhance the overall traffic network productivity and efficiency. In conclusion one of the constraints of the proposed logic is its inability to account for development among traffic signals, and it's noted that such development would be fruitful in arterial type of control networks and not in a typical grid operation that most of the intersecting arterials are heavily worked [2].

(MASON, A., et al, 2010) consider the Road Transport system as the main causes of air pollutions in urban environments. By measuring the effects at regional and national levels that show bleak pictures helping people to be capable of tackling or mitigating the air problems. It is important to locate and verify air pollution places and conditions, to help manage traffic according conditions. Their job applies the integration of Wireless Sensor Networks (WSNs) and Geographic Information System (GIS) to display real time pollution map to make decisions towards traffic management. This system enables authorities to promote route traffic in urban areas [9].

(DE LOTTOA, Roberto, et al) apply Wireless Sensor Networks (WSNs) by listing the broad range of applications to urbanist problems, thus sensing their relevant parameters like building strains, level of noise, level of pollutions, and video feeds. Their job shows two-folds; first, introducing Wireless Sensor Network technologies as an attractive solution to many monitoring applications in urban scenarios. Then, producing preliminary set of experimental results to assess the main involved parameters. Finally, they discussed the integration of a WSN with the GIS; in order to associate physical measurements with geographical information. They also discussed the characteristics and challenges of WSNs [7].

III. TRAFFIC SIGNALS MANAGEMENT SYSTEM (TSMS)

Traffic network is supposed to be a complicated system consisting of many different agents interacting together;
their actions are strongly coupled. Traffic networks are
supposed to be a system consisting of smart agents that
each one control intersection. Practically, traffic signal
controllers have been located at intersections that can be
seen as autonomous agents, since the number of agents is
high in real urban networks [1].

Traffic Management: The main objective of such system
is to reduce congestion of traffic network and optimizing
the usage of road capacity. This is performed by traffic
optimization and real-time traffic light control. Challenges
of ITS applications: (Reliability, Real-Time.,
Heterogeneity, Security and Multimodal sensing) [8].

A. Traffic Signals Management Methodology

Conditions including average speed, max speed and
time interval of each link monitored on a large scale
using a spatially distributed WSN, which can count from
tens to thousands of nodes to help avoid traffic jams and
move within traffic signs as fast as possible. TSMDC
algorithm has been developed to detect and avoid these
problems.

According to Software Engineering Science Traffic
signals control Use Case can be stated as follow:
Traffic Signals control Use Case: Main Success
Scenario (Basic flow):
1. Cars stop at the traffic signs waiting for permission to
move.
2. Sign detects the stopping cars then estimates all
available paths for those cars (Figure 1).
3. TSMDC check the states of all available destinatio ns
(path and signals change to green light).
4. The other signs respond with their states.
5. If there are no problems the sign gives the permission
to the cars to move.
6. After cars pass sign returns to its initial state (closed
state).
7. Repeat the above steps finitely.

Extensions (Alternative Flows): the last algorithm may
be stopped according to the following exceptions; any
exception that occurs in the above mentioned steps can be
shown as follows, each with previous corresponding step
number.

*a. at any time.

Step 2: Sign detects no cars stop, the sign then sign keep
on its initial state (closed state).

Step 4a: Next sign of the current sign is congested:
1. Keep the current sign closed in this direction only but
open the other directions.
2. Send message to the next sign again to change its state
when possible.
3. Change the moving direction for that direction to the
open sign.

Step 4b: The next sign of any of the four neighbors' signs
is congested:
1. Keep the sign closed in that direction.
2. Change the moving direction for that direction to the
open sign.

B. Proposed System Algorithm (TSMDC)

Traditionally, Traffic management at the current traffic
signs occurs according to the number of cars stopping at
the signs and the time period those cars spend waiting.

Such methods lack the ability of dynamic controlling of
Traffic signals and cause a lot of waiting time at each
intersection if there is no cars waiting at this link. Cars
have to wait its turning for link to be opened for a period
of time. But our system solves these problems. The signals
are open in dynamic period depending on the existence of
cars at the signals. We classify traffic signals into two
types of intersections (cross and rounded) intersections.
Then TSMDC operates as follow:

a. The initial state is all signals are red at all intersections.
b. The sensor detects car at any link.
c. TSMDC checks the states of all available destinations
   for the current path.
d. The paths that has no collision are open for the current
   path and signals change to green light.

All these steps are stated in TSMDC algorithm shown in
(Figure 3). TSMDC variables:
- SLM(L,A,B): spatial location matrix.
- ast : algorithm start time.
- RS(X) : Reservation State.
- CS :collision State.
- Vs(max, min) : Vehicle speed.
- ad: available destinations.
- tGl: time of Green light.

IV. EXPERIMENTAL RESULTS

A. Data Measurements

The proposed methods have been tested on a large
network. (Mat lab R2013a Simulink module, Core I5
CPU, 4 GB RAM and Windows 10 OS) has been used to
create the network topology. The lanes’ number for each
path is 4. Pre-data files (paths, routing protocols and light
tables) are configured randomly to simulate the real time
systems. The case-study scenario consists of rounded and
cross intersection, as displayed in (Figure 4). The cars
have arrived or departed within 4 paths, through 2 lanes of
inflow/outflow per link and 2 lanes per road (see Figure 5).
The methods performance depends on the parameters
value. During Experiment, each car has sent via the
communications module, (its speed, location, time
topped, travel time, and travelled distance). Most of them
affect the system performance. Using the car’s position,
the system has measured the distance from the car to the
intersection. When the car has been entered in a
predetermined control radius, for all car requests, the
algorithm has produced a collision free path to be
performed by the car, during travelling the intersection.

B. Data Presentation

At the beginning of the experiment, the system prints
car states as follows:

Time = 0/50 (s) | Cars created = 0/Inf | Cars active = 0 |
Computation time = 0.000000 (s)

While experiment processing system continuously print
its states:

Time = 28/50 (s) | Cars created = 10/Inf | Cars active = 8 |
Computation time = 48.570924 (s).

The simulation has been performed for 50 Cycles and
the following results has been shown:
The application results can be seen in Figure 6 (shows the velocities of cars respect to time for all paths during simulations); “X_Axis” represents the occupation cells of the path, “Y_axis” represents the time of occupation of the cells and color map represents the Velocity values of the paths. Then the summary of the simulation can be show as follow:

Table 1: show the numbers of cars in the simulation during execution cycles.

<table>
<thead>
<tr>
<th>Car Status</th>
<th>No.of Cars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Created</td>
<td>17</td>
</tr>
<tr>
<td>Waiting to enter</td>
<td>0</td>
</tr>
<tr>
<td>In Simulator</td>
<td>5</td>
</tr>
<tr>
<td>Exit From simulator</td>
<td>12</td>
</tr>
</tbody>
</table>

The total Distance [m] = 124.5184 m during simulation execution cycles.
The total Time in simulator [s] = 18.3358
Time in simulator per dist. [s/m]= 0.13252

<table>
<thead>
<tr>
<th>Time</th>
<th>Value (Seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Move [s]</td>
<td>18.0725 (98.9558 %)</td>
</tr>
<tr>
<td>stopped [s]</td>
<td>0.26333 (1.0442 %)</td>
</tr>
<tr>
<td>stopped per car [s/car]</td>
<td>0.021944</td>
</tr>
<tr>
<td>stopped per dist. [s/m]</td>
<td>0.001647</td>
</tr>
</tbody>
</table>

The average velocity [m/s] = 6.8671
The average velocity while moving [m/s]= 6.9385

<table>
<thead>
<tr>
<th>Velocity</th>
<th>Time Value (Seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>vel &lt; 10Km/h</td>
<td>2.5283 (13.3724 %)</td>
</tr>
<tr>
<td>vel &lt; 20Km/h</td>
<td>7.1333 (38.7197 %)</td>
</tr>
<tr>
<td>vel &lt; 30Km/h</td>
<td>9.205 (49.9445 %)</td>
</tr>
</tbody>
</table>

Time accelerating = 16.0567 [s] / 87.9233 %
Time breaking = 2.2792 [s] / 12.0767 %
Average time cars are stopped = 0.275 (s)
Percentage of time cars are stopped = 1.1072 (%)
Average time cars are in motion = 18.0608 (s)
Percentage of time cars are in motion = 98.8928 (%)
Average velocity during all route = 24.7523 (Km/h)
Average velocity only when cars are in motion = 25.0253 (Km/h).

V. CONCLUSIONS AND FUTURE WORK

Finally, in our job, we have shown the reason for developing Traffic signals management systems. The discussion states that this system will allow the authorities for traffic routing. There are many benefits behind this system. Since recent technology provides powerful platform upon which other services can operate in terms of results. The integration of GIS & WSN techniques for traffic signals management shows great promise to solve the problems of “Traffic Signals Management” by changing from ordinary control of it that is based on (queue length and wait time) to more smart control that is based on existing of vehicles at intersections. Therefore, the proposed system reduces the waiting time of all cars, manages traffic signals in dynamic ways and reduces traffic at traffic sections. More improvement needs to be performed and system needs to be applied on a large number of intersections and a large number of vehicles.

REFERENCES


AUTHOR'S PROFILE

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Figure 1. Simple intersection with 4 Signals Group

Figure 2. Two Intersections communicating with each other's
Fig. 3. The Flowchart of TSMDC algorithm
Figure 4. Topology network of the system consists of two types of traffic intersections (Rounded and cross)

Figure 5. Map that illustrate all available paths for each link
Fig. 6. The velocities of cars respect to time for all paths during simulations: (a) path 1; (b) path 2; (c) path 3; (d) path 4; (e) path 5; (f) path 6