Control of Urban Traffic Using Low-Cost and Energy-Saving for Wireless Sensor Network: Study and Simulation

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Abstract— **Urban traffic is the heart of many problems: more recent years, this critical aspect involved every day is un favorable for many fields, such as economics or ecology. This paper presents a low-cost and energy-saving urban mobility monitoring system based on wireless sensor networks (WSNs). For these reasons, intelligent transportation systems (ITS) are emerged since the late 1990s, to optimize the best costs and experience of the user on the often complex networks. In this paper, after studying the horizons such systems will focus a large part of our state of the art technology dynamic and used particularly in distributed systems: fixed wireless sensor networks. We will see that these devices can be flexible in the context of ITS and participate low cost to obtain interesting results using GLD and SUMO simulator.**

Index Terms— **WSNs, Intelligent transport systems, urban traffic, ITS.**

I. Introduction

Road transport an issue which implies several aspects. Among the most important ones, we can quote some ones: (accidents, traffic jams, energy consumption, pollution...). These samples reveal the whole extent of our daily movements. The road traffic was developed in order to respond to the need for moving.

The deployment of a sensor network in urban areas is needed to handle the traffic. Each deploy sensor node is equipped with a battery provided limited because energy is a scarce resource for sensors that must be managed to prolong life duration. The energy consumption may be due to the transmitting and receiving of data to neighboring nodes or traffic controller. The waste of energy can be due to one or more facts. According to [1,2] the number of sent data is a main sources of wasted energy.

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Several studies have been conducted on methods of saving energy in sensor networks. Are interested in dealing with this problem, in our situation detailed below, based on the literature [3-17], [22-24] and simulation[16,18,19].

This paper aims at providing a solution to the simulation of the urban traffic by responding to the issue of energy consumption of the used sensors in the management of the traffic in case of crossroads.

At first, let's deal with some tasks related to the subject [12-14]. We suggest an architecture to the network of the sensors used at a junction.

At a second step, we feature two simulators we used (GLD & SUMO) in order to design and simulate road traffic. The simulation results are involved in the algorithm to deal with the stated problem.

Finally, a conclusion is drawn to display the results and summarize the main contribution of our work and further research.

II. RELATED WORK

Today many tools of simulation are able to simulate and achieve studies to the motorway traffic.

On the other side fewer tools are designed to suggest solutions for simulation of road traffic in an urban field.

This is due to the fact that urban networks present not only junction (points) of flow fusion (i.e intersection in a flow of vehicles), but crossroad intersections of flows (i.e crossing of a flow of vehicles) as well.

Besides these intersections or crossroad (junction) are different because they imply conflict areas, the latter are located in a road traffic. The issue, therefore is to simulate the urban intersections, to link the various traffic flows or to coordinate the simulated vehicle actions by using sensors by roads lanes.

The management of road traffic is involved in the ITS. The latter have a very wide field of application in an urban: The ITS change the management and control of intersections equipped with traffic lights.

Our study is going to focus on our main interest: The application of fixed network of wireless sensors (Electro-magnetic sensors) to the ITS in the case of an intersection. The objective is to reduce the energy consumption of the sensors, in order to lengthen the life duration, in decreasing the number of packages sent to the controller.

III. TOOLS SIMULATOR

Use In this part, we chose both GLD and SUMO simulators:

A. *Green Light District Simulator (GLD)*

GLD [19,20] is a program that performs discrete simulations of road networks. The full application consists of two part: an Editor and Simulator. The Editor enables the user to create an infrastructure (a road map) and save it to disk. The simulator can then load the map and run a simulation based on that map. Before starting a simulation, the user can choose which traffic light controller and which driving policy will be used during the simulation (i.e., it specifies traffic-lights green-red policy).

A traffic light controller is an algorithm that specifies the way traffic lights are set during the simulation.
Figure below shows the software interface [20]

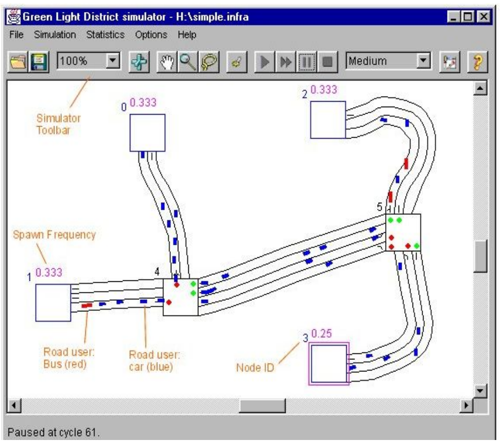

Fig.1: Green Light District Simulator

B. *Simulator of Urban Mobility (SUMO)*

SUMO is a simulator open source at a discreet time, continuous space and microscopic fully realized in C ++ to modelize road traffic flow. [18]

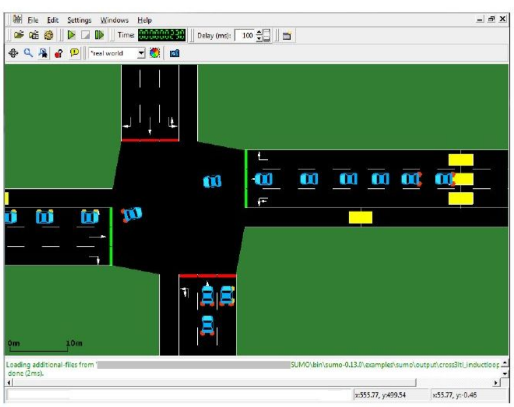

Fig. 2: Simulator of Urban Mobility

Studies are outstanding. We will present them in future work. Order to compare them with the results of GLD simulator.

IV. PROCEEDING AND CONTEXT

Yousef & al. [19], Tubaishat & al. [20] and Zhou & al. [21] used the wireless sensors networks to manage traffic lights. The infrastructure used is shown on Fig. 3 by setting the hypothesis that each lane has two sensors, the first sensor (C_1) is placed before the traffic lights, and second (C_2) is placed after, (d) is the distance between the two sensors.
Moreover, a controller is present on the side of the road to collect sensors data. This model allows us to properly measure the length of queues and the average waiting time at a junction.

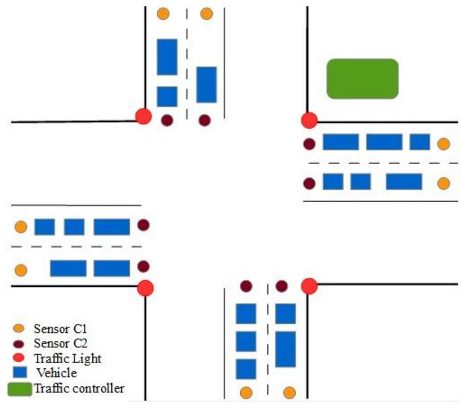

Fig. 3: Model on a generalized intersection with two sensors per lane

We use in that case the electric-magnetic sensors [21]. they have the same behavior regardless of the junction : when a metal object passes over, this sensor detects variations in the terrestrial magnetic field. When a variation has occurred means that a vehicle is detected, in order to know its type (according to the intensity of the variations), to measure its speed or its length.
Authors S. Faye & al . [15, 16] made a comparison between models formerly presented.

Authors	Number of sensor	Position	Decisions	Management of energy sensor	Simulators
Yousef & al. [14]	2/lane	At the light/before the light	By cycle	Take into account	Inner simulator
Tubaishat & al. [12]	2/lane	Ditto	By cycle	No detailed	GLD
Zhou & al. [13]	2/lane	Ditto	By cycle	No detailed	iSensNet

We provide a detailed aspect of the sensors energetic management that represents one of the major constraints (A sensor is limited by energy <1.2V). It is for this reason that current research focuses primarily on ways to reduce this consumption [1, 2].

V. PROPOSED WORK

In this part we suggest a method based on the number of messages sent by the sensor C_1 to the traffic light controller let's describe the method in details.
When a crossing of vehicle is detected by a sensor, it produces a detection message and send it to the controller in order to real time traffic management. However the repeated

forwarding of the messages generates an important consumption of energy.
To reduce energy consumption, we suggest to reduce number of sent packages. We define the presence of a vehicle as the fact of being located in the detection zone of the sensor. Besides, each detection or vehicle passage is referenced by the time (T). Fig. 4 illustrates the vehicles detection through a fixed sensor.

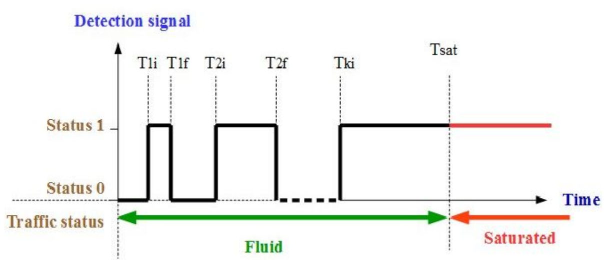

Fig. 4: Detection signal of the vehicles by sensor C1

T_0 : Date and time of the performance

K : Number of vehicles(between the 2 sensors)

T_{ki} : Beginning of the vehicle detection

T_{kf} : End of the vehicle detection

$T_d = T_{ki} - T_{kf}$: Time of the detection

T_{sat} : Starting time from which the queue is saturated

The sensor involves two status:

- Status 0: No vehicle detected
- Status 1: Vehicle detected. We're interested in status 1.

When a vehicle has just been detected by the sensor, the latter stands (status 0), we there for say that it is the beginning of the detection.
When the detected vehicle goes by the sensor changes its status (status 0) that's the end of the detection. The time elapsed between the change of the sensor from $0 \rightarrow 1 \rightarrow 0$ is called the detection duration (Fig. 4).
We also define the T_{sat} the time when the queue is saturated. when $T_d \geq T_{sat}$ that mean queue is saturated , the sensor will send a package to the controller.

- *Algorithms Of Packages Transfer*

In this sub-section, we will present the average number of the sent packages during the algorithm execution. It's based on the simulations which were performed on a intersection with probabilities entry the nodes ([1]Spawn Frequency) 0.2; 0.4 and 0.8.
We will present the graphs according to the two following algorithms:

a) Classic Algorithm

if ($T_d \geq T_{sat}$)
 then Transfer of packets
 else Normal functioning

[1] Spawn frequency: is the frequency(or probability) at which a node spawns new road users. Its values range between 0 and 1. For example, a spawn frequency of 0.2 for a node means that the node will spawn one car every other time step(or cycle).

In the previous cases (GLD,) each simulation is launched during the 7000 cycles and estimate the average waiting time of vehicle. The latter is compared to the saturation time of the waiting line T_{sat} . We define T_{sat} is the average value of the AJWT (results of the GLD- Section VI).
The sensor (C_1) measure the permanent arrivals (by verifying the classic algorithm), whereas the sensor (C_2) operate at a green light, which will to send a package to the (C_1)sensor (the line is freed).

Table 1: Total number of sent packets during 7 000 cycles -
-Classic Algorithm-

Spawn frequency	0.2	0.4	0.8
T_{sat} (Average of AJWT)	8.59	25.78	35
Total number of sent packets.	190	338	772

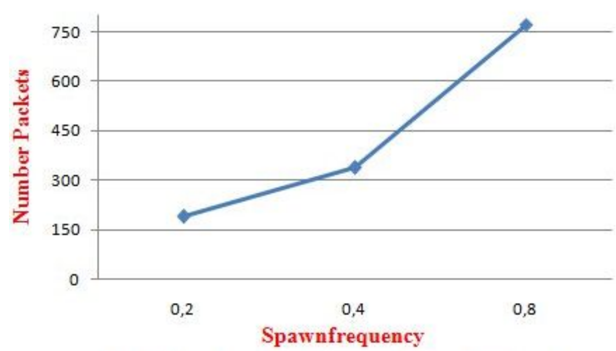

Fig 5: Number of packets sent during 7000 cycles

b) Proposed Algorithm

In order to simplify and make our algorithm efficient, we focused on the objectives indentified previously.
The updated algorithm b) T_{sat} (Average of AJWT, we note $T_{sat} = T_{SatRef}$. The value of AJWT is compared to the new value of T_{sat} (semi-dynamic). We define T_{sat} as following: $T_{sat} = T_{SatRef} + \frac{I_{SatRef}}{2}$

A part of the algorithm is described below: (developed by programming language C Sharp)

```
foreach (double ajwtMoy in rowsValues)
{
    if(ajwtMoy >= tSatRef)
    {
        nbBrute++;
    }
    if (ajwtMoy >= tSat)
    {
        ++nbrPaquetsEnv;
        paquetEnvoye = true;
    }
    else
    {
        paquetEnvoye = false;
    }
    if (paquetEnvoye)
    {
         tSat = tSatRef + tSatRef / 2.0;
    }
    else
    {
        tSat = tSatRef;
    }

}
return nbrPaquetsEnv;
```

Table 2: Total number of sent packets during 7 000 cycles -Algorithm b)-

Spawn frequency	0.2	0.4	0.8
T_{sat} (Average of AJWT)	Semi-dynamic		
Total number of sent packets.	105	288	417

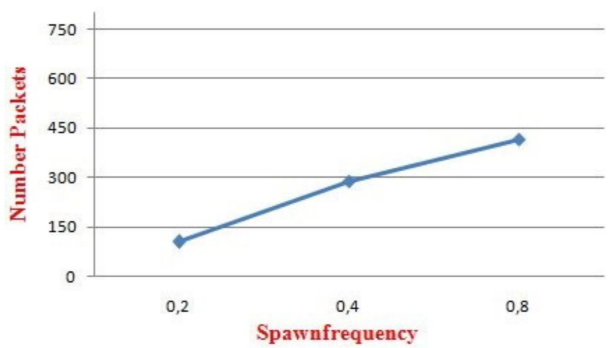

Fig 6: Number of packets sent during 7000 cycles

Fig. 5 and Fig. 6 show the number of packets sent by the network C1 sensor during 7 000 cycles according to Spawn frequency. Fig. 5 shows that the number of packets sent is high (772 packets/C1 for the entry probability of hedge knots 0.8).

We also notice that this number increases with the entry probability of the knots, this is justified by the fact the total of the waiting time increases as well as length of the waiting.

However, if we compare the graphs of sent packets Fig. 7 according to algorithm a) (normal) and algorithm b) (Optimized) for the same spawn frequency, we remark that the number of sent packets by C1 sensor has decreased twice less.

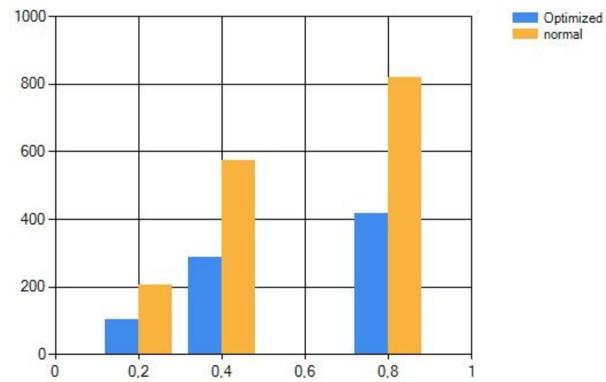

Fig. 7: Comparison between the two algorithms

VI. SIMULATION RESULTS

in our case, we chose a simple infrastructure (an intersection). A screen shot of the software is available in Fig. 7

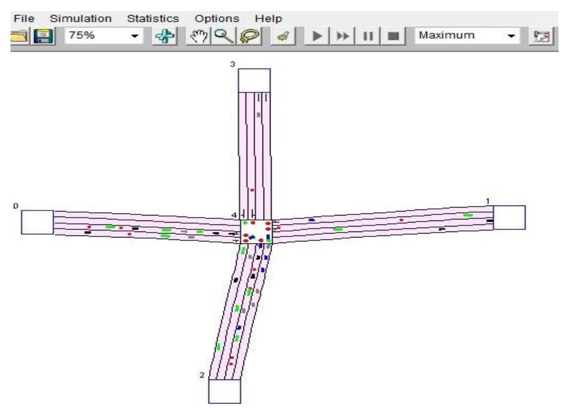

Fig. 7: Green Light District Simulator

While running a simulation, GLD can track different types of statistics such as the number of road users that reached their destination, the average junction waiting time (AJWT) or the average trip time shows in Fig. 8

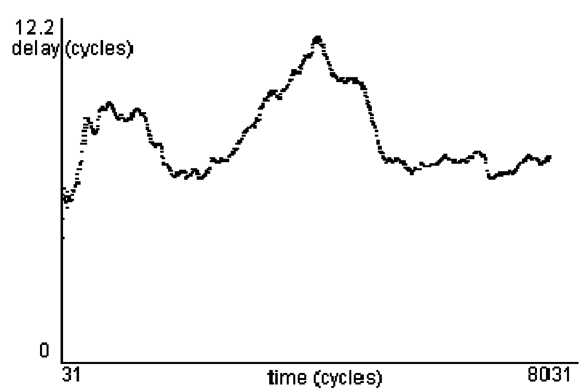

Fig. 8a Spawn frequency 0.2

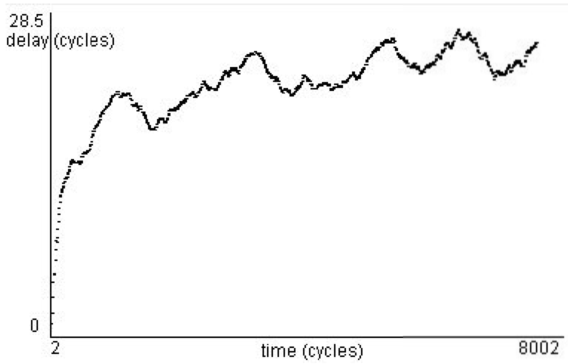

Fig. 8b Spawn frequency 0.4

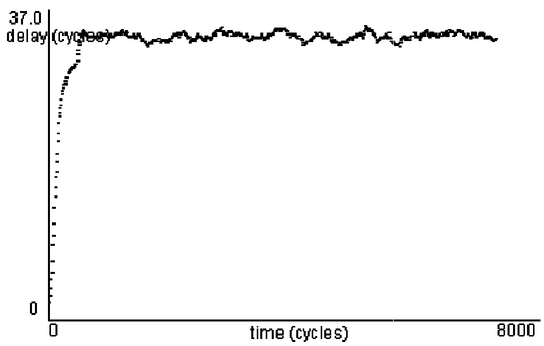

Fig. 8c Spawn frequency 0.8

Fig. 8 displays the average junction waiting time (AJWT) illustrated through the simulation of 7000 cycles. The cycle being a time unit of GLD, and it corresponds to a software movement, the simulations were performed on an intersection with entry probability of edge node 0.2 ; 0.4 and 0.8 (for each cycle, for each edge node).

The enclosed table sums up the values achieved:

Table 3: Results of simulation: Average AJWT during the last 7.000 cycles

Spawn frequency	0.2	0.4	0.8
Average of the AJWT	8.59	25.78	35

Simulation results are used in the algorithms mentioned previously (Sections V. a) and V. b))

VII. CONCLUSION AND FUTURE WORK

In this paper we briefly described our method to treat with the energy constraint of sensors implemented in the urban traffic management as well as the simulator GLD used to evaluate the method suggested.

Then, we have show the efficiency of our solution according to the following metric: - the consumed energy is proportional to the number of packets sent by the sensor.

The simulations graphs show the optimization of the number of packets sent to the controller, which leads to lower energetic consumption, and therefore lengthens the life duration of the system, also results in a lower cost of shipping packet (As the latter is three to four times more costly than the reception cost of a sensor). This makes hypothesis more valid.

In order to give to our work continuation, we provide a more complex case: several intersections, C2 sensor and the algorithms that control manage traffic lights.

It is also necessary to perform again the simulation with SUMO and compare them to the obtained results.

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