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ENERGY SAVING IN WIRELESS SENSOR NETWORKS: URBAN TRAFFIC MANAGEMENT APPLICATION

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ABSTRACT

Since ten years, researches on the technology of wireless sensor network (WSN) in the field of urban traffic management succeed without proposing a reliable solution for all the constraints suffered. In this article, we study the scenario of using a wireless sensor network to control traffic lights an urban transport network and optimize its functioning by reducing the average waiting time of users and traffic fluidity. We are interested in a simple network at an intersection. Our study provides primarily, a study of the researches work that were done, and who are at the present time, in order to solve the number of communication problem between network of sensor node and the traffic light controller (each node collects data and sends them) with the consideration of energy consumption. it is termed the energy of communication. Note that the energy of communication represents the largest portion of the energy consumed by a sensor node. So, it is necessary minimize energy costs, because energy is a key constraint in sensor networks. For this, we have proposed an algorithm to reduce the number of packets sent by the sensor. The results of our simulations show that our algorithm is effective and practical.

Keywords: *Wireless sensor Networks (WSNs), Energy saving, Algorithm, urban traffic, Energy consumption, energy of communication*

1. INTRODUCTION

The sector of transport , mainly the road transport ,involves several problems in cities where traffic is too heavy ,let us quote some of them: accidents, congestions ,energy consumption and pollution. The road network is developed in order to solve these problems and ameliorate the quality of urban services (for example: the management of urban traffic) or the reduction of costs, by using the Information and Communication Technologies (ICT), that is the principle of how smart cities work. Existing ITS solutions based on bulky and power-hungry devices, which use wired technologies for communication and power supply. This increases their installation, maintenance, and reparation cost and subverts the scalability of ITS affecting thus their major objectives [1]. Advances in embedded systems and wireless technology give birth to wireless sensor networks (WSNs), which are composed of cheap and tiny devices that communicate wirelessly and sense the surrounding environment. Each device node contains sensors, a processor, a memory, a radio, and energy source. With WSNs, can be used to sense, process and transmit data to optimally manage complex situations and enabling to fluidify and manage the road traffic, especially at intersections where they can directly act on the traffic lights. knowing that Energy consumption is one of the most

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fundamental but crucial factor determining the success of the deployment of sensors and wireless sensor networks (WSNs). Efforts have been made to minimize the energy consumption of wireless sensor networks and lengthen their useful lifetime at different levels and approaches.

In this article, we are particularly interested in traffic management in a single intersection [2] by a wireless sensor network. Our aim is to provide a solution to the simulation of urban traffic by responding to the problem of energy consumption of sensors used in traffic management in case of crossroads.

At first, we quote some models of the literature, we propose an architecture for sensor network has deployed an intersection [2,4-8].
At a second step, we talk in more detail in the interest of the use of wireless sensor networks to control urban traffic, and we establish the architecture of a sensor node. However the rest of this paper is organized as follows:

After having presented the sensor network architecture deployed at an intersection, we describe the main causes of energy consumption in WSN, and then we present in the following different techniques used to minimize this consumption [3], in order to get an overview of our solution.

The next part will be devoted to the presentation of our proposed algorithm, and used the simulator. We will finish this study with a conclusion describing the results of the work and addressing the perspectives of this project.

2. LITERATURE MODELS

Yousef & al. [4], Tubaishat & al. [5] and Zhou & al. [6] used the wireless sensors networks to manage traffic lights. Figure 1 shows the infrastructure model which is typically used in the literature: an intersection composed of four directions with a fixed number of channels for each.

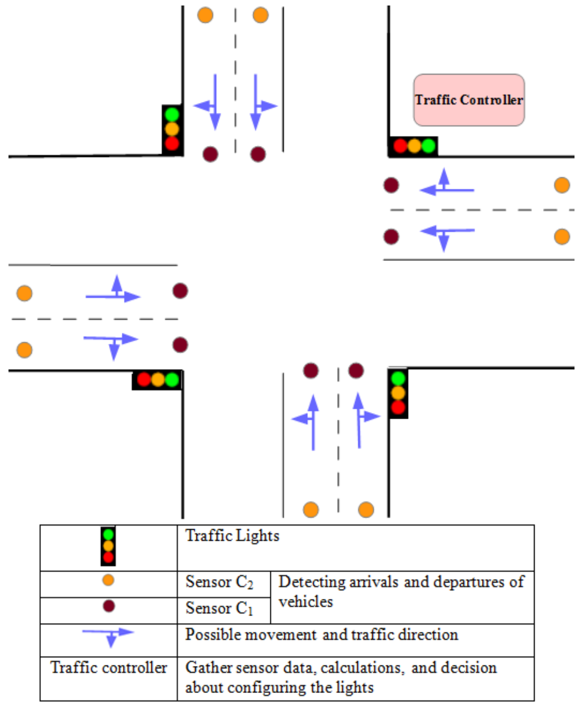

Figure 1: The Literature Model Of A 4-Directions Intersection.

Often considered, in the literature that each incoming lane is equipped with two sensors:

- One located in front of the fire in order to record departures (Sensor C1), and the other at a fixed distance, to detect the arrivals (Sensor C2). The distance between the two sensors (C1 and C2) is variable and must be long enough to measure the evolution of the queue during a green light but not too important, in order to minimize errors due to lane changing users. The literature advocated a distance of the order of 5 to 8 Vehicles entering , [4-5], or a distance according to the maximum time of green light [5]. Moreover, a controller is present on the side of the road to collect sensors data.
- The other, only one sensor is sufficient to estimate the arrivals process, but provides a less accurate result. A direction sensor also allows to obtain the results [7].

As specified in [11], wireless sensor networks need to communicate over short distances using a minimum of energy, why we study the aspect of energy management a sensor. Because it is limited in power (<1.2V). In most cases the battery replacement is not possible. Which means that the lifetime of a sensor depends greatly on the

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lifetime of the battery [12,13]. It is for this reason that current research focuses primarily on ways to reduce this consumption [14,15].

3. ARCHITECTURE OF A SENSOR NODE

A sensor node is composed of four main units [16, 17,18], which are presented in Figure 2

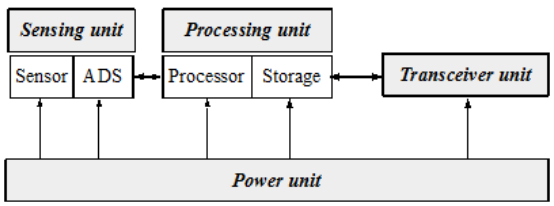

Figure 2. The components of a sensor node

- **Sensing unit:** It is usually composed of two subunits: sensors and Analog-to-Digital convertors (ADC's). Analog signals produced by sensors based on observed phenomenon are converted to digital signals by ADC, and then fed into processing unit
- **Processing unit:** It manages the procedures that make the sensor node collaborate with other nodes to carry out assigned sensing tasks. It is generally associated with a small storage unit.
- **Transceiver unit:** it is composed of a transmitter / receiver (radio module) for communication between the various nodes of the network.
- Concerning the **power unit**, it's the battery which is an important component of a sensor. In general, its neither replaceable nor rechargeable. The limited energy capacity at the sensors is the main constraint for sensor.

We noticed that Wireless Sensor Networks are characterized upon by limited energy capacity making it the optimization of energy consumption a critical task to prolong the network lifetime. In the next section we will discuss the different factors involved in the consumption of energy and we will present some techniques to conserve this energy.

4. ENERGY CONSUMPTION AND CONSERVATION IN WSN

The sensors are designed to operate for months or even years. Thus, the sensor energy capacity to be used efficiently to maximize network lifetime. To note that once the sensor node has exhausted its energy, it is considered as failing.

In this section, we describe the problem of energy consumption in sensor networks. We will also present the main solutions proposed in the literature for the management of energy consumption and the overall overview of our solution.

4.1 Energy consumption in WSN

The energy consumed by a sensor node is mainly due to the following: Sensing, processing and communication of data [20]. We can classify them according to their energy consumption:

- **Sensing energy:** The sources of energy consumption nodes for detection or capture operations are: sampling, analog-digital conversion and signal processing. In general, the capture energy represents a small percentage of the total energy consumed by a node. The treatment energy is low relatively to that required for communication [21,22].
- **processing energy:** The energy of treatment is divided into two parts: the switching energy and energy leakage. In general, the treatment energy is small compared to that needed for communication[24,25].
- **Communication energy**: The energy of communication is divided into two parts: the reception energy and the energy of the emission. This energy is determined by the amount of data (number of packets) sent to the traffic controller, and the transmission distance, as well as by the physical properties of the radio module [20,26-28]. Let us note that the energy of communication represents the largest portion of the energy consumed by a sensor node.

In our study, we interested in our study the number of data packets sent.

4.2 Global overview of our solution

After the description of the main causes of energy consumption in WSNs used in traffic management, in this step we are going to present our solution to minimize this consumption. The following diagram (Figure 3) provides an overview of our method, and outstanding research related with our subject.

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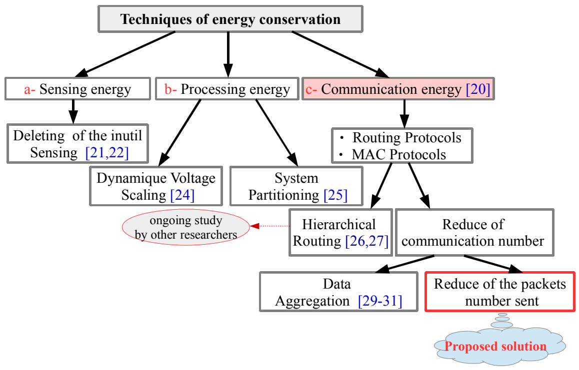

Figure 3. Global overview of our solution

The sensor of energy can be saved either to (a) Sensing level, (b) Processing level or (c) Communication level. We interested in level (c).

5. TOOLS SIMULATOR: GREEN LIGHT DISTRICT SIMULATOR (GLD)

GLD [32, 33, 34] 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 [32]:

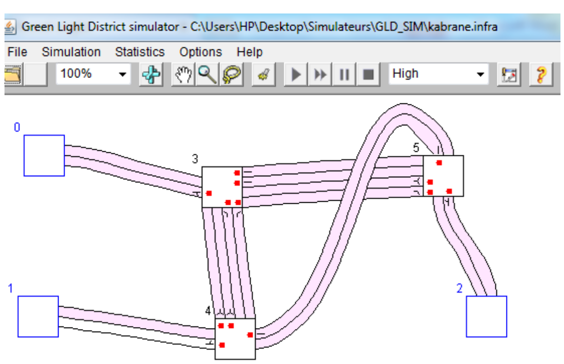

Figure 4. Green Light District Simulator
A simple map with 6 nodes (3 junctions & 3 edge nodes)

An infrastructure consists of roads and nodes. A road connects two nodes, and can have several lanes in each direction (see Figure 4). A node is either a junction where traffic lights are operational (although when it connects only two roads, no traffic lights are used), or an edge-node. Every junction is controlled by a traffic light controller (TLC) that decides on the best configuration of red and green lights. A TLC will only consider safe configurations, that is, configurations in which moving cars do not intersect. A TLC can share information with other controllers to improve global performance. GLD has several built in TLCs, and allows for custom TLCs

6. RELATED WORK

This part we suggest a method based on the number of messages sent by the sensor C1 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 reducing number of sent packets. 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). Figure 5 illustrates the vehicles detection through a fixed sensor [35,36].

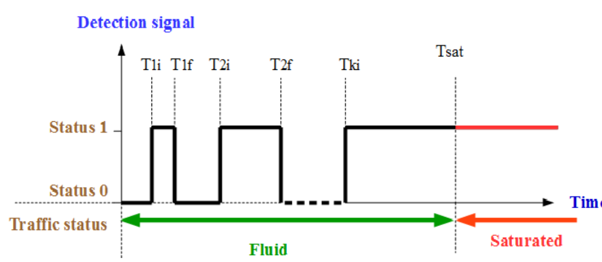

Figure 5. Detection signal of the vehicles by sensor C_1

T_0: Date and time of the performance

k : Number of vehicles (between the 2 sensors) with $k = \{1; 2; 3; \ldots\}$

T_{1f} : End of the first vehicle detection

$T_d - T_{ki} - T_{kf}$: Time of the vehicle 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. Were interested in status 1.

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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 (Figure 6). We also define T_{sat} the time when the queue is saturated. When $T_d \geq T_{sat}$ that mean queue is saturated.

- **Algorithms of Packets 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 (Spawn Frequency) 0.1 ; 0.2 ; 0.3 ; 0.4 ; 0.5 ; 0.6 ; 0.7; 0.8 and 0.9, knowing that 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 0.3 for a node means that the node will spawn one car every other time step(or cycle). We will present the graphs according to the two following algorithms:

a) Classic Algorithm:

if ($T_d > T_{sat}$)
then Transfer of paquets
else Normal functionning

In the previous cases (GLD) each simulation is launched during the 1000 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 V).

The sensor (C1) 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 2. Total Number of sent packets during 1000 cycles Classic Algorithm

Spawn Frequency	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
T_{sat} (Average of AJWT)	7.82	9.76	11.49	17.21	25.79	27.89	28.94	29.42	30.31
Total Number of sent packets	203	298	382	479	547	638	664	689	709

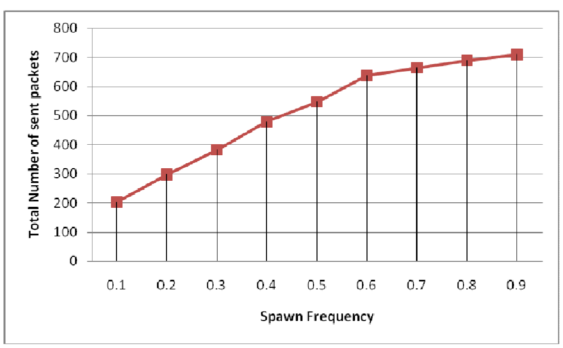

Figure 6. Total number of sent packets during 1000 cycles - Classic Algorithm -

b) Organizational Chart :

The flowchart in the figure below shows the general operation of our proposed algorithm. It shows the time or a node can transmit a data packet to the traffic controller. The main objective of our work is to conceive an algorithm (using simulation data) which minimizes the number of packet sent in order to save energy and increase the lifetime of the network [36].

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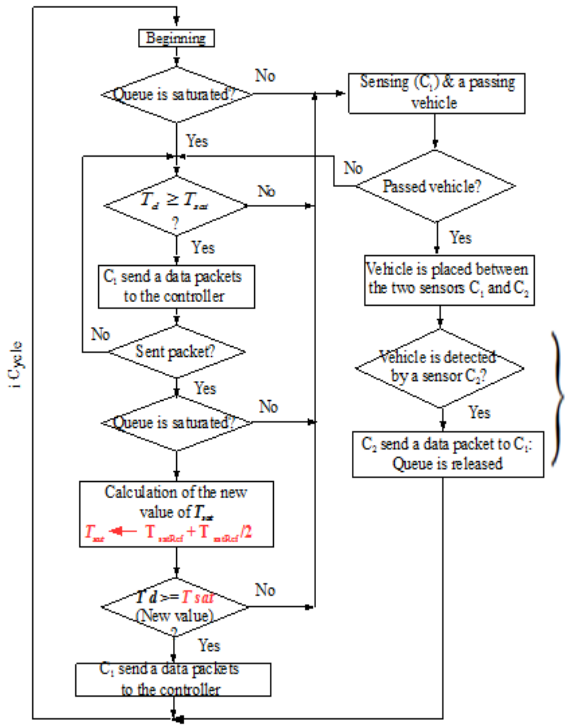

c) Proposed Algorithm:

In order to simplify and make our algorithm efficient, we focused on the objectives indentified previously. The updated algorithm (Proposed) 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: $T_{sat} - T_{satRef} + \frac{T_{satRef}}{2}$

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

```
//Calcul Tsat
tSatRef = rowsValues.Average();
double tSat = tSatRef;
bool paquetEnvoye = false;
//Algorithm
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;
```

Table 3. Total Number of sent packets during 1000 cycles Proposed Algorithm

Spawn Frequency	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
T_{sat} (Average of AJWT)	Semi-dynamic								
Total Number of sent packets	101	149	196	239	273	329	332	344	362

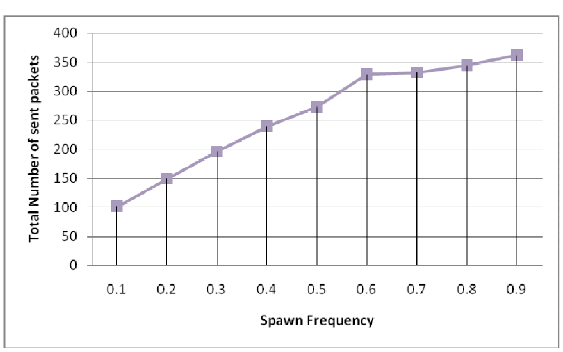

Figure 7. Total number of sent packets during 1000 cycles -Proposed Algorithm-

Figure 6 and Figure 7 show the number of packets sent by the network C_1 sensor during 1000 cycles according to Spawn frequency. Figure 6 shows that the number of packets sent is high (709 packets/C_1 for the entry probability of hedge knots 0.9). 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 Figure 8. according to classic algorithm (normal) and proposed algorithm (Optimized) for the same spawn frequency, we remark that the number of sent packets by C_1 sensor has decreased twice less.

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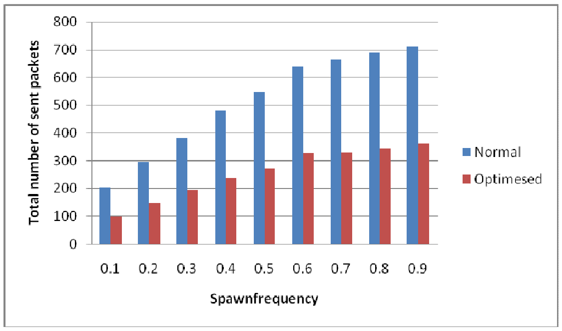

Figure 8: Comparison between the two algorithms

In our case, we chose a simple infrastructure (an intersection). A screen shot of the software is available in Figure 9.

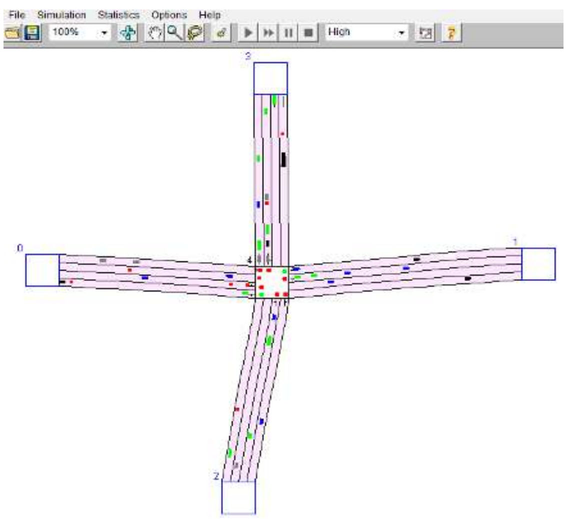

Figure 9: Green Light District Simulator

Road users are allowed to: Turn left, Go straight ahead, or Turn right, as shown in Figure 10.

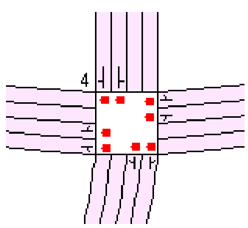

Figure 10. Direction of movement on each line

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 Figure. 11

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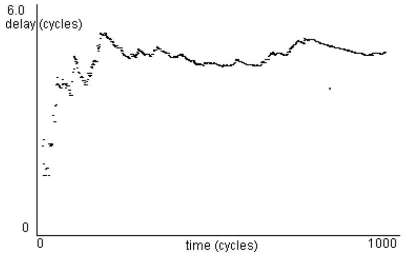

Figure 11 a) Spawn frequency 0.1

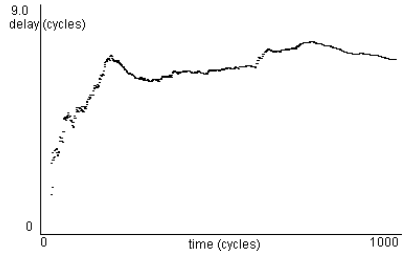

Figure 11 a) Spawn frequency 0.2

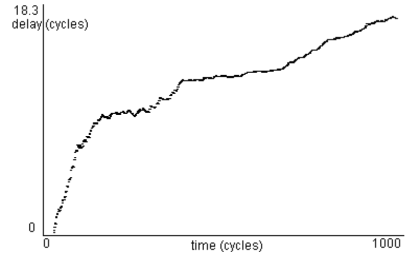

Figure 11 a) Spawn frequency 0.3

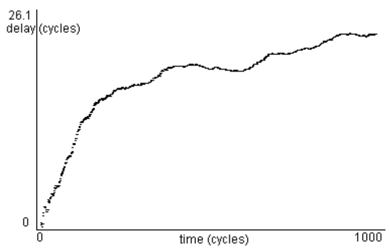

Figure 11 a) Spawn frequency 0.4

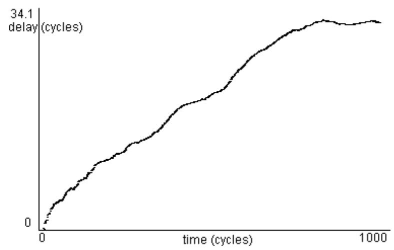

Figure 11 a) Spawn frequency 0.5

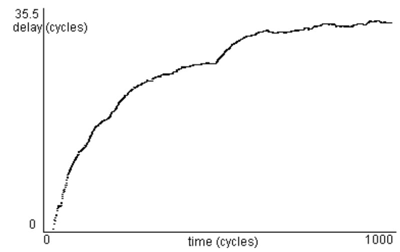

Figure 11 a) Spawn frequency 0.6

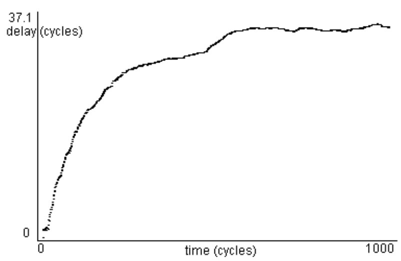

Figure 11 a) Spawn frequency 0.7

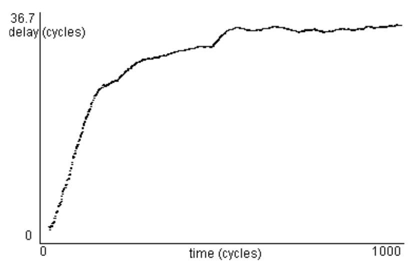

Figure 11 a) Spawn frequency 0.8

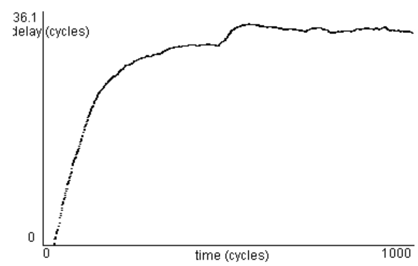

Figure 11 a) Spawn frequency 0.9

Figure 11. displays the average junction waiting time (AJWT) illustrated through the simulation of 1000 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 0.1 ; 0.2 ; 0.3 ; 0.4 ; 0.5 ; 0.6 ; 0.7; 0.8 and 0.9 (for each cycle, for each edge node).

The enclosed table sums up the values achieved:

Table 4. Results of simulation: Average AJWT during the last 1000 cycles

Spawn Frequency	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
T_{sat} (Average of AJWT)	7.82	9.76	11.49	17.21	25.79	27.89	28.94	29.42	30.31

Simulation results are used in the algorithms mentioned previously [Section 6-b) and 6-a)]

7. CONCLUSION AND FUTURE

In this article, we investigated the constraint energy in wireless sensor network, in the field of urban traffic management. We proposed our solution to extend the life of the sensor, so as to reduce power consumption by minimizing the number of packets sent. We run simulations for diffirentes spawnfrenquency values (value between 0 and 1: The scenario with a high traffic density). The values obtained are used in our algorithm. The results demonstrate the efficiency of our algorithm to reduce the number of packets sent (communication data) and reducing unnecessary waiting time for vehicles and traffic load.

In future works, we will construct network models based on real urban main roads to evaluate the performance of our algorithm under more complicated scenarios (several intersections). In

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addition, we will combine our algorithm with other parameters using the SUMO simulator and then compare results with those obtained previously.

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