A study of Wireless Sensor Network Architectures and Projects for Traffic Light Monitoring

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A study of Wireless Sensor Network Architectures and Projects for Traffic Light Monitoring

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Abstract

Vehicular traffic is increasing around the world, especially in urban areas. This increase results in a huge traffic congestion, which has dramatic consequences on economy, human health, and environment. Traditional methods used for traffic management, surveillance and control become inefficient in terms of performance, cost, maintenance, and support, with the increased traffic. Wireless Sensor Networks (WSN) is an emergent technology with an effective potential to overcome these difficulties, and will have a great added value to intelligent transportation systems (ITS) overall.
In this survey, we review traffic light projects and solutions. We discuss their architectural and engineering challenges, and shed some light on the future trends as well.

Keywords: WSN, ITS, traffic management.

1. Introduction

Urban and metropolitan areas worldwide witness tremendous increase of vehicular traffic. This increase results in huge traffic congestion that induces dramatic consequences on economy, human health, and environment. The classical methods for traffic management, surveillance and control become inefficient in terms of performance, cost, maintenance, and support.

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Conventional Intelligent transportation systems (ITS) detect vehicles in predefined positions, and use wired technologies (for communication and power supply), which increases their construction and maintenance cost.
Different vehicles detection techniques are used by conventional ITS such as aboveground sensors (video image processing, microwave radar, laser radar, passive infrared, ultrasonic, and passive acoustic array) but their accuracy is environment dependent. Other detection techniques use underground sensors (inductive loops, micro-loop probes, and pneumatic road tubes). These techniques cause disruption of traffic upon installation and repair. These detection techniques are bulky, power-hungry, and expensive to install, maintain and repair. These characteristics subvert the scalability of ITS and affect their major objectives [1].

Developments in embedded Systems and wireless technology have enabled the creation of small sized and cheap wireless sensors. Wireless sensor networks (WSNs) are composed of spatially distributed nodes that communicate and sense the surrounding physical world. Each node contains sensors, a processor, a memory, a radio, and an energy source. WSN have many advantages in terms of wireless enabled communication, low cost and flexibility. This technology has a great potential to overcome existing difficulties of ITS.

With WSN, different types of motes can be used to sense, process and send sensed data in purpose of mastering complex situations in an optimized manner and enabling online adaptive traffic control systems. Data of interest include position, traffic condition, local weather, images, acceleration, etc. Some possible sensors for ITS include magneto resistive, light, pressure, video, etc.

In [2], a survey of only vehicular sensor networks (VSN) platforms was presented, while [3] discusses many urban applications. In our survey we review WSN based (on road or on vehicles) traffic light projects and solutions. We discuss their architectures and highlight some open issues.

The remainder of this paper will be organized as follows. In section 2, we present some applications of ITS. In section 3, we discuss some requirements of WSN usage in ITS systems. We present in section 4 relevant architectures that are used in ITS traffic light projects based on WSN technology. In section 5, we present and analyze some projects of traffic light management relying on WSN. In section 6 a brief discussion is presented. Finally, we end up this paper with conclusions and open issues in section 7.

2. ITS applications

Intelligent Transportation Systems (ITS) aim to improve traffic quality by enhancing safety and reducing traveling time and fuel consumption through gathering, organizing, analyzing, using, and sharing traffic information.

In traditional ITS heavy and expensive detection systems are used to collect traffic data. In [4], a summary of traditional Vehicle Detection and Surveillance Technologies is presented. Communicating this information to decision maker system is done in wired costly manner. These two drawbacks are deleted by the evolution of embedded systems and wireless technologies which give birth to WSN networks based ITS characterized by their miniature size, ease of installation and certainly their wireless communication that offer scalability with less cost. ITS applications are numerous and can be categorized depending on many factors. [5] Authors' present a large variety of ITS possible applications in both developed and developing countries. Following a possible classification is presented.

- Drivers' safety by transmitting accidents and weather information and dispatch ambulances and fire trucks.

•Traffic Management to minimize congestion and optimize road capacity utilization. This category includes traffic optimization by applying automated traffic assistance decisions and real-time traffic light handling in both isolated and interconnected intersections.

•Smart cities. This category includes: navigation orientations before and during a trip to minimize cost, pollution prevention, parking locations finding and optimization, road maintenance and repair, public transport management, electronic transactions to allow fees payment on roads and parking.

3. Requirements and challenges

We distinguish five main fundamental requirements that should be fulfilled by any enabling technology: reliability, security, interoperability, real-time communication, and multimodal sensing.

Data reliability is of a high importance for urban traffic monitoring and management, but this becomes challenging when using WSN due to the low coverage and limited capacity of sensor motes, added to the lossy nature of wireless communication channels. Therefore, ensuring reliable end-to-end communication must be taken into account by any proposed WSN architecture and communication protocols.
Many applications need real-time information collection to take in-time decisions. Traffic light monitoring is a typical example, where dynamic crossroad management depends on real-time traffic distribution.

The rapid development of wireless technologies and different types of sensors imposes on the proposed solutions to take into account hardware heterogeneity to ensure interoperability and scalability.

Communication security must be handled efficiently by the proposed solutions. Indeed, wireless nature of communications in WSN is more prone to security attacks that wired technologies. Wireless communication can be easily eavesdropped or denied through jamming. This constitutes a privileged target for hackers and terrorism with potentially high collateral damage. Moreover, motes may be deployed without physical protection or surveillance. This increases the risk of compromising the motes by intruders and get access to sensitive data or credentials to pursue attacks through privilege escalation. Motes may also store sensitive information relating to users privacy. Therefore, traffic management solutions based on WSN must take into consideration the vulnerable nature of WSN and their components. Specifically, the communication protocols must be secure enough to prevent attacks and sufficiently reliable and fault tolerant to guarantee service continuity in case of failures.

Traffic control is a multi-objective optimization problem that requires the optimization of various weighted variables as: gas emissions, number of stops, noise levels due to traffic, etc.This diversity in optimization variables requires a diversity of sensors that is actually one of the fundamental design objectives of WSN. We believe that the multimodal nature of WSN is a strong point that allows feeding the traffic control multi-objective problem with the required information in real-time to take the best traffic management decisions on time.

These challenges should be overcome by any WSN based traffic management solution. Some requirements are already fulfilled by WSN technology which make it a favorite candidate for effective ITS systems.

4. WSNs architectures for Traffic light management

Network architecture for ITS applications using WSN technology changes from an application to another, depending on the needs and the cost.
Information exchange can be performed either through ad-hoc communication, or using infrastructure, or hybrid. We also distinguish two types of sensors: on-road sensors and on-vehicle sensors. The

combination of sensor types and communication paradigms gives birth to various wireless sensor network architectures for ITS applications as illustrated in Figure 1.

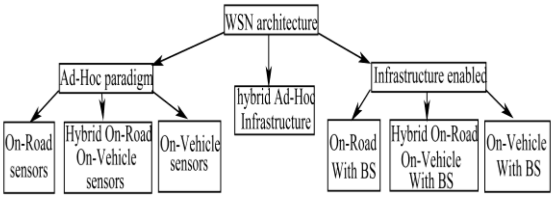

Figure 1WSN Architectures for ITS

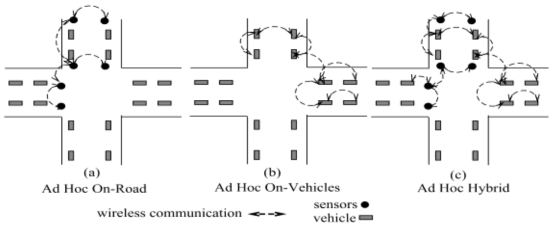

Figure 2Ad-Hoc architectures

4.1. *Ad-hoc paradigm*: In this paradigm sensors do not have a specific backbone but they exchange and forward collected data in an ad-hoc manner. Node deployment can be classified into: (i) On road sensor network, where all sensors are implanted shallowly inside the carriage or on poles next to the road. In this case, sensors are static. Sensors communicate in a multi-hop way (without using any infrastructure) as shown in Figure 2.a. (ii) Vehicular sensor network, where all sensors are included in vehicles.

In V2V (vehicle-to-vehicle*)* communications, mobile nodes directly communicate to each other without any need of infrastructure. Decisions can be taken even locally or cooperatively. In Figure 2.b, a communication example is presented. (iii) Hybrid ad-hoc sensor network, which is more robust and combines the two previous deployments. Both on-road and in-vehicle sensors, (Figure 2.C) exchange traffic information to cooperatively take correct and real-time decisions.

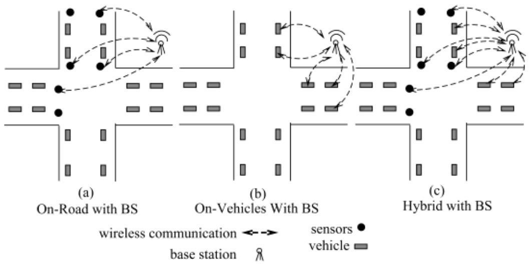

Figure 3 Infrastructure-based architectures

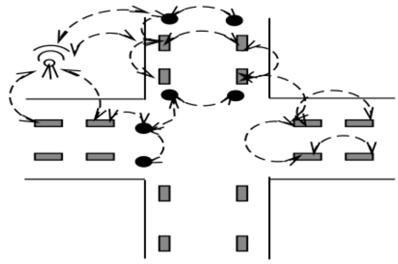

Figure 4Hybrid Adhoc and infrastructure

*4.2 Infrastructure-enabled monitoring:*In this kind of communications all the above sub classes can be found but in the presence of base stations (BSs) that can be also relayed to each other or to servers and Internet through either wireless or wired links. This includes wifi, Wimax, cellular, DSRC, and sensors. DSRC (Dedicated Short-Range communication) [6] is a Wireless Access Protocol used in Vehicular Environments. It operates in the 5.9 GHz frequency range, supports vehicle speed up to 120 mph (192 Km/h), transmission range of 300m (up to 1000 m), and data rate of 6 Mbps (up to 27 Mbps).

(i) On-road sensors with BS, as in Figure 3.a.(ii) Vehicular sensors with BS, as in Figure 3.b. (iii) Hybrid on-road and on-vehicles sensors with BS, as shown in Figure 3.c. The BS makes decisions and notifies actuators. It may also communicate to take global decisions.

4.3 Hybrid ad-hoc and infrastructure-enabled monitoring: In this paradigm, static on-road and mobile on-vehicle sensors and devices communicate using available infrastructures (wifi, Wimax, cellular, BS) or using multi-hop ad-hoc communications in the absence of infrastructure as shown in Figure 4. This kind of architecture is the most efficient and takes advantage of all the available architectures.

5. Traffic Light Control Projects

The goal of traffic light signals in an intersection is to schedule conflicting traffic to move in a secure and manner and exploiting the road capacity as possible. For managing a traffic light controlled intersection, there are many parameters to be defined [7], following the most important ones.

S*ignal cycle* is the repetition of the signal combinations and its duration is a "cycle time". A *stage (or phase)* is a part of the signal cycle, during which one set of streams can move securely. Constant lost times (a few seconds) between stages are necessary to avoid streams interference. *Split* is the green duration of each stage that should be optimized according to the demands. *Offset* is the time difference between green phases of successive intersections that may give rise to a "green wave", where traffic flows over several intersections without need to stop on multiple intersections.

Traffic light control system can manage one intersection or a network of intersections giving so birth to: isolated strategies and coordinated strategies. Also, the system control can use "fixed-time" strategies derived off-line based on historical demands. It uses optimization codes. The system can be "traffic-responsive" using real-time measurements. Optimizing isolated intersection behavior using local traffic information achieves locally optimal performance which often provides a suboptimal system performance. To achieve global optimal performance, neighbouring intersections must exchange their traffic information. TRANSYT [8] is the most fixed-time coordinated strategy used. It is also used as a reference to test real-time methods' improvements. Optimization algorithms introduce small changes to the control parameters (cycle time, split…) to enhance system performance. Many optimizing algorithms were proposed, including fuzzy logic algorithms [9], neural network-fuzzy [10], multi-objective genetic algorithms [11-13], Markov Process [14], etc.

Many parameters for quantifying the effectiveness of such algorithms were introduced such as the control delay or average waiting time, which is the delay that a vehicle spends due to the presence of the signal control, the maximum intersection throughput which is the number of vehicles passing through the intersection, etc. Minimizing the delay at intersections can be achieved by selecting a shortest cycle length to produce less "red" signal time length and shorter queues but without influencing the delay by phase changing overhead.

Several adaptive traffic control systems have been implemented. The most important ones are Split, Cycle and Offset Optimization Technique (SCOOT) [15] and Sydney Coordinated Adaptive Traffic System (SCATS) [16]. SCOOT is the traffic adaptive version of TRANSYT. It is based on inductive loop detectors placed on every link to an intersection (just downstream from the previous junction). It is designed to optimize signal timing by continuously measuring traffic demand. It adapts to changing traffic using a series of optimization routines. A few seconds before every phase change, the SCOOT split optimizer calculates whether it is better to advance or delay the scheduled change by up to 4 s, or to leave it unaltered. In a similar manner, the cycle time of a group of junctions may be incremented or reduced by a few seconds every few minutes.

SCAT contains three types of controllers: a central controller, regional controllers, and local controllers.
The local controller is installed at each intersection. It collects data from detectors, processes it, and executes taken traffic control decisions. The regional controller controls several local controllers.
It analyzes local controller information and implements the corresponding signals. The central controller monitors the entire system and provides management support, backups, and fault analysis.

5.1. On-road only sensors

5.1.1. Hierarchical architecture for urban traffic system

In this work, Curiac and Volosencu [17] propose using a hierarchical three-level strategy to control urban traffic in cities. The lowest level controls single intersection traffic lights by using a wireless sensor-actuator network (WSAN) cluster. The second level (base stations), or ZTC unit, executes the zonal traffic coordination. The highest level is Traffic Coordination unit (TCU) that optimizes the traffic parameters for the city; it is implemented as a knowledge-based decisional system on a secured computer. This hierarchical control provides flexibility for changing the control application (adding or removing monitored entities, integrating other applications, etc).

Each WSAN cluster contains several sensors and one actuator (cluster head) -also termed ITU (intersection traffic unit) - that replaces the intersection traffic light controller by aggregating sensor measurement (vehicles queue length, vehicle time to cross the intersection, etc) and performs the local control algorithm (optimizing traffic parameters for a specific crossroad) and forwards data to other clusters (intersections) or to base station with the role of ZTC. ZTC unit coordinates the ITUs to optimize the traffic by redirecting the traffic flow, implementing “green waves”, etc.

TCU distributes the tasks to the ZTC units and coordinates interactions between different city utilities systems (Disaster Management, Transportation, Public Health, etc).
But authors don’t give details on the algorithms used in this system. They focus only on the architectures and large lines on the possible relation between elements. Also the exploitation of TCU decisions is not so detailed. How does the system inform clients or drivers to use these collected information (through displays or internet browsers…). The security mechanisms involved to meet requirements is not highlighted enough. Also the kind of sensors used is not discussed sufficiently. But the architecture used is appropriate if components are well crafted.

5.1.2. Sensys

Sensys Networks’ [18] wireless vehicle detection system (WVDS) was designed to work seamlessly within SCOOT’s architecture, which was originally deployed with inductive loops. Each WVDS sensor is placed at the middle of a lane, transmitting detection information to a repeater located at short distance away, typically at the nearest pole to the traffic control cabinet.

The system consists of two parts: the wireless sensor network and the access point. Traffic information is generated at the sensor nodes and then transferred to the access point. The communication protocol PEDAMACS (Power Efficient and Delay Aware Medium Access Protocol for Sensor Networks) [19] is used to increase the lifetime of the system up to several years, while still guaranteeing the timely arrival of information from the sensor nodes to the access point. The traffic management center collects the information from each access point to analyze traffic conditions and take appropriate actions such as adjusting the traffic light durations. It permits archiving and doing Statistics, using its statistics (SNAPS) proprietary software or the Sensys System Manager (SSM) appliance, by connecting to the AP via Ethernet or cellular modem. SNAPS/SSM collects WVDS parameters (RF signal strengths, link quality, battery levels) to generate diagnostic alarm alerts for maintaining agency to insure high levels of detector availability.

But authors don’t give information on security mechanisms used to protect communication. Also the algorithms used to implement networked intersection are not presented. The communication protocol used is efficient to enhance the system life time and reduce overhead.

5.1.3. Tubaishat et al.

Tubaishat et al. [20] propose a system composed of wireless sensors (on the lanes going in and out the intersection), localized traffic flow model policy, and the coordination of the traffic lights agents.

Sensors send vehicles' information (number, speed, queue length, etc) to the nearest Intersection Control Agent (ICA) which determines the intersection flow model and dynamically control the traffic lights in real-time by maximizing vehicles flow and reducing waiting time while maintaining fairness among the other traffic lights. Each traffic light is responsible for controlling traffic on three lanes (the right lane turns right only, center lane goes straight or left and the left lane goes left only). Every lane contains sensors monitoring the traffic before entering and after leaving the intersection. Multiple intersection agents exchange information to control intersection network.

Authors use the same sensors and communication protocol as Sensys [18]. But authors don't give information on the flow policy used or the security requirements.

5.1.4. TSCA & TSTMA

Youcef et al. [21] present an adaptive traffic light control system based on Wireless Sensor Network (WSN) for controlling the traffic flow sequences on single and multiple intersections. The system consists of two parts. The first one is the WSN -or TSNs (traffic sensor nodes) - installed on roadside. It collects, periodically, the traffic data (vehicle speed, and length of the vehicles), and sends it to control box (base-station) that run control algorithms.

The second part is the controller, which contains the traffic system communication algorithm (TSCA), and the traffic signals time manipulation algorithm (TSTMA). TSCA finds and controls the communication routes between sensors and the BS by a simple scheduling algorithm that minimizes the collecting data time, as well as the interfacing with the traffic control box.

The TSTMA sets time durations for the traffic signals according to the vehicles' number on each segment and the control box applies it on the traffic signals. The selection process of phases is performed every cycle, with dynamic order of phases based on the queues (lanes) that hold maximum lengths, so that the average queue length and the average waiting time are minimal. For multiple intersections management, TSTMA performs the efficient dynamic control to perform the green wave synchronization. A testbed was also developed and deployed for real measurements.

Authors present the algorithm for signal sequences in both isolated and interconnected intersections. But they don't talk about security of communication nor kind of sensor used (magnetic…). Also the possibility of connecting the system with internet is not enough highlighted to explain the exploitation with other ITS systems or to be displayed by drivers.

5.1.5. Adaptive sequenced Traffic Light Control

Zhou et al. [22, 23] propose an adaptive traffic light control algorithm to adjust both the sequence and length of traffic lights depending on the real time traffic detected instead of just adjusting the green light length in a fixed sequence of traffic lights in the purpose of maximizing intersection throughput and minimizing average waiting time. The algorithm contains three steps: vehicle detection, green light sequence determination and light length determination. It considers a number of traffic factors (traffic volume, waiting time, vehicle density, etc) to determine green light sequence and the optimal green light length.

In this system the intersection has four directions, each one with two lanes (going forward and turning left) and on each lane two sensors are used (arrival and departure). A total of sixteen sensor nodes are placed on the eight lanes to detect the traffic flow.

Another version of this algorithm is also proposed for multiple intersections in the purpose to schedule the sequences and lengths of traffic lights of intersections cooperatively, to decide next green light establishment and duration. The objective is to increase the network throughput, decrease the average delay and average number of stops. Light length determination algorithm can determine the duration of next green light in each intersection using local traffic volume and traffic condition from neighbor intersections. The proposed algorithm is implemented on transportation testbed iSensNet [24].

Authors propose traffic light management algorithms for both isolated and interconnected intersections. But they don't give information about the communication scheme to be used or security protocols. Also the sensors used are not mentioned. The integration of this traffic light system with other ITS possible systems or internet is not discussed.

5.2. Combined on-road and on-vehicles sensors

5.2.1. Adaptive Traffic Lights Using Car-to-Car Communication

Gradinescu et al. [25] propose an adaptive traffic light system using vehicles and fixed intersection controller nodes, equipped with short range wireless communication. Vehicles periodically transmit information (position, identification number, speed, direction, state and a timestamp) about themselves and other cars they know about. The traffic light controller listens to this information to take appropriate decisions.

Neighbor intersection controllers may have wired communications (exchanging additional information). The upstream signal controller forwards information to the downstream one (helping it taking timing decision in advance). At each cycle, the timing plan generation process establishes a plan for the following cycle to minimize control delay (the vehicles' delay caused by the signal control). After determining the cycle length, the green splits for each phase are allocated to produce equal degrees of saturation on each link. If the green phase for a lane has finished, but cars keep coming while there is no demand on the conflicting lanes, the green phase is extended until an acceptable maximum pedestrians waiting time.

Authors present the communication scheme between vehicles and the controller but their algorithm to optimize the traffic is not so detailed. They don't present how to manage multiple intersections. Also they don't present any security mechanism. How does the system react to vehicles don't involving in the system? The authors don't also precise how to join this system to internet or other ITS systems, or drivers displays.

5.2.2. WITS (A Wireless Sensor Network for Intelligent Transportation System)

Chen et al. [26] present a system for gathering and transferring traffic information. It contains three types of nodes, the vehicle unit (in vehicle), the roadside unit (along both sides of road); and the intersection unit (on the intersection).

The vehicle unit measures the vehicle parameters, such as location (through broadcasting from road side units), etc and transfers them to the roadside units. The roadside unit gathers the information of the vehicles around (each unit collects vehicles' information in one direction) and transfers it to the intersection unit. The intersection unit receives and analyzes the information from other units, and passes them to the strategy sub-system.

Intersection unit needs the number of vehicles in every lane that will reach the intersection before the signal phase ends. Roadside units collect the vehicle message and transform them into the data required by the intersection unit. Roadside unit collects the vehicle information in its scope, aggregates them with the data from its upstream node, and passes them to the downstream node. The strategy sub-system calculates an optimized scheme to control and/or guide the execution sub-system.

Authors suppose that all vehicles dispose the vehicle unit, which is not always the case, and base their system on this assumption. The system use road side unit just to collect and defuse information but if used also to sense vehicles, system reliability will be enhanced and the above vehicle unit assumption will not be needed. The authors propose a system for travel minimizing, but they don't propose an algorithm for interconnected intersections and their algorithm don' take into account other parameters to minimize such as cost and fuel consumption. They don't also give details on security mechanisms and how drivers will consume information (through displays…) or how to connect the system with internet.

5.2.3. RFID & sensor-based Traffic Management

Salama et al. [27] design a system for managing and controlling traffic lights based on distributed long range photoelectric sensors in distances prior to and after the traffic lights. The algorithm is based on the total calculated relative weight of each road. The system accepts information about any emergency case through RFID. The system can open a complete path for such emergency cases from the next traffic until reaching the destination. Reporting the emergency is done by installation of RFID (Radio Frequency Identification) tag in the concerned vehicles (police cars, ambulance, fire trucks, etc) and it is detected by RFID reader located besides road. The emergency vehicle driver can be equipped with a mobile device that sends a specific radio signal to the central control system to open the road.

Authors don't give enough details on the algorithm and the possibility to monitor multiple intersections. The position of multiple sensors before the intersection is not justified because vehicles can be detected just with the first sensor and the following can be used as relays. Authors don't also involve security mechanisms or how to extend the system to work with other ITS systems or how to join it to internet.
Using RFID to handle emergency is interesting so that the light signal be emergency enabled.

5.3. On-vehicles only sensors

5.3.1. Virtual traffic lights (VTL)

Ferreira et al. [28] replace traffic lights from roadside infrastructures to dynamic in-vehicle virtual signs protocol through vehicle-to-vehicle communications. This solution optimizes the throughput of the entire road network (rather than only materialized traffic lighted intersections).

The vehicles act as mobile traffic state sensors resolving intersection conflicts, while elected vehicles act as temporary road junction infrastructures and broadcast traffic light messages to drivers through in-vehicle displays. This is done by vehicle-to-vehicle communications (using DSRC). It is supposed that all vehicles have: DSRC devices, the same digital road map, and a global positioning system GPS device (to guarantee global time and position synchronization). Each vehicle contains a database of intersections supporting virtual traffic light VTL. When approaching intersection, the vehicle requests for a running VTL to be obeyed.

If it does not exist and crossing conflicts is perceived, a VTL must be created between approaching vehicles. The vehicles approaching the intersection elect one of them to become the leader of the VTL. This leader will be presented with a red light, and stopped at the intersection while leading it. During this operation, other vehicles are passive, receiving traffic light messages and presenting them to the driver. When the green light is in the leader's lane, a new leader must be elected to maintain the VTL.

If there are vehicles stopped before a red light, the leader selects one to become the new leader. If there are no stopped vehicles, then a new leader will be elected by the same process whenever necessary. If the VTL is no longer required, the cycle is interrupted and vehicles proceed without stopping.

Authors don't explain the algorithm used in this paradigm and if the system support multiple intersection data or not. Also supposing that all vehicles dispose this system is so strong because applying the algorithm in this manner don't only give poor results as the case of supposition of previous works in this paper but engender catastrophic results because a vehicle suppose having green signal but another one suppose having right priority.

6. Discussion

Mobile systems, such as vehicular sensor networks, sense the environment with better granularity and at higher scale, compared to static sensor networks (particularly over large areas), and instrument a larger geographical area with a less number of sensors. But with traffic management applications where critical decisions must be taken in real-time, such as traffic light monitoring, supposing all vehicles dispose on-board sensors or displays is not yet the case. Therefore, the taken decisions may be wrong and engender catastrophic results in life and materials. So, using VSNs or hybrid on-road and VSNs for requesting real time traffic information and avoiding traffic jam is very efficient but not for taking vital decisions in real time manner (as traffic light monitoring in [28]).

For traffic light signaling systems using WSNs, many parameters may be used to enhance the efficiency of the whole system, added to the collected real-time data concerning vehicles (speed, queue length…). For example, a traffic light network of a whole city can use weather and climate (air pollution) values to choose sequences time length.

To benefit completely from WSN and VSN capabilities, the conception of a whole system combining the two paradigms is very interesting. A complete ITS system using the two technologies permit the monitoring and management of traffic vehicles and furthermore the traffic infrastructure. In literature and through the previous study a complex but complete scheme combining on road and on vehicles sensors using different kinds of communication technologies will clearly permit the overall monitoring.
It is explicit that many drawbacks need more investigation and research to permit full commercialization, which is already starting. Applying security communications, privacy protocols, middle-ware platforms different wireless technologies will gracefully assist WSN based ITS systems.

7. Conclusion

Road traffic is becoming an important problem in all countries through the world, especially in industrialized countries. This state obliges thinking to build ITS systems with high dynamicity and low congestion and incidents. WSNs technology helps a lot in designing flexible and cheaper ITS systems because of its easy installation, extension and maintenance. In last years, many projects using WSNs for ITS systems were established. In this paper, we surveyed some existing works on ITS traffic lights, showing their architectural aspect and some weaknesses observed related to each type of architectures to help in designing WSNs based ITS systems.

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