Event traffic detection using heterogenous wireless sensors network

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Abstract—**Deaths due to traffic accidents is a major problem in several countries principally because of the fact that emergency actions are not provided at the place of accident at required time, Basically, in the event of a road accident, a real time traffic accident detection system can intelligently inform the site of accident, reporting it to the proper authorities, informing about the number of injured people so that the type and the amount of emergency services needed can be provided. This paper aims to introduce an approach to the traffic event detection, especially in highways, by the means of heterogeneous WSNs (using unmanned aerial vehicles called UAVs, vehicular sensors, smartphones and ground WSNs). The work includes a system overview and the proposed event detection approach.**

Keywords-Traffic Surveillance; heterogenous WSNs; event detection, UAV, vehicular sensors, smartphones.

I. INTRODUCTION

With the immense use of vehicles nowadays, accidental death number has increased. Due to these accidents, in most of the cases, people lose their life. The main reason for this is due to lack of information about the incident so as to intervene efficiently and as quickly as possible [1]. Event detection in WSNs (Wireless sensors Networks) is commonly used for tasks such as fire or hazard detection in roads, vehicle tracking, area surveillance, undersea monitoring or the classification of human motion sequences. Depending on the application, a variety of sensors can be employed, including unnamed ground sensors (UGV) and Aerial ground sensors (UAV), fixed road side sensors, or vehicular sensors. In general, designers of a WSN-based event detection system need to make two major architectural choices: the first one is about how far the sensor nodes should cooperate during the detection process, the second one concerns how to extract semantically relevant information from raw data. The first of these questions involves trade-offs related to the communication architecture, while the second one deals with algorithmic issues during data processing. The overall goals when tackling these questions are, of course, to minimize communication overhead (and thus energy expenditure) and to maximize the detection accuracy, while minimizing the response time, for a variety of use cases [2]. What characterizes our work from other systems is the uses of heterogeneous ground WSNs in collaboration with vehicular sensors, smartphones and UAVs. UAVs have the potential to be used for traffic event detection, when access with vehicular sensors is not possible. They are cost-effective and can be equipped with cameras that provide useful information. They are programmed off-line and controlled in real-time to navigate, collect information and event data and inform the base station or other entities in case of emergency, infraction or accidental situations It also permits to view incident area in real time enabling the rapid evaluation of severity of damage. UAVs can also help in search and rescue support operations [3]. Hence deploying heterogeneous WSNs can greatly help in preventing road accidents, in particular, along rural roads to help preventing vehicle-animal collision accidents. The WSN nodes can detect a dog for e.g. on the road and propagates the information within the nearby area. Approaching vehicles will get the warning beforehand and the UAV is sent to this place to confirm the threat existence [8].

Another contribution, in our system is the new defection approach, which relay on fuzzy logic algorithm and neural networks. The resulting algorithm, will help on improving detection accuracy and minimizing false alarm rates.

In this paper, we present an approach that uses heterogeneous WSNs to perform surveillance traffic operations and incident detection in roads. The rest of the paper is organized as follows. Section II sets some related works. Section III gives an overview of the proposed approach, its main goals and functionalities and the global architecture of our approach. Section IV focus on our solution for event detection and data processing. Finally, the paper is concluded.

II. RELATED WORKS

Event detection remains an essential task in various WSN applications. There are a number of recent works on traffic monitoring and incident detection. In [4] authors present the design and implementation of an WSN system for traffic safety measurement, [5] presents a Roadway Traffic Monitoring system from an Unmanned Aerial Vehicle, [1] is about monitoring road accidents using sensors and providing medical facilities, [6] proposes an approach of vehicle detection and tracking in airborne and [7] presents an

Unmanned Aerial Vehicles for Road Traffic Monitoring. However, all these works don't benefit from the collaboration of the all elements: WSNs, vehicular sensors and UAVs. In [8], [9] [10] Unmanned Aerial Vehicles are used in collaboration with ground or vehicular sensors. In [8] the Unmanned Aerial Vehicles are used for data collection in Wireless Sensor Networks. However, in this work, authors deal only with linear ground sensors and exclude vehicular and multimedia sensors. In [9], authors present the concept, design and experiments of an integrated network of roadside sensors and vehicles for driving safety whereas [10] presents a secure and resilient WSN roadside architecture for intelligent transport systems. Those two last works deal with the collaboration with only roadside and vehicular sensors.

Moreover, several works have tried to solve the event detection problem in traffics roads, and a numbers of Roadway-Based algorithms with different data requirements, principles, and complexity have been proposed. A reviews on incident detection have been summarized above [11].

1) *Comparative Algorithms, to which belongs:*
   a) *The decision tree DT algorithms,* or so-called California algorithms.
   b) *The pattern recognition PATREG algorithm,* which was developed by the Transport and Road Research Laboratory (TRRL) as part of their Automatic Incident Detection (AID) system.
   c) *The All-Purpose Incident Detection (APID) algorithm,* which was developed for use in the COMPASS advanced traffic management system implemented in Metropolitan Toronto.
2) *Statistical Algorithms, where we find:*
   a) *The SND algorithm,* this last was developed by the Texas Transportation Institute for use in the initial surveillance and control center in Houston
   b) *The Bayesian algorithm,* which uses Bayesian statistical techniques to compute the likelihood that an incident signal is caused by a lane-blocking incident.
3) *Time Series Algorithms: where we find:*
   a) *The ARIMA model,* this model is used to develop short-term forecasts and confidence intervals of traffic variables.
   b) *The HIOCC algorithm,* which also monitors detector data for changes over time, but relies on 1-second occupancy data.
4) *Traffic Modeling Algorithms, in which we find:*
   a) *dynamic model,* which was developed to apply macroscopic traffic flow models to capture the dynamic nature of traffic.
   b) *The catastrophe theory model,* or the so-called McMaster model, which is based on a two dimensional analysis of traffic data.
   c) *The LV algorithm* was designed specifically for detecting incidents under low volume conditions, using an input-output analysis of individual vehicles on a section of roadway.
5) *Artificial Intelligence Algorithms* to which belongs:
   a) *Neural networks*, which are data processing structures used to simulate the thought process and reasoning of the human brain.
   b) *Fuzzy logic*, which is another artificial intelligence technique used for incident detection, that provides a mechanism for applying inexact or imprecise data to a set of rules.
6) *Image Processing Algorithms:* One famous algorithm is The AIDA.
7) *Sensor Fusion-Based Algorithms* we find a works of:
   a) Westerman et al. that attempted to integrate probe vehicle and loop detector data for travel time estimation and incident detection,
   b) Ivan and his colleagues developed two data fusion methods, i.e., algorithm output fusion and integrated fusion, combining fixed detector and probe vehicle data for urban arterial incident detection.
   c) Bhandari et al. also proposed an integrated arterial incident detection method in the ADVANCE project.

Each of those algorithms have their advantages and drawbacks and using only single algorithm in the detection approach gives generally a lot of false alarms rates, wrong measurements and in several cases earlier warnings to drivers. Furthermore, combining multiple algorithms for road event detection from multiple sources gives more reliable and efficient results than using each individual algorithms, which has significant practical applications. In this paper, we present an integrated VANET (Vehicular Ad-Hoc Network)-WSN-UAV system for driving safety. To the best of our knowledge, there is no work that addresses driving safety issue while using VANET, UAVs and other sensors. In the next, we give an overview of our solution

III. PROPOSED APPROACH

This section explores the proposed solution associated with detecting car accidents or events using a heterogeneous sensor data. Such network, if deployed with sufficient road coverage, can significantly help in improving road safety by detecting traffic events in real time and alerting the appropriate authorities as we as other nearby drivers.

A. System Overview

The proposed approach offers the possibility of road accident detection in real time, detection of obstacles in roads, as well as other abnormal situations, including emergencies and other traffic hindrances, Elimination of abnormal situations consequences, Prevention of road accidents and so forth. The proposed system consists of vehicle nodes, ground sensors nodes and UAVs, in order to make the detection system "smarter".

In our case, ground devices used in event detection are: Inductive loop/magnetic sensors, Crash/ impact sensors, Obstacle / ultrasonic sensor, infrared sensor, Sonic sensors, punctual radar, onboard device and toll cards. Furthermore, sensors mounted on UAV are visible-light camera, IR camera (NEC), digital Camera, laser Scanner GPS, and Inertial Measurement Unit (IMU). In vehicles, new technologies have recently been integrated into cars, like Human sensing technologies and pre-crash system thanks to Infra-Red sensor used to detect human, animals and obstacles in roads [1]. Besides, smartphone could also collaborate with all sensors, detect events and send data to the relay nodes. According to their roles, sensor nodes can be regular sensor node or relay nodes. Regular sensor node can only sense measures and send alarms to the relay nodes, while relay nodes have extra responsibilities of discovering and communicating with vehicles, UAVs, ground sensors, smartphone, base station, managing the network, processing data and even deciding if there is a real event or only false alarm. Relay nodes are much fewer than regular nodes. Data collected from vehicles ground sensors are sent to relay nodes, those last are responsible of the processing of information, filtrating alarms, storing data and sending data to the base station. If a dangerous condition is detected (e.g., a dog is roaming on the road), the detecting sensor node (which could be ground sensor, vehicle or smartphone) will generate a warning message and send it to the nearest relay node. This last will process collected data and decides, thanks to a specific application, if it is a threatening event or not, and then propagates the warning along the direction opposite to the moving direction of the vehicles (called backward direction hereafter). Then, the warning message can be propagated within the clusters of vehicles by using data dissemination protocols. In case of accident an alarm is sent to the base station to confirm that accident has really occurred before sending information to medical services or police that should reach to accident place immediately so as to provide help. So, a UAV is immediately sent to the accident place to give reliable and accurate data capture and needed information for the event with high spatial and temporal resolution. The placement of different sensors and components proposed in our approach is illustrated in the picture bellow.

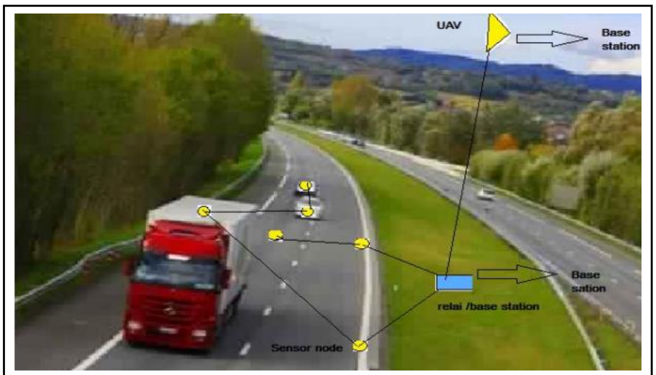

Fig. 1. Node placement

Wireless sensor nodes are external devices that can mainly measure road conditions data more accurately than an on-board sensor. Measurements and procedures carried out by the sensor nodes and vehicles are sent to relay nodes. The relay node is placed in a road side. This node has usually more resources, in terms of processor capacity, memory size or other peripheral devices (as GPS) than the sensor nodes deployed on the road. If these data are considered important events (a framework is used to decide if the event is considered important or not), the relay node will transmit them to a server sited in the monitoring center where the events will be interpreted. Transmission from relay node is usually carried by wireless networks using protocols of mobile systems like GPRS or UMTS. UAVs could also collect data from relay nodes, detect moving obstacles and get real time imagery from roads, which help on accident prevention more accurately than using only WSNs and vehicular sensors. Once the relay node, vehicle or a smartphone has processed the sensor data, it may interpret the data as a dangerous situation and trigger a safety warning message. From this message, the geographical region is defined and the message is broadcasted to its neighbor vehicles and to the base station.

As a result, vehicles that receive the information are warned about dangerous spots ahead of time, and the base station sends immediately an UAV to confirm the accident occurrence in order to take appropriate countermeasures. After the detection of the alert, the UAV which play a role of investigation, is sent to the incident place. On its way, the UAV performs video monitoring of a specific road section (patrolling), detecting the vehicles, and estimating their movement characteristics. Furthermore, if on its way to the accident place the UAV detects another abnormal situation, the base station must be notified and the available UAV should be sent to the incident place.

In accordance with the situation class, UAV collects and transmits the information necessary to make decisions, disseminate alerts to the road users so as to help them to deal with the situation or even intervene in the rescue operation.

B. System components

The architecture of the proposed system in figure 2. Illustrates the combined ground WSN, vehicles, smartphones and UAVs, system which aims at provisioning two complementary services: Accident prevention and accident investigation.

It is obvious that depending on the characteristics and severity of the predicted consequences of abnormal situations, the operator (which could be a person on the base station, relay nodes), should confirm the incident occurrence (automatically or by human involvement), plan and take a range of appropriate measures, e.g., call emergency services or road safety service. For this purpose, it is necessary to provide the operator with video information, allowing him to analyze various facts related to this special situation with precision thanks to the use of UAVs.

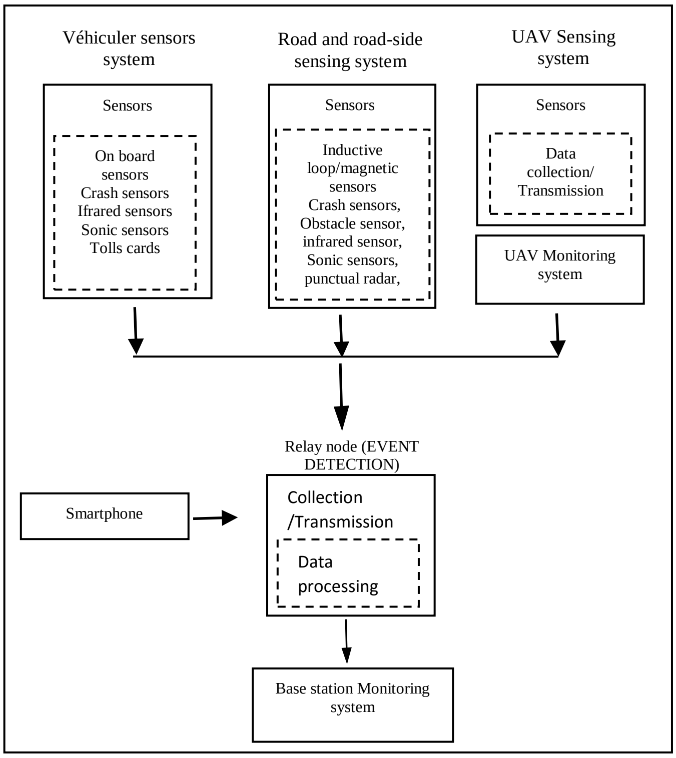

Fig. 2. System components

In our system sensors that have been used are listed below:

- **Ground sensor node**: are deployed in a fixed distance beside or on the road. Ground sensors used in our system are: Inductive loop/magnetic sensors, Crash/ impact sensors, Obstacle / ultrasonic sensor, infrared sensor, Sonic sensors, punctual radar, onboard device and toll cards.

- **Unnamed Aerial Vehicles UAV** main components are: Sense & Avoid System, UAV Monitoring system, Electro-optical Sensing Systems and Scanners, Infra-Red Systems, Radars, Dispensable loads and Environmental sensors.

- **Smartphones:** Smartphone can also be used as sensors. It can be connected to the car through Bluetooth and when an event is detected the smartphone can automatically sense data and send it to the nearest relay node placed in the road side.

- **Vehicular sensors**: consist of some sensors embedded on the vehicles. The onboard sensors' readings can be displayed to the drivers via monitors to be aware of the vehicle condition or emergency alarms, and also can be broadcasted to the other adjacent vehicles. We can list: Crash sensors, Obstacle sensors, infrared sensors and onboard sensors.

- **Relay nodes:** is a special node that contains an emission/ reception module, a monitoring system that processes data and transmits alarms, and a GPS system to track the location of the incident.

IV. EVENT DETECTION

Event detection and classification are two such classes of applications that are broadly representative and which have received considerable attention in the literature. Our approach complements and improves upon existing systems by proposing a new and improved solution for event detection in Highways using heterogeneous WSNs. Such an approach will enable real time detection and accuracy. We also propose a classification of events in Highways so as to delimit the system and to perform a realistic and practical solution.

A. Event classification

In our approach we consider that an event could be:

- Congestion
- traffic slowdown
- Crash/ impact
- Obstacle in the road (Animal, people, stationary car in the middle of the road, fallen object (Tree, stone, Fallen Light pole, Road guardrail broken...), fire in the road, flood in the road, deep Pit, uneven road surface, debris)
- Car in the inverse direction
- Abnormal conductor's behavior

The most important incidents are those that result in stopped vehicles in the middle of roads (either by breakdown, out of fuel, or by accident) or obstacles. The rapid detection of these situations and the early removal of the offending vehicles or obstacles is most critical. A highway automatic incident detection system is imperative. Coupling this system to means to automatically alert other vehicles and emergency of a detected incident will significantly reduce the number of deaths and accidents in highways [12].

TABLE I. EVENT CLASSIFICATION

Sensors	**Incident/Event category**					
	Obstacle in the road	**traffic slowdown**	**Congestion**	**Car in the inverse direction**	**Abnormal conductor's behavior**	**Crash/ Impact**
Inductive loop/magnetic sensors		X	X	X	X	X
Crash/ impact sensors						X
Obstacle / ultrasonic sensor	X		X	X		
infrared sensor	X		X	X	X	
Sonic sensors			X			X
punctual radar	X	X	X	X		
onboard device	X	X	X	X	X	X
toll cards		X	X			

Table 1 presents different classes of events that could be detected in Highways and sensors responsible of the detection of each class of events.

The performance of incident detection algorithms is highly dependent on the quality of collected traffic data. It is reasonable to expect that using multiple data sources, could enhance the input data reliability and completeness and hence improve the performance of an incident detection system. In our work, we consider that using only one sensor to confirm an accident or an event is not enough. Using only one sensor will obviously increase false alarm rate and consequently, the detection accuracy and degree of trust of the approach will decrease. Collaboration between at least two sensors is necessary to detect a real accident/event occurrence.

To solve this problem, we propose a sensor-fusion algorithm that combines fuzzy logic algorithm and neural network. The thresholds exceeded will be supported by networks of neurons that deal in advance with trained pattern recognition for the incident.

B. Proposed approach

In our solution, we propose heterogeneous Wireless sensors network for event detection in highways. To deal with the heterogeneity of used sensors and to meet the accuracy needed we propose an Improved measures-based Fuzzy Logic Event Detecting Algorithm combined with neural networks. The input layer contains the fuzzifiers, hidden layer contains the rule of pattern incident recognition and finally the incident is detected and then classified.

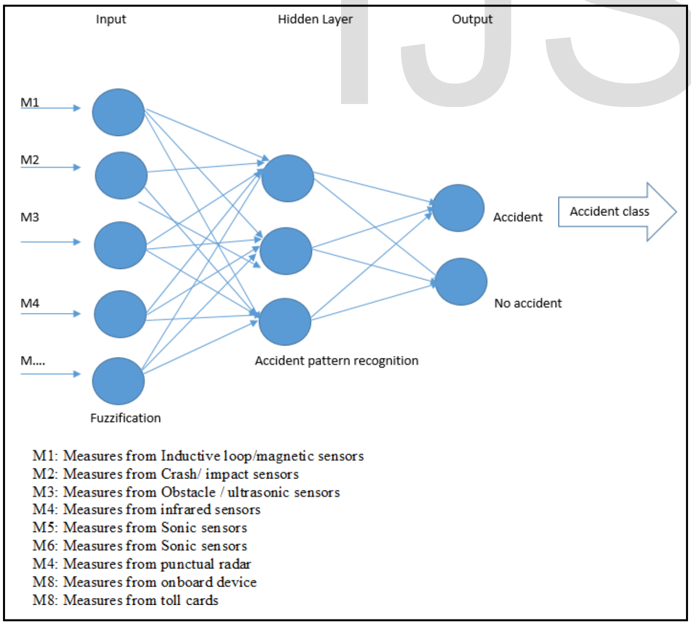

Fig. 3. The layers in ou approach

At the first stage, data collected from sensors are interpreted via fuzzy logic algorithm, once measure confidence is 80% high, then an alert is sent to vehicles and panels first to inform them about a possible threat and finally to the base station. After that, the Relay Node Run the Pattern recognition algorithm to confirm accident occurrence. Otherwise, if measure confidence is not 80% high, the Relay node, first Run the Pattern recognition algorithm to confirm accident occurrence, so as to reduce false alarm rate, and then an alert is sent to vehicles and panels to inform them about a possible threat, if the event occurrence is confirmed through the neural network algorithm. At the final stage, accident is classified.

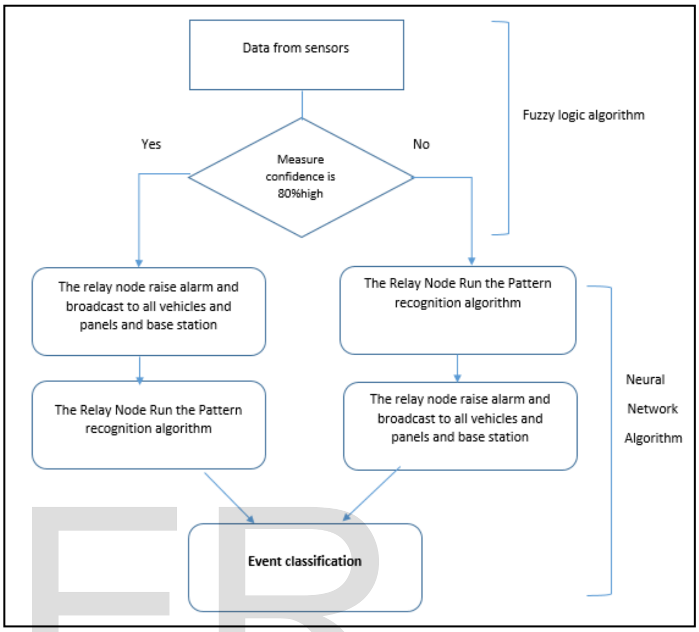

Fig. 4. Event detection process

To conclude, we highlighted the event detection process that is used in our event recognition approach for traffic safety. The detection is performed at the relay node level, then the decision is sent to the base station or forwarded to nearest vehicles and panels in the road. The base station process the received data to confirm the event occurrence so as to take the decision of sending UAVs and emergency.

V. Conclusion

Automatic accident detection became very important topic in traffic management systems. Detection of accident will avoid future accidents and will help emergency to intervene quickly. In this paper, we have proposed an event detection approach based on heterogeneous. It aims to deal with the abnormal situation on roads and real time accident detection. We have implemented part of the process which deals with the first layer. We are working on implementing the rest of the process. In the future work, we will study the possibility of extending the solution to be used in all kinds of roadways.

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