ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijircce.com

Vol. 5, Issue 3, March 2017

Intrusion Detection System in Road Safety

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ABSTRACT: Road traffic accidents are one of the main causes of death and disability worldwide. Workers responsible for maintaining andrepairing roadways are especially prone to suffer these events, given their exceptional exposure to traffic. Since these actuationsusually coexist with regular traffic, an errant driver can easily intrude the work area and provoke a collision. Some authors haveproposed mechanisms aimed at detecting breaches in the work zone perimeter and alerting workers, which are collectively calledintrusion alarm systems. However, they have several limitations and have not yet fulfilled the necessities of these scenarios. In thispaper, we propose a new intrusion alarmsystembased on aWireless Sensor Network (WSN). Our systemis comprised of twomainelements: vehicle detectors that forma virtual barrier and detect perimeter breaches by means of an ultrasonic beamand individualwarning devices that transmit alerts to the workers. All these elements have a wireless communication interface and forma networkthat covers the whole work area.This network is in charge of transmitting and routing the alarms and coordinates the behavior ofthe system.We have tested our solution under real conditions with satisfactory results.

KEYWORDS: Wireless Sensor networks.

I. INTRODUCTION

Each year, road accidents are the cause of an unacceptable number of fatalities and injuries everywhere in the world. As a result, road safety is one of the main concerns for citizens and governments nowadays and a lot of effort has been put into reducing these figures. For instance, road accidents and fatalities in the EU in 2015 have fallen by 22% and 46%, respectively, since 2004, according to data published by the European Road Safety Observatory. Despite these encouragingresults, there is still a lot of work ahead. One of themain action points in reducing traffic accidents is improving the conditions of roads and other infrastructures. These actions usually encompass the deployment of construction sites on roads and highways. In many cases, the complete shutdown of the roadway is not possible and these work zones have to share the road surfacewith regular traffic, with little or no protection between them. This results in an evident hazardous environment for both workers and road users. A survey released by theUKHighwaysAgency in 2006 stated that up to 20% of road workers had suffered some injury caused by passing vehicles in the course of their careers and 54% had experienced a near miss with a vehicle.

In order to increase the visibility and safety of workers, construction sites are typically marked by signs, cones, and other channelizing devices, as seen in Figure 1. Their goal is to warn and guide road users creating a barrier around theperimeter of the work zone. A very important characteristic of these barriers is that they have to be composed of crashworthy devices, such as cones and barrels, in order to cause minimal damage if hit by a vehicle. However, this implies that distracted errant drivers caneasily intrude into the work area.

Over the years, several systems and methods have been proposed to address this problem, with the particular goal of alerting workers about the immediate danger. They are generally called intrusion alarm systems.

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II. RELATED WORKS

We propose an intrusion alarm system forroad work zones based on a WSN. Our system is composedof two main elements: vehicle detectors to monitor theperimeter and warning devices to individually alert theworkers. All these elements are connected forming a networkthat covers the whole work area. Its main features are asfollows:

(i) Individual alerts: workers are warned of the incomingdanger by means of their individual warning device.This way we can ensure that workers are effectivelyalerted even if they are far from the source of thealarm or in a noisy environment, which was one ofthe most worrying problems of previous intrusionalarm systems. In addition, these devices can be used to monitor and control the working conditions, suchas temperature and impacts. They are also light andcomfortable towear, guaranteeingworker acceptance.

(ii) Wireless Sensor Network: WSN provides a way of Communication within the work zone. Not only couldWSNs reliably transmit and present alarms, but theycould also be used to communicate any other type ofinformation relevant to the particular scenario. Forinstance, the crew manager can monitor the activityand location of workers by means of their individualwarning devices.

(iii) Robustness: Vehicle detectors can detect invasions of the perimeter whether the cone is hit or not. This isan advantage over previous systems.

(iv) Easy deployment and setup: Our vehicle detectorsdo not have separate transmitter and receiver units.Thus, there is no need for a precise alignment whendeploying the system. They are also lightweight andeasy to mount. This expedites the deployment andsetup phase in comparison to most previous systems.

(v) Autonomy: all the elements are powered by rechargeable batteries, whose duration is completely adequatefor regular work zone schedules.

III. PROPOSED SYSTEM

Our intrusion alarm system is especially aimed at improving safety in short-term work zones. On these works, it iscommon for the workers to share the road with the adjacenttraffic with not enough safety measures that protect themfrom errant drivers. The most common entry point into thework zone is the first part of the perimeter, which is usuallydelimited by cones, so these are the places where the vehicledetectors are placed .Theworkerswill be alertedby a personal warning device that all of them carry duringtheir work activities. The vehicle sensors and warning device are connected by a wireless network to deliver the alerts andconfigure the system.In order to design our system, some key goals weredefined to ensure the suitability to the target scenario:

(i) The deployment should be easy, allowing workers tosetup the system in a reasonable time.

(ii) The system should be usable in the majority of theroad scenarios, so there should not be special placementconsiderations that limit the usage scenario.

(iii) All devices should be battery-powered, since poweris not usually available at these locations.The battery recharge/replacement should be easy enough to bedone by people with no technical skills.

(iv) Thewarning devices will be worn continuously by the workers, so they should be comfortable to use andwarn workers in a quick, safe, and reliable way thatdoes not interfere with common road maintenancetasks.

(v)The total cost of the solution should be moderate aspossible to encourage its incorporation to the targetscenarios.

2.1. SensorNode.

Thesensor nodes are responsible for detectingvehicles breaching the perimeter of the work zone. Theywill be installed on cones or on any other barrier that delimitsthe work area. These nodes also have wireless networkingcapabilities to transmit the alarms and exchange and routethe messages that the system uses to achieve its functionality.

Optionally, they may include a siren to warn errant drivers and nearby workers. The sensor node is a custom development built around an MSP430F249 microcontroller. This microcontroller has a low power consumption and all the required interfaces to communicatewith the vehicle detector, the wireless transceiver, and other built-in modules.

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The vehicle detection is achieved with the MaxBotixMB7076 ultrasonic range sensor. It was chosen because itprovides an adequate measure rate needed to detect passingvehicles and its protective covering is convenient for its use inharsh construction zones.

This sensor has a digital data output that returns the distance to objects in its line of sight. At the system deployment,each sensor node is configured with a particular thresholddistance. If any sensor node detects an object closer than thatdistance on its line of sight, it will generate an intrusion alertthat will be sent to the workers and cause the siren (if present)to be activated. Inside the sensor nodes, there are some other modulesrequired for the application. Since they are powered froma LiPo battery, they include a common USB charger, a fuelgauge to manage lowbattery situations, and a power moduleto provide the necessary voltage levels in the different parts ofthe node. It also incorporates a MEMS-based accelerometer, used to detect impacts from errant vehicles in case theydirectly hit the cone or barrier on which the sensor ismounted, rather than trespassing on its virtual line of sight. The network capabilities of the node are provided bya CC1101 wireless transceiver operating on the 868MHzShort Range Devices (SRD) band allocated by the EuropeanETSI. The transceiver output is coupled to a PCB meandermonopole antenna allowing a transmission power of up to16mW.The radio module allows the node to communicate in point-to-point or point-to-multipoint configurations.

According to its own circumstances and the networkconditions, each sensor has four possible working states:

(i) Power off: when the system is not deployed, the noderemains in a soft power-off mode preventing batterydrain.
(ii) Ready: at the system deployment stage, alarm eventsare not desired, so the sensor nodes maintain the networkconnection, but they do not transmit intrusionalerts to the warning devices.
(iii) Detection: this is the usual working state in whichthe nodes are activelymonitoring their virtual barrier.If any of the sensor nodes detect any object in theirdefined line of sight, the alarmmodewill be triggered.
(iv) Alarm: when a vehicle is detected, the sensor nodeswake up and activate the siren if present. This situationcan be reverted fromthe crewmanager's personalwarning device.The final node is enclosed in a protective casing..

2.2. Warning Devices.
These devices will be carried by eachworker in the area and are in charge of receiving andpresenting the danger alerts generated on the sensor nodes.

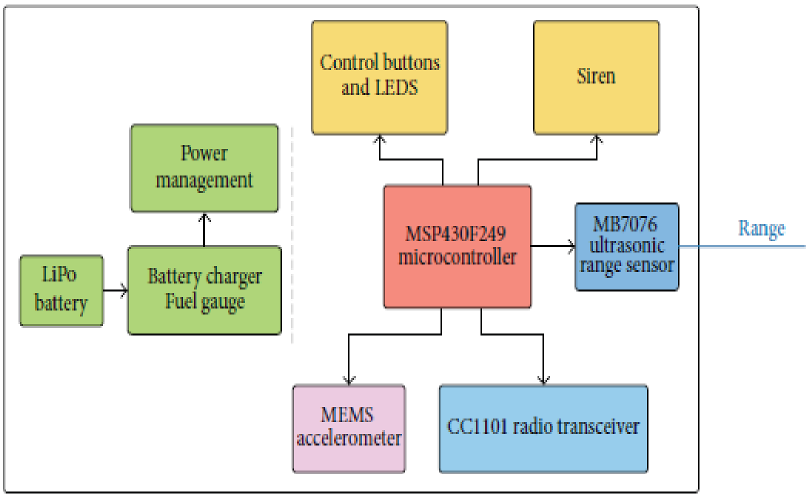

Fig. 1 Block Diagram of the Proposed System

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Since this device has to be carried by the workers forthe entire duration of their shift without affecting theirusual activities, its main requirements are lightness, compactness, and comfort of use.Thus, a commercially availableprogrammable watch was selected, the ez430-Chronos. In order for it to work as a warning device, some software was developed to communicate with the sensor nodes and present warnings or information to the user.
The ez430-Chronos watch was developed byBM Innovations and it is offered by Texas Instruments as acomplete development kit for its line of wireless System onChip (SoC) solutions.The watch includes a CC430F6137 SoCwhich combines an MSP430 microcontroller and a CC1101-based wireless transceiver. Along with it, the watch includesa 96-segment LCD screen and a piezo buzzer which are usedto show the warnings to the workers.

The wireless transceiver built inside the watch is used to communicate with the sensor nodes in the 868MHz band. This communication is based on a periodic polling scheme in order to save battery. The polling period is dynamically tuned according to the wireless link quality to ensure prompt warning reception.

*2.3. Wireless Network.:*As stated previously, all the nodes in the system communicate using the 868MHz SRD band.This band was chosen because it provides an adequate range and it can be used without a license. The physical level is built in on the CC1101 transceivers. Over that level, a wireless star topology has been developed, using one of the sensor nodes as the central hub. This topologywas chosen in order tofacilitatea coordinated behavior of the network. A sensor node was chosen for this role due to its higher battery capacity since the central hub's radio has to be continuously active. The wireless network is used to synchronize the state of each sensor node and distribute the danger alarms that any of them may trigger. When an alarm is triggered, each node is informed so the warning devices will alert the worker.

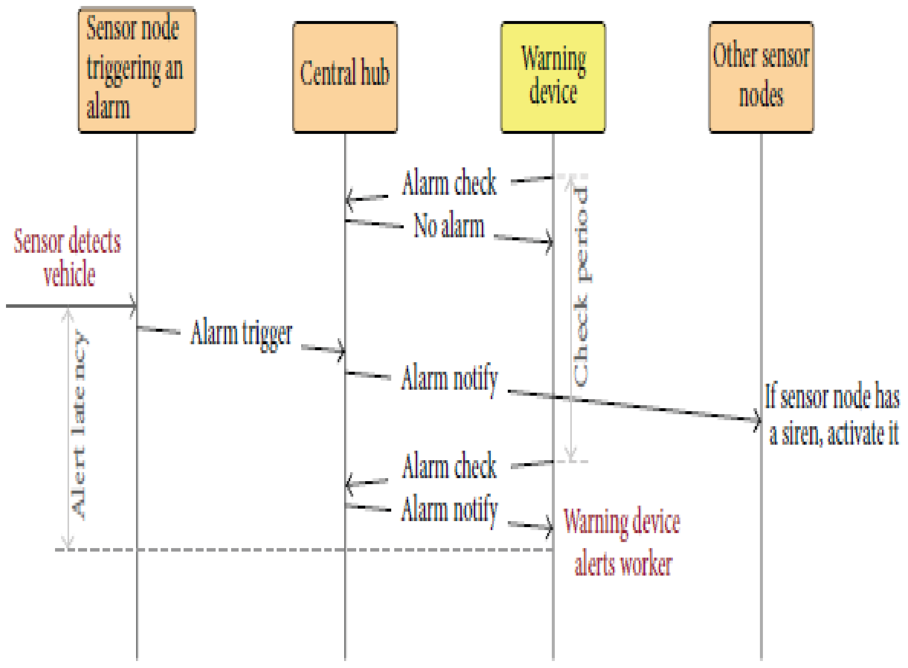

Fig. 2Overall Flow Diagram

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IV. CONCLUSION AND FUTURE WORK

Road maintenance and repair actuations often create ahazardousenvironment for both workers and drivers. Generally,these work zones are simply delimited by cones and coexistwith regular traffic, so a distracted driver can enter theperimeter and provoke an extremely dangerous situation.

In the past decades, several systems have been proposed to address this particular issue, although reviews and surveysagree on their limitations and defects.In this paper, we propose and describe an innovativeintrusion alarm system aimed at improving safety on thesescenarios. Our solution consists of two main elements: Sensor nodes based on ultrasonic beams to detect breachesin the perimeter and individual warning devices worn bythe workers. All the elements in our system have wireless connectivity and are deployed forming a WSN that coversthewholework zone.This network effectively coordinates theoperation of the system and is in charge of transmitting the alarms.

We have evaluated the performance of our system in aseries of tests carried out under real conditions. The results of these tests confirm the effectiveness and usefulness of oursolution and its suitability to the target scenario. The inclusion of the WSN is the most innovative andsubstantial contribution of our solution. In addition to itscurrent role, it presents a huge potential for additionalapplications which we will investigate in future works. For instance, individual working conditions could be monitored by means of the warning devices.

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