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Sensors and wireless communication for improving the performance of Explosive detector

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Abstract – Automatic detection of explosives using wireless sensor networks are used in human life is increasing day by day. The main problem behind this massacre is the group which is acting behind this who already know the ineffectiveness of our security systems. Even now we are following traditional metal detection doors and hand held metal detectors. No autonomous system is being used by any security forces in India till now. The main problem with the traditional systems is their bulkiness so that the intruder can easily bypass the security mechanism by following an alternate path. Here we are proposing a highly effective wireless sensor network solution; intelligent Wireless Explosive Detection System (iWEDS) to tackle this problem. The sensors are organized in such a manner that it has been embedded with the road reflectors, so that nobody even knows about the security system and no one can bypass it. Other key advantages are: these systems are low powered, fully automated and can support real-time tracking. Though iWEDS can perform automated operation we are proposing it only for assisting the police and military forces

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1. Introduction

The main reason behind this concept is the increased rate of terrorist attacks in India in recent years. There are several reasons for this and one of the main reasons is terrorists utilizing the advantage of the lack of a full proof security system. According to the report published by Times of India, more than 600 people have been killed and various terrorist attacks in India in the last 6 years. Traditional explosive detection systems are bulkier in size, expensive, and always require manual attention. Because of its public visibility intruder can easily bypass the system using another route. Our work is mainly based on explosive detection using wireless sensor networks.This mote can support various types of sensors including both passive and active sensors. In a typical wireless sensor network there are hundreds of nodes spread across a particular geographical area for collective monitoring. The main functionalities of these nodes are detection, classification and tracking of both static and moving objects. Some of the main advantages of these micro sensors are their miniature size, low power consumption and support to distributed operation. An explosive is a chemical mixture which can create a huge explosion usually accompanied by production of light, heat, sound and pressure.The classifications are high explosives (materials that detonate) and low explosives (materials that deflagrate).containing molecular bound oxygenitrates,chlorates, perchlorates or organic compounds with nitro-, nitamine- or nitrate-groups or peroxides. There are more than one hundred types of military and civilian explosives and around twenty commonly used drugs. A number of explosive characteristics can be used for their detection:

- Geometry (the presence a metallic detonator can be detected using image shape analysis),
- Material density (explosive material is denser than most organic materials),
- Elemental composition (e.g. vapor emission analysis can be used to detect them),
- Vapor emissions (e.g. nitrogen or its compounds can be detected in a vapor sample).

2. Related work:

One of the promising work done in this filed was UGS(unattended Ground sensors). UGS can support several types of sensors such as acoustics, seismic, opto-electrical, magnetic and infra red break beam devices. This system takes large amount of time for analyzing this whole bunch of data because of their limited signal processing capability. At this point L-3 communications developed a new type of remotely monitored Battle field sensor system (REMBASS, Department of Transportation FAA Technical Center, and Los Alamos National Laboratory. In this work they have screened every luggage through a highly penetrating radiation (energetic gamma radiations). When subjected to these high radiations gamma rays are produced depending upon the characteristics of the particular elements. Target tracking is one of the essential problems to be addressed using a sensor network. CSIP solves this problem to a large extent by dynamically designing and grouping sensor nodes based on task requirement and resource availability[5]. So we are considering this work also as an essential relative work in thd of explosive detection.

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3. Sensor and system for the explosive detection device

Techniques such as X- rays, gamma rays, millimeter imaging have been used for detecting explosives and weapons [6]. Based on the type of measurement obtained, Explosive sensors are largely categorized into electrochemical, mass, optical sensors and Biosensors [7].

3.1 Electrochemical sensors

Electrochemical sensors convey changes in the environment through changes in current, when chemicals interact with the electrodes. Three main types ofelectrochemical sensors are in use namely, potentiometric, amperometric, and conductometric.Such sensors can be used for the detection of TNT in marine environments [8.These sensors have limited sensitivity, and need mobile electrolyte. Nanocomposites of metal nanoparticles with carbon nanotubes solubilised in Nafion have been demonstrated for the detection of TNT and other nitroaromatic explosives [9]. Glassy carbon electrodes containing copper nanoparticles and single walled carbon nanotubes have shown a reproducible detection limit of 1 ppb. Glass carbon electrode modified by single walled carbon nanotubes has been demonstrated to detect TNT [10].

3.32 Fibre optic based sensors

Fibre optical sensors have been used for detecting explosives.They rely on changes in frequency, or intensity of electromagnetic radiation for detection of explosives.. Explosives such as DNT and DNB have been detected at low ppb level within seconds using optical sensors that rely on changes in fluorescence properties [12]. Optic fibre based explosive detection is based on defect free zeolite film, utilises a change in sensor reflectivity on exposure. Such sensors have not demonstrated selectivity and sensing time is about 200 seconds.Absorption based detection based on the change in colour,.This method has demonstrated a detection limit of 0.2 ng for DNT.Nanosized molybdenum hydrogen bronze react with TATP to change colour from dark blue to yellow. The colour change property can be used both for titration neutralization and for detection of explosives [14].

4. Various Detection methods

4.1 Photoluminescence based detection

Photoluminescence based detection, is based on Monitoring the photoluminescence of an nanocrystalline porous silicon film that is exposed to ananalyte in flowing air stream. Nitro aromatic compound explosives have been detected using this Method. Fluorescence based detection of explosives relies on quenching of fluorescence when a target molecule is acquired. The advantage of this technique is the ability to detect from a distance. Fluorescence quenching method using pyrene as fluorophore is applied for the detection of RDX, HMX, TNT, nitromethane and ammonium nitrate [16]. Quantum dots of cadmium selnide with zinc sulphide shell have been used to detect TNT. Fluorescent nanofibrous membranes prepared by electro-spinning have demonstrated very high sensitivity to trace vapours of TNT. Highly porous structures of these nanofibres have been reported to provide it high sensitivity to analytes with detection limit of 10 parts per billion [16]. Nanofibrous membranes have been reported to act as both chemiresistor sensors and fluorescence quenched sensors. These sensors based on conductive polymer nanotubes have uses in detection of explosive, biological and chemical agents [17]

4.2 Spectroscopic methods

Explosives have been detected using techniques such as laser induced breakdown spectroscopy. The explosive is detected by means of laser that is used to create plasma over the explosive surface. High pulsed lasers have been demonstrated to create plasma that is detected using an optical probe to determine the explosive material composition.

Detection of TNT on brass and molybdenum substrates and RDX on molybdenum substrates has been demonstrated. Nuclear Resonance fluorescence has been demonstrated in detection of explosives using the signatures of carbon, hydrogen and oxygen of the elements. The experimentally demonstrated technique offers advantages such as short detection times and high probability of detection [18].

4.3 single energy x-ray systems

It is operated at airports use electron energies of 120 keV. They provide good resolution pictures to detect weapons with metal elements. In the case of explosives placed behind or within items characterized by a higher atomic number, the technique is inefficient. These devices cannot distinguish between a thin sheet of a strong absorber and a thick slab of a weak absorber[24]. The standard system cannot identify the actual explosive material, but allows detecting control wires, batteries, detonators and other components of a bomb. Simplify, the system does not detect explosives but only explosive devices.

4.4 Computer tomography (CT)

Computer tomograghy is one of the two of data analyses based on information from X-ray projections at several angles around an investigated object. The CT image is obtained using both absorption and scattering attenuation properties of each volume element. In the detection procedure, the transmitted radiation is measured. The detector does not provide the image but cumulates the amount of photons[28]. The collected rays are processed to obtain a real image. The efficiency of such a procedure is determined by the number of projections used to form the CT scan image. The CT resolution is determined by the spatial and contrast parameters. The X-ray methods are still developed. There are a lot of new scientific ideas of\ obtaining a low fast alarm rate and a good resolution of imaging, for example angular dispersive X-ray diffraction (ADXRD) [29], multi-energy X-ray computed tomography, coded aperture imaging using backscattered X-ray radiation.

4.5Bulk detection systems

A number of techniques based on X-rays, gamma rays, infrared, terahertz-waves, and millimeter waves have been employed to detect weapons and explosives. The techniques of detection of explosives are detailed below.\The bulk detection method includes:

- X-ray and gamma ray systems,
- Neutron methods
- Electromagnetic systems.

Bulk detection is usually not applicable for the direct scanning of persons (health hazard).

In the X-ray detection method, the penetrating depth of radiation is high in most materials.For the detection of explosives X-rays are used with energy from a thousand up to millions of electron volts (10-4 – 10-7 □m). In these methods the beam of X rays passing through a material is absorbed.

4.6 Vapor detection method

Vapor detection methods are non-invasive and measure traces of characteristic volatile compounds that evaporate from the explosive. Various explosives have different volatilities. Volatility is characterized by the concentration of saturated vapors near the surface of the explosive. The vapor concentration from some explosives at the temperature of 25ºC is equal to: nitroglycerine - 4,1·102 ppb, TNT - 7,7ppb, PETN - 18 ppt, RDX - 6 ppt [30].Low temperatures and a strong wind decrease the detection sensitivity as well. Modern vapor sensors can reliably detect explosives with vapor pressure in the range of 102-103 ppb. Explosives with a vapor pressure less than 1 ppb (RDX, PETN, HMX) cannot be detected without preconcentrators. Vapors and traces are currently detected by means of ectronic/chemical sensors,- optical sensors,- biosensors. Electronic/chemical sensors can be divided into four main groups.The following subsections discuss specific detection technologies[31]. An electronic nose, or ENose, is usually composed of a chemical sensing system and a pattern-recognition system, such as an artificial neural network. Each vapor presented to the system produces a signature (‘fingerprint’). Presenting many different chemicals to the sensor. biosensors. Electronic/chemical sensors can be divided into four main groups . The following subsections discuss specific detection technologies. An electronic nose, or ENose, is usually composed of a chemical sensing system and a pattern-recognition system, such as an artificial neural network. Each vapor presented to the system produces a signature ('fingerprint'). Presenting many different chemicals to the sensor-ray photons in the beam is determined by three effects:- photoelectric absorption.

5 .Algorithms

This section explains the algorithms followed in the system. The main algorithm followed is Advanced Explosive Detection Algorithm (AEDA). This algorithm is designed in such a manner that it avoids ambiguity in detecting and classifying the targets[36]. One of the main problems faced by automated explosive detection systems is its reliability. We have to make sure that the false alarm rate of the system should be less than 10%. By keeping all this design constraints in mind we have developed AEDA.

AEDA Algorithm:
step1: Initialize all the nodes in the network
step 2.:Go to sleep mode after synchronization
step3:.Positive presence of explosive detected by chemical sensor (CS)
step4: CS triggers the Gas sensor
step5.:CS triggers the Trigger Control Unit (TCU) from sleep mode to active
step6:TCU stores the data from CS and wait for Gas Sensor (GS) value
step7: TCU triggers the TWT radar and starts tracking the object
step8:GS detects the particle concentration and passes the data to the TCU
step9:TCU combines the data and matches with the data base for identifying the explosive
step10:If the chemical compound is known TCU will mark the target with the name of the explosive and pass the information to the cluster head.
step11:If an unknown chemical compound is found , TCU will make a data base entry and pass the information to the cluster head
step12: Parallel TCU will invoke the mica mote from sleep mode
step13:TCU will inform the presence of the target to the nearest neighbors and also feeds the current position coordinates of the target
step14:The entire network gets alerted about the presence of the target and starts tracking.
step15:Cluster heads will calculate the approximate amount of explosive present based on the data provided by the leaf node and informs the base station. Along with this base station will also get the current position of the target with node ID.

6. Tables

The analyzed compounds reach the end of the capillary at different times depending on the relation between the solubility of the compounds in the sorbent and in the carrier gas,

Table 1: comparative assessment of the sensor performance used for the detection of explosio n as:

Sensors type	Field of application	Explosive detected	Detection limit
electrochemical	Soil samples	rdx	0.12ppm
electrochemical	Marine water	tnt	25ppb
electrochemical	Forensic laboratory	DNB and TNT	60ppb for both
SAW	Laboratory samples	2,4-DNT	
SAW	Laboratory samples	DNT	92ppt
SAW	Laboratory samples	2,4-DNT,TNT	
Micro cantilever	For detection of explosive vapour	PETN and RDX	A low femtogram(10-15g)
Micro cantilever		TNT	520PPT
optical	Field test(soil samples)	DNT	120ppb
Optical(fiber optic based)	Ground water ans soil extracts	TNT and RDX	0.1ppm
Optical(photoluminesence based)	Air and sea water	TNT ,picric acid	4ppb for TNT vapour in air,1.5ppt

			for TNT in sea water,6ppb for picric acid in sea water
Optical(fluorescence based)	Laboratory samples	TNB,TNT, DNB teriyl, and 2,4-DNT	1ppm for all these explosives
Optical (fluorescence based)		TATP and HMTD	2x10*-6 moll L-1 for both TATP and HMTD
Optical(LIBS)		DNT	NB 40ppb for DNT and 17-24 ppb for nitrobenzene
Optical fiber(bio sensor)	Ground water	TNT and RDX	0.o5ppb for both RDX and TNT
Electrochemical	Soil extract and ground water	RDX,TNT, 2,4-DNT,2,3-DNT,2,4-DNT	RDX 0.2PPM,TNT 0.11ppm,2,4 DNT 0.15ppm.
Optical (flurocense based)	Water samples	DNP	1.0*10^-6 mol L-1

Table.2: List of commonly used explosives and their chemical formulas:

Explosive	Name	Name/Contents
Standard	TNT	2,4,6-Trinitrotoluene
	RDX	1,3,5- Trinitro-1,3,5-triazacyclohexane
	PETN	Pentaerythritol tetra nitrate
	NG	Nitroglycerin(glycerol trinitrate)
	EGDN	Ethyleneglycol dinitrate
Improvised	ANFO	Ammonium nitrate+fuel oil
	Urea Nitrate	Urea nitrare
	TATP	Triacetone triperoxide
Plastic	C-4	c-4 RDX+plasticizer
	Semtex	Semtex RDX+PETN plasticizer
	Detasheet	Detasheet PETN+Plasticizer

7. Proposed system:

The proposed system will overcome the limitations in both the traditional and the current systems that are using for explosive detection. In this proposed system the paper sensors are used for the detection of IED.The paper sensors consists inbuilt communication system and these sensors are coated with chemical compounds that are frequently used in IEDs[38].These system works by detecting the traces of chemical compounds in the atmosphere and as these sensors are coated with chemical compound it directly detect the type of IED without any expert systems.

A. System architecture

The proposed explosive detection system architecture consists of solar panel, Radar unit, paper sensor[40] and communication unit ,processor and memory unit and a buzzer

B. Operation

This section explains the operation of modules present in the explosive detection system architecture

1) Radar unit:

The Radar module is used to track the IED. When a target is found the radar will continuously tracks the the target till it moves out of its range

2) Paper sensor and communication unit:

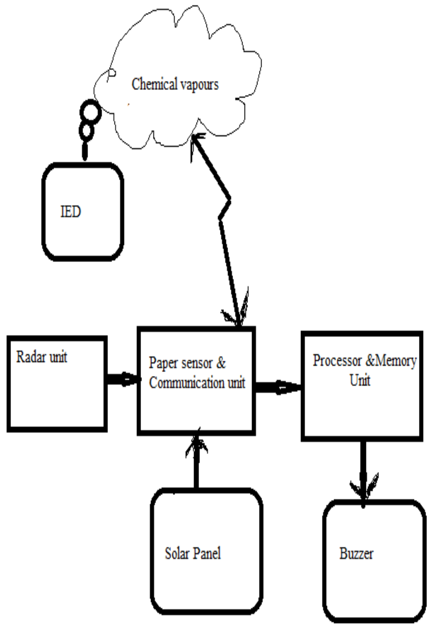
The sensor is used to trace the vapours of explosives in the atmosphere and depending on the type of chemical compounds the type of IED can be detected. The communication unit is used to communicate with the other
wireless sensor nodes present in that area and it also used to send the data to the security officials[41]

3) Processor and Memory unit:

The sensor after acquiring the data about the explosive, sends it to the processor[42] which process it and compares with the database present in the memory .If the matching is found it enables the buzzer.

4)Solar panel:

This solar panel module is the extra power supply unit besides battery which was used for increasing the life time of the system.



8. Conclusion

The proposed automatic explosive detection system automatically detects the IED without any human intervention.There are many advantages with the proposed system when compared with the traditional detection techniques[44].The advantages include less cost,low power consumption and less analysis time.By this proposed system the exact location of the IED can easily located which will deactivated immediately so that many lives can be saved... The paper deals with actually applied methods of detecting vapors of explosives[45]. Many investigations are so far rather scientific attempts, and the achieved results are still far from being able to be practically applied widely. The main advantages are its miniature size, low power consumption, distributed operation, and easy implementation. iWEDS is organized in such a manner that only security officials know about the presence of the system[51].. We are also focusing on the security aspects of iWEDS while transmitting the data to the base station[52]. This includes avoiding data theft, multiple black hole attack problems u nauthorized access and digital identity.

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