DESIGN OF AN AUTOMATED DEPLOYMENT ORDER SYSTEM FOR EXPLOSIVE DETECTION USING WIRELESS SENSOR NETWORK

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Abstract: Due to the tremendous and continuous rise globally in the use of explosives to attacks government infrastructures, public places and facilities, various institutions are now equipping their infrastructures with devices that can detect explosives. Most traditional explosive detection systems require manual intervention in the form of human operation for them to effectively function well and are bulky in size thereby allowing attackers to bypass them. However, there are lots of scenarios in explosive detection where manual intervention is unsafe due to the nature of explosives and where the detection system is required to be stealth. These limitations coupled with the need for distributed operations gave rise to automated explosive detection systems that are strategically distributed for wider area coverage with a miniature size. Wireless Sensor Networks have been utilized in the development of explosive detection systems by incorporating intelligent sensor networks and deployment mechanism. This paper discusses the design of an automated and intelligent explosive detection system that uses a wireless sensor network with automated deployment order technology. It is expected that designed system will address some of the challenges encountered by existing automated explosive detection systems. The designed system will be simulated followed by a construction of a prototype as a proof of concept as part of our future work.

Keywords: ADOT detection, explosives, network, sensors, wireless

Introduction

In the last few decades, several countries have witnessed massive increase in the use of explosives to attack public places including shopping malls, motor parks, airports, worship centres and other government infrastructures such as oil pipelines. This has posed great threat to lives and economies of these countries (Chaturvedi, 2012; Adeyiga *et al.,* 2016). Explosives are of different types each with peculiar characteristics. Hence there is a need for efficient and effective automated techniques for detecting explosives to safeguard lives and properties.

The recent rapid increase in the use of Improvised Explosive Devices (IEDs) by terrorists to attack their unsuspecting victims from a remote place using mobile phones and other devices indicates a serious drawbacks and flaws in the existing explosive detection systems (Shoba, 2012). It is essential to have a reliable explosive detection system to protect people and property from dangerous attacks.

Wireless sensor network (Bielecki *et al.,* 2012; Nuhu *et al.,* 2016) is one of the common techniques used in development of explosive detection systems. However, the shortcomings of the existing explosive detection systems using wireless sensor networks include the bulky size, publicly visible to anyone and very expensive. The size and high visibility makes it easier for terrorists to device mechanisms to bypass these systems. Also, most of the existing systems required manual attention and intervention. For instance, in banks, airports, and military bases, traditional metal detector doors and metal detector baggage checking still require manual operators to a large extent. However, an efficient explosive detection system is required to operate with minimal human intervention (Vanimireddy & Kumari, 2012; Gozani *et al.,* 1990). Another drawback is that most traditional explosive detection systems consume a lot of power and therefore not energy efficient. Building an automated detection sensor network which can be deployed easily with the network inconspicuous and not really visible is very important but challenging (Wang & Zhang, 2008).

This paper discusses the design of automated explosive detection system using Wireless Sensor Network (WSN) with an automated deployment of sensor nodes. Our Automated Deployment Order Technique (ADOT) addresses some of the challenges faced by existing WSN systems. Section 2 analyses related work while Section 3 explains the proposed systems architecture. Sections 4 and 5 provide a discussion of the proposed system operation and conclusion, respectively.

The use of Surface Acoustic Wave (SAW) and Electronic Nose has been studied for detection of explosives (Watson & McGuire, 1999). Explosives were dumped in the water by US government for military security purpose to carry out their research. Their work involved detection of explosives by quantifying vapours from a Vapour Analysis System and identifying different materials used in the experiments.

A Perimeter Intrusion Detection System (PIDS) based on WSN has also been previously proposed (David & Lewis, 2008). The main purpose was to detect explosives in an open field across the perimeter intrusions, self-contained power, and the system is based on a very small acceleration sensor. The proposed system was inexpensive and easy to deploy and designed specifically to detect the vicinity of infiltration. The limitations of this work are the fact that the deployment has to be in an open field and within an intrusion zone. An attacker who is aware of the perimeter where the system is deployed could find an alternate route to the target.

Organic explosives have been studies using Ion Mobility Spectrometry (IMS) (Koyuncu *et al.,* 2005). An analytical method was proposed and implemented. IMS systems operate under ambient conditions with the disadvantage that the system contains a small quantity of radioactive material as an ionizing source which can harm operator health. The major limitation of IMS is that the system has to be operated by human who would have to approach the attacker for the system to detect if the attacker has an explosive or not. This is very dangerous to the operator.

Intelligent Wireless Explosive Detection System (iWEDS) was proposed to tackle the problem of explosive detection size (Harihara & Sasidhara, 2011). The sensors (Chaturvedi, 2012; Vanimireddy & Kumari, 2012; Harihara & Sasidhara, 2011) are organized in such a manner that it has been embedded with the road reflectors, so that nobody even knows about the security system so it cannot be easily bypassed. The system is low powered, fully automated and can support real-time tracking. However it was proposed only to assist the police and military forces. Its drawback is that it's time consuming due to limited signal processing capability.

Explosive traces have previously been detected using MEMS based resonant structures (Mlcak *et al.*, 2010). Gravimetric MEMS Sensors were being used for trace detection of chemical substances such as explosives, chemical warfare agents and toxic industrial chemicals. Sundram & Sim (2007) proposed a surveillance system to detect Improvised Explosive Devices (IEDs) (Nomadics Inc., 2004) in public places. Infrared and magnetic sensors were employed for his experiments in a public mall and its nearby street. A collection of sensors were built and positioned in the environment with ferromagnetic materials are used as explosives. Magnetic sensors were able to detect the explosives while the infrared sensors could not detect correctly due to background infrared radiation. The developed system can be used to protect communal areas and public places.

Proposed ADOT WSN-based Explosive Detection System

An automatic deployment order technique (ADOT) wireless sensor network (WSN) consists of several hundreds of sensor nodes distributed in a random fashion. Fig. 1 depicts the architecture of an ADOT wireless sensor system.

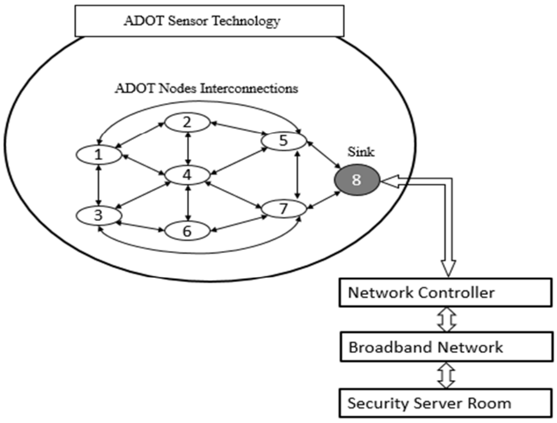

Fig. 1: ADOT wireless sensor architecture

The nodes in this type of WSN have the ability to communicate with each other and can take decisions based on the sensor data (Chaturvedi, 2012). In an ADOT based system, each node should be able to communicate with the other nodes and update its information if necessary. Tracking of a target node can be done in an easier and faster way because all the nodes are synchronized.

In relation to the proposed explosive detection system, all nodes stays in the idle state, until the presence of an explosive is detected. This characteristic makes the system more power efficient through random selection of best route to the sink. The area of coverage as a constraint on the existing systems has been taken care of by the random deployment of sensors. All nodes are randomly deployed in a way that if a node is down or manoeuvred by the attacker, the system selects another route to communicate the detected data (explosives information) and other tracking information to the network controller. Each node can randomly choose a shortest path to the security server. The advantage of this deployment technique is that deployment is non-predictive. All nodes in the proposed system use the recursive least squares (RLS) algorithm (Cattivelli & Sayed, 2010), to select the best route to the server. In this way, if a node goes down, the network will reconfigure itself and chose a different route to forward sensed data to the server. The RLS has a better performance, but requires a high complexity. Additionally, the cost function is redefined by the least squares error (Haykin, 1996).

Figure 2 shows the block diagram of the proposed system. The system consists of four main subsystems: power, communication processing system, memory and sensory.

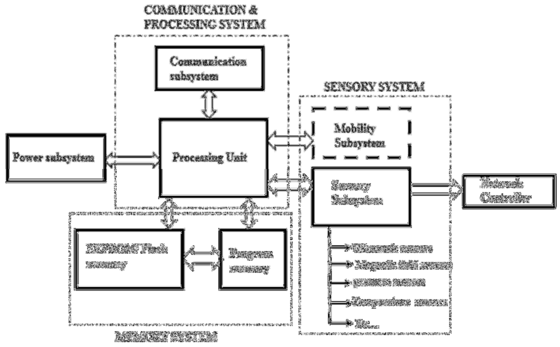

Fig. 2: Block diagram of the proposed system

Power subsystem

The nodes of Wireless Sensor Networks are usually battery powered because of their size. This limits the lifetime of a sensor node since batteries have limited energy. In our design, sensor nodes are kept in the idle mode (standby) most of the time to conserve power. Also, our design allows the wiring of some nodes to a continuous power source since most detection system requires longer lifetime. In a developing country like Nigeria where power supply is always a challenge due to power failures, our design uses alternative power sources such as solar cells or energy generated from wind.

Communication and processing subsystem

The processing and communication unit is the most important unit of the system. The processor executes different tasks and controls the functionality of other components. The ADOT algorithm manages route selection, location management and the threshold of the processing and communication unit is the most important unit of the system. The processor executes different tasks and controls the functionality of other components. The ADOT algorithm manages route selection, location management and the threshold of the measured parameter. It then compares it to the data stored in the database pre-programmed and loaded into the processor of sensor nodes.

The variation in the performance of the processor is influenced by the evaluating factors like processing speed, data rate, memory and peripherals supported by the processors. Computations are performed in the processing unit and the acquired result is transmitted to the base station through the communication unit. A transceiver act as a communication unit and it is mainly used to transmit and receive the information among the nodes and base station and vice versa. There are four states in the communication unit: transmit, receive, idle and sleep.

Memory subsystem

This includes both program memory (memory for the instruction set of the processor) and data memory (for storing measured data and other local information, such as the location of the node). The size of the memory for the system can be limited due to economic reasons.

Sensory subsystem

The sensing unit senses the environment to measure different parameters such as magnetic field, chemical vapour, pressure, temperatures and ultrasonic waves corresponding to the one emitted by explosives. The sensing unit of sensor nodes integrates different types of sensors like thermal sensors, magnetic sensors, vibration sensors, chemical sensors, bio sensors, and light sensors. The measured parameters from the external environment by sensing unit of sensor node are fed into the processing unit. The analog signal generated by the sensors are digitized by using Analog to Digital converter (ADC) and sent to controller for further processing.

Proposed System Operation

When the ultra-sonic waves generated by signal generator from the sensory subsystem fall on an explosive material there will be some change in frequency for both the explosive and ultra-sonic waves. As the receiver receives the resultant signal from the many receivers it combines to form a multiplexed output. Then the output signal is amplified and sent to the frequency comparator.

The frequency comparator, within the processing unit, compares the frequency of the received signal with the desired frequency of explosive materials or related objects. If the frequency matches, result is sent to the microcontroller and the microcontroller checks the attenuation changes in the resultant wave. With the help of the attenuation and frequency of the resultant wave the microcontroller defines the type of explosive material with already stored information about the explosive from tested samples.

The sensor nodes communicate with each other and send information to the other nodes using ADOT technology described in Section 3. Each node tracks the target node (that detects any explosive) with the shortest path taken by them. Fig. 3 shows the flowchart for the ADOT algorithm. As a networked embedded system, the ADOT involves sensor node hardware, its drivers, operating systems, and networking protocols. The performance of the ADOT depends on all of these factors in addition to its implementation. Various types of sensors, such as physical sensors, electro-sensors, chemical sensors and biosensors, can be used with the ADOT technology.

To analyse the measured data, it is important to know in which location, the data was monitored. Unfortunately, due to random deployment of nodes, the system design will not allow location of sensor nodes to be pre-configured. Nevertheless, the system is designed to work both for outdoor and indoor operations using location finding systems normally based on satellite GPS. Hence, the system will use a localization algorithm for nodes location management.

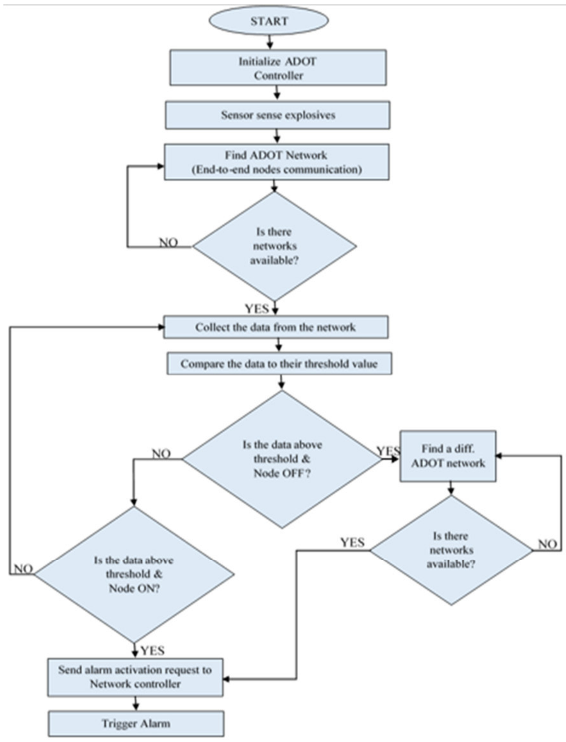

Fig. 3: Flowchart for the ADOT algorithm

An alternative to the use of a localization algorithm is for sensors to be allocated spatially in conflict-free slots for each node within a cluster to gather data in the lowest level drums and inter-cluster scheduling which occurs after the data has reached the cluster-heads at the lowest cluster. Here, each level of communication is separated into time, and hence does not conflict with each other (PalChaudhuri *et al.,* 2004). The limitation of this method is the enormous computation time required by each level clusters. GPS deployment would have been another alternative but can't work indoors. However, our proposed system is designed to work for both indoor and outdoor situations.

Conclusion

This paper has proposed the design of automated explosive detection system using Wireless Sensor Network with an automated deployment order to address some of the challenges faced by existing systems. The proposed system consisted of four subsystems which interrelate to achieve an efficient and effective explosive detection system. We intend to properly simulate the designed system followed by a prototype construction as a proof of concept in the nearest future.

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