Explosives Detection Techniques using Wireless based Technologies: A Review

Assist Prof. Dr. Saad. A. Makki, M.Sc. Ali Jamil Hashim

[1]*(Department of Computer Science, / Al-Mustansiryia university, Iraq)*
[1]*(Department of Computer Science, / Al-Mustansiryia university, Iraq)*

Abstract: *Explosives and Bombs represents a great danger to the human life. It's important to use the modern technologies and science to detect and defuse the bombs. There are multiple technologies in wireless systems as a bombs detection techniques. A wireless based system has a wide spread over the network fields. The wireless based systems is used to accomplish multiple objectives as in data transfer and data communication. One of the fields that using the wireless networks is to join the wireless system with the bombs detection systems for data transfer and decision making. This paper shows the modern and advanced technology in wireless based systems for detecting bombs types. This paper explain the basic strategies and technologies that is uses the wireless network technologies for detecting bombs types.*
Keywords: *Bomb, Wirelees,Detection, Technologies, Network.*

I.   Introduction

Bombs represents a massive threat to the human lives. all bombs detection types fall into two basic detection strategies, Bulk detection and Trace detection [1] bulk detection is the process of detecting the bombs throw the image processing techniques and computer vision characteristics [2] the Trace detection techniques is using the chemical and physical characteristics of the explosives materials of the bombs [3] there are several types of technologies used to detecting the bombs based on either bulk or trace detection. The wireless technology is used in verity applications. One of the applications is used in is the bombs detection fields. The wireless technologies is based on data transfer is freely through the air. A wireless networks is a type of networks that transfer the data using the free space [4]. The transmission medium can be classified into two basic types, Guided medium and unguided medium [5] in guided medium, data transferred through the cables, the unguided medium is through the free space. The wireless network is more advantage and suitable for the application that required mobility because the wireless network technology is more scalable and mobility in the properties. Bombs detection techniques requires mobility and scalability. The detection systems is a mobile system were the detection devices and sensors are handheld devices. The bombs detector techniques are different from system to another according to different specifications. One of the specification is the system coverage area were the detection system working upon a specific range. The wireless network technology is used according to the range of the application that uses the network. A wireless technology can be classified according to the coverage area into 5 basic types. Personal Area Network (PAN), Local Area Network (LAN), Metropolitan Area Network (MAN), Wide Range Area Network (WAN), and the International Network (Internet). Each of the coverage area has its own range and coverage area [6] [7]. There are two basic methodologies when constructing a review on the bombs detection techniques using wireless technologies. The first methodology focus on the using of wireless technology in the detection system, were the bombs detection systems using the wireless technologies for transferring the data between the system parts. The bombs detection techniques devices uses the wireless equipment to transfer the environment information. The second methodology is to displaying the Applications in the wireless technology in bombs detection with the system results. In this paper the information represented in both technologies were this review paper is showing an overview in the modern wireless based techniques in bombs detection systems and showing basic structure, devices, and diagrams that represents the structure of the wireless based technology. The bombs detector systems works with different ranges. There are a types of bombs requires a wide detection range other types of bombs is a short range detection. The wide range detection techniques uses the wide range coverage like Wi-Max and LTE [8]. Another detection techniques using a medium and short range network like Wi-Fi [9]. For connecting multiple systems together in a global fashion it is needed to use a global standard for communication between the system nodes, such a system using the Global System for Mobile Communication (GSM) [10]. This survey is organized in sections, each section represent a technology of detecting bombs using a wireless technology. Each section contain a basic overview about the used technology. The sections contain a basic structure and methodology with bombs detection techniques. The final part at each section contain a practical application for the system that uses the wireless network. In the final section of the survey it is shown a comparison between the technologies to analysis the best technology and preferred the best technology that is suitable for the Application area according to the result of the systems. The

technologies represented in this survey is the most popular and modern ideas in the bombs detection field. The researches of such a field is in a continuous progress towards the best and the most complete system in the detection and efficiency.

II. Wireless Sensor Network For Explosive Detection

There are many researches in the field of wireless sensors network for the military and security purposes. The wireless sensors network is a collection of sensors distributed over a specific area, collecting different information from the environment in order to analyze and process the data from the environment, looking for the threat according to the sensors readings [11] [12] [13] [14]   different types of sensors are used in the sensors network for providing the required data. Each sensors responsible for a different type of reading.. Table 1 illustrate the most popular sensors used: [15] [16] [17] [18] [19] [20]

TABLE 1

Sensor type	Sensor Description	
	Sensor Usage	Sensor Application
Temprature Sensor	Measures the temparture of around enviroment in cellecs	Heat measurement, temperature management, Watching the body heat
Magnetic Sensor	Measures the Magnetic field of the metels in micro-tesla unit	Security application, determining earth magnetic field, identifying position, medical Resonance
Pressure Sensor	Measures the Pressure force applied on a certain area	Measures vehicle weights, determining the pressure force for multiple purposes applications
Light Sensor	Measures the illuminance of light	Used in infrared camera and photography sensing
Chemical sensor	Measurses the existance of the chemical meterials	Chemical material detection
Acceleratin Sensor	Measures the Acceleration of an objects in m/s^2	Acceleration detection, vehicles alarming systems
motion Sensor	Measures the oriantation of the current state of sensor	Detecting the current device orientation state

All the mentioned sensors above is used by the wireless sensors network for gathering different information. The usage of the sensors in the bombs detection systems is different from sensor to another, the Temperature sensor sensing the environment for any change in the temperature of specific area, the temperature sensor sensing the bombs thermal effect. There are different types of explosives that can be effected on the temperature sensor due to it physical characteristics. The magnetic sensor is used to determine the magnetic field of around area in the specific range. The magnetic field sensor is can be used to determine a certain types of bombs. There are a type of bombs that can effected on the magnetic field of the averment. This change can be sensed by the magnetic field in the wireless sensors network. [21] The chemical sensor is the most important sensor in the process of detection of bombs. The chemical sensor sensing the environment for the chemical materials. Bombs are mainly consist of chemical component. The chemical sensor sends the information to the central server

A.   Structure and General function

The wireless sensors network consist of multiple sensors distributed over a specific area such as a building or a government department. The Sensors Network are connected together in a central server the figure 1 illustrate the basic structure of the wireless sensor network; [22]
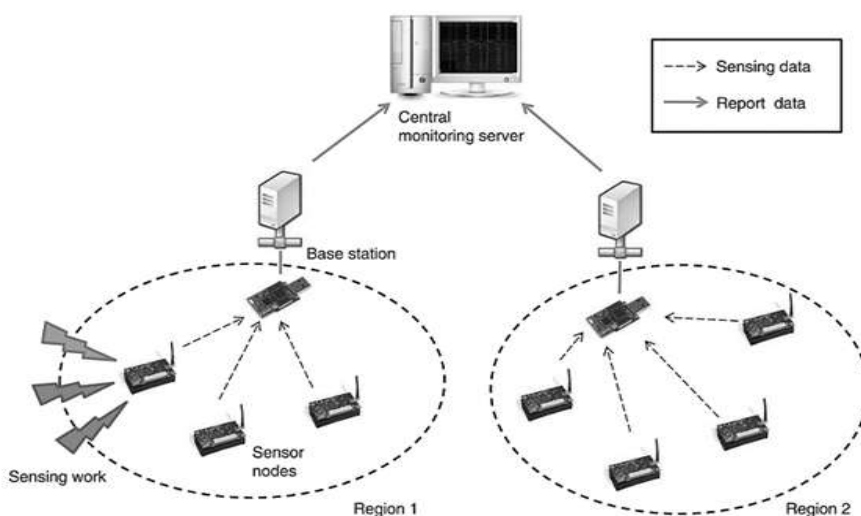

Figure 1: the main wireless sensor network structure

The sensors of the wireless sensor network are connected to each other with a base station. The base station connects one or more sensor together. The main server connects more than one base station together. The central server is make the decision according to the readings of sensors in the network.

B.   *Wireless Technology in the Sensor Network*

The wireless sensor network connects the nodes wirelessly. The sensors connects to each other using one of the medium or short range wireless technologies. The best wireless technology for the wireless sensor network is the Wi-Fi network. The Wi-Fi network is connects the sensors nodes to the central node through a wireless router device. The figure 2 summarize the process of data transfer using a Wi-Fi network:
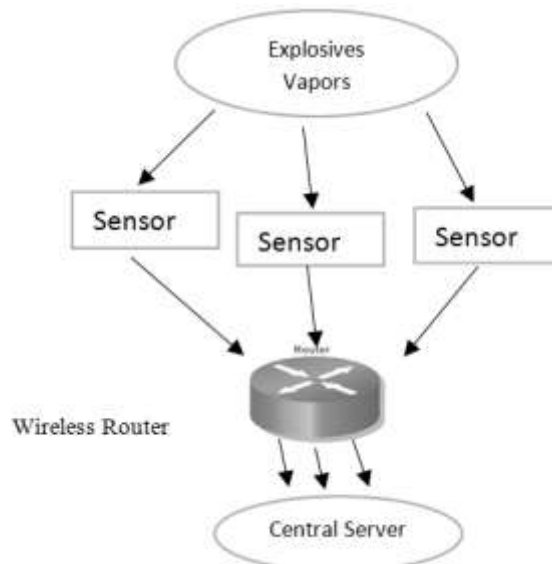

Figure 2: the main wireless Connectivity in wireless sensor network

C.   *Application of Wireless Sensor Network*

The wireless sensor network for explosive detection can be used in government departments since the implementation of such a system is easy. The implementation of wireless sensor network is implemented over the building with a wireless router attached to it. The usage of wireless sensor network can be in both civilian and military usage. The wireless sensor network is a fixed technique, so it is more suitable to the places and buildings since the buildings are fixed locations. A wireless sensor network douse not support a mobile sensing since the Wi-Fi range is not large. For adapting the wireless sensor network with the mobile ability it needs to use a different communication strategy and adapt the network with the required devices for connecting the sensor devices through a wide land area (such as Wi-Max adapter or GSM adapter) that will enables the wireless sensor network from connecting to the central server through a large area

III. Improvised Explosive Devices Detection Techniques

Improvised Explosive Devices (IEDs) is a modern bombs were these devices are made from chemical materials combined with a digital circuit for detonation and bomb unleashed, these devices is made by hand in a simple manufacture technique [23] the usage of IEDs becomes so popular in Afghanistan and Iraq after the war in 2003 [24]. The IED become an efficient weapon for assassination used by terrorist to target the civilians in cities and caused a hundreds of thousands of dead's. The terrorist construct the IEDs inside the cars made what it is known today as "car bombs". The threat of the IEDs become a global threat were lately the bombing using IEDs has taken place in Europe. This section is discuss the basic techniques for IEDs detection based on wireless network technologies.

A.   *Detection of IEDs using Spectroscopic approaches*

The Spectroscopic means converting of the air samples into a spectrum that can be ionized for analyzing process. [25] The Spectropics detection system are accurate and efficient but it's an expensive method since it uses a high coast devices. The Spectropics methods uses to capture the vapors of the bombs and converts these vapors into samples represented the samples on the form of waves. The Spectropics operation used to capture the vapors emitted from a nitro-organic explosives [26]. There are five popular type of Spectroscopic. Listed as follows:

1- Ion Mobility Spectroscopy (IMS)

This is one of the most used technology in Spectroscopic types. Two principles are combined in this technique to provide more efficiency in the response to the effect of vapors. [27] The IMS used to trace the explosives vapors under the Trace detection techniques. Chemical component of the explosives are consist of either a gas or chemical vapors. There are different type of chemical component and materials that can made an explosives such as TNT, DNT, MNT, and C4. All these materials has an effect on the spectrometer. A Spectrometer device sense the vapors of the explosive materials, converting the vapors into a central server through a wireless connection technology. This method will enables pre-separation after the process of ionization of the sample.

2- Mass Spectroscopic (MS)

Mass Spectroscopic analyze the chemical composition. This system is used in many airports as in United states Airport [28]. The MS system performs the detection process in high speed. Due to the system speed this system is work with other systems to generate more accurate and speed detection system. It is an efficient and accurate technology for detecting the vapors of the explosives materials. A main disadvantage of this system is the size of the mass spectrometer device. The size of the mass spectrometer device is too big for mobile detection. Figure bellow shown the M spectrometer

Figure 3: Mass Spectroscopic Device

3- Terahertz spectroscopy

Many researches have been made upon the terahertz Spectroscopic in recent years. The development in this field has taken place in the explosive detection techniques. For many explosives types there are a specific range of Terahertz. Most of bombs types has less than 3 THz spectral region [29]. The technology of Terahertz used to detect an explosives according to the Terahertz emitted from the explosives materials and gazes. Explosives has a different THz Spectrum that can be detected by the appropriate spectroscopic device. Figure 3 showing the Terahertz Spectroscopic waves according to the wavelength range.
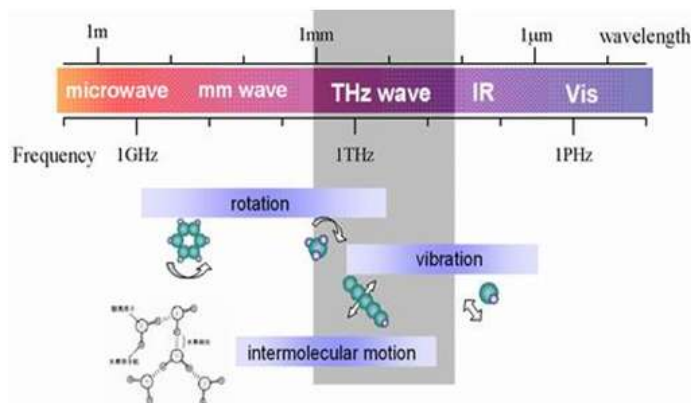

Figure 4: Terahertz wave range

4- Infrared Spectroscopy (IRS)

This technology depends on the technology of Infrared vision wavelength were explosives materials emitted a different type of wavelength that can be sensed by an appropriate infrared device. The infrared device sensor has a great sensitivity to the explosives materials the measurement unit of IR is **µ**m [30]. The usage of infrared spectroscopy has a wide spread in the thermal camera were the thermal camera is using the thermal vision based on infrared spectroscopy. The infrared spectrum display the image in different densities were each object is showing different color in the spectrum. The main aim of using the infrared spectroscopy is to identify the objects through there wavelength according to the spectral pattern. Figure 4 shows an infrared wavelength among the other waves
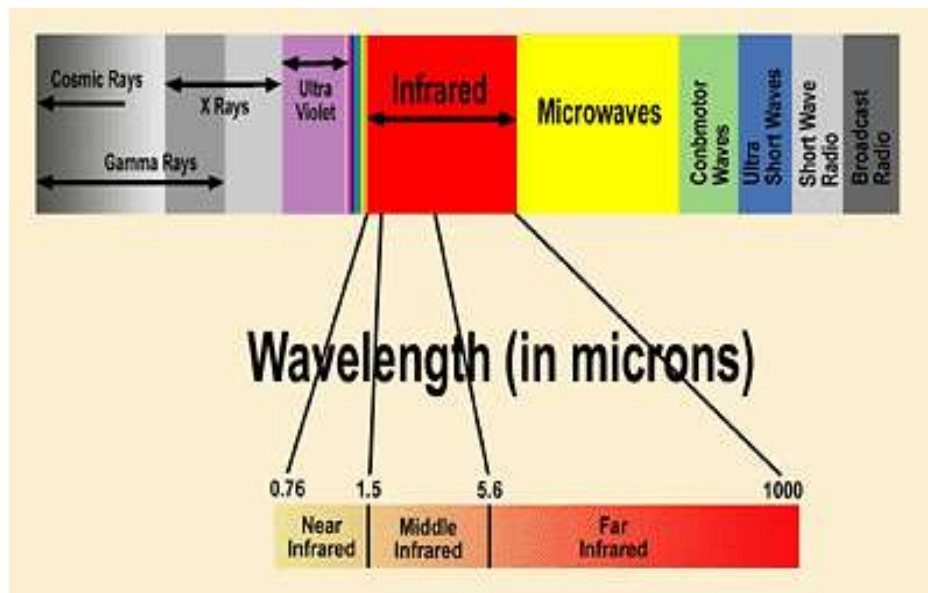

Figure 5: infrared wavelength and there bands in microns measurement unit

Infrared imaging used in wide spreader applications such as security field and commercial field. Below is a sample of an image taken by an infrared camera?
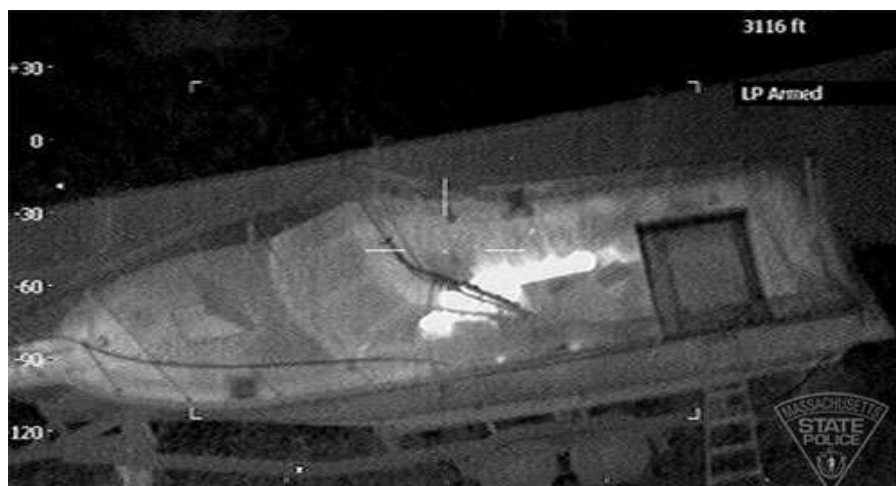

Figure 6: infrared image according to the object heat degree

Infrared vision technology used in many public places were a security level should be high such as an Airport or a government departments were these places are a valuable targets for the terrorist for hitting these places by using a handheld bombs that can be detected using infrared vision since the infrared camera are distributed over the targeted place working to find out the bombs through the wavelength characteristics of the explosives. Infrared cameras can connects to each other by using a wireless or wired communication technology.

5- Laser-induced breakdown spectroscopy (LIBS)

One of the most modern and efficient technology is the usage of the laser spectrum for detecting the explosives. This technology uses a high intensity laser to generate the vapors for the samples creating a plume of plasma. The light emitted from this plasma enables the laser sensor to detect the samples from the vaporized area and catching the wavelength of the laser sample in order to detect the required areas for the detection of the bombs. [31] This technology has an advantage and disadvantage. The main advantage of this method is the efficiency and speed in detection process. The disadvantage is that most of the detection area are in the open air, this would be a main drawback since the laser required a reflection in order to catch the samples from the specific area, this drawbacks has been handled by constructing a powerful and special types of laser equipment that can be work in the open air. Figure 6 shows the usage of the laser in military vehicles were these vehicles are equipped with a special type of laser device that can work to detect the IEDs in the ground

Figure 7: using laser device in the military vehicle's in order to detect the IEDs and other weapons using the laser sample technique

For the military applications, the connection between the vehicles should depend on a wide range wireless communication technology were vehicles needs to be connected to each other through a wide area. A base station vehicle can be used as a server for the laser vehicle that will sends information to the server vehicles. Once the vehicles with the laser equipment sensed an explosives specious in the place it will simply analyze the information and make sure of the explosives existence according to the reading of the laser spectrum. When explosive is detected. The laser vehicle sends the information to the server informing the server that there is an IED is near the place. The server will issue the required signal to the bomb diffusing vehicle to heading to the required place or removing the threat of a IEDs. In such a case, a special wireless communication technique is used. Since it's a military vehicles it uses a closed communication lines to transmitters and receivers information among the vehicles. Laser spectroscopic technology is used widely in military applications and it is also used in civilian application. The technology of laser is often expensive and there equipment are a high cost equipment. So in order to use this technique it must be using a special type of laboratories and a government support to develop methods of using laser technology in the field of explosive detection.

B. *Electronic Noses for detecting IEDs (E-Noses)*

The Electronic Noses is an artificial devices created for improving the sampling techniques in the field of explosive detection as the same as the dogs Nose [32]. Electronic nose devices consist of an array of chemical sensors, these chemical sensors interacts with the vapors emitted from the explosives. Electronic Noses contain an artificial neural network as a pattern recognition system in the device. The basic principle of the electronic noses is that each sensor in the device will gain a different information according to the pattern recognition technique combined with the electronic device. Every element in the nature is either an organic or non-organic element. The chemical sensing operation can be implemented electronically. Most of explosives are made of chemical elements. The chemical elements emitted vapors that can be detected by the use of electronic noses, electronic noses display the information on a displaying screen attached to the electronic noses devices. The electronic noses detect the vapors by collecting the change in the array value evaluating the change, and decide the change is from an exploded element or not. [33] The electronic noses is a continuous research area were the scientist developed such a devices for explosives detection purposes. Figure 7 illustrate the basic structure of the electronic noses devices with the ability to catch the vapors of gas and solid explosives materials [34].
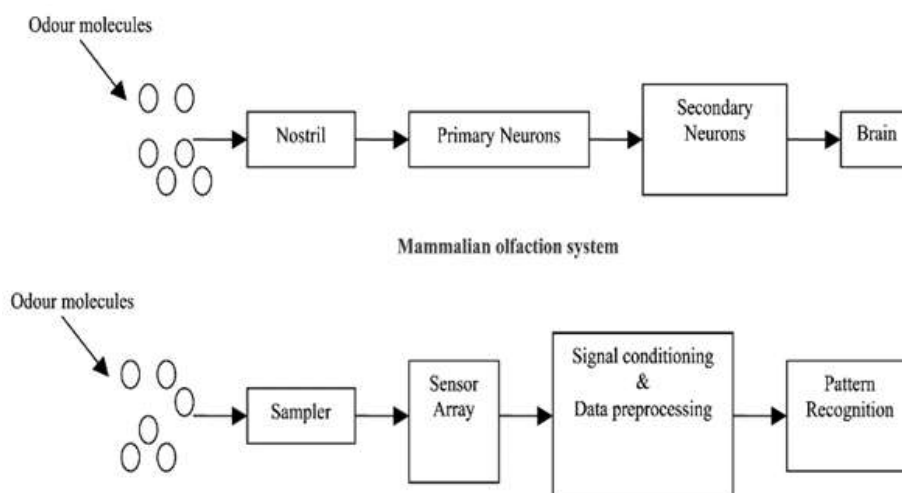
Figure 8: basic concept of electronic noses

Electronic noses sensors used in many applications such as chemical elements detection and commercial material recognition. The main usage of the electronic nose is for explosives detection. E-noses contain a pattern recognition system were such a system is used to recognize the sensors readings if the array in the e-noses system. There are multiple sensors implemented in the e-noses device, these noses are [34]:

1- Conductivity sensor
   This type of the sensors measures the conductivity in the explosives materials, the change in the explosive materials lead to a change in the resistance of the sensor. Once the sensors increased the resistance it means that there is a suspicious material that could be an exploded material.

2- Metal Oxide Sensor
   The objective of the metal oxide sensor is to determine the change in the conductance of the oxide on interaction with a gas and the change is usually proportional to the concentration of the gas. If the resistance of the sensor is gone high then this mean that an exploded chemical material has been detected.

3- Surface Acoustic Wave sensor (SAW)
   This electronic sensor is composed with the e-nose to add an extra ability to the e-nose system. The SAW sensor uses two dimensional wave generation to capture the change in the surface of an explosive material basis on the wave characteristics of the explosive material. Some explosive material is emitted a wave in frequencies between the 100 and 400 MHz The change in the resistance of the wave sensor will cause a notification by the SAW to analyze the data from the resistance source. SAW can detect some of the gases emitted from the gas material of the explosives.

4- Quartz Crystal Sensor (QCS)
   The three dimensional wave is travels through the bulk if crystal. The wave when travels through the crystal it will increases the mass and vapors became in higher form to be captured by the QCS. QCS increases the resonant of frequency of the samples and causes an alteration of the readings in the sensor readings. The Alter in the frequency is an identification of an explosive material.

All these sensors are used in the e-nose system for analyzing and processing of the data. Figures bellow illustrate the basic sensors diagram for the e-nose system.
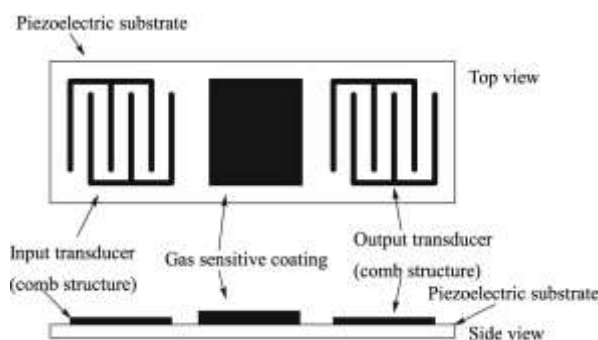

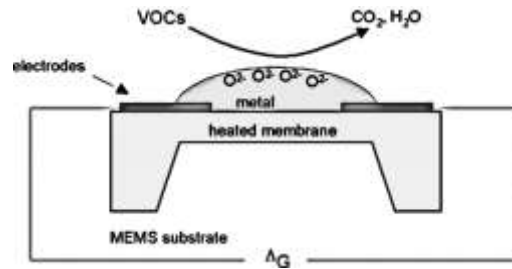**Figure 9:** Conductivity sensor in e-noses system

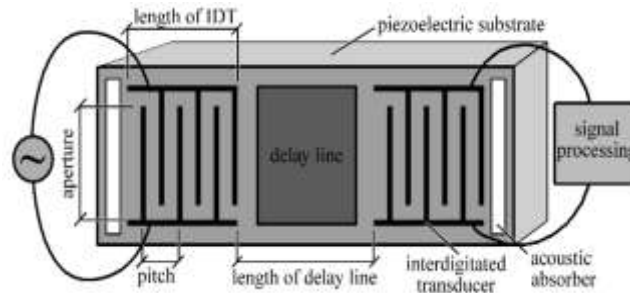**Figure 10:** Metal Oxide Sensor in e-noses

Figure 11: Surface Acoustic Wave sensor in e-nose

C. Magnetic IEDs Detection using magnetic sensor

A new technology has been improvised to detect magnetic explosives using magnetic sensor inside electronic devices [35]. The magnetic sensor is either an independent magnetic sensor or combined in an electronic devices such as smartphones [36] the magnetic sensor is an electronic device used to capture the magnetic readings from the around environment [37] the magnetic sensor captures the magnetic readings from the magnetic field objects. There are a magnetic field emitted from a magnets or an earth magnetic field. [38] There are a types of a IEDs that using the magnet to enables the bombs from being stacked to the vehicles. The magnet used in the IEDs is a strong magnet in order to prevent the bomb from being slept during the car movement. The magnetic IEDs are known as Under Vehicle Improvised Explosive Devices (UIED) or magnetic bomb [39]. Figure 8 shows a prototype of the sticky explosive.

Figure 12: a magnetic bomb stack under the vehicle

The Sticky bombs planted under the vehicles targeting the civilian's vehicle and military vehicles. The terrorist using this weapon as an efficient tool for assassination. This weapon and many IED types were heavily used in Afghanistan and Iraq [40]. There were different technology used to detect such a bombs. One of the most modern technology in detecting magnetic IEDs is the usage of handheld magnetic sensor looking for the magnetic bomb as in the Hand Held Explosive Detector Device (HHEDD) created by a German company for detecting Magnetic explosives [41]. Figure 9 shows the basic principle for the most of magnetic bombs detector systems
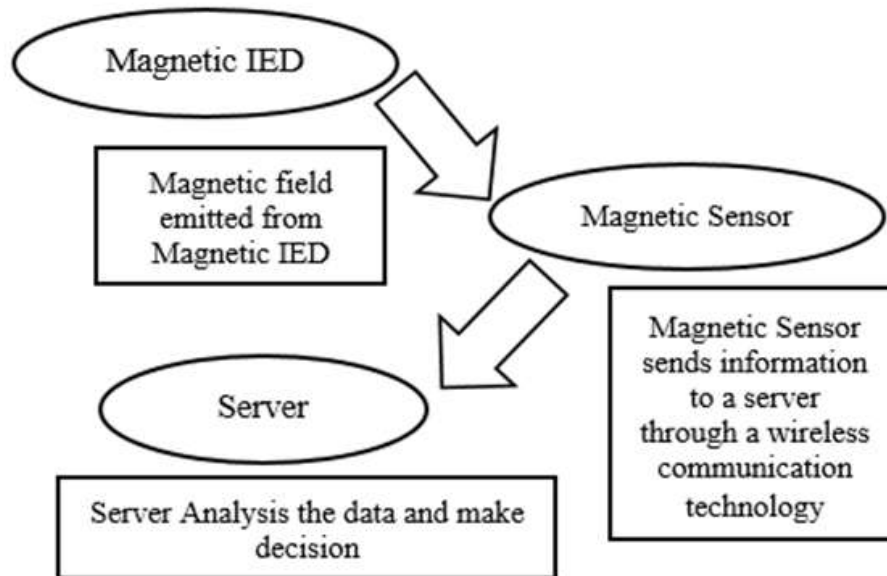
Figure 13: basic structure of Sticky IED detectors

The following techniques are the most popular techniques for detecting magnetic IEDs

D. *magnetic Sensors network for magnetic Bombs Detection*

A network of magnetic sensors distributed over a building or a government department to detect a magnetic explosives, the magnetic sensors is a part of the Sensors network for detecting explosives. The Wireless Sensors Network WSN is a collection of sensors related together to gains multiple applications, one of the basic sensor in WSN is the magnetic sensor. The magnetic sensor is used to detecting the magnetic field emitted from the under vehicles area were the explosives are expected to be placed in. the magnetic sensor checks the reading of the magnetic field and sends the information to a central server. The magnetic field is placed in an industrial speed bump. The industrial bump is placed in the street were the vehicles across the bump that contain the magnetic sensor. The magnetic sensor checks the magnetic field state of the vehicle passed across the magnetic sensor. Figure 10 shows the magnetic sensors constructed in the industrial bump

Figure 14: an industrial bump containing the magnetic sensor

The sensors is communicating between each other using a Wi-Fi network. WSN contain a basic server for getting information from/ into the sensors for detecting the magnetic explosives. For a wider range coverage it is needed to communicate between more than one servers the connection between the servers is through a broadband connection strategy. Following figure shows a basic WSN with the ability of connecting more than one server together
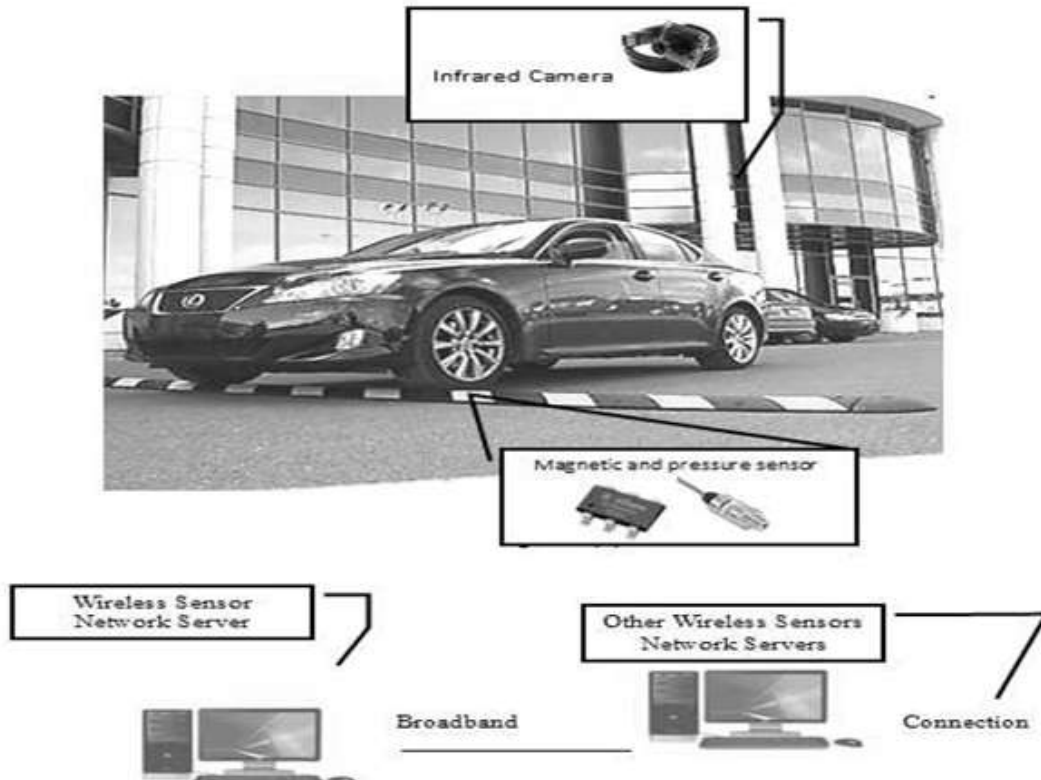
Figure 15: multiple WSN Server

1- Applications Areas of The Explosives Detection Technique

Each technique has a certain area of applications. In this section its listed the the main area of applicatable systems were each area has a spacific system for implementation. Each system using different range of wireless technology bases on the application area.

1- *Airport Security*

The airport is one of the most crowded places that required a high level of security. International airports threaten from time to time by the terrorist attacks. It is suitable for the airport to use the wireless sensors network for watching the status of the airport facilities. The WSN is suitable for the airport because the airports buildings required different sensors distributed over the airport. The airport facilities are connected together using the Wi-Fi network were several WSN nodes connected together in multiple server fashion. The servers are connected together in either a wired or wireless communication. The WSN can be used in any facility in the infrastructure of the airport.
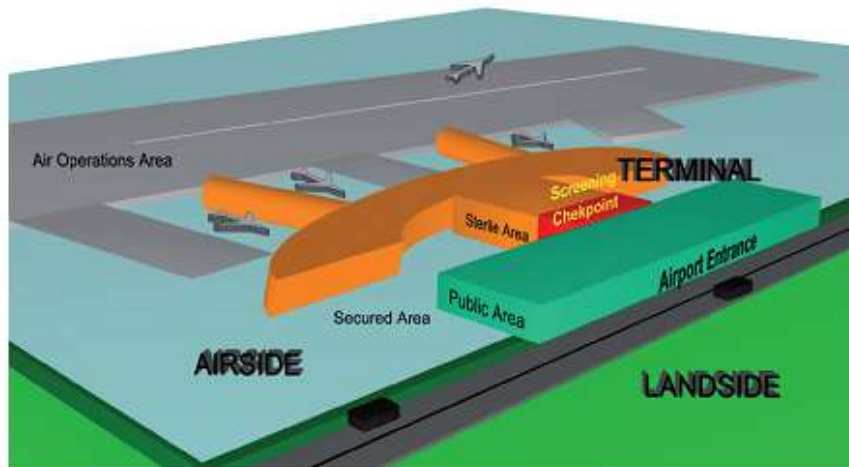

Figure 16: the Airport infrastructure

2- *Military Bases*

Military bases are the most valuable targets threaten by the terrorist attacks. Due to the military bases design, it is requires a very high security equipment for detecting the explosives and other suspicions. A high quality device is used in the gate of the base to check the vehicles and trucks for bombs detecting. Since the military bases gate. Large detecting devices such as spectroscopic devices which can provide a high quality detection for the explosives in the military gates

Figure 17: military base gate

3- *Government Departments*

One of the most valuable targets is the governments departments. Government employers working within the governments departments. To protect these buildings it is possible for implementing a WSN in the governments' gates and inside the buildings. WSN are implemented in the streets and implemented an infrared camera sensor in the top of the government buildings to watch out for the infrared vision. Industrial bumpers are constructed in the gates of the ministry were the vehicles entered the places are examined and checked for explosives.

2- Conclusion

The modern bombs techniques are almost wirelessly connected. The connection between the sensor device and the server are through either Wi-Fi, Wi-Max, GSM, or other wireless connection technologies. The detection device connection topology with the server is a client- server topology were the detection device act as the client and the server machine act as the server. Each technique has its own different detection device and special server machine. Most of the server machines in the explosives detection devices are computers (PC or Laptop) with different abilities. Each detection technology have a different range. A wireless sensor network is on the range of Wi-Fi network. Spectroscopic can be either in the range of Wi-Fi for the small range and Wi-Max for the wide range of detection. Smartphones detection technology has the range of Wi-Fi network for communication between the smartphone and server machine. Inside the buildings its preferred to use WSN as a detection technique, in the buildings gates and military bases uses large spectroscopic devices such as mass spectroscopic device. Smartphone detection techniques used build-in MEMS sensors as a detection devices.

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