Cross Border Tunnel Detection Using Sensors

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Abstract: Cross boarder tunnels are commonly used ways for illegal activities for nation security. Cross boarder tunnel detection is one of the most common concerns for national security. There are various methods already available. But unfortunately, all of them are highly expensive and cannot monitor and controlled remotely.
In this paper, a cost effective sensor based method is proposed to detect the tunnel which is accurate and with the help of Internet-of Things, the sensory data can be monitored remotely. The necessary action command can be provided remotely as well.

Index Terms **- Cross Boarder Tunnel Detection, Wireless Sensor Network, Ultra Sonic Sensor, Seismic Sensor, Internet-of-Things (IoT).**

I. INTRODUCTION

Cross border tunnel detection is the detection of tunnel deep inside the earth in border area. Now a day's national security is the major concern for any nation. There are many cross boarder tunnels existing used by terrorists and militants for smuggling of weapons, drugs and human trafficking. Therefore, a solution is required to overcome this problem. There are many topologies used in tunnel detection. The first ever Cross Border Tunnel Detection technology was experimented at U.S.-Mexico border near Otay Mesa, San Diego, CA [1]. This is experimental site for different cross boarder tunnel detection technologies. Most important technologies are Radio Imaging Method(RIM)[2], radio frequency electromagnetic method[1], Ground Penetrating Radar(GPR)[3], Tunnel Detection Focused Source Electromagnatic (TDFSEM)[4], synchronized electromagnetic wave gradiometer[5], ultrasonic sensor[6], seismic sensors[7].

RIM is having higher frequency data and provides better detection but has problem in detection in secondary radiation. Therefore, mostly closed boreholes are not detected[2]. Radio frequency electromagnetic method is robust and applicable in variety of geological settings but it is having limited potential without conductor [1]. Ground Penetrating Radar is good in far depth of investigation with high spatial resolution from the earth surface. It also automatically removes the unwanted shallow effects because it has high signal to noise ratio. GPR can detect only one dimensional inversion [3]. TDFSEM removes static noise but the produced electromagnetic field is less effective [4]. Synchronized Electromagnetic Wave gradiometer uses no physical contact from standoff transmitters to remote transmitter. In this technology, Post processing of data is not needed but the system is highly expensive [5]. Ultrasonic Sensor is better method for the distance estimation but not accurate [6].

Since the technologies which are used by different researchers are either less accurate or highly expensive. In this paper, new technology is proposed which is cost effective, more accurate, portable and easy to implement.

II. RELATED WORK

Kenneth D. Mahrer and David F. list [1] detected and delineated the tunnel using radio frequency electromagnetic at Otay Mesa site of San Diego, CA, US. They used three procedures in sequence: surface to surface, borehole to borehole and borehole to surface. It was advanced in terms of accuracy and depth detection. Kenneth D. Mahrer and William A Mondt [2] demonstrated that Radio Imaging Method (RIM) in which there are three techniques: surface-to-surface, borehole-to-surface, and borehole-to-borehole sensing technologies. Also, confirmed about its effectiveness with two basic approaches. First is the mapping between the country rock and the tunnel through electrical conductivity and second is the determine the location of cable which is embedded along the length of the tunnel. Mustafa Kuloglu and Chi-Chi Chen [3] discussed about the development, challenges and provide information about the requirements of the system as well as to detect its performance. Michael frenkel and Sofia Davydycheva [4] suggested a technique which is based on the vertical focusing on the Electromagnetic (EM) and they named this method as Tunnel Detection Focused-Source EM (TD-FSEM). This method reduces false detection. Larry G. Stolarczyka etal [5] described about the performance of Synchronized Electromagnetic Wave Gradiometer with several field studies. It uses the conductivity of advanced version which is associated with tunnels as compared to the surroundings medium so as to detect tunnels. K.V. Nibi etal [6] used ultrasonic sensors for generating and receiving ultrasonic waves. These waves penetrated the earth and returned to the receiver with the information of tunnel existence. Sang-Wook Kim and Se-Yun Kim [8] analyzed that Cross Borehole Pulse Radar to measure at different tunnel angles. This system was developed to detect deeply located (at depth of hundreds of meters) underground tunnels and to analys radar system to know its potential for the detection of the tunnel. Fernando Quivira etal [9] proposed a method named Underground Focusing Spotlight Synthetic Aperture Radar (UF-SL-SAR) for the tunnel detection under rough ground surfaces by implementing different algorithm. Ken Hauser etal [10] aimed for detecting the tunnels by Crosshole Radar Tomography in the proposed method. In subsurface along with the voids as the main focus of them is the mines. As the mines creates the concern of health as well as safety of employees and potential damage economically to the equipments which are used on daily basis at the mine. Arvin Farid et al [11] experimented with two dimensional forward model of Finite Difference Frequency Domain (FDFD) to learn more about the impending radar based tunnel detection.

Carol Christou etal [7] proposed a method which included:
1) The regional representative of geology and geophysical properties is investigated and characterized.

2) The modeling and simulation studies for different sensor systems with its sensor performance.
3) The test bed development and demonstaration of tunnel detection is validated and verified.

Shelby L. Peterie and Richard D. Miller [12] developed the travel time equations for mode-converted and oblique diffractions which demonstrated a diffraction imaging algorithm designed for the roll-along style for frequently used for near-surface surveys. Raphael Linker and Assaf Klarv [13] reported about the results of the experiment using fiber cables and discussed about the performance of system to measure the strain in the cable to detect tunnel which is buried inside the earth surface. Robert E. Abbott et al [14] precisely discussed and compared the various modes of advanced approaches for underground tunnel detection. In this paper, they discussed about seismic tomography, seismic ray path, reverse time migration, green's functions along with their phenomenon.

III. PROPOSED WORK

In this work, a wireless sensor network is developed to sense underground cross boarder tunnel and to intimate the respective authority for proper action. The detail of the system is described into two parts: Hardware Description and Software Description.

HARDWARE DESCRIPTION: The hardware part of wireless sensor network consists of sensor nodes, base station and remote server. Sensor nodes are deployed to detect tunnel with the help of ultrasonic sensors and seismic sensors. If any void or any vibration under earth surface is detected, sensor node will send alert information to base station using zigbee communication protocol. Base Station is a high speed processor which receives information from different sensor nodes. Remote server is user to receive data remotely.

A. SENSOR NODE

The important components of sensor nodes are sensing unit, processing unit, memory, radio transceiver and power supply.

- Sensing Unit

In this work, two sensors are used for tunnel detection. These are ultrasonic sensor and seismic sensor. Ultrasonic sensors are those sensors which are used to measure the distance to an object using sound waves [15]. It sends sound waves at specific frequency and receives it back so as to know the distance from the object. Seismic sensors which are used to determine the seismic vibrations by converting earth motion into electronic signal that is measured [16].

- Processing Unit and Memory

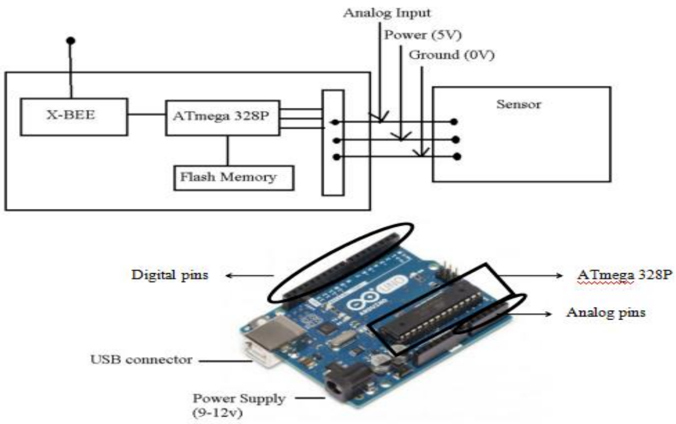
The processing unit is a unit which consists of small storage unit which manages the sensor node with other nodes to do the required work. [17]. In this work Arduino Uno is used as processing unit. Arduino is a platform which consists of both physical programmable circuit board as well as software. The microcontroller used in this platform is AT mega 328. It has 32 kilo Byte(KB) flash memory for storing the data and has also 2 KB static random access memory(SRAM) along with 1 KB Electrically Erasable Programmable Read Only Memory (EEPROM) [18].

B. RADIO TRANSCEIVER

Wireless sensor network is a network which communicates between nodes through wireless medium. Transceiver is a device which is the combined form of transmitter and receiver. The most suitable wireless sensor network is the radio frequency based communication with frequencies of 433MHz, 868MHz, 915MHz and 2.4 GHz [19].

In this work, X-bee is used as a radio transceiver. It is a wireless communication module which provides end-point connectivity embedded solutions wirelessly to devices. IEEE 802.15.4 networking protocol is used by the module for fast multipurpose and peer-to-peer networking. It is designed for high-throughput applications which requires low intermission and expected communication timing.

These modules are highly used because of its low cost, low power, power-amplified for its comprehensive range of application



[20]. Fig. 1. Shows the basic structure of sensor node used in this work.

Fig.1. Sensor node for tunnel detection

Global System Module (GSM) module: It is used to send data remotely using Internet of things (IoT). It is a digital cellular and an open technology which is mobile voice transmitter and data services operator. It is operated at different frequencies that are 850 MHz, 900 MHz, 1800 MHz and 1900 MHz Its module can be mobile phone as well as a modem device which is used to make a computer or any other processor which communicates over different network. Operating of this module is easy as it needs only a SIM card which operates a wide range of network. [21].

Power supply: Power supply is the most important part of wireless sensor network which comprised of power for sensing and data processing. Apart from sensing and data processing, the most important part of power consumption is in communication [22].

***SOFTWARE DESCRIPTION*:** The soft wares used in development of this system are Arduino IDE and XCTU. Arduino IDE is open-source software used for programming of Arduino Uno board [19]. XCTU is used for configuration of Xbee module [23].

Algorithm of working of Cross Border Tunnel Detection System (CBTDS)
Algorithm of working of the system is explained below:

1. First of all, all sensor nodes are initialized. Two sensors are used in sensor nodes: Ultrasonic Sensor (US) and Seismic Sensor (SS).
2. There will be four cases of detection:
   Case 1: US detect (1) and SS doesn't detect (0).
   Case 2: US detect (1) and SS detects (1).
   Case 3: US don't detect (0) and SS detects (1).
   Case 4: US don't detect (0) and SS doesn't detect (0).

3. When US: 1 and SS: 1(only case 2) then alert will be sent to the base station through network.
4. After this, Alert will send to the control station to take proper action. Fig. 2. Explains the above.

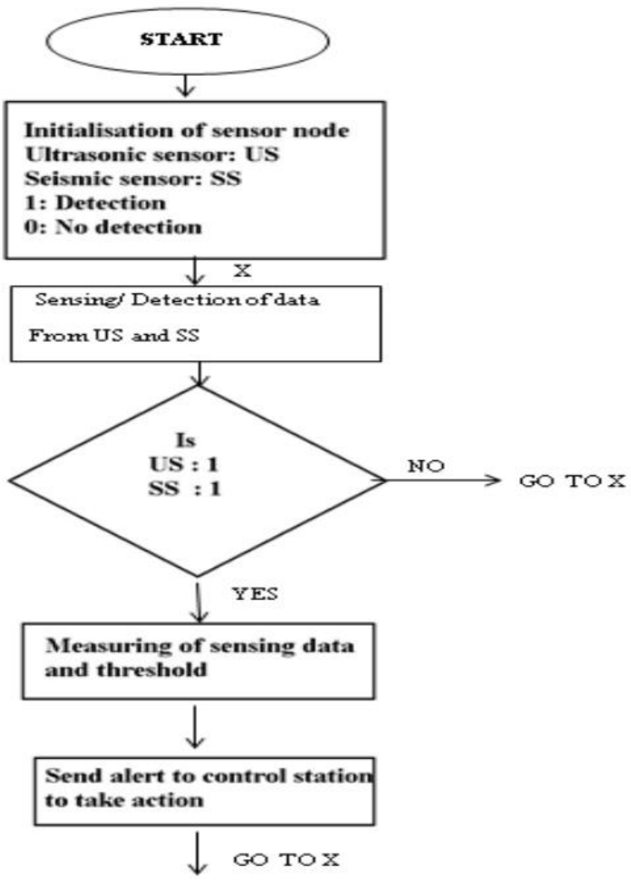
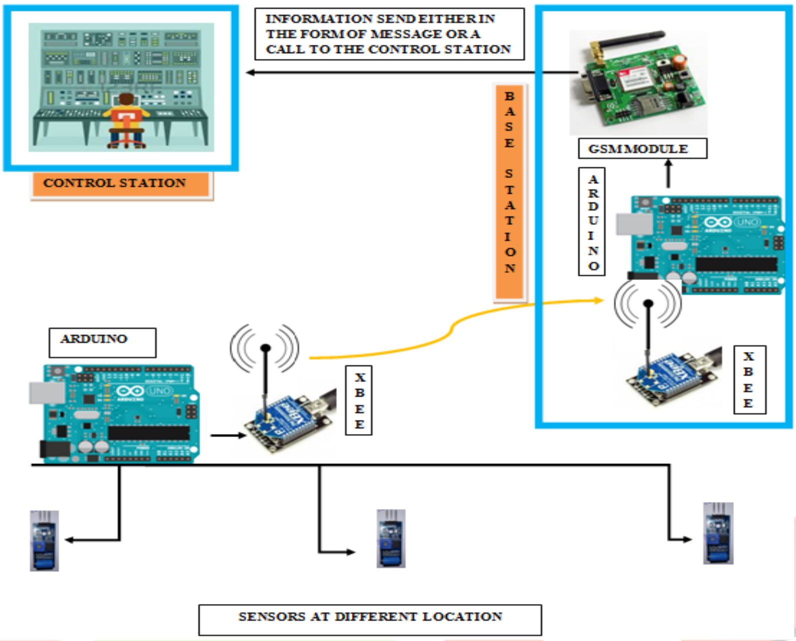


Fig. 2. Flow diagram of working

IV. WIRELESS SENSOR NETWORK DEVELOPMENT

Development of wireless sensor network will be elaborated in five segments:
Sensor, X-bee, Base station, GSM, Control room/ server

- Sensor: The sensor plays a very important role in this project as it helps to receive the vibration which will be created by the terrorists, militants or other activity going down the earth inside the tunnel. As the sensors are fixed at different location near the border area under the ground.
- X-bee: It is the wireless communication in which it creates a personal area network with larger range than Bluetooth and less power consumption than wifi. It receives the signal which is been sensed by the sensor.
- Base station: Base station is the information collecting area where the information is being received. It receives the data which is being sensed by the sensor via X-bee.
- GSM: GSM is Global System Module which is used for transmitting and collecting data. So it collects the data from the base station so as to transmit it to control center / server
- Control room/ server: It receives the information if there is any movement is going on deep inside the earth in the tunnel. So, if there is negative sign then the action could be taken immediately before anything could happen. Fig. 3. Explains the architecture of wireless sensor network development.



.Fig. 3. Architecture of wireless sensor network development

V. CONCLUSION

In this work, a robust cross boarder tunnel detection method is proposed which is easy to implement and cost-effective as well. The wireless sensor network is used to send the sensory data to control server which may far away from the site. The necessary commands can also be given by control server to perform real time actions.

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