INTRUDER TRACKING USING WIRELESS SENSOR NETWORK

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Abstract - **Nowadays, almost all the countries are facing threats from terrorists and intruders from their border areas, challenging the internal security of the country in those areas. So many civilian and military applications require locating an intruder in a secured area. Target tracking, data processing and analysis play a major role in this type of applications. The proposed system is to develop a centralized computer application that needs to identify moving objects in a specific area using sensors. The system will be basically designed to detect human intruders. The objective is to design and implement an object tracking system using a wireless sensor network. This application is able to detect and track objects, and report direction and speed of the intruder to a central base station. The human intruder is detected using a passive infrared (PIR) sensor. The sensor is connected to a MICAz sensor node. The PIR sensor is able to detect the humans and provide information about the direction of the movement. The gathered information from the sensor network is to be given to the base station for processing. The proposed system provides an environment for easy deployment and which does not require any existing infrastructure or constant monitoring by humans.**

Keywords - Infrared, Intruder, PIR, Sensor node, Wireless Sensor Network.

I. INTRODUCTION

Target tracking in Wireless Sensor Network (WSN) is the major problem in this application. Target tracking in the given application mainly deals with locating moving objects and finding the average speed of the moving object and being able to track its movements. In the tracking scheme illustrated, sensors are placed in a line topology. The technique used for detection is by catching the signal at the Analog to Digital Converter (ADC) pin. The object is being tracked by PIR sensors. The sensors are placed in static position. Using the gathered information from the sensor nodes, moving path, average speed and direction of the movement are predicted. The proposed scheme can detect objects moving at an average speed of 5Km/Sec. A Passive Infrared Sensor is used to identify whether the intruder is a human being or not. The main goal is to obtain the record of the trajectory of the moving object by processing the sensor data.

Internal Security of a country is a major issue now. India is also facing the cross border terrorism in different border areas of the country. We lost lot of lives as well as lot of money because of cross border terrorism. It is not possible to place enough men to guard all sections of the border even with more than 200,000 military personnel [16]. So here we can use the wireless technology to provide a feasible solution to detect intruders. The paper mainly focused to provide a software solution to detect human intruders.

II. RELATED WORK

The moving path of the intruder can be tracked using different technologies. To locate moving objects in wireless sensor networks, various researchers came up with different ideas. Reference [4] describes some important aspects of sensor networks including sensor node architecture, different remote sensing applications and characteristics of sensor networks. The key idea of this paper[7] is to allow sensor coverage areas to overlap to reduce the number of sensors. Y.Tseng [8] introduces location tracking in wireless sensor networks to reduce communication overheads. Reference [9] provides an algorithm to maximize the sensor field coverage. Reference [10] covers information collection protocol used in sensor networks for tracking applications. The main difference between our application and the above mentioned techniques is that the low cost sensor used for this application and the integration of that with MICAz -it will be a thermal sensor, precisely a Passive Infrared Sensor (PIR). A couple of sensor network hardware that was developed specifically for monitoring animals and tracking them is explained by P Sikka [14]. Hsieh [12] came up with highway and traffic applications by using sensor networks. Here magnetometer located on the MICAz sensor board can be used to detect magnetic materials such as vehicles (cars). Based on the signal strength readings to get the distance between nodes is the basic technology used. This information is basically used for this particular traffic application. Apart from this, we can apply the same for security to track moving object. Reference [13] deals with different issues related to sensor networks communication architecture. Hussain [15] combined Wireless Sensor Node (WSN) and Radio frequency Identification (RFID) technology. Their work deals with Radio Signal Strength Indicator (RSSI) of WSNs. To identify the person who is carrying the badge is possible with RFID technology. So authorized/unauthorized person identification is possible with this technology. An effective intrusion detection strategy implements several layers of defences. G. Jacoby [11] monitors power behaviour to detect potential intrusions by noting irregularities of power consump-

tion. Battery-based Intrusion Detection should also be incorporated to ensure security in the existing system.

The organization of the rest of the paper is as follows. Section III describes sensor choice, working and operation. Section IV mainly deals with the system architecture. Testing is described in section V of the paper; finally conclusion and future work is made in section VI.

III. SENSOR CHOICE , WORKING AND OPERATION

An Intrusion Detection system will use different types of sensors, which are capable of detecting moving objects. The main requirements for the selection of a sensor include low-power operation, reasonable size, low cost and sensor should not give false positive or negative readings. Sensor scalability is another important factor .We have to maintain a balance between the number of the sensors required and the coverage area, $\mu(R) = (N. \pi. R^2)/A$. where N is the number of scattered sensor nodes in region A and R is the radio transmission range. Here, $\mu(R)$ gives the number of nodes within the transmission radius of each node in region [5].

A Passive Infrared Sensor is used to develop this application. Because Infrared Sensor has better detection property which provides better result for direct movement detection. The analog output of the sensor will give the movement direction also. Another important factor is that the PIR sensor can be easily placed on a wireless sensor node.

The application is mainly focused on detecting human Intruders in a secured area. Human body generates heat. Objects that emit heat also generate infrared radiation in 8 to $14\mu m$ range, which includes the infrared radiation from human bodies [1]. Usually a PIR sensor package contains two elements next to each other and the output of the PIR sensor is based on the difference between the two elements [2]. See Fig. 1.

The PIR sensor used for this application is an all-in-one package, containing a PIR sensor, some circuitry (including an amplifier) and a Fresnel lens. The PIR sensor used for capturing IR signals is connected to the MICAz node. The MICAz and the sensor are connected using a 51 pin connector. The PIR sensor used in the application needs a 3-12 V as operating voltage with 1.5 *mA* which can be drawn from the 2xAA batteries in the sensor node. The sensor has an output used to indicate
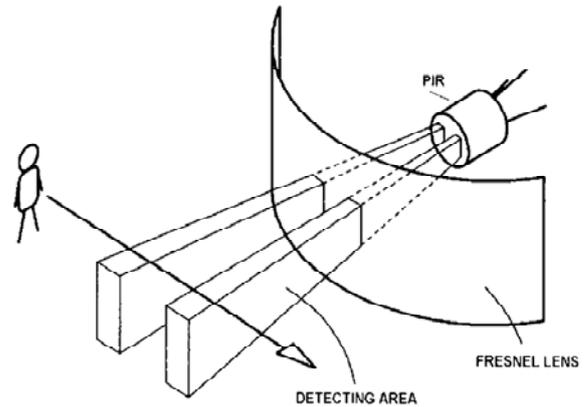

Fig. 1 PIR Sensor operation

TABLE I
PIN CONVERSION FROM PIR SENSOR TO MICAZ CONNECTOR

PIR Sensor		Micaz Connector	
Pin 1	(VCC)	Pin 2 or 50	(VCC)
Pin 2	(GND)	Pin 1 or pin 51	(GND)
Pin 4	(OUT)	Pin 42 or Pin 43	(ADC)

whether a movement occurs or not, a reference voltage (pin 2 of MICAz connector) and Ground (Pin 1 or Pin 51 of MICAz connector).The pin assignment is given in Table I which is available in the datasheet given by crossbow technologies [3].

A. Placement of Sensor

To detect movement, the sensor placement plays a major role. PIR sensor has got a direct line of sight for detection and they are not omnidirectional also. Sensor placement mainly depends on the network topology. For this particular application, sensors can follow line topology. Aggregated data is sent to the base station with the help of intermediate nodes. See Fig. 2 for sensor arrangement.

IV. SYSTEM ARCHITECTURE

This section mainly discusses the communication between the different modules of the tracking application. The object tracking system has got main modules as Object Monitoring, Object Catching, Object Tracking and Communication between nodes. The functionalities of the different modules are described in the following sections with Architectural Design (Fig 3).

A. Object Monitoring(OM Module)

This module basically reads data from the PIR sensor. After reading the data from the sensor, object monitoring module will hand over the data to the Object Catching module for further processing. When an interrupt occurs i.e., a human intruder is detected at the sensing area, the signal at the ADC pin is caught by the sensor node OM module and which is handed over to the catching module.
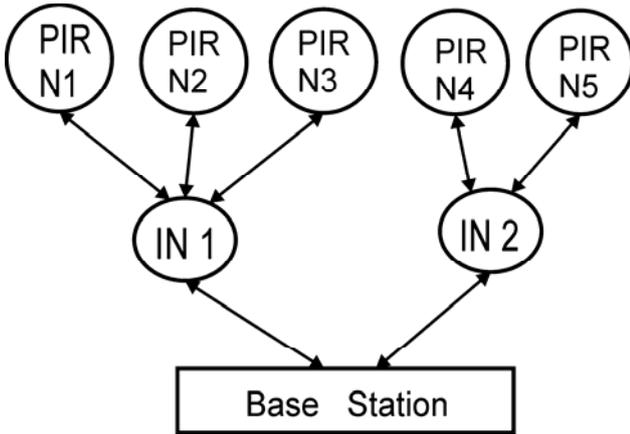
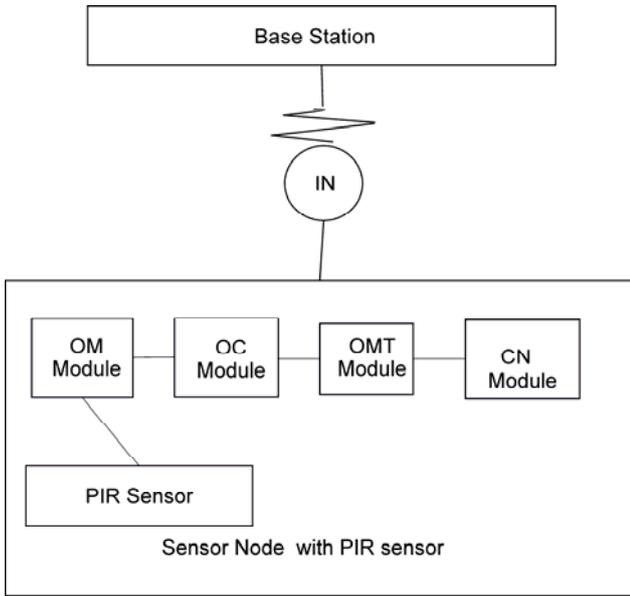Fig 2: Sensor Placement: sensors follow line topology.

Fig 3: Architectural Design

B. Object Catching(OC Module)

Once the data is obtained from the monitoring module, the catching module will decide on the starting and stopping of the event catching process based on the timer Interval and the number of samples. After a particular time period (Time Interval between an object to reach from sender to receiver) elapsed, the same object is reached at another node, which will be interpreted as a new object. This is because of the reason that PIR sensor cannot differentiate between different objects. The sensor state is also managed by this module. The path of the movement (one sensor node to another sensor node) is also detected by this module. The catching module will decide the different parameters for the sensing and will send the direction indication to the communication module. All nodes should know their neighbours. The static location is logically stored in the node. This will provide the direction indication to the nodes.

Whenever an object is detected, an event is signalled by the catching module. Direction is also contained in the message depending on the object (whether it is a new object or an already tracked object).A field is associated with each message structure to indicate whether the direction is confirmed by the neighbouring nodes or not. At the reception time of the message, this is set by the receiver. To know the direction of the movement of the object, relative position of the senor nodes is used. An object Id is also associated with each object once it is caught. So the message structure contains the following details:

- Node Positions (x,y coordinates),
- Direction (left, right)
- Directional field to get confirmation from the receiving node,
- Speed (number of nodes > 1).
- Unique Identifier for the object being caught.
- Timerval to calculate the speed at the receiver side.

This message is sent to both the left side and the right side nodes. At the same time the sender starts a timer. One of the uses of this timer is to distinguish a newly arrived object and the currently tracked object. Another important function of this timer is to calculate the speed between the nodes over a distance D.

The speed can be calculated by using the formula:

Velocity (V) = D/T.

Where V is the speed in m/sec,

The distance between the sender node and the receiver node is indicated by the D, and the Time to reach from sender node to receiver node is indicated by T.

C. Object Movement Tracing (OMT Module)

This module will act as a coordinating module, which will take care of the communication between different nodes and report those activities to the base station. The direction of the movement and the speed of the object are reported to the base station by this module. Basically this module performs two basic operations –coordination between nodes (using communication module) and communication between nodes to the base station. The same information or message is given to the neighbouring nodes as well as the base station, which is explained in the following sections.

C. Communication Module(CN Module)

This module is mainly used to send a message to a group of nodes. It is used to send the same message to multiple nodes at the same time and is used to coordinate the communication in that group. The sending of the same message several times and flooding of the messages can be avoided by using this module. Algorithm for the communication module is given in Algorithm 1.1.

Input: sensing Interval *(Timerval)*
Valid range to avoid noise *(high_range, low_range)*
Message structure *(Msg)*
Number of sensing samples in a node range   *(Bound)*

Output: Send Message to denote the detection of the event.
Begin
Detect <- False
    Ctr   <- 0
        While timerfired (timerval) do
            Call *ADC.getData ()*

```
        readMessage (msg)
      ctr<-ctr+1
      If msg.value<high_range
          && msg.value>low_range then
          Detect<- True
          If ctr==Bound then
              PostSending ()
              Ctr<-0
          End
      End
   End
End
```

Algorithm 1.1: Sender side

The Receive receives the message from the sender module of the source node. Both sender and receiver are implemented in all the nodes. Algorithm 1.2 describes the receiver side of the node.

Input: Message structure (*SMsg*)

Output: Received Message (*RMsg)* and message is re-transmitted to the base station for further processing.

```
Begin
  While true do
      event ReceiveMsg.receive(RMsg)
      call CalculateSpeed()
      call ConfirmDirection(SMsg.Direction)
      call SendMsg.send (SMsg, Success)/*Send to base
station.*/
   End
End
```

Algorithm 1.2: Receiver Side

The gathered information is reported to the base station for further processing. All nodes are not required for this process. To save energy of the sensor nodes, some of the nodes are selected as the intermediate nodes to report to the base station.

V. TESTING

The application is developed using Processor *AtmelATMega128@8MHz* with *Frequency band 2400MHz - 2483.5 MHz* and implemented using *nesC* for the *TinyOS* open source operating system that runs on MICAz[6]. Received packets at the PC is displayed using *XSniffer*.The main objective of the system is to design a human-intruder-tracking system using Wireless Sensor Network and gather the specific information like speed and direction of the movement of the object. For that PIR sensors are connected to *MICAz* node and get data from the sensor using *NesC* program. The test is repeated for a single sensor as well as multiple sensors. The sensor data is stored on the PC. For multiple sensors, the data is collected from more than three sensors arranged in a line topology. The test shows that the node should report the

Table II
DATA OBTAINED FROM SENSOR NODES

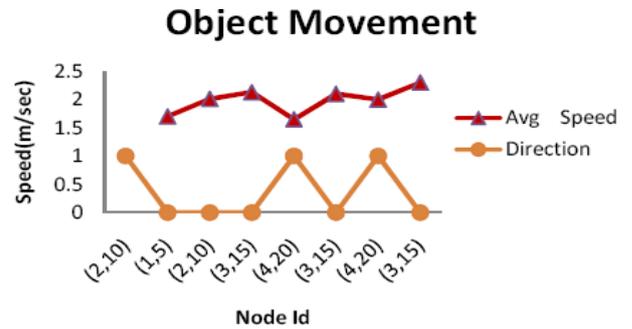| Source Node	Destination Node	Direction	Average Speed(v=D/t)
(2,10)	(1,15)	Right	1.7 m/sec
(1,5)	(2,10)	Left	2.01 m/sec
(2,10)	(3,15)	Left	2.13m/sec
(3,15)	(4,20)	Left	1.65m/sec
(4,20)	(3,15)	Right	2.1m/sec
(3,15)	(4,20)	Left	2m/sec

Fig. 4: Data Analysis Chart

movements within the average walking speed of a man (ie, 5Km/Hr).

The application is tested in a laboratory setup with four sensors separated with a 5m distance apart, which is arranged in a line topology. For our experiment, we have selected alternate nodes as the reporting nodes. The base station will report the events to the PC. Using the *XSniffer* tool we get the received message in readable format and we store it in an Excel file. Table II shows sensor output. This data can be used to generate alarm signals or alert messages that are sent to mobile phones via GSM modem.

Fig. 4 shows the simulation result of the data obtained from the *XSniffer*.

VI. CONCLUSION AND FUTURE WORK

In summary, the moving path, average speed and direction of the human intruder are detected by integrating PIR sensor and MICAz.As of now the application can detect a single person in the sensing range of a sensor. i.e., more than one person is coming in a sensor range, which cannot be detected by the application or can be interpreted as a single intruder. So we can provide an improvement over the system to include sensor fusion for better and accurate movement detection. The future work is mainly focusing on other types of intruder-tracking mechanisms like vehicles (military tankers), animals, explosives etc, by using a combination of sensors.

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