DJILLALI LIABES UNIVERSITY OF SIDI BEL ABBES
FACULTY OF EXACT SCIENCES
DEPARTMENT OF COMPUTER SCIENCES

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Invention Document

Students:
HADJAZI M.Hisham
MLETTA Mohammed Moncif
SAHRAOUI M.Taher Amine
DJEBAR Yahya

Supervisor:
Pr. BOUCLI-HACENE SOFIANE
Co-Supervisor:
Pr. Yousfate Abderhmane

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Chapter 1

Invention Description

1.1 Invetion title

"Border surveillance and monitoring using solar powered Wireless Sensor Network equipped with 24GHz mmWave sensors and GPS Modules for tracking and ESP-NOW and LoRa protocols for communication"

1.2 Technical field of invention

This invention "Border surveillance and monitoring using solar powered Wireless Sensor Network equipped with 24GHz mmWave sensors and GPS Modules for tracking and ESP-NOW and LoRa protocols for communication" is a technical solution that involves the use of a wireless sensor network to monitor and track all activities at border areas or any large scale spaces.

The system can detect and track illegal border crossings, suspicious activities, and other potential security threats. The data collected can be used to improve border security and provide real-time information to law enforcement agencies.

1.3 Previus related work

The idea of using sensors scattered over a peice of land to monitor border crossings is not new, and there are many implementations of it over the previus years. however our implementation builds over what other people have already accomplished and we add what we think are shortcommings in thier ideas in order to further improve the concept and make it a more fiesable solution.

1.3.1 "DESIGN AND IMPLEMENTATION OF SCALABLE WIRELESS SENSOR NETWORK BEYOND WI-FI" by Wilfred J Vaz and Mrinal Sarvagya

Wilfred J Vaz and **Mrinal Sarvagya** from India with the **"DESIGN AND IMPLEMENTATION OF SCALABLE WIRELESS SENSOR NETWORK BEYOND WI-FI"**[4] which is a system that uses ESP32 microcontroller equipped with LoRa modem and GPS module and I2C interfaced-multiplexed sensors, they used the ESP32 as nodes for their Wireless sensor network.[4] Their system was used for three tasks first to monitor soil and help improve smart farming, second to monitor pollution inside cities, and finally to do environmental monitoring to help with natural disasters.[4]

As our application is to monitor different border crossing, we will be using a different type of monitoring sensors which are the "24GHz mmWave sensors", second since our sensors will be closer to each other we will be using the "ESP-NOW" protocol to for communication between nodes, this will drastically improve power consumption as it consumes much less power than LoRa, and we will only use LoRa protocol when our nodes start to die and the need for a long-distance form of communication is required to maintain the network.

Our system also uses solar power to charge the batteries, making them lasting much longer.

1.3.2 "WSN MONITORING SYSTEM" by LIU JIANYUAN, PAN ZHONGMING,ZHANG HENG, ZHANG ZHUOHANG, and WANG HUITANG

Here **LIU JIANYUAN**, **PAN ZHONGMING**, **ZHANG HENG**, **ZHANG ZHUOHANG**, and **WANG HUITANG** from Chaina with their **"WSN MONITORING SYSTEM"** have made a very complicated system that consists of many types of sensors in one node the sensors are a magnetic sensor module, a sound array sensor module, a vibration sensor module, a Doppler microwave sensor module, and an infrared sensor module.[1] now the use of all these sensors will complicate the system and make it more expensive not to mention the power consumption.[1] and as they have mentioned that the system is battery powered they will need a larger battery making their system not suitable for border control, and much more suitable for monitoring smaller scale areas like airports and Buildings.[1]

Our system is more of a disposable system that can last for years without the need for any field maintenance. this is due to using fewer sensors to save resources. and using solar power to charge the batteries. which means they can work for the lifetime of their components.

Another difference is the use of ESP-NOW protocol for all short-distance communications and only use LoRa protocol when it is impossible for the nodes to communicate using ESP-NOW due to large distance or the malfunction of nearby nodes.

Our system doesn't use CCTV cameras as it is more suitable for rural areas where CCTV cameras will make the system more complicated for very little benefit.

1.3.3 "SYSTEM FOR CONTROLLING AND MONITORING SOLAR-POWERED, WIRELESS SENSOR NODES IN PRECISION AGRICULTURE" by Dr. Pravin P Patil, Dr. Rupa Khanna Malhotra, Dr. Savita, and Dr. Bhasker Pant

Dr.Patil, **Dr.Malhotra**, **Dr. Savita**, and **Dr.Pant**describes systems and methods related to wireless sensor networks that harvest ambient energy for intelligent agricultural control.[3]

They have made Solar energy harvesting wireless sensor networks (SEH-WSNs) added to WSN.[3]

Our system is used for a different application as we are trying to monitor the movements of land objects in largely rural areas.

Not to mention the differences in communication protocols as we are not using ZigBee in our system.

1.3.4 "INTRUDER MOTION DETECTION SYSTEM" by Mrunal Mohan Khedkar and Gajendra Mahadeorao Asutkar

Khedkar and **Asutkar** have made a wireless intruder motion detection system using digital cameras. The system can detect intruders, animals, or objects through a motion detection technique that turns on the camera when movement is detected. The camera can capture videos during both day and night, and the system can transmit the captured videos to a base station or server wirelessly.[2]

The system uses solar-powered batteries to keep the system alive, and the cameras only turn on once movement is detected to save energy.[2]

Our system doesn't use cameras for monitoring. we use microwave sensors to detect the movement that can be analyzed at the base to identify the object solely on sensor data.

Our system can also be deployed on very large areas that stretch for hunderds of kilometers.

1.4 Objective of the invention

1. **Border security**: The primary objective of this invention is to enhance border security by providing a reliable and efficient system for monitoring and detecting any unauthorized activity across the border. The sensors can detect and report any movement of people or vehicles in real-time, which can help authorities to take appropriate action.

2. **Cost-effectiveness**: The use of low-cost and low-power wireless sensors, solar power, and LoRa communication technology makes this system cost-effective compared to other border surveillance systems that require a constant supply of electricity and high-speed internet connectivity.

3. **Real-time monitoring**: The use of GPS modules and real-time data transmission using LoRa for long range and ESP-NOW for shorter range communication allows authorities to monitor the movement of people and vehicles across the border in real-time. This can help in preventing illegal activities such as smuggling and trafficking.

1.5 How the Invention is made ?

A wireless sensor network is a collection of small, low-power, and low-cost wireless devices called sensors that are distributed over a wide area to monitor various environmental and physical conditions. The sensors in a WSN are typically equipped with various types of sensors to measure different parameters.

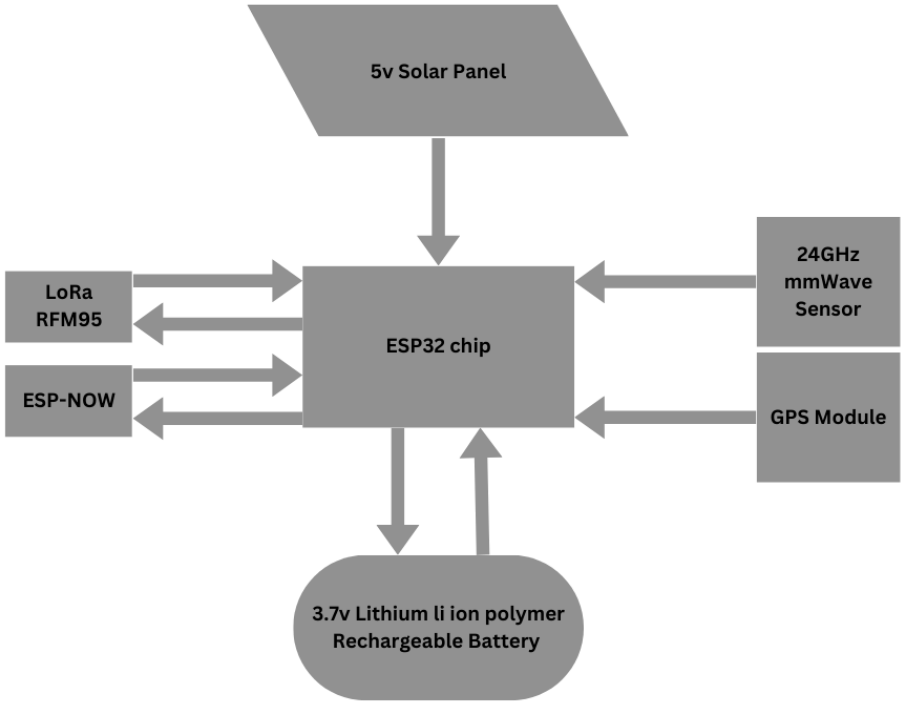


FIGURE 1.1: Sensor node componnents

In the case of the described invention, the wireless sensor nodes are equipped with ESP32 modules, which are small, low-power, and low-cost microcontrollers. The nodes are also equipped with 24GHz mmWave sensors, which are used for short-range radar sensing applications. These sensors operate at frequencies above 30 GHz and provide high-resolution and accuracy in detecting targets.

The system utilizes 24GHz mmWave sensors to detect and track movement, along with GPS modules to provide location data. The mmWave sensors use a high frequency electromagnetic signal to detect objects and measure their distance and speed, making them suitable for detecting human and vehicle activity at long distances.

The wireless sensor network is powered by solar panels, which ensures that the system can operate independently of the electrical grid and in remote areas. The sensors are interconnected and communicate with each other wirelessly, sending data to a central server where it is analyzed and processed.

Finally, ESP-NOW is a low-power, low-latency, and high-throughput protocol developed by Espressif Systems that operates over the 2.4GHz frequency band. By incorporating ESP-NOW into the system, the sensors can communicate with each other over short distances without the need for a Wi-Fi or cellular network, making

it an ideal solution for border areas where such networks may be unavailable or unreliable. ESP-NOW also offers the advantage of being highly secure and resistant to interference, which is important in border security applications where unauthorized access to the network or data can pose a significant risk.

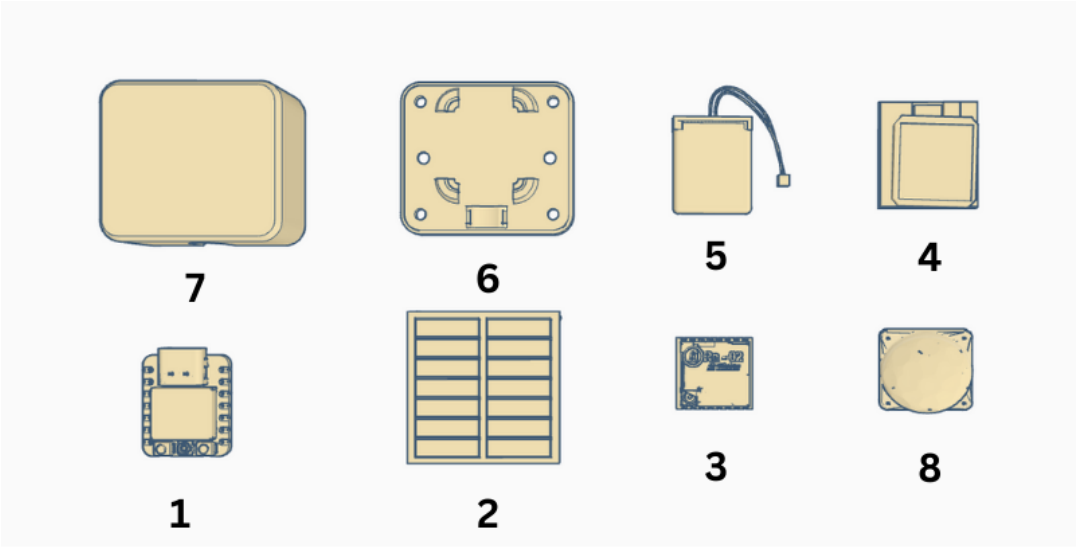


FIGURE 1.2: Sensor node componnents

The wireless sensors are also equipped with LoRa (Long Range) communication technology, which is a low-power, long-range wireless communication protocol that allows the sensors to transmit data over long distances without consuming too much power. This is important as it acts as a back-up for ESP-NOW protocol and to increases the life of the system by allwing the sensor nodes to communicate with each other over longer distances, as sensor nodes start to die over time, it will insure the system will still be functional as it is able to send data over longer distances.

Incorporating the MQTT protocol can further enhance the functionality of the system. MQTT is a lightweight and efficient messaging protocol designed for use in machine-to-machine (M2M) and Internet of Things (IoT) applications. In this case, the closest node to the Raspberry Pi can use MQTT protocol to communicate with it. This allows for the transmission of real-time data from the sensors to the Raspberry Pi.

Overall, the described invention is a sophisticated system that combines various advanced technologies to provide an effective and reliable border surveillance and monitoring solution.

1.6 How the Invention works ?

Border surveillance and monitoring is a critical aspects of national security, and technology has played an essential role in enhancing this capability. A recent development in this area is the use of wireless sensor networks (WSN) equipped with 24GHz mmWave sensors and GPS modules for border surveillance and monitoring. This system is designed to provide reliable and real-time data on human and vehicle activity along the border, enabling quick and appropriate action when necessary.

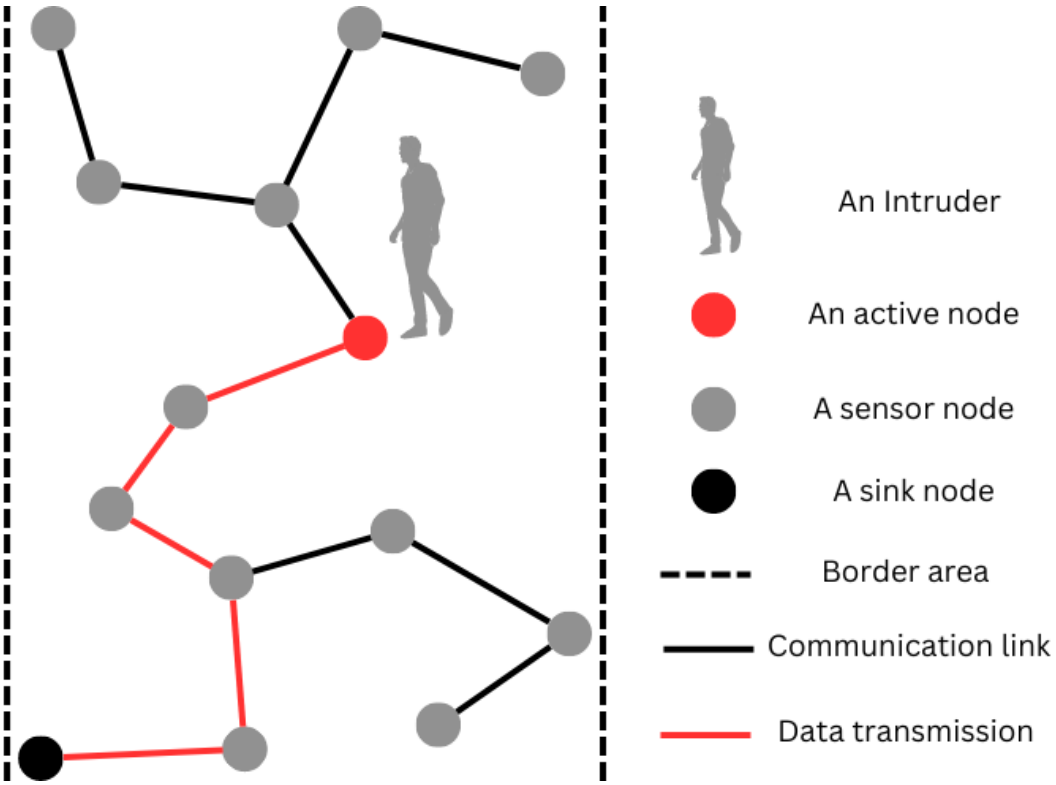


FIGURE 1.3: Example of Inturder setection

The system works by creating a wireless sensor network in the area to be monitored. The nodes are scattered across the area, with around 10 to 20 meters between each node. When the nodes are turned on, they automatically create a network between each other using ESP-NOW technology. This technology allows the nodes to communicate with each other over short distances without the need for Wi-Fi or cellular networks, making it ideal for border areas where such networks may be unavailable or unreliable.

Each node is equipped with a 24GHz mmWave sensor and a GPS module. The 24GHz mmWave sensor can detect moving objects, such as humans and vehicles, at long distances. The GPS module enables accurate location tracking, which is essential for effective border monitoring. The nodes communicate with each other, sending data and location information until it reaches the node closest to the Raspberry Pi, which acts as the base station.

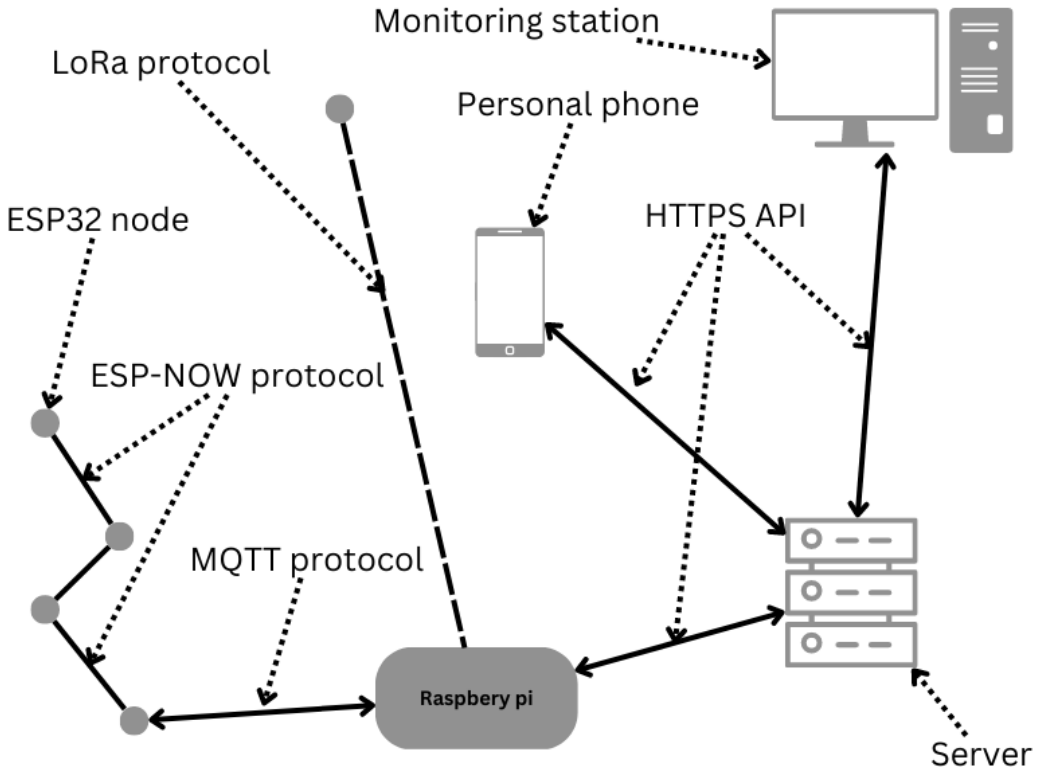


FIGURE 1.4: Complete system outlook

Communication between the last node and the Raspberry Pi is achieved using the MQTT protocol. MQTT is a lightweight and efficient messaging protocol designed for use in machine-to-machine (M2M) and Internet of Things (IoT) applications. The use of the MQTT protocol enables the transmission of real-time data from the sensors to the Raspberry Pi, which can then be processed, analyzed, and visualized.

In case a node is far from the rest of the network and cannot send data via ESP-NOW, it can use LoRa technology. The nodes are equipped with LoRa, and they can send data to other nodes equipped with LoRa or directly to the Raspberry Pi. LoRa technology provides redundancy, ensuring that data transmission is not disrupted, and real-time information is always available to monitoring stations and mobile phones.

Each node is equipped with a 5V solar panel for charging the 3.7V lithium battery. This feature ensures that the nodes can work 24/7 non-stop for many years, making them ideal for remote or challenging environments. The nodes also have a tamper protection system that activates a capacitor when the case is opened. This capacitor sends a high current to the chips inside, frying them to protect sensitive data.

The system's ability to transmit real-time data to a centralized database and notify monitoring stations and mobile phones of any incidents is an effective approach to border surveillance and monitoring. This capability provides critical information for quick and appropriate action, enabling authorities to respond to incidents in a timely and effective manner.

In conclusion, the use of wireless sensor networks equipped with 24GHz mmWave

sensors and GPS modules for border surveillance and monitoring is a significant development in national security. The system's use of multiple technologies, including ESP-NOW, MQTT, LoRa, and solar panels, provides reliable and efficient detection of human and vehicle activity, accurate location tracking, redundant data transmission, and long-term operation in remote or challenging environments. The tamper protection system further enhances the system's security, ensuring the protection of sensitive data. Overall, this system provides an effective and comprehensive approach to border surveillance and monitoring, enabling authorities to maintain national security and respond to incidents in a timely and effective manner.

Chapter 2

Our claims

1. A border surveillance system comprising a wireless sensor network (WSN) built on ESP32 chips, said network powered by lithium batteries that can be charged with solar power, said system utilizing ESP-NOW and LoRa communication technology for short and long-distance communication, respectively, and said WSN incorporating GPS chips and 24GHz microwave sensors for detecting movements.

2. A border surveillance system according to claim 1, further comprising a Raspberry Pi configured to receive data from the sensor nodes of the WSN via the MQTT protocol, said system also including a base station for monitoring and control.

3. A border surveillance system according to claim 2, wherein the base station utilizes a graphical user interface to display real-time data received from the sensor nodes of the WSN, said data including movement detection information and GPS location data.

4. A border surveillance system according to claim 1, wherein the sensor nodes of the WSN are mobile and can be deployed to monitor and secure various locations along the border.

5. A border surveillance system according to claim 1, wherein the system allows for remote access and control via mobile phones, allowing users to track the location of sensor nodes and view real-time data from the base station.

Chapter 3

Designes and figers

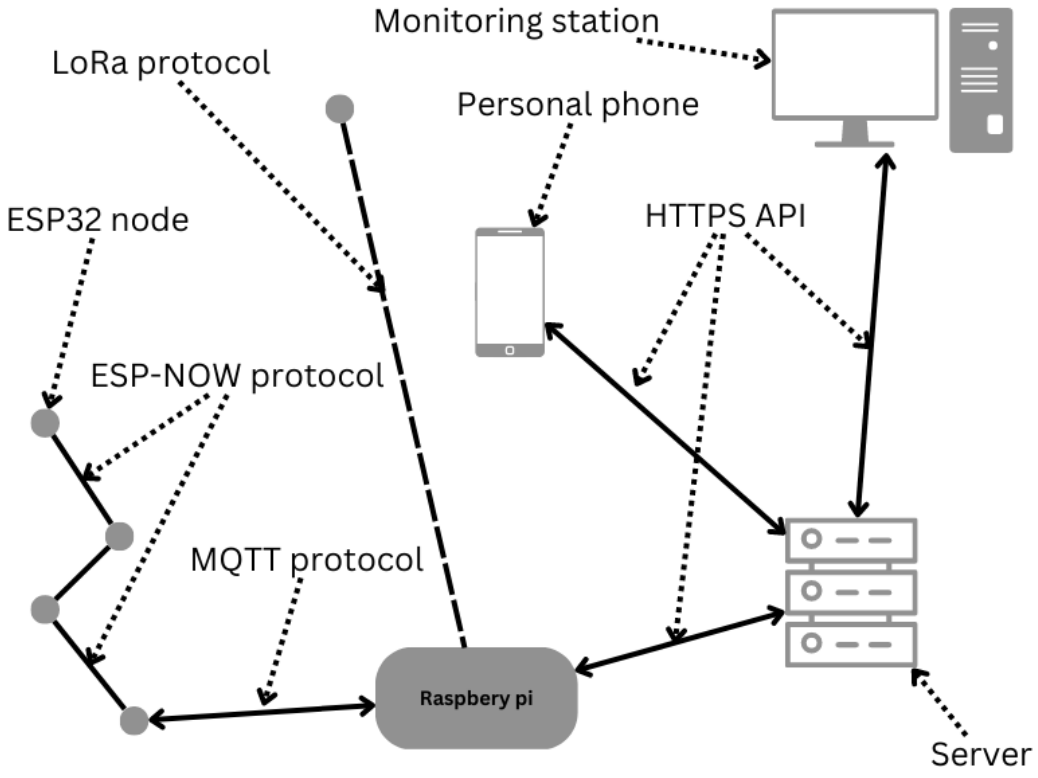


FIGURE 3.1: Complete system outlook

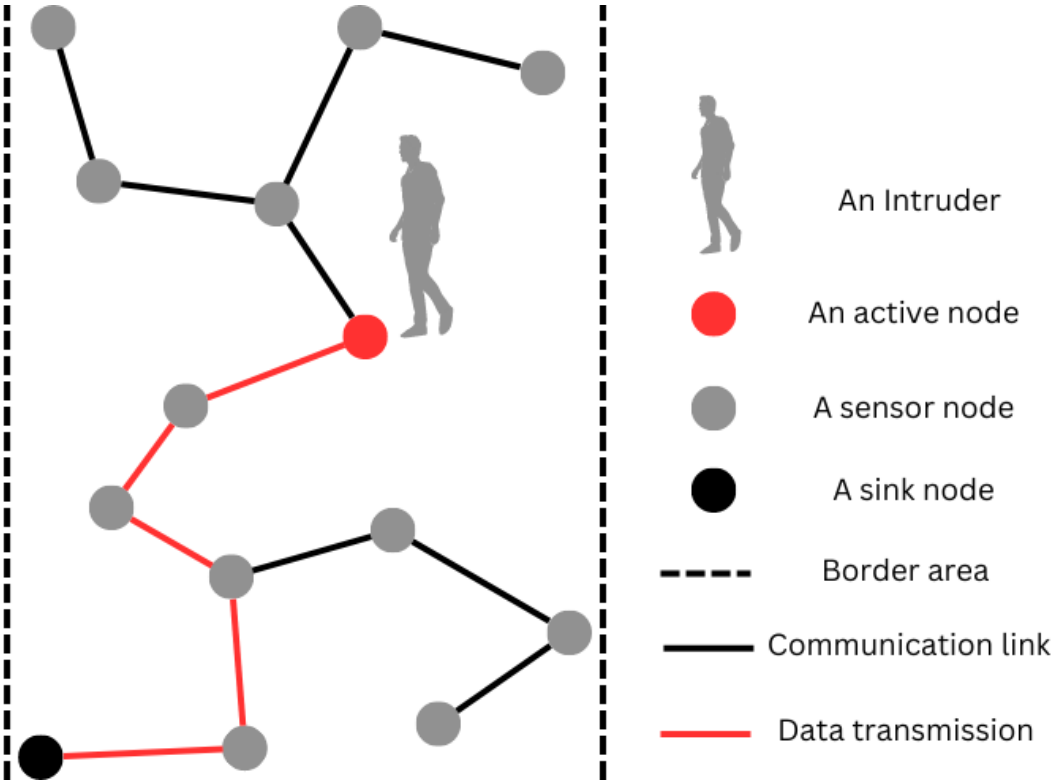


FIGURE 3.2: Example of Inturder setection

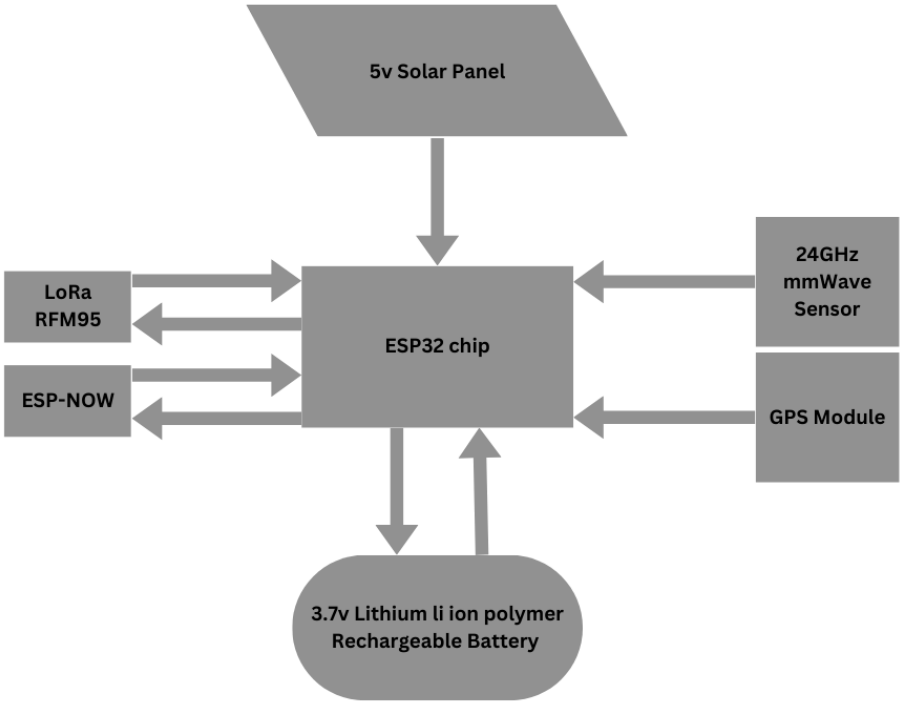
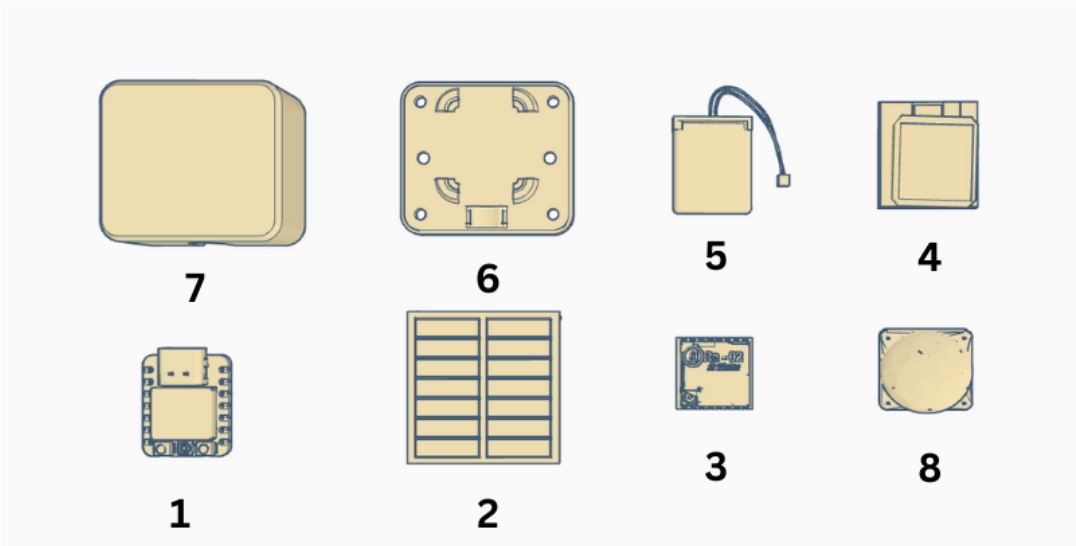


FIGURE 3.3: Sensor node Schema



1. ESP32 Micro-controler
2. Solar panel
3. LoRa module
4. GPS module
5. Rechargeable Li-Ion Battery
6. Bottom case
7. Top case
8. Movement sensor

FIGURE 3.4: Sensor node componnents

Chapter 4

Summery

Our border surveillance system utilizes wireless sensor networks (WSN) built with ESP32 chips, which are powered by lithium batteries charged with solar power. The system employs advanced technologies such as ESP-NOW and LoRa for short and long-distance communication, respectively. The nodes of the system also include GPS chips for location tracking and 24GHz microwave sensors for detecting movements.

The sensor nodes communicate with a base station made with a Raspberry Pi via the MQTT protocol, and data is transmitted to a central base station for monitoring and control. Additionally, the system allows for the tracking of the sensor nodes' locations via mobile phones.

Overall, this border surveillance system provides an efficient and cost-effective solution for monitoring and securing border areas. By utilizing advanced technologies such as wireless sensor networks, GPS tracking, and microwave sensors, the system can detect any unauthorized movement in real-time, allowing for swift action to be taken. Moreover, the use of solar power and lithium batteries makes the system environmentally friendly and cost-effective, reducing the need for frequent maintenance and electricity supply.

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