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ESP-NOW based Two Way Data Transferring

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Abstract:

This Project develops the simple two-way communication system based on ESP32 modules and the ESP-NOW protocol. ESP-NOW protocol was designed for communication between low-power IoT devices such as ESP32 and it allows equipment to communicate directly without a central point of access. This project depicts the complete plan of the system architecture in hardware setup and communication flow, as well as step-by-step approach in the function submission to project the conceptual simplicity and efficiency. This project demonstrates a wide range of the innovative product's applications through both theoretical and practical approach, which includes remote sensing and control.

Keywords: ESP-NOW, MAC-Address, Peer-to-Peer, I2C Address, Latency.

1. Introduction:

ESP-NOW is a specialized protocol tailored for Internet of Things (IoT) applications, optimized for low-power microcontrollers such as the ESP8266 and ESP32. Unlike traditional Wi-Fi, which necessitates a connection through a central access point, ESP-NOW facilitates direct communication between two devices. This approach eliminates the need to establish a network, conserving power when deployed on low-energy devices like the Spark Fun ESP8266 Thing. ESP-NOW is easy to use, enabling devices to transmit data swiftly and reliably with minimal latency. This efficiency and simplicity make ESP-NOW ideal for real-time communication applications or scenarios that demand quick event responses.

2. Significance of the Study

Deploying an ESP32-based two-way communication system has a big impact on the effectiveness, dependability, and expandability of Internet of Things (IoT) systems. This method simplifies data exchange procedures by allowing direct device-to-device connection, in contrast to conventional arrangements that depend on a central access point. Utilizing the low-power capabilities of the ESP32, the system may function effectively, prolonging the battery life of linked devices and cutting down on energy usage. Additionally, by reducing network congestion and single points of failure, this architecture improves reliability by producing stronger communication channels. Furthermore, the ease of use and scalability of ESP32-based communication make it possible to install IoT networks in a variety of settings, including smart homes and industrial settings, which promotes creativity and advances IoT technology.

3.Review of Related Studies

In 2023, a team of researchers including Dnislam Urazayev, Aida Eduard, Muhammad Ahsan, and Dimitrios Zorbas from Nazarbayev University got their hands dirty with some field experiments. They dived into a study called "Indoor Performance Evaluation of ESP-NOW." Their mission? To understand how well ESP-NOW performs indoors, looking at stuff like range, packet success rate, and power usage. They tested both the regular and fancy-schmancy proprietary modes of ESP-NOW. What did they find? Well, it turns out ESP-NOW can shoot data a tad farther than your regular Wi-Fi, especially when there are obstacles all over the place. And when it comes to success rates, ESP-NOW does a smidge better in the middle-to-far ranges. But here's the kicker: the fancy LR mode didn't blow anyone's socks off compared to the regular ESP-NOW. Oh, and did I mention ESP-NOW is a bit of a power saver? Yup, it guzzles down over 30% less power than your typical Wi-Fi setup.

Roberto Pasic delved deep into the world of "ESP-NOW Communication Protocol with ESP32" and discovered something pretty nifty. Turns out, this protocol is like a superhero when it comes to fetching data from sensor nodes in places where there's no local Wi-Fi network in sight. The ESP32 MCU, with all its bells and whistles like robust design, super low power usage, and a chip that can do both Wi-Fi and Bluetooth, is basically the perfect sidekick for solving tough problems in measuring stuff and collecting data from sensor gangs.

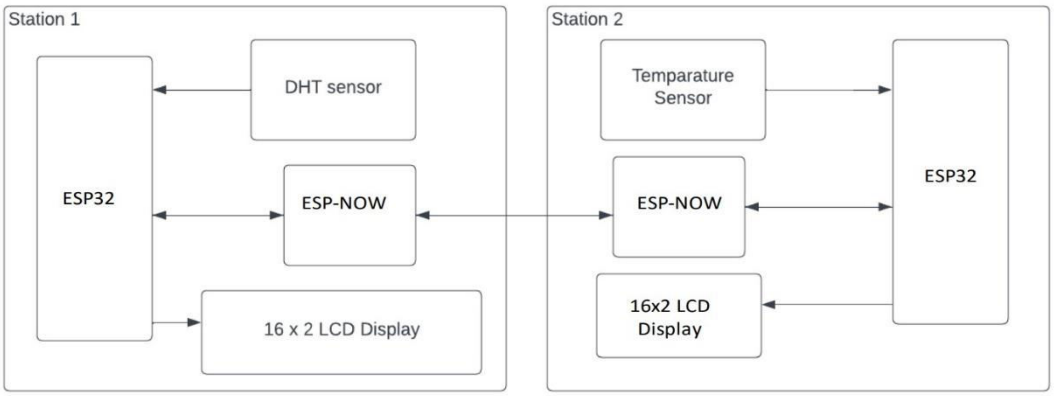
And then, there's this cool study called "Secure Home Automation System Based on ESP-NOW Mesh Networking," led by J. Cujilema, G. Hidalgo, D. Hernåndez-Rojas, and J. Cartuche. They cooked up a system that's like a fortress for your smart home, using ESP-NOW mesh networking, MQTT, and Home Assistant. It's like they combined all the best tech ingredients to whip up a recipe for a super secure and reliable way to boss around your smart devices and keep an eye on them, all snug within the cozy walls of your home.

4. Objectives of The Study

- Enable direct communication between ESP32 devices without a central access point.
- Reduce latency and enhance efficiency in data transmission.
- Utilize the low-power capabilities of ESP32 to prolong battery life in connected devices.
- Enhance reliability by minimizing single points of failure and network congestion.
- Ensure seamless communication channels for improved robustness.

- Enable scalability across various IoT applications while maintaining simplicity and cost-effectiveness.

5.Block Diagram

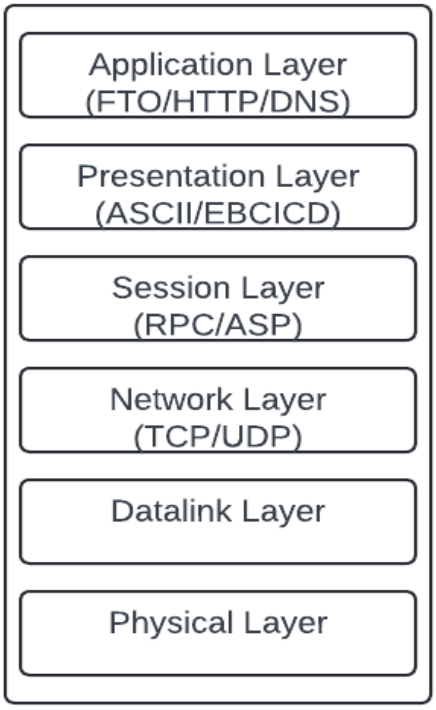


ESP32

The ESP32 and ESP8266, both represent significant advancements in the realm of microcontrollers for IoT applications. The ESP32 boasts a dual-core processor, affording it enhanced processing power and multitasking capabilities compared to the ESP8266's single-core architecture. Moreover, the ESP32 supports dual-band Wi-Fi (2.4 GHz and 5 GHz), a feature absent in the ESP8266, which is limited to the 2.4 GHz band. Additionally, the ESP32 integrates Bluetooth functionality, opening avenues for applications reliant on Bluetooth communication, a capability absent in its predecessor. Furthermore, the ESP32 offers an expanded array of GPIO pins and peripheral interfaces, augmenting its versatility for interfacing with diverse sensors and devices. However, this increased functionality often comes at the cost of slightly higher power consumption compared to the more frugal ESP8266.

ESP-NOW

ESP-NOW is a unique wireless communication protocol that stands out from Wi-Fi and Bluetooth by simplifying the traditional OSI model from five layers to just one. This leaner design means it uses less CPU power and flash memory compared to other connection protocols, yet it can still work alongside Wi-Fi and Bluetooth LE. While Bluetooth is great for short-range device connections and Wi-Fi excels in delivering high-speed internet, ESP-NOW brings a special edge. It enables direct communication between ESP8266 or ESP32 devices without needing a central server or access point like a Wi-Fi router. Each device has its own unique MAC address, making it easy for them to identify and talk to each other.



Data Link Layer :

a. At the data-link layer, ESP-NOW stipulates a direct peer-to-peer communication protocol between ESP32 and ESP8266 devices.
b. It operates over the 2.4 GHz ISM band and uses a proprietary protocol optimizedfor low-power, low-latency communication.
c. ESP-NOW does not rely on Wi-Fi access points or routers; instead, it establishes direct connections between devices, allowing for efficient communication without the overhead of TCP/IP.

Network Layer :

a. While ESP-NOW primarily handles in the data link layer, it can be considered to have some characteristics of the network layer.
b. ESP-NOW does not provide routing or addressing functionality typical of traditional network layer protocols like IP. Instead, it relies on MAC addresses for communication between devices.
c. In a sense, ESP-NOW creates a simplified network where devices communicate directly with each other, like a peer-to-peer network.
d. However, ESP-NOW does not provide features like dynamic addressing, routing, or network segmentation, which are typically associated with the network layerin the OSI model.

Finding the MAC Address of ESP32 :

First, you'll need to identify the MAC address of your receiving board so that the sender knows exactly where to send the data. To find the MAC address of your board, follow these steps:

Step-1: Open Arduino IDE and open new sketch

Step-2: Open preferences (file>preferences)

Step-3: Paste the ESP32 board URL

Step-4: Now copy the following code and upload it after selecting proper port.

```
include <WiFi.h>

void setup (){
  Serial.begin(115200);
  WiFi.mode(WIFI_MODE_STA);
  Serial.println(WiFi.macAddress());
}
void loop () {
}
```

Step-5 : Open Serial monitor to get the MAC address

- **esp_now_init :** this syntax or function is used to initializes the esp-now protocol in esp32.
- **esp_now_set_pmk :** this function is used make an encrypted connection between esp32s via esp-now.
- **esp_now_add_peer :** is used to pair both esp32s to where the data will be transferred.
- **esp_now_send :** sends the data to the paired devices frame by frame.
- **esp_now_register_send_cb:** operates for a callback for sending ESP-NOW received data.

ESP-NOW shines when it comes to sending smaller chunks of data, with a limit of 250 bytes per message. It uses something called action frames for communication. These are special types of data packets that carry details about the action being performed. Thanks to these action frames, ESP-NOW devices can swap data efficiently without the extra baggage that usually comes with more general data frames.

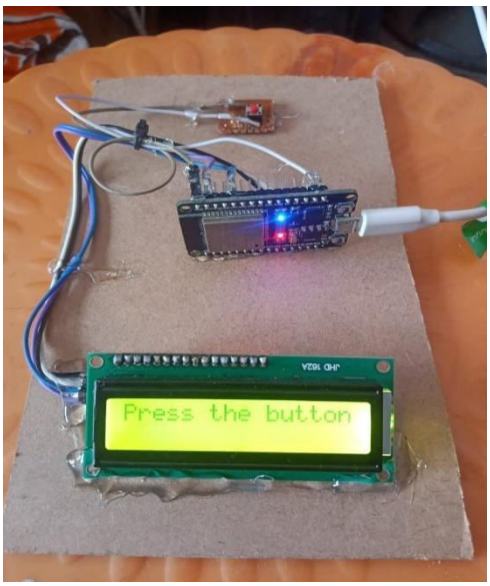
MAC Header	Category Code	Organization Identifier	Random Values	Vendor Specific Content	FCS
24 Bytes	1 Byte	3 Bytes	4 Bytes	7-257 Bytes	4 Bytes

Element ID	Length	Organization Identifier	Type	Version	Body
1 Byte	1 Byte	3 Bytes	1 Byte	1 Byte	0-250 Bytes

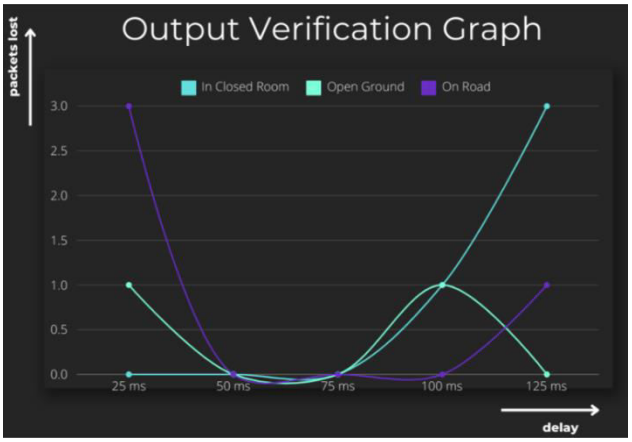
Frame Format

In ESP-NOW, the way data is formatted is key to making sure it gets transmitted efficiently and reliably between ESP32 devices. This means organizing the data in a specific way before sending it. Because ESP-NOW deals with smaller amounts of data and has a lightweight design, it keeps latency low, enabling devices to swap data quickly. This rapid data exchange makes ESP-NOW perfect for applications like remotely controlling other devices.

Results



The above figures expresses the project outlook after the immensive connections which are soldered on zero PCB.



a. This graph indicates the variation in packets i.e loss of data with respect to delay.
b. The ideal and the practical latency between the message transfering rate is between the 50ms-75ms.
c. When we tried to change the latency values the loss packets has been occured in different conditions.

Conclusion

A new age of effective and adaptable two-way communication systems with enormous potential across a wide range of applications is heralded by the merging of ESPNow and ESP32 modules. ESPNow enables smooth bidirectional communication between devices, sensors, and central hubs thanks to its low power consumption, strong performance, and simplicity of use. Real-time data interchange, remote control, and monitoring capabilities are made possible by this, propelling innovations in industrial IoT, smart home automation, healthcare, agriculture, and other fields. Additionally, the availability of ESP32 modules encourages creativity in education and do-it-yourself projects, thereby influencing the next wave of innovators and technologists. The combination of ESP32 and ESPNow modules emerges as a key technology, positioned to define the future of automation and connection in a wide range of sectors, as the demand for intelligent and connected systems grows.

Future Scope

Looking into the future, the scope of two-way communication systems utilizing ESPNow technology appears immensely promising. As advancements in Internet of Things (IoT) solutions continue to unfold, ESPNow-based systems are poised to play a pivotal role across a myriad of sectors. From smart homes to industrial automation, healthcare to agriculture, the versatility of ESPNow enables seamless bidirectional communication between devices, sensors, and central hubs. This facilitates real-time data exchange, remote control, and monitoring capabilities, leading to enhanced efficiency, productivity, and responsiveness. Furthermore, the affordability and

accessibility of ESP32 modules make them ideal for educational purposes, fostering innovation and creativity among students and hobbyists. As the demand for interconnected and intelligent systems grows, ESPNow stands at the forefront, offering scalable and adaptable solutions to meet the evolving needs of tomorrow's interconnected world.

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