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EXPERIMENT NO. 07

Aim

To design and implement a weather monitoring system using a DHT sensor for temperature and humidity measurement, an ESP32 BLE module for notifications, and an OLED display for real-time data visualization.

Apparatus

1. **ESP32** microcontroller
2. **DHT11 or DHT22** sensor for temperature and humidity measurement
3. **OLED Display** (e.g., 0.96" or 1.3" I2C OLED)
4. Jumper wires and a breadboard (for connections)
5. Computer with **Arduino IDE** and required libraries

Theory :

A weather monitoring system is designed to continuously measure and display environmental conditions, focusing on parameters like temperature and humidity. In this project, an **ESP32 microcontroller** serves as the system's core, utilizing its built-in Wi-Fi and Bluetooth Low Energy (BLE) features to both gather sensor data and provide remote notifications. The **DHT sensor** measures temperature and humidity with reasonable accuracy, making it suitable for applications where precise control of environmental conditions, such as in smart homes or small greenhouses, is essential.

An **OLED display** connected to the ESP32 offers a clear, real-time visualization of the sensor data. OLED technology is highly suitable here due to its sharp contrast, low power consumption, and compact design, allowing the display to be easily read in varying light conditions. Additionally, BLE functionality on the ESP32 enables seamless, low-energy communication with nearby mobile devices, sending temperature and humidity notifications without the need for a wired setup or physical access to the device.

This configuration exemplifies a **simple IoT (Internet of Things) application**, where data from sensors can be monitored both locally and remotely. IoT setups like this make environmental data easily accessible and can be applied to numerous fields, enhancing monitoring and control of indoor conditions for improved comfort, energy efficiency, and even crop management in controlled environments.

Procedure

Step 1: Set Up Hardware Connections

1. Connect the DHT sensor to the ESP32:
    - **VCC** of DHT to **3.3V** of ESP32
    - **GND** of DHT to **GND** of ESP32
    - **Data** pin of DHT to **GPIO 15** (or any other GPIO pin) of ESP32
2. Connect the OLED display:
    - **VCC** to **3.3V** of ESP32
    - **GND** to **GND** of ESP32
    - **SCL** to **GPIO 22** of ESP32
    - **SDA** to **GPIO 21** of ESP32

Step 2: Set Up Software Environment and Libraries

1. Open Arduino IDE and install the following libraries:
    - DHT sensor library
    - Adafruit Unified Sensor
    - Adafruit SSD1306
    - ESP32 BLE Arduino

Step 3: Coding

Server Code:

```
#include <BLEDevice.h>
#include <BLEServer.h>
#include <BLEUtils.h>
#include <BLE2902.h>

#include <DHT.h>
#define bleServerName "ESP32_DHT091"

#define DHTTYPE DHT11 // DHT 22 (AM2302), AM2321
```

```
#define SERVICE_UUID (BLEUUID((uint16_t)0x181A))

BLECharacteristic dhtTemperatureCharacteristic(BLEUUID((uint16_t)0x2A6E),
BLECharacteristic::PROPERTY_NOTIFY);
BLEDescriptor dhtTemperatureDescriptor(BLEUUID((uint16_t)0x2902));
BLECharacteristic dhtHumidityCharacteristic(BLEUUID((uint16_t)0x2A6F),
BLECharacteristic::PROPERTY_NOTIFY);
BLEDescriptor dhtHumidityDescriptor(BLEUUID((uint16_t)0x2902));
// DHT Sensor
const int DHTPin = 14;
// Initialize DHT sensor.
DHT dht(DHTPin, DHTTYPE);
bool deviceConnected = false;
//Setup callbacks onConnect and onDisconnect
class MyServerCallbacks: public BLEServerCallbacks {
void onConnect(BLEServer* pServer) {
 deviceConnected = true;
 Serial.println("Device Connected");
};
void onDisconnect(BLEServer* pServer) {
deviceConnected = false;
 Serial.println("Device Disconnected");
}
};
void setup() {
// Start DHT sensor
dht.begin();
// Start serial communication
Serial.begin(9600);
```

```
// Create the BLE Device
BLEDevice::init(bleServerName);
// Create the BLE Server
BLEServer *pServer = BLEDevice::createServer();
pServer->setCallbacks(new MyServerCallbacks());
// Create the BLE Service
BLEService *dhtService = pServer->createService(SERVICE_UUID);
// Create BLE Characteristics and corresponding Descriptors
dhtService->addCharacteristic(&dhtTemperatureCharacteristic);
dhtTemperatureCharacteristic.addDescriptor(&dhtTemperatureDescriptor);
dhtService->addCharacteristic(&dhtHumidityCharacteristic);
dhtHumidityCharacteristic.addDescriptor(&dhtHumidityDescriptor);
// Start the service
dhtService->start();
// Start advertising
pServer->getAdvertising()->start();
Serial.println("Waiting a client connection to notify...");
}
void loop() {
if (deviceConnected) {
 // Read temperature as Celsius (the default)
 float t = dht.readTemperature();
 // Read temperature as Fahrenheit (isFahrenheit = true)
 float f = dht.readTemperature(true);
 // Read humidity
 float h = dht.readHumidity();
 // Check if any reads failed and exit early (to try again).
 if (isnan(h) || isnan(t) || isnan(f)) {
 Serial.println("Failed to read from DHT sensor!");
```

```
 return;
 }
 //Notify temperature reading from DHT sensor
 uint16_t temperatureCTemp = (uint16_t)t;
 //Set temperature Characteristic value and notify connected client
 dhtTemperatureCharacteristic.setValue(temperatureCTemp);
 dhtTemperatureCharacteristic.notify();
 Serial.print("Temperature Celsius: ");
 Serial.print(t);
 Serial.print(" *C");
 //Notify humidity reading from DHT
 uint16_t humidityTemp = (uint16_t)h;
 //Set humidity Characteristic value and notify connected client
 dhtHumidityCharacteristic.setValue(humidityTemp);
 dhtHumidityCharacteristic.notify();
 Serial.print(" - Humidity: ");
 Serial.print(h);
 Serial.println(" %");

 delay(10000);
}
}
```

Client code With OLED display:

```
#include "BLEDevice.h"
#include <Wire.h>
#include <Adafruit_SSD1306.h>
#include <Adafruit_GFX.h>
```

```
//BLE Server name (the other ESP32 name running the server sketch)
#define bleServerName "ESP32_DHT"
//UUID's of the service, characteristic that we want to read
static BLEUUID dhtServiceUUID(BLEUUID((uint16_t)0x181A));
//Temperature Characteristic
static BLEUUID temperatureCharacteristicUUID((uint16_t)0x2A6E);
//Humidity Characteristic
static BLEUUID humidityCharacteristicUUID((uint16_t)0x2A6F);
//Flags stating if should begin connecting and if the connection is up
static boolean doConnect = false;
static boolean connected = false;
//Address of the peripheral device. Address will be found during scanning..
static BLEAddress *pServerAddress;
//Characteristic that we want to read and characteristic that we want to

static BLERemoteCharacteristic* temperatureCharacteristic;
static BLERemoteCharacteristic* humidityCharacteristic;
//Activate notify
const uint8_t notificationOn[] = {0x1, 0x0};
const uint8_t notificationOff[] = {0x0, 0x0};
#define SCREEN_WIDTH 128 // OLED display width, in pixels
#define SCREEN_HEIGHT 64 // OLED display height, in pixels
//Declaration for an SSD1306 display connected to I2C (SDA, SCL pins)
#define OLED_RESET 4 // Reset pin # (or -1 if sharing Arduino reset pin)
Adafruit_SSD1306 display(SCREEN_WIDTH, SCREEN_HEIGHT, &Wire);
//Variables to store temperature and humidity
#define MAX_STRING_LENGTH 10
char temperatureR[MAX_STRING_LENGTH];
char humidityR[MAX_STRING_LENGTH];
```

```
//Flags to check whether new temperature and humidity readings are available
boolean newTemperatureR = false;
boolean newHumidityR = false;
//Connect to the BLE Server that has the name, Service, and Characteristics
bool connectToServer(BLEAddress pAddress) {
 BLEClient* pClient = BLEDevice::createClient();
// Connect to the remove BLE Server.
pClient->connect(pAddress);
Serial.println(" - Connected to server");
// Obtain a reference to the service we are after in the remote BLE server.
BLERemoteService* pRemoteService = pClient->getService(dhtServiceUUID);
if (pRemoteService == nullptr) {
 Serial.print("Failed to find our service UUID: ");
 Serial.println(dhtServiceUUID.toString().c_str());
 return (false);
}
// Obtain a reference to the characteristics in the service of the remote

temperatureCharacteristic = pRemoteService->getCharacteristic(temperatureCharacteristicUUID);
humidityCharacteristic = pRemoteService->getCharacteristic(humidityCharacteristicUUID);

if (temperatureCharacteristic == nullptr || humidityCharacteristic == nullptr) {
 Serial.print("Failed to find our characteristic UUID");
 return false;
}
Serial.println(" - Found our characteristics");
//Assign callback functions for the Characteristics
temperatureCharacteristic->registerForNotify(temperatureNotifyCallback);
```

```
humidityCharacteristic->registerForNotify(humidityNotifyCallback);
return true;
}
//Callback function that gets called, when another device's advertisement has

class MyAdvertisedDeviceCallbacks: public BLEAdvertisedDeviceCallbacks {
void onResult(BLEAdvertisedDevice advertisedDevice) {
 if (advertisedDevice.getName() == bleServerName) { //Check if the name

 advertisedDevice.getScan()->stop(); //Scan can be stopped, we found

 pServerAddress = new BLEAddress(advertisedDevice.getAddress());
//Address of advertiser is the one we need
 doConnect = true; //Set indicator, stating that we are ready to connect
 Serial.println("Device found. Connecting!");
 }
}
};
//When the BLE Server sends a new temperature reading with the notify property
static void temperatureNotifyCallback(BLERemoteCharacteristic*
pBLERemoteCharacteristic,
 uint8_t* pData, size_t length, bool
isNotify) {
// Reinterpret the received data as a uint16_t value
uint16_t temperatureValue = (uint16_t)pData;
// Convert the temperature value to a string for display
snprintf(temperatureR, MAX_STRING_LENGTH, "%d", temperatureValue);
newTemperatureR = true;
}
```

```
//When the BLE Server sends a new humidity reading with the notify property
static void humidityNotifyCallback(BLERemoteCharacteristic*
pBLERemoteCharacteristic,
 uint8_t* pData, size_t length, bool
isNotify) {
// Reinterpret the received data as a uint16_t value
uint16_t humidityValue = (uint16_t)pData;
// Convert the humidity value to a string for display
snprintf(humidityR, MAX_STRING_LENGTH, "%d", humidityValue);
newHumidityR = true;
}
//function that prints the latest sensor readings in the OLED display
void printDHTReadings(){
display.clearDisplay();
display.setTextColor(WHITE);
//display temperature
display.setTextSize(1);
display.setCursor(0,0);
display.print("Temperature: ");
display.setTextSize(2);
display.setCursor(0,10);
display.print(temperatureR);

display.print(" ");
display.setTextSize(1);
display.cp437(true);
display.write(167);
display.setTextSize(2);
display.print("C");
```

```
Serial.print("Temperature:");
Serial.print(temperatureR);
Serial.print("ºC");
//display humidity
display.setTextSize(1);
display.setCursor(0, 35);
display.print("Humidity: ");
display.setTextSize(2);
display.setCursor(0, 45);
display.print(humidityR);
display.print(" %");
Serial.print(" Humidity:");
Serial.print(humidityR);
Serial.println("%");
display.display();
}
void setup() {
//OLED display setup
// SSD1306_SWITCHCAPVCC = generate display voltage from 3.3V internally
if(!display.begin(SSD1306_SWITCHCAPVCC, 0x3C)) { // Address 0x3C for 128x32
 Serial.println(F("SSD1306 allocation failed"));
 for(;;); // Don't proceed, loop forever
}
//Start serial communication
Serial.begin(115200);
Serial.println("Starting Arduino BLE Client application...");
//Init BLE device
BLEDevice::init("");
// Retrieve a Scanner and set the callback we want to use to be informed
```

```
// have detected a new device. Specify that we want active scanning and

// scan to run for 30 seconds.
BLEScan* pBLEScan = BLEDevice::getScan();
pBLEScan->setAdvertisedDeviceCallbacks(new MyAdvertisedDeviceCallbacks());
pBLEScan->setActiveScan(true);
pBLEScan->start(30);
}
void loop() {
// If the flag "doConnect" is true then we have scanned for and found the

// BLE Server with which we wish to connect. Now we connect to it. Once

// connected we set the connected flag to be true.
if (doConnect == true) {
 if (connectToServer(*pServerAddress)) {
 Serial.println("We are now connected to the BLE Server.");
 //Activate the Notify property of each Characteristic
 temperatureCharacteristic->getDescriptor(BLEUUID((uint16_t)0x2902))-
>writeValue((uint8_t*)notificationOn, 2, true);
 humidityCharacteristic->getDescriptor(BLEUUID((uint16_t)0x2902))-
>writeValue((uint8_t*)notificationOn, 2, true);

 connected = true;
 } else {
 Serial.println("We have failed to connect to the server; Restart your device to scan
for nearby BLE server again.");
 }
 doConnect = false;
```

```
}
//if new temperature readings are available, print in the OLED
if (newTemperatureR && newHumidityR){
 newTemperatureR = false;
 newHumidityR = false;
 printDHTReadings();
}
delay(1000); // Delay a second between loops.
}
```

Observations

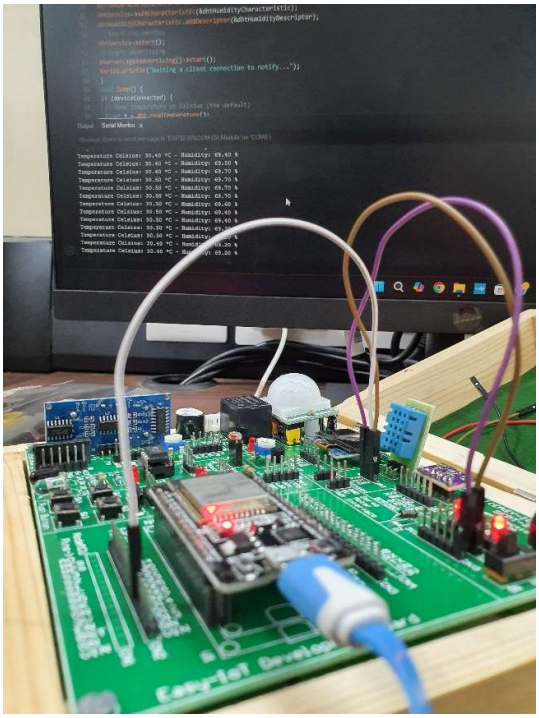
The weather monitoring system successfully measured and displayed temperature and humidity in real-time using the OLED display, with readings updating consistently every two seconds. The DHT sensor proved responsive to environmental changes, accurately reflecting variations when transitioning between indoor and outdoor settings. The BLE notification feature enabled seamless remote monitoring, as BLE-enabled devices received timely updates, mirroring the display readings. This functionality demonstrated the system's effectiveness for applications where real-time environmental data is essential and physical access may be limited, such as in remote home monitoring.

Conclusions

This experiment effectively showcased a practical weather monitoring system that integrates ESP32, a DHT sensor, and BLE notifications for versatile use. The system provided reliable, real-time temperature and humidity data with convenient notifications for remote users, making it suitable for applications in smart homes or greenhouses. The project illustrates a robust solution for environmental monitoring, offering both local and remote accessibility for essential climate data, demonstrating its potential for broader IoT applications.

RESULTS:

Server Setup and Result:



Client Setup and results :