All Embedded C ++ Codes, Node Red Flow JSON, Simulation Link And Wiring Diagram(Latrine Fill Level And Hygiene Monitor)

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Bluetooth communication

Blue tooth sender.

```
#include <BLEDevice.h>

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

#define PIR 2
#define ULTRASONIC_PIN 34

BLECharacteristic *sensorCharacteristic;
int pirState = 0; int distance = 0;

void setup() {
Serial.begin(9600);   pinMode(PIR,
INPUT);
  pinMode(ULTRASONIC_PIN, INPUT);

  BLEDevice::init("NodeA-BLE");
  BLEServer *pServer = BLEDevice::createServer();
  BLEService *pService = pServer->createService("180C");  // Custom service UUID
   sensorCharacteristic = pService-
>createCharacteristic(
    "2A56",  // Custom characteristic UUID
    BLECharacteristic::PROPERTY_READ | BLECharacteristic::PROPERTY_NOTIFY
  );    sensorCharacteristic->addDescriptor(new
BLE2902());   pService->start();
  BLEAdvertising *pAdvertising = BLEDevice::getAdvertising();   pAdvertising-
>start();
  Serial.println("BLE Node A ready...");
}  void
loop() {
  int sensorValue = analogRead(ULTRASONIC_PIN);
distance = map(sensorValue, 0, 4095, 0, 400);   pirState
= digitalRead(PIR);

  String payload = String("{\"distance_cm\":") + distance +
                   ",\"handwash\":" + (pirState == HIGH ? "1" : "0") + "}";
sensorCharacteristic->setValue(payload.c_str());   sensorCharacteristic-
>notify();
```

```
  Serial.println("Updated BLE characteristic:");
Serial.println(payload);   delay(2000);
}
```

BLUE TOOTH RECEIVER

```
#include <BLEDevice.h>
#include <BLEUtils.h>
#include <BLEScan.h>
#include <BLEAdvertisedDevice.h>

#define SERVICE_UUID        "180C"
#define CHARACTERISTIC_UUID "2A56"

BLEAdvertisedDevice* myDevice;
BLERemoteCharacteristic* pRemoteCharacteristic;
bool doConnect = false; bool connected = false;
BLEClient* pClient;

// ---------------- Notification callback ---------------- static void
notifyCallback(BLERemoteCharacteristic* pBLERemoteCharacteristic,
uint8_t* pData, size_t length, bool isNotify) {   String received = "";
  for (size_t i = 0; i < length; i++) received += (char)pData[i];
  Serial.print("Received payload: ");
  Serial.println(received);
}

// ---------------- Callback class for scanning ---------------- class
MyAdvertisedDeviceCallbacks : public BLEAdvertisedDeviceCallbacks {
void onResult(BLEAdvertisedDevice advertisedDevice) {
    // Look for our Node A name
    if (advertisedDevice.getName() == "NodeA-BLE") {
Serial.println("Found NodeA-BLE! Stopping scan...");
advertisedDevice.getScan()->stop();       myDevice = new
BLEAdvertisedDevice(advertisedDevice);       doConnect =
true;
    }
  }
};

// ---------------- Connect to server ---------------- bool
connectToServer() {
  Serial.print("Connecting to ");
  Serial.println(myDevice->getAddress().toString().c_str());
pClient = BLEDevice::createClient();   if (!pClient-
```

```
>connect(myDevice)) {     Serial.println("Connection
failed.");     return false;
  }
  Serial.println("Connected to NodeA-BLE");

  BLERemoteService* pRemoteService = pClient->getService(SERVICE_UUID);
if (pRemoteService == nullptr) {
    Serial.println("Failed to find service UUID.");
pClient->disconnect();     return false;
  }    pRemoteCharacteristic = pRemoteService-
>getCharacteristic(CHARACTERISTIC_UUID);   if (pRemoteCharacteristic == nullptr)
{
    Serial.println("Failed to find characteristic UUID.");
pClient->disconnect();     return false;
  }

  // Register notification callback   if
(pRemoteCharacteristic->canNotify()) {
pRemoteCharacteristic->registerForNotify(notifyCallback);
  }    return
true;
}

// ---------------- Setup ---------------- void
setup() {
  Serial.begin(9600);
  Serial.println("Starting BLE Node B (Receiver)...");

  BLEDevice::init("");
  BLEScan* pBLEScan = BLEDevice::getScan();
  pBLEScan->setAdvertisedDeviceCallbacks(new MyAdvertisedDeviceCallbacks());
pBLEScan->setInterval(1349);   pBLEScan->setWindow(449);   pBLEScan-
>setActiveScan(true);   pBLEScan->start(5, false);
}

// ---------------- Loop ----------------
void loop() {   if (doConnect) {     if
(connectToServer()) {
      Serial.println("We are now connected and listening for updates...");
connected = true;
    } else {
      Serial.println("Connection failed. Restarting scan...");
      BLEDevice::getScan()->start(5, false);
    }     doConnect =
false;
```

```
  }    if
(!connected) {
delay(2000);
  }
}
```

LoRa commnuication

LoRa receiver

```
#include <Arduino.h>
#include "LoRa_E32.h"

// LoRa connected: TXD → GPIO17, RXD → GPIO16 (same as sender)
#define LORA_RX_PIN 16
#define LORA_TX_PIN 17

LoRa_E32 e32ttl(&Serial2);

String getValue(const String &msg, const String &key) {
int start = msg.indexOf(key);   if (start < 0) return
"N/A";   int colon = msg.indexOf(':', start);   if
(colon < 0) return "N/A";   int i = colon + 1;   //
skip spaces   while (i < (int)msg.length() &&
isspace(msg[i])) i++;   int j = i;
  // read until whitespace or end    while (j <
(int)msg.length() && !isspace(msg[j])) j++;   return
msg.substring(i, j);
}

void printHexDump(const String &s) {
Serial.print("Raw hex: ");   for (size_t i
= 0; i < s.length(); ++i) {     uint8_t b =
(uint8_t)s[i];     if (b < 16)
Serial.print('0');
    Serial.print(b, HEX);
    Serial.print(' ');
  }
  Serial.println();
}
void setup() {
  Serial.begin(115200);
  // Explicitly set Serial2 pins and format for ESP32
Serial2.begin(9600, SERIAL_8N1, LORA_RX_PIN, LORA_TX_PIN);
e32ttl.begin();
```

```
  Serial.println("🌿 Node B — LoRa Receiver Ready");
  Serial.println("Waiting for incoming data...\n");
}  void loop() {   if
(Serial2.available() > 0) {
    // Read all currently available bytes into a String
String msg = "";
    unsigned long start = millis();
    // read for up to 50 ms to gather a full packet (adjust if needed)
while (millis() - start < 50) {       while (Serial2.available() > 0)
{         char c = (char)Serial2.read();         msg += c;
      }     }
msg.trim();
    if (msg.length() == 0) return;

    // Debug: raw print and hex dump
    Serial.println("📥 Received via LoRa → " + msg);
printHexDump(msg);

    // Robust parsing
    String distanceStr = getValue(msg, "DISTANCE");
    String pirStr = getValue(msg, "PIR");
    String statusStr = getValue(msg, "STATUS");

    Serial.println("📌 Parsed Data:");
    Serial.println("  Distance → " + distanceStr);
    Serial.println("  PIR → " + pirStr);
    Serial.println("  Status → " + statusStr);

    // ---- Send ACK back to sender ----
delay(10); // small safety gap
e32ttl.sendMessage("ACK");     delay(10);
    Serial.println("📤 ACK sent to Node A");
    Serial.println("--------------------------------\n");
  }
}
```

LoRa Sender

```
#include <Arduino.h>
#include "LoRa_E32.h"

// Sender (Node A) pins for ESP32
#define LORA_RX_PIN 16 // this is ESP32 RX pin (connect to LoRa TX)
#define LORA_TX_PIN 17 // this is ESP32 TX pin (connect to LoRa RX)
```

```
LoRa_E32 e32ttl(&Serial2);

float readDistance() {

  return random(20, 200) / 1.0; // simulated cm
}
int readPIR() {
  return random(0, 2); // simulated 0/1
}
String readStatus() {
  // TODO: your logic for status
  return "OK";
}
String readFromLoRaTimeout(unsigned long timeoutMs) {
  String s = "";
  unsigned long start = millis();
  while (millis() - start < timeoutMs) {
    while (Serial2.available() > 0) {
      char c = (char)Serial2.read();
      s += c;
    }
  }
  s.trim();
  return s;
}

void setup() {
  Serial.begin(115200);
    Serial2.begin(9600, SERIAL_8N1, LORA_RX_PIN, LORA_TX_PIN);
  e32ttl.begin();

  Serial.println("🌿 Node A — LoRa Sender Ready");
  Serial.println("Sending periodic telemetry to Node B...\n");

  randomSeed(analogRead(0));
}

void loop() {
  // --- Gather sensor data (replace with real sensors) ---
  float dist = readDistance();
  int pir = readPIR();
  String status = readStatus();
```

```
  String msg = "DISTANCE:" + String(dist, 1) + " PIR:" + String(pir) + " STATUS:"
+ status + "\n";

  // Log locally
  Serial.print("📤 Sending → ");
  Serial.println(msg);

  // Send via LoRa
  e32ttl.sendMessage(msg);

  // Wait a short time for ACK from Node B (and read any response bytes)
  String ack = readFromLoRaTimeout(200); // 200 ms timeout, adjust if needed
  if (ack.length() > 0) {
    Serial.print("📥 From LoRa (reply): ");
    Serial.println(ack);
    if (ack.indexOf("ACK") >= 0) {
      Serial.println("✅ ACK received from Node B");
    } else {
      Serial.println("ℹ️ Received non-ACK reply");
    }
  } else {
    Serial.println("⚠️ No reply received (timeout)");
  }

  Serial.println("--------------------------------\n");

  // Wait before next transmission (adjust as needed)
  delay(2000);
}
```

Wi-Fi communication

Wi-Fi sender

```
/* Node A - UDP sender (ESP32)
   Sends JSON payloads via UDP broadcast every 2000 ms.
```

```
   Payload example:
   {"seq":12,"send_ms":12345678,"distance_cm":125,"handwash":1}
*/

#include <WiFi.h>
#include <WiFiUdp.h>
#include <Wire.h>
 const char* WIFI_SSID = "TECNO SPARK 10 Pro";      // <--
replace const char* WIFI_PASS = "#keine21";      // <-- replace

const IPAddress destIP = IPAddress(10,57,85,66); // broadcast (change to Gateway
IP if desired) const uint16_t UDP_PORT = 4210;

#define PIR_PIN 2
#define ULTRASONIC_PIN 34

WiFiUDP Udp; unsigned long seq = 0;
unsigned long sendIntervalMs = 2000;
unsigned long lastSend = 0;
 void setup() {
pinMode(PIR_PIN, INPUT);
pinMode(ULTRASONIC_PIN, INPUT);
Serial.begin(115200);
delay(100);

  Serial.printf("Connecting to Wi-Fi SSID: %s\n", WIFI_SSID);
  WiFi.mode(WIFI_STA);
  WiFi.begin(WIFI_SSID, WIFI_PASS);
   unsigned long start = millis();
while (WiFi.status() != WL_CONNECTED) {
delay(200);
    if (millis() - start > 10000) {
      Serial.println("Still trying to connect to Wi-Fi...");
start = millis();
    }
  }
  Serial.print("Wi-Fi connected, IP: ");
  Serial.println(WiFi.localIP());

  Udp.begin(UDP_PORT); // local port for sending doesn't strictly matter for
broadcast
  Serial.printf("UDP ready, broadcasting to %s:%u\n", destIP.toString().c_str(),
UDP_PORT);
}  void loop() {   if (millis() - lastSend <
sendIntervalMs) return;   lastSend = millis();
```

```
  // Read sensors   int sensorValue =
analogRead(ULTRASONIC_PIN);
  int distance = map(sensorValue, 0, 4095, 0, 400); // calibrate experimentally
int pirState = digitalRead(PIR_PIN);

  // Build JSON payload
seq++;
  unsigned long send_ms = millis();
  String payload = String("{\"seq\":") + seq +
                   ",\"send_ms\":" + send_ms +
                   ",\"distance_cm\":" + distance +
                   ",\"handwash\":" + (pirState == HIGH ? 1 : 0) +
                   "}";

  // Send UDP packet (broadcast or specific gateway IP)
  Udp.beginPacket(destIP, UDP_PORT);
  Udp.write((const uint8_t*)payload.c_str(), payload.length()); Udp.endPacket();

  Serial.print("Sent: ");
  Serial.println(payload);
}
```

Wi-Fi receiver

```
/* Node B - UDP receiver (ESP32)
   Listens on UDP_PORT and expects JSON payloads from Node A.
   Computes one-way latency = (now_ms - send_ms), tracks seq numbers for PRR,
prints per-packet info and periodic summaries (every 60s) and final summary
after 5 minutes.
*/

#include <WiFi.h>
#include <WiFiUdp.h>
 const char* WIFI_SSID = "TECNO SPARK Pro ";      // <--
replace const char* WIFI_PASS = "#Keine";      // <--
replace
 const uint16_t UDP_PORT =
4210;

WiFiUDP Udp; unsigned long
startTime = 0;
```

```
// Metrics unsigned long
packetsReceived = 0; unsigned long
highestSeqSeen = 0; unsigned long
sumLatencyMs = 0;
unsigned long reportsIntervalMs = 60000; // show metrics every 60s unsigned
long lastReport = 0;
const unsigned long testDurationMs = 5UL * 60UL * 1000UL; // 5 minutes

void setup() {
Serial.begin(115200);   delay(100);

  Serial.printf("Connecting to Wi-Fi SSID: %s\n", WIFI_SSID);
  WiFi.mode(WIFI_STA);
  WiFi.begin(WIFI_SSID, WIFI_PASS);
   unsigned long s = millis();   while
(WiFi.status() != WL_CONNECTED) {
delay(200);
    if (millis() - s > 10000) {
      Serial.println("Still trying to connect to Wi-Fi...");
s = millis();
    }
  }
  Serial.print("Wi-Fi connected, IP: ");
  Serial.println(WiFi.localIP());

  if (Udp.begin(UDP_PORT) == 1) {
    Serial.printf("UDP listening on port %u\n", UDP_PORT);
  } else {
    Serial.println("Failed to start UDP listener.");
  }    startTime =
millis();   lastReport =
millis();
}

String extractValue(String &s, const char* key) {
  // crude JSON extractor: finds "key":NUMBER and returns NUMBER string (no
quotes)
  String pattern = String("\"") + key + "\":";   int
idx = s.indexOf(pattern);   if (idx < 0) return
String("");   idx += pattern.length();   int endIdx =
idx;   while (endIdx < (int)s.length()) {     char c =
s[endIdx];     if ((c >= '0' && c <= '9') || c == '-'
) endIdx++;     else break;
  }
  return s.substring(idx, endIdx);
```

```
}  void
loop() {
  int packetSize = Udp.parsePacket();
if (packetSize) {     // receive into
a buffer     char incoming[512];
    int len = Udp.read(incoming, sizeof(incoming) - 1);
if (len > 0) incoming[len] = 0;
    String payload = String(incoming);

    // crude parsing of fields
    String seq_s = extractValue(payload, "seq");
    String sendms_s = extractValue(payload, "send_ms");
    String dist_s = extractValue(payload, "distance_cm");
    String hw_s = extractValue(payload, "handwash");
     unsigned long seq = seq_s.length() ? (unsigned long) seq_s.toInt() : 0;
unsigned long send_ms = sendms_s.length() ? (unsigned long) sendms_s.toInt()
: 0;     int distance = dist_s.length() ? dist_s.toInt()
: -1;     int handwash = hw_s.length() ? hw_s.toInt() : -
1;
     unsigned long now_ms = millis();     unsigned long latency =
(now_ms >= send_ms) ? (now_ms - send_ms) : 0xFFFFFFFF;

    // update metrics     packetsReceived++;     if
(seq > highestSeqSeen) highestSeqSeen = seq;     if
(latency != 0xFFFFFFFF) sumLatencyMs += latency;

    // print packet info
    Serial.printf("Pkt #%lu : seq=%lu distance=%d handwash=%d latency_ms=%lu\n",
packetsReceived, seq, distance, handwash, latency);
  }

  // Periodic reports and final summary after testDurationMs   unsigned long
now = millis();   if (now - lastReport >= reportsIntervalMs) {
lastReport = now;     unsigned long seen = highestSeqSeen;     float prr =
seen > 0 ? (100.0f * (float)packetsReceived / (float)seen) :
0.0f;
    float avgLatency = packetsReceived ? ((float)sumLatencyMs /
(float)packetsReceived) : 0.0f;
    Serial.println("========== METRICS (interval) ==========");
    Serial.printf("Elapsed: %lu s\n", (now - startTime) / 1000);
    Serial.printf("Packets received: %lu\n", packetsReceived);
    Serial.printf("Highest seq seen: %lu\n", highestSeqSeen);
    Serial.printf("Packet success rate (PRR) approx: %.2f %%\n", prr);
    Serial.printf("Average latency: %.2f ms\n", avgLatency);
    Serial.println("========================================");
  }
```

```
  // Final result after 5 minutes   if
(now - startTime >= testDurationMs) {
unsigned long seen = highestSeqSeen;
float prr = seen > 0 ? (100.0f *
(float)packetsReceived / (float)seen) :
0.0f;     float avgLatency = packetsReceived ?
((float)sumLatencyMs /
(float)packetsReceived) : 0.0f;

    Serial.println("========== FINAL 5-MIN SUMMARY ==========");
    Serial.printf("Total packets received: %lu\n", packetsReceived);
    Serial.printf("Highest seq seen: %lu\n", highestSeqSeen);
    Serial.printf("Estimated Packet Success Rate: %.2f %%\n", prr);
    Serial.printf("Average one-way latency: %.2f ms\n", avgLatency);
Serial.println("========================================");
    )       // packetsReceived = 0; highestSeqSeen = 0; sumLatencyMs = 0;
startTime = millis();
    // Or halt further reporting by sleeping the MCU (not done here). We'll just
keep reporting periodically.
    while (true) { delay(1000); } // stop here so you can read final results;
press reset to run again
  }
}
```

MQTT CODE.

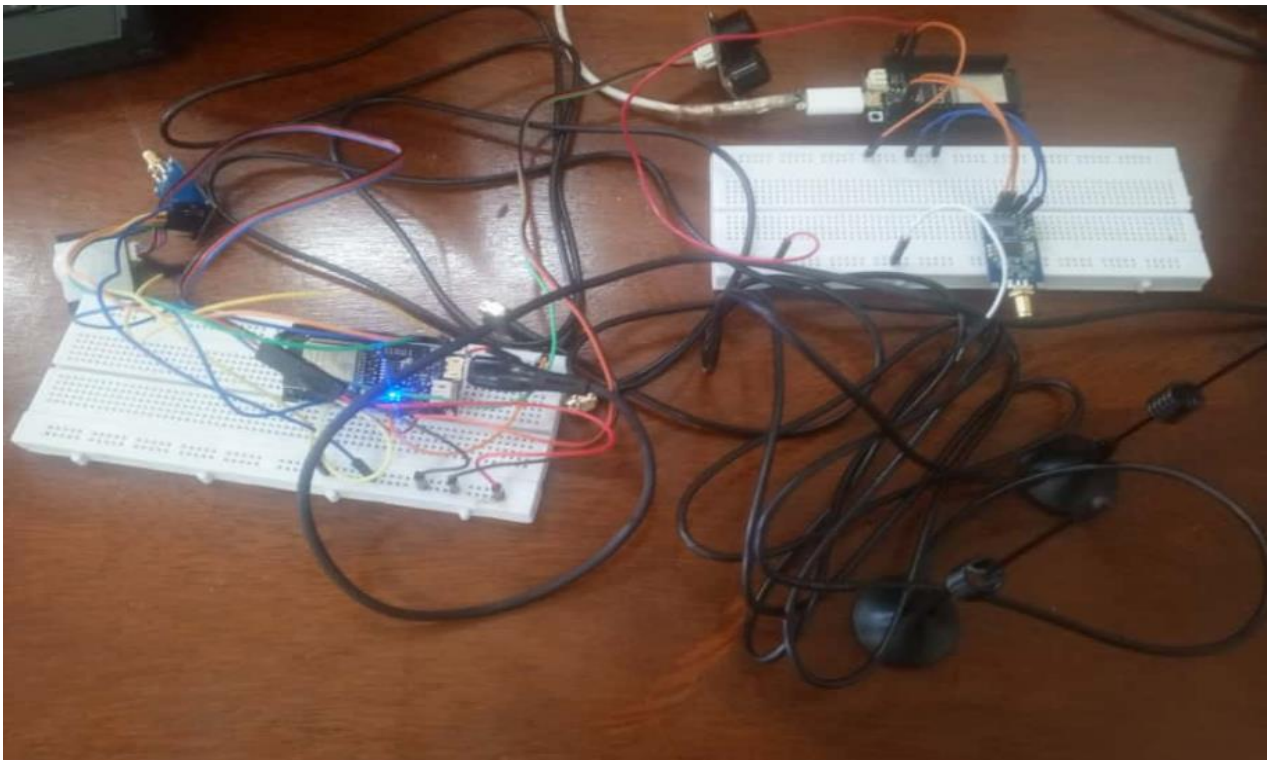
```
#include <WiFi.h>
#include <PubSubClient.h>
#include <Wire.h>

// ------------------- Wi-Fi Credentials -------------------
const char* ssid = "linco";       // ◆ Change to your Wi-Fi SSID
const char* password = "12345678";   // ◆ Change to your Wi-Fi password

// ------------------- MQTT Broker Settings -------------------
const char* mqtt_server = "broker.hivemq.com";  // ◆ Public broker (can replace
with local IP)
const int mqtt_port = 1883;

const char* topic_distance = "latrine_monitor/distance";
const char* topic_motion   = "latrine_monitor/motion";
```

```
const char* topic_alert    = "latrine_monitor/alert";

// ------------------- Pins ------------------
#define PIR 2
#define ULTRASONIC_PIN 34   // Analog output from 3-pin ultrasonic

// ------------------- Variables ------------------
int pirState = 0;
int distance = 0;

// ------------------- MQTT Client ------------------
WiFiClient wifiClient;
PubSubClient client(wifiClient);

// ====================================================
//                   Helper Functions
// ====================================================

// --- Connect to Wi-Fi ---
void setup_wifi() {
  Serial.print("Connecting to Wi-Fi: ");
  Serial.println(ssid);
  WiFi.begin(ssid, password);

  int retry = 0;
  while (WiFi.status() != WL_CONNECTED) {
    delay(500);
    Serial.print(".");
    if (++retry > 20) {
      Serial.println("\n⚠ Wi-Fi connect timeout, restarting...");
      ESP.restart();
    }
  }

  Serial.println("\n✅ Wi-Fi connected!");
  Serial.print("IP address: ");
  Serial.println(WiFi.localIP());
}

// --- Reconnect MQTT ---
void reconnect_mqtt() {
  while (!client.connected()) {
    Serial.print("Connecting to MQTT broker...");
    if (client.connect("ESP32_Latrine_Node")) {
      Serial.println("✅ connected!");
```

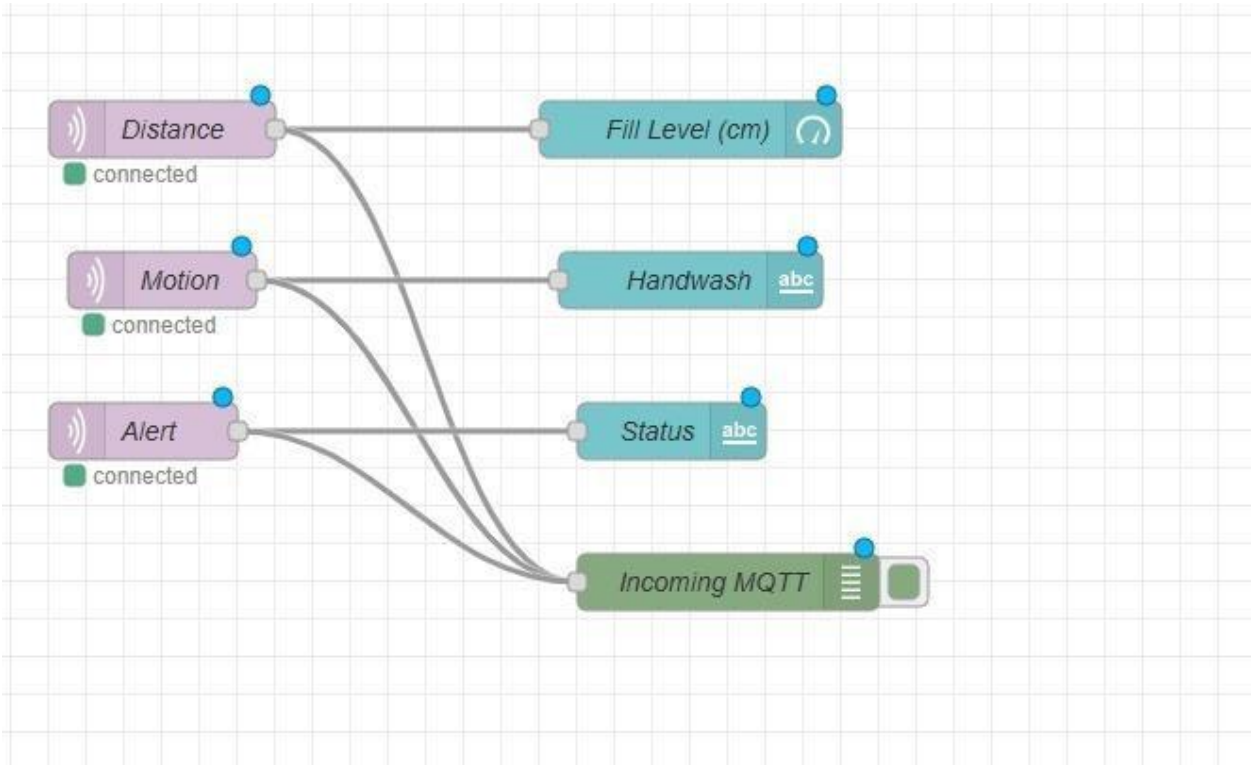
```
    } else {
      Serial.print("❌ failed, rc=");
      Serial.print(client.state());
      Serial.println(" — retrying in 5 seconds...");
      delay(5000);
    }
  }
}

// ====================================================
//                        SETUP
// ====================================================
void setup() {
  pinMode(PIR, INPUT);
  pinMode(ULTRASONIC_PIN, INPUT);

  Wire.begin();
  Serial.begin(9600);
  Serial.println("System initializing...");
  delay(1000);

  setup_wifi();
  client.setServer(mqtt_server, mqtt_port);
}

// ====================================================
//                        LOOP
// ====================================================
void loop() {
  // Keep MQTT alive
  if (WiFi.status() != WL_CONNECTED) setup_wifi();
  if (!client.connected()) reconnect_mqtt();
  client.loop();

  // ---------------- Read Sensors ----------------
  int sensorValue = analogRead(ULTRASONIC_PIN);
  distance = map(sensorValue, 0, 4095, 0, 400);
  pirState = digitalRead(PIR);

  // ---------------- Publish Data ----------------
  // 1️⃣ Distance
  String distancePayload = "{\"distance_cm\":" + String(distance) + "}";
  client.publish(topic_distance, distancePayload.c_str());
  Serial.println("📡 Sent distance → " + distancePayload);
```

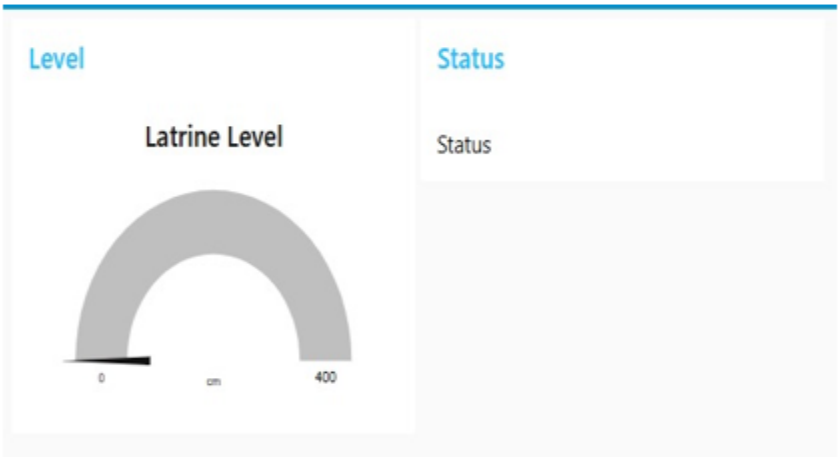
```
  // 2️⃣ PIR
  String motionState = (pirState == HIGH) ? "Detected" : "None";
  String motionPayload = "{\"motion\":\"" + motionState + "\"}";
  client.publish(topic_motion, motionPayload.c_str());
  Serial.println("📡 Sent motion → " + motionPayload);

  // 3️⃣ Alert
  if (distance < 10) {
    String alertPayload = "{\"alert\":\"Latrine Full!\"}";
    client.publish(topic_alert, alertPayload.c_str());
    Serial.println("⚠️ Sent alert → " + alertPayload);
  }

  Serial.println("----------------------------");
  delay(3000);  // Send every 3 seconds
}
```

WIRIING DIAGRAM



NODE RED FLOW DIAGRAM





Simulation link in tinker cad

https://www.tinkercad.com/things/0otRpwz9k5G-start-simulating?sharecode=cguxJbMZIGlG2i0_O65iasud1rh6-K6ayjE9Us3zEpk