AQMD

Air Quality Monitoring Delivery

Microsoft

Problem statement

We know that the intensity of air pollution is increasing all over the places, yet we are ignoring this fact in an assumption that we are immune to it. It is found recently by scientists that how bad this could impact us. Health impacts extends way beyond the respiratory illness. Through research it is found that , foetal development ,mental health and metabolic syndrome are impacted due to increase in air pollution.

Based on Dr. Sarath Guttikunda article, "**A general understanding is that an ambient monitoring station can represent an area covering 2 km radius, which translates to 15 sq.km (rounded off).**" But if we consider Chennai Metropolitan area, it is spread across **1189 sq km** (planned to expand up to **8878 sq km**), whereas we have only **8** air quality monitoring stations as of 23rd Jan 2023. It is evident that we don't have enough stations to cover entire area.

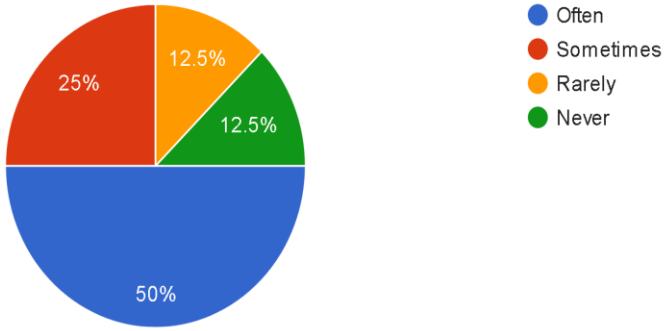
Proposed solution is to make use of BOV Garbage Collector, food delivery partners/ Cabs (Ola, Uber, Swiggy, Zomato …etc.) to mount the air quality sensor that detects PM 2.5, 10 concentrations in the air and visualize it as a live heat map. It will be an effective solution than ambient monitoring station as it shows us exactly where the intensity of air pollution is higher on street basis.

* All the references are attached at the end of document

Public survey

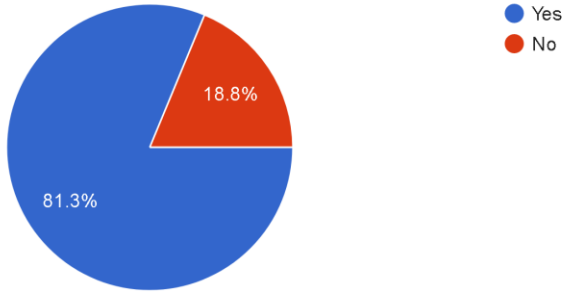
How frequently are you affected due to air pollution?

16 responses



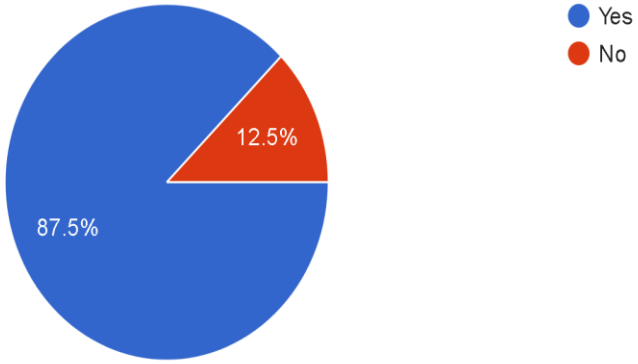
Do you wish to leave the world a better place for the next generation?

16 responses



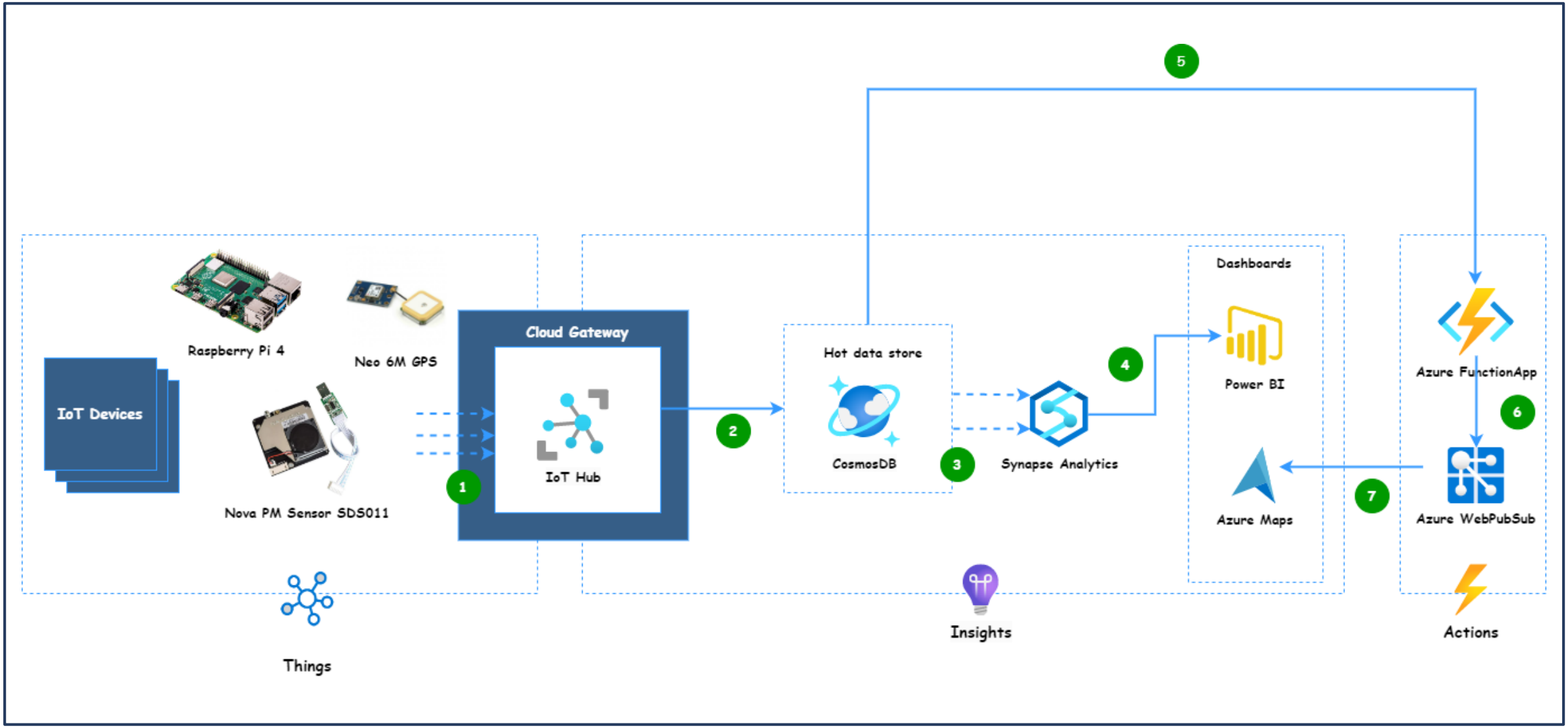
Provided we give you funds and installation, will you allow air quality monitoring device to be mounted in your vehicle?

16 responses



* Before proceeding with the solution , initial survey has been conducted with various people who works for Uber ,Ola, Zomato, Swiggy etc....

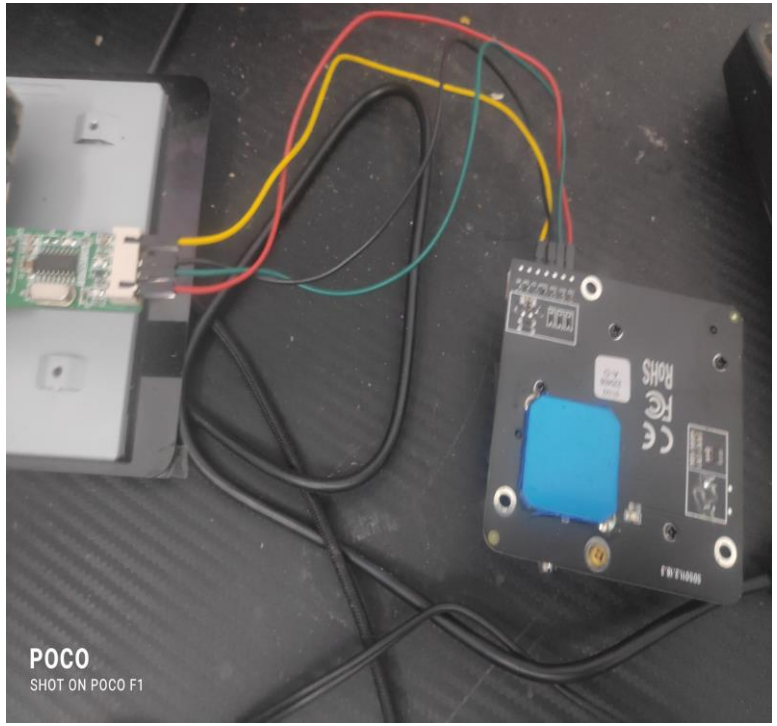
Proposed Architecture



Data Flow

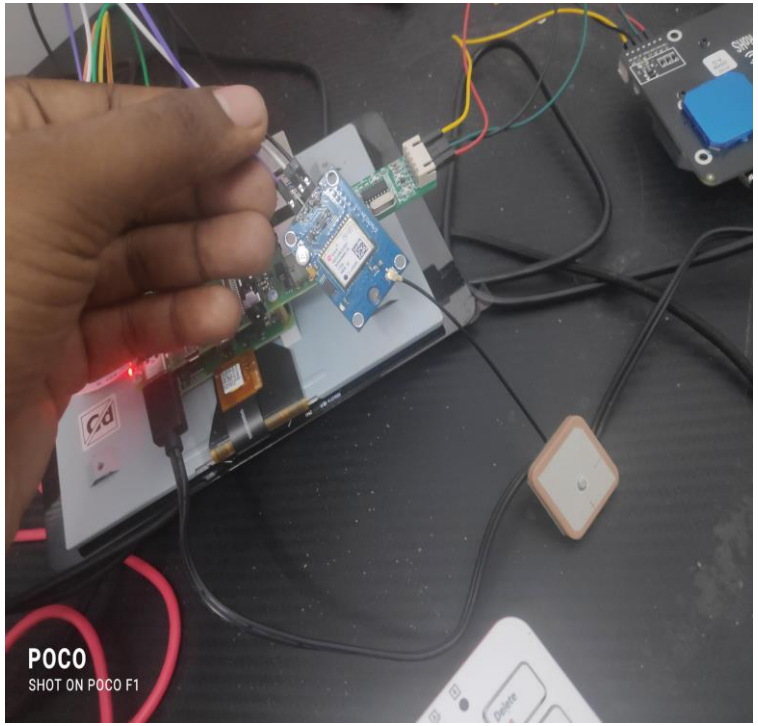
1. IoT devices push the telemetry to cloud gateway (IoT Hub)
2. Message routing feature of IoT hub enables us to forward the telemetry to different store path. In our proposed architecture we have used Azure Cosmos DB as a hot store path to store data. Azure cosmos DB is ideal for IoT workloads as it is highly capable of ingesting high volume of data at low latency and high rates. IoT hub is also capable of filtering only specific messages to be pushed into Azure Cosmos DB.
3. Hybrid Transactional and Analytical Processing (HTAP) capability of Azure Synapse link for Azure Cosmos DB integrates data into analytical store which is highly efficient for analytical purposes.
4. Power BI helps us to visualize data in a Azure Map layer. Heat Map is used in our proposed architecture to better depict our scenario.
5. Azure Cosmos DB change feed triggers an Azure Functions
6. Change Feed trigger is used to publish the message to a Azure Web PubSub service
7. As a presentation layer we have a Azure Map integration in a web app and with the websockets we will have near real-time updates about the telemetry and could visualize it.

Device Setup



Nova PM Sensor SDS011 High Precision Laser pm2.5 Air Quality Detection Sensor

BUY NOW



Ublox Neo-6M GPS Module with EEPROM and Antenna

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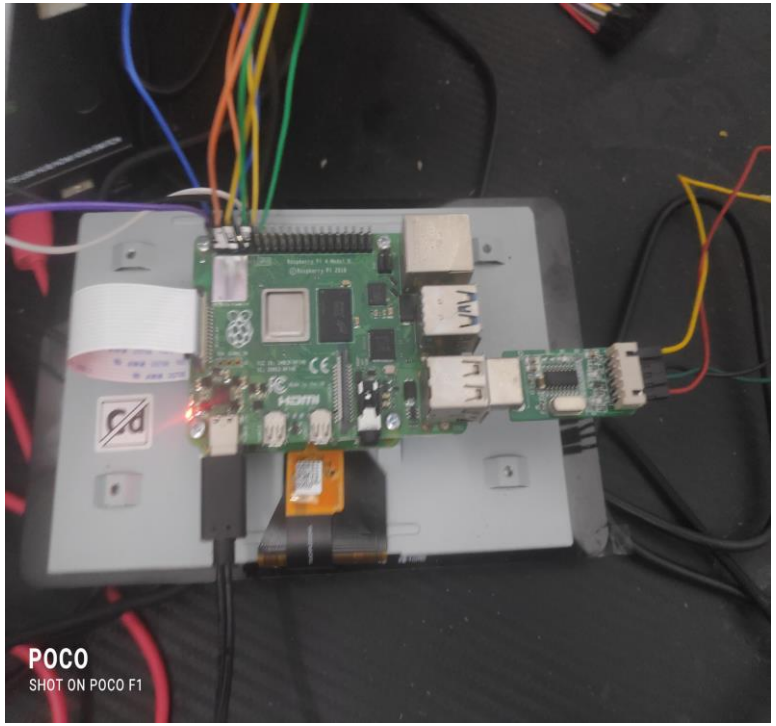


RaspberryPi 4 + PM Sensor SDS011 + Neo-6M GPS Module

BUY NOW

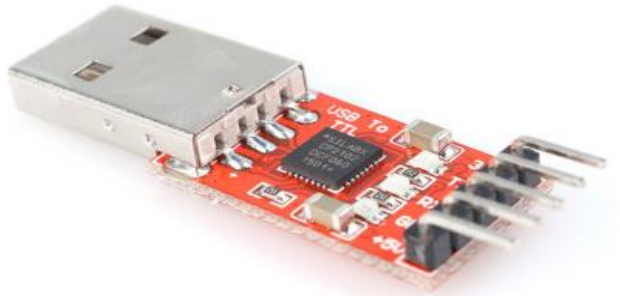
Connect PM sensor and GPS module with RaspberryPi

1. I have used USB 2.0 to TTL UART serial converter module for connecting PM sensor with Raspberry pi , which could be easily plugged into the USB port.
2. GPS module doesn't come with a soldered header pins. Hence we need to solder berg strip male connectors (4 pins) on the GPS module, prior to connecting with RaspberryPi

    2.a. For connecting Neo6M GPS module , jumper wires are required to connect with RaspberryPi. Follow the pin out diagram below for establishing connection between them.

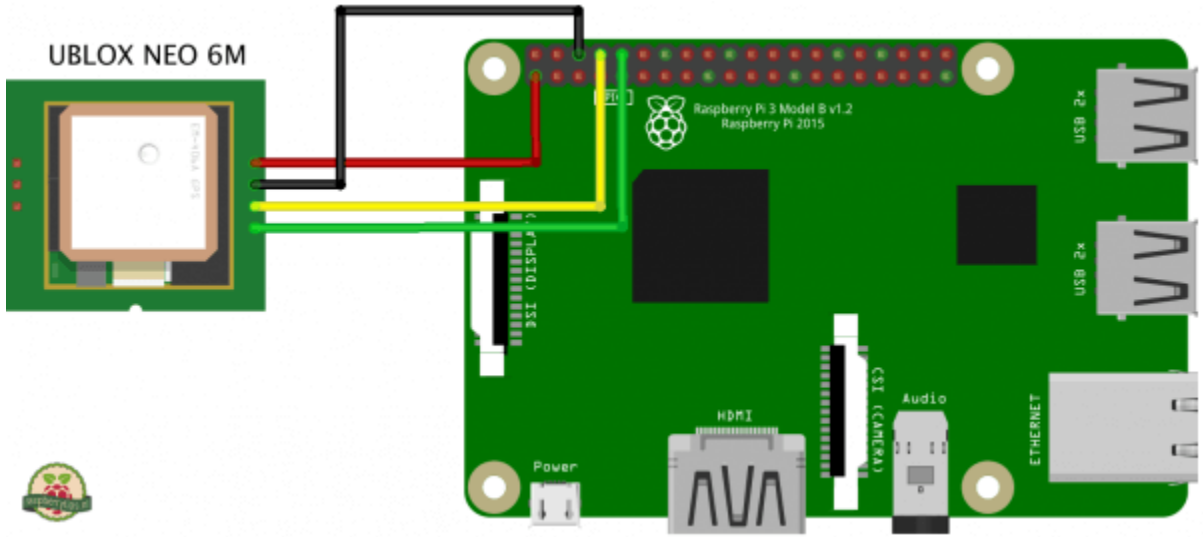
    2.b. Optionally you can skip the jumper wire part connection to RaspberryPi module , if you have an extra USB 2.0 to TTL UART serial converter.

USB 2.0 to TTL UART Serial Connector



BUY NOW

Neo 6M GPS module with Jumper wires

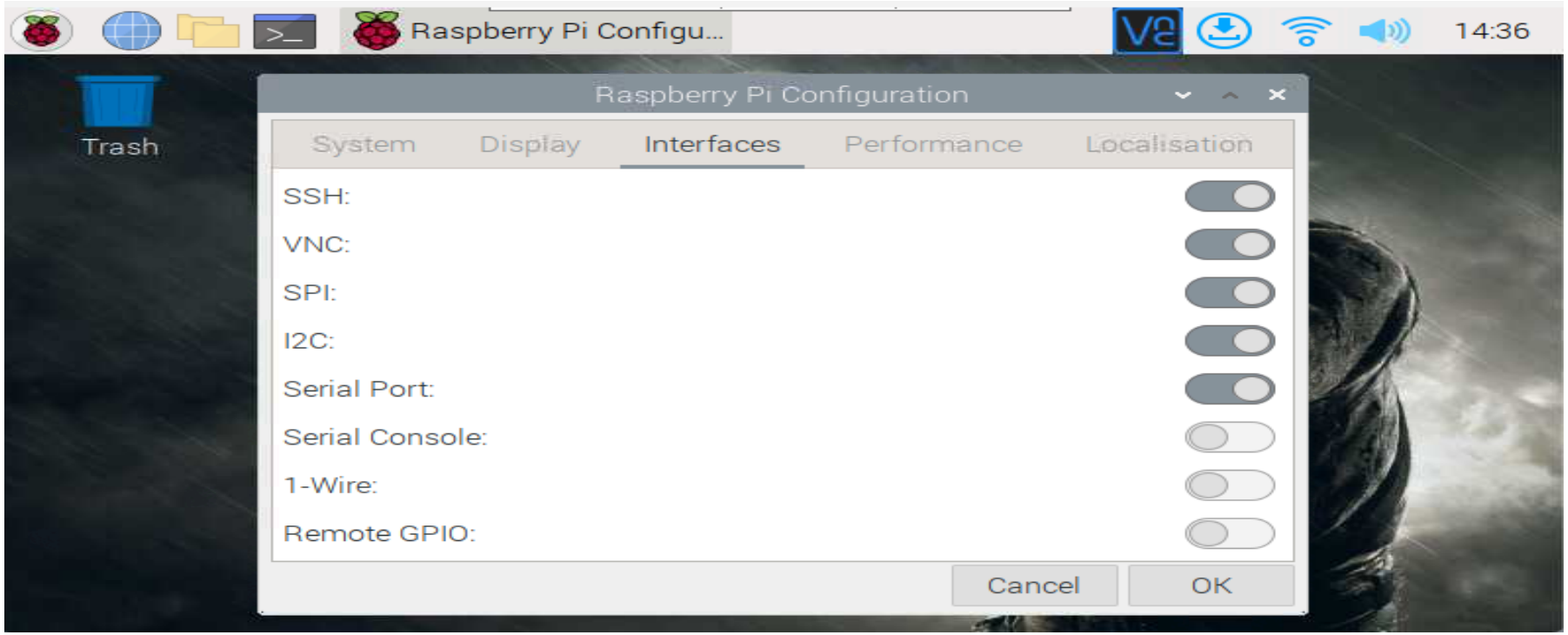


Berg strip male connector

BUY NOW

RaspberryPi setup

1. Setting up RaspberryPi can be done by following the official documentation here .
2. After the setup is done , use command prompt to enter raspi-config or under Preferences->select RaspberryPi Configuration.
3. Enable Serial Port interface.



PM2.5 & PM10 safe levels

$PM_{2.5}$ Particles

Based on the daily mean concentration for historical data, latest 24 hour running mean for the current day.

Index	1	2	3	4	5	6	7	8	9	10
Band	Low	Low	Low	Moderate	Moderate	Moderate	High	High	High	Very High
μgm^{-3}	0-11	12-23	24-35	36-41	42-47	48-53	54-58	59-64	65-70	71 or more

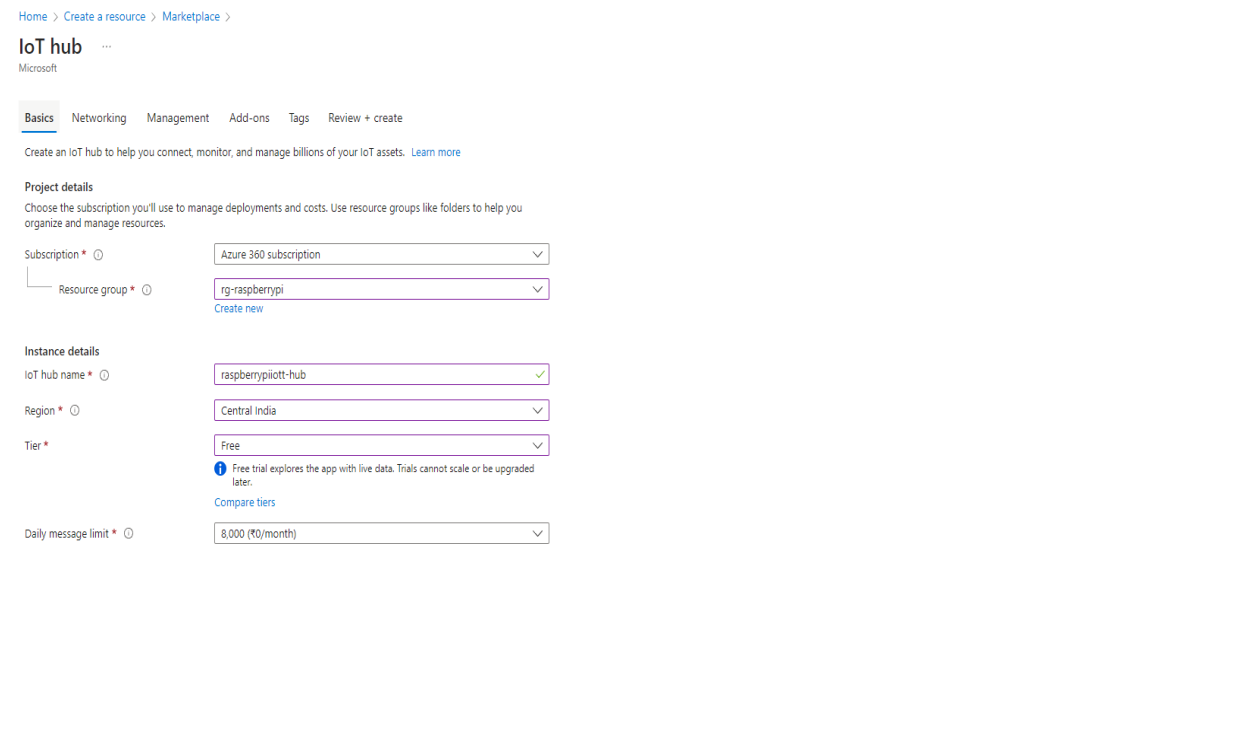
PM_{10} Particles

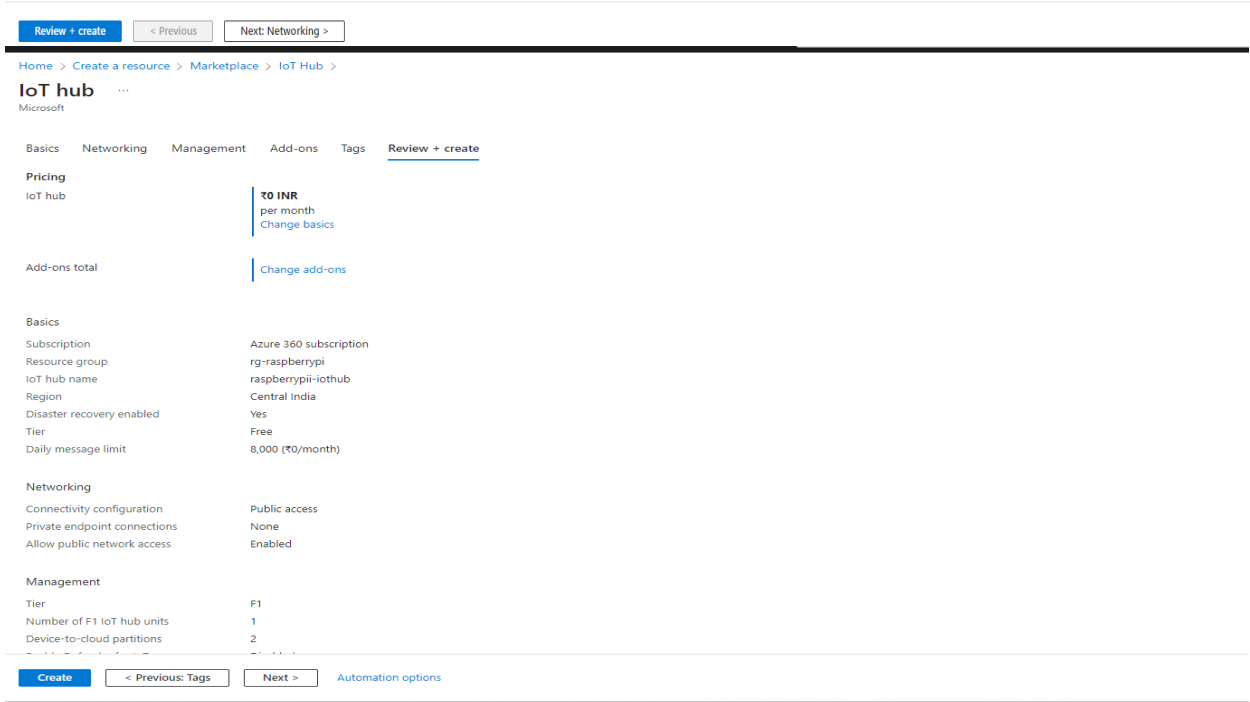
Based on the daily mean concentration for historical data, latest 24 hour running mean for the current day.

Index	1	2	3	4	5	6	7	8	9	10
Band	Low	Low	Low	Moderate	Moderate	Moderate	High	High	High	Very High
$\mu g/m^3$	0-16	17-33	34-50	51-58	59-66	67-75	76-83	84-91	92-100	101 or more

Create IoT hub

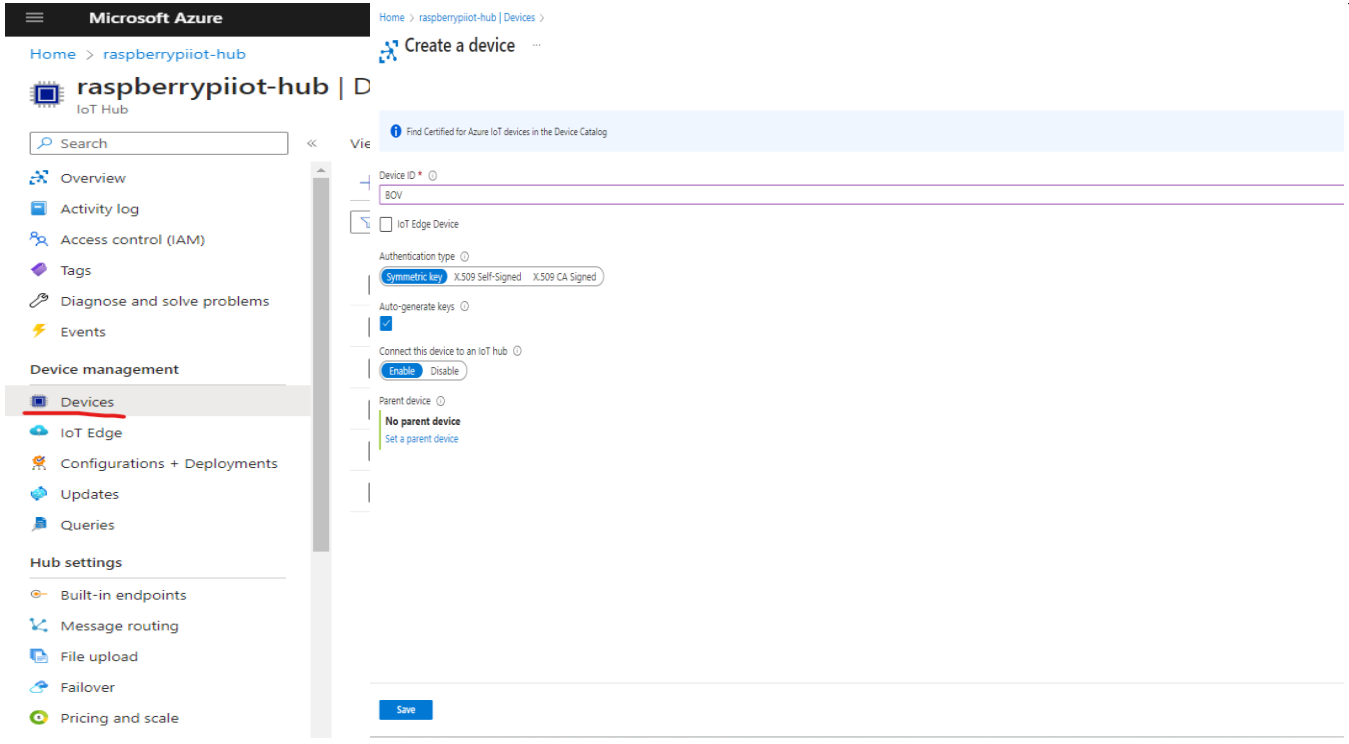
1. Azure subscription is required and you can create a free account here.
2. Create an IoT Hub by clicking on **+ Create a resource** button or using the search bar.
3. Choose a subscription and create a **resource group** “rg-raspberrypi” if not created one earlier
4. Provide **IoT hub name** and choose the **region** closest to you
5. For the tier I have started with Standard tier , but **Free tier** should be more than enough for testing and evaluating AQMD.
6. Daily **message limit** can be updated based on the preferences for higher tier, however for the free tier we should go with the default one which is 8000 message per day quota.
7. Proceed to the next step **Networking** and accept the defaults for now and click on next step **Management ,** you can optionally change the permission mode and assign yourself the contributor role.
8. Proceed to the final step and click on **Create** button.

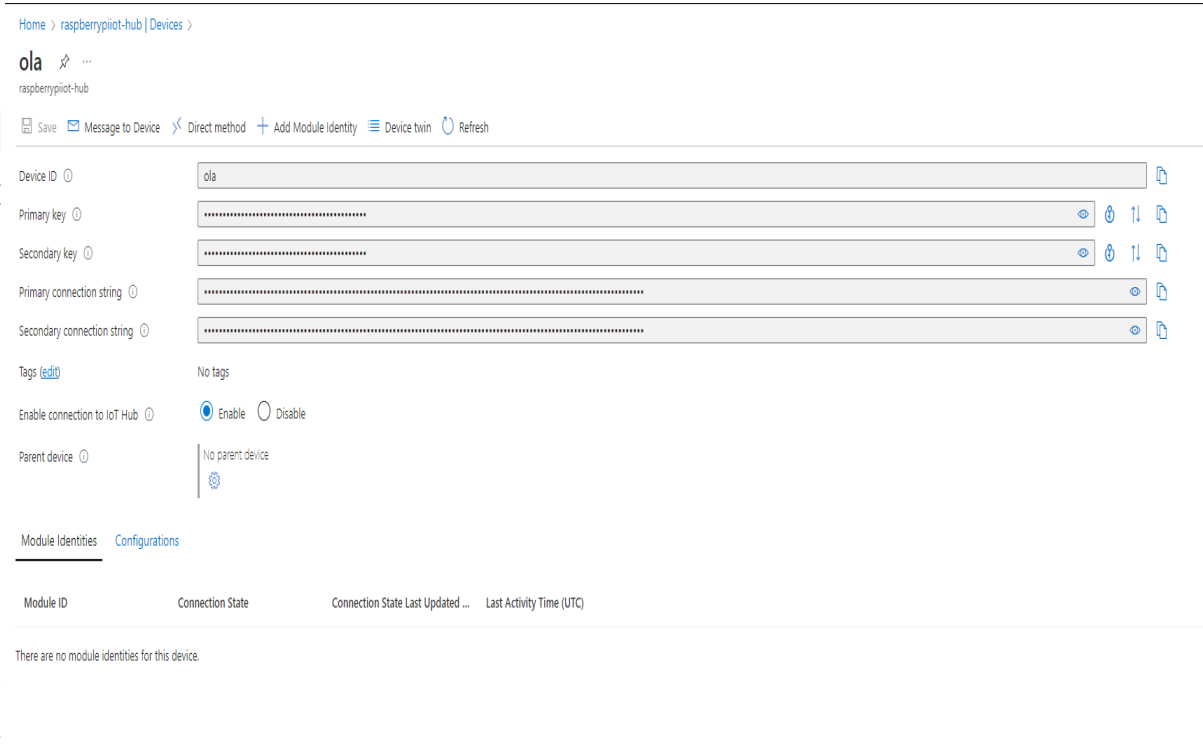




Register device

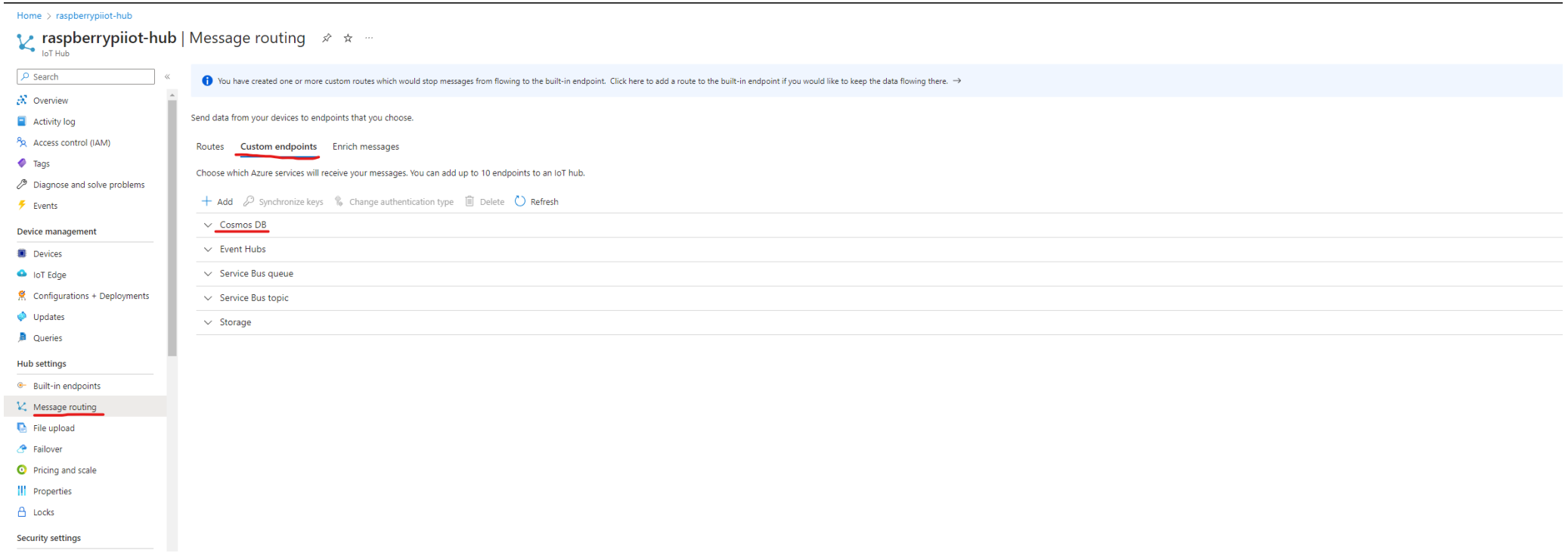
1. Under the device management in the left pane , click on **Devices,** then select **Add Devices** button
2. In the Create device pane , mention the device ID (Ola, Uber, Zepto, BOV, etc..) from which we will be collecting the telemetry.
3. Let's leave the default authentication type and let's use auto-generate keys
4. Once you click on **Save** button , device will be created along with autogenerated connection string for you to connect with.





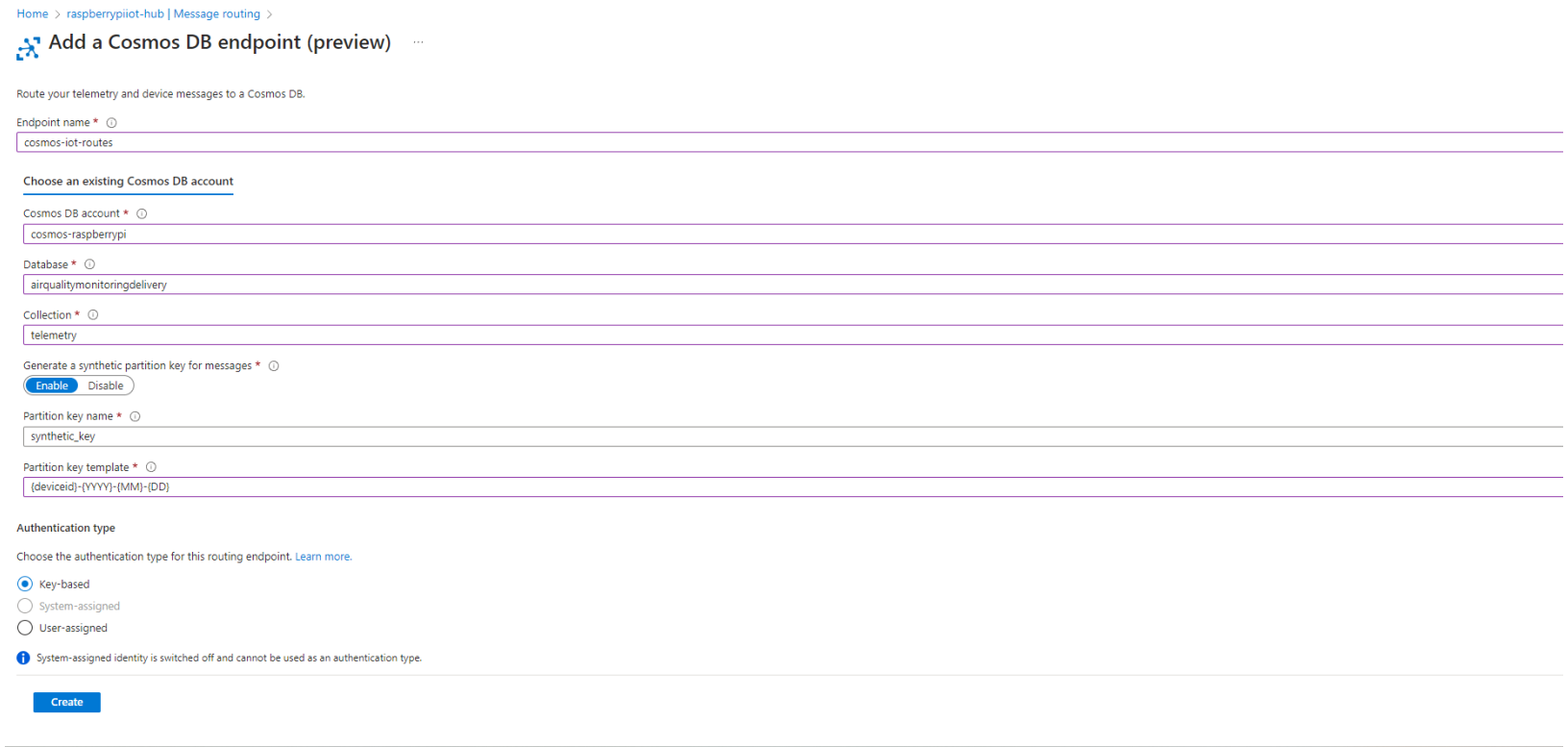
IoT Hub Message routing

1. For the hot store path we will make use of Cosmos DB, prior to this step make sure to Create a Cosmos DB in a serverless mode. Follow the steps here to create Cosmos DB.
2. Create account name as **cosmos-raspberrypi** , database name as **airqualitymonitoringdelivery** and collection as **telemetry** with **synthetic_key** as partition key.
3. Now all the telemetries from IoT Hub should be ingested to this hot store path. In order to do that we should create a Message routing that routes all the data to Cosmos DB.
4. First step is to create Custom endpoints. In our case it is Cosmos Db (at the time of creating this blog , this feature is still in Preview)



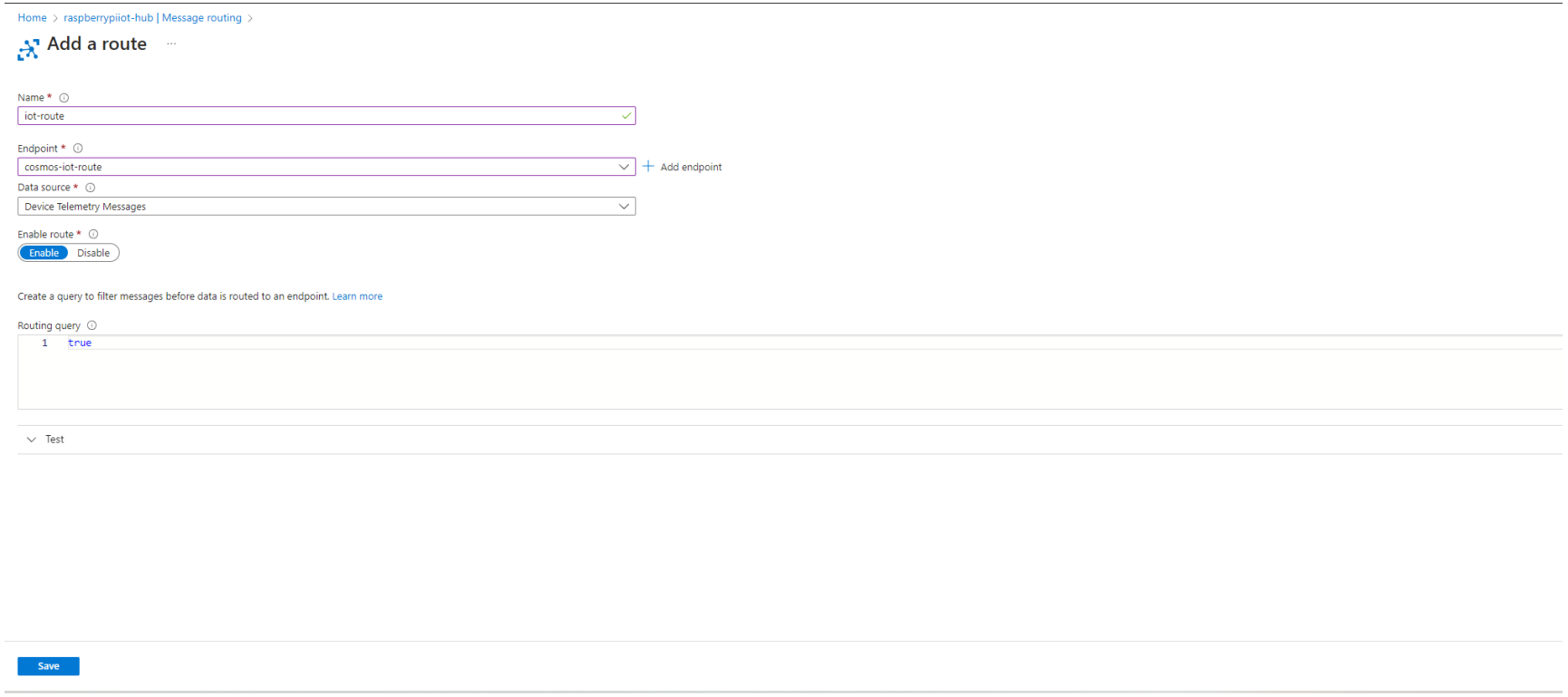
Cosmos DB Custom endpoint

1. Provide a name for the Cosmos DB endpoint
2. Choose the Cosmos DB account and respective collection to which the data should be ingested into
3. Choose Synthetic partition for the message
4. Provide the partition key template
5. Leave the default authentication type
6. Click on create button

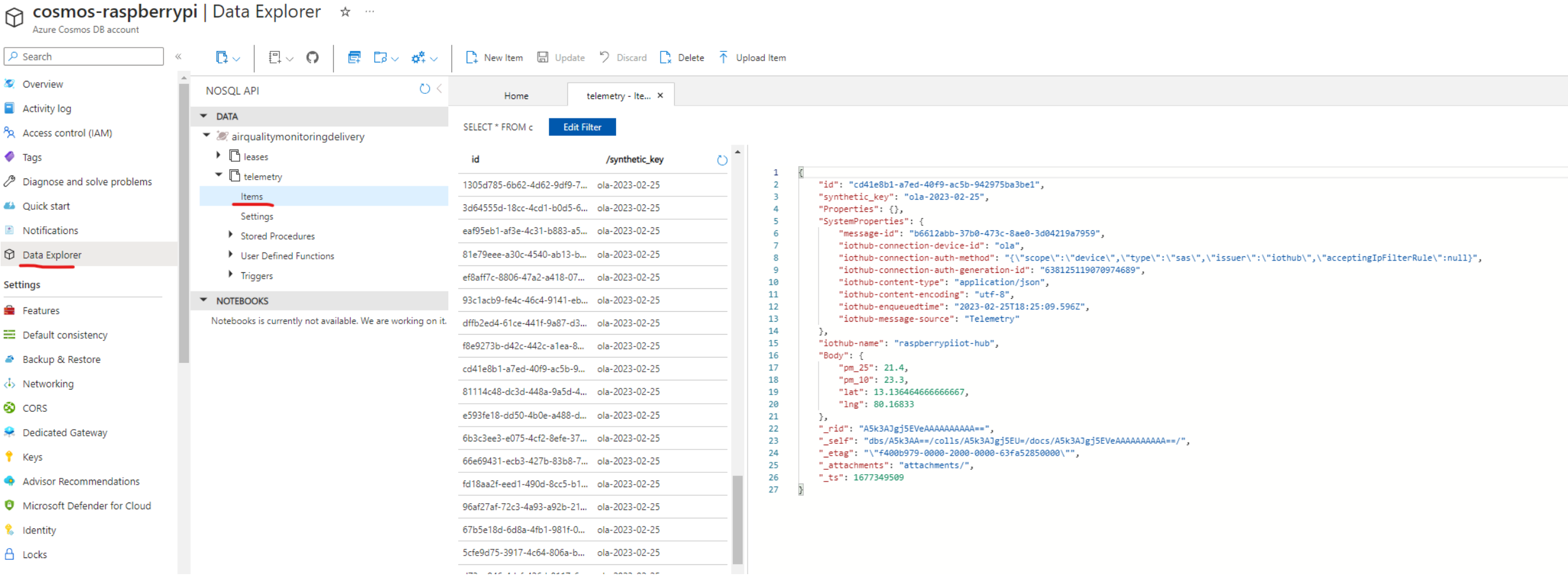


IoT Hub Add routes

1. Click on Add routes
2. Provide a name for the route
3. Select the Cosmos DB endpoint created in the previous step
4. Choose data source to be device telemetry messages
5. Select Enable route
6. Optionally you can modify the routing query to push only specific messages to Cosmos Db , In our case it is set to true (push all messages to Cosmos Db)



Telemetry in Cosmos DB



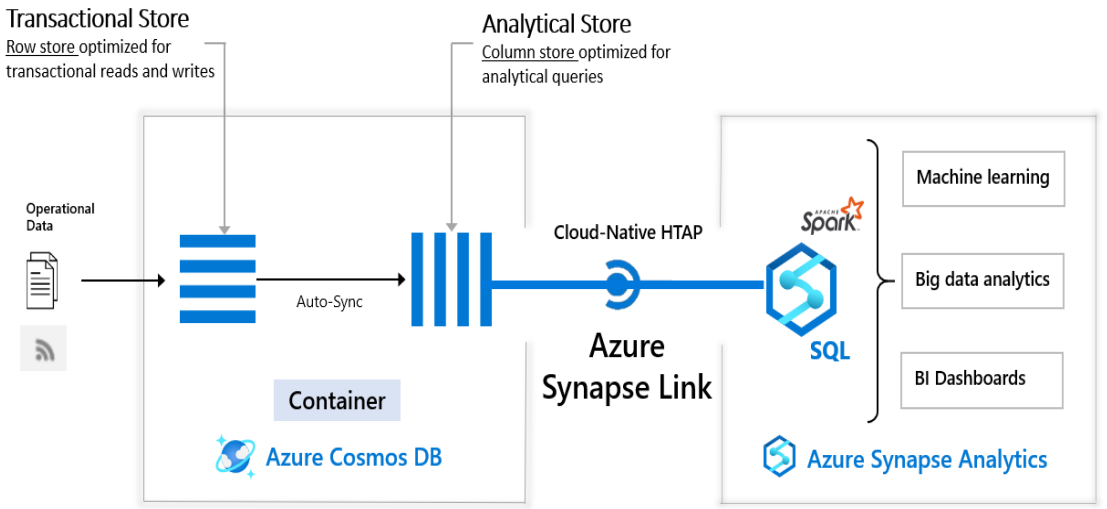
Sample telemetry

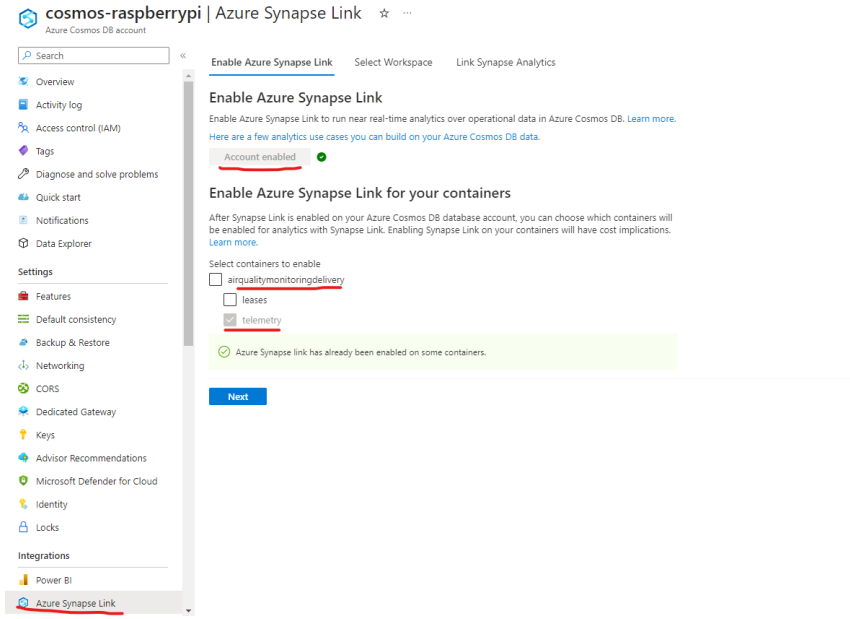

```
{
    "id": "09a0341b-a981-4e1e-ae6b-834dd16faa07",
    "synthetic_key": "ola-2023-03-21",
    "Properties": {},
    "SystemProperties": {
        "message-id": "89bab089-1609-48d0-bebc-63e8c00de358",
        "iothub-connection-device-id": "ola",
        "iothub-connection-auth-method": "
{\"scope\":\"device\",\"type\":\"sas\",\"issuer\":\"iothub\",\"acceptingIpFilterRule\":null}",
        "iothub-connection-auth-generation-id": "638125119018935233",
        "iothub-content-type": "application/json",
        "iothub-content-encoding": "utf-8",
        "iothub-enqueuedtime": "2023-03-21T04:43:35.149Z",
        "iothub-message-source": "Telemetry"
    },
    "iothub-name": "raspberrypiiot-hub",
    "Body": {
        "pm_25": 25.3,
        "pm_10": 28.4,
        "lat": 13.136398666666667,
        "lng": 80.16815083333333
    },
    "_rid": "A5k3AJgj5EUkAQAAAAAAAA==",
    "_self": "dbs/A5k3AA==/colls/A5k3AJgj5EU=/docs/A5k3AJgj5EUkAQAAAAAAAA==/",
    "_etag": "\"010076b4-0000-2000-0000-641935f70000\"",
    "_attachments": "attachments/",
    "_ts": 1679373815
}
```

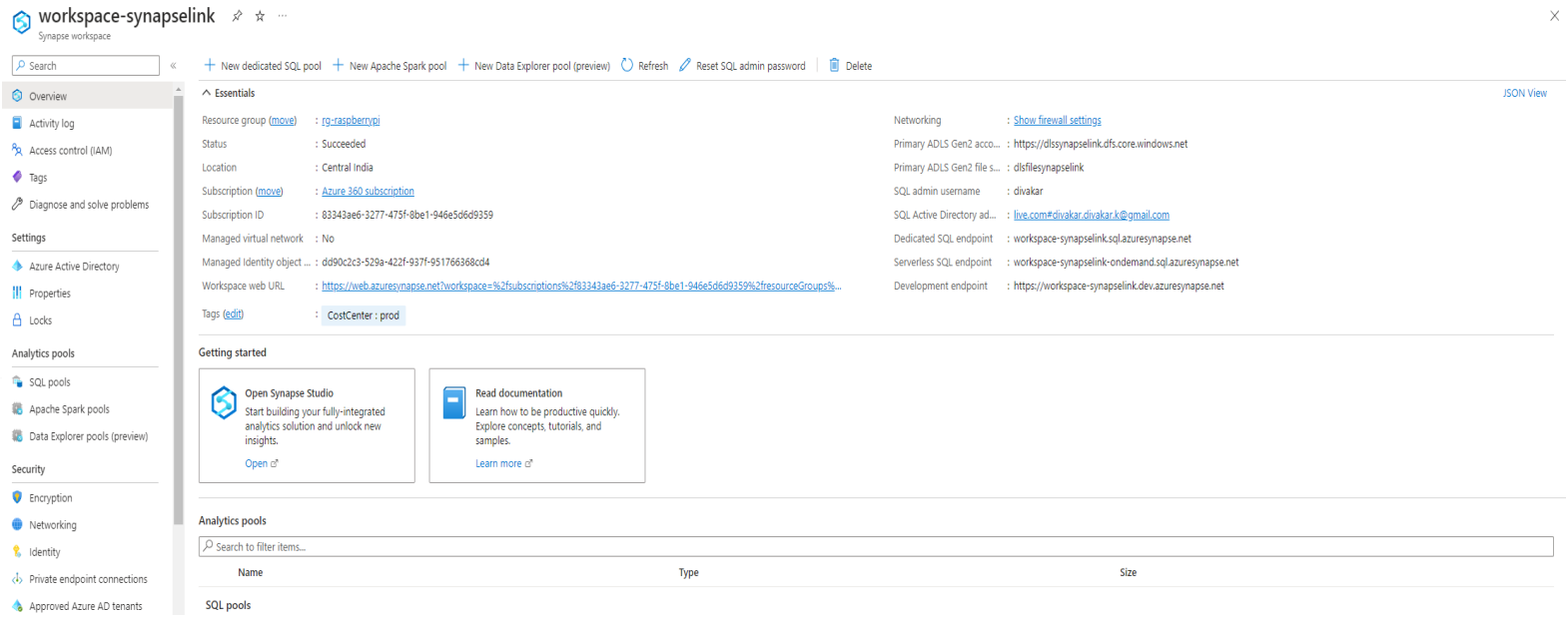
Azure Synapse flow

Enable Azure Synapse link for Azure Cosmos DB

1. Now that we have ingested data into Azure Cosmos DB , next step is to visualize and analyze the data to get meaningful insights from the telemetries
2. Azure Synapse link provides a cloud-native hybrid transactional and analytical processing (HTAP) capability that enables near real time analytics over operational data in Azure Cosmos DB.
3. Under Integrations in Azure Cosmos DB account , select Azure Synapse Link and click on Enable button
4. Once Azure synapse link is enabled, make sure to choose the collection if it is created already and create a workspace in the next screen.

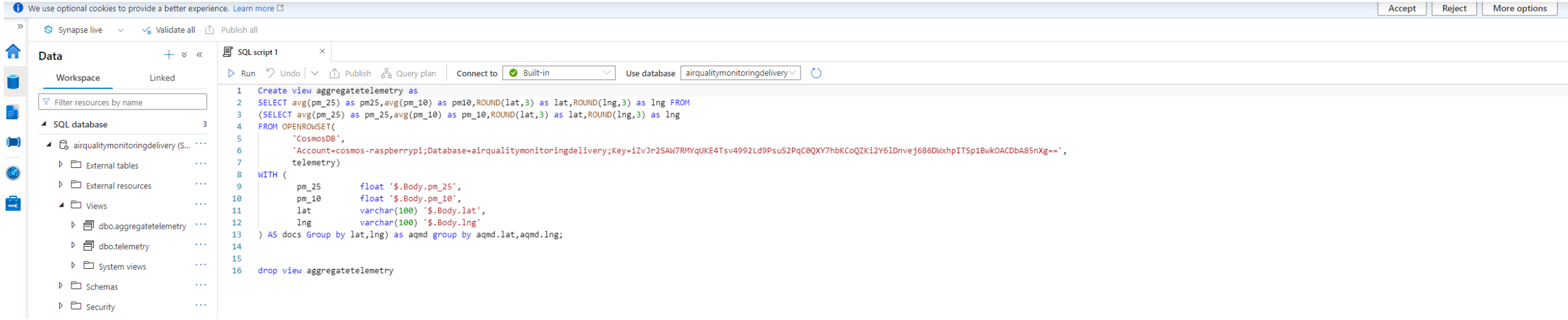






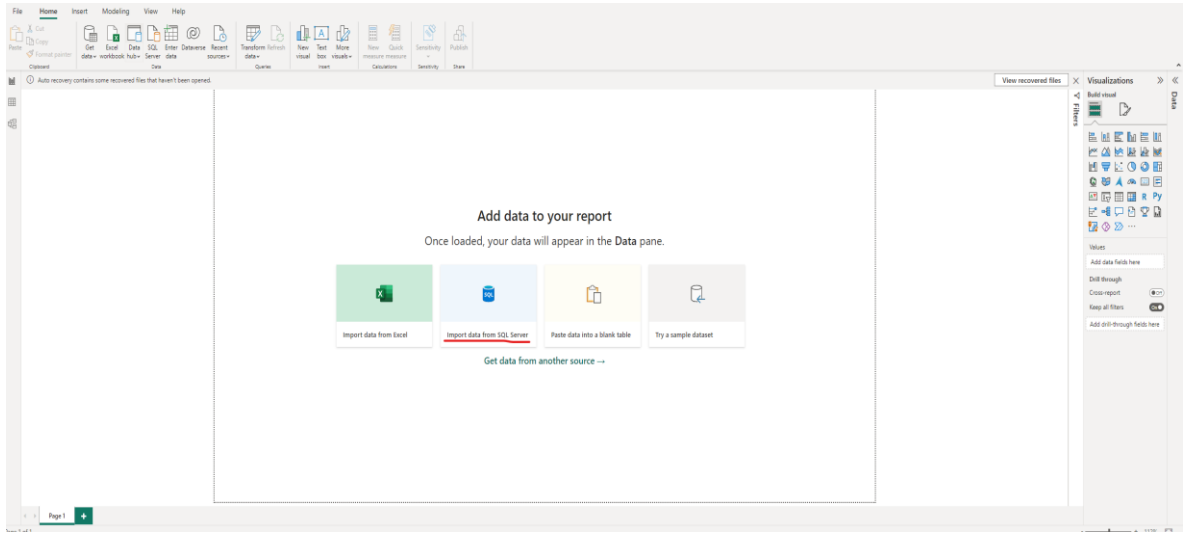
Create SQL View in Azure Synapse analytics workspace

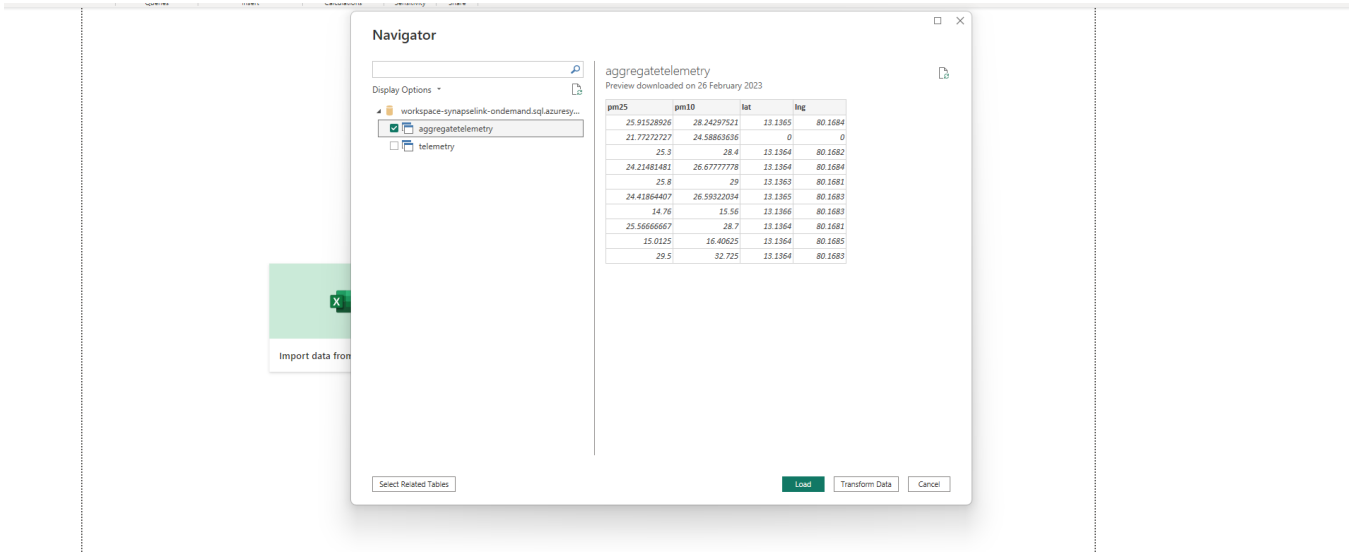
1. Enter into the Azure synapse analytics workspace
2. Select the database "**airqualitymonitordelivery**" in the top pane and proceed to create a view
3. Create a view named "**aggregatetelemetry**" which aggregates the data by rounding off latitude and longitude to 3 points, to avoid any discrepancies while visualizing the data as a heatmap

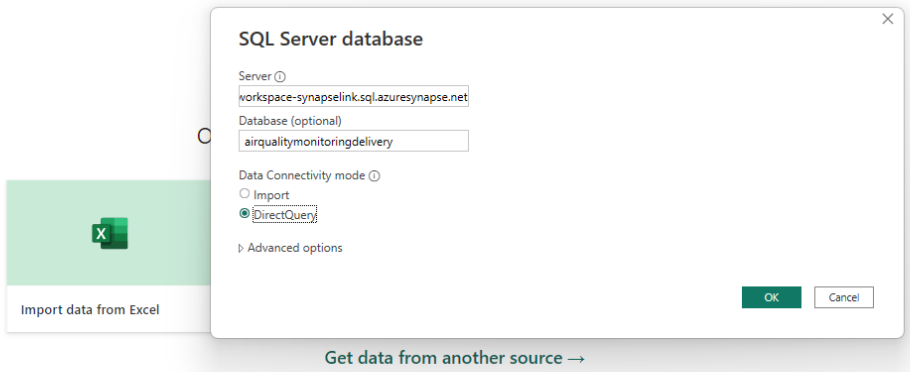


Enable Power BI Integration

1. Sign up for a free Power BI account if you don't have one here.
2. You can optionally download Power BI Desktop tool from here or you can use app.powerbi.com
3. Select Import data from SQL server.
4. Provide the connection details (Serverless SQL endpoint) in the server text box and choose **DirectQuery** as Data Connectivity mode
5. Click on OK button
6. In the next screen , sign in if prompts and then click on **connect** button.
7. Now Choose the view created in the earlier step and click on **Load** button







Python code – Initialize IotHubDeviceClient

1. Import **IoTHubDeviceClient** and **Message** from **azure.iot.device**
2. Set the serial port to **"/dev/ttyUSB0**" for listening PM sensor data
3. Set the serial port to **"/dev/ttyAMA0**" for listening GPS module data
4. Initialize the IotHubDeviceClient using the connection String copied from the Device registration screen

```
from azure.iot.device import IoTHubDeviceClient, Message

port = "/dev/ttyUSB0" # Set this to your serial port.
baudrate = 9600

gpsPort="/dev/ttyAMA0"
gpsBaudrate= 9600


device_client= IoTHubDeviceClient.create_from_connection_string("HostName=raspberrypiiot-hub.azure-
devices.net;DeviceId=ola;SharedAccessKey=rbLJZLH3zB/khja5Ul++Xkh+nmvbScBg8z+i+9RoGUI=")
```

Python code – Form Message payload and send to IoT Hub

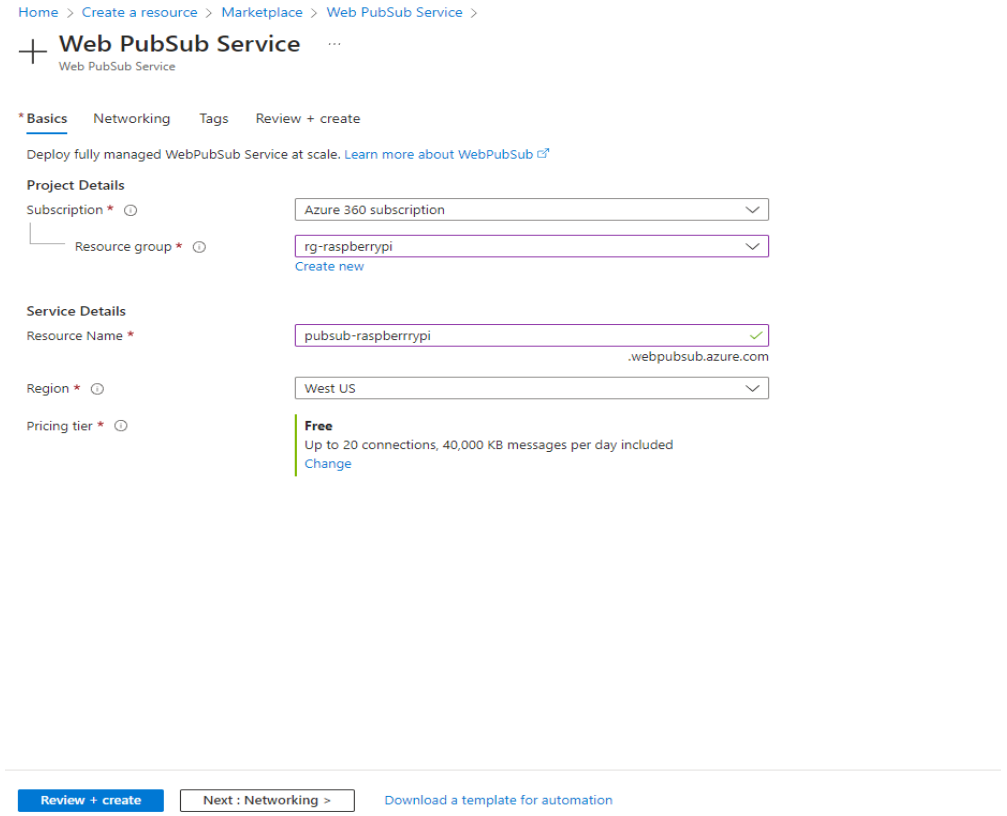
1. Form the schema for the message payload that will be sent to IoT Hub MSG_PAYLOAD= '{{"pm_25": {pm_25},"pm_10": {pm_10},"lat": {lat},"lng": {lng}}}'
2. Get the readings from GPS module to capture latitude and longitude and PM sensor to capture Pm_2.5 and Pm_10 readings
3. Populate the message payload
4. Send the Message payload to IoT Hub by calling **device_client.send_message(msg)**

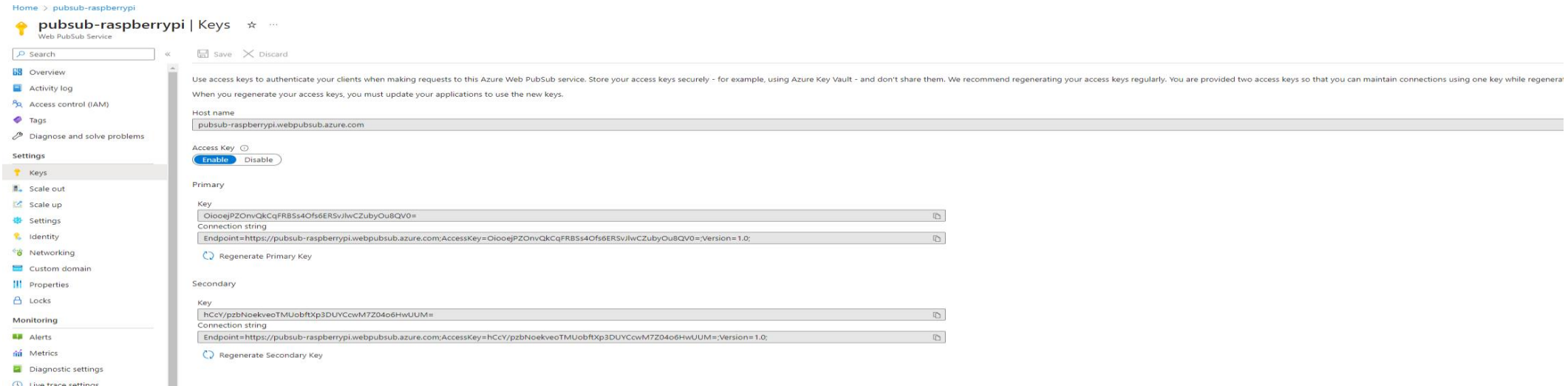
```
MSG_PAYLOAD= '{{"pm_25": {pm_25},"pm_10": {pm_10},"lat": {lat},"lng": {lng}}}'
ser = Serial(port, baudrate=baudrate, bytesize=EIGHTBITS, parity=PARITY_NONE, stopbits=STOPBITS_ONE)
ser.flushInput()

HEADER_BYTE = b"\xAA"
COMMANDER_BYTE = b"\xC0"
TAIL_BYTE = b"\xAB"

byte, previousbyte = b"\x00", b"\x00"

while True:
    previousbyte = byte
    byte = ser.read(size=1)
    if previousbyte == HEADER_BYTE and byte == COMMANDER_BYTE:
        packet = ser.read(size=8) # Read 8 more bytes
        readings = struct.unpack('<HHcccc', packet)
        pm_25 = readings[0]/10.0
        pm_10 = readings[1]/10.0
        gpsSer= Serial(gpsPort,9600,timeout=0.5)
        dataout= pynmea2.NMEAStreamReader()
        newdata= gpsSer.readline().decode('utf-8',errors='ignore')
        lat=0
        lng=0
        id = packet[4:6]
        checksum = readings[4][0]
        calculated_checksum = sum(packet[:6]) & 0xFF
        checksum_verified = (calculated_checksum == checksum)
        tail = readings[5]
        if tail == TAIL_BYTE and checksum_verified:
            if newdata[0:6] == "$GPRMC":
                newmsg= pynmea2.parse(newdata)
                lat= newmsg.latitude
                lng=newmsg.longitude
                payload= MSG_PAYLOAD.format(pm_25=pm_25, pm_10=pm_10, lat=lat, lng=lng)
                msg= Message(payload)
                msg.message_id= uuid.uuid4()
                msg.content_encoding= "utf-8"
                msg.custom_properties["deviceId"]= "ola"
                msg.content_type= "application/json"
                print("sending message: {}".format(msg))
                device_client.send_message(msg)
                time.sleep(2)
                print("PM 2.5:", pm_25, "µg/m³  PM 10:", pm_10, "µg/m³  ID:", bytes(id).hex())
```

Real-time Azure Maps flow

Create Azure Web PubSub

1. Azure subscription is required and you can create a free account here.
2. Create a WebPubSub instance by clicking on **+ Create a resource** button or using the search bar.
3. Choose a subscription and create a **resource group** “rg-raspberrypi” if not created one earlier
4. Provide **Resource name** and choose the **region**
5. For the tier I have chosen **Free tier,** that should be more than enough for testing and evaluating AQMD.
6. Proceed to the final step and click on **Create** button.
7. After resource is created add a hub (**AQMD**) to the instance
8. Copy the ConnectionString from the key session





C# code – Telemetry trigger

1. Create Azure Function
2. Create Cosmos DB Trigger for the **telemetry** collection in **airqualitymonitoringdelivery** database.
3. Use Azure WebPubSub client to publish the changes to the **AQMD** hub created in the previous step

```
public class TelemetryTrigger
    {
        private readonly IConfiguration _configuration;
        public TelemetryTrigger(IConfiguration configuration)
        {
            _configuration = configuration;
        }

        [FunctionName("TelemetryToPubSub")]
        public async Task TelemetryToPubSub([CosmosDBTrigger(
            databaseName: "airqualitymonitoringdelivery",
            collectionName: "telemetry",
            ConnectionStringSetting = "cosmosconnection",
            LeaseCollectionName = "leases",
            CreateLeaseCollectionIfNotExists = true)]IReadOnlyList<Document> input,
            ILogger log)
        {
            if (input != null && input.Count > 0)
            {
                log.LogInformation("Documents modified " + input.Count);
                log.LogInformation("First document Id " + input[0].Id);

                var serviceClient = new
WebPubSubServiceClient(_configuration["WebPubSubConnectionString"], _configuration["HubName"]);
                await serviceClient.SendToAllAsync(JsonConvert.SerializeObject(input));
            }
        }
    }
```

C# code – Get Connection URL for Web PubSub

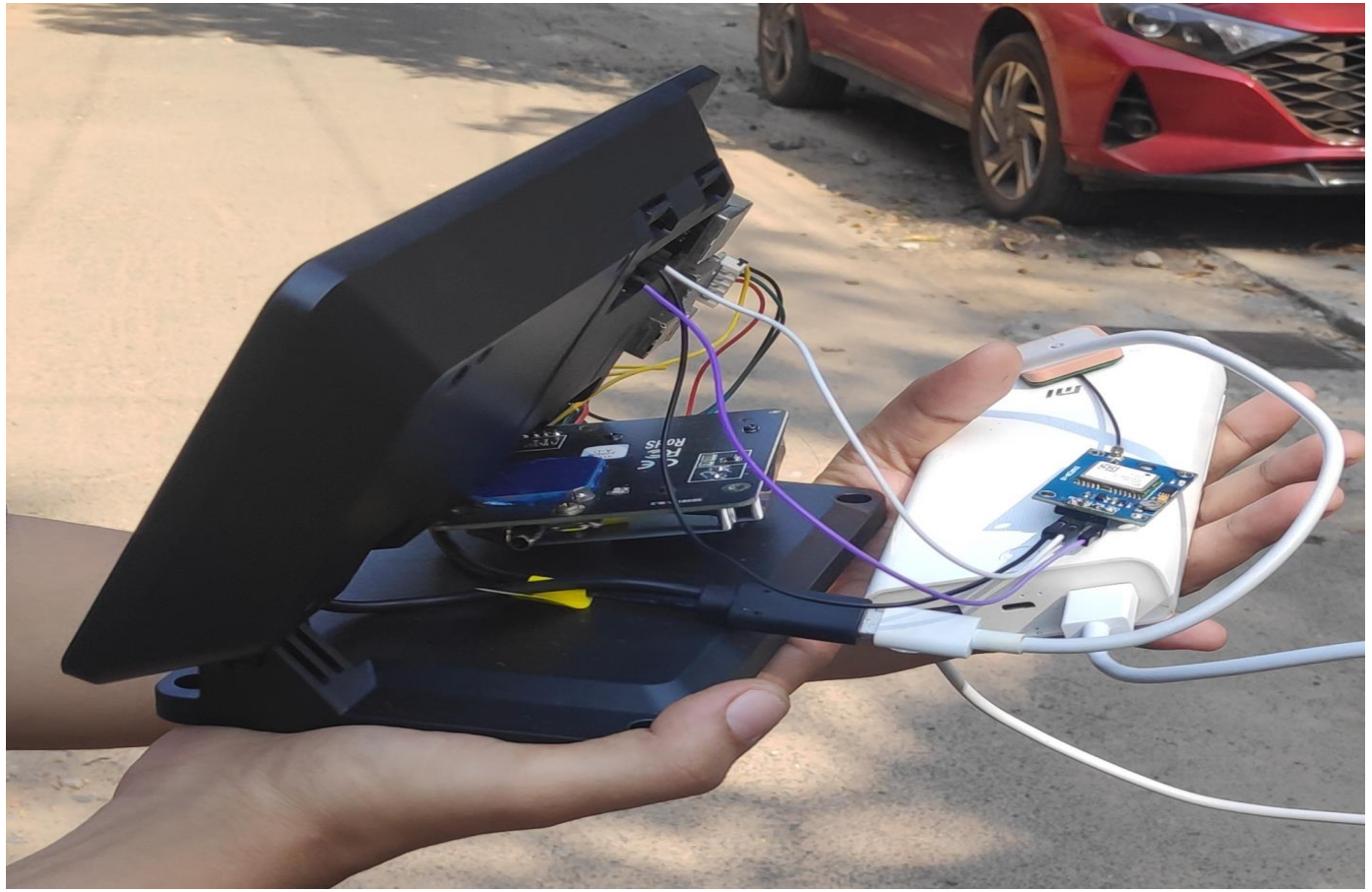
1. In order to establish connection with Azure Web PubSub instance created over the previous step in the frontend , we need a ConnectionURL
2. HTTP trigger with Azure WebPubSub input bindings is used to generate ConnectionURL for a given user.

```
public class Connection
    {
        private readonly ILogger<Connection> _logger;

        public Connection(ILogger<Connection> log)
        {
            _logger = log;
        }

        [FunctionName("GetConnectionUrl")]
        [OpenApiOperation(operationId: "Run", tags: new[] { "name" })]
        [OpenApiParameter(name: "name", In = ParameterLocation.Query, Required = true, Type =
typeof(string), Description = "The **Name** parameter")]
        [OpenApiResponseWithBody(statusCode: HttpStatusCode.OK, contentType: "text/plain", bodyType:
typeof(string), Description = "The OK response")]
        public async Task<WebPubSubConnection> GetConnectionUrl(
            [HttpTrigger(AuthorizationLevel.Anonymous, "get", "post", Route = "negotiate")] HttpRequest
req, [WebPubSubConnection(Hub = "AQMD", UserId = "{query.userid}")] WebPubSubConnection connection)
        {
            Console.WriteLine("login");
            return await Task.FromResult(connection);
        }
    }
```

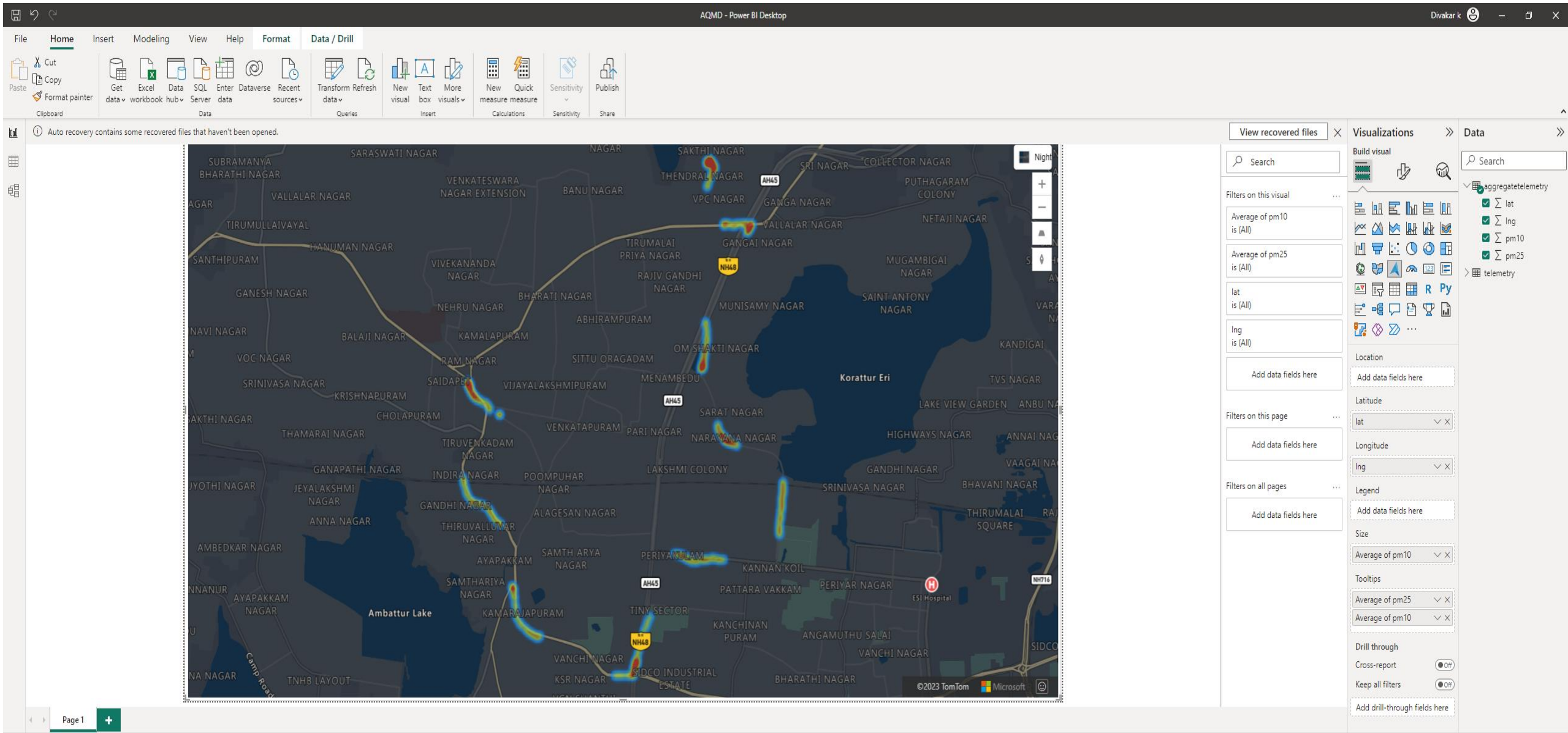
Demo

It’s time to ride!

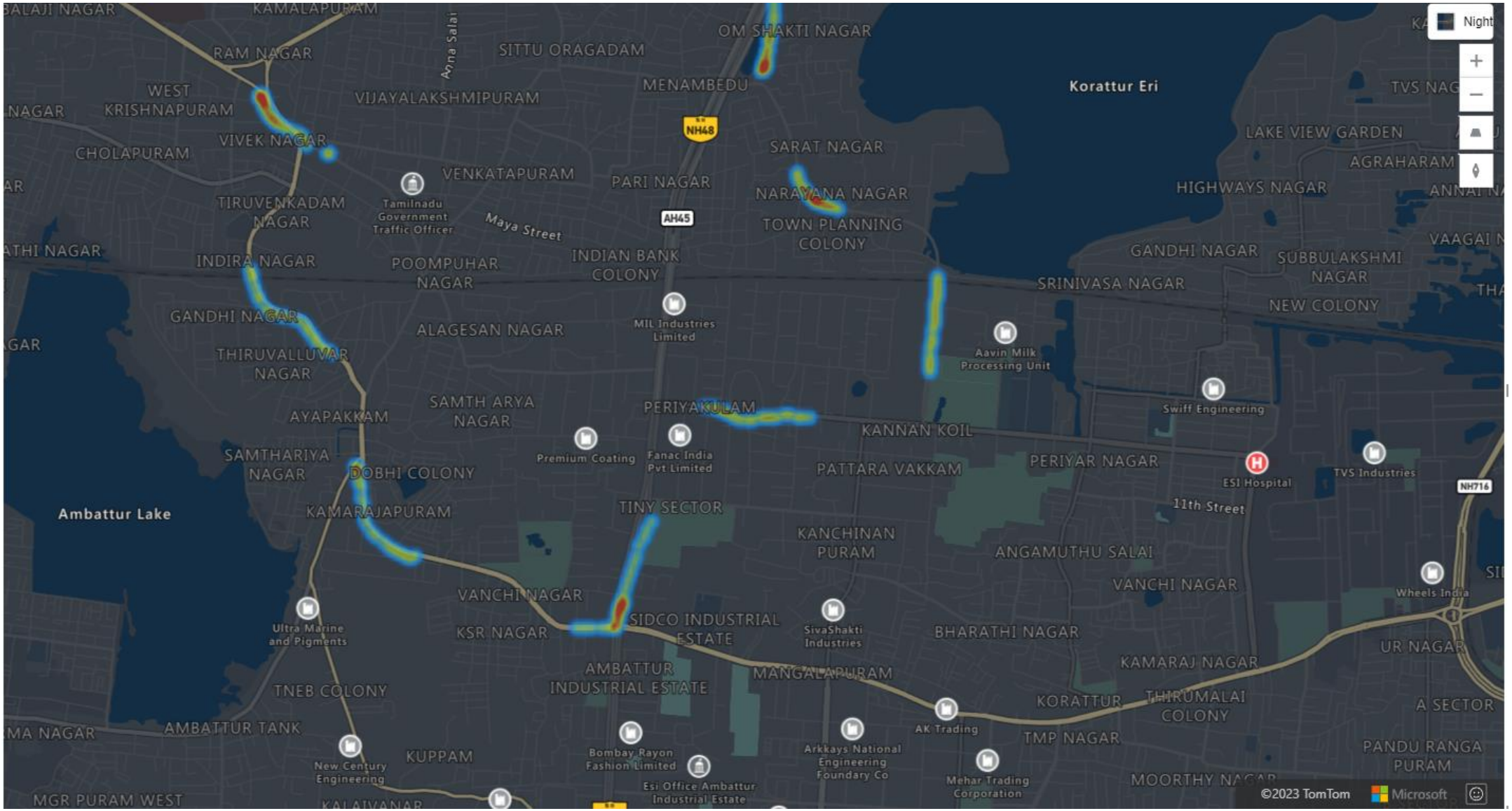
It is optional to buy a case for raspberry pi model . In my case I have bought a case to hold my touch screen + raspberry Pi. Myself and my wife decided to take it for a ride in and around our residence (**Ambattur estate**). Outcome of the ride can be seen in the next slide, which feels more accurate as we felt the same before while crossing those streets!



Visualize telemetry as heatmap in Power BI



Heatmap closer look



Challenges

Sensor maintenance

Data management

Privacy concerns

Vehicles can experience harsh conditions that can impact the performance of air quality sensors.

Data management can be challenging as it involves collecting, storing and analyzing data from millions of vehicles.

Data collected by vehicle-based air quality sensors can contain sensitive information about individuals and their driving habits.

How overcome challenges:

Sensor maintenance:

- Encouraging widespread adaption of air quality sensors in vehicles requires significant effort and investment in awareness and education.

- Timely notification to drivers about the calibration of devices.

Data management:

In our implementation we have used Azure IoT hub, that is capable of ingesting data from millions of devices and for the warm path store, Azure Cosmos DB is used that provides us the benefits of ingesting device telemetry data at high rates and return indexed queries with low latency and high availability.

- TTL for Hot store path is set to 90 days

- TTL for Azure Synapse analytics is set to infinite to look back historical data

Business Benefits

Wider Coverage:

Data can be collected from a wider range of locations, including areas where fixed monitoring stations may not exist

Real-time data:

The Sensors in vehicles can provide real-time data on air quality, allowing for more immediate responses to changing conditions.

Able to visualize data in a heatmap street by street basis.

Dynamic monitoring:

Vehicles can travel to different locations and provide data on air quality in a variety of places, such as urban, suburban and rural areas.

Exposure information:

Individuals can receive information about their personal exposure to air pollution, which can inform decisions about daily activities and travel

Source Code

https://github.com/Cloud-Jas/AQMD

References

Air quality monitoring Insights	Link
	Dr. Sarath Guttikunda study on Ambient monitoring system
	Experts say five air quality monitoring stations not enough, seek 3 more
	Interview with Dr. Sarath Guttikunda who wins AGU Award
	Live Air Quality monitoring stations
	Chennai Metropolitan Area to be trifurcated, will cover 5,904 sqkm
	PM2.5, PM10 safe levels breached in Delhi throughout summer

Raspberry Pi	Link
	Setting up your Raspberry Pi