

# Lab 5: Connecting IoT to the Cloud with Microsoft Azure

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## Group Members:

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## 1. Introduction

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In this lab, we utilized Azure IoT Central to simulate a cloud-based IoT application. Azure IoT Central is a FaaS that simplifies device management and telemetry data collection. Our goal was to create an IoT Central application, configure virtual devices to send telemetry data, and visualize this data on a custom dashboard. Each group member created and deployed their own virtual device to the cloud.

## 2. Development Process

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In this section, we document the steps taken during the development of our IoT Central integration and highlight the challenges we faced along the way.

## 1. Project Planning and Initial Setup

The initial phase of development involved researching the Azure IoT Central platform and setting up the environment. The main goals were:

- Set up Azure IoT Central.
- Create a virtual device to simulate telemetry data transmission.
- Develop Python scripts for device-to-cloud communication.

Resources that helped during this phase:

- **Azure IoT Central Documentation:** Provided guidance on how to configure the IoT Central application and set up device credentials.
- **Open-source projects and Python IoT libraries:** These were referenced for implementing device command handling and telemetry data transmission.

## 2. Coding and Device Implementation

Each team member created a Python script to simulate a virtual device using the `iotc` Python library. Below were the key steps:

- **IoT Central connection:** We used the scope ID, device ID, and device key from our IoT Central application to connect each device.
- **Command Handling:** The devices were designed to receive a `sendData` command from IoT Central. When the command was received, telemetry data for temperature, wind speed, and humidity was generated and sent to the cloud.
- **Telemetry Data:** In addition to command-based data transmission, devices sent telemetry data at regular intervals (every 60 seconds).

## 3. Challenges and Troubleshooting

Several challenges arose during development, and the following troubleshooting techniques were used:

- **IoT Central Connection Issues:** At times, devices failed to connect due to incorrect credentials. The error was traced back to a misconfiguration in the device key or scope ID. Double-checking credentials resolved this issue.
- **Telemetry Data Format:** Initially, telemetry data was not displayed properly on the IoT Central dashboard. We discovered that the data format being sent was incorrect, and converting numerical data to strings resolved the problem.
- **Command Execution Failures:** While testing command execution, some devices failed to respond to the `sendData` command. This was resolved by ensuring that the `on_commands`

function was properly registered and called upon receiving commands.

## 4. Testing and Validation

After resolving the major issues, the devices were tested thoroughly to ensure they could:

- Connect to IoT Central.
- Respond to commands.
- Send telemetry data at regular intervals.

We used the IoT Central dashboard to monitor the devices in real-time and validate the data being received.

## 5. Lessons Learned

Through the development process, we gained valuable insights into the complexities of IoT integration. Azure IoT Central simplifies many tasks, but ensuring accurate device communication and telemetry data requires careful attention to detail.

## 3. Device Configuration

While the rest of the code remains same, the IoT central credentials are different for each member. So, we only change the following 3 lines of code and replace the credentials with our own.

Images of device configurations here

Khalil device configuration on Azure IOT Central

The screenshot displays the Azure IoT Central interface for configuring a device model named 'khalil'. The left sidebar shows navigation options like 'Connect', 'Devices', 'Device groups', 'Device templates', 'Edge manifests', 'Analyze', 'Data explorer', 'Dashboards', 'Manage', 'Jobs', 'Extend', 'Rules', 'Data export', 'Security', 'Audit logs', 'Permissions', 'Settings', 'Application', and 'Customization'. The main area shows the 'khalil' device template with a 'Model' dropdown set to 'khalil'. Below this, a table lists the configured capabilities:

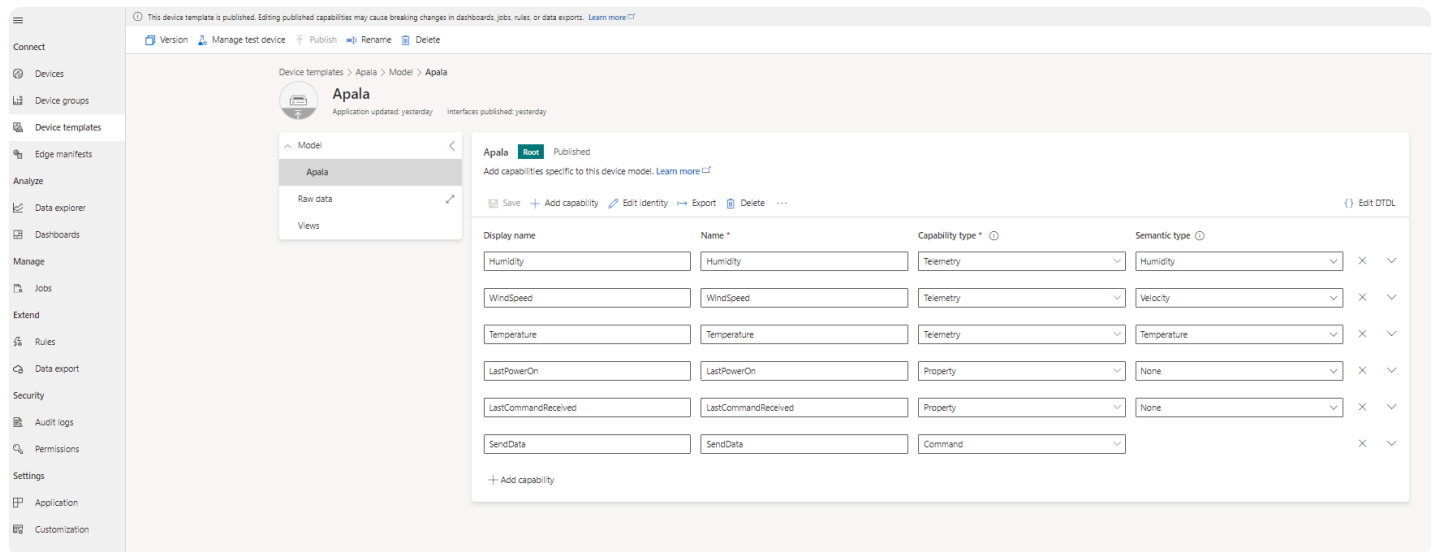
Display name	Name *	Capability type *	Semantic type		
Temperature	Temperature	Telemetry	Temperature	×	✓
WindSpeed	WindSpeed	Telemetry	Velocity	×	✓
Humidity	Humidity	Telemetry	Humidity	×	✓
LastCommandReceived	LastCommandReceived	Property	None	×	✓
LastPowerOn	LastPowerOn	Property	None	×	✓
SendData	SendData	Command		×	✓

At the bottom of the table, there is a '+ Add capability' button. The top of the main area shows the device template details: 'khalil' (Root), 'Published', 'Application updated: yesterday', and 'Interfaces published: yesterday'.

## Khalil IOT Central credentials

```
6
7 # Replace these with your IoT Central credentials
8 scopeId = '0ne00CE8964' # From lab 5.txt
9 device_id = '26znol6fzh7' # From lab 5.txt
10 device_key = 'qoCaBmM9hRi7QJhw4HKIM9t68Od55cv2VhC5/NqNzWE=' # From lab 5.txt
11
```

## Apala device configuration on Azure IOT Central



Device templates > Apala > Model > Apala

Apala **Root** Published  
Add capabilities specific to this device model. [Learn more](#)

Save Add capability Edit identity Export Delete ... [\(\) Edit DTDL](#)

Display name	Name *	Capability type *	Semantic type		
Humidity	Humidity	Telemetry	Humidity	X	▼
WindSpeed	WindSpeed	Telemetry	Velocity	X	▼
Temperature	Temperature	Telemetry	Temperature	X	▼
LastPowerOn	LastPowerOn	Property	None	X	▼
LastCommandReceived	LastCommandReceived	Property	None	X	▼
SendData	SendData	Command		X	▼

+ Add capability

## Apala IOT Central credentials

```
7 # Replace these with your IoT Central credentials
8 scopeId = '0ne00CE8964' # From lab 5.txt
9 device_id = '2mt69me4w6q' # From lab 5.txt
10 device_key = '9PRKb8z6zBhPddc3X/iiVxo8J266+yvJpPZ1LRNTp2g=' # From lab 5.txt
11
```

## Audrey device configuration on Azure IOT Central

Device templates > Audrey > Model > Audrey

Audrey **Root** Published  
Add capabilities specific to this device model. [Learn more](#)

Save + Add capability Edit identity Export Delete ... Edit DTDL

Display name	Name *	Capability type *	Semantic type		
Temperature	Temperature	Telemetry	Temperature	X	✓
WindSpeed	WindSpeed	Telemetry	Velocity	X	✓
Humidity	Humidity	Telemetry	Humidity	X	✓
LastCommandReceived	LastCommandReceived	Property	None	X	✓
LastPowerOn	LastPowerOn	Property	None	X	✓
SendData	SendData	Command		X	✓

+ Add capability

## Audrey IOT Central credentials

```
# Replace these with your IoT Central credentials
scopeId = '0ne00CE8964' # From lab 5.txt
device_id = 'rb20scn64p' # From lab 5.txt
device_key = 'a+4I6iBCu9fonE08b2PAf6Ej+YgYeFI2G+rFnbwe1jE=' # From lab 5.txt
```

## Raoul device configuration on Azure IOT Central

Device templates > Raoul > Model > Raoul

Raoul **Root** Published  
Add capabilities specific to this device model. [Learn more](#)

Save + Add capability Edit identity Export Delete ... Edit DTDL

Display name	Name *	Capability type *	Semantic type		
LastPowerOn	LastPowerOn	Property	None	X	✓
LastCommandReceived	LastCommandReceived	Property	None	X	✓
Temperature	Temperature	Telemetry	Temperature	X	✓
WindSpeed	WindSpeed	Telemetry	Velocity	X	✓
Humidity	Humidity	Telemetry	Humidity	X	✓
SendData	SendData	Command		X	✓

+ Add capability

## Raoul IOT Central credentials

```
7 # Replace these with your IoT Central credentials
8 scopeId = '0ne00CE8964' # From lab 5.txt
9 device_id = '242baqqe14v' # From lab 5.txt
10 device_key = 'ntBkjFjjNA35KlewRc8aurAf7625u3xvimsi08InBC0=' # From lab 5.txt
11
```

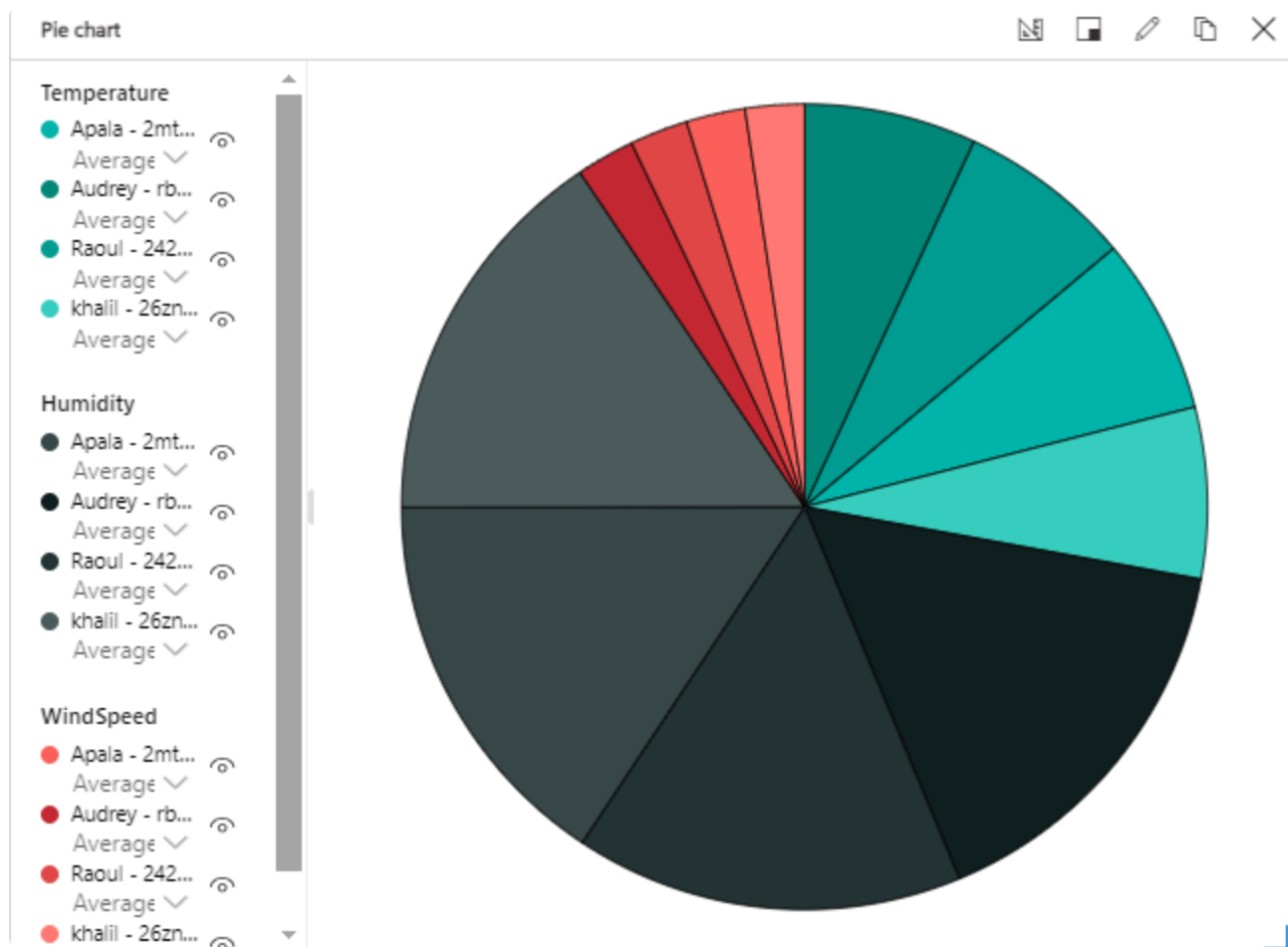
## 4. Dashboard Creation

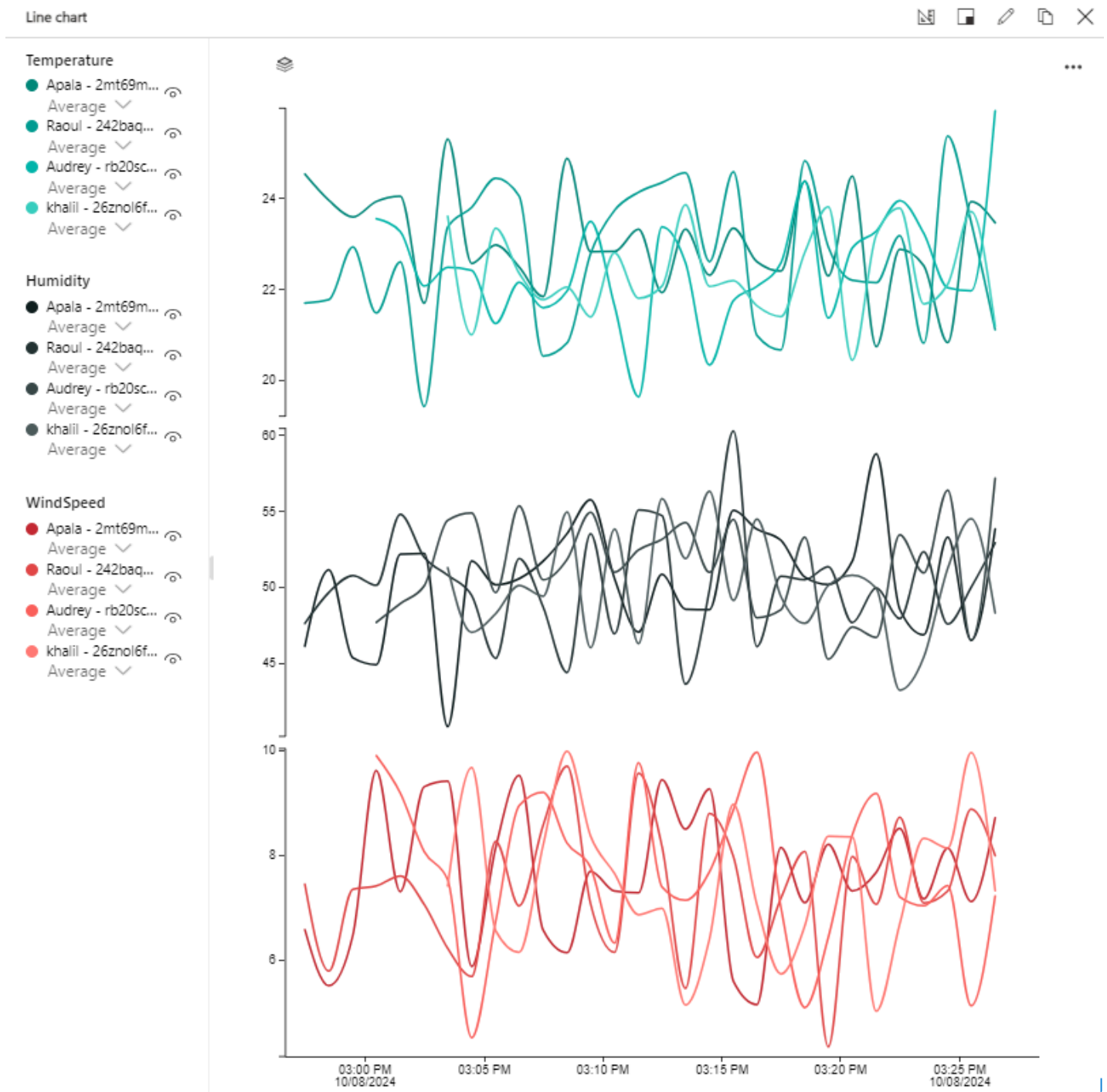
---

We created a custom dashboard to visualize the telemetry data from all devices. The following charts were included:

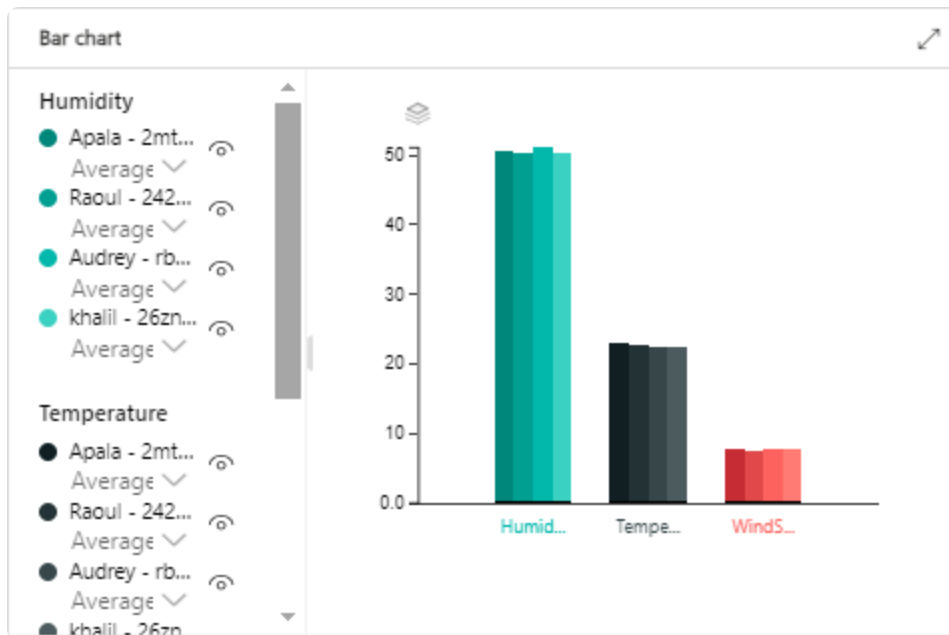
1. **Pie Chart:** Visualizes temperature, humidity and windspeed readings from all 4 devices as a pie chart.
2. **Line Chart:** Visualizes temperature, humidity and windspeed readings from all 4 devices as a line chart.
3. **Bar Chart:** Visualizes temperature, humidity and windspeed readings from all 4 devices as a bar chart.

**Dashboard screenshots here**









## 5. Virtual Device Implementation

Each group member implemented their virtual device using the `iotc` Python library. Below is the code for one of the devices:

### 1. IoT Central Credentials

While the rest of the code remains same, the IoT central credentials are different for each member. So, we only change the following 3 lines of code and replace the credentials with our own. The scope ID, device ID, and device key are set with values obtained from a configuration file ( `lab 5.txt` ). These credentials allow the device to securely connect to IoT Central.

```
scopeId = '0ne00CE8964' # From lab 5.txt
device_id = '26znol6fzh7' # From lab 5.txt
device_key = 'qoCaBmM9hRi7QJhw4HKIM9t680d55cv2VhC5/NqNzWE=' # From lab 5.txt
```

### 2. Command Handling Function

This function handles incoming commands sent from IoT Central. If the `sendData` command is received, the device generates and sends telemetry data (temperature, wind speed, and humidity) and updates a property ( `LastCommandReceived` ).

```
def on_commands(command: Command):  
    print(f"Command received: {command.name}")  
  
    if command.name == "SendData":  
        print("Sending data as per the SendData command")  
        iotc.send_telemetry({  
            'Temperature': str(random.uniform(15.0, 30.0)),  
            'WindSpeed': str(random.uniform(0.0, 15.0)),  
            'Humidity': str(random.uniform(30.0, 70.0))  
        })  
        iotc.send_property({  
            "LastCommandReceived": time.time()  
        })  
        print("Telemetry and LastCommandReceived property sent")  
  
    command.reply()
```

### 3. IoT Central Client Initialization

The IoT Central client is initialized with the device credentials and the connection type is set to use a device key. This establishes the device's connection to IoT Central.

```
iotc = IoTCClient(  
    device_id,  
    scopeId,  
    IOTCConnectType.IOTC_CONNECT_DEVICE_KEY,  
    device_key  
)  
  
iotc.connect()
```

### 4. Setting Up Command Listener

Once the connection is established, a listener is set up to handle incoming commands. The `on_commands` function is passed to the command event handler.

```
iotc.on(IOTCEvents.IOTC_COMMAND, on_commands)
```

## 5. Sending Device Properties

Upon powering up the device, it sends an initial property ( `LastPowerOn` ) to IoT Central, which contains the timestamp of when the device was last powered on.

```
iotc.send_property({
    "LastPowerOn": time.time()
})

print("Device connected and LastPowerOn property sent")
```

## 6. Telemetry Data Generation and Transmission

In a continuous loop, telemetry data for temperature, wind speed, and humidity is randomly generated and sent to IoT Central every 60 seconds. The `is_connected()` method ensures that the loop runs only when the device is connected.

```
while iotc.is_connected():
    temperature = random.uniform(15.0, 30.0)
    wind_speed = random.uniform(0.0, 15.0)
    humidity = random.uniform(30.0, 70.0)

    iotc.send_telemetry({
        'Temperature': str(temperature),
        'WindSpeed': str(wind_speed),
        'Humidity': str(humidity)
    })

    print(f"Telemetry sent - Temperature: {temperature}, Wind Speed: {wind_speed},
    time.sleep(60)
```

## 6. Results

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- All devices successfully sent telemetry data to IoT Central.
- The commands from the IoT Central were executed on the virtual devices.
- We monitored the data in real-time using the dashboard, observing telemetry values and device status.

**Images of data on Azure IoT Central here**

**Khalil's Data**

```

PS C:\Users\kahmad2\desktop\lab5>
PS C:\Users\kahmad2\desktop\lab5>
PS C:\Users\kahmad2\desktop\lab5>
PS C:\Users\kahmad2\desktop\lab5>
PS C:\Users\kahmad2\desktop\lab5> python3 khalil.py
Syncing property '$version'
Device connected and LastPowerOn property sent
Sending telemetry message: {'Temperature': '18.118128673075773', 'WindSpeed': '0.6434469549032323', 'Humidity': '62.37203119258928'}

Telemetry sent - Temperature: 18.118128673075773, Wind Speed: 0.6434469549032323, Humidity: 62.37203119258928
Sending telemetry message: {'Temperature': '19.619694587887587', 'WindSpeed': '7.388749466883024', 'Humidity': '49.77968679312538'}

Telemetry sent - Temperature: 19.619694587887587, Wind Speed: 7.388749466883024, Humidity: 49.77968679312538
Sending telemetry message: {'Temperature': '20.27455802022707', 'WindSpeed': '1.6235225255041097', 'Humidity': '62.33343200480319'}

Telemetry sent - Temperature: 20.27455802022707, Wind Speed: 1.6235225255041097, Humidity: 62.33343200480319
Command received: SendData
Sending data as per the SendData command
Sending telemetry message: {'Temperature': '29.10632896640142', 'WindSpeed': '8.317005025601587', 'Humidity': '58.41585678487014'}

Telemetry and LastCommandReceived property sent
Command received: SendData
Sending data as per the SendData command
Sending telemetry message: {'Temperature': '25.28265855791901', 'WindSpeed': '6.732743479077184', 'Humidity': '43.95249622807604'}

Telemetry and LastCommandReceived property sent
Sending telemetry message: {'Temperature': '29.12713099419058', 'WindSpeed': '2.6979515400438063', 'Humidity': '43.14369840604783'}

Telemetry sent - Temperature: 29.12713099419058, Wind Speed: 2.6979515400438063, Humidity: 43.14369840604783
Command received: SendData
Sending data as per the SendData command
Sending telemetry message: {'Temperature': '27.29867310808949', 'WindSpeed': '13.248563468902477', 'Humidity': '59.27518440557587'}

Telemetry and LastCommandReceived property sent
Command received: SendData
Sending data as per the SendData command
Sending telemetry message: {'Temperature': '22.925703228495472', 'WindSpeed': '4.502406246315697', 'Humidity': '59.97958804788951'}

Telemetry and LastCommandReceived property sent
Command received: SendData
Sending data as per the SendData command
Sending telemetry message: {'Temperature': '28.88950116551797', 'WindSpeed': '10.79207524667342', 'Humidity': '31.540614487911295'}

Telemetry and LastCommandReceived property sent
Sending telemetry message: {'Temperature': '26.564037838889718', 'WindSpeed': '3.7145350383813938', 'Humidity': '49.15990199578594'}

Telemetry sent - Temperature: 26.564037838889718, Wind Speed: 3.7145350383813938, Humidity: 49.15990199578594
Sending telemetry message: {'Temperature': '22.787014754281163', 'WindSpeed': '11.82564325216387', 'Humidity': '58.86785044208952'}

Telemetry sent - Temperature: 22.787014754281163, Wind Speed: 11.82564325216387, Humidity: 58.86785044208952
|

```

khalil IoT device1		Search for devices			
Connect	10/9/2024, 3:03:24 PM	Command response	10/9/2024, 3:03:20 PM	{ data: 'Command received ...	
Devices	> 10/9/2024, 3:03:24 PM	Command request	10/9/2024, 3:03:20 PM	['connectTimeoutSeconds...	
Device groups	> 10/9/2024, 3:03:24 PM	Command response	10/9/2024, 3:03:19 PM	['data':'Command received'...	
Device templates	> 10/9/2024, 3:03:24 PM	Command request	10/9/2024, 3:03:19 PM	['connectTimeoutSeconds...	
Edge manifests	> 10/9/2024, 3:03:24 PM	Telemetry	49.15990199578594	26.564037838889718	3.7145350383813938
Analyze	> 10/9/2024, 3:03:22 PM	Property			1728417801.8633695
Data explorer	> 10/9/2024, 3:03:21 PM	Telemetry	31.540614487911295	28.88950116551797	10.79207524667342
Dashboards	> 10/9/2024, 3:03:20 PM	Property			1728417800.7618253
Manage	> 10/9/2024, 3:03:20 PM	Telemetry	59.97958804788951	22.925703228495472	4.502406246315697
Jobs	> 10/9/2024, 3:03:19 PM	Property			1728417799.7948694
Extend	> 10/9/2024, 3:03:19 PM	Telemetry	59.27518440557587	27.29867310808949	13.248563468902477
Rules	> 10/9/2024, 3:03:19 PM	Command response	10/9/2024, 3:03:18 PM	['data':'Command received'...	
Data export	> 10/9/2024, 3:03:19 PM	Command request	10/9/2024, 3:03:18 PM	['connectTimeoutSeconds...	
Security	> 10/9/2024, 3:03:19 PM	Command response	10/9/2024, 3:03:17 PM	['data':'Command received'...	
Audit logs	> 10/9/2024, 3:03:19 PM	Command request	10/9/2024, 3:03:16 PM	['connectTimeoutSeconds...	
Permissions	> 10/9/2024, 3:03:18 PM	Telemetry	43.14369840604783	29.12713099419058	2.6979515400438063
Settings	> 10/9/2024, 3:03:18 PM	Property			1728417796.2073445
Application	> 10/9/2024, 3:03:18 PM	Telemetry	43.95249622807604	25.28265855791901	6.732743479077184
Customization	> 10/9/2024, 3:03:17 PM	Property			1728417797.1795728
	> 10/9/2024, 3:03:17 PM	Telemetry	58.41585678487014	29.10632896640142	8.317005025601587
	> 10/9/2024, 3:03:13 PM	Telemetry	62.33343200480319	20.27455802022707	1.6235225255041097
	> 10/9/2024, 3:03:08 PM	Telemetry	49.77968679312538	19.619694587887587	7.388749466883024
	> 10/9/2024, 3:03:03 PM	Telemetry	62.37203119258928	18.118128673075773	0.6434469549032323
	> 10/9/2024, 3:03:03 PM	Property			1728417783.6323893
	> 10/9/2024, 3:03:03 PM	Device connected			

khali IoT device1

ConnectManage templateManage device

Devices

Device groups

Device templates

Edge manifests

Analyze

Data explorer

Dashboards

Manage

Jobs

Extend

Rules

Data export

Security

Audit logs

Permissions

Settings

Application

Customization

Search for devices

Devices > Lab 5 > khali - 26zno16fzh7

khali - 26zno16fzh7

connected | Last data received: 10/8/2024, 3:03:34 PM | Status: Provisioned | Organization: khali IoT device1

CommandRaw dataMapped aliasesFiles

Timestamp	Message type	Event creation time	Humidity	Temperature	WindSpeed	LastCommandReceived	LastPowerOn	SendData	Unmodeled data
> 10/8/2024, 3:03:49 PM	Telemetry		64.45603020997138	23.53622124863768	8.823795737219454				
> 10/8/2024, 3:03:44 PM	Telemetry		67.92056796603608	16.510632137672538	14.806594981816275				
> 10/8/2024, 3:03:39 PM	Telemetry		34.762244903811414	28.422020598223387	2.3198086132660146				
> 10/8/2024, 3:03:34 PM	Telemetry		36.61386559549692	15.72073061207818	12.57744262184038				
> 10/8/2024, 3:03:29 PM	Telemetry		58.86785044208952	22.787014754281163	11.62594325216387				
> 10/8/2024, 3:03:24 PM	Command response	10/8/2024, 3:03:22 PM							[ "data": "Command received" ...
> 10/8/2024, 3:03:24 PM	Command request	10/8/2024, 3:03:21 PM							[ "connectTimeoutInSeconds": ...
> 10/8/2024, 3:03:24 PM	Command response	10/8/2024, 3:03:20 PM							[ "data": "Command received" ...
> 10/8/2024, 3:03:24 PM	Command request	10/8/2024, 3:03:20 PM							[ "connectTimeoutInSeconds": ...
> 10/8/2024, 3:03:24 PM	Command response	10/8/2024, 3:03:19 PM							[ "data": "Command received" ...
> 10/8/2024, 3:03:24 PM	Command request	10/8/2024, 3:03:19 PM							[ "connectTimeoutInSeconds": ...
> 10/8/2024, 3:03:24 PM	Telemetry		49.15990199578594	26.564037838889718	3.7145350383813938				
> 10/8/2024, 3:03:22 PM	Property					1728417801.8633695			
> 10/8/2024, 3:03:21 PM	Telemetry		31.540614487911295	28.88950116551797	10.79207324667342				
> 10/8/2024, 3:03:20 PM	Property					1728417800.7618253			
> 10/8/2024, 3:03:20 PM	Telemetry		59.97958804788951	22.925703228495472	4.502406246315697				
> 10/8/2024, 3:03:19 PM	Property					1728417799.7948594			
> 10/8/2024, 3:03:19 PM	Telemetry		59.27518440557587	27.2986731008949	13.2489363468902477				
> 10/8/2024, 3:03:19 PM	Command response	10/8/2024, 3:03:18 PM							[ "data": "Command received" ...
> 10/8/2024, 3:03:19 PM	Command request	10/8/2024, 3:03:18 PM							[ "connectTimeoutInSeconds": ...

Apala's Data



Connect

Devices

Device groups

Device templates

Edge manifests

Analyze

Data explorer

Dashboards

Manage

Jobs

Extend

Rules

Data export

Security

Audit logs

Permissions

Settings

Application

Customization

Connect

Manage template

Manage device

Devices > Lab 5 > Apala - 2mt69me4w6q

Apala - 2mt69me4w6q

Connected | Last data received: 10/8/2024, 2:59:23 PM | Status: Provisioned | Organization: knall IoT device1

Command

Raw data

Mapped aliases

Files

Timestamp ↓	Message type	Event creation time	Humidity	Temperature	WindSpeed	LastCommandReceived	LastPowerOn	SendData	Unmodeled data
> 10/8/2024, 2:59:23 PM	Telemetry		30.469920593077212	15.001675422972106	3.482050116473827				
> 10/8/2024, 2:59:18 PM	Telemetry		41.40506448426863	19.045860121423978	2.0649421114418836				
> 10/8/2024, 2:59:13 PM	Telemetry		34.74847772868293	22.783228612443985	7.480136430118087				
> 10/8/2024, 2:59:08 PM	Telemetry		33.7933605020944	25.90855289467777	4.858709962707458				
> 10/8/2024, 2:59:03 PM	Telemetry		56.40659730108816	15.639939566172844	3.4118932686160577				
> 10/8/2024, 2:58:58 PM	Telemetry		51.95240293401561	21.25884852875905	1.0776899153257684				
> 10/8/2024, 2:58:53 PM	Telemetry		58.820415649494485	23.1243083813496	3.9094698172568627				
> 10/8/2024, 2:58:48 PM	Telemetry		55.44022294364654	24.405043930878964	13.583586387395068				
> 10/8/2024, 2:58:43 PM	Telemetry		31.28747064891527	22.499926581781455	11.802025652943432				
> 10/8/2024, 2:58:38 PM	Telemetry		48.1901496262866	23.916170663398564	2.5833956525039143				
> 10/8/2024, 2:58:33 PM	Telemetry		69.6185898313049	29.31948201280925	1.1784328023814539				
> 10/8/2024, 2:58:28 PM	Telemetry		45.41778609631289	26.313562825268997	6.2446064487115285				
> 10/8/2024, 2:58:23 PM	Telemetry		32.104246738317165	16.93037476619139	9.523074088108006				
> 10/8/2024, 2:58:18 PM	Telemetry		53.009578364743296	25.71993808846555	0.09973075986256241				
> 10/8/2024, 2:58:12 PM	Telemetry		63.33999926252413	29.28560401907903	6.837895149935603				
> 10/8/2024, 2:58:07 PM	Telemetry		66.02791173269037	29.61415767715416	4.301994893848118				
> 10/8/2024, 2:58:02 PM	Telemetry		38.41953491123921	15.103837812666264	4.819624144848908				
> 10/8/2024, 2:57:57 PM	Telemetry		34.673047407515355	27.07063931066128	0.9749685805688674				
> 10/8/2024, 2:57:52 PM	Telemetry		37.196103003105705	29.13917392311374	10.124432119176225				
> 10/8/2024, 2:57:47 PM	Telemetry		40.618299703681027	24.927880787878114	0.84771188816201086				

Audrey's Data



```
Device connected and LastPowerOn property sent
Sending telemetry message: {'Temperature': '27.98933687513839', 'WindSpeed': '2.0257362784817836', 'Humidity': '52.0909479464964'}

Telemetry sent - Temperature: 27.98933687513839, Wind Speed: 2.0257362784817836, Humidity: 52.0909479464964
Sending telemetry message: {'Temperature': '26.486423607108517', 'WindSpeed': '12.939817200198133', 'Humidity': '39.79806240853122'}

Telemetry sent - Temperature: 26.486423607108517, Wind Speed: 12.939817200198133, Humidity: 39.79806240853122
Sending telemetry message: {'Temperature': '16.17942569491931', 'WindSpeed': '14.719101661272841', 'Humidity': '51.10547122064736'}

Telemetry sent - Temperature: 16.17942569491931, Wind Speed: 14.719101661272841, Humidity: 51.10547122064736
Sending telemetry message: {'Temperature': '17.70794605377311', 'WindSpeed': '10.355354320592664', 'Humidity': '48.93687247310278'}

Telemetry sent - Temperature: 17.70794605377311, Wind Speed: 10.355354320592664, Humidity: 48.93687247310278
Command received: SendData
Sending data as per the SendData command
Sending telemetry message: {'Temperature': '29.626980706140934', 'WindSpeed': '11.162051029645701', 'Humidity': '37.27593142362505'}

Telemetry and LastCommandReceived property sent
Sending telemetry message: {'Temperature': '17.93767890552671', 'WindSpeed': '12.398664928196474', 'Humidity': '53.67527106150339'}

Telemetry sent - Temperature: 17.93767890552671, Wind Speed: 12.398664928196474, Humidity: 53.67527106150339
Command received: SendData
Sending data as per the SendData command
Sending telemetry message: {'Temperature': '26.77807002655427', 'WindSpeed': '8.722287330985994', 'Humidity': '42.105739979908755'}

Telemetry and LastCommandReceived property sent
Command received: SendData
Sending data as per the SendData command
Sending telemetry message: {'Temperature': '22.30849219273089', 'WindSpeed': '11.899857573274893', 'Humidity': '63.39174830453417'}

Telemetry and LastCommandReceived property sent
Command received: SendData
Sending data as per the SendData command
Sending telemetry message: {'Temperature': '24.172770978916787', 'WindSpeed': '10.324742925489096', 'Humidity': '45.32791300187543'}

Telemetry and LastCommandReceived property sent
Sending telemetry message: {'Temperature': '24.071245883469576', 'WindSpeed': '14.640179816117683', 'Humidity': '41.8582854899856'}

Telemetry sent - Temperature: 24.071245883469576, Wind Speed: 14.640179816117683, Humidity: 41.8582854899856
Command received: SendData
Sending data as per the SendData command
Sending telemetry message: {'Temperature': '20.354820901974268', 'WindSpeed': '9.389411012899105', 'Humidity': '35.286751886467414'}

Telemetry and LastCommandReceived property sent
Command received: SendData
Sending data as per the SendData command
Sending telemetry message: {'Temperature': '20.126932059251274', 'WindSpeed': '7.058834054616527', 'Humidity': '49.741192833936836'}

Telemetry and LastCommandReceived property sent
Sending telemetry message: {'Temperature': '29.80845927068396', 'WindSpeed': '2.8332755127906544', 'Humidity': '58.96881184363305'}
```

Connect	Connect	Manage template	Manage device				
Devices	>	10/8/2024, 3:01:15 PM	Command response	10/8/2024, 3:01:10 PM			[\"data\": \"Command received\"...
Device groups	>	10/8/2024, 3:01:14 PM	Command request	10/8/2024, 3:01:10 PM			[\"connectTimeoutInSeconds...
Device templates	>	10/8/2024, 3:01:14 PM	Telemetry	49.741192833936836	20.126932059251274	7.058834054616527	
Edge manifests	>	10/8/2024, 3:01:13 PM	Property				1728417673.4366777
Analyze	>	10/8/2024, 3:01:13 PM	Telemetry	35.286751886467414	20.354820901974268	9.389411012899105	
Data explorer	>	10/8/2024, 3:01:12 PM	Telemetry	41.8582854899856	24.071245883469576	14.640179816117683	
Dashboards	>	10/8/2024, 3:01:12 PM	Property				1728417671.9759429
Manage	>	10/8/2024, 3:01:11 PM	Telemetry	45.32791300187543	24.172770978916787	10.324742925489096	
Jobs	>	10/8/2024, 3:01:10 PM	Property				1728417670.2221047
Extend	>	10/8/2024, 3:01:10 PM	Telemetry	63.39174830453417	22.30849219273089	11.899857573274893	
Rules	>	10/8/2024, 3:01:09 PM	Command response	10/8/2024, 3:01:09 PM			[\"data\": \"Command received\"...
Data export	>	10/8/2024, 3:01:09 PM	Command request	10/8/2024, 3:01:08 PM			[\"connectTimeoutInSeconds...
Security	>	10/8/2024, 3:01:09 PM	Command response	10/8/2024, 3:01:07 PM			[\"data\": \"Command received\"...
Audit logs	>	10/8/2024, 3:01:09 PM	Command request	10/8/2024, 3:01:06 PM			[\"connectTimeoutInSeconds...
Permissions	>	10/8/2024, 3:01:09 PM	Property				1728417668.8536332
Settings	>	10/8/2024, 3:01:08 PM	Telemetry	42.105739979908755	26.77807002655427	8.722287330985994	
Application	>	10/8/2024, 3:01:07 PM	Telemetry	53.67527106150339	17.93767890552671	12.398664928196474	
Customization	>	10/8/2024, 3:01:07 PM	Property				1728417666.9038403
	>	10/8/2024, 3:01:06 PM	Telemetry	37.27593142362505	29.626980706140934	11.162051029645701	
	>	10/8/2024, 3:01:02 PM	Telemetry	48.93687247310278	17.70794605377311	10.355354320592664	
	>	10/8/2024, 3:00:57 PM	Telemetry	51.10547122064736	16.17942569491931	14.719101661272841	
	>	10/8/2024, 3:00:52 PM	Telemetry	39.79806242853122	26.486423607108517	12.939817200198133	
	>	10/8/2024, 3:00:47 PM	Telemetry	52.0909479464964	27.98933687513839	2.0257362784817836	
	>	10/8/2024, 3:00:47 PM	Property				1728417646.9610677

Connect

Devices

Device groups

Device templates

Edge manifests

Analyze

Data explorer

Dashboards

Manage

Jobs

Extend

Rules

Data export

Security

Audit logs

Permissions

Settings

Application

Customization

IoT Central Monitor

Connect

Manage template

Manage device

Devices > Lab 5 > Audrey - rb20scn64p

Audrey - rb20scn64p

Last data received: 10/8/2024, 3:00:57 PM | Status: Provisioned | Organization: khali IoT device1

Command

Raw data

Mapped aliases

Files

Timestamp ↓	Message type	Event creation time	Humidity	Temperature	WindSpeed	LastCommandReceived	LastPowerOn	SendData	Unmodeled data
> 10/8/2024, 3:01:15 PM	Command request	10/8/2024, 3:01:14 PM						[{"data":{"Command received": ...	
> 10/8/2024, 3:01:15 PM	Command response	10/8/2024, 3:01:13 PM						[{"data":{"Command received": ...	
> 10/8/2024, 3:01:15 PM	Command request	10/8/2024, 3:01:13 PM						[{"data":{"Command received": ...	
> 10/8/2024, 3:01:15 PM	Command response	10/8/2024, 3:01:12 PM						[{"data":{"Command received": ...	
> 10/8/2024, 3:01:15 PM	Command request	10/8/2024, 3:01:11 PM						[{"data":{"Command received": ...	
> 10/8/2024, 3:01:15 PM	Property					1728417674.687573			
> 10/8/2024, 3:01:15 PM	Command response	10/8/2024, 3:01:10 PM						[{"data":{"Command received": ...	
> 10/8/2024, 3:01:14 PM	Command request	10/8/2024, 3:01:10 PM						[{"data":{"Command received": ...	
> 10/8/2024, 3:01:14 PM	Telemetry		49.741192833936836	20.126932059251274	7.058834054616527				
> 10/8/2024, 3:01:13 PM	Property					1728417673.4366777			
> 10/8/2024, 3:01:13 PM	Telemetry		35.286751886467414	20.354820901974268	9.389411012899105				
> 10/8/2024, 3:01:12 PM	Telemetry		41.8592854699956	24.071245863469576	14.640179616117663				
> 10/8/2024, 3:01:12 PM	Property					1728417671.9759429			
> 10/8/2024, 3:01:11 PM	Telemetry		45.32791300187543	24.172770978916787	10.324742925489096				
> 10/8/2024, 3:01:10 PM	Property					1728417670.2221847			
> 10/8/2024, 3:01:10 PM	Telemetry		63.39174830433417	22.30649219273089	11.899857573274893				
> 10/8/2024, 3:01:09 PM	Command response	10/8/2024, 3:01:09 PM						[{"data":{"Command received": ...	
> 10/8/2024, 3:01:09 PM	Command request	10/8/2024, 3:01:08 PM						[{"data":{"Command received": ...	
> 10/8/2024, 3:01:09 PM	Command response	10/8/2024, 3:01:07 PM						[{"data":{"Command received": ...	
> 10/8/2024, 3:01:09 PM	Command request	10/8/2024, 3:01:06 PM						[{"data":{"Command received": ...	

Raouls's Data

```
Sending telemetry message: {'Temperature': '28.6624958030558', 'WindSpeed': '10.37665090358967', 'Humidity': '37.694733137360416'}

Telemetry and LastCommandReceived property sent
Sending telemetry message: {'Temperature': '27.760088153911198', 'WindSpeed': '0.6407438704540103', 'Humidity': '34.70783773634718'}

Telemetry sent - Temperature: 27.760088153911198, Wind Speed: 0.6407438704540103, Humidity: 34.70783773634718
Command received: SendData
Sending data as per the SendData command
Sending telemetry message: {'Temperature': '23.500485015085275', 'WindSpeed': '8.496314720363888', 'Humidity': '59.39253655885143'}

Telemetry and LastCommandReceived property sent
Command received: SendData
Sending data as per the SendData command
Sending telemetry message: {'Temperature': '20.38256374918049', 'WindSpeed': '11.396404080659044', 'Humidity': '65.96011547257973'}

Telemetry and LastCommandReceived property sent
Sending telemetry message: {'Temperature': '24.77692747506338', 'WindSpeed': '2.8723550407945626', 'Humidity': '36.1403386917345'}

Telemetry sent - Temperature: 24.77692747506338, Wind Speed: 2.8723550407945626, Humidity: 36.1403386917345
Command received: SendData
Sending data as per the SendData command
Sending telemetry message: {'Temperature': '25.092103013419162', 'WindSpeed': '3.2407166220846046', 'Humidity': '55.704898371432385'}

Telemetry and LastCommandReceived property sent
Sending telemetry message: {'Temperature': '27.345004162272893', 'WindSpeed': '14.949501374982978', 'Humidity': '56.0731395145529'}

Telemetry sent - Temperature: 27.345004162272893, Wind Speed: 14.949501374982978, Humidity: 56.0731395145529
Sending telemetry message: {'Temperature': '23.751324096485988', 'WindSpeed': '6.303104644463858', 'Humidity': '34.23396594904239'}

Telemetry sent - Temperature: 23.751324096485988, Wind Speed: 6.303104644463858, Humidity: 34.23396594904239
Sending telemetry message: {'Temperature': '20.22796172288212', 'WindSpeed': '4.206377567597767', 'Humidity': '35.83861406846003'}

Telemetry sent - Temperature: 20.22796172288212, Wind Speed: 4.206377567597767, Humidity: 35.83861406846003
Sending telemetry message: {'Temperature': '22.68606347952422', 'WindSpeed': '10.87675340133471', 'Humidity': '69.40340469559132'}

Telemetry sent - Temperature: 22.68606347952422, Wind Speed: 10.87675340133471, Humidity: 69.40340469559132
Sending telemetry message: {'Temperature': '18.338724295122887', 'WindSpeed': '7.1646893677838825', 'Humidity': '43.825107637184466'}

Telemetry sent - Temperature: 18.338724295122887, Wind Speed: 7.1646893677838825, Humidity: 43.825107637184466
Sending telemetry message: {'Temperature': '21.382951589560978', 'WindSpeed': '14.355735969555356', 'Humidity': '65.41629479567999'}

Telemetry sent - Temperature: 21.382951589560978, Wind Speed: 14.355735969555356, Humidity: 65.41629479567999
Sending telemetry message: {'Temperature': '19.20161144689449', 'WindSpeed': '9.838482600807781', 'Humidity': '67.41270413839217'}

Telemetry sent - Temperature: 19.20161144689449, Wind Speed: 9.838482600807781, Humidity: 67.41270413839217
Sending telemetry message: {'Temperature': '26.508170116768877', 'WindSpeed': '6.8284333895316465', 'Humidity': '39.93400896253121'}

Telemetry sent - Temperature: 26.508170116768877, Wind Speed: 6.8284333895316465, Humidity: 39.93400896253121
Sending telemetry message: {'Temperature': '29.393518036074802', 'WindSpeed': '0.43492981805735464', 'Humidity': '57.7064024470768'}

Telemetry sent - Temperature: 29.393518036074802, Wind Speed: 0.43492981805735464, Humidity: 57.7064024470768
```

	Connect	Manage template	Manage device						
Connect	> 10/8/2024, 2:55:13 PM	telemetry	36.00131395145529	27.243004162272893	14.949501374982978				
Devices	> 10/8/2024, 2:55:13 PM	Command response	10/8/2024, 2:55:10 PM						[{"data":{"Command received": ...
Device groups	> 10/8/2024, 2:55:13 PM	Command request	10/8/2024, 2:55:10 PM						[{"connectTimeoutSeconds": ...
Device templates	> 10/8/2024, 2:55:10 PM	Property				1728417310.5275404			
Edge manifests	> 10/8/2024, 2:55:10 PM	Telemetry	55.704898371432385	25.092103013419162	3.2407166220846046				
Analyze	> 10/8/2024, 2:55:08 PM	Telemetry	36.1403386917345	24.77692747506338	2.8723550407945626				
Data explorer	> 10/8/2024, 2:55:07 PM	Command response	10/8/2024, 2:55:07 PM						[{"data":{"Command received": ...
Dashboards	> 10/8/2024, 2:55:07 PM	Command request	10/8/2024, 2:55:06 PM						[{"connectTimeoutSeconds": ...
Manage	> 10/8/2024, 2:55:07 PM	Command response	10/8/2024, 2:55:04 PM						[{"data":{"Command received": ...
Jobs	> 10/8/2024, 2:55:07 PM	Command request	10/8/2024, 2:55:03 PM						[{"connectTimeoutSeconds": ...
Extend	> 10/8/2024, 2:55:07 PM	Property				1728417306.0713677			
Rules	> 10/8/2024, 2:55:06 PM	Telemetry	65.96011547257973	20.38256374918049	11.396404080659044				
Data export	> 10/8/2024, 2:55:04 PM	Property				1728417304.5696754			
Security	> 10/8/2024, 2:55:04 PM	Telemetry	59.39253655885143	23.500485015085275	8.496314720363888				
Audit logs	> 10/8/2024, 2:55:03 PM	Telemetry	34.70783773634718	27.760088153911198	0.6407438704540103				
Permissions	> 10/8/2024, 2:55:02 PM	Command response	10/8/2024, 2:55:01 PM						[{"data":{"Command received": ...
Settings	> 10/8/2024, 2:55:02 PM	Command request	10/8/2024, 2:55:00 PM						[{"connectTimeoutSeconds": ...
Application	> 10/8/2024, 2:55:01 PM	Property				1728417301.0461724			
Customization	> 10/8/2024, 2:55:00 PM	Telemetry	37.694733137360416	28.6624958030558	10.37665090358967				
	> 10/8/2024, 2:54:58 PM	Telemetry	34.95022748991197	15.006311067699968	11.648151048554732				
	> 10/8/2024, 2:54:53 PM	Telemetry	44.471275950261216	22.805323865453214	6.991384426403373				
	> 10/8/2024, 2:54:48 PM	Telemetry	45.726139731906535	25.861847416244032	7.695388035117948				
	> 10/8/2024, 2:54:43 PM	Telemetry	53.09251517445214	17.40503709074543	4.908478088510108				
	> 10/8/2024, 2:54:42 PM	Device connected							
	> 10/8/2024, 2:54:42 PM	Property				1728417282.7676969			

Connect

Devices

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Rules

Data export

Security

Audit logs

Permissions

Settings

Application

Customization

Connect

Manage template

Manage device

Devices > Lab 5 > Raoul - 242baqqe14v

Raoul - 242baqqe14v

Connected | Last data received: 10/8/2024, 2:55:48 PM | Status: Provisioned | Organization: khali IoT device1

Command

Raw data

Mapped aliases

Files

Timestamp ↓	Message type	Event creation time	Humidity	Temperature	WindSpeed	LastCommandReceived	LastPowerOn	SendData	Unmodeled data
> 10/8/2024, 2:55:43 PM	Telemetry		67.41270413839217	19.20161144689449	9.8334826200207781				
> 10/8/2024, 2:55:38 PM	Telemetry		65.41629479567999	21.382951589560978	14.355735969553356				
> 10/8/2024, 2:55:33 PM	Telemetry		43.825107637184486	18.338724295122887	7.16468893677838625				
> 10/8/2024, 2:55:28 PM	Telemetry		69.40340469599132	22.68606347952422	10.87673340133471				
> 10/8/2024, 2:55:23 PM	Telemetry		35.83861406846003	20.22796172288212	4.206377567997767				
> 10/8/2024, 2:55:18 PM	Telemetry		34.2339659494239	23.751324096485988	6.303104644463858				
> 10/8/2024, 2:55:13 PM	Telemetry		56.0731395145529	27.345004162272893	14.949501374982978				
> 10/8/2024, 2:55:10 PM	Command response	10/8/2024, 2:55:10 PM						[{"data":{"Command received"...	
> 10/8/2024, 2:55:10 PM	Command request	10/8/2024, 2:55:10 PM						[{"connectTimeoutInSeconds"...	
> 10/8/2024, 2:55:10 PM	Property					1728417310.5275404			
> 10/8/2024, 2:55:10 PM	Telemetry		55.704898371432385	25.092103013419162	3.3407166220646046				
> 10/8/2024, 2:55:08 PM	Telemetry		36.1403386917345	24.77692747506338	2.8723550407945626				
> 10/8/2024, 2:55:07 PM	Command response	10/8/2024, 2:55:07 PM						[{"data":{"Command received"...	
> 10/8/2024, 2:55:07 PM	Command request	10/8/2024, 2:55:06 PM						[{"connectTimeoutInSeconds"...	
> 10/8/2024, 2:55:07 PM	Command response	10/8/2024, 2:55:04 PM						[{"data":{"Command received"...	
> 10/8/2024, 2:55:07 PM	Command request	10/8/2024, 2:55:03 PM						[{"connectTimeoutInSeconds"...	
> 10/8/2024, 2:55:07 PM	Property					1728417306.8713677			
> 10/8/2024, 2:55:06 PM	Telemetry		65.96011547257973	20.38256374918049	11.396404080659044				
> 10/8/2024, 2:55:04 PM	Property					1728417304.5696754			
> 10/8/2024, 2:55:04 PM	Telemetry		59.3925365585143	23.500485015085275	8.496314720363888				

## 7. Conclusion

This lab allowed us to understand how IoT devices connect to the cloud using Azure IoT Central. We were able to create virtual devices, send telemetry data, and respond to cloud commands. The simplicity of the IoT Central platform made it easier to manage multiple devices and analyze the data.

## 8. Appendix: Code

Python script with proper documentation.

```
import random
import time
from datetime import datetime
from iotc.models import Command
from iotc import IoTCCClient, IOTCConnectType, IOTCEvents

# Replace these with your IoT Central credentials
scopeId = '0ne00CE8964' # From lab 5.txt
device_id = '26znol6fzh7' # From lab 5.txt
device_key = 'qoCaBmM9hRi7QJhw4HKIM9t680d55cv2VhC5/NqNzWE=' # From lab 5.txt

# Function to handle incoming commands
def on_commands(command: Command):
    print(f"Command received: {command.name}")

    if command.name == "SendData":
        # Send data when the "SendData" command is received
        print("Sending data as per the SendData command")
        iotc.send_telemetry({
            'Temperature': str(random.uniform(15.0, 30.0)),
            'WindSpeed': str(random.uniform(0.0, 15.0)),
            'Humidity': str(random.uniform(30.0, 70.0))
        })
        # Update the LastCommandReceived property
        iotc.send_property({
            "LastCommandReceived": time.time()
        })
        print("Telemetry and LastCommandReceived property sent")

    # Acknowledge the command
    command.reply()

# Initialize IoT Central client
iotc = IoTCCClient(
    device_id,
    scopeId,
    IOTCConnectType.IOTC_CONNECT_DEVICE_KEY,
    device_key
)

iotc.connect()

# Set up the command listener
iotc.on(IOTCEvents.IOTC_COMMAND, on_commands)

# Send the LastPowerOn property once the device is powered on
iotc.send_property({
    "LastPowerOn": time.time()
})
```

```
})
```

```
print("Device connected and LastPowerOn property sent")
```

```
# Start sending telemetry data every 60 seconds
```

```
while iotc.is_connected():
```

```
    # Generate and send telemetry data for temperature, wind speed, and humidity
```

```
    temperature = random.uniform(15.0, 30.0) # Simulated temperature in Celsius
```

```
    wind_speed = random.uniform(0.0, 15.0) # Simulated wind speed in km/h
```

```
    humidity = random.uniform(30.0, 70.0) # Simulated humidity in percentage
```

```
    # Send telemetry data
```

```
    iotc.send_telemetry({
```

```
        'Temperature': str(temperature),
```

```
        'WindSpeed': str(wind_speed),
```

```
        'Humidity': str(humidity)
```

```
    })
```

```
print(f"Telemetry sent - Temperature: {temperature}, Wind Speed: {wind_speed},
```

```
# Wait for 60 seconds before sending the next telemetry data
```

```
time.sleep(5)
```