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Message Queue Telemetry Transport (MQTT)

Current Topics in Distributed Systems: Internet of Things and Cloud Computing

Narges Mehran, MSc.
Dr. Dragi Kimovski,

SS23

Message Queue (MQ)

What is MQ

- Message queue (MQ) is a temporary message storage when the destination application is busy or not connected
- Message queuing allows applications to communicate by sending messages to each other
- Message queue provides **asynchronous communications protocol**
- The sender and receiver of the message do not need to interact with the message queue at the same time
    - Email is probably the best example of asynchronous communication.

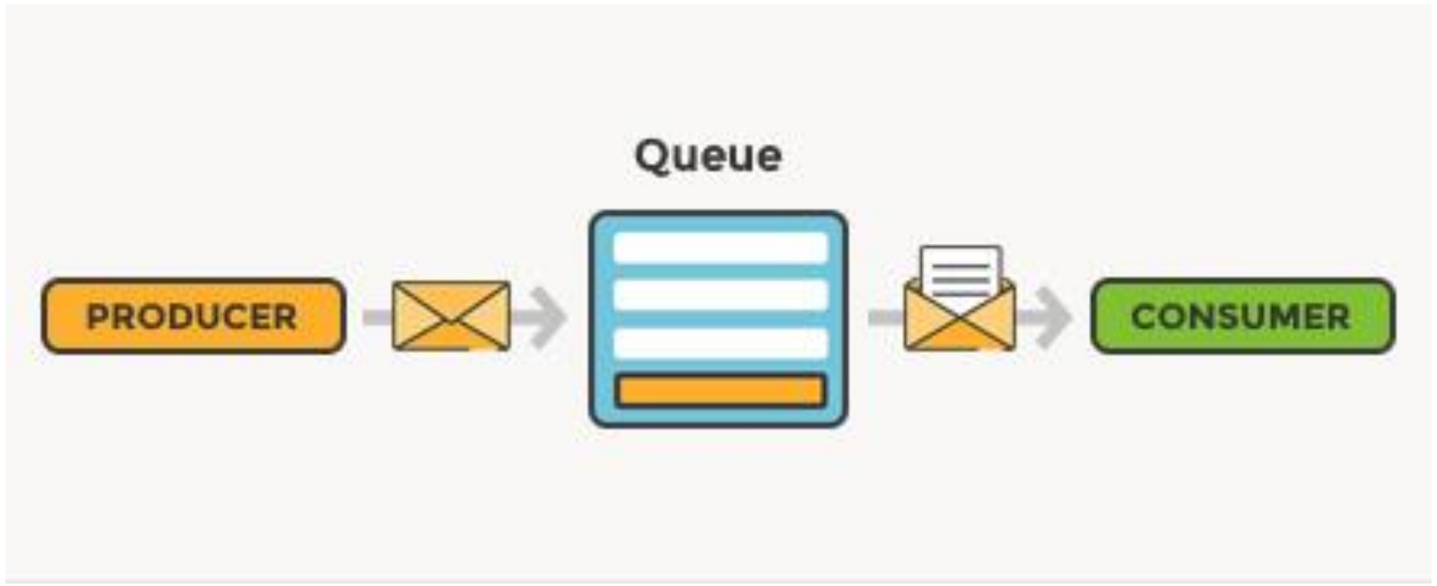
Message queuing - a simple use case

- Imagine that you have a web service,
  - receives many requests every second
  - no request can get lost
  - should not be locked by processing previously-received requests
  - all requests need to be processed by a function that has a high throughput
- Solution:
  - placing a queue between the web service and the processing service is ideal
- The queue will persist with the requests even if their number grows.

Basic architecture of message queue

- The basic architecture of a **message queue** is simple:
  - There is a client application, called producer, that creates messages and sends them to the message queue
  - Another application, called a consumer, connects to the queue and retrieves the messages to be processed
  - Messages in the queue are stored until the consumer retrieves them

Basic architecture of message queue



https://www.cloudamqp.com/blog/what-is-message-queuing.html

MQ Telemetry Transport (MQTT)

MQTT History

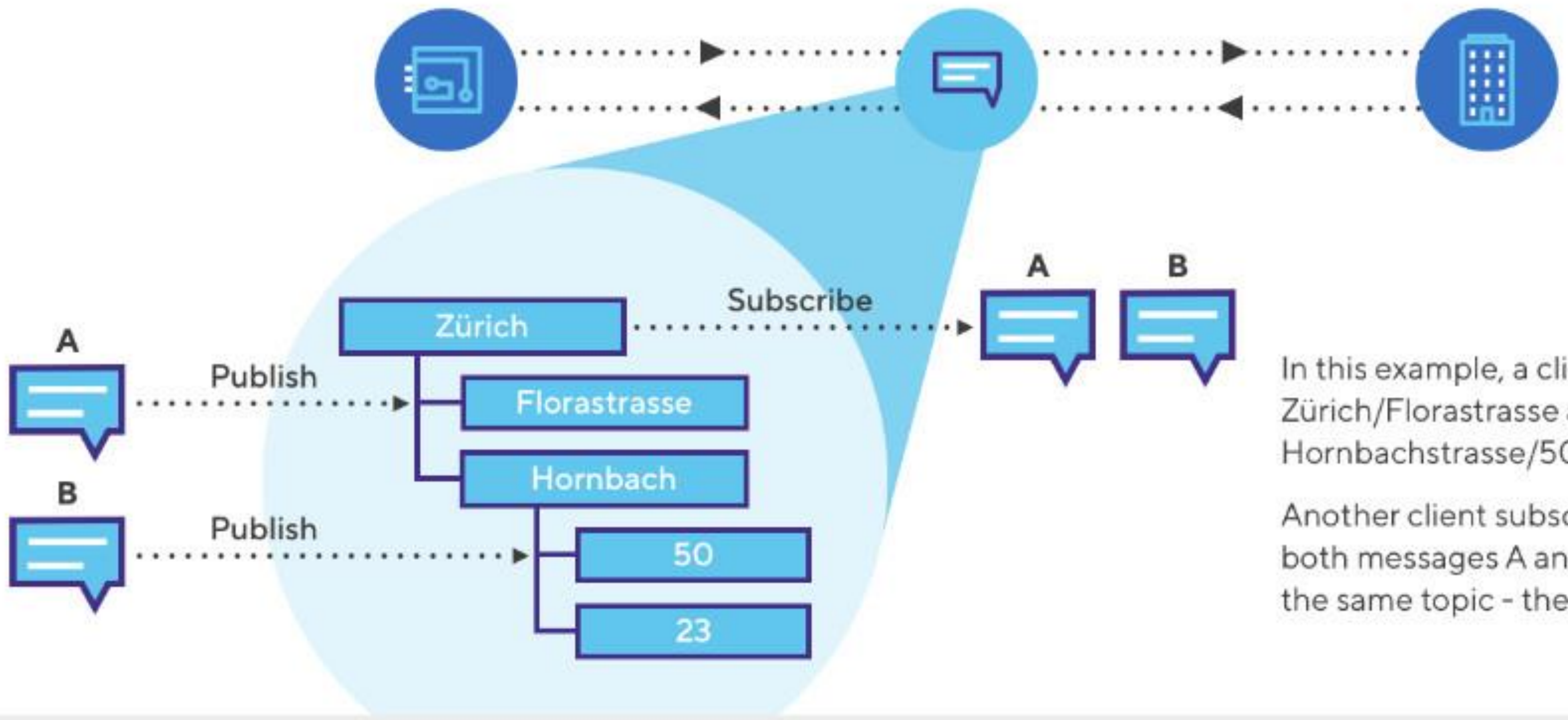
- MQTT messaging protocol was created in 1999 by IBM's Andy Stanford Clark and Eurotech's Arlen Nipper.
- MQTT is now an ISO/IEC (International Organization for Standardization and the International Electrotechnical Commission) standard.
- Standard ports for MQTT to use?
  - TCP/IP port 1883 is reserved with IANA for use with MQTT.
  - TCP/IP port 8883 is also registered, for using MQTT over SSL.

Intro.

- There are a million ways to get data from A to B and back again,
  - but doing so reliably isn’t always a cakewalk.
- For IoT devices and applications – also known as “Things” – a reliable, robust and secure messaging protocol is required.
- That’s where the messaging protocol, MQTT comes in.

What is MQTT?

THINGSTREAM



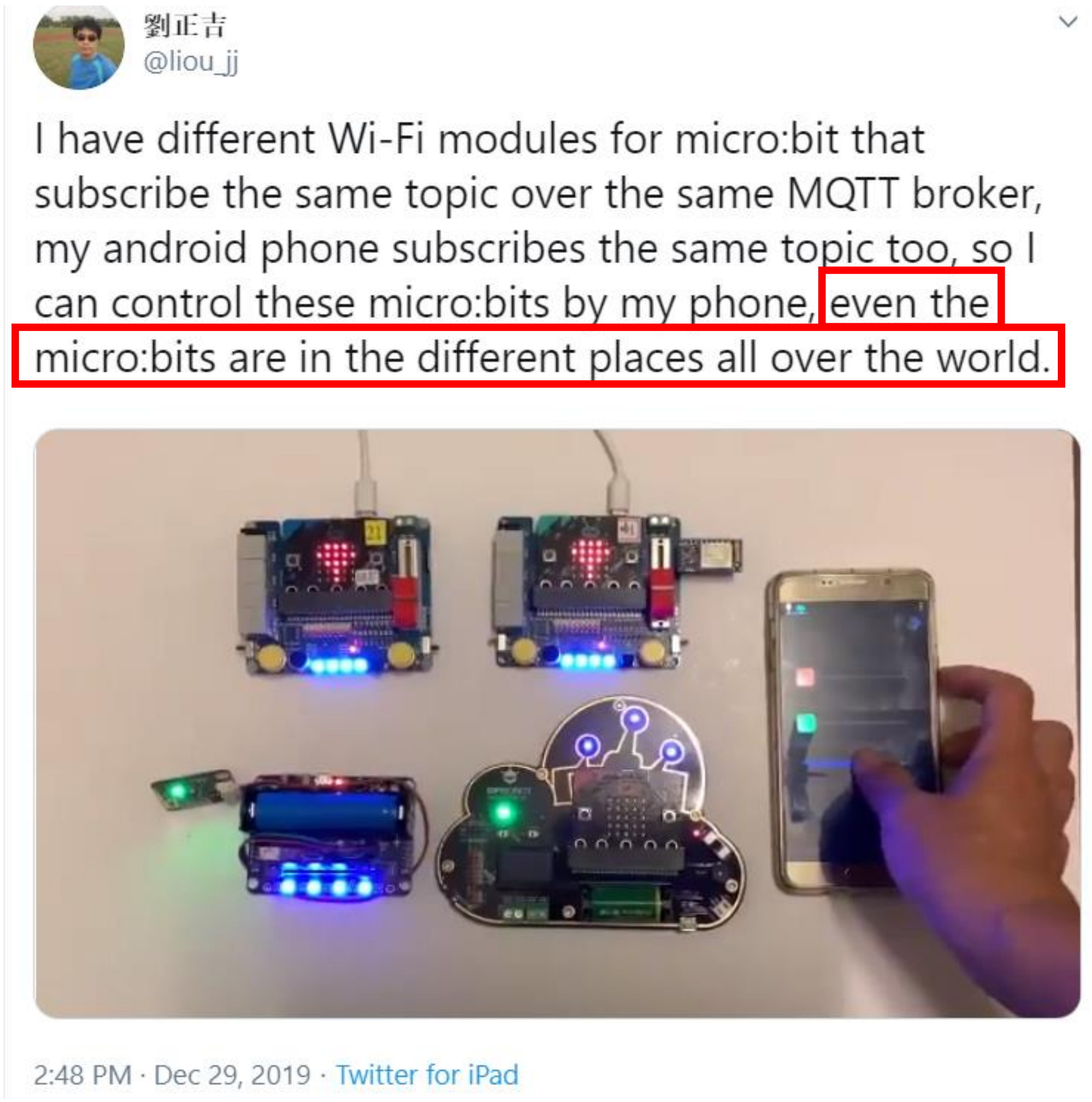
In this example, a client publishes message A to topic Zürich/Florastrasse and message B to topic Zürich/Hornbachstrasse/50.

Another client subscribes to topic Zürich. It will receive both messages A and B. Many clients can subscribe to the same topic - they will all receive the messages.

- MQTT has become the de-facto **standard for IoT communication** because of its efficiency and flexibility. **Thingstream** uses this to **overlay various radio networks** (2G-4G cellular and LoRa) **and protocols** (USSD, UDP) providing developers a familiar and simple experience.
- MQTT is a **protocol that allows devices and systems** (clients) to **communicate** by sending messages. Messages are not sent directly from client to client but are published by a client to a topic stored in an **MQTT broker**.
- **Topics** are like street addresses - they form a tree which becomes more specific the further down the tree you travel.
- Clients receive messages by **subscribing to one or more topics** - but they will receive messages from that point onwards.
- Messages can be published with different **Quality of Service** levels which define how reliably and whether receipts are generated for delivery.

The micro:bits and the phone communicate with each other through the MQTT protocol on the Internet.

https://twitter.com/i/status/1211282793633742848



劉正吉
@liou_jj

I have different Wi-Fi modules for micro:bit that subscribe the same topic over the same MQTT broker, my android phone subscribes the same topic too, so I can control these micro:bits by my phone, even the micro:bits are in the different places all over the world.

2:48 PM · Dec 29, 2019 · Twitter for iPad

micro:bit is a tiny programmable computer, designed to make learning and teaching easy and fun! https://microbit.org/

Facebook using MQTT

- Facebook uses MQTT for messenger chats. Each “Chat” has a generated *Topic*, and all members in the chat subscribe and publish to that generated *Topic*.
- “One of the problems we experienced was long latency when sending a message. The previous method was reliable but slow, and there were limitations on how much we could improve it. With just a few weeks until launch time, we built a new mechanism that maintains a persistent connection to our servers. Without killing battery life, we used a protocol called MQTT that we had experimented with within Beluga (the new Facebook messenger app). MQTT is specifically designed for applications like sending telemetry data to and from space probes. Therefore, it is designed to use bandwidth and batteries sparingly. By maintaining an MQTT connection and routing messages through our chat pipeline, we often achieved phone-to-phone delivery in the hundreds of milliseconds rather than multiple seconds.”

https://www.facebook.com/notes/10158791547142200/

Intro. (cont.)

MQTT

- is a lightweight protocol
- uses a publish/subscribe model
- typically uses IP (Internet Protocol) as its
- has low network overhead
- can be implemented on low-power devices such as microcontrollers connected to the sensors
- therefore, it is suitable for "machine to machine" messaging such as low power sensors and mobile devices.

Why is MQTT perfect for IoT?

- IoT devices:
  - ➢get data from the network and send the collected data to the network
  - ➢these networks could be anywhere in the world

- Some of the main features are:
  1. Reliability
     - MQTT QoS levels
       - ➢ MQTT and MQTT-SN support multiple levels of QoS for guaranteeing message delivery.
  2. Bidirectional messaging
  3. Messaging at scale

MQTT client and broker

- Don’t think, “client and server”
  - ➢think, “client and broker” instead.

- In a traditional client/server model:
  - ➢the client and server connect to each other.
  - ➢the remote server is treated as a storage and compute machine for the data.

- With MQTT:
  - ➢the broker acts more like a signpost for where the data should go.

MQTT client

- Any Thing (from a microcontroller to a high-performant server), that runs an MQTT library and connects to an MQTT broker over a network,
  - ➢can effectively become an MQTT client.
- Clients don’t send messages directly between each other but instead communicate to topics managed by the broker.
- These topics work a little bit such as email inboxes.
- Messages are published by Things to topics,
  - ➢messages are then picked up by a Thing previously subscribed to those topics.

MQTT broker

- The broker handles authentication of Things on the network as well as managing connections, sessions and subscriptions.

- Its main responsibility is to receive all published messages,
  - ➢then send them to subscribed clients.

- The broker also queues messages for subscribed clients, delivering them according to the agreed QoS level.

How to Register Devices to IBM Watson IoT Platform?

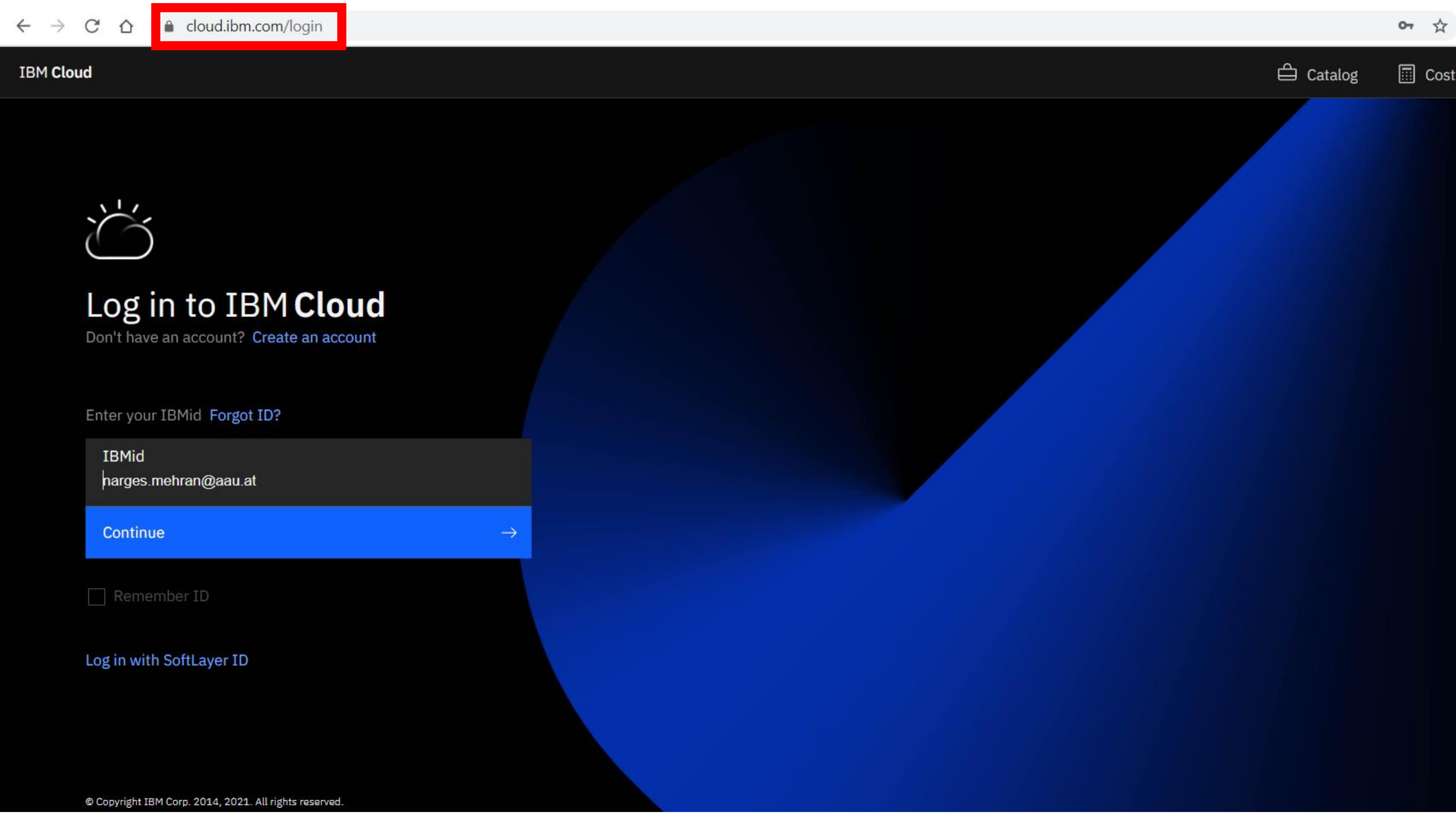
- The IBM Watson IoT Platform is a fully managed, cloud-hosted service that makes it simple to derive value from Internet of Things (IoT) devices.

- The following link shows how one can setup a Watson IoT organization and register devices in it: https://cloud.ibm.com/docs/IoT/index.html

- https://cloud.ibm.com/catalog#services

- https://cloud.ibm.com/catalog/services/internet-of-things-platform

- https://internetofthings.ibmcloud.com/



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Don't have an account? Create an account

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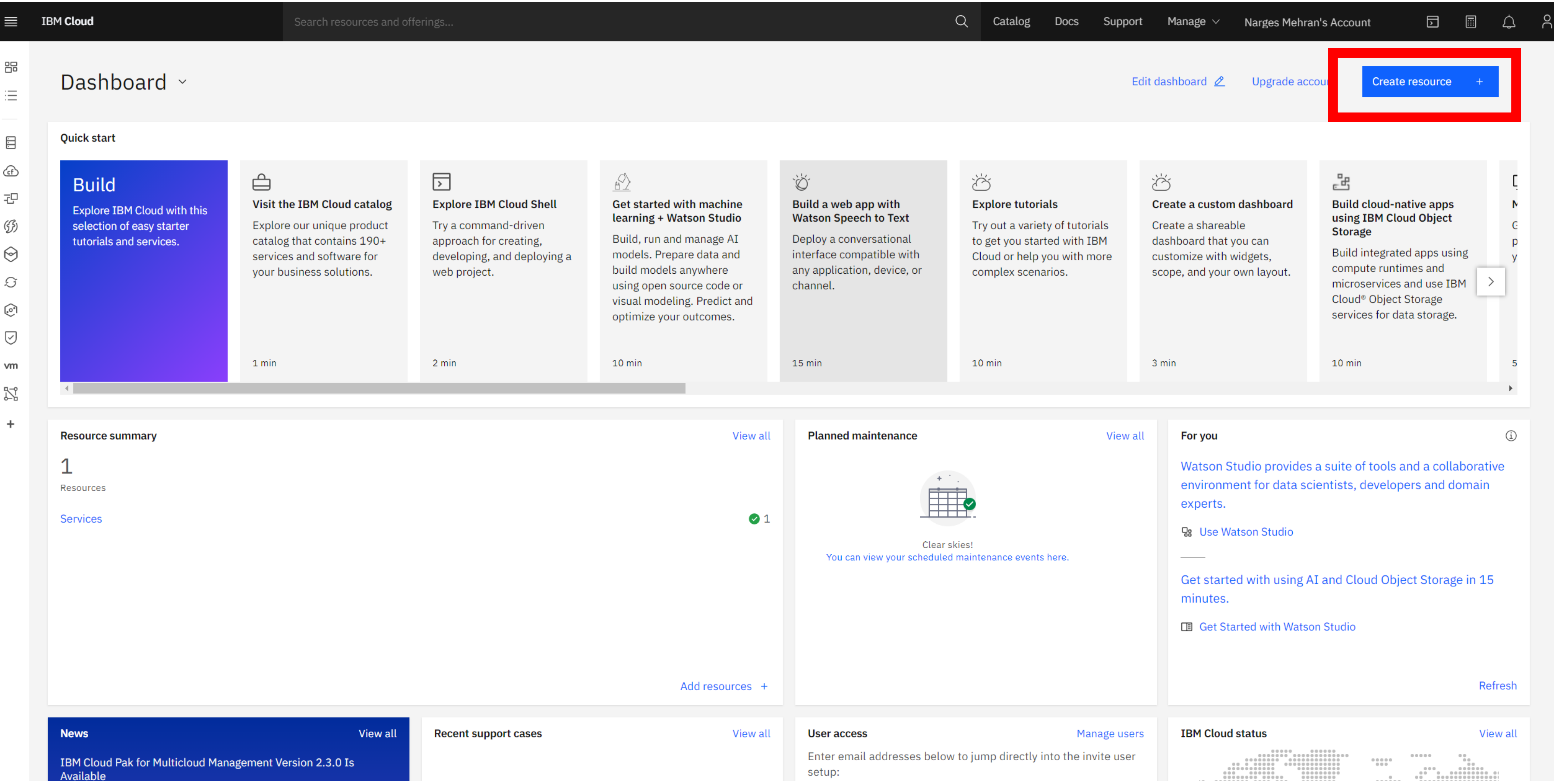
IBMid
narges.mehran@aau.at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1
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Enter email addresses below to jump directly into the invite user setup:

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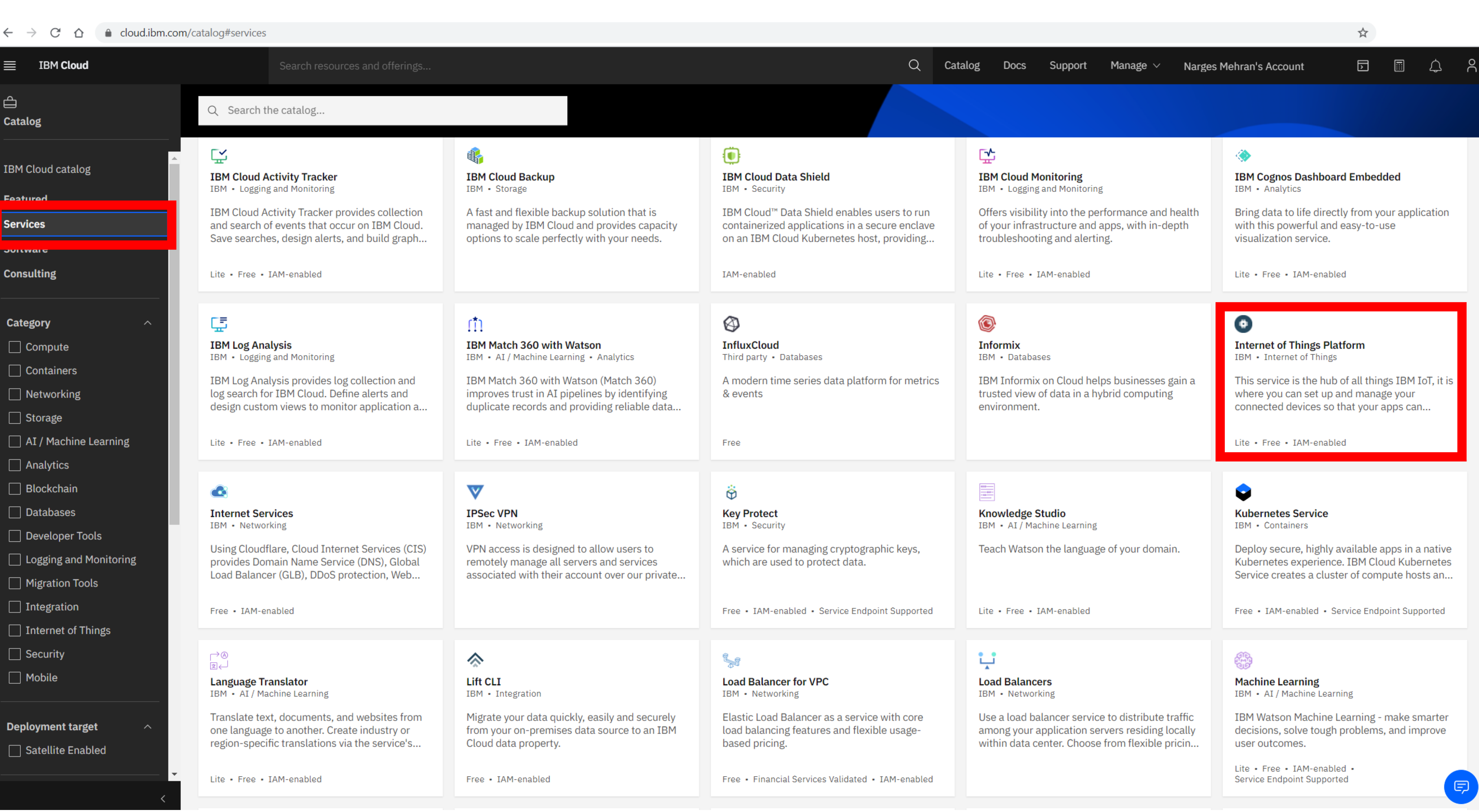

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This service is the hub of all things IBM IoT, it is where you can set up and manage your connected devices so that your apps can...
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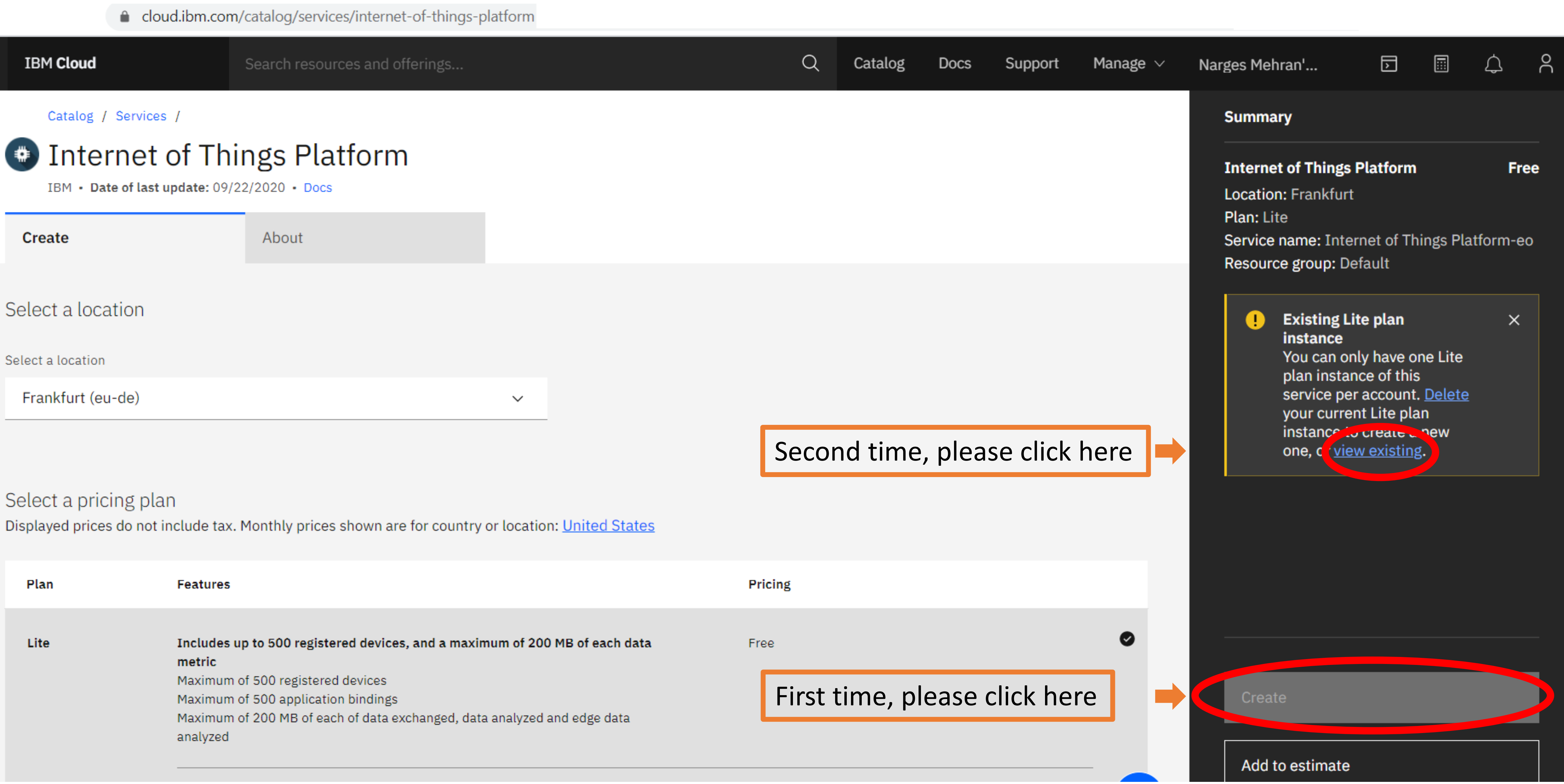

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Internet of Things Platform

IBM • **Date of last update:** 09/22/2020 • Docs

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Select a location

Frankfurt (eu-de)

Select a pricing plan

Displayed prices do not include tax. Monthly prices shown are for country or location: United States

Plan	Features	Pricing
Lite	**Includes up to 500 registered devices, and a maximum of 200 MB of each data metric** Maximum of 500 registered devices Maximum of 500 application bindings Maximum of 200 MB of each of data exchanged, data analyzed and edge data analyzed	Free

Summary

Internet of Things Platform **Free**

Location: Frankfurt

Plan: Lite

Service name: Internet of Things Platform-eo

Resource group: Default

Existing Lite plan instance
You can only have one Lite plan instance of this service per account. Delete your current Lite plan instance to create a new one, or view existing.

Create

Add to estimate

Second time, please click here

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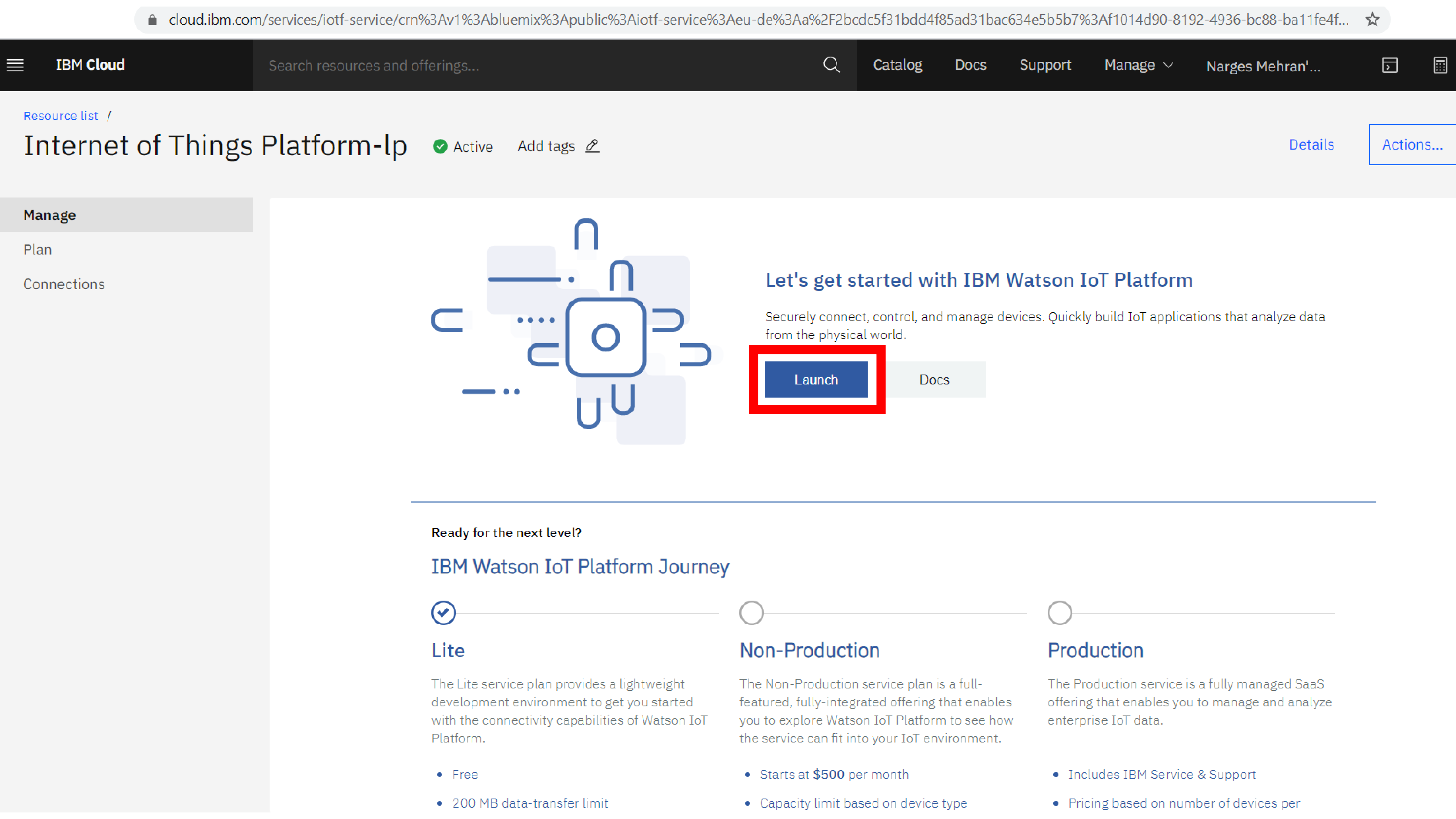

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Internet of Things Platform-lp

Let's get started with IBM Watson IoT Platform

Securely connect, control, and manage devices. Quickly build IoT applications that analyze data from the physical world.

Ready for the next level?

IBM Watson IoT Platform Journey

Lite

The Lite service plan provides a lightweight development environment to get you started with the connectivity capabilities of Watson IoT Platform.

- Free
- 200 MB data-transfer limit

Non-Production

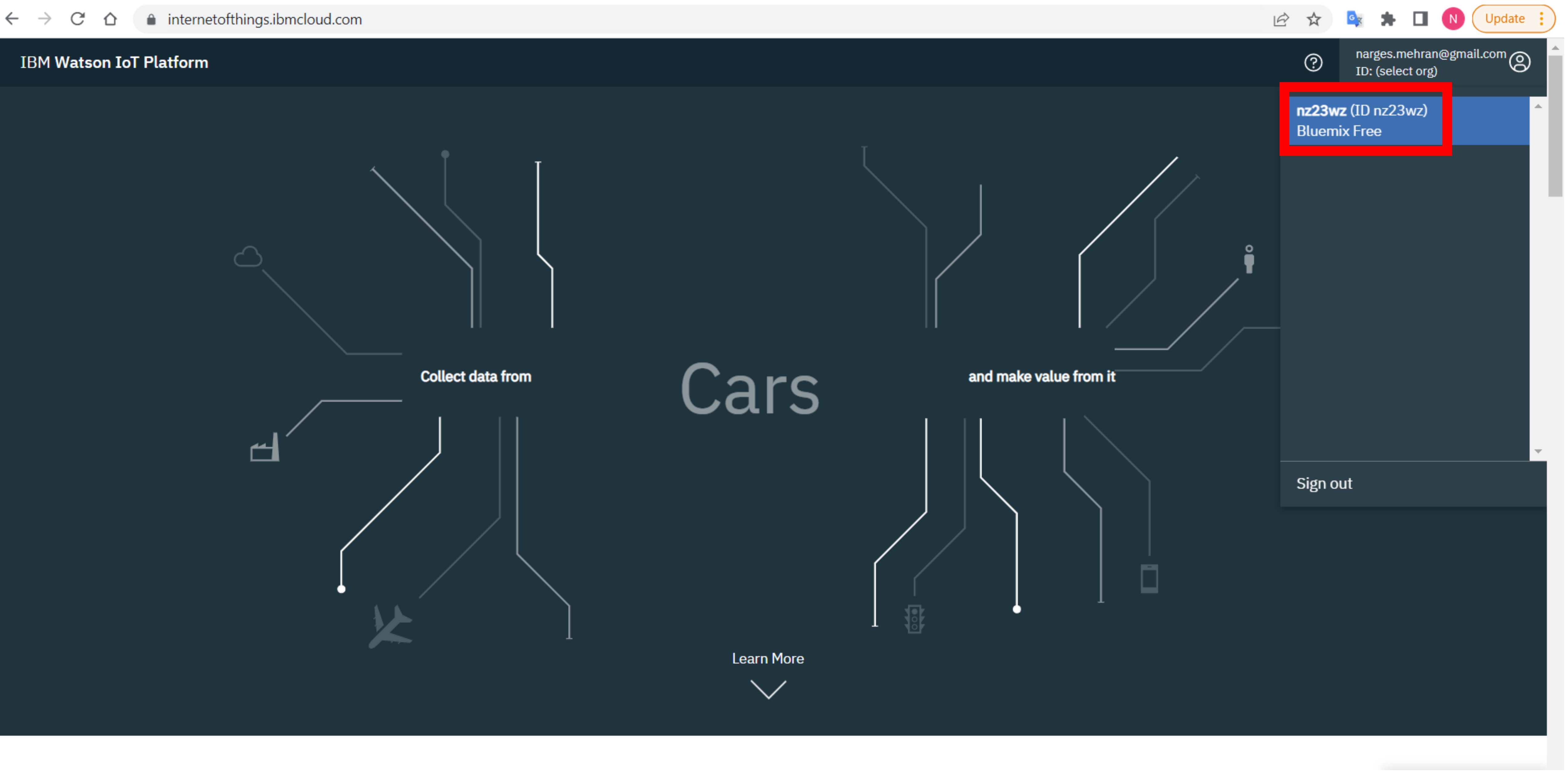
The Non-Production service plan is a full-featured, fully-integrated offering that enables you to explore Watson IoT Platform to see how the service can fit into your IoT environment.

- Starts at $500 per month
- Capacity limit based on device type

Production

The Production service is a fully managed SaaS offering that enables you to manage and analyze enterprise IoT data.

- Includes IBM Service & Support
- Pricing based on number of devices per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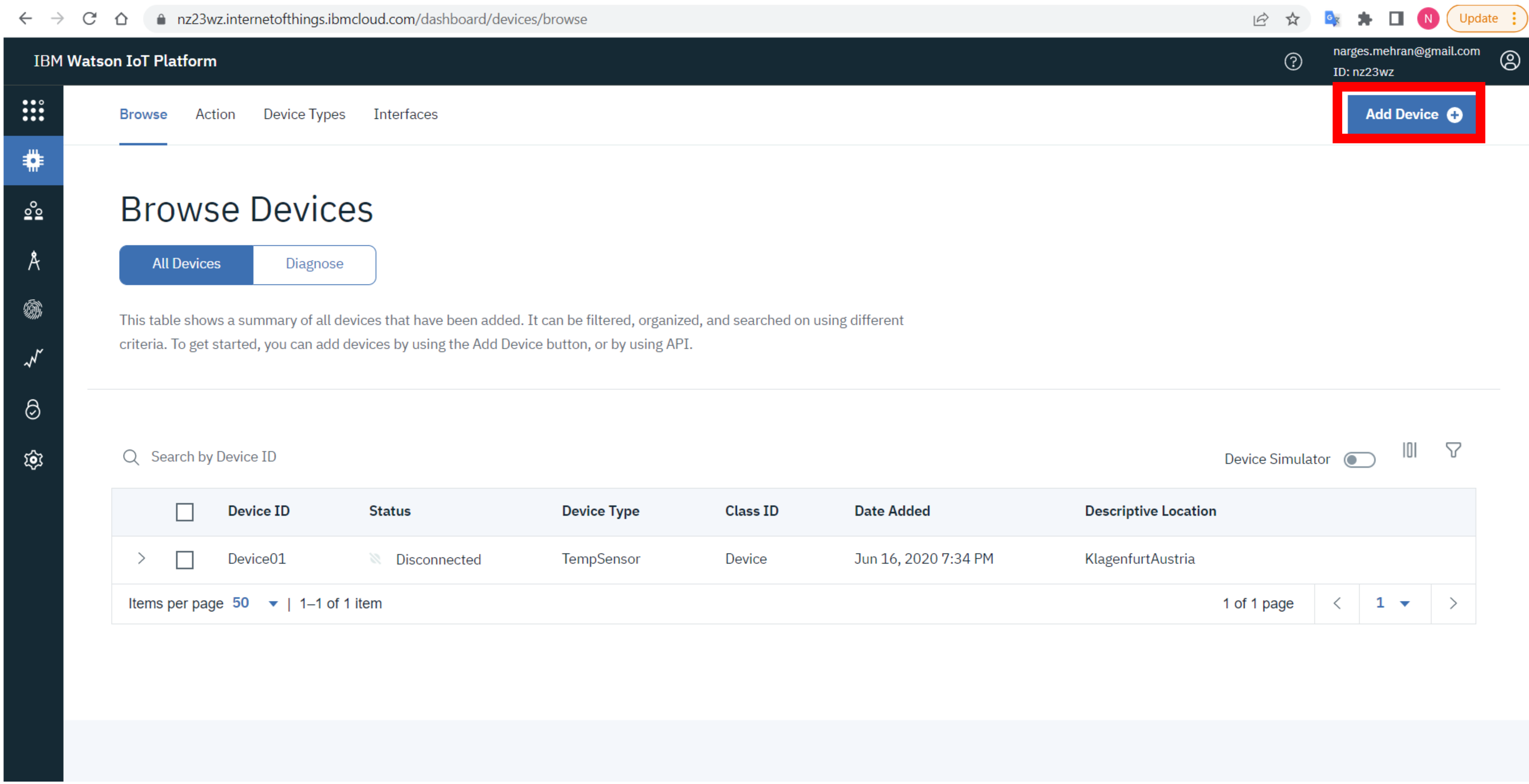
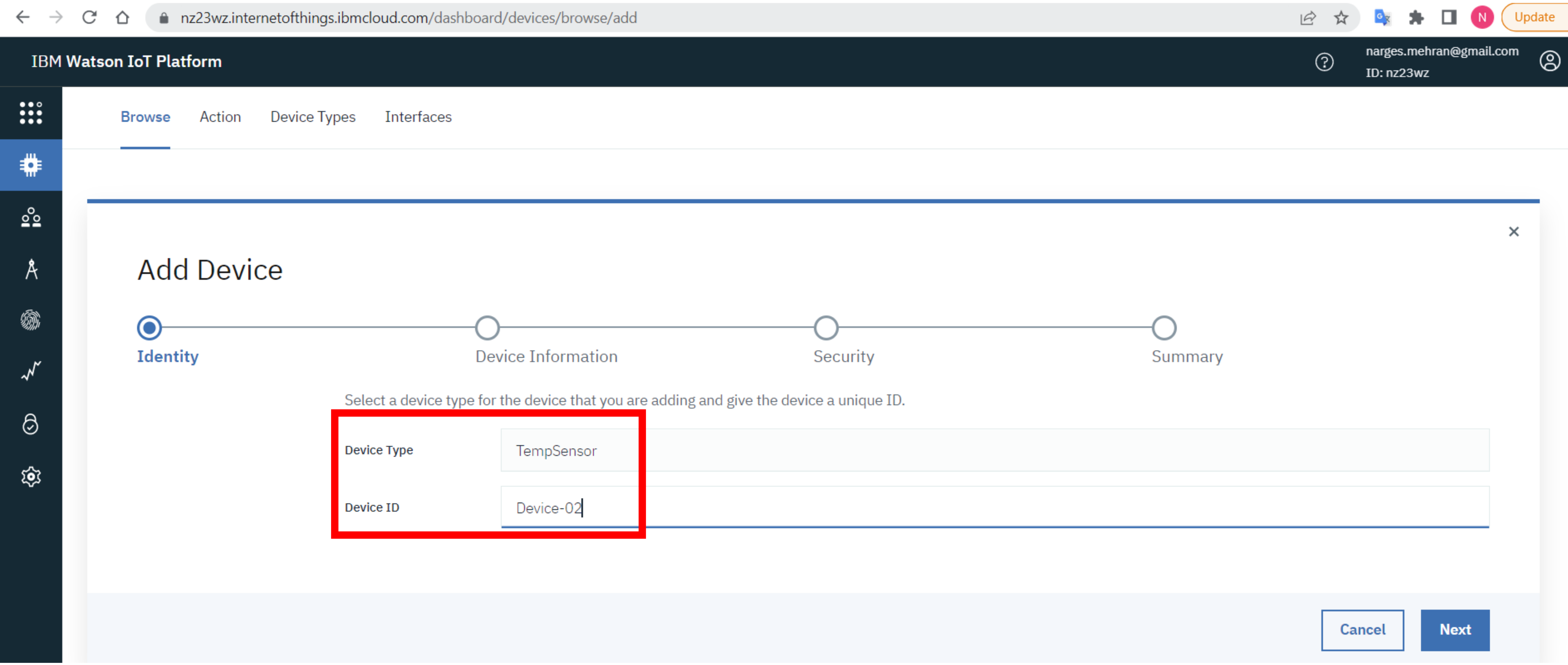


Browse Devices

This table shows a summary of all devices that have been added. It can be filtered, organized, and searched on using different criteria. To get started, you can add devices by using the Add Device button, or by using API.

Device ID	Status	Device Type	Class ID	Date Added	Descriptive Location
Device01	Disconnected	TempSensor	Device	Jun 16, 2020 7:34 PM	KlagenfurtAustria

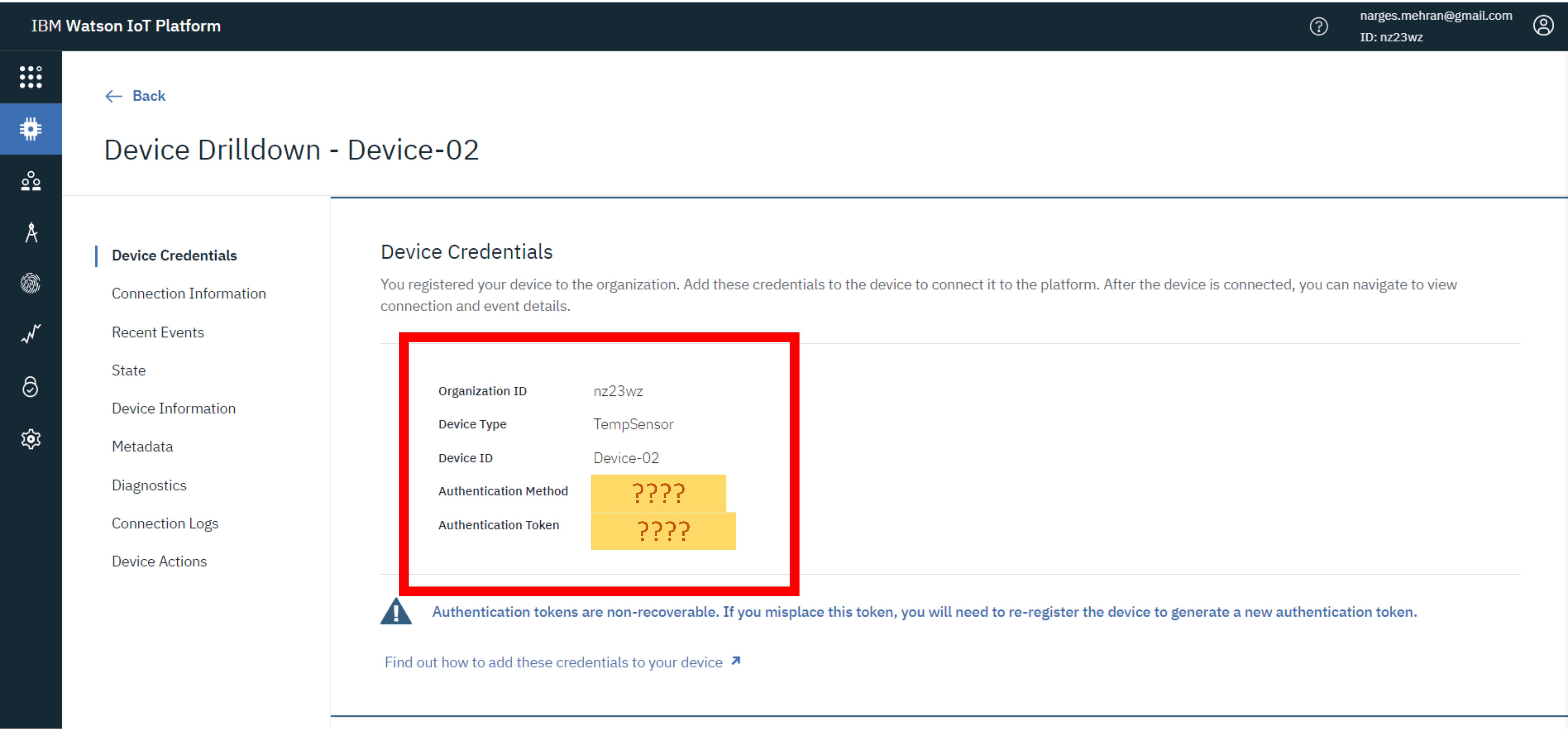
Items per page 50 | 1–1 of 1 item 1 of 1 page 1



Add Device

Select a device type for the device that you are adding and give the device a unique ID.

Device Type	TempSensor
Device ID	Device-02



Device Drilldown - Device-02

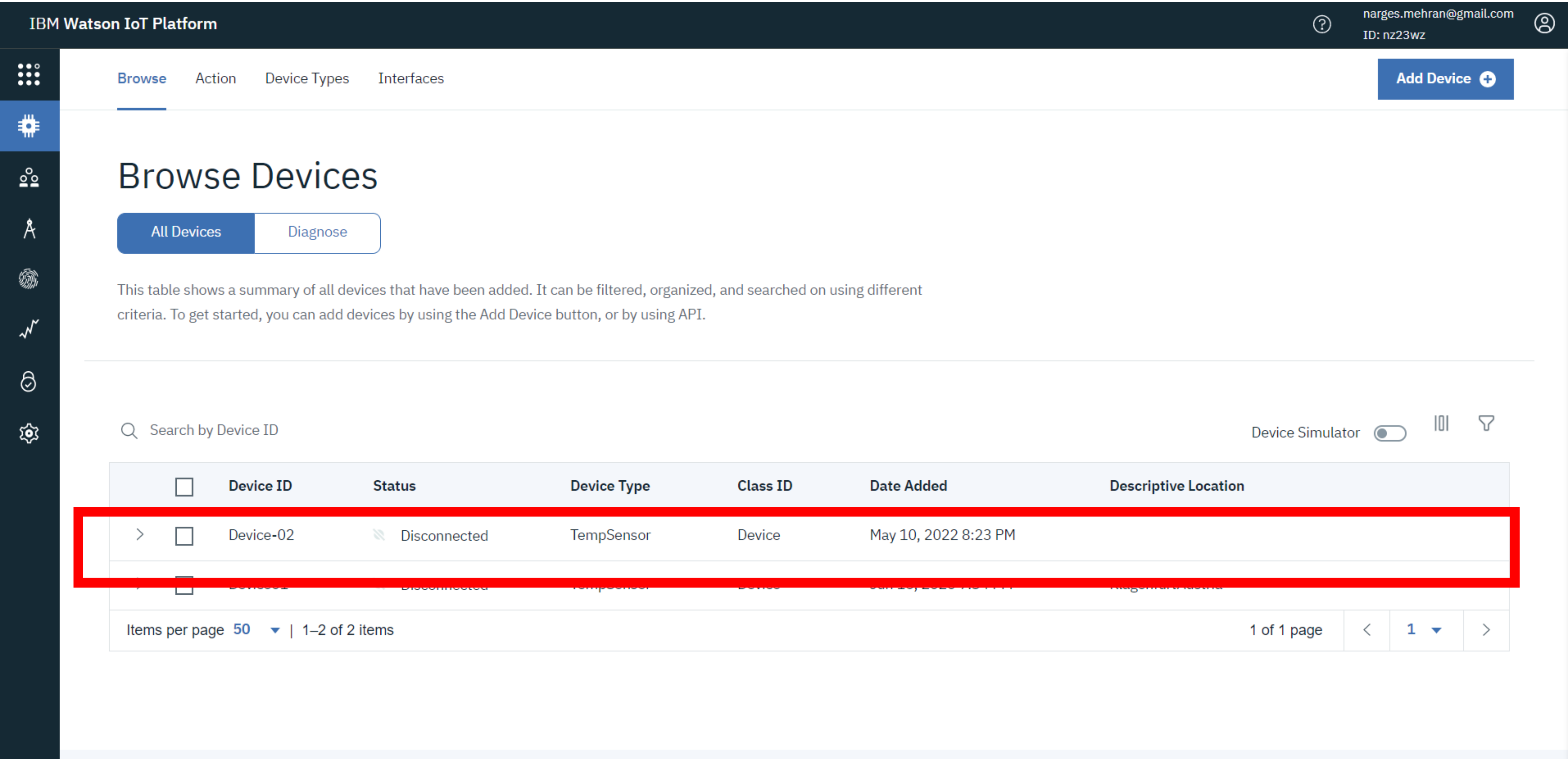
Device Credentials

You registered your device to the organization. Add these credentials to the device to connect it to the platform. After the device is connected, you can navigate to view connection and event details.

Organization ID	nz23wz
Device Type	TempSensor
Device ID	Device-02
Authentication Method	????
Authentication Token	????

Authentication tokens are non-recoverable. If you misplace this token, you will need to re-register the device to generate a new authentication token.

Find out how to add these credentials to your device



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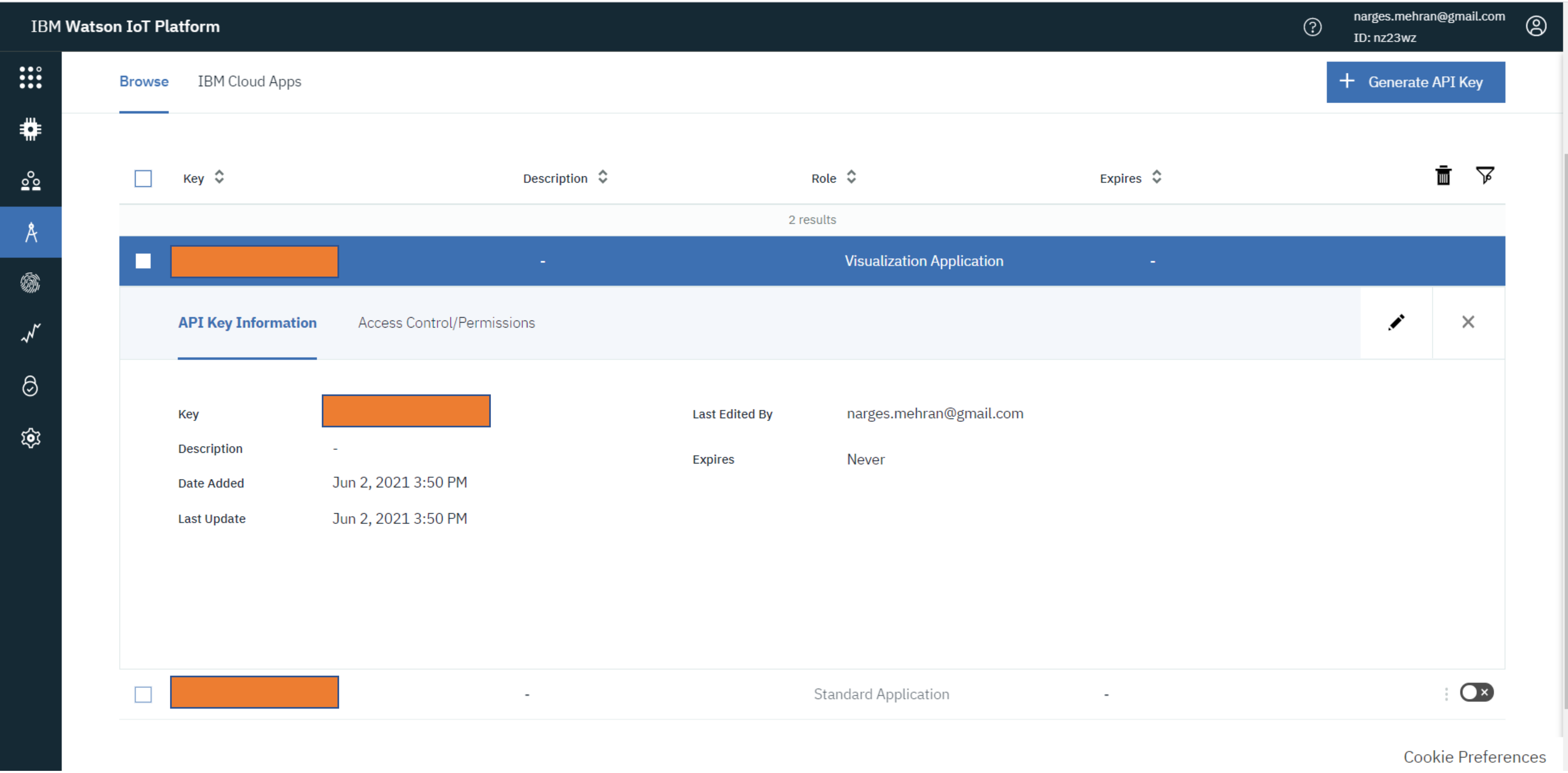
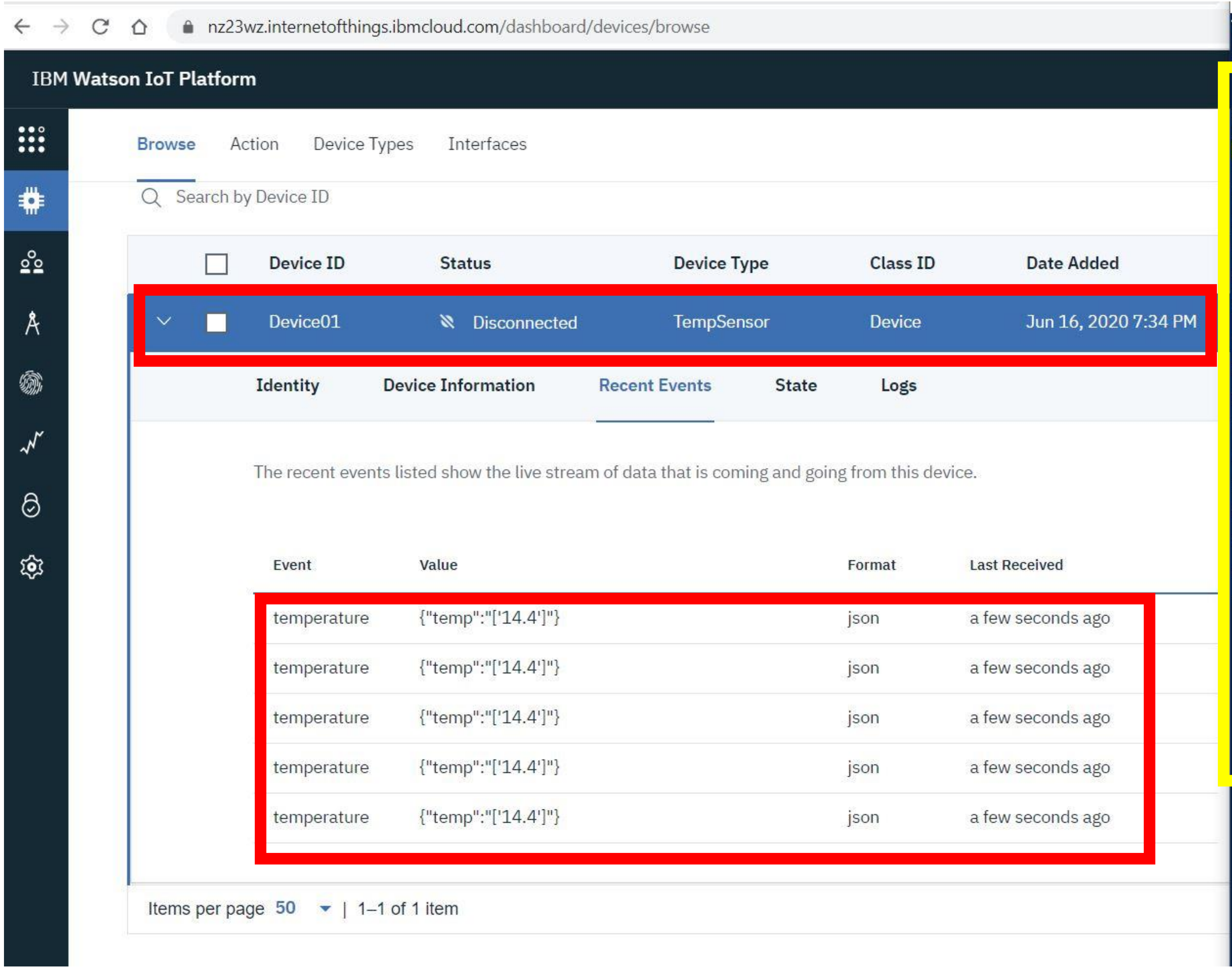
Device ID	Status	Device Type	Class ID	Date Added	Descriptive Location
Device-02	Disconnected	TempSensor	Device	May 10, 2022 8:23 PM	
[illegible]	Disconnected	TempSensor	Device	[illegible]	Klagenfurt/Austria

Items per page 50 | 1–2 of 2 items   1 of 1 page   1



Key	Description	Role	Expires
2 results			
[redacted]	-	Visualization Application	-
[redacted]	-	Standard Application	-

Key	[redacted]	Last Edited By	narges.mehran@gmail.com
Description	-	Expires	Never
Date Added	Jun 2, 2021 3:50 PM		
Last Update	Jun 2, 2021 3:50 PM		



nz23wz.internetofthings.ibmcloud.com/dashboard/devices/browse

IBM Watson IoT Platform

Browse | Action | Device Types | Interfaces

Search by Device ID

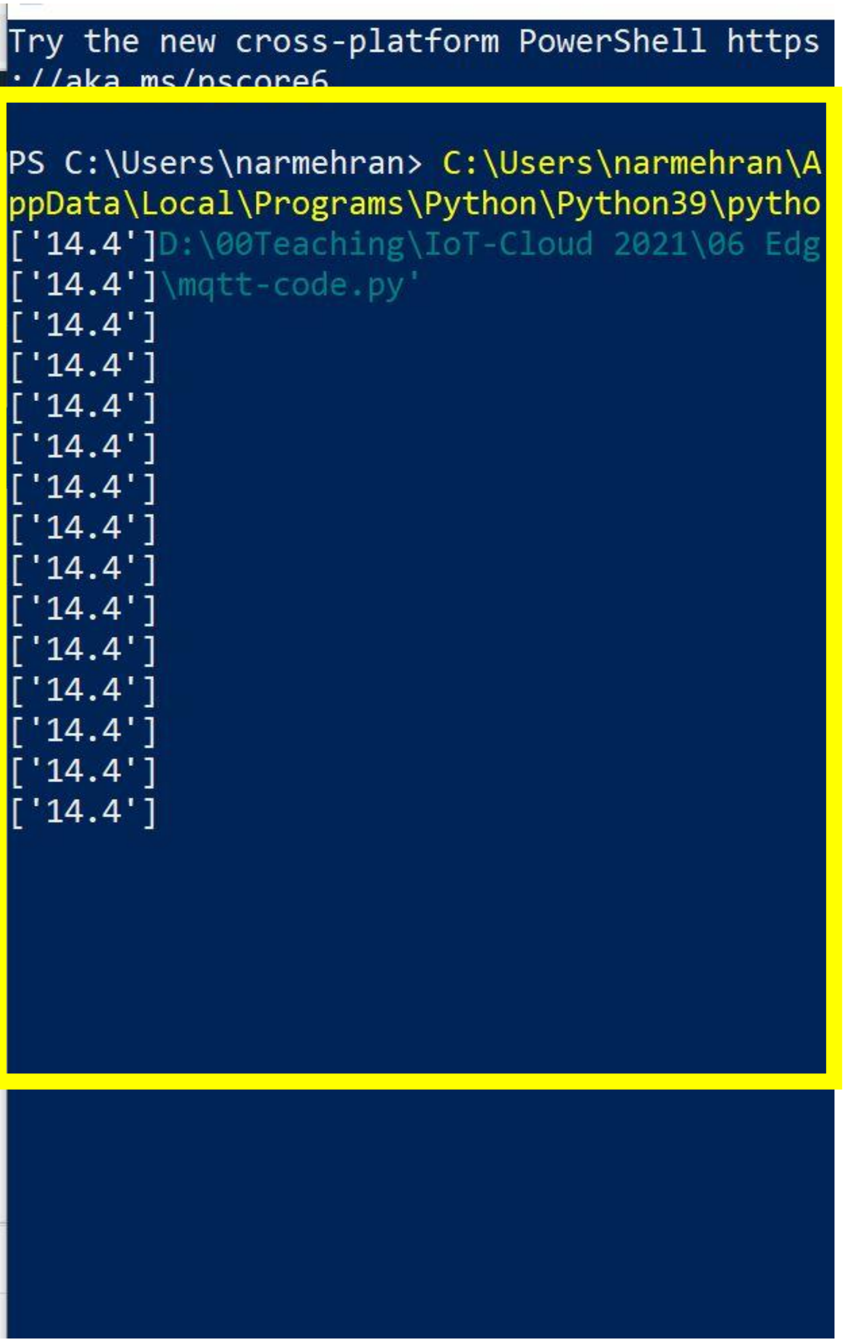
Device ID	Status	Device Type	Class ID	Date Added
Device01	Disconnected	TempSensor	Device	Jun 16, 2020 7:34 PM

Identity | Device Information | Recent Events | State | Logs

The recent events listed show the live stream of data that is coming and going from this device.

Event	Value	Format	Last Received
temperature	{"temp":"['14.4']"}	json	a few seconds ago
temperature	{"temp":"['14.4']"}	json	a few seconds ago
temperature	{"temp":"['14.4']"}	json	a few seconds ago
temperature	{"temp":"['14.4']"}	json	a few seconds ago
temperature	{"temp":"['14.4']"}	json	a few seconds ago

Items per page 50 | 1–1 of 1 item



```
Try the new cross-platform PowerShell https
://aka.ms/pscore6

PS C:\Users\narmehran> C:\Users\narmehran\A
ppData\Local\Programs\Python\Python39\pytho
['14.4']D:\00Teaching\IoT-Cloud 2021\06 Edg
['14.4']\mqtt-code.py'
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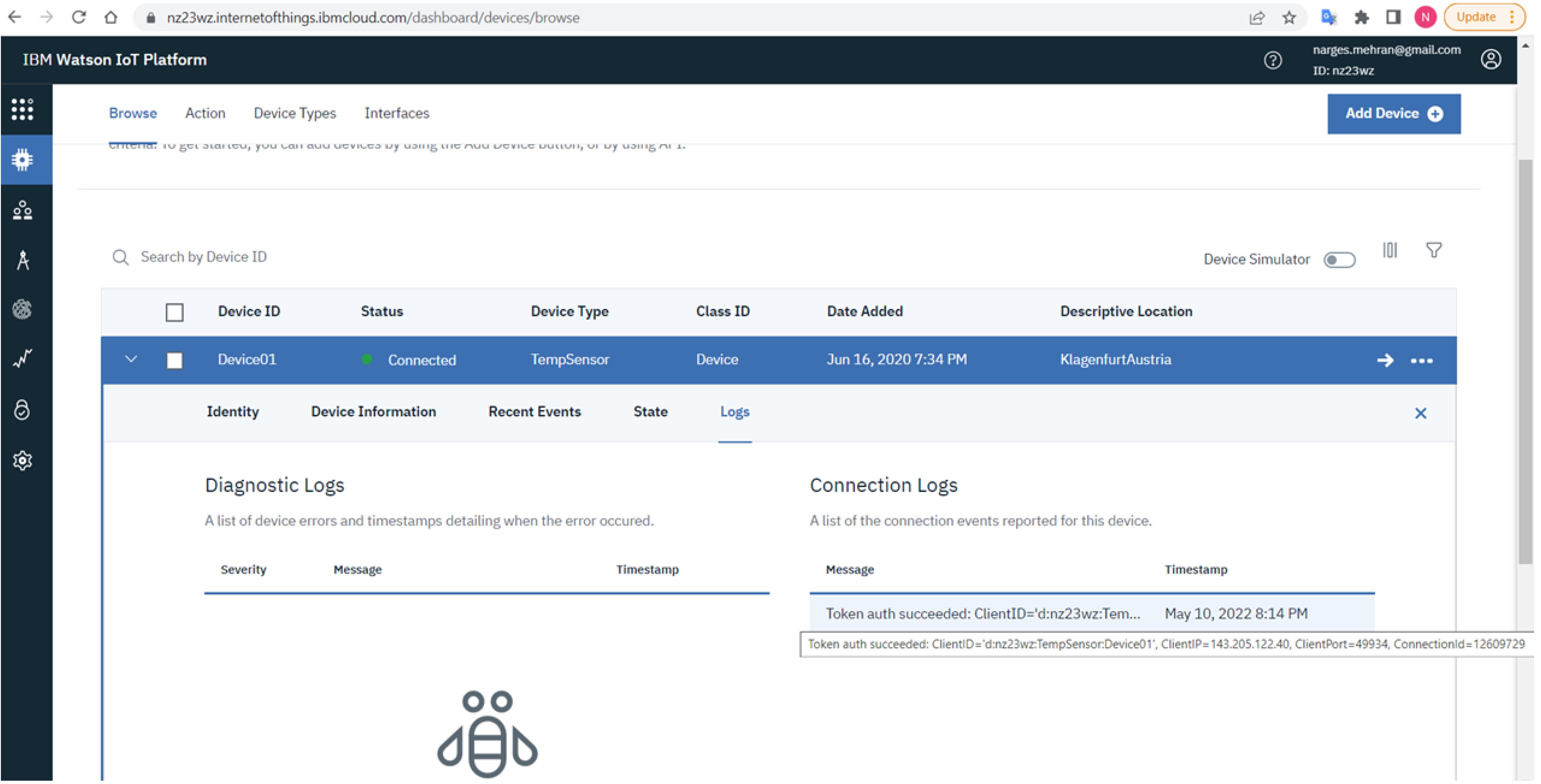

Device ID	Status	Device Type	Class ID	Date Added	Descriptive Location
Device01	Connected	TempSensor	Device	Jun 16, 2020 7:34 PM	KlagenfurtAustria

Diagnostic Logs

A list of device errors and timestamps detailing when the error occured.

Severity	Message	Timestamp

Connection Logs

A list of the connection events reported for this device.

Message	Timestamp
Token auth succeeded: ClientID='d:nz23wz:Tem...	May 10, 2022 8:14 PM

```
Token auth succeeded: ClientID='d:nz23wz:TempSensor:Device01', ClientIP=143.205.122.40, ClientPort=49934, ConnectionId=12609729
```

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QoS levels in MQTT protocol

Current Topics in Distributed Systems: Internet of Things and Cloud Computing

Narges Mehran, MSc.

Dr. Dragi Kimovski,

SS23

QoS (-1) – fire and forget

- QoS -1 (minus one) is ideal for low-power non-critical applications where it doesn’t matter if every message is received by its destination or not.
- By not making a hard connection with the broker and receiving no acknowledgment, considerably less power is used to complete the transaction.

- QoS -1 key features:
  - Only available for devices using MQTT-SN
  - Does not require an MQTT connection to be established
  - No acknowledgment from the recipient
  - Not retried by the sender
  - Analogous to QoS 0 by the time it reaches the broker

- When to use QoS -1:
  - Ideal for power-constrained Things to minimize time on air
  - Minimize messaging cost
  - OK if message delivery is not critical e.g., data sent frequently

QoS 0 – at most once

- QoS 0 (zero) is used to ensure that a message reaches its destination no more than once
- Unlike QoS -1, this method requires an MQTT connection meaning it is less efficient in terms of power

- QoS 0 key features:
  - Best effort message delivery
  - No acknowledgment from the recipient
  - No retry by the sender
  - No queuing by the broker for disconnected clients with a valid subscription to the topic

- When to use QoS 0:
  - Good for power-constrained Things to minimize time on air
  - Minimize messaging cost
  - OK if message delivery is not critical e.g., data sent frequently
  - Not as efficient as MQTT-SN QoS -1 due to the requirement of MQTT CONNECT

QoS 1 – at least once

- QoS 1 is used when message delivery is critical
- Queues messages until the subscriber can receive it

- QoS 1 key features:
  - Guarantees that a message is delivered at least once to the recipient
  - Sender stores the message until it receives a PUBACK from the recipient
  - Messages may be sent or delivered multiple times

- When to use QoS 1:
  - You have to receive every message, but make sure you handle duplicates
  - You want messages to be queued on the broker for delivery to offline Clients
  - If the overhead of QoS 2 is too high

QoS 2 – exactly once

- QoS 2 is used when the message needs to arrive once and only once
- Used when delivery is essential

- QoS 2 is the safest and slowest Quality of Service level
  - Guarantees that each message is received only once by the intended recipients
  - By using at least two request/response flows (a four-part handshake)

- When to use QoS 2:
  - Use if message delivery is critical and duplicate data is harmful to subscribers

References

- http://mqtt.org/faq
- https://test.mosquitto.org/
- https://thingstream.io/resources/mqtt-beginners-guide-2020/
- https://sites.cs.ucsb.edu/~rich/class/cs293b-cloud/papers/mqtt-s.pdf
- https://randomnerdtutorials.com/what-is-mqtt-and-how-it-works/
- https://randomnerdtutorials.com/raspberry-pi-publishing-mqtt-messages-to-esp8266/
- https://github.com/fischly/weather-station-backend-dockerized