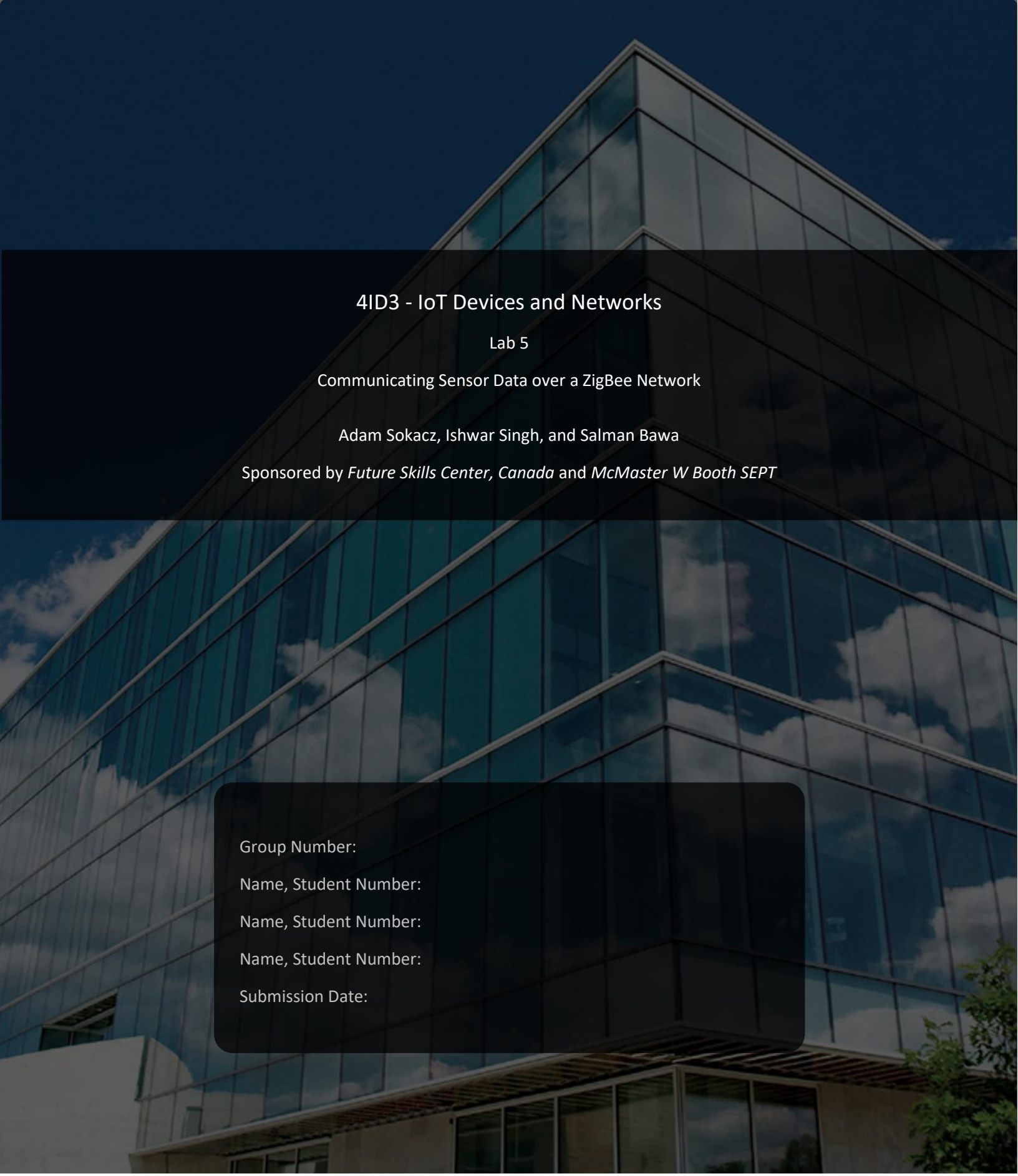


4ID3 - IoT Devices and Networks

Lab 5

Communicating Sensor Data over a ZigBee Network

Adam Sokacz, Ishwar Singh, and Salman Bawa

Sponsored by *Future Skills Center, Canada* and *McMaster W Booth SEPT*

Group Number:

Name, Student Number:

Name, Student Number:

Name, Student Number:

Submission Date:

W BOOTH SCHOOL OF ENGINEERING PRACTICE AND TECHNOLOGY

McMaster-Mohawk Bachelor of Technology Partnership

McMaster University ENGINEERING

mohawk

Objective

In this lab, sensor data will be collected on a node in the ZigBee network. This data will be passed on to the controller node while the devices are in API mode. Once at the controller, it will be communicated to the PC using wired serial communication, and aggregated into a database.

Contents

Feedback

Q1 - What would you rate the difficulty of this lab?

(1 = easy, 5 = difficult)

1 **2** **3** **4** **5**

Comments about the difficulty of the lab:

Q2 - Did you have enough time to complete the lab within the designated lab time?

YES **NO**

Q3 - How easy were the lab instructions to understand?

(1 = easy, 5 = unclear)

1 **2** **3** **4** **5**

List any unclear steps:

Q4 - Could you see yourself using the skills learned in this lab to tackle future engineering challenges?

(1 = no, 5 = yes)

1 **2** **3** **4** **5**

Additional Resources

Lab GitHub Repo (https://github.com/sokacza/4ID3)

MySQL Basics (https://youtu.be/Cz3WcZLRaWc)

NodeRED Fundamentals Tutorial (https://youtu.be/3AR432bguOY)

Pre-Lab Questions

Q1 - Name **6** advantages of ZigBee over other **access technologies**.

(Suggested: List)

Q2 – ZigBee devices operate as a **mesh network**. Draw the mesh network topology using **4 devices.**

(Suggested: Sketch)

Q3 - ZigBee builds on the IEEE standard **802.15.4** physical layer. What layer of the **ISO model** does ZigBee operate in?

(Suggested: Sentence)

Q4 – Since ZigBee networks ping data across many devices, what **security features** are built into ZigBee to prevent data from being exposed with malicious intent?

(Suggested: List)

Q4 – In documentation, you may hear the terms **XBee** and **ZigBee** being used **interchangeably**. What is the **difference** between these two terms?

(Suggested: A few sentences)

Post-Lab Questions

Q1 - Draw a **diagram** to identify **each component** of the IoT network produced in this lab and describe the **information being exchanged** between the components.

(Suggested: Sketch)

Q2 – There are **3** types of XBee devices: **Coordinators**, **Routers**, and **End Devices**. In a table, compare and contrast the role of each category of device in the ZigBee network.

https://www.digi.com/resources/documentation/Digidocs/90001942-13/

(Suggested: Table)

Q3 – **AT commands** are typically used when communicating with low-level **embedded** devices such as **communication modules**, especially for **device configuration**. Using page **40** in the **product manual**, describe how the AT commands for this product are **structured**. Relate AT commands with what happens when you press **write setting** in the **XCTU** XBee software?

https://www.digi.com/resources/documentation/Digidocs/90001942-13/

(Suggested: Paragraph)

Q4 – There are **two operating modes** for these XBee3 units: **API** and **Transparent**. Using the manual, research each of these modes and compare and contrast **3** points of each in a **table**.

https://www.digi.com/resources/documentation/Digidocs/90001942-13/

(Suggested: Table)

Q5 – The END_DEVICE publishes the message **GPIO4 ON** to the network address **00 00 00 00 00 00 00 00**. The ROUTER device is just within range of the END_DEVICE, and the COORDINATOR is just within range of the ROUTER. The END_DEVICE is out of range of the COORDINATOR. Which device(s) receives the message? Explain why?

(Suggested: Paragraph)

Q6 - You are tasked with making a desktop application that has a user log in. The username and password are stored in a MySQL database. Investigate the topic of password hashing:

https://youtu.be/cczlpiiu42M

Write and execute a **Python script** that hashes the following password:

Password: 9055259140

https://www.geeksforgeeks.org/how-to-hash-passwords-in-python/

Paste a screenshot of your terminal output:

Write a **MySQL query** to **insert** the hashed password into the following database:

Accounts	
Email	Password
test@example.com	<Your password hash>

Q7 - What is the difference between **hashing** and **encryption**? Write and execute a **python script** to **encrypt** and **decrypt** the following string:

message = " { \"GroupA\": { \"DeviceA\": { \"Temperature\": 23.9 } } } "

https://www.geeksforgeeks.org/how-to-encrypt-and-decrypt-strings-in-python/

Paste a screenshot of your terminal output:

Q8 - Write a brief LinkedIn post about **4 key learning takeaways** from this lab.

(Suggested: Short paragraph)

Exercise A Results:

Exercise B Results:

Exercise C Results:

Project Setup

Issue the following commands from the root directory of your existing local repository for this class:

git pull origin main

<Create your folders and README.md file>

git add .

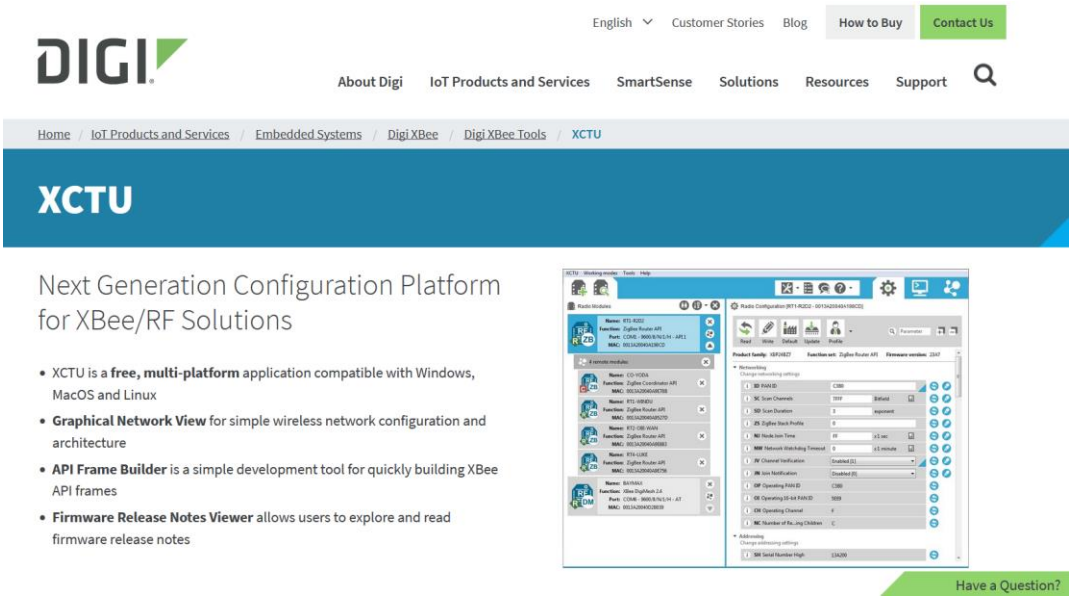
git commit -m "lab 6"

git push origin main

Installing XCTU

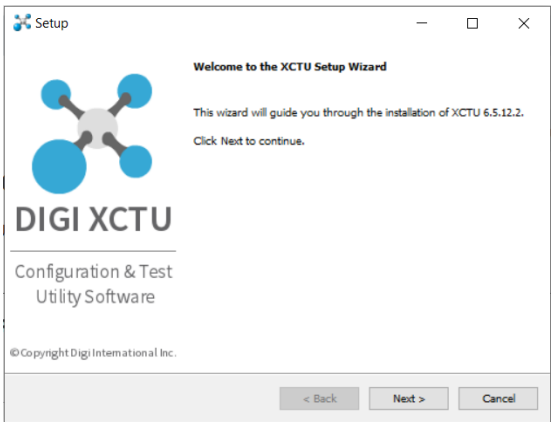
Navigate to the following URL and install the XCTU XBee3 configuration utility:

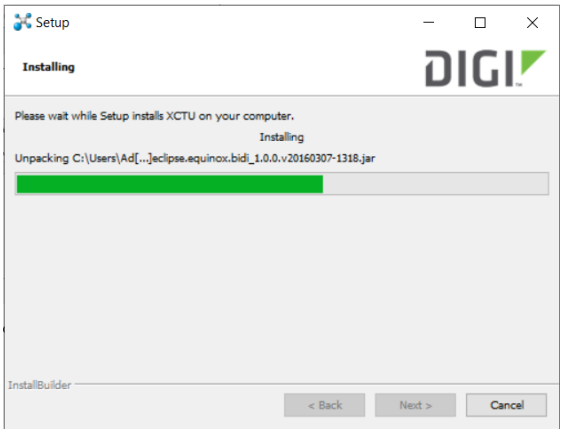
https://www.digi.com/products/embedded-systems/digi-xbee/digi-xbee-tools/xctu#productsupport-utilities



What is XCTU?

Install both the utility and drivers for your PC. Select **Add Drivers to Windows** when prompted.

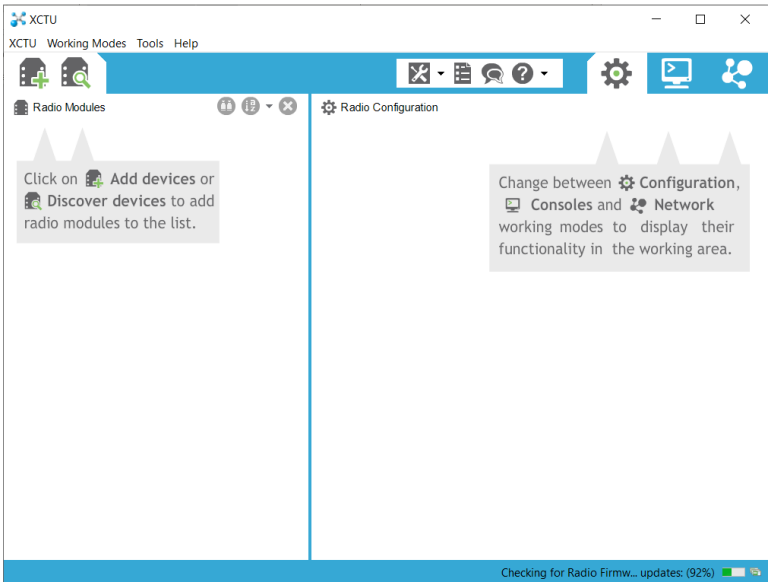




Once installed, **restart** your PC.

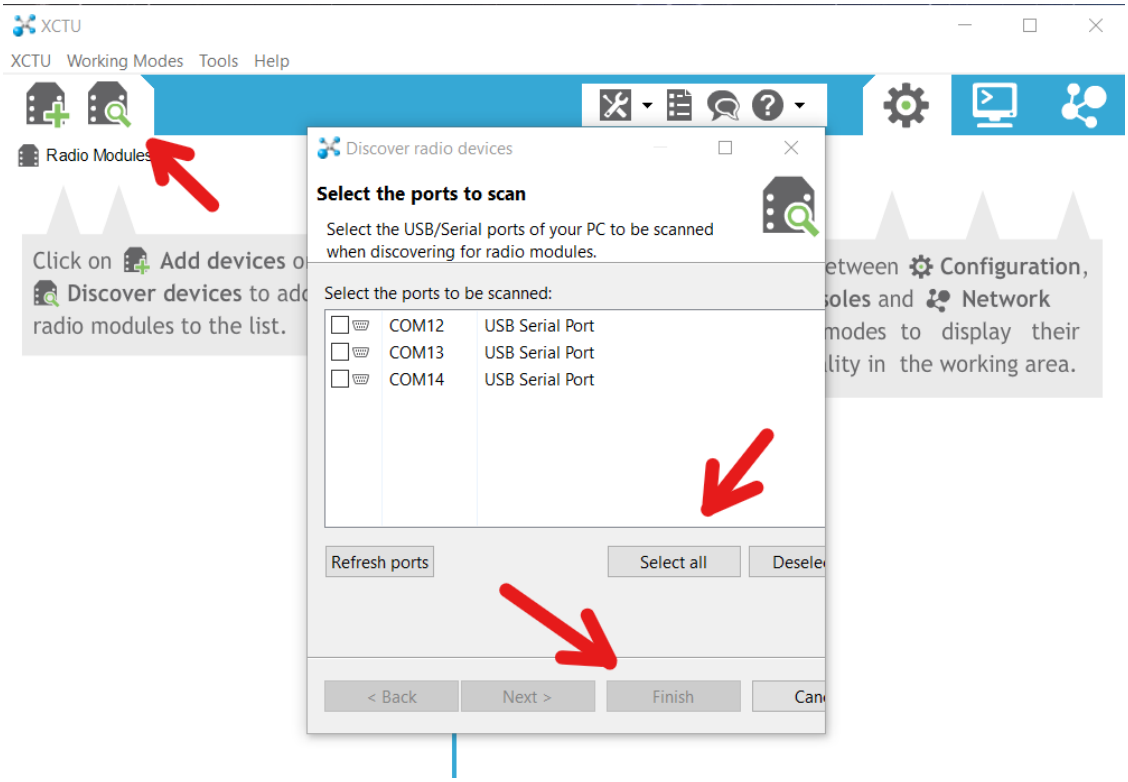
Connecting and Updating the XBee3 Modules

Open the XCTU XBee3 configuration utility.

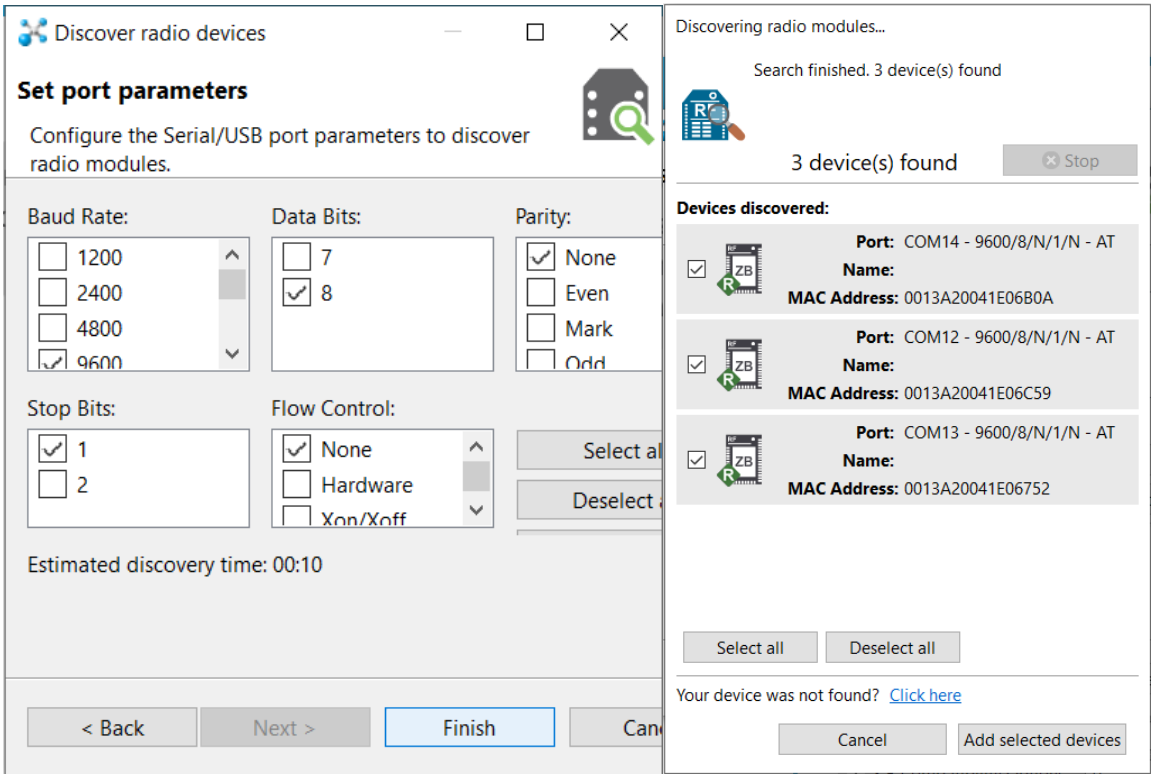


Plug in your XBee devices

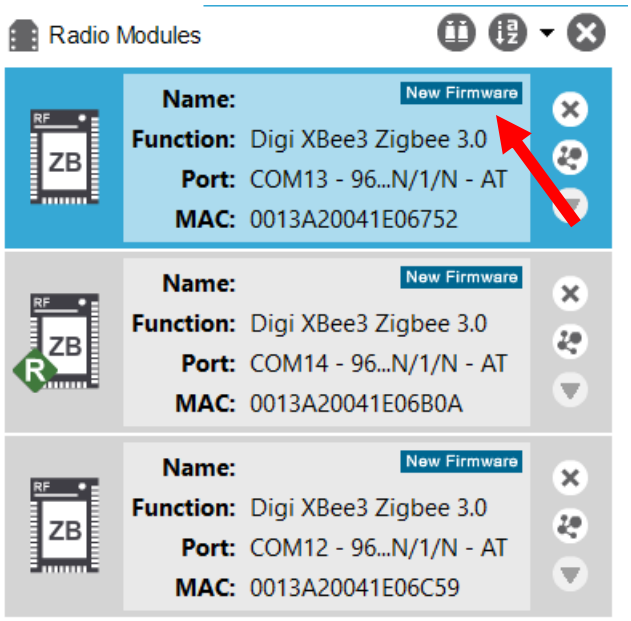
Connect the devices using the **Device Search** button on the **top toolbar**.

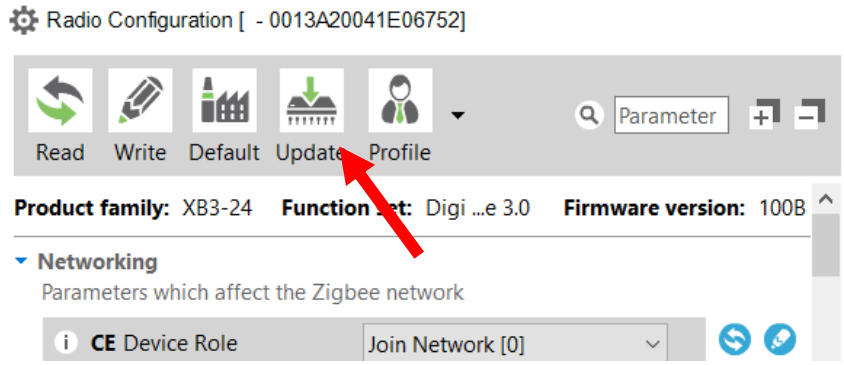


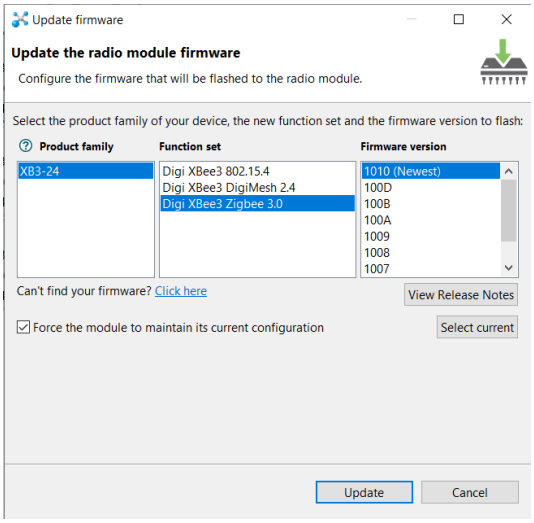
Use **default** parameters when prompted and add each of your **COM** devices.

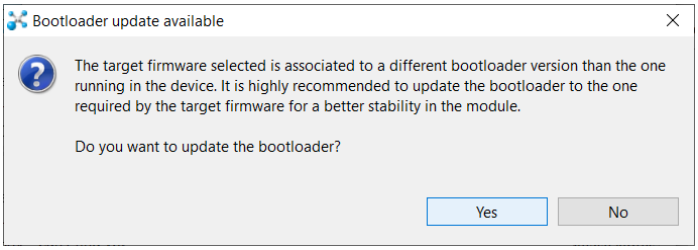


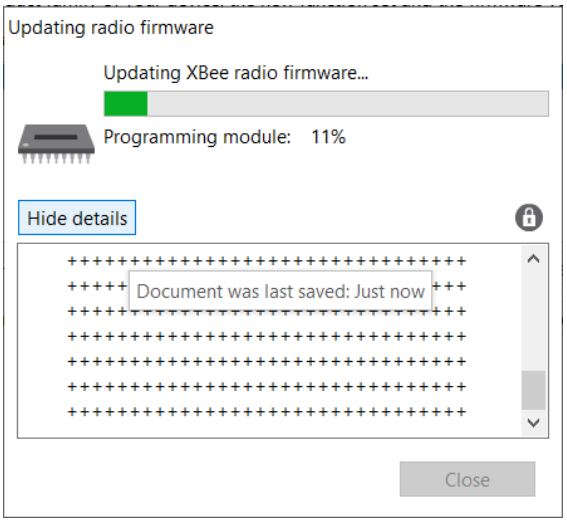
You may see a **new firmware** prompt above each device. If so, update the firmware of each development board to the latest version.





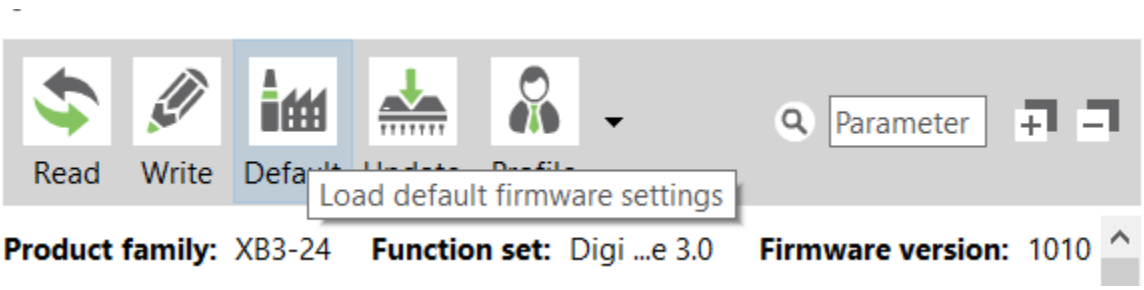



Bootloader update available
The target firmware selected is associated to a different bootloader version than the one running in the device. It is highly recommended to update the bootloader to the one required by the target firmware for a better stability in the module.
Do you want to update the bootloader?
Yes
No


Updating radio firmware
Updating XBee radio firmware...
Programming module: 11%
Hide details
Document was last saved: Just now
Close

Configuring Boards using XCTU

Use the **Load Default Firmware** to reset the configuration of each device.



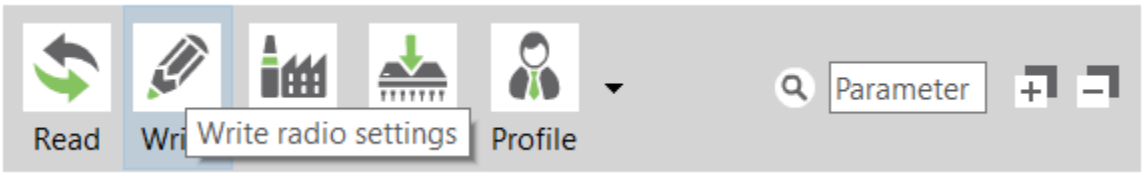
Following the table below, configure each device. (-- symbol means leave default)

USE A UNIQUE ID VARIABLE THAT IS THE SAME FOR EACH NODE IN YOUR NETWORK.

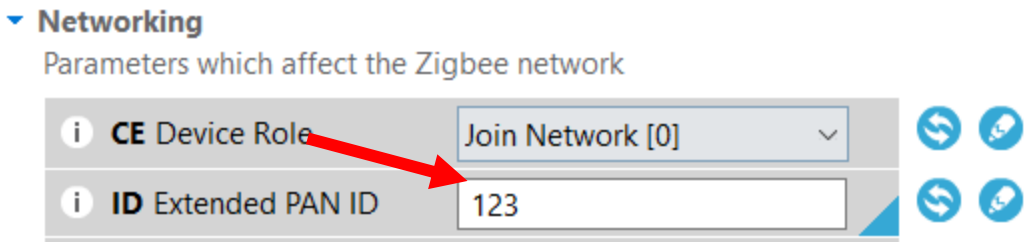
Device Setup				
Parameter	XBee A (Coordinator)	XBee B (Router)	XBee C (End Device)	Effect
ID	123	123	123	Network ID
JV	—	Enabled [1]	Enabled [1]	Join or become coordinator
CE	—	—	—	Force as coordinator
DH	—	0	0	Destination address (high)
DL	—	0	0	Destination address (low)
NI	COORD	ROUTER	END_ DEVICE	Node name
SP	1F4	1F4	1F4	Sleep time = 1F4 (hexadecimal) = 500 (decimal) x 10 ms = 5 seconds.
SM	—	—	Cyclic sleep [4]	Sleep setting (only end devices sleep)
SO	—	—	2	Keep awake

There are 2 ways to write configurations:

1. Write all configurations



2. Write individual configuration



Once all of these configurations are changed and written to each XBee module, we will attempt to transmit data using **transparent mode** from the **router** to the **coordinator**.

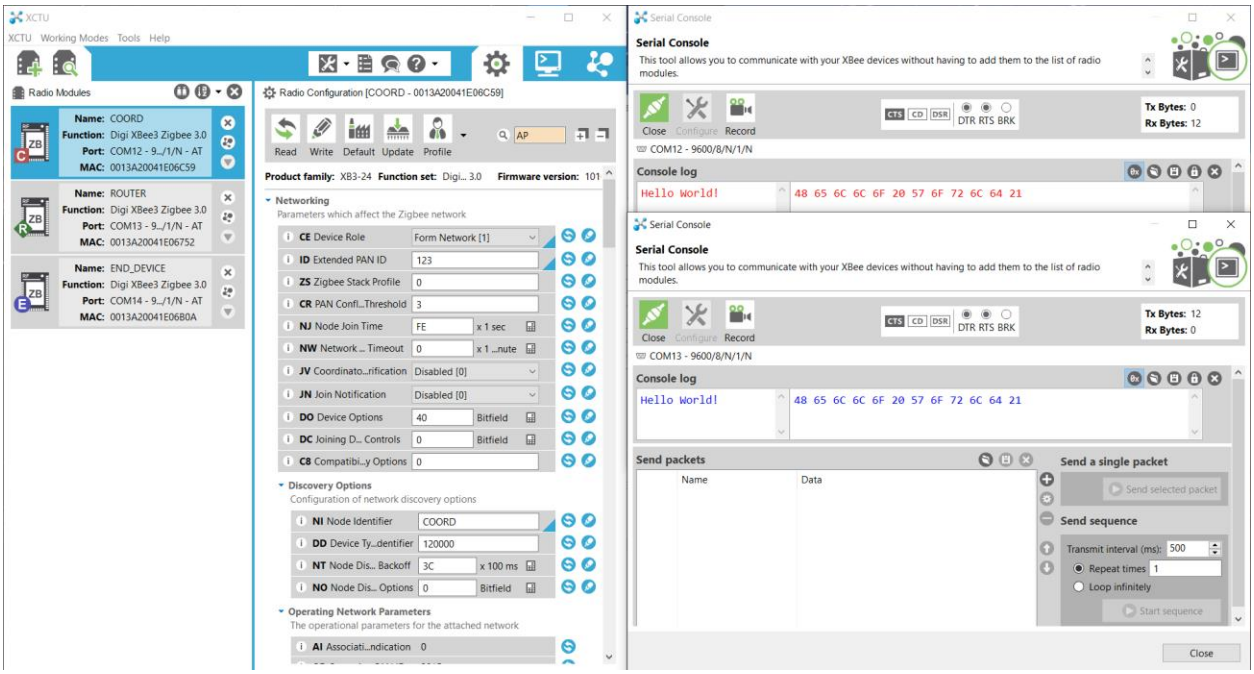
Transparent Mode

In one **console** window, open the **COORD** device.

In another **console** window, open the **ROUTER** device.

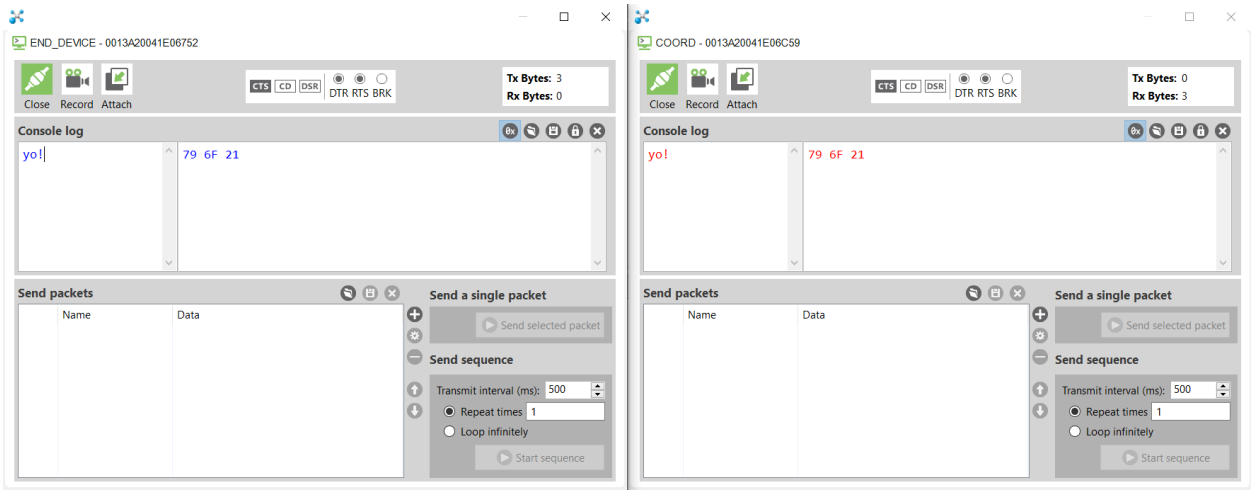
Type **Hello World!** into the **ROUTER** console window.

The data should print in the **COORD** window.

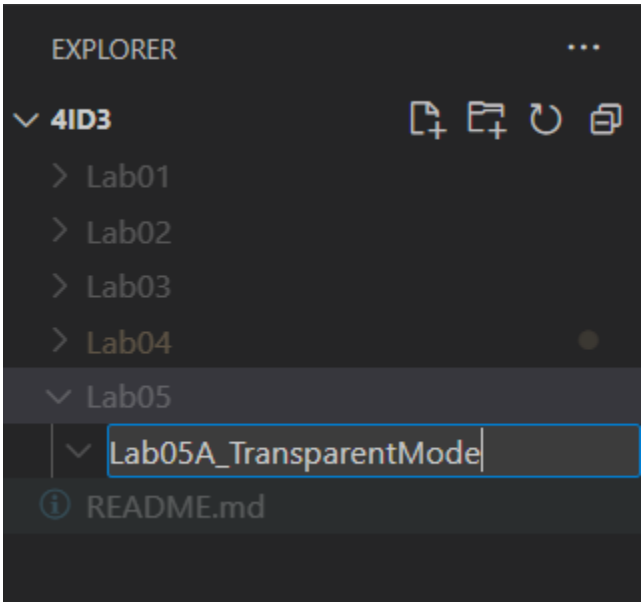


Next, type **Yo!** into the **END_DEVICE** console window.

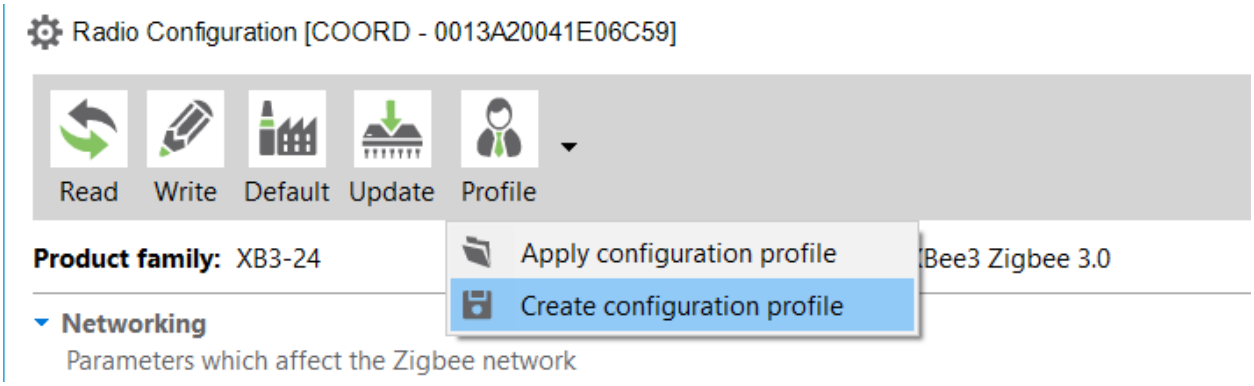
The data should print in the **COORD** window.

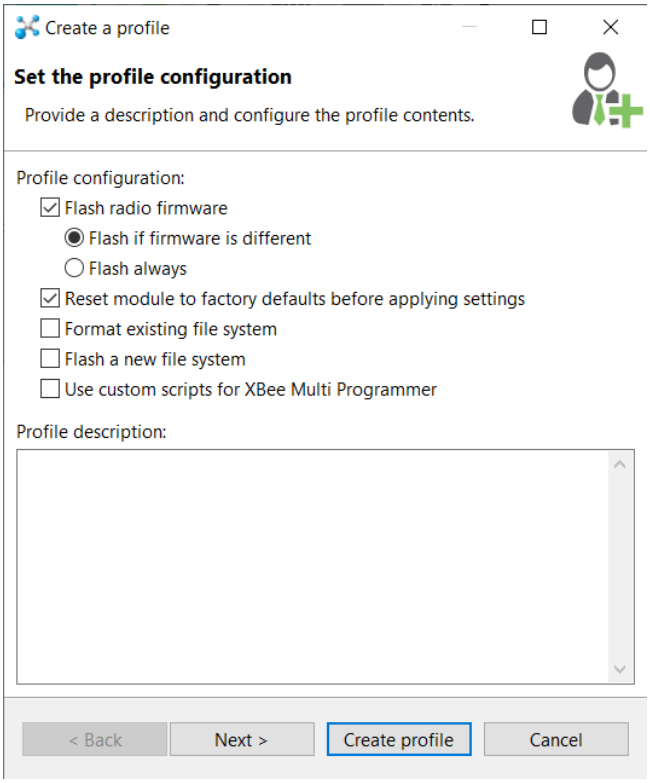


Create a new folder in your lab folder called **Lab05A_TransparentMode**.

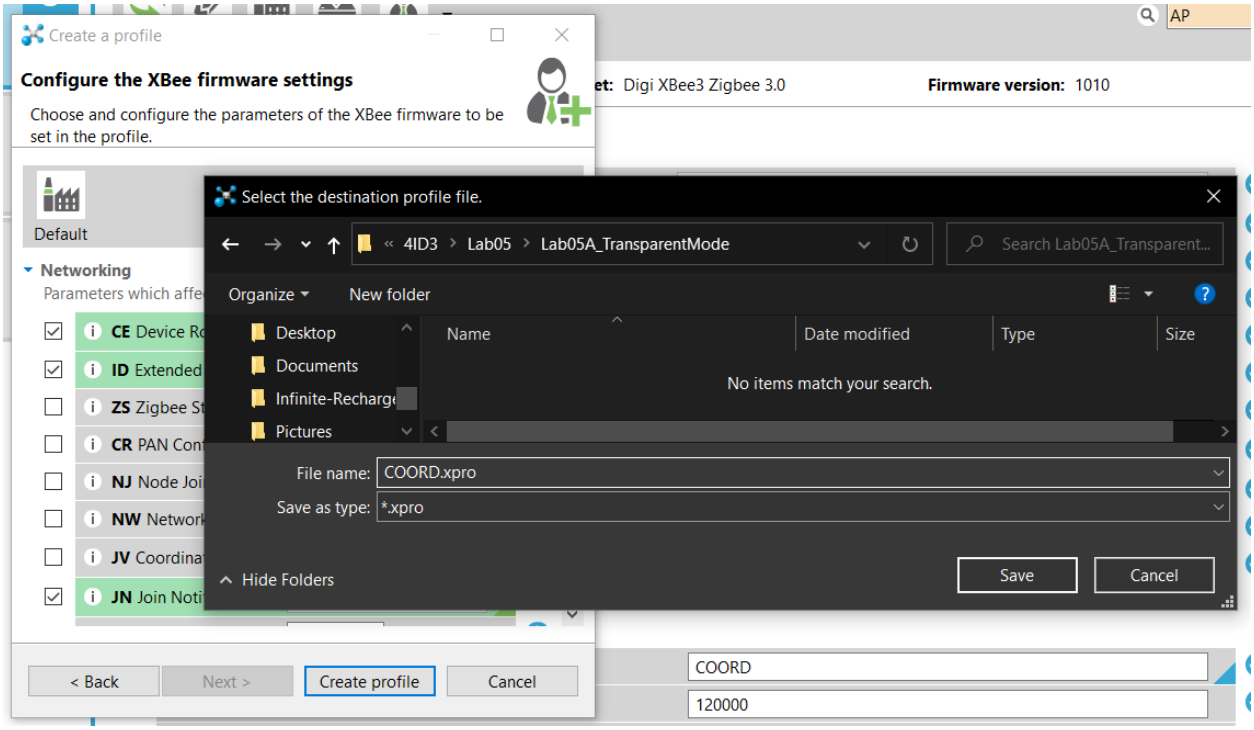


In XCTU, for each device, select **Profile > Create Profile.**





Press **Next** three times, then select **Create profile**. **Rename** this profile to match the device type, then **save** it to your lab folder.



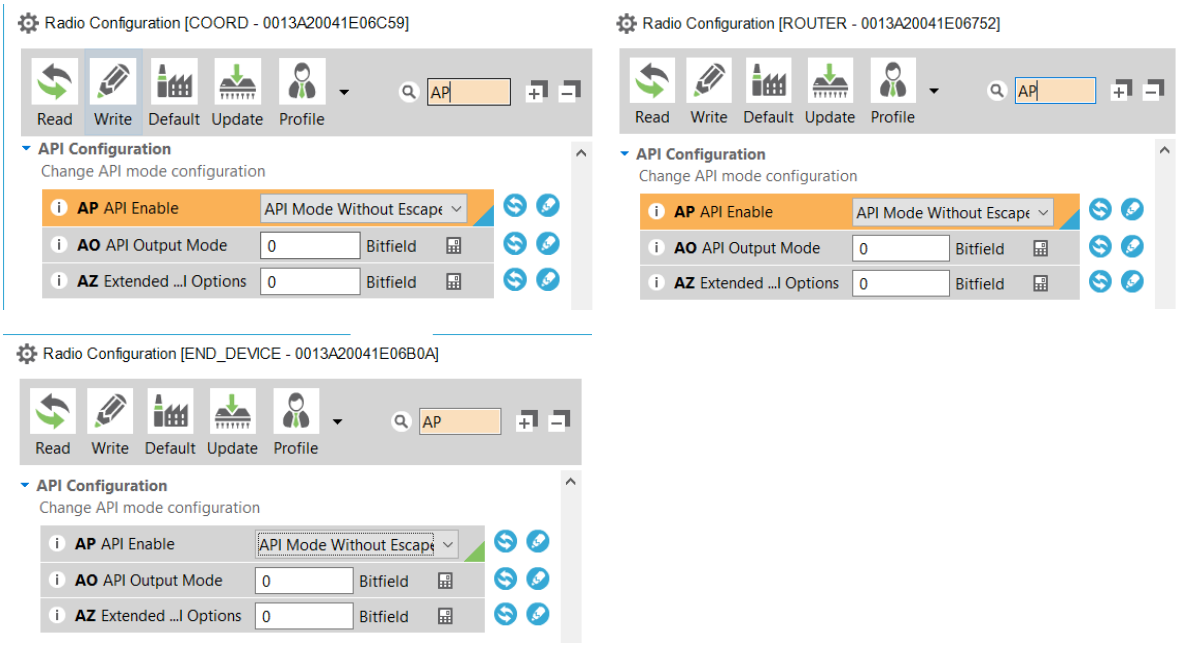
Repeat for each device.

API Mode

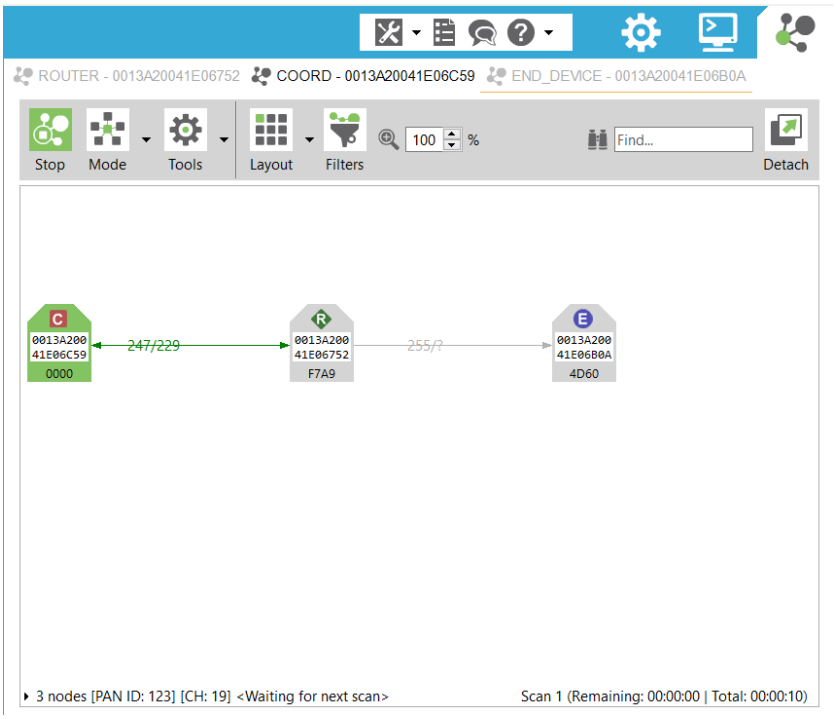
Navigate to the XCTU configure and modify the **AP** parameter in each device's configuration.

Modify **AP 0 (transparent) -> AP 1 (API mode without escape).**

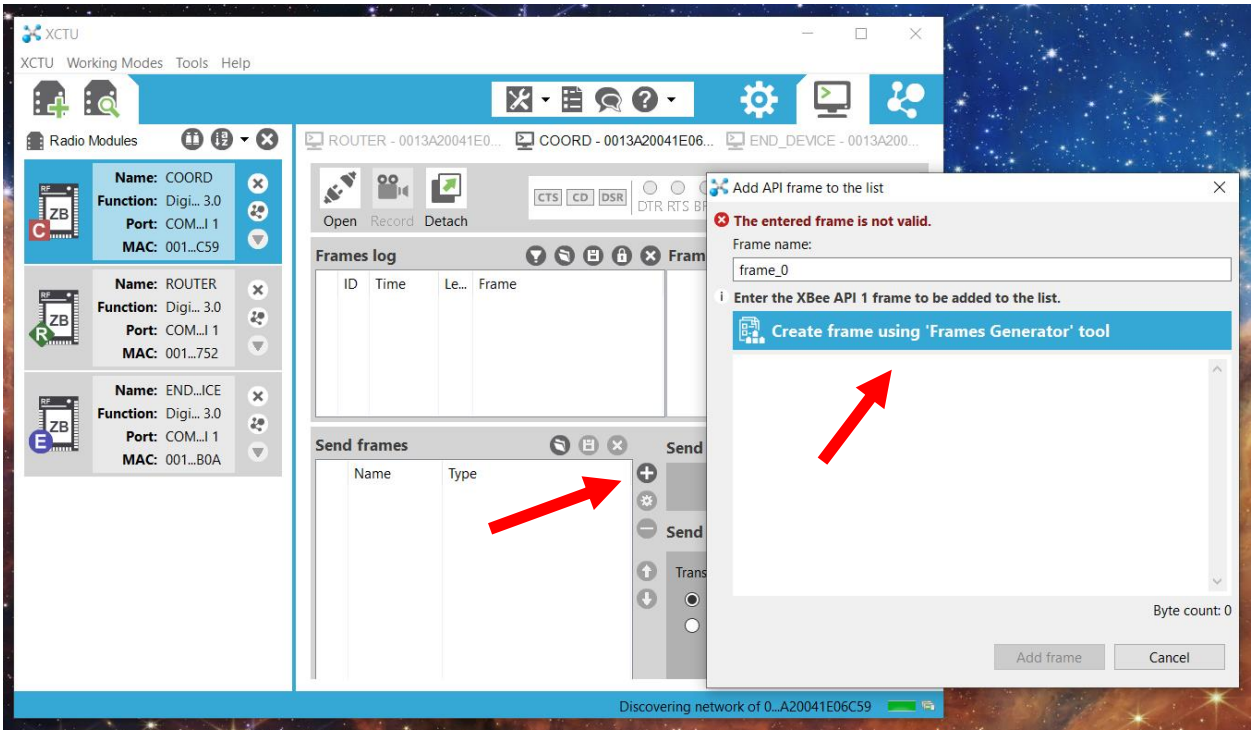
Press **Write**.



To verify that the network has been established correctly, navigate to **COORD** > **Networks tab** (top right).

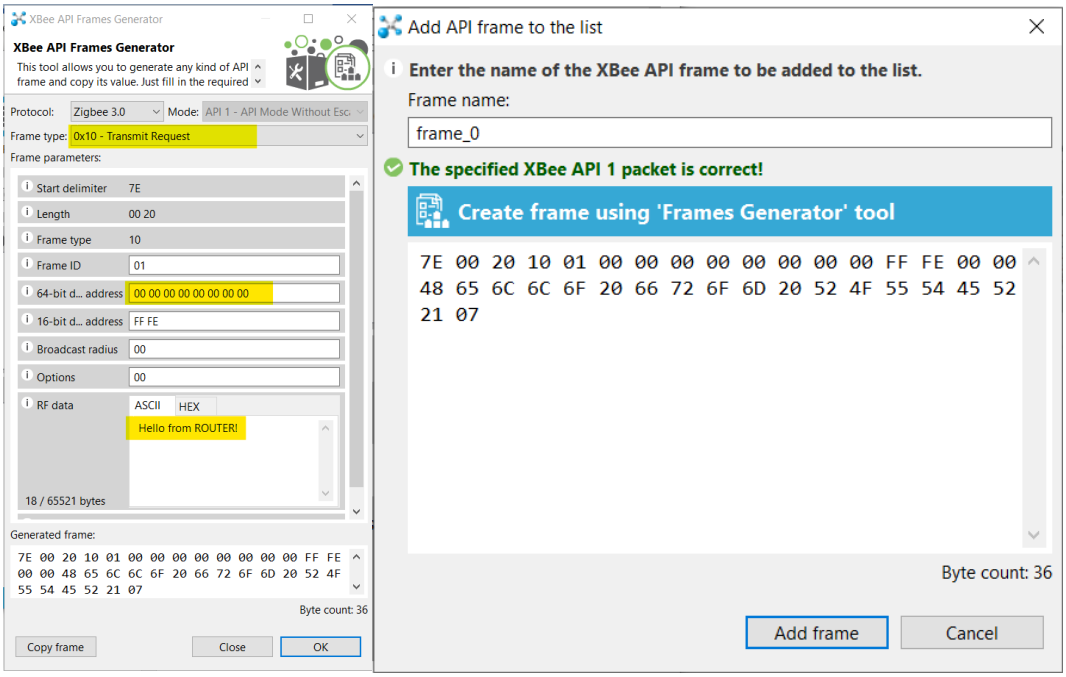


In the **ROUTER** device, create a new packet.

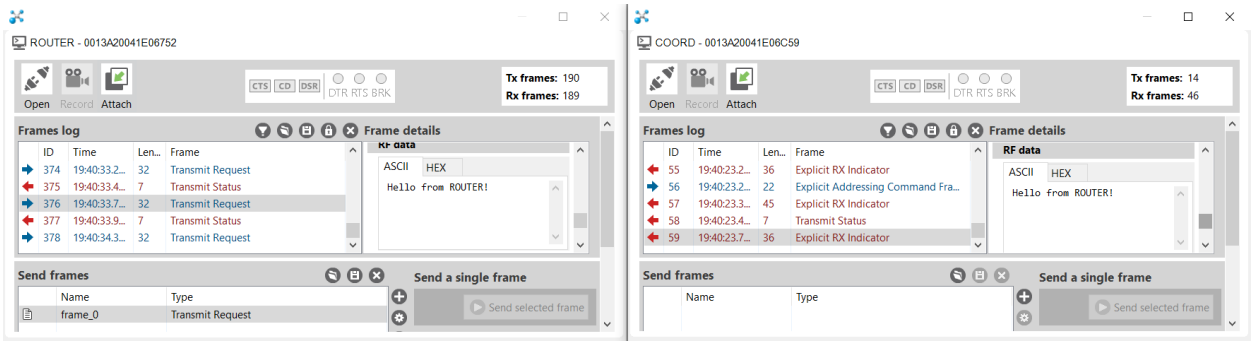


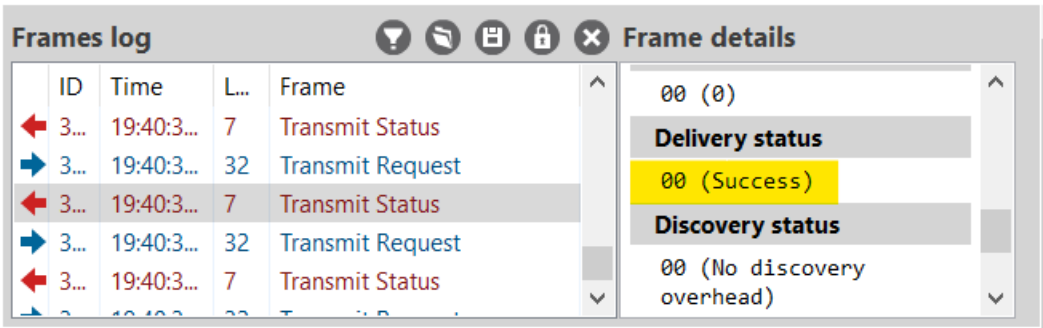
Select 0x10 – **Transmit Request** as the frame type. In the **address** field, ensure that it is 0x00. This is the automatic address for the coordinator device on the network. Lastly, type some ASCII characters in the **RF data** field.

Press **OK** to add the new frame.

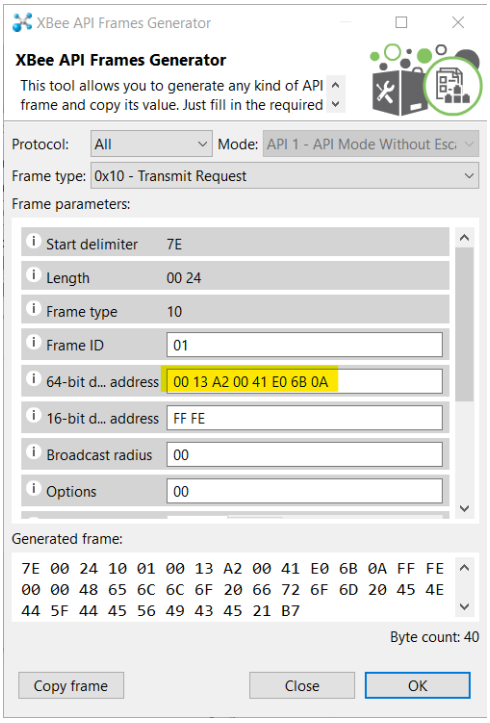


Open both the **ROUTER** and the **COORD** devices in separate console windows. Transmit the packed from the **ROUTER** to the **COORD**. Ensure that it arrives correctly, and an **OK** status is received on the **ROUTER**.

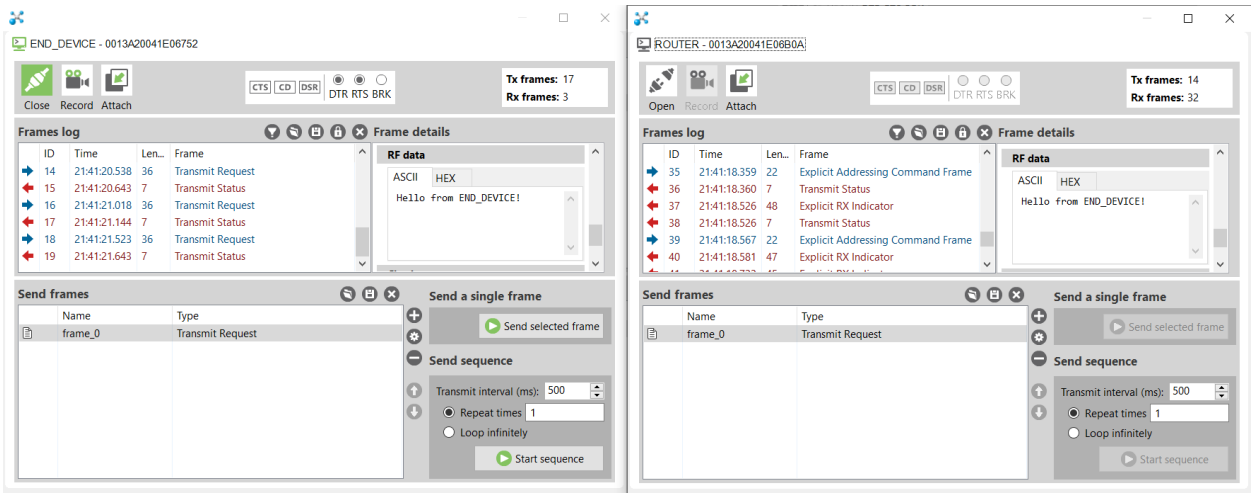




Next, open both the **END_DEVICE** and **ROUTER**. Create a packed for the END_DEVICE to transmit and set its destination address to the ROUTERS MAC address.

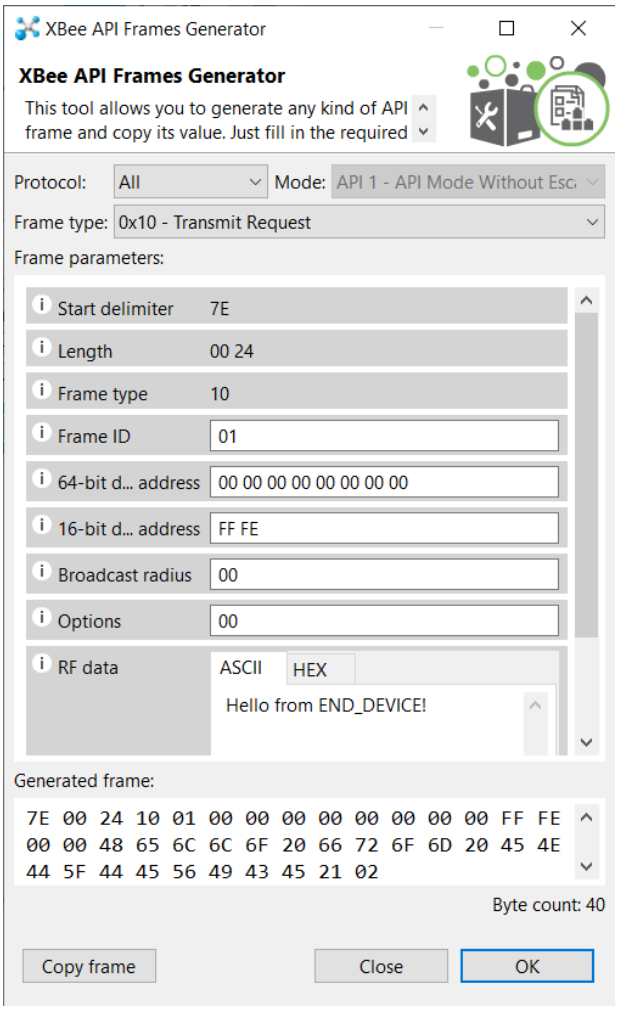


Send the packet.

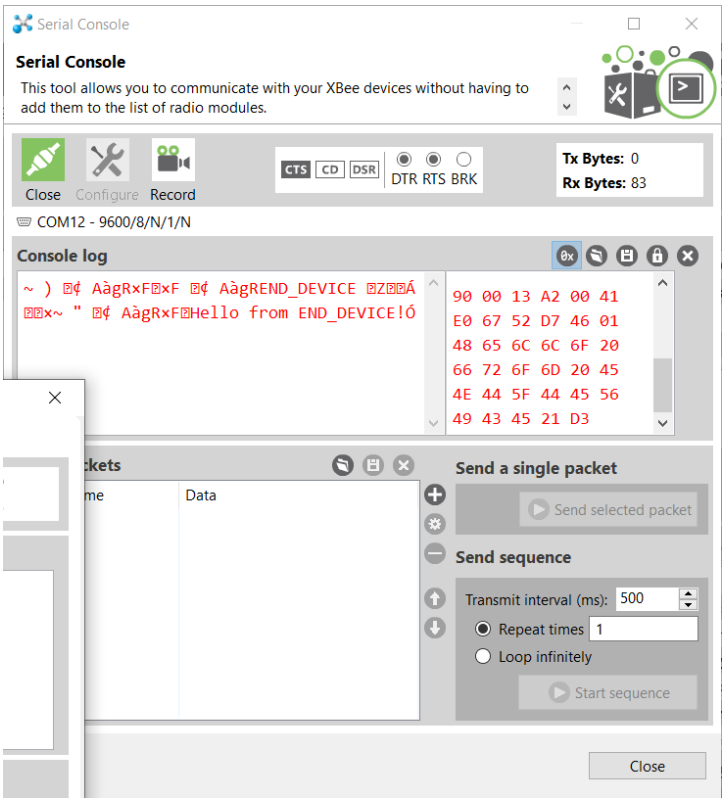


You will see that the data has been sent to the ROUTER.

Now, modify that packet to contain the destination address 00 00 00 00 00 00 00 00.

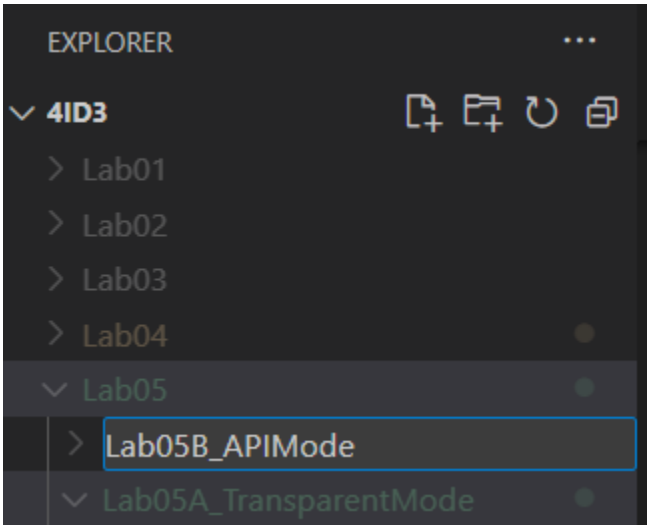


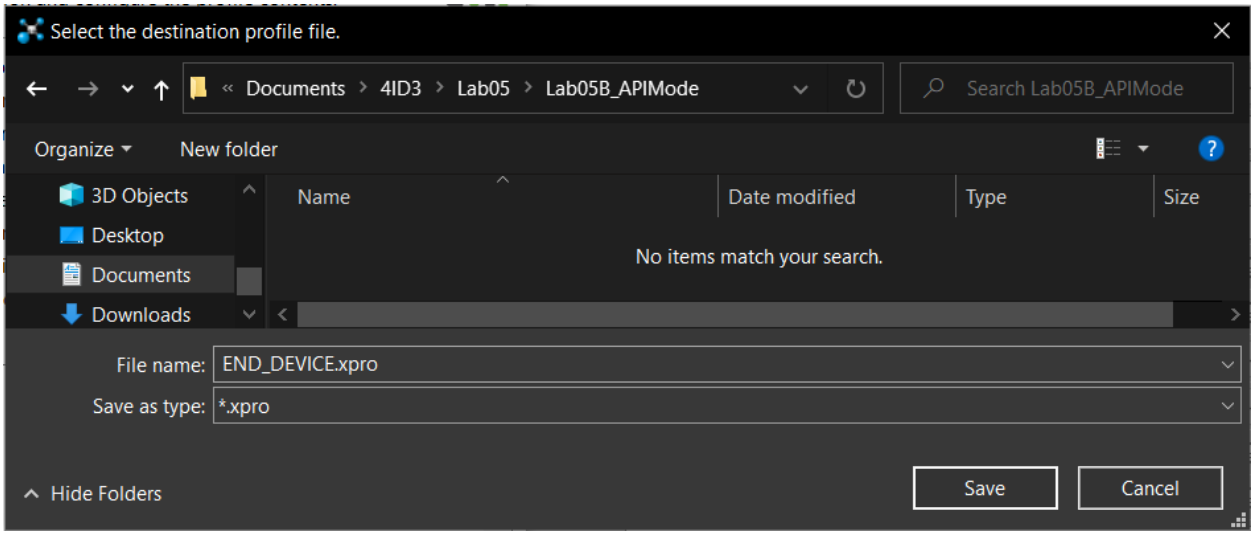
Save and transmit this message. Observe that **on END_DEVICE wake**, the data is transmitted to the **COORD** device.

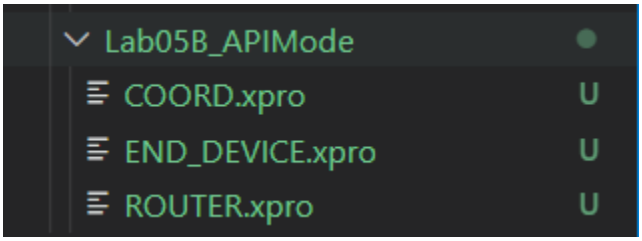


Create a new folder in your lab called **Lab05B_APIMode**.

Generate and export your profiles to this folder.



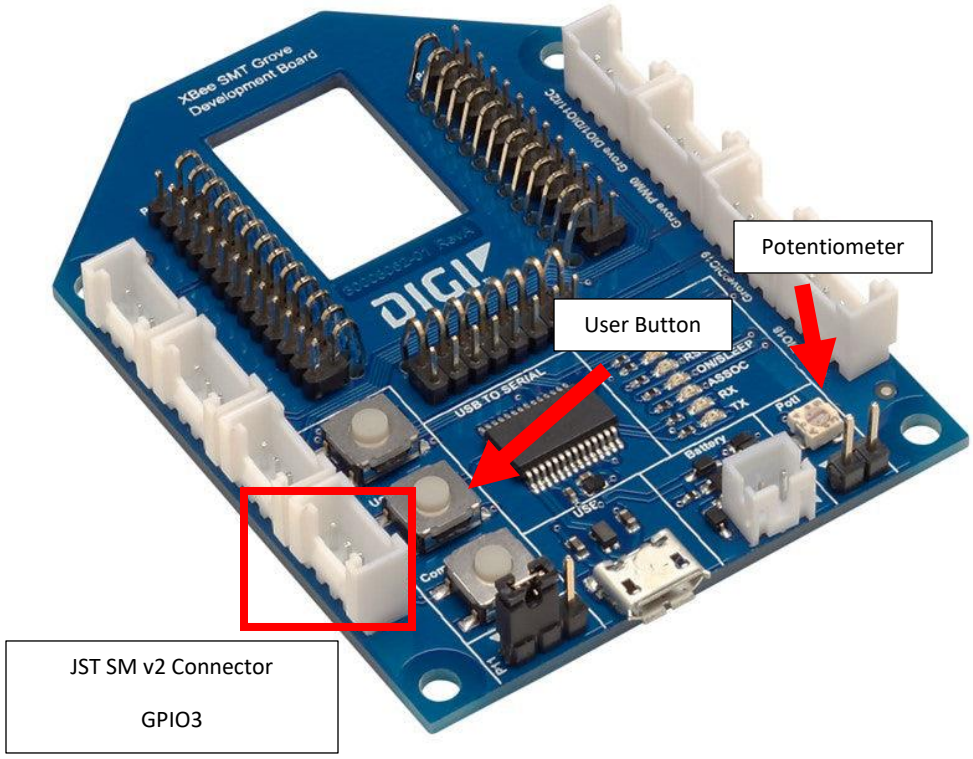

Select the destination profile file.
Documents
4ID3
Lab05
Lab05B_APIMode
Search Lab05B_APIMode
Organize
New folder
3D Objects
Desktop
Documents
Downloads
Name
Date modified
Type
Size
No items match your search.
File name:
END_DEVICE.xpro
Save as type:
*.xpro
Hide Folders
Save
Cancel


Lab05B_APIMode
COORD.xpro
U
END_DEVICE.xpro
U
ROUTER.xpro
U

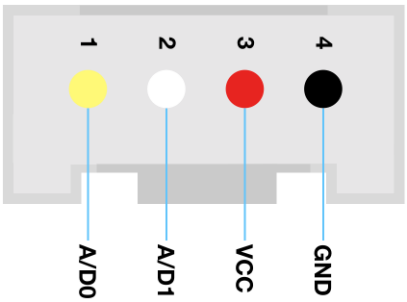
GPIO Forwarding

Connections

Make all connections on the **ROUTER** development board.



JST SM v2 (Grove) connector pinout:



Wiring Diagram:

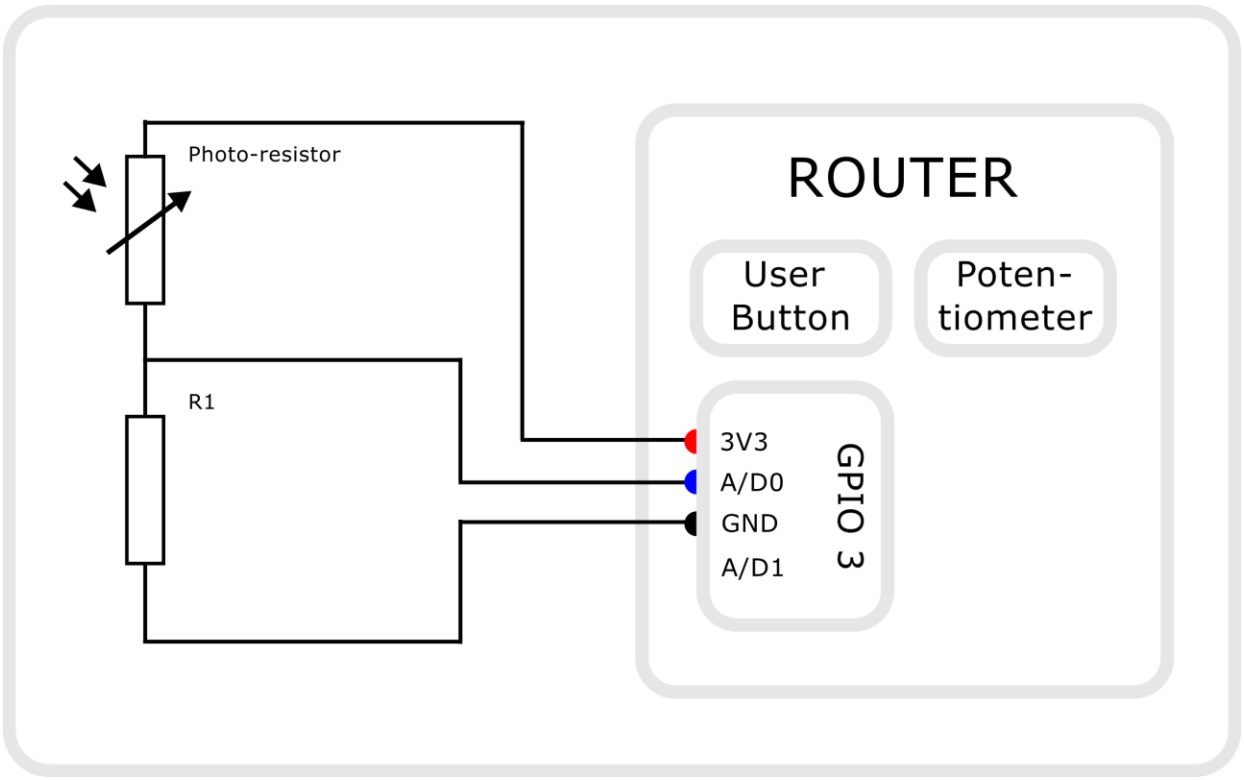
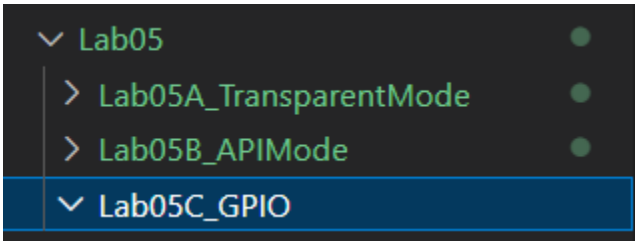


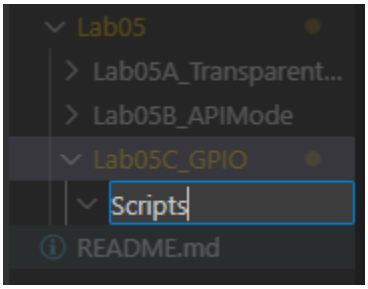
Photo-resistor
R1
ROUTER
User Button
Poten-tiometer
3V3
A/D0
GND
A/D1
GPIO 3

Python script setup

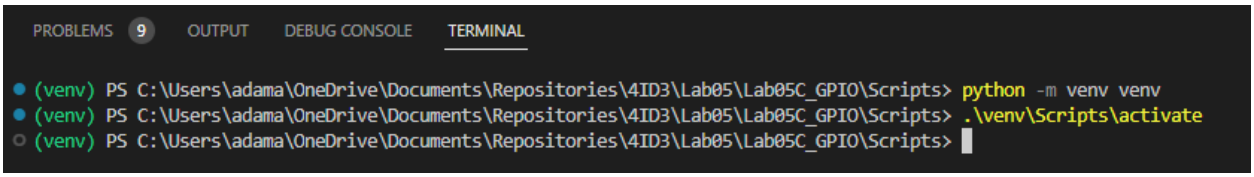
Create a new folder in your project folder called **Lab05C_GPIO**.



Inside of **Lab05C_GPIO**, create a new folder called **Scripts**.



Inside of **Scripts**, create a new virtual environment and source that virtual environment.



First, lets start off by installing the required libraries:

paho-mqtt

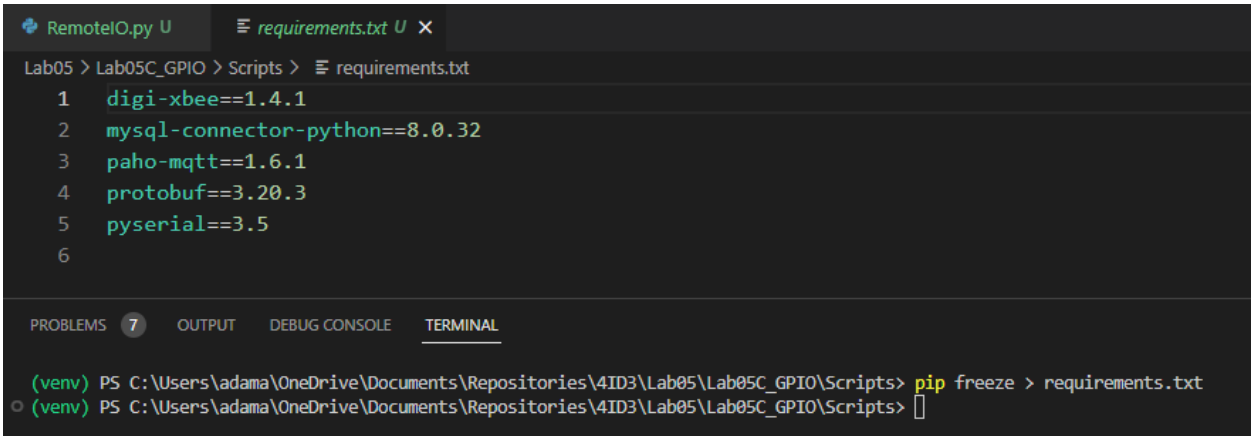
digi-xbee

mysql-connector-python

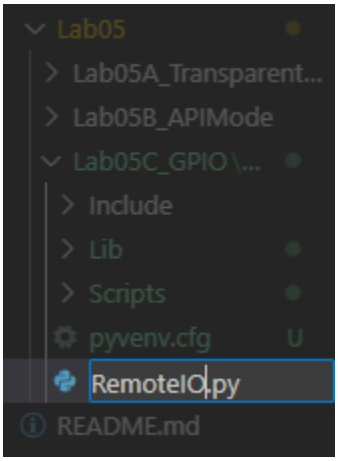
```
(venv) PS C:\Users\adama\OneDrive\Documents\Repositories\4ID3\Lab05\Lab05C_GPIO\Scripts> pip list
Package               Version
--------------------- -------
digi-xbee             1.4.1
mysql-connector-python 8.0.32
paho-mqtt             1.6.1
pip                   22.3.1
protobuf              3.20.3
pyserial              3.5
setuptools            65.5.0
```

Freeze the libraries into a requirements.txt file:

pip freeze > requirements.txt



Create a new Python script named **RemoteDIO.py**.



Inside this blank script, paste in the provided example template.

https://github.com/sokacza/4ID3/blob/main/Lab05/Lab05C_GPIO/Scripts/RemoteIO.py

Change the configuration parameters at the top of the file. Use the **PORT** of the **COORDINATOR** device.

```
 9
10  #-------------------------------------
11  #       CONFIGURATIONS
12  #-------------------------------------
13
14  #   Database Connection
15  HOST_IP = "localhost"
16  USER = "root"
17  PASSWORD = "9055259140"
18
19  #   MQTT Connection
20  MQTT_IP = 'test.mosquitto.org'
21  MQTT_PORT = 1883
22  GROUP_NAME = "GroupA"
23  DEVICE_ID = "DeviceA"
24
25  #   Device Connection
26  PORT = "COM7"
27  BAUD_RATE = 9600
28  REMOTE_NODE_ID = "ROUTER"
29  IO_SAMPLING_RATE = 5  # 5 seconds.
30
```

The first thing we have is a dictionary that stores what sensors are on which GPIO, what the name is, and what type of GPIO it is.

```
36  #-------------------------------------
37  #       CONNECTIONS
38  #-------------------------------------
39
40  #   IO initialization
41  io = dict({
42      "UserButton": {
43          "IO": IOLine.DIO4_AD4,
44          "Prev": None,
45          "Curr": None,
46          "Type": "DIO"
47      },
48      "Potentiometer": {
49          "IO": IOLine.DIO2_AD2,
50          "Prev": None,
51          "Curr": None,
52          "Type": "AIO"
53      },
54      "Photoresistor": {
55          "IO": IOLine.DIO3_AD3,
56          "Prev": None,
57          "Curr": None,
58          "Type": "AIO"
59      }
60  })
61
```

In the class, there is a **parse** method that looks at the raw string returned by the **digi-xbee** library.

```
80
81      def parse(self, data: str):
82          for d in range(str(data).count('[')):
83              key = list(self._profile.keys())[d]
84              sensor = self._profile[key]
85              s = str(sensor["IO"])
86              start = str(data).index(s)
87              end = str(data).index(']', start)
88              parsed = str(data)[start + len(s) + 2 : end]
89
90              if(sensor["Type"] == "DIO"):
91                  sensor["Prev"] = sensor["Curr"]
92                  sensor["Curr"] = parsed[8:]
93
94              elif(sensor["Type"] == "AIO"):
95                  sensor["Prev"] = sensor["Curr"]
96                  sensor["Curr"] = parsed
97
98          return self._profile
99
100 sman = IOWrapper(io)
```

This breaks up the string depending on how many items there are and updates the current and previous values of the dictionary.

Each time the script runs, the database is **reset** and MQTT is connected to.

```
104 try:
105     print("---\nDatabase reset:")
106     connection = mysql.connector.connect(host=HOST_IP,
107                                          user=USER,
108                                          password=PASSWORD)
109     if connection.is_connected():
110         db_Info = connection.get_server_info()
111         print("    > Connected to MySQL Server version ", db_Info)
112         cursor = connection.cursor()
113         cursor.execute(f"DROP DATABASE `{GROUP_NAME}`")
114         print("    > Database dropped successfully")
115         cursor.close()
116         connection.commit()
117         cursor = connection.cursor()
118         cursor.execute(f"CREATE SCHEMA IF NOT EXISTS `{GROUP_NAME}` DEFAULT CHARACTER SET utf8;")
119         cursor.close()
120         connection.commit()
121         print("     > Created Database")
```

```
150
151   #   Instantiating MQTT and callback functions
152   def on_connect(client, userdata, flags, rc):
153       print("Connected to  "+str(rc))
154
155   def on_message(client, userdata, msg):
156       print(msg.topic+" "+str(msg.payload))
157       data = str(msg.payload.decode('utf-8'))
158
159   client = mqtt.Client()
160   client.on_connect = on_connect
161   client.on_message = on_message
162   client.connect(MQTT_IP, MQTT_PORT, 60)
163   client.subscribe('Light', 2)
164
```

Lastly, the main method handles all the setup required.

```
174   #-----------------------------------
175   #       MAIN METHOD
176   #-----------------------------------
177
178   def main():
179       print(" +---------------------------------------------+")
180       print(" | XBee Python Library Handle IO Samples Sample |")
181       print(" +---------------------------------------------+\n")
182
183       device = XBeeDevice(PORT, BAUD_RATE)
184
185       try:
186           device.open()
187
188           # Obtain the remote XBee device from the XBee network.
189           xbee_network = device.get_network()
190           remote_device = xbee_network.discover_device(REMOTE_NODE_ID)
191           if remote_device is None:
192               print("Could not find the remote device")
193               exit(1)
194
195           # Set the local device as destination address of the remote.
196           remote_device.set_dest_address(device.get_64bit_addr())
197           # Enable periodic sampling every IO_SAMPLING_RATE seconds in the remote device.
198           remote_device.set_io_sampling_rate(IO_SAMPLING_RATE)
199
200
```

For each sensor reading parsed out of the string, we insert a database entry and publish to an mqtt topic.

```
            for x in data.keys():
                print(f'{GROUP_NAME}/{DEVICE_ID}/{x}', str(data[x]["Curr"]).encode('utf-8'))
                try:
                    client.publish(f'{GROUP_NAME}/{DEVICE_ID}/{x}', str(data[x]["Curr"]).encode('utf-8'))
                except:
                    print("Failed to send to MQTT")

                try:
                    connection = mysql.connector.connect(host=HOST_IP,
                                                         user=USER,
                                                         password=PASSWORD,
                                                         database=GROUP_NAME)
                    cursor = connection.cursor()
                    ts = now.strftime("%d/%m/%Y %H:%M:%S")
                    query = f"INSERT INTO `{GROUP_NAME}`.`{DEVICE_ID}` (`Time`, `Sensor`, `Value`) VALUES ('{str(ts)}', '{str(x)}', '{str(data[x]['Curr'])}'); "
                    print(query)
                    cursor.execute(query)
                    cursor.close()
                    connection.commit()
                    connection.close()
                except:
                    print("Failed to send to MySQL")

```

Finally, run the Python script:

```
PROBLEMS 9   OUTPUT   DEBUG CONSOLE   TERMINAL

 +---------------------------------------------+
 | XBee Python Library Handle IO Samples Sample |
 +---------------------------------------------+

New sample received from 0013A20041E06B0A - {[IOLine.DIO4_AD4: IOValue.HIGH], [IOLine.DIO2_AD2: 830], [IOLine.DIO3_AD3: 14]}
{'UserButton': {'IO': <IOLine.DIO4_AD4: ('DIO4/AD4', 4, 'D4')>, 'Prev': None, 'Curr': 'HIGH', 'Type': 'DIO'}, 'Potentiometer': {'IO': <IOLine.DIO2_AD2: ('DIO2/AD2', 2, 'D2')>,
}, 'Photoresistor': {'IO': <IOLine.DIO3_AD3: ('DIO3/AD3', 3, 'D3')>, 'Prev': None, 'Curr': '14', 'Type': 'AIO'}}
GroupA/DeviceA/UserButton b'HIGH'
INSERT INTO `GroupA`.`DeviceA` (`Time`, `Sensor`, `Value`) VALUES ('03/03/2023 23:46:35', 'UserButton', 'HIGH');
GroupA/DeviceA/Potentiometer b'830'
INSERT INTO `GroupA`.`DeviceA` (`Time`, `Sensor`, `Value`) VALUES ('03/03/2023 23:46:35', 'Potentiometer', '830');
GroupA/DeviceA/Photoresistor b'14'
INSERT INTO `GroupA`.`DeviceA` (`Time`, `Sensor`, `Value`) VALUES ('03/03/2023 23:46:35', 'Photoresistor', '14');
```

Click your button change your potentiometer, and cover your photoresistor as data is being collected.

And check your database:

```
mysql> USE `GroupA`;
Database changed
mysql> SELECT * FROM `GroupA`.`DeviceA`;
+----+---------------------+--------------+-------+
| id | Time                | Sensor       | Value |
+----+---------------------+--------------+-------+
|  1 | 03/03/2023 23:53:45 | UserButton   | HIGH  |
|  2 | 03/03/2023 23:53:45 | Potentiometer | 830  |
|  3 | 03/03/2023 23:53:45 | Photoresistor | 1023 |
|  4 | 03/03/2023 23:53:50 | UserButton   | HIGH  |
|  5 | 03/03/2023 23:53:50 | Potentiometer | 830  |
|  6 | 03/03/2023 23:53:50 | Photoresistor | 1023 |
|  7 | 03/03/2023 23:53:55 | UserButton   | HIGH  |
|  8 | 03/03/2023 23:53:55 | Potentiometer | 830  |
|  9 | 03/03/2023 23:53:55 | Photoresistor | 22   |
| 10 | 03/03/2023 23:53:57 | UserButton   | LOW   |
| 11 | 03/03/2023 23:53:57 | Potentiometer | 830  |
| 12 | 03/03/2023 23:53:57 | Photoresistor | 22   |
| 13 | 03/03/2023 23:53:58 | UserButton   | HIGH  |
| 14 | 03/03/2023 23:53:58 | Potentiometer | 830  |
| 15 | 03/03/2023 23:53:58 | Photoresistor | 22   |
| 16 | 03/03/2023 23:53:58 | UserButton   | LOW   |
| 17 | 03/03/2023 23:53:58 | Potentiometer | 830  |
| 18 | 03/03/2023 23:53:58 | Photoresistor | 22   |
| 19 | 03/03/2023 23:53:58 | UserButton   | HIGH  |
| 20 | 03/03/2023 23:53:58 | Potentiometer | 830  |
| 21 | 03/03/2023 23:53:58 | Photoresistor | 22   |
| 22 | 03/03/2023 23:54:00 | UserButton   | HIGH  |
| 23 | 03/03/2023 23:54:00 | Potentiometer | 830  |
| 24 | 03/03/2023 23:54:00 | Photoresistor | 19   |
| 25 | 03/03/2023 23:54:02 | UserButton   | LOW   |
| 26 | 03/03/2023 23:54:02 | Potentiometer | 830  |
| 27 | 03/03/2023 23:54:02 | Photoresistor | 19   |
| 28 | 03/03/2023 23:54:02 | UserButton   | HIGH  |
```

Exercise A

Use NodeRED to create a dashboard and visualize the data. Submit a screenshot with your report.

Exercise B

Can be done at home. Either modify the original code or create a separate Python script to export the data to an CSV file. Graph each sensor as its own graph. Submit those 3 screenshots with your report.

Hint: Look at the previous lab

(Optional) Exercise C

Can be done at home. Create a .Net WinForms desktop application to query the database and display the data. A template has been provided in the lab GitHub. Submit a screenshot with your report.

Syncing with GitHub

Use the following commands to resync your Git repo with your GitHub remote repo.

git add .

git commit -m "Lab 04 completed"

git push origin main

git pull origin main

END