

Universidad Politécnica de Valencia

ESCUELA TÉCNICA SUPERIOR DE INGENIERÍA INFORMÁTICA

RFID-RC522 KEY READING

Internet of Things

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June 2024

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1 Introduction

This project involves developing an access control system using RFID technology (RFID-RC522 reader). The system will allow user registration and access control using RFID keys and cards. To switch the reader mode between registration and access, Bluetooth communication will be used. Registered users and accesses will be stored in a database accessible via a REST API within a container. For visualization, Ubidots will be used. The entire project is available in a GitHub repository [RFID-RC522 Key Reading](#) [1].

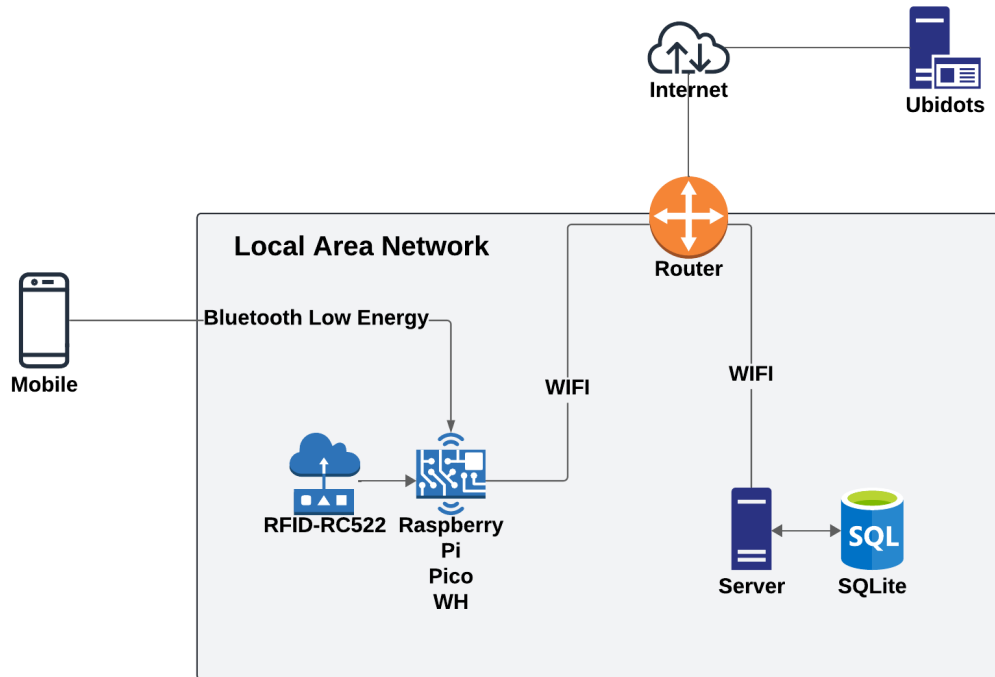
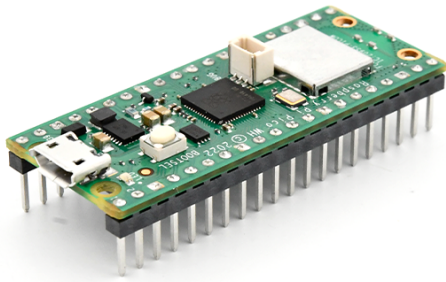


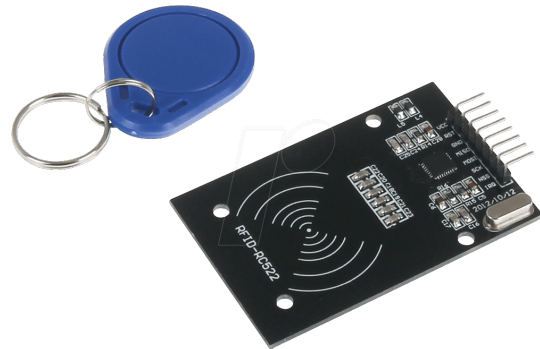
Figure 1: Project diagram.

2 Hardware Used

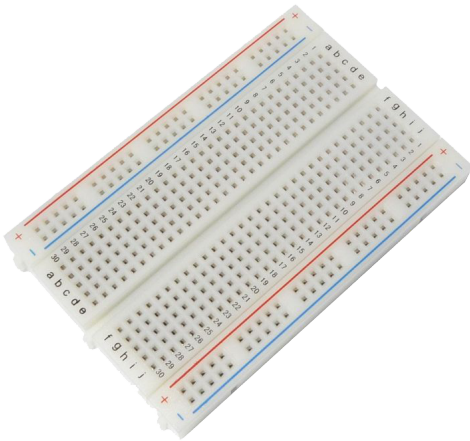
The following hardware was used for the project:



Raspberry Pi Pico WH Microcontroller



RFID-RC522 Radio Frequency Reader



Protoboard



Tri-color LED KY-016 SP00



Dupont Male-Male Cable x3



Dupont Female-Male Cable x5



500 Ω Resistor x2

3 Software Used

The following software was used for the project.

3.1 Microcontroller

MicroPython was used as the programming language for the Raspberry Pi Pico WH microcontroller. To establish and manage Bluetooth communication on the microcontroller, the [BLE \(Bluetooth Low Energy\) libraries](#) [3] were utilized. For the communication of the mobile device with the microcontroller, the [Serial Bluetooth Terminal](#) app [5] available on Play Store was used. For reading RFID keys and cards, the [MFRC522 library](#) [4] was employed. In communication with the server, a REST API was implemented to enable structured data exchange. Finally, the standard machine library was used to turn LEDs on and off.

3.2 Server

For the server implementation, a Docker container with the base image of Ubuntu was used. Python was installed on the image along with the Flask package to manage server logic through HTTP requests. For data persistence, a Docker volume was used along with an SQLite database. For server development, the code from the [Lab 6 - REST](#) [2] was modified.

3.3 Ubidots

The [Ubidots](#) platform was used for visualization through a STEM account. Ubidots allows real-time data visualization with a request rate of 1 req/s.

4 Steps to Complete the Project

The following steps should be followed to complete the project.

4.1 Step 1: Pre-installation of Necessary Software

Server Application Installations:

1. Install [Thonny](#).
2. Install [Visual Studio Code](#).
3. Install [Docker](#).
4. Install [Python interpreter](#).

File Installation on Raspberry Pi Pico WH:

1. Install MicroPython firmware:
 - (a) Insert the USB into the computer while pressing the BOOTSEL button.
 - (b) Open Thonny and follow these steps:

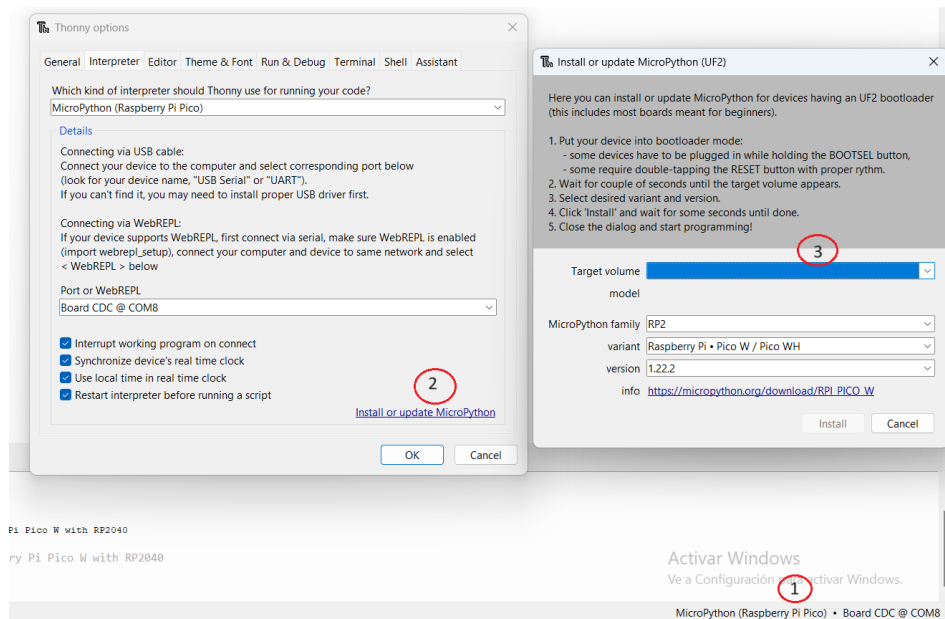


Figure 5: Steps to install the firmware.

2. Copy the contents of the ‘‘microcontroller’’ folder from the project to the Raspberry Pi Pico WH.
3. Configure the ‘‘ssid’’ and ‘‘password’’ variables inside the ‘‘microcontroller/wifi.connect.py’’ file with your network’s ssid and password.

Ubidots Registration and Configuration:

1. Create an account on [Ubidots Stem](#).
2. Create a new device.

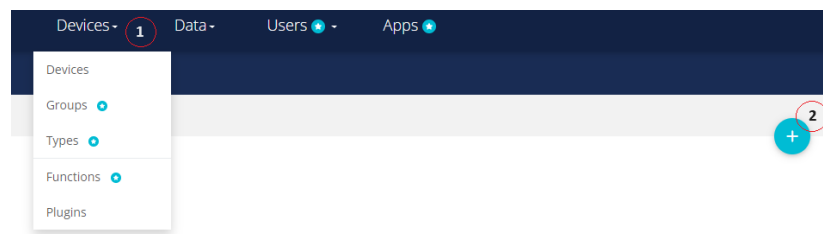


Figure 6: Creating a new device on Ubidots.

3. Add the device name to the ‘‘DISPOSITIVE_NAME’’ variable inside the ‘‘api/ubidots_conf.py’’ file.
4. Within the device, create two ‘‘raw variable’’, one for user registration ‘‘add.user.register’’ and another for user access registration ‘‘add.time.registry’’.

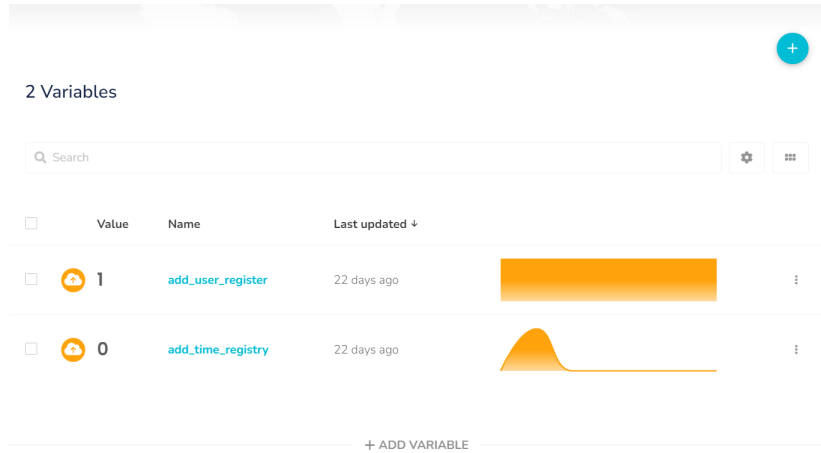


Figure 7: Creating a variable on Ubidots.

5. Obtain the API token.

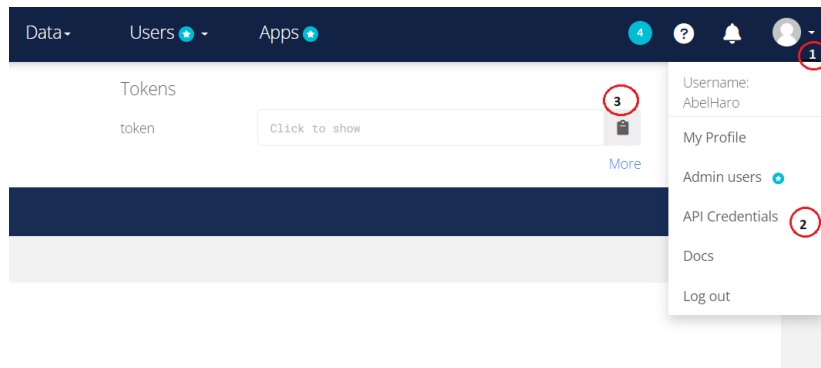


Figure 8: Obtaining the API token on Ubidots.

6. Copy the API token to the ‘‘TOKEN_UBIDOTS’’ variable inside the ‘‘api/ubidots_conf.py’’ file.

4.2 Step 2: Circuit Assembly

For circuit assembly, the following video was used as a reference ‘RFID RC522 with Raspberry Pi Pico and MicroPython Codes for Simple Access Control’ [6].

Connect the RFID-RC522 reader to the Raspberry Pi Pico WH following this table:

RFID-RC522 Reader	Raspberry Pi Pico WH
VCC	3.3V
RST	GP0
GND	GND
IRQ	Not connected
MISO	GP4
MOSI	GP3
SCK	GP2
SDA	GP1

Table 1: Connections between the RFID-RC522 reader and the Raspberry Pi Pico WH.

Connect the KY-016 SP00 tri-color LED to the Raspberry Pi Pico WH following this table:

KY-016 SP00	Raspberry Pi Pico WH
R	GP13
G	GP12
B	Not connected
-	GND

Table 2: Connections between the KY-016 SP00 tri-color LED and the Raspberry Pi Pico WH.

The circuit assembly should look like the following figure:

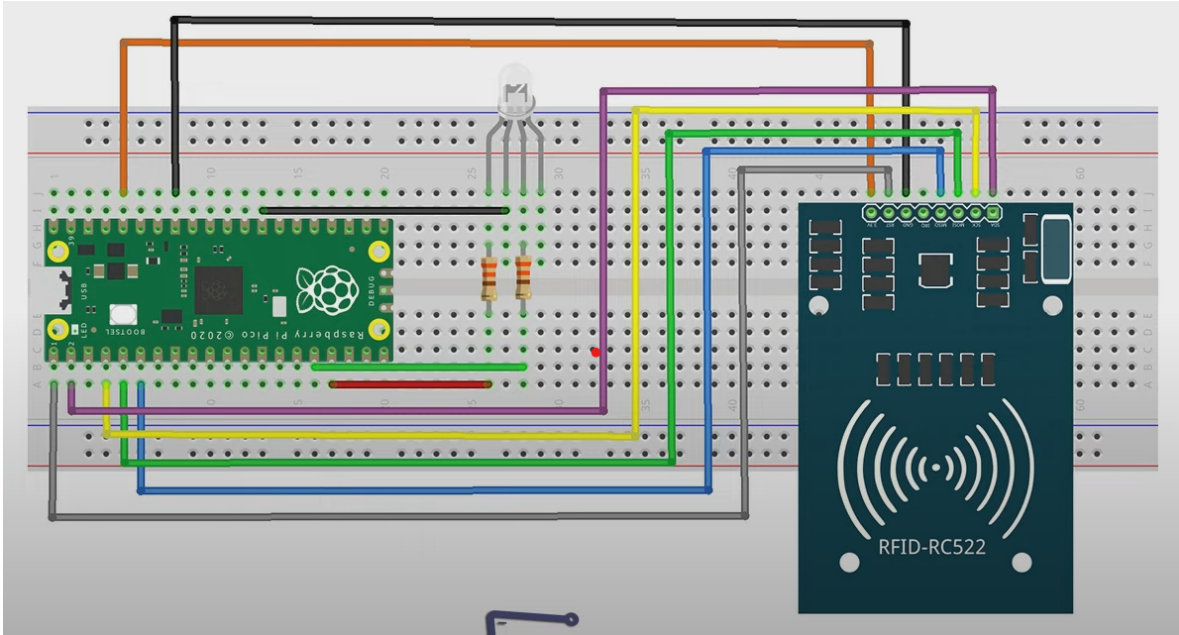


Figure 9: Project circuit diagram.

4.3 Step 3: Mobile Application Configuration

To configure the mobile application, follow these steps:

1. Install the [Serial Bluetooth Terminal](#) app on your mobile device.
2. Pair the Raspberry Pi Pico WH with the mobile device via Bluetooth.
3. Open the Serial Bluetooth Terminal app and connect to the Raspberry Pi Pico WH.
4. Send the message ‘‘ADD_USER_REGISTER’’ to the Raspberry Pi Pico WH to change the mode to user registration.
5. Send the message ‘‘ADD_TIME_REGISTRY’’ to the Raspberry Pi Pico WH to change the mode to access registration.

This is how it’s shown in the Serial Bluetooth Terminal app:

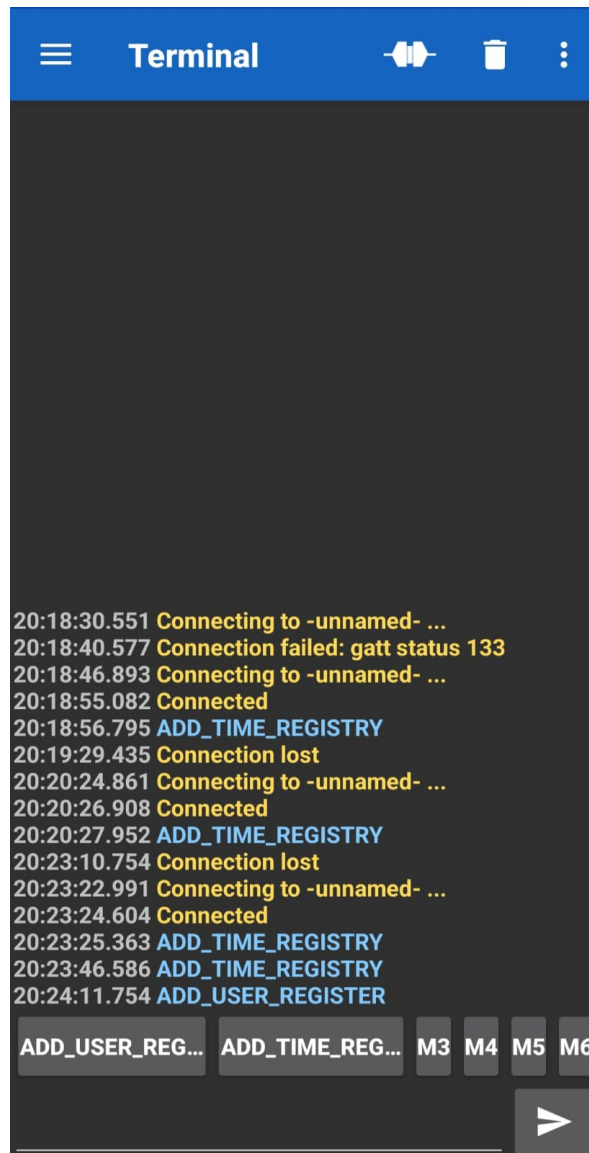


Figure 10: Serial Bluetooth Terminal app.

4.4 Step 4: Project Execution

To execute the project, follow these steps:

1. Connect the Raspberry Pi Pico WH to the computer.
2. Open Thonny and run the ‘‘microcontroller/main.py’’ file on the Raspberry Pi Pico WH.
3. Start the Docker daemon.
4. Run the ‘‘build.bat’’ file on the server.
5. Open Ubidots and visualize the data.
6. Perform registration and access tests.

This is how it’s shown in Ubidots:

The screenshot shows the Ubidots dashboard with two data visualization tables. The top table, 'Registered Users', has columns: DEVICE NAME, VARIABLE NAME, DATE, and UID FROM REGISTERED USER. It contains one row with the data: 'Controlador de acceso', 'add_user_register', '06/04/2024 20:24', and '688232451'. The bottom table, 'Time Registry', has columns: DEVICE NAME, VARIABLE NAME, DATE, UID FROM USER TIME REGISTERED, and ENTERED. It contains one row with the data: 'Controlador de acceso', 'add_time_registry', '06/04/2024 20:23', '239600531', and '1.00'.

DEVICE NAME	VARIABLE NAME	DATE	UID FROM REGISTERED USER
Controlador de acceso	add_user_register	06/04/2024 20:24	688232451

DEVICE NAME	VARIABLE NAME	DATE	UID FROM USER TIME REGISTERED	ENTERED
Controlador de acceso	add_time_registry	06/04/2024 20:23	239600531	1.00

Figure 11: Ubidots data visualization.

In the variable ‘‘add_user_register’’ shows the user UID and the date of the registration. In the variable ‘‘add_time_registry’’ shows the user UID, the date of the access, and a column ‘‘entered’’, which is 1 if the user was registered and 0 if not.

5 Project Programming

In this section, the code of the main project files is detailed.

5.1 Microcontroller

The microcontroller code is divided into several files:

5.1.1 main.py

This file is the main script for the microcontroller. It contains the configuration for Bluetooth communication and the function ‘‘on_rx(data)’’ where the Bluetooth message is received to change the reading mode. In the ‘‘main()’’ function, ‘‘wifi.connect()’’ is called to connect to the WiFi network, and the main loop of the program is started. In the loop, the ‘‘sensor.read_sensor()’’ function is called to get the UID of the RFID key or card. If the mode is registration, the ‘‘sender.add_user_register(uid)’’ function is called, and if the mode is entry registration, the ‘‘sender.add_time_registry(uid)’’ function is called. Finally, the ‘‘led.blink_led(response[‘api_status’])’’ function is called to turn on the tricolor LED based on the API response.

```

1 import bluetooth # Bluetooth module
2 from ble.ble_simple_peripheral import BLESimplePeripheral # BLE module
3 import time
4 import wifi_connect as wifi
5 import data_sending_api as sender
6 import sensor
7 import led_control as led
8 import ubidots
9
10 # Initialize Bluetooth Low Energy (BLE) interface and Simple Peripheral
11 ble = bluetooth.BLE()
12 sp = BLESimplePeripheral(ble, name="Pico WH")
13
14 # Default mode for RFID sensor operation
15 MODE = 'ADD_USER_REGISTER' # Default mode is to add user registration
16
17 def on_rx(data):
18     """
19     Callback function for receiving data from BLE.

```

```

20
21 Parameters:
22     data (bytes): Received data as bytes.
23
24 Global Variables Modified:
25     MODE (str): Updated mode based on received data.
26     """
27     global MODE # Access global variable MODE within the function
28     print("Data received:", data)
29
30     # Update mode based on received data
31     if data == b'ADD_USER_REGISTER\r\n':
32         MODE = 'ADD_USER_REGISTER'
33     elif data == b'ADD_TIME_REGISTRY\r\n':
34         MODE = 'ADD_TIME_REGISTRY'
35
36
37 if __name__ == '__main__':
38     # Connect to WiFi
39     wifi.connect()
40
41     try:
42         while True:
43             if sp.is_connected():
44                 sp.on_write(on_rx) # Register callback for BLE data reception
45                 # Read UID from sensor
46                 uid = sensor.read_sensor()
47
48                 # Determine mode and call appropriate API
49                 if MODE == 'ADD_USER_REGISTER':
50                     response = sender.add_user_register(uid) # Call API to add
51                     user registration
52                 elif MODE == 'ADD_TIME_REGISTRY':
53                     response = sender.add_time_registry(uid) # Call API to add
54                     time registry
55                 else:
56                     print('Error: Invalid mode')
57                     raise Exception('Invalid mode detected') # Raise an exception
58                     for invalid mode
59
60                 # Blink LED based on API response status
61                 led.blink_led(response['api_status'])
62                 time.sleep(1)
63     except KeyboardInterrupt:
64         print('Programa abortado con CTRL+C desde main.py') # Handle keyboard
65         interrupt

```

Figure 12: Code for the ‘‘microcontroller/main.py’’ file of the microcontroller.

5.1.2 sensor.py

This file contains the ‘‘read_sensor()’’ function which reads the RFID sensor and returns the UID of the read RFID key or card.

```

1 from lib.mfrc522.mfrc522 import MFRC522 # RFID reader module
2 import time # Time-related functions
3
4 def read_sensor() -> str:
5     """

```

```

6     Function to read RFID sensor and perform actions based on the received
       data.
7
8     Returns:
9         str: UID from card or key readed.
10    """
11    # Initialize the MFRC522 RFID reader
12    reader = MFRC522(spi_id=0, sck=2, miso=4, mosi=3, cs=1, rst=0)
13
14    print("RFID sensor active...\n")
15
16    try:
17        while True:
18            reader.init() # Initialize the RFID reader
19            (stat, tag_type) = reader.request(reader.REQIDL) # Request tag
              detection
20
21            if stat == reader.OK:
22                (stat, uid) = reader.SelectTagSN() # Select detected tag
23                if stat == reader.OK:
24                    # Convert UID bytes to integer for identification
25                    identifier = int.from_bytes(bytes(uid), "little", False)
26                    print("UID: " + str(identifier)) # Print detected UID
27
28                    return str(identifier) # Convert UID to string
29
30                time.sleep(1) # Sleep for 1 second between iterations
31
32    except KeyboardInterrupt:
33        print("Program terminated with CTRL+C from sensor.py") # Handle
          keyboard interrupt

```

Figure 13: Code of the file ‘microcontroller/sensor.py’ of the microcontroller.

5.1.3 data_sending_api.py

This file contains the functions to send data using the server’s REST API. It includes the functions ‘add_user_register(uid)’ and ‘add_time_registry(uid)’ to send user registration and access data respectively.

```

1     import time # Standard Python time module
2     import ujson # Module for handling JSON data
3     import urequests as requests # Module for making HTTP requests (alias for
         urequests)
4
5     URL = 'http://192.168.1.2:8888/api/'
6     URL_add_user_register = URL + 'user_register/add'
7     URL_add_time_registry = URL + 'time_registry/add'
8     URL_get_user_registered_by_uid = URL + 'user_register'
9
10    def get_local_time() -> str:
11        """
12        Returns the timestamp formatted.
13        """
14        local_time = time.localtime()
15        formatted_time = "{:04d}-{:02d}-{:02d} {:02d}:{:02d}:{:02d}".format(
16            local_time[0], # year
17            local_time[1], # month
18            local_time[2], # day
19            local_time[3], # hour

```

```

20     local_time[4], # minute
21     local_time[5] # second
22 )
23 return str(formatted_time)
24
25 def add_user_register(uid):
26     """
27     Adds the user to the database using a POST request.
28
29     Parameters:
30         uid (str): The UID (Unique ID) of the user to be registered.
31
32     Returns:
33         dict: A dictionary containing the response message from the server
34         .
35     """
36     data_sending = {
37         "UID": uid,
38         "user_creation_tstamp": get_local_time()
39     }
40
41     response = requests.post(URL_add_user_register, headers={'Content-Type': 'application/json'}, data=ujson.dumps(data_sending))
42     return ujson.loads(response.content)
43
44 def add_time_registry(uid):
45     """
46     Adds the time registry to the database using a POST request.
47
48     Parameters:
49         uid (str): The UID (Unique ID) of the user to be registered.
50
51     Returns:
52         dict: A dictionary containing the response message from the server
53         .
54     """
55     data_sending = {
56         "UID": uid,
57         "user_registry_tstamp": get_local_time()
58     }
59
60     response = requests.post(URL_add_time_registry, headers={'Content-Type': 'application/json'}, data=ujson.dumps(data_sending))
61     return ujson.loads(response.content)
62
63 def get_user_registered_by_uid(uid):
64     """
65     Retrieves user registration details from the server based on UID using
66     a GET request.
67
68     Parameters:
69         uid (str): The UID (Unique ID) of the user to be registered.
70
71     Returns:
72         dict: A dictionary containing the response message from the server
73         .
74     """
75     response = requests.get(URL_get_user_registered_by_uid + '%s'.format(
76         uid))
77     return ujson.loads(response.content)

```

Figure 14: Code of the file ‘‘microcontroller/data_sending_api.py’’ of the microcontroller.

5.2 Server

5.2.1 api.py

This file contains the REST API of the server. It includes functions to connect to the database, add users and access records, retrieve users and access records based on UID, and send user and access records to Ubidots. Only the functions for user registration ‘‘insert_user_register()’’, ‘‘get_user_register_by_uid(uid)’’, and ‘‘add_user_ubidots(uid)’’ are shown in the following figure.

```
1  import sqlite3
2  from flask import Flask, request, jsonify
3  import requests
4  from api.ubidots_conf import URL_UBIDOTS, TOKEN_UBIDOTS
5
6  ...
7
8  def insert_user_register(user):
9      """
10     Inserts a new user registration record into the 'user_register' table
11     and send it to Ubidots.
12
13     Parameters:
14         user (dict): Dictionary containing user information with keys:
15             - 'UID': Unique ID of the user.
16             - 'user_creation_tstamp': Timestamp of user creation.
17
18     Returns:
19         dict: Dictionary containing the status of the operation and error
20             message (if any).
21             Keys:
22             - 'api_status': Boolean indicating the success of the
23               operation.
24             - 'error': Error message if an error occurred during the
25               operation.
26             - 'ubidots_status': HTTP status code of the request to
27               Ubidots.
28             - 'UID': Unique ID of the user.
29             - 'user_creation_tstamp': Timestamp of user creation.
30     """
31     inserted_user = {'api_status': False, 'error': None, 'ubidots_status':
32                     False, 'UID': None, 'user_creation_tstamp': None}
33     try:
34         conn = connect_to_db()
35         conn.row_factory = sqlite3.Row
36         cur = conn.cursor()
37         cur.execute("SELECT * FROM user_register WHERE UID = ?", (user['
38             UID'],))
39         rows = cur.fetchall()
40         if len(rows) > 0:
41             inserted_user['error'] = "User already exists"
42             return inserted_user
43
44         cur.execute("INSERT INTO user_register (UID, user_creation_tstamp)
45             VALUES (?, ?)",
46                     (user['UID'], user['user_creation_tstamp']) )
```

```

39         conn.commit()
40         inserted_user.update(get_user_register_by_uid(user['UID']))
41         ubidots_status = add_user_ubidots(user['UID'])
42         if ubidots_status == 200:
43             inserted_user['api_status'] = True
44         else :
45             inserted_user['error'] = "Error adding user to Ubidots"
46
47         inserted_user['ubidots_status'] = ubidots_status
48     except:
49         conn.rollback()
50     finally:
51         conn.close()
52     return inserted_user
53
54     def get_user_register_by_uid(uid):
55         """
56         Retrieves a user record from the 'user_register' table based on the
57         provided UID.
58
59         Parameters:
60             uid (str): The UID (Unique ID) of the user to retrieve.
61
62         Returns:
63             dict: A dictionary representing the user record if found,
64                   otherwise an empty dictionary.
65                   The dictionary contains keys 'UID' and 'user_creation_tstamp'
66                   with corresponding values.
67         """
68         user = {}
69         try:
70             conn = connect_to_db()
71             conn.row_factory = sqlite3.Row
72             cur = conn.cursor()
73             cur.execute("SELECT * FROM user_register WHERE UID = ?", (uid,))
74             rows = cur.fetchall()
75
76             # convert row objects to dictionary
77             for i in rows:
78                 user["UID"] = i["UID"]
79                 user["user_creation_tstamp"] = i["user_creation_tstamp"]
80
81         except:
82             user = {}
83         return user
84
85     def add_user_ubidots(uid):
86         """
87         Sends an HTTP POST request to Ubidots API to add a user registration.
88
89         Parameters:
90             uid (str): The UID (User ID) of the user to register.
91
92         Returns:
93             int: HTTP status code of the request.
94         """
95         data = {
96             'add_user_register': {
97                 'value': 1,
98                 'context': {
99                     'UID': uid
100                 }
101             }
102         }

```

```

98     }
99 }
100 request = requests.post(
101     URL_UBIDOTS,
102     headers={'X-Auth-Token': TOKEN_UBIDOTS, 'Content-Type': '
103         application/json'},
104     json=data
105 )
106 return request.status_code
107
108 @app.route('/api/user_register/<uid>', methods=['GET'])
109 def api_get_user_register_by_id(uid):
110     return jsonify(get_user_register_by_uid(uid))
111
112 @app.route('/api/user_register/add', methods=['POST'])
113 def api_add_user_register():
114     user = request.get_json()
115     return jsonify(insert_user_register(user))
116
117 app.run(host="0.0.0.0")

```

Figure 15: Code of the file ‘‘api/api.py’’ of the server.

5.2.2 initdb.py

This file contains the initialization of the database. It creates the ‘‘database’’ directory if it does not exist and the ‘‘database.db’’ file if it does not exist. It creates the ‘‘user_register’’ and ‘‘time_registry’’ tables if they do not exist.

Column Name	Data Type	Constraints
UID	TEXT	PRIMARY KEY, NOT NULL
user_creation_tstamp	TEXT	NOT NULL

Table 3: Table user_register schema.

Column Name	Data Type	Constraints
id	INTEGER	PRIMARY KEY AUTOINCREMENT
user_registry_tstamp	TEXT	NOT NULL
UID	TEXT	NOT NULL, REFERENCES user_register(UID)

Table 4: Table time_registry schema.

```

1 import sqlite3
2 import os
3
4 if __name__ == '__main__':
5     try:
6         # Create the directory if it doesn't exist
7         os.makedirs('database', exist_ok=True)
8         print("Database directory created successfully.")
9
10        # Create the database file if it doesn't exist
11        open('database/database.db', 'a').close()
12        print("Database file created successfully.")
13

```



```

14 # Establish connection to the database
15 conn = sqlite3.connect('database/database.db')
16 print("Connection to the database established successfully.")
17
18 # Create user_register table
19 conn.execute('''
20     CREATE TABLE IF NOT EXISTS user_register (
21         UID TEXT PRIMARY KEY NOT NULL,
22         user_creation_tstamp TEXT NOT NULL
23     )
24 ''')
25 print("Table 'user_register' created successfully.")
26
27 # Create time_registry table
28 conn.execute('''
29     CREATE TABLE IF NOT EXISTS time_registry (
30         id INTEGER PRIMARY KEY AUTOINCREMENT,
31         user_registry_tstamp TEXT NOT NULL,
32         UID TEXT NOT NULL REFERENCES user_register(UID)
33     )
34 ''')
35
36 print("Table 'time_registry' created successfully.")
37
38 # Commit changes
39 conn.commit()
40 print("Changes committed successfully.")
41 except Exception as e:
42     print(e)
43     print("Table creation failed")
44 finally:
45     conn.close()

```

Figure 16: Code of the file ‘‘api/initdb.py’’ of the server.

5.2.3 build.bat, Dockerfile, and start.sh

These files are necessary for creating the Docker container for the server. The file ‘‘build.bat’’ contains the commands for building the image and starting the container. The file ‘‘api/Dockerfile’’ contains the instructions for building the container image. The file ‘‘api/start.sh’’ contains the instructions for initializing the database and running the API.

```

1 REM Change directory to the location of the Dockerfile
2 cd ./api
3
4 REM Build Docker image
5 docker build -t server_rfid .
6
7 REM Run Docker container
8 docker run --rm -it -v database:/home/database -p 8888:5000 --name
   server_rfid server_rfid

```

Figure 17: Code of the file ‘‘build.bat’’ of the server.

```

1 FROM ubuntu
2
3 # Instalar Python 3 y Flask

```

```

4 RUN apt update
5 RUN apt install python3 python3-pip -y
6 RUN apt install python3-flask -y
7 RUN apt install python3-requests -y
8
9 # Establecer el directorio de trabajo y copiar los archivos
10 WORKDIR /home/
11 COPY initdb.py .
12 COPY api.py .
13 COPY start.sh .
14 COPY ubidots.py .
15
16 # Dar permisos para ejecutar el script
17 RUN chmod +x start.sh
18
19 # Exponer el puerto
20 EXPOSE 5000
21
22 # Ejecutar los scripts
23 CMD ["/start.sh"]

```

Figure 18: Code of the file ‘‘api/Dockerfile’’ of the server.

```

1  #!/bin/sh
2
3  # Check if the database directory exists, if not, create it (Only for the
   first run)
4  if [ ! -d "database" ]; then
5      mkdir database
6  fi
7
8  # Initialize the database
9  python3 initdb.py
10
11 # Start the API
12 python3 api.py

```

Figure 19: Code of the file ‘‘api/start.sh’’ of the server.

5.2.4 ubidots_conf.py

This file contains the configuration of Ubidots. It includes the Ubidots URL, device, and API token.

```

1 DISPOITIVE_NAME = '' # Device name in Ubidots
2 URL_UBIDOTS = f'http://industrial.api.ubidots.com/api/v1.6/devices/{
   DISPOITIVE_NAME}'
3 TOKEN_UBIDOTS = '' # Token of the API

```

Figure 20: Code from the file ‘‘api/ubidots_conf.py’’ on the server.

6 Issues Encountered

The following sections describe the issues encountered during the project and the proposed solutions:

6.1 Problem 1: Static Server Address

In order to access the server from the Raspberry Pi Pico WH consistently without having to modify the code, a static IP address must be set for the server. This can be achieved by configuring the router's DHCP settings.

Access the router's configuration page using a web browser. Typically, this can be done by entering the router's IP address, in my case 192.168.1.1, in the address bar and logging in with the username ‘‘admin’’ and the password. Once logged in, navigate to the advanced configuration or DHCP settings section to assign a static IP address to the server. In my case, as shown in Figure 21, the router dynamically assigns IP addresses to devices connected in the range of 192.168.1.10 - 192.168.1.150. Therefore, the IP address 192.168.1.2 was assigned to the server to ensure it always has the same IP address and does not collide with other devices.

The screenshot shows the Livebox 6 router configuration interface. At the top, the URL is 192.168.1.1/index.htm. The page has a navigation bar with links: mi red local, Wi-Fi, mis archivos, mi teléfono, información y diagnóstico, and configuración avanzada (highlighted with a red circle 1). Below the navigation bar, there's a section for 'servidor de impresión' and a message about IPv6 DNS information. The main section is 'configuración de DHCP'. It has options to 'activar' or 'desactivar' the DHCP server. Below this, there are input fields for 'dirección IP del Router en la LAN' (192.168.1.1), 'máscara de subred LAN' (255.255.255.0), 'dirección IP inicial' (192.168.1.10, highlighted with a red circle 2), and 'dirección IP final' (192.168.1.150). There are 'cancelar' and 'guardar' buttons. Below this, a message says 'Puedes ver las direcciones IP dinámicas asignadas por el servidor DHCP'. There is a table titled 'dirección IP dinámica' with columns: nombre, dirección IP, and dirección MAC. The table lists several devices, including 'PORT-TIL-DE-ABE' with IP 192.168.1.2. Below this, another message says 'Puedes reservar una dirección IP estática para cada dispositivo de tu red local. El dispositivo siempre tendrá la misma dirección IP'. There is a table titled 'dirección IP estática' with columns: nombre, dirección IP, and dirección MAC. It lists 'PicoW' with IP 192.168.1.3. There are 'añadir' and 'borrar' buttons for each row. A red circle 3 highlights the 'añadir' button for the 'PicoW' entry.

nombre	dirección IP	dirección MAC
name unavailable	192.168.1.10	84:01:12:3A:23:7C
A14-de-Francoisco	192.168.1.113	A2:EF:FC:AE:67:57
name unavailable	192.168.1.111	00:F3:61:60:73:69
S23-de-Abel	192.168.1.115	0E:8D:00:48:3E:6F
PORT-TIL-DE-ABE	192.168.1.2	94:08:53:90:96:1B

nombre	dirección IP	dirección MAC
name unavailable	192.168.1.10	84:01:12:3A:23:7C
name unavailable	192.168.1.2	94:08:53:90:96:1B
PicoW	192.168.1.3	D8:3A:DD:74:17:22

Figure 21: Router network configuration.

6.2 Problem 2: Docker Volume

To maintain database data persistently, a Docker volume must be created. In the Docker Desktop application, navigate to the ‘‘Volumes’’ option and create a volume named ‘‘database’’ as shown in Figure 22.

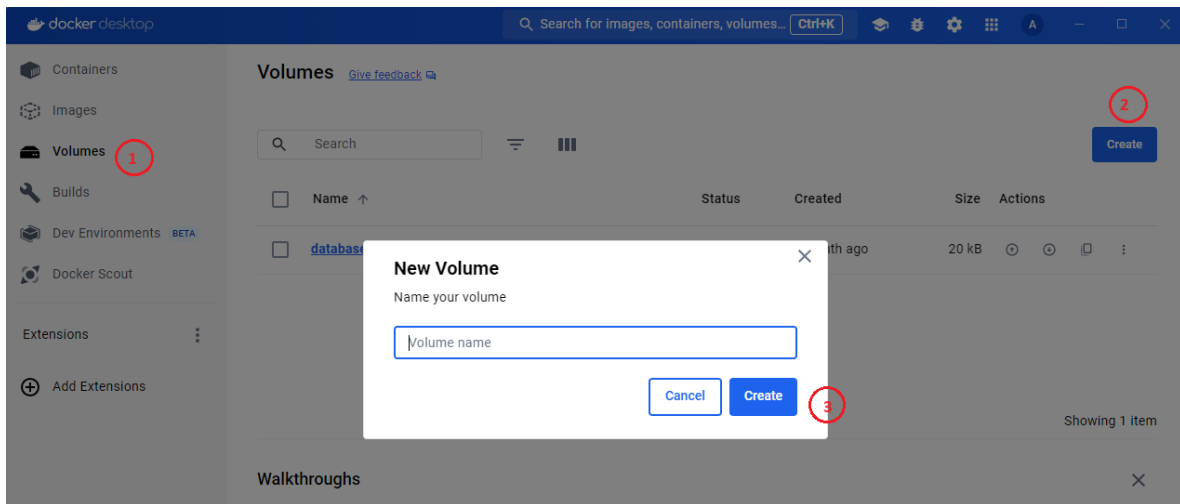


Figure 22: Creating a Docker volume.

In the ‘‘build.bat’’ file, the volume is linked to the container using the command ‘‘-v database:/home/database’’.

6.3 Problem 3: Sending Data to Ubidots

To send data to Ubidots, the device must be configured in Ubidots and the API token must be obtained. The API token must be sent in the HTTP request header. To do this, refer to the Ubidots documentation to find the request format and send the data in the correct format with the ‘‘X-Auth-Token’’ header.

```

1 def add_user_ubidots(uid):
2     ...
3     request = requests.post(
4         URL_UBIDOTS,
5         headers={'X-Auth-Token': TOKEN_UBIDOTS, 'Content-Type': 'application/
6             json'},
7         json=data
8     )
9     ...

```

Figure 23: Code for sending data to Ubidots from the file ‘‘api/api.py’’.

7 Results Obtained

A access control system using RFID keys and cards has been successfully implemented with a Raspberry Pi Pico WH microcontroller and a server with a SQLite database and a REST API.

User registration and access data has been successfully sent to Ubidots for real-time visualization. The reading mode of the RFID key or card has been successfully changed using Bluetooth Low Energy. A tricolor LED has been successfully turned on based on the API response.

The application has been successfully tested and user registration and access have been correctly recorded.

Future work includes improving the system’s security by encrypting data and scalability of the system with multiple Raspberry Pi Pico WHs and RFID readers communicating with the server. The technology for reading RFID keys and cards could also be changed to NFC, a facial recognition system, or fingerprint recognition to enhance the system’s security.

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References

- [1] A. Haro. Rfid-rc522 key reading, 2024. GitHub Repository.
- [2] P. Manzoni. Lab 6: Rest, 2024. Notion.
- [3] MicroPython. Micropython bluetooth examples, 2023. GitHub Repository.
- [4] Daniel Perron. Micropython mfrc522 library, 2022. GitHub Repository.
- [5] Sam. Cómo usar ble bluetooth low energy con micropython, November 2023. Video File.
- [6] Computadoras y Sensores. Rfid rc522 con raspberry pi pico y códigos en micropython para simple control de acceso, September 2022. Video File.