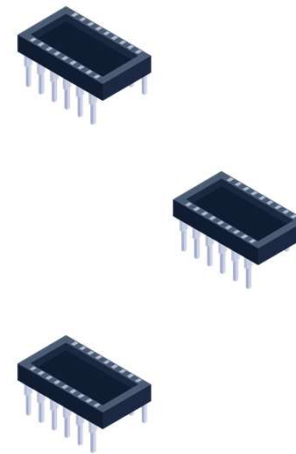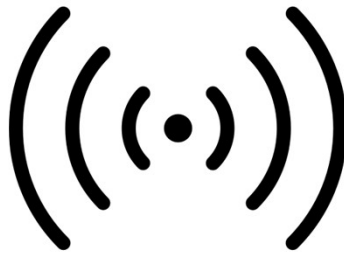# BLE-based Motion Data Logger for IoT Applications

Alessandro Albrigo and Giuseppe Boniver Conte

01 Project Goal

The goal of the project was to modernize an existing IoT motion-tracking device based on IMU sensors by replacing the ANT protocol with Bluetooth® Low Energy (BLE) to ensure broader device compatibility and improved connectivity.

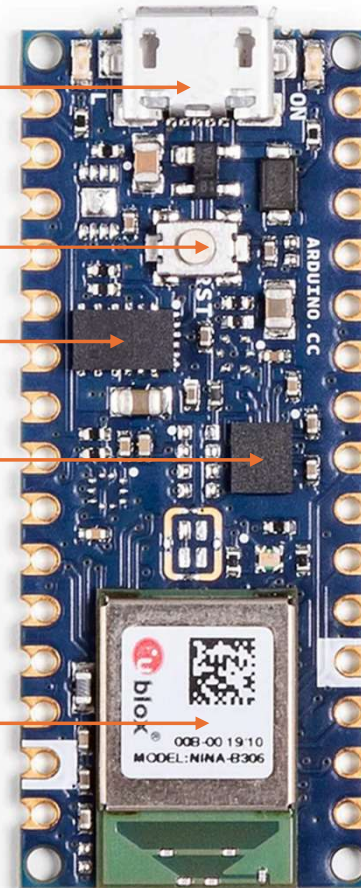Central   Peripherals

02 Peripheral - Arduino Nano 33 BLE

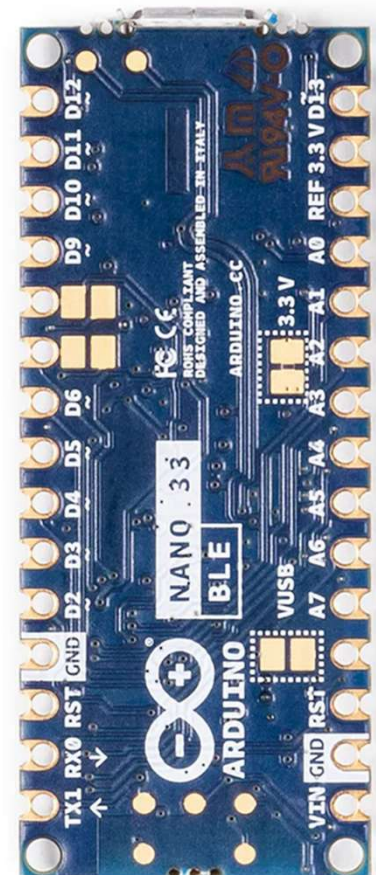**Micro-USB Port** for power supply & I/O operations.

RESET Button

nRF52840 Microcontroller with built-in support for Bluetooth® Low Energy

9-Axis IMU (accelerometer, gyroscope, magnetometer)
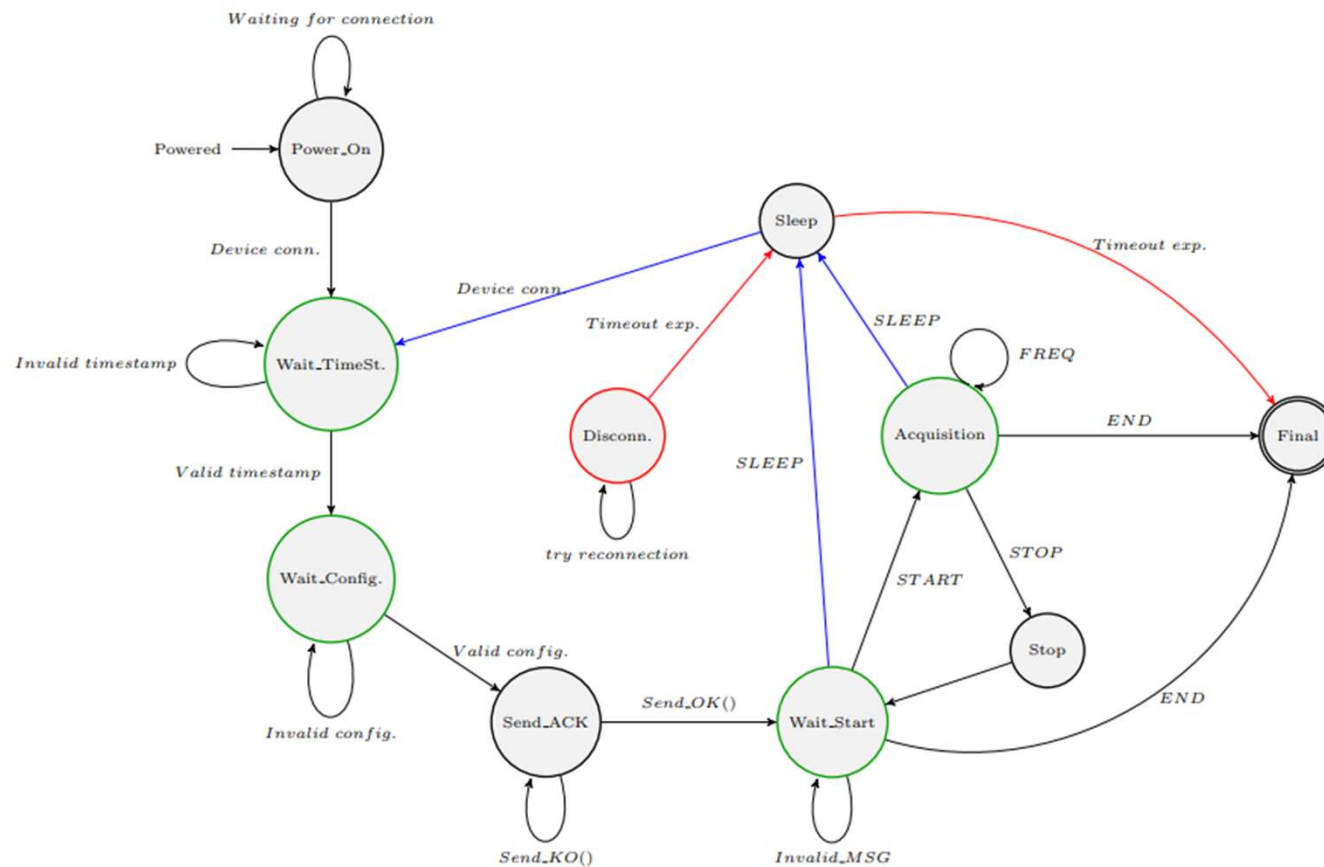
u-blox Bluetooth® Low Energy module

Front

Back

02 Peripheral

Alessandro Albrigo improved and implemented in C language for Arduino a state machine previously designed by Professor Cristiana Bolchini.

03 'BLE Central' Tool

Giuseppe Boniver Conte has developed a cross-platform command-line tool written in Python for managing peripherals and storing data received via BLE.

The program can be configured via a configuration file. Below is an example.

```json
{
  "imus":               ["1-IMU", "2-IMU"],
  "timeout":            300,
  "init_counter":       0,
  "sampling_frequency": 1,
  "store_method":       "csv",
  "mqtt_broker":        "131.175.*.*",
  "mqtt_port":          1883,
  "mqtt_topic":         "aaac/campaign/imu",
  "csv_store_dir":      "csv"
}
```

At startup, the tool attempts to automatically connect to all IMUs listed in the configuration file.
If the IMU are not initialized, the system initiates the configuration process.


```
[info] found device: 1-IMU
[info] connected to 1-IMU
[info] 1-IMU is not configured
[info] sent timestamp: 1754123996
[info] sent campaign parameters:
 {'init_counter': 0, 'sampling_frequency': 1}
>>
```
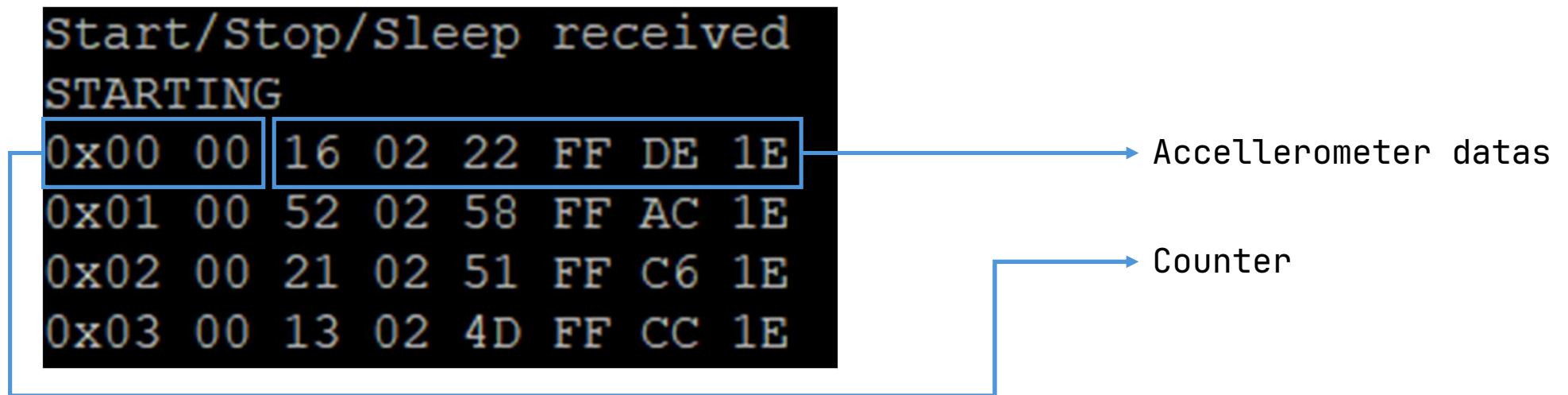
```
Waiting for timestamp
Timestamp received: 1754123614 >
 2025-08-02T08:33:34.002
Waiting for configuration
counter: 0
 sampling frequency (Hz): 1
 sampling interval (ms): 2000
Sending an OK to let you know I am ready
```

Central side   Peripheral side (1-IMU)

04   Use Cases - Start of data acquisition

After all IMUs have been connected and configured, data acquisition can be triggered using the *start* command.
The IMUs start collecting accelerometer data at the predefined sampling rate and transmit it to the central unit in raw byte format.

```
Start/Stop/Sleep received
STARTING
0x00 00  16 02 22 FF DE 1E          ──────►  Accellerometer datas
0x01 00  52 02 58 FF AC 1E
0x02 00  21 02 51 FF C6 1E          ──────►  Counter
0x03 00  13 02 4D FF CC 1E
```

Data collection and transmission are halted via the *stop* command.

04 Use Cases - Data storage

The data received from the IMUs can either be saved locally in a CSV file or forwarded via the MQTT protocol.

This is how a CSV file looks after receiving the data.

```
1  IMU,Counter,Acceleration X,Acceleration Y,Acceleration Z
2  1753268493,1-IMU,0,1002,-2896,7788
3  1753268493,2-IMU,0,-288,403,7867
4  1753268495,1-IMU,1,1325,-3190,7263
5  1753268495,2-IMU,1,-292,402,7869
6  1753268497,1-IMU,2,1408,-3151,7270
7  1753268497,2-IMU,2,-292,410,7860
```

04 Use Cases – Disconnections (1)

If one of the transmitting IMUs disconnects due to going out of range (*~100m*), the central unit waits for it to reconnect without interrupting communication with the other IMUs.

1) Disconnection detected

```
[warning] device 1-IMU disconnected
```

2) The IMU has returned within range

```
[info] found device: 1-IMU
[info] connected to 1-IMU
[info] sent START to 1-IMU (0x00)
```

If the disconnection occurs due to a reset of one of the connected IMUs, then upon its reconnection, the central unit detects that the IMU has been reset. To avoid data misalignment, it terminates all communication with the IMUs and exits.

```
[warning] device 1-IMU disconnected
[info] found device: 1-IMU
[info] connected to 1-IMU
[warning] 1-IMU has been resetted. Quitting...
[info] press ENTER to exit
[info] sent SLEEP to 1-IMU (0xFF)
```

04   Use Cases – Program exit

The central tool can be closed using two different commands.

quit   It does not power off all connected IMUs but puts them into a
            low-power state (SLEEP) and exits.

shutdown   Powers off all connected IMUs and exits.

N.B. The IMUs can be powered back on by pressing the RESET button.

05 Conclusions

We are confident that this project can find practical applications in fields like sports and healthcare, and we look forward to seeing its impact in real-world scenarios.

A special thanks to professors **Cristiana Bolchini** and **Antonio Rosario Miele** who supported and advised us throughout the entire design phase.

(For further information, please refer to the Technical Documentation)