Poster Abstract: OpenIoT-Lab1: an Open Source cost-efficient sensor based Fog-IoT Testbed: An initial prototype

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Abstract

The need for reliable test environments grows as IoT applications become more complex. The hardware testbeds are crucial for evaluating network protocols, device interoperability, security mechanisms, and performance optimization. However, because of the growing demand, most state-of-the-art IoT testbeds are either not available or are costly and are not open-source for reproduction. In this paper, we propose OpenIoT-Lab1, which uses low-cost devices, and with its code available online, it can be easily reproduced at scale in various industries and academic institutions to support research in sensor networks and Fog/IoT networks.

Keywords

IoT, Contiki-NG, nRF52840 dongle, Sensor, Testbed

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1 Introduction

The rapid expansion of Internet of Things (IoT) technologies and their applications across diverse domains has promoted the development of IoT testbeds as a critical area for research. IoT testbeds offer realistic conditions for the experimentation, validation, and optimization of IoT devices, systems, and applications. These platforms enable researchers, developers, and industry stakeholders to address the complexities of the IoT ecosystem, including scalability, security, interoperability, and performance challenges. To cater to the requirements of today's IoT applications, a testbed needs to have the following features:

- **Open access**: Users can submit jobs and collect traces of the experiments.
- **Sensors**: Real-time data collection through various sensors.
- **Fog/Cloud Support**: Compute nodes to perform local computation and forward data to the cloud.
- **Wireless Technologies**: Support for various wireless communication standards like IEEE 802.15.4, BLE.
- **Reproducible**: Availability of the software stack to locally replicate the testbed.

Table 1 lists some of the prominent state-of-the-art testbeds used by the researchers for experimentation. None of these testbeds can fulfill all of the above mentioned features. Hence, we propose OpenIoT-Lab1, which is capable of providing all the functionalities and reproducible if someone wants to set up their own testbed.

2 OpenIoT-Lab1 Architecture

Fig. 1 shows the high-level overview of the testbed. A three-tier architecture is used in the development of the testbed, which consists of a sensor layer, a compute layer, and a server layer.

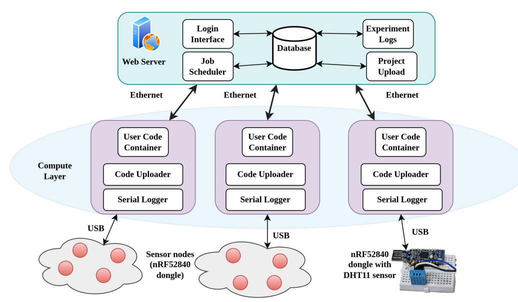

Figure 1: OpenIoT-Lab1 Architecture Overview

2.1 Sensor layer

The sensor layer comprises IoT nodes that have sensors connected to them. We have used the nRF52840 dongle as the IoT end node that supports BLE, Zigbee, and 802.15.4 communication stacks. These sensor nodes are connected to the fog nodes (in our case, Raspberry PI) with the help of USB cables. Hence, the length of the cables can be varied to cover a larger area. In our tests, we realized that even with 10 meters of cable length, there is no significant delay in the transmission of code/data.

We have also interfaced various sensors with IoT nodes, such as temperature, humidity, hall, flame, ultrasonic, and mq2. These nodes can run different IoT OSes viz: Contiki-NG, RIOT-OS, and Zephyr. Currently, we have programmed the sensors in Contiki-NG. The support for these sensors is not available by default in

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Table 1: Existing Testbed comparison with OpenIoT-Lab1

Testbed	Open Access	External Sensors	Fog Support	Wireless Technology	Reproducibility
Fit Iot-LAB [1]	✓	–	✗	BLE, LoRA, 802.15.4	✗
UMBRELLA [5]	✓	Camera, VOC, NO_2, Pressure, Accelerometer, Temperature, Humidity	✓	BLE, Sub-GHz	✗
Indriya2 [2]	✓	Pressure, Accelerometer, Temperature, Humidity	✗	BLE, 802.15.4	✗
LinkLab2 [3]	✗	Temperature, Humidity, Light, Pressure, PIR	✓	LoRa, BLE, 802.15.4	✗
FlockLab2 [6]	✓	–	✗	BLE, Sub-GHz, 802.15.4	✓
OpenIoT-Lab1 (proposed)	✓	Temperature, Humidity, Flame, MQ2, Ultrasonic	✓	802.15.4, BLE, LoRa	✓

Contiki-NG, so to add functionality to OpenIoT-Lab1, the code for these sensors is written and made public on the GitHub repository. OpenIoT-Lab1 users can design their application in Contiki-NG and can submit the code to the testbed interface. The code is made to run on these IoT end nodes.

2.2 Compute layer

The compute layer consists of the Raspberry Pi network, which is connected via ethernet. Raspberry Pi 5, with an 8GB variant and 64GB SD card, is used in the testbed. Each Pi can directly connect to four IoT nodes with USB cables. The Pi runs a serial logger service to gather the experiment logs from the sensor nodes and also runs a service to upload the code onto the nodes. Importantly, the nrf52840 supports automatic programming without human intervention. In the experiments, the compute nodes can act as fog nodes at run-time. For security reasons, the user code on Pi is run using containers.

2.3 Server layer

The server layer comprises a server system that hosts a database to implement user authentication, store job details, and save traces of the experiments. OpenIoT-Lab1 supports multiple job runs at the same time on non-overlapped IoT nodes with the help of the scheduler service. The server compiles the user code for the end devices to generate a `.hex` file, which is forwarded to the relevant compute nodes through a wired network that programs the end devices.

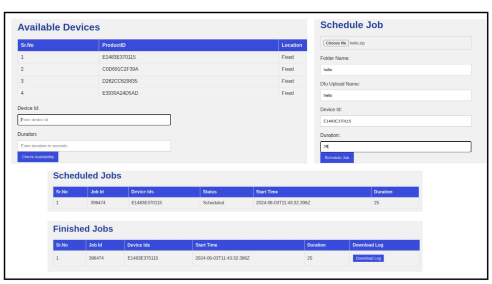

Figure 2: Interface for experiment scheduling

3 Experiment overview and Conclusion

Upon successful authentication of the user credentials on the portal, the user is redirected to the web interface. The preliminary interface for OpenIoT-Lab1 is shown in Fig. 2. Users can select the device on which they want to run the application, check the availability of those nodes, and schedule their experiment. After completion, the user is provided with experiment logs, which can be downloaded for further analysis.

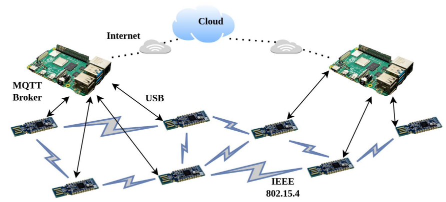

Figure 3: Overview of Experiment

Fig. 3 illustrates the experiment in which multiple sensor nodes sense the data and then relay the information to one of the IoT nodes (border router) through the 6LowPAN protocol stack. The border router pushes data to the MQTT broker that runs on the Raspberry Pi node as a container service. The broker publishes the received data from sensor nodes to the cloud, from where subscribers can get data. In the near future, we plan to host our testbed in the public domain and support long-range communication. Also, because it is cost-effective, anyone can purchase nrf52840 devices (approx. `$12` each) with a few Pi nodes (`$80`), a server, and USB cables to set up the infrastructure. The entire software stack of OpenIoT-Lab1 is distributed in an open-source license on GitHub and can be accessed through [4].

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