CityLab: A Flexible Large-scale Multi-technology Wireless Smartcity Testbed

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***Abstract*—In this paper we present an overview of the CityLab smart-city testbed, highlighting the offered diverse technical features to experimenters, in particular the multiple wireless technologies and easy access. Also, we present the experimentation challenges that CityLab testbed has addressed.**

I. Introduction

The are several Internet and Communications solutions (ICT) solutions that play a major role in the citizen's every day, ranging from eGovernment, eHealth to simply having the real-time information about the transportation means. All these solutions come together under the Smart-city paradigm empowered by the use of the Internet of Things (IoT) applications, connectivity, and devices. Smart-cities are becoming more and more a reality than a futuristic vision only, as it was couple of years ago. Nevertheless, smart-cities have still a long way to go in order to fulfill current and potential new services that users have or may have. Testbeds facilities provide an excellent environment to validate Research & Development (R&D) results in realistic conditions. In this paper we present the Citylab testbed, which is a highly flexible smart cities testbed, capable to offer to the experimenters advance experimentation tools, bare metal access to multi-technology nodes, called them Gateways, located within the streets of the city of Antwerpen, Belgium.

In order to provide low-level network experimentation, our Citylab tested fulfills the following key requirements that a Smart-city should fulfill [1]:

Reliable experimentation: High reliability is a must, a testbed facility should offer reliable experimentation and results to users/experimenters, allowing them to have full control of their experiments. Furthermore, experimenters require to be able to remotely manage the testbed to lower the operational overhead for testbed operators and to be able to interoperate with other testbeds, leveraging existing federations. This requires the need for remote-node recovery mechanisms, whenever on-site local maintenance/support is limited. At an infrastructure level, this translates into the need for continuous high-speed and low-latency access to the testbed nodes/equipment.

Heterogeneous network technologies: Currently, there are several wireless technologies that enable wireless communication with different features and for different services. Since smart-cities are a relatively early IoT domain within the IoT ecosystem, there is no one dominating wireless technology or

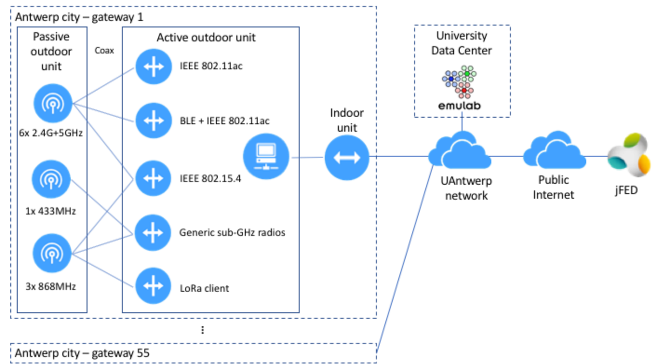

Fig. 1. CityLab architecture overview.

technologies among all the pool. Hence, smart cities testbeds should offer multiple technologies and capable to offer upcoming new technologies when they arise.

Close-to-real environments: Currently, there are testbed facilities for wireless experimentation, often in a controlled environment, which are an step further from simulation. Nevertheless, such facilities still suffer from limited realism. The deployment of experimental outdoor hardware, that offer a real environment, should be a must for smart-city testbeds.

II. CityLab

The CityLab[1] testbed is located in the city of Antwerp, Belgium. The testbed is part of the City of Things[2] programme, providing the experiment platform for such programme.

1) Overall Architecture: The CityLab testbed is based on the architecture shown in Figure 1. Experimenters use jFed[3] to access the experiment management system to control gateways (nodes) distributed in the city of Antwerp. The management system is based on Emulab[4] and it located in the datacentre of University of Antwerp - imec. The experiment management system is connected to the gateways over an academic fiber network.

2) Gateways: The CityLab testbed nodes are called gateways, which are composed of three main component units: i)

[1]https://doc.lab.cityofthings.eu
[2]https://www.imec-int.com/cityofthings
[3]https://jfed.ilabt.imec.be/
[4]https://www.emulab.net

Fig. 2. CityLab gateway components, at the top the passive and active outdoor units, at the bottom the indoor unit.

TABLE I
CITYLAB GATEWAY RADIOS AND ANTENNAS

Network Technology	Antennas and Bands
IEEE 802.11ac (2.4GHz+5GHz, client+AP)	3x 2.4+5GHz
IEEE 802.11ac (2.4GHz+5GHz, client) + Bluetooth Low Energy	2x 2.4+5GHz
IEEE 802.15.4 at 2.4GHz and 868MHz	1x 433MHz + 1x 868MHz
Sub-GHz protocols e.g., DASH-7, IEEE 802.15.4g	1x 433MHz + 1x 868MHz
Single-channel LoRa client	1x 868MHz

an indoor, ii) an active outdoor ,and iii) a passive outdoor unit, as shown in Figure 2.

Using the jFed tool, the experimenter gets access to the outdoor unit, where an X86 PCEngines APU embedded device allows the experimenter to run Linux on top of the bare metal equipment, booting over Preboot eXecution Environment (PXE). The embedded system is then connected to multiple radios, supporting a variety of network technologies as summarized in Table I. The outdoor unit also relies strongly on an embedded USB hub, which allows connecting additional network technologies easily in order to enable flexible addition of new and arising network technologies.

Each radio is connected to dedicated antenna(s) enclosed in the passive outdoor unit.

The indoor unit then connects the outdoor units to the academic network over two Power Over Ethernet+ cables. Since these cables provide both power and data, a simple power switching component in the indoor unit allows remotely rebooting the outdoor unit and recovering it in almost any situation.

3) Experiment Management: As mentioned before, the gateways are managed by an EmuLab installation which is available through jFed over a Slice-based Federation Architecture (SFA), building on the foundations of the Fed4FIRE+ European project[5].

[5]https://www.fed4fire.eu

Fig. 3. Map of CityLab gateway locations and example deployment, center right in the picture.

4) Deployment: The CityLab gateways are deployed in the City Campus neighborhood of the city of Antwerp, the second largest city in Belgium. As shown in Figure 3, about 30 gateways are actively deployed, with 20 being installed in the coming months. Moreover, a *smart zone* is currently being designed, where a dense multi-purpose sensor deployment will be supported by 20 more gateways. Figure 3 also shows an example deployments of a CityLab gateway in the streets of Antwerp.

5) Enabling experimentation: CityLab enables researchers to perform experimentation in the following experimentation areas: cross-technology heterogeneous network experimentation; bare-metal outdoor network research and smart city IoT network research. The testbed also supports researchers and companies to bring custom or own sensors to evaluate their performance in real-life conditions.

III. CONCLUSIONS

In this paper, we have briefly presented the CityLab testbed which provides flexible experiment with multiple wireless technologies. CityLab is part of the City of Things programme that addresses not only the topics related to smart-cities, but also livinglabs.

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