Demo: Platform for Collecting Data From Urban Sensors Using Vehicular Networking

Pedro M. Santos[*][†], Tania Calcada[*][†], Diogo Guimarães[†], Tiago Condeixa[‡], Susana Sargento[*][§], Ana Aguiar[*][†], João Barros[*][†][‡]

[*] Instituto de Telecomunicações
[†] DEEC, Faculdade de Engenharia, Universidade do Porto
[‡] VENIAM
[§] Departamento de Electrónica, Telecomunicações e Informática, Universidade de Aveiro

{pedro.salgueiro,tcalcada,ee10158}@fe.up.pt, tcondeixa@veniamworks.com, susana@ua.pt, {anaa,jbarros}@fe.up.pt

ABSTRACT

A large-scale urban sensing platform, composed of multiple Data Collection Units (DCUs) equipped with sensor hardware scattered accross the city, allows pervasive monitoring of environmental parameters. Gathering sensor data from a number of disparate locations at a backend server can be supported by delay-tolerant services provided by existing vehicular networks. Our real-world sensing platform takes advantage of an existing vehicular network with more than 400 vehicles equipped with On-Board Units (OBUs). A purposely-developed implementation of a delay tolerant service is installed in all elements involved in the communication flow, from DCUs to the backend server. In this demo, we showcase the full end-to-end data flow with the actual equipment being used in our real-world deployment. Data produced at a DCU is collected by an OBU installed in a vehicle and delivered to a Road-Side Unit (RSU), which then forwards the data to the backend server.

Categories and Subject Descriptors

C.2.1 [**Network Architecture and Designs**]: Store and forward networks

Keywords

urban sensors, delay-tolerant, vehicular network

1. INTRODUCTION

In recent years, pervasive monitoring became possible by the development of small sensing devices with communication capabilities. The UrbanSense project aims to perform pervasive sensing in the city of Porto, Portugal. A number of processing devices equipped with environmental sensors and a WiFi interface, called Data Collection Units (DCUs), are being deployed at several strategic locations of the city of Porto. Figure 1 shows a DCU deployed at an important artery of the city. One of the major challenges in such large-scale sensing platform is to perform low-cost aggregation of the collected data at a central database. Solutions such as cellular networks, dedicated M2M systems ([5, 3]) or physical wiring to all sensors may be impractical or costly when compared with data benefits.

Data collection via vehicular networks provides an alternative cost-efficient solution, as it takes advantage of an already deployed, cost-free infrastructure. In Porto, the public transportation and municipal services vehicles are equipped with wireless On-Board Units (OBUs), creating a vehicular network that provides WiFi access points to passengers and utilizes DSRC for V2X communication. This set of vehicles covers a significant area of the city on a daily basis, creating opportunities to collect data from the various DCUs. To cope with the opportunistic and disruption-prone nature of communications in this scenario, we use Delay Tolerant Networking (DTN) [2]. A purposely-developed DTN service exists in all physical elements of the architecture.

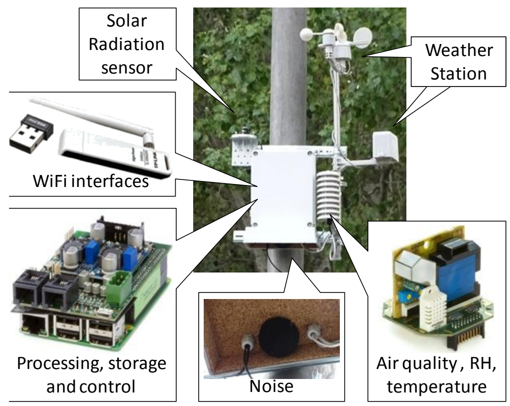

Figure 1: Data Collection Unit (DCU) deployed in R. Damião de Góis, Porto, Portugal. DCUs are composed of processing devices (Raspberry Pi) that gather data from environmental sensors and communicate via a IEEE 802.11b/g/n interface.

MobiCom'15, September 7–11, 2015, Paris, France.
ACM 978-1-4503-3619-2/15/09.
DOI: http://dx.doi.org/10.1145/2789168.2789169.

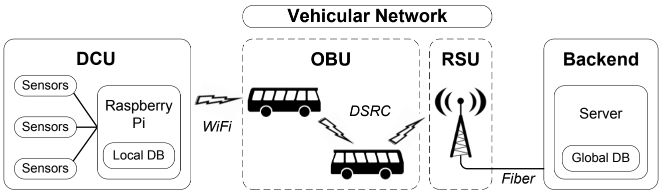

Figure 2: Physical architecture of the collection platform. Sensor data is gathered at the DCUs, transmitted through the vehicular network, and delivered to a backend server.

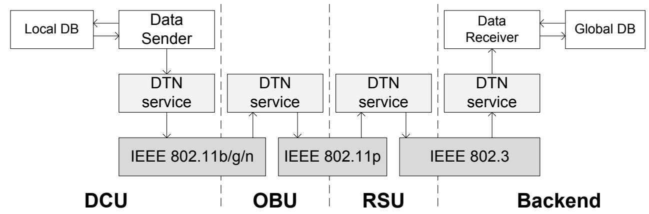

Figure 3: Logical architecture of the collection platform and data collection flow (indicated by arrows). ***DataSender*** **and** ***DataReceiver*** **modules reside at communication end-points.**

This demo showcases a proof-of-concept of the data collection platform using the actual equipment deployed on site. It is composed of one DCU, one OBU installed on a vehicle (a scooter), one Road-Side Unit (RSU) that interfaces the mobile node and the backend server, and a laptop representing the backend server. Communication between the DCU and the mobile OBUs uses WiFi, whereas the OBU and the RSU communicate with DSRC.

2. COLLECTION INFRASTRUCTURE

We present the physical and logical architecture of the data collection platform.

2.1 Physical Architecture

Our collection platform is composed of three main physical elements: (i) the Data Collection Units, (ii) the vehicular network, and (iii) the backend server. Fig.2 presents the physical architecture and the wireless technologies used.

The core of the DCUs are off-the-shelf Raspberry Pi devices, equipped with a number of environmental sensors and a IEEE 802.11b/g/n interface. Sensors monitor wind direction and speed, rain, solar radiation, luminosity, humidity, temperature, and noise. All hardware is encapsulated in hermetic casing and deployed at sites of interest. Collected data is stored in a local database.

The vehicular network is composed of On-Board Units, installed in mobile nodes, and static Road-Side Units. OBUs have IEEE 802.11b/g/n and 802.11p interfaces [1] and provide a WiFi Access Point (AP) service for the bus passengers. The Road Side Units are infrastructural devices, located at strategic locations of the city, that interface the vehicular network and the Internet. RSUs are equipped with 802.11p hardware to communicate with the mobile nodes, and an optical fiber-based connection to the Internet. The backend server receives, acknowledges and stores the data collected by all sensing devices in a global database.

2.2 Logical Architecture

We created a software DTN implementation that supports delay-tolerant communication over all elements of the architecture, and application software modules at the end-points (the DCUs and the backend server) to manage the end-to-end data flow, named communication modules. Fig.3 presents the logical architecture and depicts the collection data flow.

The DTN implementation used in our collection platform is based on the end-to-end architecture of the *bundle protocol*, described in RFC 5050 [4]. The bundle protocol defines the bundle layer, that sits between the application and data-link layers; corresponding datagrams are called *bundles*. Our version of the bundle protocol implements a subset of functionalities defined in RFC 5050 to support store-and-forward operation: (i) *neighboring* – keep track of current neighbors in the multiple interfaces/networks; (ii) *routing* – decide which bundles to send to which neighbors; (iii) *storage* – keep bundles in storage and provide easy access.

The communication modules are named *DataSender* and *DataReceiver*, and are deployed at the DCU and server respectively. The DCU constantly searches for opportunistic connections to passing OBUs. When a connection is initiated, the *DataSender* module fetches sensor data from the local database and stores it into a bundle, which delivers to the bundle layer. The information about which data was sent is locally stored. Upon reception of an acknowledgement of the previously sent data, the DCU deletes that data from the local database. The *DataReceiver* module, the communication module at the backend server, is in charge of receiving and processing the bundles delivered by the bundle layer and storing them in the global database, and sends acknowledgements to the sensing device that originated the data via the bundle layer.

3. DEMONSTRATION

We now present the elements and operation of our demonstration. Fig. 4 depicts the overall setup. A demostrative video can be found in https://www.youtube.com/watch?v=Hqjx28hpuT8.

This demonstration is composed of four elements: a static Data Collection Unit, a scooter equipped with an On-Board Unit, a static Road-Side Unit, and a laptop acting as backend server. The DCU has a IEEE 802.11b/g/n interface, whereas the RSU is DSRC-capable due to a IEEE 802.11p interface. Given that they do not share a common wireless technology, the DCU and the RSU are not able to communicate wirelessly. The OBU mounted on the scooter has both technologies, and also runs a WiFi Access Point (AP) service. The RSU and the laptop are connected by a standard ethernet cable.

The demonstration operates as follows. The DCU collects data from sensor hardware (temperature / humidity / luminosity, etc.) and constantly scans the wireless medium in search of an WiFi AP client. When the OBU becomes in range of the DCU, collected data is off-loaded to the OBU. The scooter then physically heads to the RSU and, when the OBU and RSU come into communication range, collected data is transfered to the RSU. A TCP connection is established between RSU and laptop to transmit the sensor

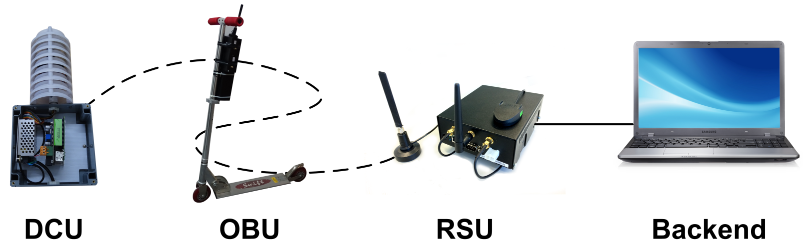

Figure 4: Diagram of demonstration setup. DCU and RSU cannot communicate wirelessly; scooter with OBU transports delay tolerant data.

data to the server, which then stores received data in the database. New data arrival is shown by means of a graph depiction updated in real-time.

4. CONCLUSIONS

We present a practical use case for delay-tolerant networking, that of sensor data collection from disparate urban location and aggregation at a backend server. A data collection platform based on vehicular networking has been developed for this purpose and successfully deployed in a real-world platform. The demonstration aims to showcase the end-to-end operation of this collection platform.

Acknowledgments

This work was supported by projects and grants SenseBusNet (PEst-OE/EEI/LA0008/2013), I-City for Future Mobility (NORTE-07-0124-FEDER-000064), FP7 – Future Cities (FP7-REGPOT-2012-2013-1, 316296), Vital Responder 2 (PTDC/EEI-ELC/2760/2012), IT (UID/EEA/50008/2013), FCT individual grant (SFRH/BD/67178/2009), and by applicable financial framework of R&D Unit 50008 (FCT/MEC through national funds and when applicable co-funded by FEDER – PT2020 partnership agreement).

5. REFERENCES

[1] C. Ameixieira, J. Matos, R. Moreira, A. Cardote, A. Oliveira, and S. Sargento. An IEEE 802.11p/WAVE implementation with synchronous channel switching for seamless dual-channel access (poster). In *Vehicular Networking Conference (VNC), 2011 IEEE*, pages 214–221, Nov 2011.

[2] V. Cerf, S. Burleigh, A. Hooke, L. Torgeson, R. Durst, K. Scott, K. Fall, and H. Weiss. Delay-Tolerant Networking Architecture. RFC 4838 (Experimental). April 2007.

[3] M2M Spectrum Networks. http://www.m2mspectrum.com.

[4] K. Scott and S. Burleigh. Bundle Protocol Specification. RFC 5050. November 2007.

[5] SIGFOX. http://www.sigfox.com.