Building a Smart City that Stimulates Innovation Using Open Source and Decentralised Technologies

Sandro Sawicki[1], **Rafael Z. Frantz**[1], **Gerson Battisti**[1], **Fabricia Roos-Frantz**[1]
Luiz Antonio Rasia[1], **Odaylson Eder**[2], **Carlos Molina–Jimenez**[3], **Jon Crowcroft**[3]

[1]Unijuí University – Ijuí/RS – Brazil

{sawicki, rzfrantz, battisti, rasia, frfrantz}@unijui.edu.br

[2]Municipal Secretariat of Economic Development, Tourism and Technology of SR

odaylson.eder@santarosa.rs.gov.br

[3]University of Cambridge – Cambridge –UK

{carlos.molina, jon.crowcroft}@cl.cam.ac.uk

Abstract. *We are developing Santa Rosa municipality as a smart and sustainable region that stimulates innovation. A place that will take advantage of the data–driven economy and data–centric applications with Equality, Diversity and Inclusion (EDI) as a priority. To this end, have built a pilot smart city lab for testing technologies in real-life conditions; we are currently exploring decentralised technologies and technologies with low environmental cost. Also, we are following competency frameworks for smart cities rather than deploying technologies indiscriminately. 12 years of work have produced tangible results and practical experience that we share in this paper*[1].

1. Introduction

The city of Santa Rosa was founded in 1931; with a current population of 73,575 inhabitants and a municipality that expands over 488.42 km^2 is becoming an important industrial and commercial hub in the south of Brazil. Its geographical location a few kilometres of Argentina's and Paraguay's borders give the city and the region a potential that the city council is determined to capitalise. Their overall objective is to develop Santa Rosa as a smart city and to launch the region as the innovation hub of the South of Brazil that will take advantage of the data-centric economy to boost the economy of the region at least for the next 20 years. They aim at a socio–technical system, therefore, have taken a multi–dimensional vision that combines technical, economic and social dimensions. Therefore, sustainability and Equality, Diversity and Inclusion (EDI) are priorities – they want Santa Rosa to be sustainable and EDI compliant by design. Further, they have an integral view where the surrounding rural area is regarded as an extension of the city as it contributes to its economy. They regard smart cities as complex systems, therefore, in the development of Santa Rosa they are following a competency framework that includes planning, testing and embedding. From a technological perspective, firstly we setup a project to build an innovation ecosystem and a hardware infrastructure based on open technologies for sensing the urban and rural areas of the municipality. We are currently developing applications on this ecosystem to provide citizens with digital services that use the sensing data. We also make the data open to academy, companies and to the general public. Here in after we will use "we" to refer to the authors of this document.

[1]Published in CIbSE 2025 https://conf.researchr.org/home/cibse-2025

2. Collaborations, projects and objectives

To progress towards the fulfilment of their overall objective, in 2021 the city council signed up a formal collaboration with the Applied Computing Research Group[2] (GCA) of Unijuí University to submit a joint project proposal to a call of the Secretary of Innovation, Science and Technology of the state of Rio Grande do Sul. Fortunately, we succeeded and the project was awarded 1.3 million Reais for the creation of the SmartLive Lab within Unijuí's premises. The lab is equipped with hardware, software for testing smart city technologies and facilities (e.g, meeting rooms) for collaborating with other institutions; for example, they have been collaborating with the University of Cambridge since 2019. We have been granted three complementary projects that cover three topics included in our multidimensional approach, use the SmartLive Lab and target specific objectives: **i) Economic sustainability** is covered by a 36 month project that investigates open source decentralised technologies for integrating digital services. **ii) Environmental sustainability** is covered by a 36 month project that is manufacturing and testing biodegradable sensors in the SmartLive Lab. **iii) Connected places** is covered by 24 month project that is deploying a hardware–software infrastructure in the rural farming area to integrate it with the smart and sustainable infrastructure of the city.

3. Development under a competency framework

We are collaborating with members of the Digital Cities for Change (DC2) [3] team in validating their DC2–FC (Digital Cities for change) competency framework for developing smart cities. In Santa Rosa, we are following the DC2–FC rather than deploying technologies indiscriminately. As required by DC2–FC, we test technologies in our SmartLive Lab and generated knowledge before full scale deployment.

The DC2–FC framework. DC2–FC was designed at the University of Cambridge [Bastidas et al. 2023] to help smart city planners to identify tasks, roles and competencies needed to deliver projects successfully. The creation of public value through responsible use of technology is central to DC2–FC and in line with our views over smart cities. Three members of Santa Rosa's development team have been interviewed to asses compliance with DC2–FC and help us identified gaps.

The SmartLive Lab. We use this lab as a pilot for testing technologies in real–life conditions (actual deployment in the city at small scale) before full scale deployment (called embedding in DC2–FC). The lab is a knowledge generator too: it is an experimental lab for undergrad, MsC and PhD students including some international ones.

4. Technologies

Currently, the SmartLive Lab has 26 LoRa outdoor 8 dBi Omni 915/923 MHz antennas; 260 sensors compatible with LoRa including 40 temperature and humidity sensors (RAK1901 WisBlock), 40 ultrasonic ambient light sensors (RAK 12010), 40 noise sensors (RAK 18000), 10 water level sensors (RAK12014), 20 ultrasonic MQ3 gas (RAK 12004), 40 sensors for assessing the water pH, and several modules for prototyping and 3D printing. We have a DELL computer with 256GB, 2TB and Linux that hosts the open source ChirpStack Network Server.

The lab is a generator of technologies needed to meet our overall objective. A priority is to retain control of Santa Rosa's data (our main asset) to be able to share it,

[2] www.gca.unijui.edu.br

[3] https://www-smartinfrastructure.eng.cam.ac.uk/projects-and-case-studies/dc2-digital-cities-change

say, under data contract agreements and not necessarily for free. Therefore, we welcome experimental open source decentralised technologies [Crowcroft et al. 2024] that enable data–sharing to stimulate innovation, fair competition (e.g. among SMEs) and redistribution of data and value [Blancato 2024]. Data is an asset and to help innovation, it should flow (like money) rather than remaining static in possession of a few. To ease its flow, we need a data sharing infrastructure —similar to the road infrastructure. We have reservations about purchasing technologies from the cloud monopolies because they make money from abusing their business power, rather than from innovation. In response, we are currently assessing emerging decentralised technologies that follow the P2P interaction model rather than the traditional client–server model prevalent in the current cloud; for example, we are comparing BlueSky *vs* X, Matrix *vs* Whatsapp, and other messaging services. Further, we believe in open governance and think that the city council should be a regulator, not a controller; therefore, we are building technologies that are secure, protect privacy and individual freedom; precisely, we are developing applications on top of decentralised ID systems like Trustchain[4] and Privacy Enhancing Technologies (PETs) like AWS Nitro and compartments created on Morello Boards[5].

5. Results

We have deployed 12 LoRa antennas that cover both the rural and urban areas: 9 in the urban space and 3 in rural area. They receive sensor measurements. Incidentally, we have installed two LoRa–based meteorological stations in town to collect metrics about air quality, wind, luminosity, temperature, humidity, noise and UV radiation. We have also deployed a LoRa antenna in the rural area and associated sensors that collect soil (temperature, humidity and luminosity) and air (temperature and humidity) properties. Each antenna potentially covers a 10 km radius. As of the writing of this paper, we have other 10 LoRa–based meteorological stations and 14 LoRa antennas being deployed to achieve 100% coverage of the city. We have been collecting sensor data since Aug 2023 and stored 410275 entries as historical series. We regard the records as open data and share them with academy, companies, and soya–bean producers. The former use them in research and innovation projects tackling real-world problems in the city, such as in traffic and health. The latter used them for understanding the relationship between rainfall and current soil humidity and temperature. We have also built plots that we share with the general public on dashboards [6].

In the SmartLive Lab, we rely on software engineering techniques. For example, we use Search-Based Software Engineering (SBSE) to solve optimisation problems like antenna deployment. We also need software engineering techniques (e.g. run–time control–loop and reflection) for building self–adaptive applications; the need emerges from our interest in decentralised applications that are underpinned by peer–to–peer networks that are inherently self–organised, self–adaptable and, in general, self*.

6. Social and economic impact

Our LoRaWan network and servers are open and available to local companies. Some of them have deployed sensors in their warehouses that send data to our server through our antennas. Similarly, in rural areas, fish farmers are also using our antennas; they have deployed sensors to monitor fish tanks. We have also developed a system that notifies

[4]https://github.com/alan-turing-institute/trustchain
[5]https://www.arm.com/architecture/cpu/morello
[6]https://livelab.unijui.edu.br/

farmers about the likelihood of the Asian Rust affecting soya–bean–growing areas. Being the regional hub, we are happy to share our facilities with neighbour cities. EDI comes naturally to us; our regions is home to more than 20 ethnics that came from different regions of the world. We treasure and retain their traditions. EDI is already visible in our research team that is composed of people from different ages, genders, races and nationalities. We have seven females and eight males, PhD students; some of them are from ethnic minorities, others from neglected regions of Brazil. We admit that in Santa Rosa there are still some inequalities that we are already solving. We can mention that the health service is deploying home and body sensors for remote monitoring of the elderly.

7. Pending tasks

At the head of our to–do list is to build a web page to bring the SmartLive Lab online with information about its facilities and opportunities for the general public. Likewise, we will endow our data repository with APIs available to the general public to retrieve (e.g. sensor data) and upload data (e.g. historical photos). We also need to release under open source licences, several pieces of code that we have implemented, including Python scrips for record management and several independent data dashboards for web applications. We are also working on a decentralised digital identity system to grant the general public, access to our repository and pieces of code.

On the technical side, we have plans to deploy 10 additional meteorological stations by 2025 to collect real–time weather data at a granularity that enables to build a map of the region's microclimates. A pressing problem is the implementation of legal and technical mechanisms for sharing data that is currently in several siloed repositories. In the list are two data silos owned by Santa Rosa's medical service. Data sharing will motivate the use and development of data–centric applications such a AI. To cite an specific example, it has come to the city council's attention that, in comparison with other regions of Brazil, Santa Rosa has a high incidence of cancer. The medical sector and researchers from Unijuí would like to have access to the medical and other repositories to correlate data to investigate the cause which might be associated to genetic, eating habits or other factors. We also have plans to make all the sensor data available to the general public.

Acknowledgements

Research partially funded by the Co-ordination for the Brazilian Improvement of Higher Education Personnel (CAPES) and the Brazilian National Council for Scientific and Technological Development (CNPq) under grants 311011/2022-5, 309425/2023-9, 402915/2023-2. EPSRC/EP/X015785/1(G115169) grant funded Carlos and Jon. Thanks to Arturo Dina and Aristeo Hernández for proof–reading this document.

References

Bastidas, V., Oti-Sarpong, K., Nochta, T., Wan, L., Tang, J., and Schooling, J. (2023). Leadership of urban digital innovation for public value: A competency framework. *IET (The Institution of Engineering and Technology) Smart Cities*, 6(3). `https://doi.org/10.1049/smc2.12063`.

Blancato, F. G. (2024). Innovation is overrated: a provocation. *Communications of the ACM*, 67(3). `https://dl.acm.org/doi/10.1145/3624727`.

Crowcroft, J., Molina-Jimenez, C., Toliver, D., and Nakib, H. D. (2024). The Centre for ReDecentralisation (CRDC). `www.cl.cam.ac.uk/research/srg/projects/crdc/`. Visited on 10 May 2024.