PAIoT Network: A Unique Regional IoT Network for Very Different Applications

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Abstract: LepidaSpa, the ICT in-house company of the Public Administrations of the Emilia Romagna region, has realized a regional IoT public network[‡], based on the LoRaWan[§] technology, free of charge for all public administrations, as well as to private citizens, potentially enabling the collection of relevant data from thousands of new sensors and making them accessible to both the owners of the sensors and, limitedly to institutional or public interest scopes, to every PA entity. The innovative aspects of the proposed solution mainly concern the extreme simplicity of the sensors installation, the low entry costs for stakeholders, both public and private, who want to deploy their own sensors, a centralized service that collects and makes data available in the cloud, the replicability of IoT projects on a regional scale.

1 INTRODUCTION

The Emilia-Romagna Region, through the in-house company LepidaScpa, has created a regional IoT network, based on in LoRaWan technology. The availability of the PAIoT (Internet of Things for the Public Administration) network at the regional level is an enabler for the installation of different types of sensors available to all the interested parties, both public and private, as it removes the costs of building the network, collecting and storing the data from the implementation costs of monitoring systems, leaving only those relating to the purchase, installation and maintenance of sensors.

In this innovative model of Public-Private partnership, individual users have the possibility to easily install new sensors and create new services, while the Region and the PAs have thousands of continuously updated data sets available, coming from the installed sensors, which allow them to learn more about what happens in cities and territories.

The first paragraph of this paper illustrates the main characteristics of the PAIoT network created by LepidaScpa, while the next paragraph describes three examples of IoT projects that use it, with particular focus to their ease of installation, their cost-effectiveness, their use in very different domains and their potential replicability at regional level.

2 THE STATE OF THE ART

Low Power Wide Area Network with wide geographic coverage and low power consumption, In are emerged the latest five years.

They operate in the band around the 868 MHz in Europe and 915 MHz in the USA.

These technologies can be considered a real innovation in the IoT world as they extend by a factor of ten the coverage range of the de facto standards such as ZigBee

A technology that fits into this new trend is the Lo-Ra™ of Semtech technology. Its advantages compared to existing technologies for sensor networks are:

• a wider range by 10 times, compared to the short-range technologies, thanks to a 198dB link budget (obtained via a spread spectrum modulation)

[*]https://www.lepida.net/
[†]http://www.unife.it/it
[‡]https://loragis.lepida.it/loragis/
[§]https://lora-alliance.org/about-lorawan

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that allows for connections of up to 15 km in the sub-urban area, 2-5 km in densely populated urban areas and 2 km inside buildings;

• simplified network architecture (nodes sensors communicate directly with the concentrators)

• low consumption of nodes (up to 10 years when battery powered);

• very high network density: a single-concentrator gateway can connect thousands of nodes (up to 50,000)

• very low cost of the transmitting nodes.

All the above features make the Lo-Ra™ system an optimal solution, in the current scenario, for the implementation of Internet of Things paradigm, because a single concentrator can cover a wide area with a star architecture, which eliminates the problems associated with multi-hop (routing problems, latency, etc.) and because is characterized by high energy efficiency which can enable the duration of the batteries of nodes even for several years, without the constraint of the presence of the power supply.

The Lo-Ra™ of Semtech technology can be used in private applications (Nanni S., Mazzini G., 2017) (that is, without necessarily requiring the presence of an operator), and actually there many LoRaWAN networks around the world, managed by many public operators or private subjects. The availability of a regional IoT network, like PaIoT, network can offer to citizens the opportunity to install thousands of sensors for their own purposes and to Public Administrations to learn more about what happens in cities and territories to better plan and manage them.

3 PAIoT NETWORK

LepidaScpa is the in-house company of Emilia-Romagna in charge of providing broadband network to all PAs in the region [Fig.1].

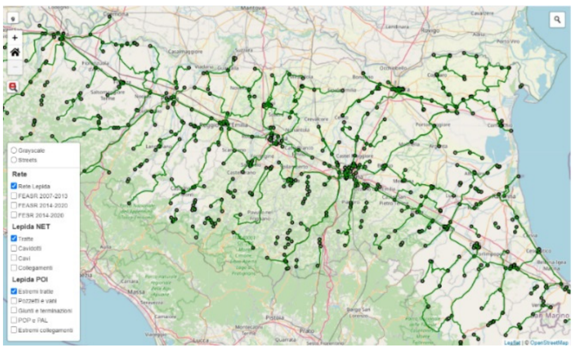

Figure 1: Lepida broadband network.

The simultaneous availability of Lo-Ra™ technology and Lepida broadband network makes a perfect synergy for the deployment of an IoT network at regional level, PAIoTnetwork, available to public administrations, companies and citizens.

Fig.2 shows the current status of implementation of the PAIoT network, which will cover all the provinces of the Emilia-Romagna region when fully operational.

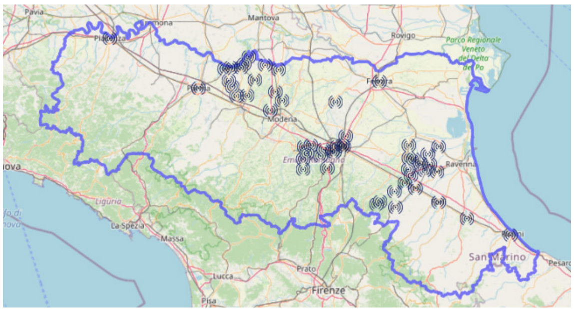

Figure 2: PAIoT network.

The architecture of PAIoT network, based on Lepida broadband network, is described in Fig.3 and relies on the following components:

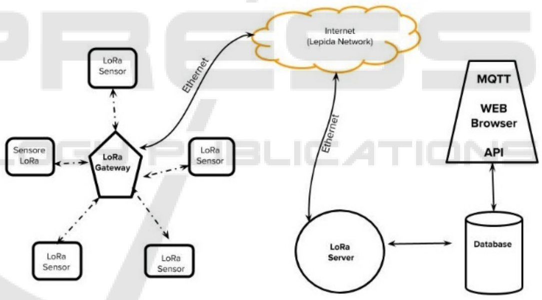

Figure 3: PAIoT network architecture.

1. Sensors (of any kind) which send data to Lo-Ra™ gateways by means of LoRaWan protocol;
2. LoraWan Gateways which receive data from LoRaWan sensors are installed in any Access Point of Lepida network (PAL), in order to use Lepida broadband network to transmit data to Lo-Ra™ Server;
3. Lo-Ra™ Server: virtual machine installed in one of the three regional data centers managed by LepidaScpa, that receives data from LoraWan Gateways through Lepida broadband network.

The data received from the LoRa server are stored in a centralized database and are made available through different interfaces: MQTT protocol, API and web interfaces.

The initiative implemented by LepidaScpa and funded by the Emilia-Romagna Region has the following main objectives:

1. create a public IOT Network where citizens, private companies and PAs can integrate their own sensors, making them available to owners and PA entities limitedly to institutional and public interest goals.
2. allow citizens and private companies to collect data from their own sensors wherever they want to install it.
3. allow PA access to data collected by all the sensors installed in the territory for monitoring purposes.
4. enable IOT development through a unique LoRa™ network managed by PA with a rational usage of the frequencies and resources optimization.
5. map all the existing sensors in the territory through a sensor register providing all the technical parameters and the owner identification.

On top of the data collection, transport, storage and data retrieval services, LepidaScpa also offers the decoding service of the payload, for immediate use of the data by the owners of the sensors and, in anonymized form, by the PA.

Their use in terms of business intelligence or in a holistic perspective, by the Public Administrations is constantly evolving and monitored because it not only depends on the type of sensors installed and on their location on the territory, but also on the future needs or opportunities.

Any development of applications or specific interfaces for analysis and synthesis, however, is entrusted to individual owners of the sensors, according to the purposes for which they have installed them.

4 CASE STUDIES

4.1 Care Residence of Novi

ASP Terre d'Argine di Carpi is a non-economic public body, which aims to deliver social and health care services to people in not self-sufficient conditions (seniors or disabled) in the Municipalities of the District (Campogalliano, Carpi, Novi of Modena and Soliera).

The hospitality centres managed by the ASP are:

- Casa Residenza “Ten. L. Marchi” – Carpi
- Care-Residence “R. Rossi” – Novi di Modena
- Centro Diurno “Il Carpine” – Carpi
- Centro Diurno “Borgofortino” – Carpi
- Centro Diurno “De Amicis” – Carpi
- Centro Diurno “R. Rossi” – Novi di Modena
- Centro Ospitalità per Adulti Ex-Carretti – Carpi

With the aim to providing innovative services, using digital technologies to support vulnerable people, a case study was launched at the Care Residence in Novi di Modena to detect some environmental parameters of the apartments where guests live independently, in order to constantly monitor their well-being conditions and report any abnormal or critical ones.

In particular, in about ten apartments, one or two motion sensors have been installed, capable of detecting the passage and time of stay of a person in a certain area, and an environmental sensor for monitoring temperature, humidity and lighting level.

Continuous monitoring of the aforementioned simple parameters makes it possible to verify that guests lead a regular life, moving during the day and resting at night, in a comfortable, properly lit and air-conditioned environment at different times of the day.

Any detections of lack of movement during the day or vice versa, of frequent movements or prolonged levels of light during the night, can be indicators of abnormal conditions and as such reported to the operators responsible, so that they can evaluate the importance and possible intervention.

Figure 4 shows the floorplan of the apartments of the Care Residence in Novi di Modena and the typical positioning of the motion sensors (blue) in the kitchen and in the bedroom in the case of two motion sensors, or in the kitchen in the case of a single sensor. The environmental sensor (green) in the kitchen in both cases.

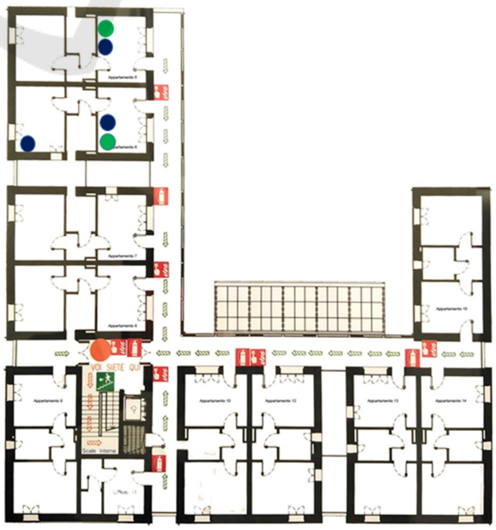

Figure 4: Apartments Floorplan in the Care-Residence “R. Rossi” – Novi di Modena.

Figure 5 shows an example of the dashboard of the daily data received and analysed: in this specific case only one movement has been detected during the night, a practically constant and pleasant temperature throughout the day (24 °C) has been measured, but a night brightness higher than the expected level (20 lumens) has been observed for a long period of time and it has been therefore reported.

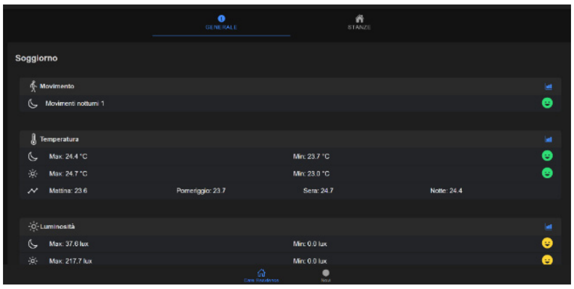

Figure 5: Dashboard.

The encouraging results obtained from this first experimentation are the basis for its possible extension in both quantitative terms, to other structures managed by the ASP, and in qualitative terms, through the addition of sensors such as, for example, a water sensor to determine the use of the shower or a magnetic sensor to determine the opening of the external door and, therefore, the good practice of properly leaving the house.

The ease of installation of the sensors, due to the battery power supply and the coverage of the PAIoT network of the other potentially involved structures, constitute the boundary conditions for this extension to be easily achieved at regional level, exploiting the know-how acquired on the use, interpretation and correlation of the parameters monitored and the correspondingly realized dashboards.

4.2 Smart City: Municipality of Carpi (Modena)

The Smart City in Carpi is becoming reality: the municipal council signed on 29 July 2020 a memorandum of understanding with the Emilia Romagna Region and Lepida Scpa started to install dozens of sensors by the year 2020 in the municipal area, which will collect data on environmental dynamics to make them “analysed, returned and monitored in real time."

The pilot project - which in terms of LoRa technology has no equal in size in the Region and perhaps in the rest of Italy, and is inspired by the most advanced European cities – includes the installation of dozens of sensors capable of recording in a capillary way extremely valuable measures such as the concentrations of fine dust and carbon dioxide, the temperature and humidity of the air, the water levels in the canals and the flows of vehicular traffic.

The data generated by the various sensors installed on the territory define a punctual reality, made up of constantly updated information, which allows us to better understand what happens in the cities and territories.

It should be emphasized that the data will not be intended only for insiders, but will be available for consultation by citizens, through dashboard that will be developed by Lepida Scpa.

Table 1 summarizes the number of sensors expected within the Smart City project of Carpi.

Table 1.

TYPE	DESCRIPTION	PROJECT
A	TEMPARTAURE HUMIDITY-NO-NO2-PM2.5-PM5-PM10	30
B	TEMPARATURE-UMIDITY-CO2-NO-NO2-PM2.5-PM5-PM10	4
C	WEATHER STATION	4
D	TEMPERATURE - AIR & SOIL	4
E	HIDROMETER	3
F	RAIN GAUGE	3
G	NUMBER AND SPEED OF VEHICLES	83
	TOTAL	131

Figure 6 shows the distribution of the different types of sensors expected within the urban area of the Municipality of Carpi.

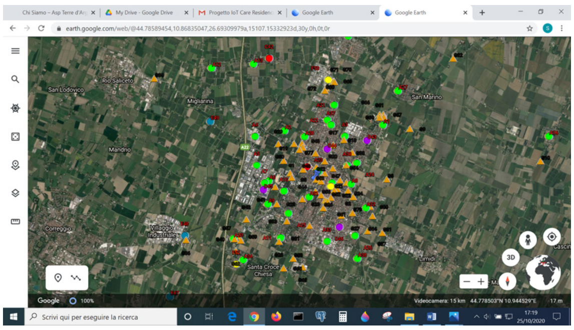

Figure 6: Distribution of Sensors in Carpi.

Figures 7 and 8 respectively show the graphs of a rain gauge and an air control unit installed in the Municipality of Carpi, through which it is possible to highlight the amount of precipitation and the concentration of fine dust with greater detail on the territory than already taken place at the regional level.

Figure 7: Graph of Rain Gauge Sensors.

Figure 8: Graph of Air Control Sensors.

The star architecture that characterizes the PAIoT network, in which the sensors communicate directly with the LoRa gateways, is a key feature for the installation of a large number of sensors, as required by a Smart City project.

For that reason, Carpi project can be considered a pilot project that not only provides the Public Administration with a very useful knowledge tool to support Governance and the management of environmental risks, but also to define guidelines, at a technological level , in the identification of the most performing sensors, functional and applicative level, in the design of the summary dashboards, to support its replicability in the other 328 Municipalities of the Emilia-Romagna region, already covered by the PAIoT network, and interested in the project.

4.3 Smart Agriculture: University of Bologna

The third case study concerns the deployment of a platform for smart water management in agriculture (Kamienski C., Soininen J., Taumberger M., Fernandes S., Toscano A., Salmon Cinotti T., Filev Maia R., and Neto A. T., 2018) (Zyrianoff I., Heideker A., Silva D., Kleinschmidt J., Soininen J.-P., Salmon Cinotti T., and Kamienski C., 2020) (Kamienski C., Kleinschmidt J., Soininen J., Kolehmainen K., Roffia L., Visoli M., Filev Maia R., and Fernandes S., 2018). The platform was developed within SWAMP, a research project[1] funded by the EU and by Brazil, within the H2020 framework (EUB-02-2017 IoT Pilots Call, Grant agreement N. 777112) [2] and focused on the demonstration of Internet of Things (IoT) technologies in real-world scenarios.

Four pilots in the agricultural domain were proposed by SWAMP: one in Spain, one in Italy and two in Brazil. The case study considered in this paper is focused on the Italian pilot, located close to Reggio Emilia within the area managed by the Consorzio di Bonifica dell'Emilia Centrale (CBEC)[3].

CBEC manages the delivery of water to farmers through a network of open canals and the goal of the pilot is twofold: using sensors and models to detect crop water needs, and optimizing water delivery based on water requests made by the farmers (i.e., at present time more than 15K requests were filed during the ongoing irrigation season).

One of the main critical aspects in such a scenario is related to data collection and transmission. The lack of power sources and the extension of the area covered impose two main requirements: to use battery powered sensors and to have access to a low-power wide area network.

Both requirements were satisfied by adopting the LoRaWAN technology, supported by the PAIoT network implemented and maintained by LepidaScpa and by designing a battery powered multi-sensor node (see Figure 9), using in this use case to tune the soil to optimize the irrigation plan.

[1]http://swamp-project.org/
[2]https://cordis.europa.eu/project/id/777112
[3]https://www.emiliacentrale.it/

Figure 9: Battery Powered multi-sensors node.

Figure 10 shows the sensors of the project: in green the already installed ones, in yellow the ones in activation phase, and in gray the Lora gateway of the PAIoT network that cover the interested area.

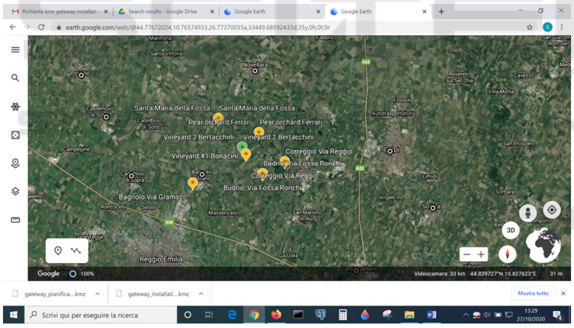

Figure 10: Sensors installed in Smart-Agriculture.

5 CONCLUSIONS

The applications presented in this paper are a few examples of how many different domains can take benefit of the recent advances in technology. In particular, the advent of LoRaWAN broadens the range of possible IoT applications.

The effort made by LepidaScpa in providing an open LoRaWAN network to collect and store data from the field is a fundamental asset to reduce entry costs for stakeholders, both public and private, who want to deploy their own sensor network within the Emilia Romagna region.

The aim of the PAIoT network is to enable the installation of thousands of sensors through the availability of a network infrastructure for the collection, storage and consultation of data available to all PAs, companies and citizens of the territory, delegating to all users interested only in the purchase, installation and maintenance of the sensors according to the needs and application areas of interest.

Finally, the PAIoT network coverage is extended at regional level, and it constitutes the prerequisite and opportunity for the replicability of pilot projects on a regional scale.

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