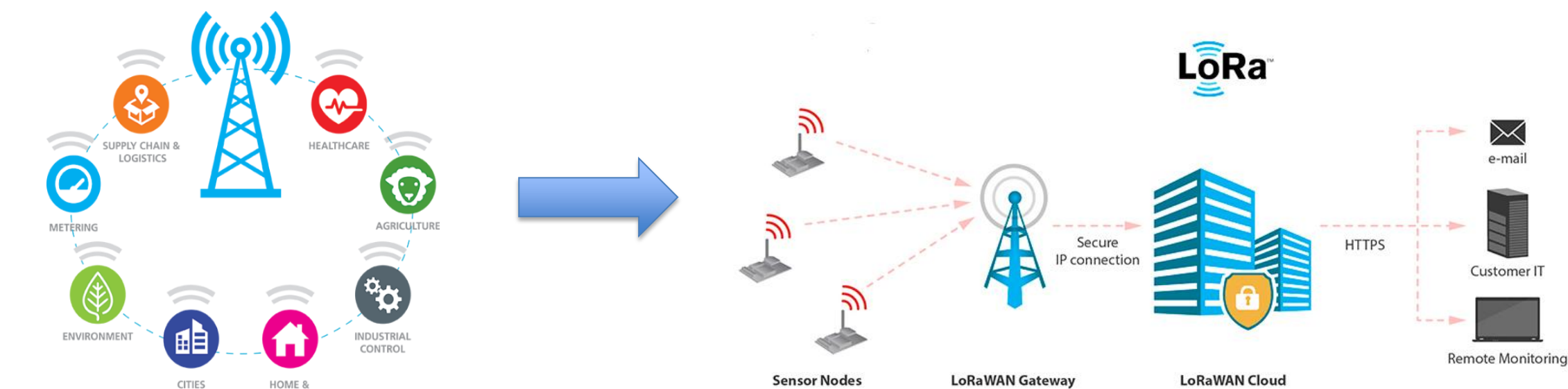
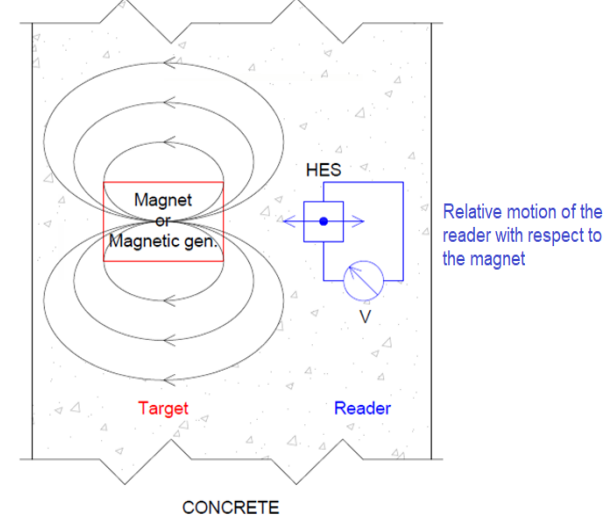


Research context and motivation

- SHM – Structural Health Monitoring with multi-measure sensing nodes** to understand the real behavior of structures during life cycle and in critical situations (even extreme). These nodes could be used for:
 - determination of local displacements;
 - diagnosis of crack patterns;
 - determination of deformations spectrum;
 - management of maintenance activities;
 - analysis of thermal expansions.
- An innovative control network with star topology based on LoRa Protocol**, a radio communication technology exploiting license free frequency bands, allowing information exchange over long distances with low-power consumption. The infrastructure is organized in different layer. The sensing nodes are installed in different part of structure and acquire information on internal parameters. Gateways receive and relay it to the supergateway. This receives and keeps track of the correct operation of end-nodes.



Addressed research questions/problems

- Analysis of propagation performance of LoRa Technology in urban environment**

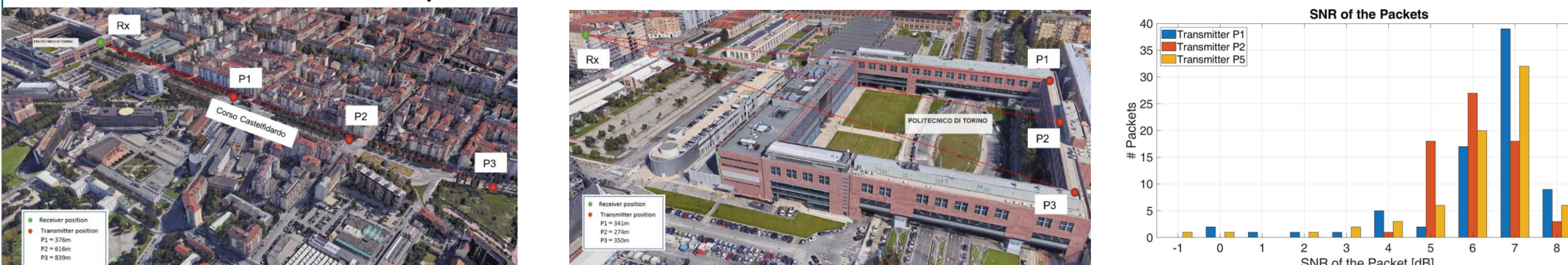
Goal: Analysis in term of range and received power

Methods: Determination of path loss, shadowing and multipath fading

Possible solutions:

Empirical solutions : Received power equation – Okamura-Hata model

Measurements: Point-to-point or star network

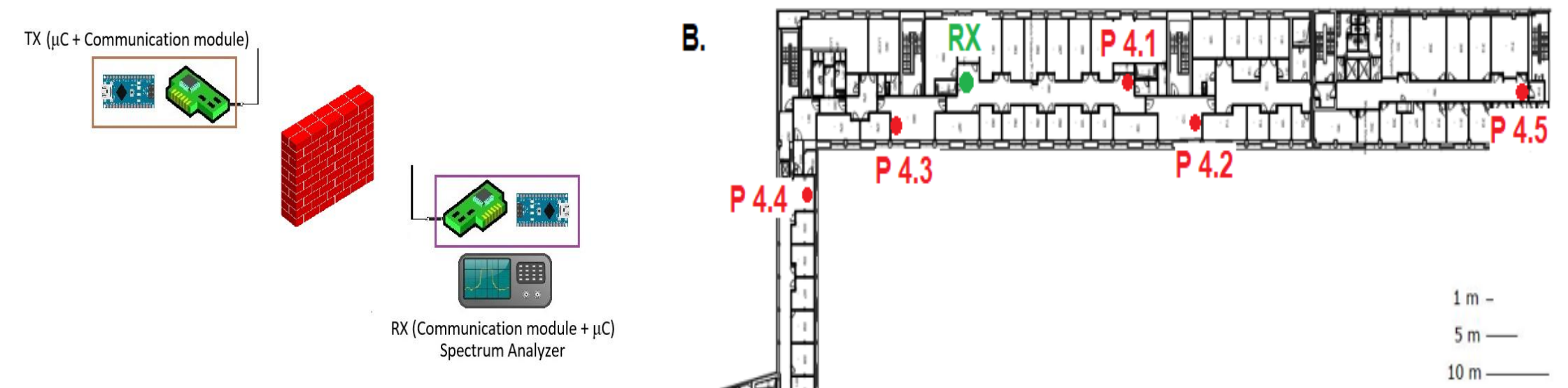


Submitted and published works

- Miryam, Paredes; Bertoldo, Silvano; Carosso, Lorenzo; Lucianaz, Claudio; Marchetta, Emanuele; Allegretti, Marco; Savi, Patrizia, Propagation measurements for a LoRa network in an urban environment, JOURNAL OF ELECTROMAGNETIC WAVES AND APPLICATIONS, Taylor & Francis online, pp. 15, 2019, Vol. 33, ISSN: 1569-3937, DOI: 10.1080/09205071.2019.1661287 (**Published**)
- Carosso, L.; Gaiki, D.; Bertoldo, S.; Allegretti, M., A new modular control board for pulse-jet cleaning of dust collector filter bags, ENGINEERING TECHNOLOGY AND APPLIED SCIENCE RESEARCH, Dr. D. Pylarinos, pp. 6, 2018, Vol. 8, ISSN: 1792-8036 (**Published**)
- Bertoldo, Silvano; Carosso, Lorenzo; Marchetta, Emanuele; Paredes, Miryam; Allegretti, Marco, Feasibility Analysis of a LoRa-Based WSN Using Public Transport, APPLIED SYSTEM INNOVATION, MDPI, pp. 12, 2018, Vol. 1, ISSN: 2571-5577, DOI: 10.3390/asi1040049 (**Published**)
- Bertoldo, S.; Paredes Quintanilla, M.; Carosso, L.; Allegretti, M.; Savi, P., Empirical indoor propagation models for LoRa radio link in an office environment, In: 13th European Conference on Antennas and Propagation (EuCAP), IEEE, 13th European Conference on Antennas and Propagation (EuCAP), Krakow, Poland 31 March - 5 April, pp. 5, 2019 (**Published**)
- Carosso, Lorenzo; Bertoldo, Silvano; Miryam, Paredes; Allegretti, Marco, ON THE REALIZATION OF A COMMUNICATION SYSTEM FOR ATMOSPHERIC PROBES BASED ON LORA TECHNOLOGIES: PRELIMINARY MEASUREMENTS AND RESULTS, In: Abstract collection book, World Multidisciplinary Earth Sciences Symposium (REPUBBLICA CECA), WMES 2018, Prague - Czech Republic 03-07 September 2018, pp. 1, 2018 (**Published**)
- Bertoldo, Silvano; Miryam, Paredes; Carosso, L.; Lucianaz, C.; Allegretti, M.; Canavero, F.; Perona, G., Progress on the realization of a LoRa® based communication system for atmospheric monitoring probes, In: Proceedings XXII RiNEm, Società Italiana di Elettromagnetismo (SIEm) (ITALIA), XXII Riunione Nazionale di Elettromagnetismo (RiNEm), Cagliari 3-6 Settembre 2018, pp. 4, 2018, Vol. 1 (**Published**)
- Bertoldo, Silvano; Miryam, Paredes; Carosso, Lorenzo; Lucianaz, Claudio; Allegretti, Marco; Savi, Patrizia, Feasibility study of LoRa ad-hoc network in a urban noisy environment, In: Proceedings MMS 2018, 18th Mediterranean Microwave Symposium, IEEE, MMS 2018, 18th Mediterranean Microwave Symposium, Istanbul (TR) 31/10 - 02/11, pp. 4, 2018, ISBN: 9781538671320 (**Published**)
- Carosso, L.; Bertoldo, S.; Lucianaz, C.; Allegretti, M., A LoRaWAN based network for monitoring operation of environmental pollution and meteorological parameters using public transport, In: Geophysical Research Abstracts, European Geosciences Union, European Geosciences Union General Assembly 2018 (EGU GA 2018), Vienna (AUT) 8-13 Aprile 2018, 2018, Vol. 20 (**Published**)
- Carosso, L.; Allegretti, M.; Bertoldo, S., A new wireless sensor network module for health monitoring of civil structures, In: Proceedings of 2017 IEEE-APS Topical Conference on Antennas and Propagation in Wireless Communications (APWC), IEEE, 2017 IEEE-APS Topical Conference on Antennas and Propagation in Wireless Communications (APWC), Verona (ITA) 11-15 September 2017, pp. 4, 2017, ISBN: 978-1-5090-4454-2, DOI: 10.1109/APWC.2017.8062226 (**Published**)
- Carosso, Lorenzo; Allegretti, Marco; Perona, Giovanni Emilio; Gilli, Luigi; Dirita, Antonio, PROCESSO PER IL RECUPERO INTEGRALE DI METALLI PREZIOSI E TERRE RARE DA MATERIALE ELETTRONICO IN DISUSO RECUPERATO DA RIFIUTI DI APPARATI ELETTRICI ED ELETTRONICI (ITALIA), 2019 (**Presented**)

Novel contributions

- Evaluate the possibility to use LoRa in urban complex environment;
- Propagation measurements and simulation in urban environment using ad-hoc and multi-configuration transmitters and receivers;
- Comparison of measurements results with commonly used empirical propagation models;
- Study the use of network redundancy to detect faults
- Determination of LoRa Propagation in indoor environment.



Adopted methodologies

THEORETICAL ANALYSIS OF PROPAGATION PERFORMANCE

- Use the empirical Okumura-Hata model to define the maximum distance that could be covered in urban areas at the frequency on which Lora modules operate in Europe. The equation yields the path loss L_p by knowing the operating frequency f in MHz, the transmitter and receiver heights h_t and h_r and the correction parameters $\alpha(h_r)$:

$$L_p|_{dB} = 69.55 + 26.16 \log_{10} f - 13.82 \log_{10} h_t - \alpha(h_r) + (44.9 - 6.55 \log_{10} h_r) \log_{10} d$$

Transmitted power (dBm)	Maximum range (m)	
	$h_r = 3 \text{ m}$	$h_r = 20 \text{ m}$
0	552	923
5	727	121
14	1194	1998

where for large cities $\alpha(h_r) = 3.2[\log_{10}(11.75 \cdot h_r)]^2 - 4.97$.

Future work

- Improve the quality of gateway's antennas, in order to be able to cover long distances (very useful for large infrastructure, such as bridges) with a smaller number of intermediate nodes;
- Modify the network topology from a single super gateway configuration to the deployment of a series of central nodes;
- Analyze and design the characteristics of reader and target of sensing nodes.
- Develop a system for energy harvesting to extend the lifetime of nodes;
- Development of a fully reliable sensor to be used in each node of the developed infrastructure able to measure millimeter displacements;

List of attended classes

- External training activities - Training School on Ground Penetrating Radar for civil engineering and cultural heritage management - Roma, Italy, May 14-18, 2018 - TU1208 GPR Association, Associazione Italiana del Georadar, Sapienza University of Rome and University College London – Sapienza University of Rome, Rome (Italy) – 14-19 May 2018
- External training activities – AIT Summer School on Tribology – Associazione Italiana di Tribologia - Politecnico di Milano (Bovisa) – Dipartimento di Meccanica – 26-30 August 2019;
- 01LGSRV – Characterization and planning of small-scale multigeneration systems (13/9/2019 – 5 CFU);
- 01PJHRV – Cloud computing per applicazioni e-science (To Register – 4 CFU)
- 02LWHRV - Communication (02/12/2018 – 1 CFU);
- 01SHMRV – Enterprenuerial Finance (28/02/2019 – 1 CFU);
- 01RRPRV – Lean startup e lean business for l'innovation management (06/08/2019 – 4 CFU);
- 08IXTRV – Project Management (24/02/2019 – 1 CFU);
- 01RISRV – Public Speaking (01/03/2019 – 1 CFU);
- 01SYBRV – Research integrity (09/03/2019 – 1 CFU);
- 01SWQRV – Responsible research and innovation, the impact on social challenges (16/03/2019 – 1 CFU);
- 01LEXRP – Strumenti e tecnologie per lo sviluppo del prodotto (To Register – 5 CFU);
- 01QEZRv – Sviluppo e gestione di sistemi di acquisizione dati (To register – 5 CFU);
- 02RHORV – The new internet society; entering the black-box of digital innovations (02/03/2019 – 1 CFU);
- 01SWPRV – Time management (27/02/2019 – 1 CFU);
- 01TGRRV – Uso degli strumenti e delle strategie per un efficace uso del tempo (22/03/2019 – 1 CFU).