1. Title of the Tutorial

Low Power Wide Area Networks for the Internet of Things: Framework, Optimization, and Challenges of LoRaWAN and NB-IoT.

2. Abstract of the Tutorial

Low-Power Wide Area Networks (LPWAN) have recently gained considerable attention in the Internet of Things (IoT). The key objective of these wireless technologies is to connect low-power devices over very large areas, with low data rates. LPWANs are promising for various emerging IoT applications, complementing the traditional cellular and short-range technologies.

In this tutorial, we present the recent advances of LPWAN technologies with focus on LoRaWAN and NB-IoT. We analyse the link level and system level design aspects. We further focus on link budget analysis and radio network dimensioning for both LoRaWAN and NB-IoT. Precisely, we present best practices in the network design and deployment of these technologies. Acquiring such best practices is of paramount importance for the engineering and optimization of LPWANs. We also provide a comparative scientific analysis of the performance of LoRaWAN and NB-IoT in terms of coverage and capacity.

Finally, we cover the research directions and scientific challenges in these technologies. Particularly, we present research directions for radio resource management in both LoRaWAN and NB-IoT.

3. Outline of the Tutorial and the Topics the Speakers Will Cover

- Services and applications that foster low power wide area networks; Samer Lahoud; 10 minutes
- Architecture and characteristics of low power wide area networks; Samer Lahoud; 15 minutes

- Optimized modulation and access method for low power consumption and large coverage in LoRaWAN; Melhem El Helou; 15 minutes
- Leveraging and adapting 3GPP LTE infrastructure and mechanisms for NB-IoT; Melhem El Helou; 15 minutes

- LoRaWAN specification: Radio interface, physical architecture, protocol architecture; Samer Lahoud; 20 minutes
- NB-IoT standard: Radio interface, physical architecture, protocol architecture; Melhem El Helou; 20 minutes

- Link budget analysis for LoRaWAN; Melhem El Helou; 15 minutes
- Link budget analysis for NB-IoT; Melhem El Helou; 15 minutes

- ALOHA based model for LoRaWAN dimensioning; Samer Lahoud; 20 minutes
- Bandwidth based dimensioning for NB-IoT; Samer Lahoud; 20 minutes

- Research directions for radio resource management in LoRaWAN and NB-IoT; Samer Lahoud; 15 minutes

4. The Tutorial Speakers

Samer Lahoud, ESIB, Saint Joseph University of Beirut, Lebanon, samer.lahoud@usj.edu.lb

Melhem El Helou, ESIB, Saint Joseph University of Beirut, Lebanon, melhem.helou@usj.edu.lb

5. Brief CVs for each Tutorial Speakers

Samer Lahoud is an Associate Professor at the Saint-Joseph University of Beirut where he lectures computer networking courses at the Faculty of engineering (ESIB). His research activities focus on routing and resource allocation algorithms for wired and wireless communication networks. He has co-authored more than 80 papers published in international journals and conference proceedings. Mr. Lahoud received the Ph.D. degree in communication networks from Telecom Bretagne, Rennes, in 2006. After his Ph.D. degree, he spent one year at Alcatel-Lucent Bell Labs Europe. From 2007 to 2016, he was with the University of Rennes 1 and with IRISA Rennes as an Associate Professor.

Melhem El Helou received the engineer's degree and master's degree in telecommunications and networking engineering from the Ecole Supérieure d'Ingénieurs de Beyrouth (ESIB), Faculty of Engineering at the Saint Joseph University of Beirut, Beirut, Lebanon, in 2009 and 2010, respectively and the Ph.D. degree in computer and telecommunications engineering from IRISA Research Institute, University of Rennes 1, Rennes, France and Saint Joseph University of Beirut, in 2014. He joined ESIB in September 2013 where he is currently an Assistant Professor (*fr:* Maître de conférences). His research interests include wireless networks, radio and energy resource management, Internet of Things, and quality of service.

6. Importance and Timeliness of the Tutorial

Low-Power Wide Area Networks (LPWAN) represent a novel wireless communication paradigm, which will complement traditional cellular and short-range wireless technologies in addressing diverse requirements of IoT applications. LPWANs are attracting a lot of attention primarily because of their ability to offer large coverage and long battery life operating devices. Machina Research (2016) expects 11 percent of IoT connections in 2025 to use LPWAN technologies. This tutorial is of strong interest to the ICT community working in the fields of communications technology. First, engineers and professionals will benefit from an overview on the two major technologies in LPWAN, namely LoRaWAN and NB-IoT. They will acquire deep understanding of the major design choices of both technologies, and best practices in link budget analysis for capacity and coverage planning. Second, academic and industry researchers will benefit from a scientific overview on the state-of-the-art, and the promising research perspectives for radio resource management in LPWANs. Finally, graduate students will benefit from a technology overview on the radio interface, and the physical and protocol architectures for LoRaWAN and NB-IoT. This tutorial is accessible to a broad audience in the ICT community as it only requires familiarity with communication and networking concepts.

7. Previous Lecture and Tutorial Experience of the Tutorial Speakers

- Future Access Networks: Cloud-RAN and Optimization problems, Labex DigiCosme Seminar, Paris Saclay, http://bit.ly/2B2ak1f, 20 attendees
- Course on Internet of Things Technologies, Saint-Joseph University of Beirut, http://bit.ly/2BcXU7I, 18 attendees
- The speakers are participating in the deployment of the first academic LPWAN network in Lebanon. The network supports monitoring of micro-climate conditions in vineyards. The experimental platform implements an end-to-end LoRaWAN solution (http://wiki.lahoud.fr/doku.php?id=exploring_lorawan). Currently, the speakers are leading scientific and experimental studies for measuring, assessing, and modelling the coverage, capacity, and quality of service of the LoRaWAN deployment. The tutorial will also be an occasion to present the latest results of these scientific studies.