Network Research Group

PhD thesis
2023–2026

# Energy-efficient routing in multi-technology low-power and lossy wireless networks

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| **Location** | Network Research Group – ICube (UMR CNRS 7357), University of Strasbourg (France) |
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## Keywords

Wireless Sensor Networks (WSN); Internet of Things (IoT); Wake-Up Radios (WUR); Routing

## Context

Since the 2000s, a plethora of wireless technologies appeared to satisfy or go beyond today's requirements, ranging from best effort to strict constraints on reliability or delays. Low-Power and Lossy Wireless Networks (LLWN) emerged in the same era [2] thanks to advances in integrated circuits. However, each technology has its pros and cons, some focusing on the radio range, the throughput, or trading off one factor with another. It is now envisioned to combine several wireless technologies in the same network to compensate for the shortcomings of one(s) with the advantages of the other(s). Regarding their characteristics, it is likely that the radio ranges and properties of one technology does not match the ones proposed by a second. As a result, with two distinct radio technologies, the network is simply composed of two graphs ($G_1$ and $G_2$) as illustrated in Figure 1.

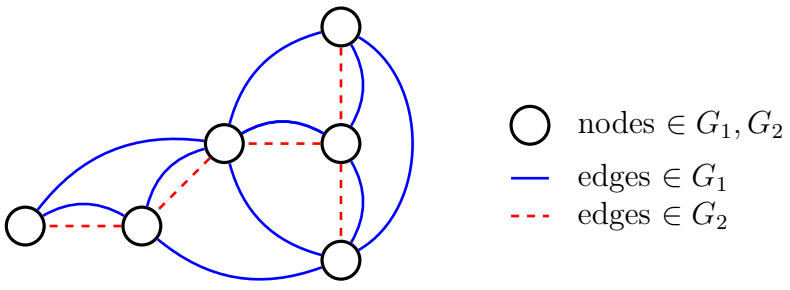


Figure 1: Example of a multi-technology low-power and lossy wireless network: red dashed links exhibit the short-range control feature among devices while blue plain ones indicate their long-range transmission capability (in this simple example, blue links include red ones).

## Scientific Objectives

In this PhD thesis, we will investigate the problem of energy efficient routing in a multi-technology LLWN. To limit energy consumption and improve the network life-time and performance, we will consider that one technology is short-range, and exclusively used for control ($G_2$), while the other is long-range, power consuming and, as such, solely used when data transmissions are required ($G_1$). One of the targeted

use-case we envision to explore is to combine Wake-Up radios [1] and a more classical transceiver such as 802.15.4 to compute and deploy the best and reliable multi-metric paths. Full link state routing protocols, such as CTP-WUR [4], require exchanging numerous control messages on both graphs, impacting energy consumption significantly. In the context of Wake-Up radios, we already proposed a reactive routing protocol [3] that focuses on complete graphs ($G_1$ forms a full-mesh, i.e. a one hop network). This PhD thesis will extend this work by considering multi-hop networks: $G_1$ may not be complete as in Figure 1, $G_2$ sub-paths are combined to form multi-metric and multi-hop $G_1$ paths for data transmissions.

## Skills

The expected skills are:

- Excellent programming skills in C, and embedding programming;
- Wireless networks (protocols and radio propagation), energy efficiency;
- Good knowledge in graph theory and distributed algorithms;
- Applicants should possess good verbal and written English skills. French is **not** a requirement;
- Holding an MSc in Computer Science (CS) or Electrical and Computer Engineering (ECE), or Electrical and Computer Engineering (ECE) is mandatory.

## Application

Please send an email to `reseaux-pos-2023@icube.unistra.fr` including:

- a detailed CV ;
- your possible list of publications if applicable ;
- the grades for the last three years, with your position after the final exams ;
- a cover letter

## References


[1] R. Piyare, A. L. Murphy, C. Kiraly, P. Tosato, and D. Brunelli. Ultra low power wake-up radios: A hardware and networking survey. IEEE Communications Surveys Tutorials, 19(4), 2017.

[2] G.J. Pottie. Wireless sensor networks. In proc. of the IEEE Information Theory Workshop (ITW), 1998.

[3] S.L. Sampayo, J. Montavont, and T. Noël. REFLOOD: Reactive Routing Protocol for Wake-Up Radio in IoT. Elsevier Ad Hoc Networks, 121, 2021.

[4] A.V. Sheshashayee and S. Basagni. Multi-hop Wake-up Radio Relaying for the Collection Tree Protocol. In proc. of the IEEE Vehicular Technology Conference (VTC), 2019.