PhD proposal: "Energy-efficient IoT networks"

February 27, 2019

Keywords: IoT networks, NOMA, energy efficiency, online optimization and machine learning

1 ANR-ELIOT project

This PhD scholarship is funded by the French National Research Agency (ANR) and falls within the scope of the recently funded research project ANR-ELIOT - *"Enabling technologies for IoT"* in collaboration with FAPESP, Sao Paulo, Brazil. The project is built around four pillars in terms of objectives for future IoT networks: a) energy efficiency; b) security; c) latency; d) self-optimization capabilities.

The context of ELIOT consists of networks of communicating devices such as: distributed control systems (i.e., autonomous vehicles, delivery drones or other UAV systems) and sensor networks (i.e., health monitoring, smart cities, smart homes, etc.). These applications depend on reliable and low-energy communication systems, as envisaged by the Internet of Things (IoT) paradigm that will connect billions of wireless "things" (sensors, wearables, biochip transponders, etc.) in a vast network with drastically different characteristics and requirements in terms of: energy efficiency, security, latency and self-optimization capabilities, and demand for innovative enabling technologies [1].

2 Motivation and research proposal

Because of the unprecedented degree of temporal variability of IoT networks due to the inherent wireless channel characteristics, device mobility attributes, their intermittent activity and behavior, the energy efficiency resource optimization calls for tools from *online optimization and regret minimization*. This allows us to develop new and improved resource allocation algorithms that are capable of adapting on-the-fly to the changing environment and effectively accounting for devices' mobility [2], [3]. The major advantage of such online algorithms is that they do not rely on any assumptions on the dynamics of the underlying network, which, thus, can be completely arbitrary, offering the appropriate flexibility to take into account the specificities of IoT networks.

With billions of interconnected devices, wireless IoT networks are expected to exhibit massive node densities and thus inevitably experience high interference levels. An orthogonal spectrum allocation will likely become unfeasible given the scarcity of RF spectral resources. NOMA protocols can be considered instead, which reduce the impact of the multi-user interference by using more complex decoding techniques compared with single-user decoding. NOMA allows overlapping among the signals from different devices by exploiting power- or code-domain multiplexing. In power-domain NOMA, signals from multiple users are superimposed and successive interference cancellation is used at the receiver to decode the messages [4], [5]. Although NOMA can improve the spectrum efficiency, it has several shortcomings that need to be addressed in the IoT context: the multi-user detection increases the decoding complexity and energy consumption of the receivers; the channel state information is often assumed to be perfect; the inherent lack of fairness among the devices.

However, there is little work on wireless-powered NOMA networks from an energy-efficiency perspective. Exiting works focus on rate maximization objectives with various fairness considerations and assuming the circuit power consumption (to receive/process information) is negligible compared to the power for information transmission. Recent results question the benefits of NOMA over orthogonal protocols when the circuit power consumption is taken into account. Moreover, existing works do not take into account the temporal dynamics of the network.

Thesis objective: Design energy-efficient NOMA communications and resource allocation policies for dynamic IoT networks exploiting tools from online optimization and machine learning.

Advisors: E. Veronica Belmega (Associate Professor in ENSEA, Cergy-Pontoise) and Arsenia Chorti (Associate Professor in ENSEA, Cergy-Pontoise)

3 Additional information

3.1 PhD scholarship

Location: The successful candidate will be a member of the Wireless Communications group (approximately 29 members), of the research unit ETIS (website: `https://www-etis.ensea.fr//en/homepage.html`), UMR 8051; a common research unit including researchers from the ENSEA, the University of Cergy-Pontoise, and the CNRS.

The PhD student will be located at ENSEA, a Graduate School in Engineering and Computer Science; and currently counts about 105 researchers, including 51 non-permanent researchers working in the areas of Artificial Intelligence & Robotics, Signal & Telecoms, Electronics of Autonomous Systems, Big Data & Multimedia Indexing, and Data Learning.

ETIS Lab is situated in Cergy-Pontoise, at 40 minutes by the RER suburban train from center Paris, France.

Start date: The successful candidate can start as early as September 2019.

This PhD scholarship offers three years funding and a gross salary of approximately 24,000 euros per year (20,000 net amount excluding income tax). The salary could be supplemented by a family supplement and a transport allowance.

The successful candidate will have access to a robust doctoral research training programme, dedicated research resources, training in giving seminars / presentations and associate with:

- existing PhD students of the *Ecole Doctorale Economie, Management, Mathematiques, Physique et Sciences Informatiques (EM2PSI)* within the University of Cergy-Pontoise;
- researchers of the ETIS Lab and, in particular, within the ICI group (website: `https://www-etis.ensea.fr/en/ici-team.html`);
- international ANR-ELIOT consortium including researchers from Brazil, more specifically, from the University of Sao Paulo and the Pontifical Catholic University of Rio de Janeiro.

The successful candidate will also receive support for attending international conferences and workshops, and exchange programs with Brazil in the context of the ANR-ELIOT. In addition, students can take up light teaching responsibilities on a paid basis (around 40 euro per hour) to further enhance their experience in preparation for their future careers.

Our support services could provide further assistance regarding administrative procedures and housing search (possibility of temporary studio rental in ENSEA, upon availability).

University registration fees: All doctoral candidates (French, EU, non-EU) are required to pay approximately 500 euro per year in registration fees. These registration fees are not included in the PhD scholarship.

3.2 Entry requirements

Applications are sought from France, EU and international candidates with an outstanding academic background, particularly in wireless communications, optimization theory, machine learning, signal processing or related disciplines. Demonstrable mathematical skills will be essential and an interdisciplinary background (e.g., computer science, electrical engineering, mathematics) will be an advantage. The candidate should be familiar with key engineering programming languages (e.g., MATLAB, Python, R, etc.). Applicants must have an MSc degree (M2, engineer degree or equivalent in France). A good and working knowledge of the English Language is required.

3.3 How to apply

Interested candidates have to send their detailed CV, academic records (from BSc to MSc level), at least two academic referees and a short motivation letter (one page maximum) via email to the contact below. Applications will be received until the **31st of May 2019**.

Contact: E. Veronica Belmega
Email: belmega@ensea.fr
Webpage: `https://sites.google.com/site/evbelmega/home`
Address: ETIS/ENSEA, 6 Avenue du Ponceau, 95014 Cergy-Pontoise cedex, France

References

[1] D. Singh, G. Tripathi and A. J. Jara, "A survey of Internet-of-Things: Future vision, architecture, challenges and services," in *Internet of things (WF-IoT), 2014 IEEE World Forum on*, 2014, pp. 287–292.

[2] A. Marcastel, E. V. Belmega, P. Mertikopoulos and I. Fijalkow, "Online interference mitigation via learning in dynamic IoT environments," in *IEEE IoE Workshop GLOBECOM*, 2016.

[3] E. V. Belmega, P. Mertikopoulos, R. Negrel and L. Sanguinetti, "Online convex optimization and no-regret learning: Algorithms, guarantees and applications," *Arxiv preprint arxiv:1804.04529*, 2018.

[4] S. R. Islam, N. Avazov, O. A. Dobre and K.-S. Kwak, "Power-domain non-orthogonal multiple access (NOMA) in 5G systems: Potentials and challenges," *IEEE Commun. Surveys Tuts.*, vol. 19, no. 2, pp. 721–742, 2017.

[5] W. Yu, A. Chorti, L. Musavian, H.V. Poor, Q. Ni, "Effective secrecy capacity for a downlink NOMA network," *IEEE Trans. Wireless Commun.*, in second round review, 2019.