Post-doc position: Channel coding, resource allocation and signal processing for short packet communications

Laboratory:
IETR – Institut d'Electronique et de Télécommunications de Rennes (UMR CNRS 6164)
Start : October 2018 **-** ***Duration*** 24 months

Topic

This research position takes part of the ANR project ARBurst and will be fully funded including travel expenses for conferences and publications.

The ANR project ARBurst (https://project.inria.fr/arburst/) aims at providing fundamental bounds for machine-to-machine (M2M) communications and internet-of-things (IoT) networks. The characteristics of these networks are a large number of connected nodes, short packet communications and impulsive transmissions due to the uncoordinated communication protocols for a such large number of nodes. While the small packet size invalidates the use of the asymptotic Shannon capacity as a performance indicator, the consequent bursty nature also invalidates the Gaussian assumption usually used to model the interference distribution. Moreover, the high density of nodes advocates for a continuum model of users in the cell, allowing to derive the capacity of a cell with a continuum distribution of users [1]. Finite blocklength information theory, recently revisited by Polyanskiy, Poor and Verdu [2], provides the tools to assess the achievable coding rate (and converse) when the number of channel uses remains bounded. However, the fundamental bounds in impulsive and dense wireless networks, in broadcast channel (BC) or multiple access channel (MAC) remain unknown. In ARBurst, we aim at characterizing the fundamental performance of dense and impulsive IoT networks in terms of latency, spectral-efficiency and energy-efficiency (SE-EE) tradeoff, reliability and nodes density for a given transmit power in BC and MAC. In that context, the performance of classical coding schemes such like LDPC, turbo or polar codes, known for their high performance in the context of large throughput with long packet sizes, have to be re-considered in the context of short packet communications. Moreover, superposition coding (SC) is also known to achieve the BC capacity in asymptotic regime. However, recent results in finite blocklength suggests that SC is not always optimal, in terms of energy-efficiency spectral efficiency (EE-SE) tradeoff for small packet sizes and dense user scenario [3].

The goal of the research position is twofold. In a first place, the candidate will evaluate classical coding and resource allocation strategies compared to the fundamental bounds developed in this project. The performance criteria will be those relevant for small packets communications and IoT networks, i.e. not only SE but also EE, latency and reliability. The first goal is then to evaluate the margin gap between current coding and waveform design for IoT, e.g. chirp modulation in LoRa, to achievable and converse bounds derived in the project in impulsive noise and for high nodes density. This first step will allow to identify the most promising communication techniques to fill the gap between theoretical limits and current solutions. In a second time, new practical strategies will be proposed to get closer from theoretical bounds. In particular, practical strategies implementing dirty paper coding (DPC) will be proposed and evaluated in BC. Moreover, since the amount of useful information and overhead signaling becomes of the same order of magnitude in short packet communications, coding strategies constructed over these both fields of the packet will be evaluated in case of large number of nodes [4]. New waveforms and receivers adapted to impulsive noise, such like p-norm receiver, will be evaluated in small packet transmission and MAC scenario. Moreover, demodulating high number of nodes in MAC scenario relies on a fine time/frequency analysis and the performance of frequency-hopping in a pure ALOHA mode will be evaluated.

This work proposed in this position could be of a great importance for industrial actors and researchers in the deployment of the future IoT networks. The solutions proposed during this position could sustain the dramatic increase of the number of connected devices in the near future.

References

[1] J.-M. Gorce, H. Vincent Poor, J.-M. Kelif, "Spatial Continuum Model: Toward the Fundamental Limits of Dense Wireless Networks", *IEEE Globecom 2016*, USA.
[2] Y. Polyanskiy, H. V. Poor and S. Verdu, "Channel coding rate in the finite blocklength regime", *IEEE Transactions on Information Theory*, vol. 56, no. 5, pp. 2307-2359, May 2010.
[3] J.-M. Gorce, P. Mary, D. T. Anade Akpo, J.-M. Kelif, "Fundamental Limits of the Ultra Dense Users Broadcast Channel with Superposition Coding", Submitted to IEEE/ACM WiOpt 2018
[4] K. F. Trillingsgaard and P. Popovski, "Downlink Transmission of Short Packets: Framing and Control Information Revisited", *IEEE Transactions on Communications*, Vol. 65, no 5, May 2017.

Key skills

The candidate should have earned a PhD degree in one of the following field: electrical engineering, signal processing, information theory. The candidate should be an expert with Matlab and C/C++ languages.

Key words:

Asymptotic and non-asymptotic information theory, channel coding schemes, LoRaWan, Ultra Low Latency and Reliable Communications, impulsive noise, alpha-stable.

How to apply:

- Email a motivation letter
- Full CV with exhaustive list of publications
- 2 or 3 references
- **Applications will be reviewed when they arrive until one candidate is selected**

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