PhD Proposal : Green Radio Access for Smart Sensor Networks

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Context

In future 5G communication systems, machine-to-machine (M2M) communications and sensor networks will induce new constraints on how to transmit information. Large-scale deployment of such networks should answer the following major issues: (1) the energetic issue to increase as much as possible the lifetime of transmitters, and (2) the multiple-access management issue to limit the interferences between users.

1) Energy Consumption Reduction

Batteries are more and more employed inside transmitters, hence the need to use wisely the available energy to transmit information. The most consuming element is linked to the power amplifier (PA).

Constant envelope modulations are not prone to distortions and thus highly non-linear PA can be used such as:

- Highly efficient power-amplifiers, which offer important energy savings in applications like spatial communications, telemetry or military communications ;
- Low cost PA, which save money for the large-scale deployment in applications like sensor networks (AIS, remote metering for gas or water, Bluetooth, etc.).

CPM (*Continuous Phase Modulation*) [AAS86] are constant envelope modulations with better spectral efficiency than other constant envelope modulations. However, the error rate of CPM is penalized with respect to their linear modulations counterpart, thus requiring higher transmission power to reach the same error rate.

There is a renewed interest in the study of CPM with e.g. recent work of coherent receiver robustness [MCA+15], the optimization of non-coherent receivers [PPT+18] or future mobile M2M systems [BPN+16, MAG+19].

2) Interference Management

The reduction of energy consumption is also performed through the limitation of the amount of data to transmit. The random access scheme (ALOHA) enable to save header information for multi-user (MU) access as well as the return channel. Collisions and other interferences between users are dealt with at the receiver side. In the context of sensor networks, information to be transmitted is assumed sparse. Thus, the number of collision is reduced and algorithms inspired by compressed-sensing techniques can be efficiently used [MAG+19].

Subject Description

The energy efficiency gain of CPM can increase the battery lifetime. However, under the same spectral efficiency, a CPM modulation requires more transmit power than a linear modulation. The main question to be answered in this PhD thesis is how to choose between these 2 kind of modulation so as to get the longest battery lifetime, under the same transmission performances.

The answer to this question will of course depend on the PA data sheets. The first difficulty is how to deal with the important number of parameters describing the behaviour of a PA: the most significant will have to be found. The work should start with the state-of-the art review of the non-linearity models of 2 classes of PA: the high power PA, like the ones on-board satellites (TWTA), and the low-cost PA which can be found in some M2M or IoT transmitters. Based on these models, the PA consumption will be evaluated.

The second step will focus on the linear modulation performance when taking into account the PA. Then the performance of some non-linear modulations like CPM or other waveforms such as LoRa or SigFox will be addressed when amplified by the same PA.

For the 2 PS classes, a comparison of uncoded transmission consumption will be performed for a given spectral efficiency and a given error rate. The Doppler effect will also be included for spatial communications: indeed, the low and medium earth orbits are mainly considered for spatial M2M, where the Doppler effect is important. Depending on the previous results, coding and/or pre-coding, iterative receivers will be investigated to improve the energy efficiency of the transmission scheme.

In the third part of the thesis, multi-user detection (MUD) for CPM will be generalized based on [MAG+19] and optimal receivers using its Laurent decomposition [BGP+]. Several MUD strategies will be investigated: « model-based » techniques like compressed sensing/LASSO as first explored in [MAG+19], data-driven techniques like Deep Learning as proposed in [BAC18, QWH19].

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