

Postdoc research topic

- Title of the proposed topic: **Learning and coordination at the wireless edge in future IoT**
 - Funding from 3IA Chair on “Internet of Learning Things: A machine learning approach to future IoT networks”)
 - **Supervisor (name, affiliation, email): David Gesbert (EURECOM), gesbert@eurecom.fr**
 - The laboratory and/or research group: Communication Systems Department, EURECOM
-

Apply by sending an email directly to the supervisor.

The application will include:

- Curriculum vitæ.
 - Motivation Letter.
 - Academic transcripts of a master’s degree(s) or equivalent.
 - One to three references.
-

- Description of the topic:

Title: Learning and coordination at the wireless edge in future IoT

Wireless communication networks such as the future Internet of Things (IoT) will highly benefit from various forms of cooperation established between communication nodes, especially those at the edge of the networks (small cell base stations, user terminals). Cooperation can take place over various domains. They include wireless operation domains when the node’s primary function is a data communication one. In this case cooperation domain is directly related to communication parameter design, such as power control, beam design, time-frequency resource assignment etc. However the node may also cooperate to perform non-communication related tasks [1]. For instance several terminals may want to communicate between each other and collaborate to joint localize themselves, or jointly perform any other cooperative tasks (such as robots in a factory).

Inter-node cooperation generally require two basic functions to be devised. One is a protocol to carry information between the nodes to that they inform each other of their local environment. This protocol involves some form of signaling between the cooperating devices. For instance if nodes seek to jointly localize themselves, they in a first phase may exchange local mapping information and/or some local visual or radio input. The second function to be devised is called “decision making”. This function exploits the local+shared information from the first phase and turns it into an estimate or action.

Distributed and federated learning approaches

The above signaling and decision making problems can be generally recast as decentralized control problems which are known to be extremely challenging if solved to optimality [2,3,4,5] especially when the local data is noisy in addition to being partial [6,7].

In this PhD work, we are interested in the use of machine learning in order to automate the solution and capitalize of the massive amounts of data that are inherent to dense networks of connected objects in the future IoT.

First a novel algorithm architecture will be studied which aims at solving the signaling problem and the decision making problems. One key instance will be that where signaling and decision making engines will the take the form of neural networks. In this case, a key challenge will be the efficient training of the networks, especially when the network of nodes has globally access to lots of training data yet each node separately can access to only limited training data. For this problem we will consider the recently developed concept of distributed and federated learning [10] which allow distinct nodes to exploit the availability of training data at other nodes without ever having to exchange this data (hence saving on bandwidth and maintaining privacy).

For the signaling and decision making design per-se will capitalize on our preliminary work using DNN which has revealed some promising results [8,9] but needs considerable further understanding. First the optimization of DNN architecture is completely open. Secondly we need more understanding on why DNN can solve our problem and under what conditions. Finally we need to investigate scalability issues when the number of agents tends to grow large (hundreds).

Bibliography

- [1] D. Gesbert, P. de Kerret "Team Methods for Device Cooperation in Wireless Networks", in *Cooperative and Graph Signal Processing: Principles and Applications*, P. Djuric and C. Richard editors, Elsevier, 2018.
- [2] R. Radner, "Team decision problems," *The Annals of Mathematical Statistics*, 1962.
- [3] Y. C. Ho, "Team decision theory and information structures," *Proceedings of the IEEE*, vol. 68, no. 6, pp. 644–654, 1980. *IEEE Commun. Mag.*, vol. 52, no. 4, pp. 40–48, 2014.

- [4] J. Marschak and R. Radner, *Economic theory of teams*. Yale University Press, New Haven and London, Feb. 1972.
- [5] K.-C. Chu, "Team decision theory and information structures in optimal control problems—Part II," *IEEE Trans. Automat. Contr.*, vol. 17, no. 1, pp. 22–28, Feb. 1972.
- [6] G. Gnecco and M. Sanguineti, "Smooth optimal decision strategies for static team optimization problems and their approximations," in *SOFSEM 2010: Theory and Practice of Computer Science*, 2010.
- [7] —, "Suboptimal solutions to team optimization problems with stochastic information structure," *SIAM J. Optim.*, vol. 22, no. 1, pp. 212–243, Mar 2012.
- [8] M. Kim, P. de Kerret, and D. Gesbert, "Learning to Cooperate in Decentralized Wireless Networks", in *Proc. Asilomar Conference on Signals and Systems*, 2018.
- [9] M. Zecchin, D. Gesbert, M. Kountouris, "*Team Deep Mixture of Experts for Distributed Power Control*", in *proc. IEEE Signal Processing Advances for Wireless Communications Workshop*, Atlanta, 2020.
- [10] Mingzhe Chen, Zhaohui Yang, Walid Saad, Changchuan Yin, H. Vincent Poor, Shuguang Cui "A Joint Learning and Communications Framework for Federated Learning over Wireless Networks" ARXIV <https://arxiv.org/abs/1909.07972>