Adaptive and Resilient Devices Cooperation in Ultra-Dense 5G Cellular Networks

Résumé du projet de recherche (Langue 1)

The high density of devices is an opportunity for more cooperation at the physical layer of wireless communication systems, which usually requires a high level of coordination and a high complexity. Centralizing all the communications allows to very efficiently manage interference [Gesbert2010], yet it also comes with a large infrastructure and control traffic cost, which is clearly not possible beyond a certain point, as the costs of the infrastructure and control traffic should not outweigh the possible efficiency gains [Zakhour2011]. Furthermore, centralization usually comes with insufficient performance in terms of delay and reliability, which are key drivers in the need for new 5G paradigms. Indeed, delay is the major issue for the so-called “tactile internet” which comprises use cases where humans interact with devices. This interaction requires a higher reactivity in order to provide good QoS such that lower delay, in the order of some milliseconds, is required [Nokia2016]. Small delay and high reliability is also a main target of safety related environments where the security of people or objects is at stake. To answer the very different requirements for the different use cases in this new factory scenario, we propose to shift from the usual base station centric organization to a partially centralized/distributed architecture exploiting Device-to-Device communication and computation at intermediate layers. Indeed, a partially centralized architecture with computational capabilities spread across the network and using communication links between the nodes provides a high degree of flexibility and many degrees of freedom in the signal processing domain, which, if properly exploited, could significantly boost the performance and provide efficient solutions for the factory setting considered. Yet, this new architecture comes with many new challenges as exploiting optimally this architecture and the distributed computational resource at the devices represents a difficult optimization problem. The signal processing at the devices should be able to exploit in the most efficient way the Device-to-Device communications, storage, sensing capabilities, and the processing power available at the different devices. This requires each device to reach an effective coordination with the other devices at the minimum cost possible for the infrastructure. Examples of decision to be taken collaboratively are the design of the physical layer signals, the distributed storage, or the scheduling decisions. In previous works, the transmitter cooperation in wireless networks has been formulated as a team decision problem and some resource allocation solutions have been proposed as [kerret2013] More recently, an algorithm to efficiently design a joint precoder being robust to the imperfect information at the nodes has been proposed in [kerret2016]. Yet, the proposed solution is highly limited by the complexity and is therefore not adapted to the dense scenario formed by the factory setting. Furthermore, the communication capabilities of the devices are not exploited to improve the solution obtained at each device. Last but not least, the time dimension is not exploited in the sense that there is no learning over the different channel realizations, and the complex optimization has to be performed each time. Therefore, the main goal of this doctoral work will consist in overcoming these strong limitations so as to transform the very preliminary works from the literature into practically relevant and efficient solutions. This will require facing some important theoretical problems as this optimization problem can be formulated as a Team Decision problem [Radner1962], which are known for a long time, in particular in the control community, and are widely recognized as difficult problems. Yet, the strong development of the computation capabilities in the past decade has opened up new avenues for solving such difficult problems. In particular, Stochastic Optimization [Shapiro2014] and Machine Learning methods [Rasmussen2006] provide now very efficient tools for solving a wide range of problems.

Résumé du projet de recherche (Langue 2)

The high density of devices is an opportunity for more cooperation at the physical layer of wireless communication systems, which usually requires a high level of coordination and a high complexity. Centralizing all the communications allows to very efficiently manage interference [Gesbert2010], yet it also comes with a large infrastructure and control traffic cost, which is clearly not possible beyond a certain point, as the costs of the infrastructure and control traffic should not outweigh the possible efficiency gains [Zakhour2011]. Furthermore, centralization usually comes with insufficient performance in terms of delay and reliability, which are key drivers in the need for new 5G paradigms. Indeed, delay is the major issue for the so-called “tactile internet” which comprises use cases where humans interact with devices. This interaction requires a higher reactivity in order to provide good QoS such that lower delay, in the order of some milliseconds, is required [Nokia2016]. Small delay and high reliability is also a main target of safety related environments where the security of people or objects is at stake. To answer the very different requirements for the different use cases in this new factory scenario, we propose to shift from the usual base station centric organization to a partially centralized/distributed architecture exploiting Device-to-Device communication and computation at intermediate layers. Indeed, a partially centralized architecture with computational capabilities spread across the network and using communication links between the nodes provides a high degree of flexibility and many degrees of freedom in the signal processing domain, which, if properly exploited, could significantly boost the performance and provide efficient solutions for the factory setting considered. Yet, this new architecture comes with many new challenges as exploiting optimally this architecture and the distributed computational resource at the devices represents a difficult optimization problem. The signal processing at the devices should be able to exploit in the most efficient way the Device-to-Device communications, storage, sensing capabilities, and the processing power available at the different devices. This requires each device to reach an effective coordination with the other devices at the minimum cost possible for the infrastructure. Examples of decision to be taken collaboratively are the design of the physical layer signals, the distributed storage, or the scheduling decisions. In previous works, the transmitter cooperation in wireless networks has been formulated as a team decision problem and some resource allocation solutions have been proposed as [kerret2013] More recently, an algorithm to efficiently design a joint precoder being robust to the imperfect information at the nodes has been proposed in [kerret2016]. Yet, the proposed solution is highly limited by the complexity and is therefore not adapted to the dense scenario formed by the factory setting. Furthermore, the communication capabilities of the devices are not exploited to improve the solution obtained at each device. Last but not least, the time dimension is not exploited in the sense that there is no learning over the different channel realizations, and the complex optimization has to be performed each time. Therefore, the main goal of this doctoral work will consist in overcoming these strong limitations so as to transform the very preliminary works from the literature into practically relevant and efficient solutions. This will require facing some important theoretical problems as this optimization problem can be formulated as a Team Decision problem [Radner1962], which are known for a long time, in particular in the control community, and are widely recognized as difficult problems. Yet, the strong development of the computation capabilities in the past decade has opened up new avenues for solving such difficult problems. In particular, Stochastic Optimization [Shapiro2014] and Machine Learning methods [Rasmussen2006] provide now very efficient tools for solving a wide range of problems.

Informations complémentaires (Langue 1)
EURECOM is a highly international center and has ongoing collaborations with prestigious universities (e.g., Princeton, the Technical University of Munich, ...). The phd student will also submit to IEEE international conferences. It is also planned that the student will attend the European School of Information Theory during its first year. Finally, it will be proposed to the phd to spend at least one summer in a university abroad so as to develop its academic network.