Internship offer "LTE/LTE-A Network Optimization by Distributed Fast Algorithms"

Company/Organisation	Alcatel Lucent – Bell Labs – France
Department	Triple-Play Wireless Networks (TWN)
Address	Route de Villejust, Alcatel-Lucent Bell Labs, Centre de Villarceaux, France
Phone: 01 30 77 80 04	**Fax**
City (workplace)	Nozay, Centre de Villarceaux
Zip Code: 91620	**Country:** France
Company web site	http://www3.alcatel-lucent.com/wps/portal/belllabs
Contact person (name and e-mail address)	Chung Shue (Calvin) CHEN, cs.chen@alcatel-lucent.com
Position	Member of Technical Staff (Research Engineer)
Duration in months: 6	**Working Hours/day**
Starting date (earliest): 15/05/2013	**Starting date (latest)**

Description of the Internship

Team activities:

The internship will take place at Alcatel-Lucent Bell Labs in the TWN/O4N team, whose mission is to develop efficient and green solutions for 4G and beyond wireless networks. Research themes include small cell systems, network self-configuration and -optimization, network-based solutions for rich always-on 4G broadband service, spectrum and energy efficient strategies, and next-generation wireless network design. The team has a global expertise in various wireless communication and networking technologies including LTE/ LTE-A HetNets, SON, network MIMO, green radio, Wi-Fi, WiMAX, etc.

Training description:

The next-generation mobile networks are expected to provide a full coverage of broadband wireless service and support fair and efficient resource utilization with a high degree of operation autonomy and system intelligence. With the foreseen exponentially increasing number of users and traffic in 4G and beyond systems, existing deployment and practice of cellular radio networks that strongly rely on highly hierarchical architecture with centralized control and resource management would be economically unsustainable.

The training will study LTE/LTE-A systems and focus on network optimization problems for large wireless communication systems and resource allocation management. It aims to investigate non-concave maximization problems and looks for distributed and scalable algorithms. We will consider a locally coupled networked system or a graph of interacting nodes. The goal is to maximize the sum of the objective functions of all nodes in the network with a requirement of limited information exchange and computation efforts.

One promising approach is to use the classical framework of Markov Random Fields with Gibbs sampling or Metropolis-Hastings (Markov chain Monte Carlo) simulation algorithms. The method does not require the concavity/convexity, monotonicity or duality properties usually required in conventional optimization techniques. Besides, it supports discrete optimization which is especially useful to practical systems. Existing results of ALU Bell Labs have demonstrated its effectiveness in solving non-concave network utility maximization problems in several applications (e.g., in OFDMA cellular networks, small cell systems, LTE/LTE-A HetNets, potential delay minimization, etc) via fully distributed and

asynchronous/random node state transitions. It is a very interesting area.

The primary objective of the study is to investigate the above method in simulated annealing (SA). It is known that through adjusting the annealing speed (i.e., the cooling temperature) iteratively, the system would be driven to a state of global optimum. The cooling scheme is crucial and would impact the convergence speed and also system performance. One may consider various cooling schemes and settings of initial temperature. TWN and its partner INRIA have been working on this topic and possible solutions, in particular Gibbs sampler and spatial adaptive play algorithms. We have investigated logarithmic cooling scheme and obtained some experience. It is known that a SA with logarithmic cooling would provide optimal result but may yield unfavourable slow system convergence.

In this context, the objective of the internship will be phased as follows:

1) Literature study: review existing results of non-concave network utility maximization (NUM) methods and the literature of Gibbs sampling, Metropolis-Hastings, and MCMC simulation methods.
2) Programming and computer simulation: implement existing algorithms and conduct numerical studies.
3) Exploration and analysis: test various cooling schemes and control parameters and analyse different combinations in comparison.
4) Further investigation and scientific establishment: depending on the progress of the internship, extended investigations are possible such as finding optimal initial temperature, tradeoff between convergence speed and strict optimality, and issues of information imperfectness. Mathematical setup and scientific contribution are also possible.

The trainee will learn and benefit from the existing results of ALU Bell Labs on network optimization and distributed stochastic algorithms and also from the collaboration and experience established by TWN and its research partner INRIA. This topic could bring significant scientific impact and also technology advancement to engineering optimization algorithms. It can also be considered as a preliminary work for a PhD program.

References:

[1] C. S. Chen, F. Baccelli, L. Roullet (2011). Joint optimization of radio resources in small and macro cell networks. In Proc. of IEEE VTC, USA.
[2] S. Borst, M. Markakis, I. Saniee (2013). Non-concave utility maximization in locally coupled systems with applications to wireless and wireline networks. IEEE Trans. on Networking (TON).
[3] P. Bremaud (1999). Markov chains: Gibbs fields, Monte Carlo simulation, and queues. Springer, New York.
[4] J.N. Tsitsiklis (1989). Markov chains with rare transitions and simulated annealing. Mathematics of Operations Research 14(1), 70-90.
[5] T. Liggett (1985). Interacting particle systems. Springer, New York.

Skills

Skills	Level
1. Simulation	Intermediate: - ability to write MATLAB and/or C programs.
2. Mathematical	Intermediate: - understanding of probability and random process, Markov chains, graph theory, set theory. - understanding of basic optimization techniques (although the internship is not dedicated to developing new algorithms, it is crucial to be able to understand what is proposed in order to write

<table>
<tr><td></td><td>the program (e.g., in Matlab or C), test, and/or extend the existing algorithms).</td></tr>
<tr><td>Language skills</td><td><table>
<tr><th>Language</th><th>Level
Basic/Intermediate/Advanced</th></tr>
<tr><td>1. English</td><td>Intermediate (we are working in a multi-culture multi-language work environment)</td></tr>
</table></td></tr>
<tr><td>Qualifications</td><td>General knowledge of wireless communication systems, mobile cellular networks, and radio resource management (e.g., OFDMA, power control, base station and mobile user association, channel selection) would be appreciated; knowledge on LTE/LTE-A and numerical simulation is a definite plus.</td></tr>
</table>