Ecole Doctorale STIC

Sciences & Technologies de l'Information et de la Communication

ED STIC - Proposition de Sujets de Thèse

pour la campagne d'Allocation de thèses 2011

Titre du sujet :	Belief Propagation in Complex Networks
Mention de thèse :	Informatique
HDR Directeur de thèse inscrit à l'ED STIC :	Avrachenkov Konstantin

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Description du sujet :

FRAMEWORK

Network science [1] has emerged in the last ten years as an inter-disciplinary and yet distinct research field, seeking to discover common principles, algorithms and tools that govern networks as different as the Internet, the web, human social networks, gene regulatory networks, the brain, ecosystems, social organizations, transport networks. The pioneer work from applied mathematicians and statistical physicists, like Strogatz, Watts, Barabasi and Vespignani, has focused on (1) identifying common properties of these networks (small diameter, high clustering coefficients, presence of hubs, etc.), (2) proposing simple network growth models (e.g.~random links, preferential attachment) that may justify such commonalities across scenarios so heterogeneous, and (3) studying the consequence of these properties on performance like propagation speed in the network (of rumors, diseases, data packets), or robustness to attacks. More recently, researchers have also started studying the interplay of different networks, to lead to predictive models of the individual and composite behavior of these complex interacting

networks. For example, a significant funding from the U.S. Department of Defense has lead in 2009 to the creation of 3 academic research centers (respectively on information, social-cognitive and communication networks) and one interdisciplinary research center.

DESCRIPTION

An important issue, common to different networks, is how beliefs form: it concerns political opinion in voting, product quality as perceived by customers, intentions in potential conflict situations, but also optimization of distributed algorithms in wireless networks. Beliefs form and evolve over time on the basis of private information, but also of information exchange with "neighbours" in the specific network (neighbours may be friends, bloggers, other customers shopping or mobile devices having an opportunity to transmit each other).
As a starting point, we consider the case where the graph of the network of interactions is given and the agents can communicate only with their direct neighbors on the graph. A central question is how network characteristics---like the topology of the communication network and the type of information exchangeable among the agents---affect belief formation dynamics. For example, under what conditions do these dynamics lead to an efficient aggregation of the information disperse among all the agents, and then to the emergence of a common correct belief in the whole network? Our first results in this direction are in [2], where the agents are mobile wireless nodes in a Delay Tolerant Network, that try to collectively optimize a parameter of their routing algorithm. In this case the belief of each node is its current estimate of the optimal value of such parameter. We considered that the communication network evolves over time due to nodes mobility: a link is created (/destroyed) every time two nodes move inside (/outside) the transmission range of each other. The dynamic evolution of the topology is assumed to follow a Markovian process. As regards the learning algorithm, nodes update their belief by simply averaging it with their neighbors similarly to what is done in consensus algorithms. We show that this learning algorithm together with a distributed form of gradient descent is sufficient to guarantee the convergence to the optimal value of the parameter (i.e. the correct belief).
In this framework, the candidate would investigate how to generalize our current results to more general dynamic networks and how to reduce the convergence time of the proposed algorithm. For example an opportune choice of the weights could speed up the convergence for a given meeting process: intuitively more weight should be given to the hubs of the communication network, e.g. to the nodes that meet more often other nodes or that travel between otherwise disconnected regions.

References

[1] An introductory video to Network Science
[2] Distributed Sub-gradient Method for Delay Tolerant Networks, R. Masiero, G. Neglia, INRIA Research Report 7345, August 2010, [pdf]
[3] S. Boyd, A. Ghosh, B. Prabhakar, and D. Shah, “Randomized gossip algorithms,” IEEE Trans. Inf. Theory, vol. 52, pp. 2508–2530, Jun. 2006, [pdf]
[4] Jakovetić, D.; Xavier, J.; Moura, J.M.F.; , "Weight Optimization for Consensus Algorithms With Correlated Switching Topology," Signal Processing, IEEE Transactions on , vol.58, no.7,

pp.3788-3801, July 2010 doi: 10.1109/TSP.2010.2046635, [pdf]

CANDIDATE PROFILE
The candidate should have a solid background on probability, graph theory and good programming skills.

English version:

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