Inria international program

Associate Team

Final report
(max 6 pages)

Associate Team acronym: GANESH

Period of activity: last 3-years.

Principal investigator (Inria): Eitan Altman, MASTRO EPI

Principal investigator (partner): Prof Anurag Kumar, ECE department, IISc Bangalore

Other participants: IIT Mumbay, EE department and OR department, LIA – Univ of Avignon with whom MAESTRO has a collaboration agreement which includes hosting of Eitan Altman (the French P.I.).

1. Overview of the activities

Workshop

We organised an Indo-French Workshop on Social Networks on 16th January 2014 in conjunction with a CEFIPRA sponsored workshop on New Avenues for Network models (13-15 January 2014). The joint workshop had three tutorials of three hours each and eighteen seminars of one hour each. Two of the three tutorials were given by the PIs of this project: The tutorial on Competition in social networks was presented by Eitan Altman (INRIA), and the tutorial on Mean Field approximations was presented by Rajesh Sundaresan (IISc). In addition to the three tutorials, there were a total of 8 other speakers and 4 students from France. The remaining 10 speakers were from India. Over a hundred participants attended both workshops.

Visits to INDIA

- Parmod Kumar, 1 nov 2013 - 31 july 2014. Visits IIT Mumbay

- Parmod Kumar, 16 aug - 25 sep, 2013. Visits IISc
- Eitan Altman, January 10 - January 20, 2012. Visit of the IISc group and meeting at IISc with the group of IIT Mumbay
- Rachid El-Azouzi (July 2012): visits one week the IISc group and one week the group of IIT Mumbay
- Yezekael Hayel (July 2012): visits one week the IISc group and one week the group of IIT Mumbay
- Eitan Altman: July 12 - July 19, 2012. Visit of the IISc team. Meeting of the IIT Mumbay team (Prof Borkara and Dr Kavitha at Bsangalore). Gave a tutorial on "competition for popularity in social networks" in Bangalore (workshop on networks in Biology and Communications).

Visits to INRIA

- Visit of Prof Anurag Kumar, 26 May - 3 Jun, 2014.
- Visit of Dr Joy Kuri, 19 May - 23 May, 2014.
- Visit of Prof Rajesh Sundaresan: 24 nov - 14 4 dec, 2013.
- Visit of Prof. Vivek Borkar, nov 3 - nov 10, 2013.
- Visit of Dr. Kavitha Veeraruna, 25 May - 1 June, 2013.
- Visit of Prof A. Chockalingam, 11 June - 22 June, 2012.
- Visit of Prof Rajesh Sundaresan: 24 May - 14 June, 2012
- Visit of Prof Vivek Borkar: 11 June - 23 June, 2012

2. Scientific achievements

Briefly describe the scientific results obtained with the support of this associate team (including on-going research).

Delay Tolerant Networks (DTNs)

We pursued our study of optimal control in delay tolerant networks. We studied in **[SAKS13]** the trade-off between delivery delay and energy consumption in a delay tolerant network in which a message (or a file) has to be delivered to each of several destinations by epidemic relaying. In addition to the destinations, there are several other nodes in the network that can assist in relaying the message. The analysis is based on a mobility model in which all individuals move independently of each other. In **[PAH13]** we have studied through simulations the multicast time in DTNs where the mobility of individuals follows dependent movement such as the one of flocking birds. This model is typical to cooperative movement and could be useful to describe a rescue team in an area hit by a disaster. We showed the impact of the parameters defining the mobility on the multicast time.

In **[AABP13]** we formulated a problem where both transmission and activation of mobile terminals are controlled as a linear optimal control problem. We solved the problem by making use of this linearity in order to obtain explicit expressions for the objective function as a function of the control actions trajectories (rather than as a function of both actions and state trajectories). This allows us to compute the optimal strategies explicitly.

Competition in Social Networks

We considered in **[AKKV13]** a situation where several content producers send their content to some subscriber of a social network. These posts appear on the subscriber's timeline which is assumed to have finite capacity. Whenever a new post arrives to the timeline, an older post leaves it. Therefore to be visible, a source has to keep sending its contents from time to time. Each source is modeled as a player in a non-cooperative game in which one trades between the utility for being visible on the timeline and the cost (or effort) for keeping sending content. We solved this game in a Markovian setting and computed the performance measures of interest. We are now working on extensions of this paper.

Network neutrality and collusions

Representatives of several Internet access providers have expressed their wish to see a substantial change in the pricing policies of the Internet. In particular, they would like to see content providers pay for use of the network, given the large amount of resources they use. This would be in clear violation of the "network neutrality" principle that had characterized the development of the wireline Internet. We proposed and studied possible ways of implementing such payments and of regulating their amount. The results were reported already in the previous report, but were substantially revised during the period of this project. This results appear in [**AHS14, HAS12**].

We pursued our work on network neutrality studying various ways of collusions between an ISP and a content provider and in particular, another form of non-neutrality in which a content provider signals to an ISP information on the popularity of its content and hides this information from other ISPs. We defined and computed the price of collusion and studied the impact of such signaling on the ISP that is in collusion as well as on the other ones. The results appear in **[HA13].**

Opportunistic scheduling in the presence of noncooperative users:

A central scheduling problem in wireless communications is that of allocating resources to one of many mobile stations that have a common radio channel. Much attention has been given to the design of efficient and fair scheduling schemes that are centrally controlled by a base station (BS) whose decisions depend on the channel conditions reported by each mobile. The BS is the only entity taking decisions in this framework. The decisions are based on the reports of mobiles on their radio channel conditions. We studied in **[KAES14]** the scheduling problem from a game-theoretic perspective in which some of the mobiles may be noncooperative or strategic, and may not necessarily report their true channel conditions. We modeled this situation as a signaling game and studied its equilibria. We demonstrated that the only Perfect Bayesian Equilibria (PBE) of the signaling game are of the babbling type: the noncooperative mobiles send signals independent of their channel states, the BS simply ignores them, and allocates channels based only on the prior information on the channel statistics. We then proposed various approaches to enforce truthful signaling of the radio channel conditions: a pricing approach, an approach based on some knowledge of the mobiles' policies, and an approach that replaces this knowledge by a stochastic approximation approach that combines estimation and control. We further identified other equilibria that involve non-truthful signaling.

Spatial SINR games of base stations placement and mobile association:

We consider in **[SAKS12]** the question of base station association: for a given placement of base station, we search for a decision rule for each one of a very large number of mobiles such that given the decisions of all other mobiles, the decision of each mobile maximizes its own ratio between his received signal to the received sum of noise and interference. We then address the question of the optimal placement of the base-station. We call a "cell" corresponding to a base station all the points that are points in which mobiles connect to that base station. We obtain a paradoxical behavior in which the cells are non-convex, and where some mobiles connect to a base station where as others which are closer to that same base station do not connect to it.

Stochastic geometric games for Ad-Hoc networks

In **[HAB12, HAB12b]** we model competition of mobile terminals over collision channels in an Ad-hoc network. Mobile users determine the probability of transmission at each time slot. Their position is given according to a spatial Poisson process. The equilibrium probability is computed along with the price of anarchy. Various utilities are considered. An adversarial version of this game (a jamming context) is studied in **[HA12].**

3. Production

Journal Publication

[AHS14] Eitan Altman, Manjesh Kumar Hanawal and Rajesh Sundaresan, "Regulation of off-network pricing in a nonneutral network", to appear in the ACM Transactions on Internet Technologies, 2014.

[NAK14] K. P. Naveen, Eitan Altman and Anurag Kumar, Competitive Relay Selection in Sleep-Wake Cycling Multi-Hop Wireless Networks, Under review, 2014.

[KAES14] Veeraruna Kavitha, Eitan Altman, Rachid El-Azouzi and Rajesh Sundaresan, "Fair Scheduling in Cellular Systems in the Presence of Noncooperative Mobiles" , IEEE/ACM Transactions on Networking , 580-594, Vol 22(2), Apr. 2014.

[AABP13] Eitan Altman, Amar Prakash Azad, Tamer Basar and Francesco De Pellegrini, "Combined Optimal Control of Activation and Transmission in Delay Tolerant Networks", IEEE/ACM Transactions on Networking, Vol 21 No. 2, pp 482-494, April 2013

[SAKS13] Chandramani Singh, Eitan Altman Anurag Kumar, and Rajesh Sundaresan, Optimal forwarding in Delay Tolerant Networks with Multiple Destinations, IEEE/ACM Transactions on Networking, IEEE early access articles, 2013.

[HAB12] Kumar Hanawal, Eitan Altman, and Francois Baccelli, "Stochastic Geometry based Medium Access Games in Wireless Ad Hoc Networks," IEEE Journal on Selected Areas in Communications, Vol 30 issue 11, pp 2146-2157, 2012.

[SAKS12] Chandramani Singh, Eitan Altman Anurag Kumar, and Rajesh Sundaresan, "Spatial SINR Games of Base Station Placement and Mobile Association", IEEE/ACM Transactions on Networking. Volume 20 Issue 6, December 2012, pp. 1856-1869.

[VKA12] Ramaiyan Venkatesh, Anurag Kumar and Eitan Altman, "Optimal Hop Distance and Power Control for a Single Cell, Dense, Ad Hoc Wireless Network", ACM library IEEE Transactions on Mobile Computing, Volume 11, Issue 11, pp 1601 - 1612, 2012

[KAES12] Veeraruna Kavitha, Eitan Altman, Rachid El-Azouzi and Rajesh Sundaresan, "Opportunistic Scheduling in Cellular Systems in the Presence of Noncooperative Mobiles". IEEE Transactions on Information Theory 58(3): 1757-1773 (2012)

International Conferences

[AKE14] Eitan Altman; Joy Kuri; Rachid El-Azouzi, "A routing game in networks with lossy links", International Conference on NETwork Games COntrol and oPtimization 2014 (NetGCoop'14), Oct 2014, Trento, Italy.

[AKKV13] Eitan Altman, Anurag Kumar, and Parmod Kumar and Srinivasan Venkatramanan, "Competition over timeline in social networks", Proceedings of the 3rd IEEE/ACM workshop on Social Networks, Analysis and Applications, Niagra falls, Canada, August 2013.

[PAHR13] Sushma Patil, Eitan Altman, Manjesh Kumar Hanawal, Julio Rojas-Mora, "Modeling and Simulation of Mobility of Crowds", hal-00819653, version 1 LNCS 7984, pp 352-363, Proceedings of Analytical and Stochastic Modelling Techniques and Applications (ASMTA), Ghent, July 8-10, 2013.

[HA13] Manjesh Kumar Hanawal and Eitan Altman, "Network Non-Neutrality Through Preferential Signaling", Proc. of the 11th Intl. Symposium on Modeling and Optimization in Mobile, Ad Hoc, and Wireless Networks (WiOpt), May 13-17, 2013, Tsukuba Science City, Japan.

[HAS12] Manjesh Kumar Hanawal, Eitan Altman, Rajesh Sundaresan, "A Game Theoretic Analysis of Collusions in Nonneutral networks". Presented at WPIN 2012 , held in conjunction with ACM SIGMETRICS/Performance 2012 (London, UK, June 2012). Also in Performance Evaluation Review (PER)

[HAB12b] Manjesh Kumar Hanawal, Eitan Altman, and Francois Baccelli, "Stochastic Geometry based Medium Access Games," Proceedings of the 31st International Conference on Computer Communication (INFOCOM 2012), Orlando, Florida, USA, March 2012

[HA12] Manjesh Kumar Hanawal, and Eitan Altman, "Stochastic Geometry based Jamming Games in Mobile Ad hoc Networks," proceedings of the 9th International Conference on Wireless on-demand Networks and Services (WONS 2012), Courmayeur, Italy, January 2012

[KRA12] Veeraruna Kavitha, Sreenath Ramanath, and Eitan Altman, Analysis of small cell networks with randomly wandering users. INRIA HAL-00660647 Proc. WiOpt 2012 (Paderborn, Germany, May 14-18, page 60-67, 2012).

4. Future of the partnership

A proposal to renew the Ganesh associated team has been submitted. In any case the collaboration continues through a CEFIPRA project in which the PIs of GANESH do not participate (since they already coordinated two CEFIPRA projects together). On the other hand, they both participate with the Ganesh team in the IFCAM Indo-French Lab for Applied Math, and this project has recently been renewed for 3 more years.