

## Inria Associate Teams programme Intermediate report (Year 1 and 2)

**Associate Team acronym:** " LION: Learning In Operations and Networks"

**Period of activity:** Year 2 for the French team. The contract (MOU) with the Indian side has been signed on sept 22, 2023 only but still we have managed to advance and report below the achieved results

**Principal investigator (Inria):** Eitan Altman. **Principal investigator (Partner Institution):** Kavitha Veeraruna (IIT Bombay)

### 1. Future of the Associate Team

Would you like to pursue this Associate Team for one more year?  Yes  No

**Website of the Associate Team** <https://www-sop.inria.fr/members/Eitan.Altman/Lion/Home.html>

### 2. List of participants

**NEO:** Konstantin Avratchenkov, Giovanni Neglia and Eitan Altman- senior researchers, Samir Perlaza, Junior Researcher. Students: Mikhail KAMALOV PhD student, Ashok Ramakrishnan and Mandar Matar (postdocs)

#### IITB

Kavitha Veeraruna , Vivek Borkar and Manjesh Hanawal Kumar (Professors)  
Shiksha Singhal, **Khushboo** Agarwal, Ranbir Dhouchak, (PhD students)

### 3. Achievements and Planning activities

In [1] We explore the use of multi-type branching processes to analyze the viral properties of the post, e.g., to derive the expected number of shares, the probability of virality of the content, etc. In OSNs (Online Social Networks) the new posts push down the existing contents in timelines, which can greatly influence content propagation; our analysis considers this influence. We find that one leads to draw incorrect conclusions when the timeline (TL) structure is ignored: a) for instance, even less attractive posts are shown to get viral; b) ignoring TL structure also indicates erroneous growth rates. More importantly, one cannot capture some interesting paradigm shifts/phase transitions; for example, virality chances are not monotone with network activity parameter, as shown by analysis including TL influence. In the last part, we integrate the online auctions into our viral marketing model. We study the optimization problem considering real-time bidding.

Mikhail Kamalov has done one month internship with Prof. Borkar (IITB) on the topic of distributed methods for linear and non-linear semi-supervised learning. It is proposed to apply batch-based stochastic approximation methods to scale to large graphs linear and non-linear (graph neural network) semi-supervised learning methods. We are in the final

stage of paper preparation.

We studied in [3,4,5] the control utilities through pricing. both in resource allocation context [3,5] as well as in renting platforms [4]. In such system, the actions are determined either strategically so as to maximize utilities, or they are taken to be reactive functions, i.e. they impact demand through the inverse demand function.

With Prof. Borkar we have also continued to work on Reinforcement Learning methods for restless multi-armed bandits. Specifically, we have submitted to ACM Tompecs a journal paper on two reinforcement learning algorithms, QWI and QWINN, to learn the Whittle index for the total discounted criterion for the tabular and deep learning settings, respectively.

Samir M. Perlaza visited the IIT Bombay and presented recent results on games with noisy observations in a departmental seminar. These results are reported in [2]. During this visit several ideas for extending this work have been explored. In particular, the case in which an equilibrium does not exist has been the focus of extensive discussions and equilibrium refinements have been considered.

### **Planning activities**

During the visit of Samir M. Perlaza to IIT Bombay, the ideas on equilibrium refinements such as epsilon-equilibria or strong-Stackelberg equilibria have been considered as possible extensions of the work reported in [2]. The applications of this mathematical model in machine learning have been discussed for considering the eventual impairments to which training datasets are subject to. It is by now clear that these results are particularly adapted to developing robust supervised learning systems. Hence, to complete the work. extensions to more general sets of actions and channel models appear to be a promising research direction.

During the visit of K. Avrachenkov to IITB, we have discussed further research on reinforcement learning. In particular, we have discussed the reinforcement learning schemes for the average-reward criterion in the setting of non-ergodic Markov chains. Carrying out the regret analysis of our reinforcement learning schemes appears to be another worthwhile research direction. We have also discussed the application of stochastic approximation methods for the computation of various centrality indices in temporal networks.phase transitions, thereby making the study incomplete.

Eitan Altman together with Kavitha Veeraruna, **Khushboo** Agarwal, **Shiksha** Singhal and Manjesh Hanawal plan to model traffic optimization problems as polling systems and optimize the parameters that determine the mobility patterns of the server.

### **Publications:**

[1] Ranbir Dhouchak, Veeraruna Kavitha, Eitan Altman. Viral Marketing Branching Processes. Computer Communications, In press see <https://hal.inria.fr/hal-03858831/document>.

[2] Ke Sun, Samir M. Perlaza, Alain Jean-Marie.  $2 \times 2$  Zero-Sum Games with Commitments and Noisy Observations. ISIT 2023 - IEEE International Symposium on Information Theory, Jun 2023,

Taipei, Taiwan. ([hal-04091712v2](#))

[3] [Mandar Datar](#), Eitan Altman and [Hélène Le Cadre](#),: **Strategic Resource Pricing and Allocation in a 5G Network Slicing Stackelberg Game**. *IEEE Trans. Netw. Serv. Manag.* 20(1): 502-520 (2023)

[4] [Ashok Krishnan K. S.](#), [Samir M. Perlaza](#) Eitan Altman, **Pricing Models for Digital Renting Platforms**. *EPEW 2023*: 139-153

[5] [Raphaël Taisant](#), [Mandar Datar](#), [Hélène Le Cadre](#), Eitan Altman,: **Learning Market Equilibria Using Performative Prediction: Balancing Efficiency and Privacy**. *ECC 2023*: 1-8

#### **4. Impact of covid-19 on the Associate Team's activity**

We have been inspired from war against covid to develop protection through vaccinations in Epidemic models for cyber attacks. More generally, we used epidemic modeling to study propagation of Contents in social networks using branching processes [1].

#### **5. Summary of the expenses**

Three missions of French researchers to IITB during 2022

6.1 OM 375725 - 2700€ - Samir MEDINA

6.2 OM 359659 - 2900€ - Mikhail KAMALOV

6.3 OM 378997 - 3800€ - Konstantin AVRACHENKOV

#### **Expenses of 2023 covered by the french side**

Konstantin OM 378997 Bombay from 07/12 to 15/12/22 = 1900€

BORKAR Vivek OM 390775 Sophia from 27/06/23 to 15/07/23 = 3384€

Konstantin OM 404747 Bombay from 24/02/24 to 10/03/24 = 1842€ (Flight ticket)

**Hence altogether 7143€**

French side partly covered expenses of visit of Kavitha Veeraruna at NEO, Sophia Antipolis

#### **6. Other Expenses: Budget requested for the coming year 2024**

We request 10K€ for trips to INDIA and 10K€ for hosting visitors from India.