ERCIM "ALAIN BENSOUSSAN" FELLOWSHIP PROGRAMME

ERCIM
European Research Consortium for Informatics and Mathematics

Scientific Report

First name / Family name	Nabiul / Islam
Nationality	Indian
Name of the *Host Organisation*	NTNU, Norway
First Name / family name of the *Scientific Coordinator*	Ilangko / Balasingham
Period of the fellowship	01/12/2016 to 31/12/2017

I – SCIENTIFIC ACTIVITY DURING YOUR FELLOWSHIP

During my fellowship at NTNU I involved in two projects: 1) deriving maximal achievable throughput in underlying networks of Head Direction (HD) cells, and 2) enhancing achievable rates of mobile nodes that are using single-carrier frequency division multiple access (SC-FDMA) for the long term evolution (LTE) uplink.

Similarly to computer systems communicating with bits, neurons in human brain communicate with spikes. Underlying any behavioral functions, like moving or recognizing, or cognitive functions, like thinking or planning, thousands of neurons in different brain regions work in tandem by exchanging spikes. The spike is generated from a neuron as a sudden increase in potential when incoming signals at it rise above the threshold value of its membrane potential. The thus generated spike travels down the axon to the synapse (more technically known as pre-synapse), cause neurotransmitters to flood from the pre-synapse to post-synaptic part of the following neuron.

Investigating neural computation underlying a certain task remains a active and hot research topic throughout the history of neuroscience and neurology. Over a couple of past decade the advent of invasive sophisticated devices, such as multi-electrode array (MEA) able to capture the individual cell's activity has led the discovery of diverse special cells, such as place, grid, and head direction cells. The common feature of these various type of cells exhibits repetitive firing patterns upon certain behavioral or mental tasks. In other words, concerted behavior of cell assembly often gives rise the successful execution of the given behavior. The study of these networks of cells provide one important piece of information on its own right: mapping brain function into the network perspective. Thus exploring computational power as well as characterization of these networks bring new dimension in better understanding of brain functions.

Particularly, the characterization of the network of neuronal cells participating in a certain behavioral task elicit of new way of treatment for neurological disorders or provide us a a foundational step for using futuristic sophistical miniaturized minimally invasive devices stemmed from nanotechnology. These nanotechology-enabled devices (also known as nanodevices) might work cooperatively with existing nervous system to augment/support it. Keeping this in mind, one of the important features of the underlying networks, which is to be addressed is to derive the maximum achievable throughput – the throughput supported by these networks.

The ongoing research was started on exploring the available experimental database on head direction cells of rodents. Then we planned to apply graph-theoretic and communication networking tools to derive maximum achievable throughput in HD networks that possibly underlie the navigation process of the rodents. Firstly, we curated the HD cells from the electrophysiological recordings made from multiple anterior thalamic nuclei, primarily the anterodorsal (AD) nucleus, and subicular areas, primarily the post-subiculum (PoS). Then, we would construct a temporal network of HD cells under different behavioral setting, such as rapid eye movement sleep (REM) and slow movement sleep (SWS). It may be noted that finding out the underlying networks among cells based on individual neuron’s spike trains is a nontrivial task. We were investigating to determine an improved method that provide us the description of underlying networks (if any) using statistical methods and information theoretic tools, such as entropy and mutual information.

On the other hand, the Single-carrier frequency division multiple access (SC-FDMA) is the access scheme adopted by 3GPP for the long term evolution (LTE) uplink. Indeed SC-FDMA is an attractive alternative to orthogonal frequency-division multiple access (OFDMA) especially on the uplink owing to its low peak-to-average power ratio. This fact increases the power efficiency and reduces the cost of the power amplifiers at the mobile terminals. The use of SC-FDMA on the uplink implies that for highly loaded cells the base station allocates a single subcarrier to each user. This ends up limiting the achievable rate on the uplink. In this work, we propose a coalition game between mobile terminals that allows them to improve their performance by sharing their subcarriers without creating any interference to each other. The proposed scheme allows a fair use of the subcarriers and leads to a significant capacity gain for each user. The cooperation between the nodes is modeled using coalitional game theory. In this game, each coalition tries to maximize its utility in terms of rate. In the absence of cooperation cost, we show that the grand coalition is sum-rate optimal and stable, i.e., the mobile terminals have no incentive to leave the grand coalition. The simulation results indicated the superior performance of the proposed coalition game theory-based scheme.

II – PUBLICATION(S) DURING YOUR FELLOWSHIP

Under preparation:

1. N.Islam, and I. Balasingham “ Maximum Achievable Throughput in Underlying Networks of Head direction Cells” to be submitted to IEEE Transactions on Communication, 2018
2. A. Chelli, N. Islam, H. Tembine, M-S Alouini, and I. Balasingham "A coalition formation game for transmitter cooperation in OFDMA uplink systems" to be submitted to IEEE Access, 2018

III – ATTENDED SEMINARS, WORKHOPS, CONFERENCES

I attended the following workshop:

Event: 2nd Workshop on Molecular Communications

Venue: Science Gallery, Trinity College Dublin, Ireland

Duration: May 9 to May 11, 2017

IV – RESEARCH EXCHANGE PROGRAMME (REP)

In my research exchange programme I visited the following lab:

Location: Inria Bordeaux, and Institut des Maladies Neurodegeneratives, France

Scientific Coordinator: Dr. Frédéric Alexandre

Duration: November 12 to November 18, 2017

Dr. Alexandre's lab is mainly focused on computational neuroscience including cognitive modeling and data-driven approaches towards the treatment of neurodegenerative diseases. I had the opportunity of fruitful interactions and discussions with his team members which helped me a lot towards the shaping of my research. Furthermore, he showed keen interest to collaborate with our group.