Networking and Scheduling in Neuron-based Molecular Communication

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Research Summary

Molecular communication is an emerging research paradigm that utilizes molecules as a communication medium between nanomachines. Nanomachines are the most basic functional unit in nanoscale systems. Their scale ranges from one to a few hundred nanometers. Each of them consists of biological materials (e.g., molecules) that perform very simple computation, sensing and/or actuation tasks. Due to its advantages such as inherent nanometer scale, biocompatibility and energy efficiency, a major application domain of molecular communication is in-body or body-area nanonetworks, where nanomachines are networked through molecular communication to perform sensing and actuation tasks in the body for biomedical and prosthetic purposes (e.g., vital information sensing, targeted drug release and neural signal augmentation).

Our research work focuses on long-range (millimeters to meters) molecular communication that utilizes neurons as a primary component to build in-body sensor-actuator networks (IBSANs). A neuron-based IBSAN consists of a set of nanomachines (e.g., bio-sensors and bio-actuators) and a network of neurons that are artificially formed into a particular topology. Our IBSAN architecture allows nanomachines to interface (i.e., activate and deactivate) neurons in a non-invasive manner and communicate to other nanomachines through a chain of neurons with electric and chemical signals.

We specifically investigate a communication protocol framework, called Neuronal TDMA, which performs single-bit Time Division Multiple Access (TDMA) scheduling for neuron-based IBSANs. Neuronal TDMA allows nanomachines to multiplex and parallelize neuronal signal transmissions while avoiding signal interference to ensure that signals reach the destination nanomachine. It makes decisions of signaling schedules (i.e., when to activate neurons to trigger signal transmissions) for nanomachines with an evolutionary multiobjective optimization algorithm (EMOA). The proposed EMOA considers conflicting optimization objectives (e.g., signaling yield, signaling fairness among nanomachines and signaling delay) and seeks the optimal trade-offs among them subject to given constraints.