

Channel Estimation Techniques in Molecular Communication

This paper is a review of channel estimation techniques in molecular communication. Molecular communication (MC) is defined as communicating information over chemical signals as carriers [1]. Healthcare is one major application field for MC. For example, nanorobots that detect diseases, deliver drugs and perform nano-scale surgery in body rely heavily on MC for communicating with the outside. Such healthcare technology hasn't yet been commercialized but the cost can be extremely high compared to cost of the traditional due to its advanced nature [2]. On the other hand, some researchers from York University and University of Warwick developed a tabletop MC prototype, which costs approximately 50\$ [3]. Although there is almost no commercialized product based on MC, researchers have proposed many applications whose development cost ranges from 50\$ to millions of dollars.

Channel estimation refers to constructing estimator on the receiver's side based on observed signals from communication channel. In MC systems, the expected number of molecules observed at the receiver over time after the instantaneous release of molecules by the transmitter is referred as the channel impulse response (CIR). Knowledge of the CIR is needed for the design to detect chemical signals. Estimation techniques for CIR are mostly divided into training-based and semi-blind frameworks [4]. A training-based CIR estimation framework aims at estimating the CIR based on the observed number of molecules at the receiver due to emission of a sequence of known numbers of molecules by the transmitter. In particular, researchers from Georgia Tech proposed receiver design utilizing maximum likelihood (ML) and least sum of square errors (LSSE) estimators [5]. Semi-blind methods combine a training-based criterion with a purely blind criterion. Blind techniques do not exploit the knowledge of training symbols, and focus on deterministic or stochastic properties of the system [6]. In [6], the author proposed non-decision directed ML criterion for the estimation of channel delay. The difference between blind techniques and training-based techniques is subtle: while the former focuses more on establishing a generative model for communication channel, the latter focuses more on training a discriminative classifier for decision making. In general, the former one tends to have limited performance and more computational cost with regard to complicated channels in physical nature, but could produce a model approximating the behaviors of communication channel. The latter one doesn't create a model of communication channel. Instead, it works on the receiver side and aims only at classifying input signal as accurate as possible. Regardless of difference of the two categories, the measurement for performance is noise elimination capability. In MC, one major source of noise is the random propagation of information particles. Such propagation depends on

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the past so the channel has memory. Correlation on input sequence makes channel estimation much more difficult compared to the discrete memoryless channels.

Generalized software packages and libraries on channel estimation can be utilized to implement MC channel estimation. Matlab has built-in channel estimation functionality on its LTE System Toolbox™ product. Education version of this toolbox is free but limited only to education use. If it's needed to create a new estimation package, Matlab provides built-in Minimum Mean Square Estimation, Least Mean Square Estimator and many others to accelerate development. If free development environment is preferred, python could be the best alternative for Matlab. Many open-source packages such as *MNE-Python* and *filterpy* provide essential estimator classes. One disadvantage, however, is less reliability: packages could be poorly maintained and have version conflicts and bugs. In the rare case of commercializing MC in mobile computing, Java could be the best choice. Although MC doesn't receive much attention from mobile industry, it's still possible such technology being applied in the future. In mobile computing, Java has very well established libraries for channel estimation supported by mobile developers such as Apple and Google.

Reference

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