Nano Communication Networks 3 (2012) 65–73

Contents lists available at SciVerse ScienceDirect

Nano Communication Networks

journal homepage: www.elsevier.com/locate/nanocomnet

Interference effects on modulation techniques in diffusion based nanonetworks

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ARTICLE INFO

Article history:
Received 20 January 2012
Accepted 24 January 2012
Available online 31 January 2012

Keywords:
Nanonetworks
Molecular communication
Communication via diffusion
Interference
Modulation

ABSTRACT

Currently, Communication via Diffusion (CvD) is one of the most prominent systems in nanonetworks. In this paper, we evaluate the effects of two major interference sources, Intersymbol Interference (ISI) and Co-channel Interference (CCI) in the CvD system using different modulation techniques. In the analysis of this paper, we use two modulation techniques, namely Concentration Shift Keying (CSK) and Molecule Shift Keying (MoSK) that we proposed in our previous paper. These techniques are suitable for the unique properties of messenger molecule concentration waves in nanonetworks. Using a two transmitting couple simulation environment, the channel capacity performances of the CvD system utilizing these modulation techniques are evaluated in terms of communication range, distance between interfering sources, physical size of devices, and average transmission power.

1. Introduction

Nanonetworking is a new communication paradigm that covers various communication methods that can be used to transmit information between micro- and/or nano-scale machines [1]. Molecular communication (MC) is envisioned as a promising method as an alternative to traditional approaches such as electromagnetic wave or acoustic wave based systems. Also these systems can be used as a transmission solution for communication between nanomachines and actual living cells, which are crucial for certain applications like interaction between prosthetic smart limbs and nervous system.

In MC, the information is carried via so-called messenger molecules. Motivated by the cellular biological communication systems, various communication methods for MC systems have been proposed in the literature [1]. These systems can be categorized by their effective ranges as short range, (e.g., molecular motors [4], Fluorescence Resonance Energy Transfer [8]), short to medium range, (e.g., ion signaling [14], Communication via Diffusion (CvD) [17]), and long range molecular communication systems, (e.g., bacterium based communication [10], pheromone signaling [9]).

Among these systems, we focus on short and medium range CvD systems in nanonetworks. The main idea behind the CvD system is the usage of certain molecules, called messenger molecules, as the information carriers between two nanomachines residing in close-to-medium proximity to each other in a fluid environment (Fig. 1). The system is composed of five key processes as encoding, transmission, propagation, reception, and decoding [1,17]. First, data is encoded upon one or several properties (e.g. concentration level) of a molecule wave. Then, based on the selected encoding technique and the bit sequence, the transmitter releases a number of molecules in a time slotted fashion. These messenger molecules scatter in the medium following the probabilistic diffusion dynamics in the environment. Some of these released molecules are received into molecule via receptors in the cell membrane.

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1878-7789/$ – see front matter
doi:10.1016/j.nancom.2012.01.005

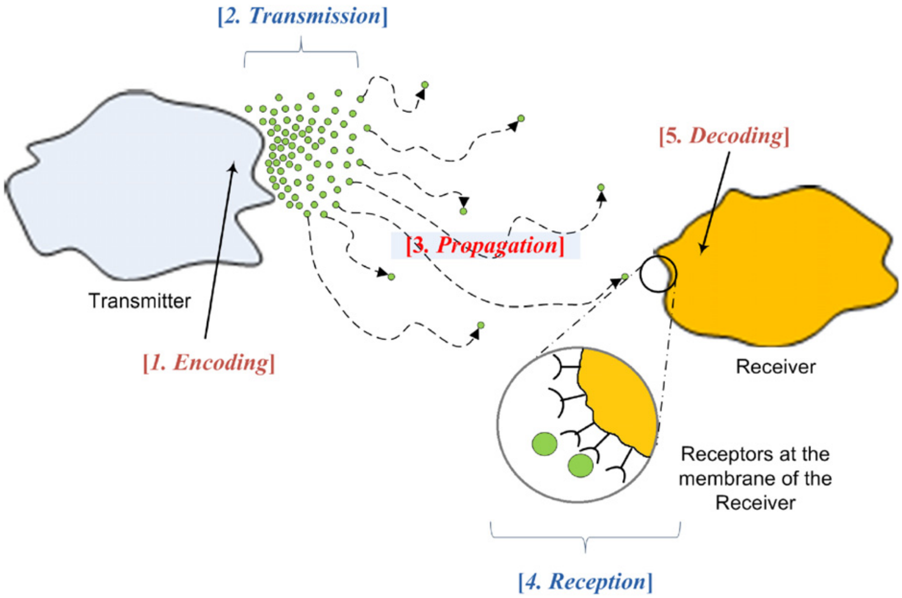

Fig. 1. The transmission model.

Finally, based on the properties of the received molecule wave, the information is decoded and understood by the receiver.

In the recent years, some elements of this aforementioned five process structure have found place in the literature. Most of these studies focus on the channel capacity and propagation dynamics of the CvD medium [15,2,12,3,13]. Some of these propagation process studies consider the probabilistic behavior of the channel as the transfer function of the system while others model it as a unique noise source inherent to a diffusion medium. According to the aforementioned studies on channel capacity and our own results in [18], it is shown that the reliability of the transmission diminishes exponentially with increasing transmission range while the average end-to-end delay increases exponentially. These results limit the effective communication range of the CvD systems to a few tens of micrometers; making it a solution for short-to-medium range inter-nanomachine communication.

Most of these studies on the CvD system focus on a single transmitter single receiver systems. However, when there are more communicating couples in the environment, additional issues arise and change the workings of the communication system. Thus, in order to develop a fully capable system for the CvD system in MC, we need to address these issues and design our communication system with these concerns in mind. An important one among these issues is the interference between closely placed transmitting couples in the same medium. When two or more transmitting pairs try to communicate simultaneously using the same technique and same type of messenger molecules, their signals affect each other and reduce/increase the signal to noise and interference ratio (SINR) of all nearby transmissions.

Apart from the interference issues, other studies show the effects of different modulation techniques on the overall performance of the system. Most of the studies in the literature use the received molecular concentration as the information carrying property of the wave, similar to the Amplitude Shift Keying (ASK) technique in classical communication literature [2,15,16]. Other modulation techniques have also been investigated in the literature. Garralda et al. describe the usage of Pulse Position Modulation (PPM) [6], Mahfuz et al. study the effects of Frequency Shift Keying (FSK) [13], and we have developed a new modulation technique called Molecular Shift Keying (MSK) unique to the CvD medium while formalizing the ASK based techniques as Concentration Shift Keying (CSK) [11].

In this paper, we study the effects of co-channel interference (CCI) over the modulation techniques proposed in [11] with respect to several system parameters and evaluate the molecular reuse distance similar to the established frequency reuse range in the wireless electromagnetic communication literature.

The remainder of the paper is organized as follows. In Section 2, we describe the interference sources that affects a communication system and explain how these sources appear in the CvD system. In Section 3, the two modulation techniques whose performances regarding interference sources are explained briefly. The channel model is explained in Section 4. In Section 5, we present analysis of intersymbol interference (ISI) and CCI effects over these modulation techniques and conclude the paper with Section 6.

2. Interference analysis

In communication systems, a given signal is affected by various sources while it propagates in the medium. All elements that affect a given signal are called interference to the signal. These effects can either be beneficial (constructive interference) or harmful (destructive interference) to the signal in question. The most important sources