Chapter 2
A Networking Paradigm Inspired by Cell Communication Mechanisms

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ABSTRACT

This chapter provides a brief review of molecular communication, a networking paradigm inspired by cell communication mechanisms. In molecular communication, information is encoded to and decoded from molecules, rather than electrons or electromagnetic waves. Molecular communication provides bio-compatible and energy-efficient solutions with massive parallelization at the nano-to-micro scale; it is expected to play a key role in a multitude of domains including health, the environment, and ICT (Information Communication Technology). Models and methods of molecular communication are also reviewed, and research challenges that need to be addressed for further advancement of the molecular communication paradigm are discussed.

INTRODUCTION

Molecular communication is an emerging technology that exploits biological materials or living matter to enable communication among biological nanomachines (or nanomachines in short) (Hiyama, 2005). Nanomachines are small-scale devices that exist in nature or are artificially synthesized from biological materials. Some examples of nanomachines found in nature are biological cells, molecular motors that produce mechanical work (e.g. myosin), and biochemical molecules, complexes, and circuits that are capable of processing chemical signals. Examples of artificially synthesized nanomachines include synthetic molecules, genetically engineered cells, artificial cells, and bio-silicon hybrid devices that are programmed to produce intended biochemical reactions.

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In molecular communication, information is encoded to and decoded from molecules, rather than electrons or electromagnetic waves. Since nanomachines are made of biological materials and not amenable to traditional communication means (i.e., electrons or electromagnetic waves), molecular communication provides mechanisms for nanomachines to communicate by propagating molecules that represent information. Molecular communication allows networking of nanomachines and potentially enables new applications in various domains including health (e.g., nanomedicine and tissue engineering), the environment (e.g., monitoring and quality control), ICT (Information Communication Technology)(e.g., implantable biological sensors and actuator networks), and military situations (e.g., biochemical sensing).

Molecular communication exhibits unique features that are not commonly found in telecommunication technology as it currently stands. The distinctive features of molecular communication compared to current telecommunication technology are highlighted in Table 1.

- **Communication Components:** Molecular communication allows networking of nanomachines while telecommunication is to communicate using silicon-based electric devices. Nanomachines in molecular communication are nano-to-micro scale devices that exist in biological systems or are artificially synthesized from biological materials.
- **Signal Types:** Molecular communication uses chemical signals to communicate information, unlike telecommunication technology which uses electrical or optical signals. Using signal molecules as carriers of information opens up new possibilities in ICT. For instance, signal molecules carry physical properties that encode a high density of information. Also, signal molecules may carry some functionality. For example, a DNA sequence that codes some biological functions can be transmitted to a receiver nanomachine which acquires new functionality (e.g., a functional protein) as a result of gene expression.
- **Communication Speed and Range:** The speed and range of molecular communication are extremely slow and strictly limited compared to existing telecommunication technology. The speed and range of molecular communication vary depending on the communication mechanisms used. The fastest and longest range communication is achieved through neural signaling which propagates electro-chemical signals (i.e., action potentials) at 100 m/sec over several meters, while the free diffusion of molecules based on Brownian motion is extremely slow and contained within a limited range.
- **Communication Media:** In molecular communication, chemical signals propagate in an aqueous environment, while

Table 1. Molecular communication and telecommunication

Communication	Telecommunication	Molecular Communication
Communication components	Electronic devices	Bio-nanomachines
Signal types	Optical/electrical signals	Chemical signals
Communication speed	Speed of light (3×10^8 m/s)	Extremely slow
Communication range	m ~ km	nm ~ µm
Communication media	Air or cables	Aqueous

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