# BIOLOGICAL CELL AND MOLECULAR COMMUNICATION TECHNOLOGY: OVERVIEW AND CHALLENGES

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**Abstract**

This paper outlines the study and overview of molecular and cell communication technology. It provides cell communication as a new paradigm in reference with engineering and communication mechanisms. Unlike current telecommunication paradigm, cell communication uses molecules as carriers of information. This study summarizes the features, characteristics and architecture of molecular communication.

**Keywords:** Biological Cell, Engineering, Communication, Biological Nanomachines and Nanonetworks

## Introduction

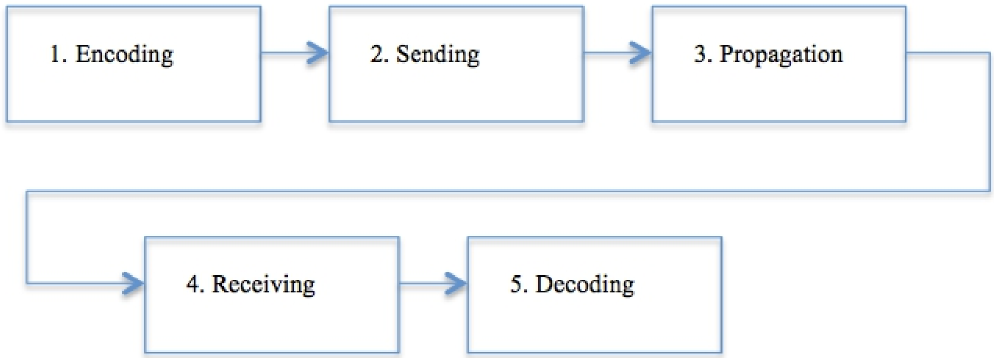
The advancement and progress in biotechnology and communication engineering today are the means to design and engineer novel networks and communication systems based on biological materials and mechanisms. A modern technology as a result of nanotechnology and bioscience is molecular or cell communication, which provides the transition from nano to micro scale communication [1]. The evolution of biomedical and Nano science technology has led to biological devices referred to as bio-nanomachines that can interact with biological cells and molecules in nano scale or micro scale environments. The area of nanosystems of cells and molecules is pulling lot of attention and it has also been facing many challenges in present era. One of the challenges faced by this research is to extend the small-scale networks to large-scale networks of bio-nanomachines, which are more robust in application environments. It is anticipated that new novel and robust communication and network protocols for cell communication networks can open the new horizons in this area of research[2].

## Molecular communication system overview

This section highlights the overview of area of molecular communication, its architecture, communication framework and protocols and possible application environments.

## An Architecture of Molecular Communication

The general molecular or cell communication architecture design is shown in Figure 1. The whole communication system comprises different functional components shown such as information molecules that represent the information to be transmitted, sender bio-nanomachines that release the information molecules, receiver nanomachines that detect the information molecules at receiving end and the environments in which information molecules propagate from transmitting nanomachines end to receiving nanomachines end[3]. It is important to note that this system may include transport molecules that transport the information molecules, guide molecules that provides the guided directional movement of transport molecules, and interface molecules that provides the interface for any type of information molecules to be transported by transport molecule. Figure 2 shows the block diagram of communication phases present in this cell communication model.




**Components of Molecular Communication System**

This section explains the components or blocks of molecular communication system[4]. The description of each block is as follows:

- Encoding
  Encoding is the first stage in this communication system where information is encoded and it is translated into information molecules by sender bio-nanomachines. Sender bio-nanomachines encode the information in pattern recognized by the receiving bio-nanomachines. Information encoding depends upon the properties of information molecules such as 3-D structure, composing molecule, or concentration of the information molecule.
- Sending
  This stage refers to the release of information molecule into related environment. This happens by freeing the information molecule from transmitting bio-nanomachines, or by gate opening that permits the information molecule to diffuse away. It can also happen by the catalytic reaction whose product will be information molecule.
- Propagation
  Propagation is the stage in which information molecules travel from sending bio-nanomachines to receiving bio-nanomachines. Information coded molecules can propagate by the aid of transport molecules, or they can move passively through the environment without using chemical energy.
- Receiving
  This is the phase where receiver bio-nanomachines retrieve the information-coded molecules that were propagated in the environment from transmitting nanomachines.

**Characteristics and features of Molecular Communication**

The molecular communication system derives its characteristics from generic telecommunication system and biological mechanisms. The main focus includes characteristics such as signal types, propagation speed, range and media environments.

**Small Scale System**

A cellular communication system is nano to micro scale ranging system. The system is three dimensional in nature and depends upon the types of cell and its formation. This system finds its application in the development of NEMS (Nano-electromechanical Systems) or MEMS (Micro-electromechanical Systems)[3].

**Information Coding Flexibility**

A molecular communication system propagates the information in terms of chemical signals from transmitting bio-nanomachines to receiving bio-nanomachines. At receiver side, a chemical reaction occurs between incoming chemical signals and receiving nanomachines. This system provides the flexibility of encoding the information through the characteristics such as type, structure, sequence and concentration of information molecules [4].

**Speed and Range**

A molecular communication system is very low range and low speed system[5]. The speed and range of this system depends upon the type of biological materials, mechanism and environments. Additionally, this type of communication suffers large degradation in SNR (Signal to Noise Ratio) as random motion of molecules makes it longer for the information to get to the receiver. This communication is very unpredictable and at some instances it can have 100% information loss rate.

**Biocompatibility**

A molecular communication system is biocompatible in such a way that cell can interact with other natural bio-components like cells, tissues and organs. This biocompatibility is due to the fact that biological systems and molecular communication systems use same communication and networking mechanisms[4]. It is highly anticipated that biological cellular communication systems will find its applications in environments where human body interactions are important.

**Energy Efficient with Low Dissipation**

A molecular communication system is energy efficient and uses chemical energy. Since it involves biological materials and mechanisms therefore it is energy efficient with low heat dissipation. This fact can be explained by considering the comparison of silicon-based systems with molecular systems. The molecular communication networks use chemical energy whereas silicon-based systems use electric batteries. These cells or molecules inherently use energy from environments such as human body thus eliminating the need for external source of energy [6].

**Applications of Molecular Communication**

The molecular communication finds several functional applications by using bio-nanomachines to sense, modify and transport molecules. These functional applications are found in the fields such as environmental, biomedical, and manufacturing.

**Environmental Applications**

**Bio-Nanomachines to monitor environment**

Integration of bio-nanomachines can be performed into large or small-scale environments to locate molecules. The environment is subject to foreign contamination such as toxins or radioactive agents. Information can be obtained from bio-nanomachines associated with molecules[7].

**Bio-nanomachines to control pollution/waste**

Bio-nanomachines can be deployed to monitor molecules in the environments to identify the location of foreign contamination or toxins. This can help to identify and amplify molecular signals, which will be helpful to remove toxins or contamination[8].

**Biomedical Applications**

- Bio-nanomachines are made of living cells that can be divided or grown to form functional cell structure. Such nanomachines can be used for regenerative medicine. Molecular communication provides the modes to control ways of communication and thus affect the growth and progress of bio-nanomachines in specific functional structures.
- Molecular communication can be used in monitoring of organism to identify the existence of specific molecules in the body[9]. Bio-nanomachines are implanted in the body and cellular communication provides means for gathering, manipulating, and transmitting the information to external devices.
- Molecular communication is also used in lab-on-a-chip applications[10]. Molecular communication gives techniques to transport specific molecules to particular location in a biomedical chip. This is helpful particularly in determining a certain disease or in the study of biological samples.

**Current issues and challenges in molecular communication**

The field of molecular communication is facing several challenges. Some of those challenges include implementation of Body Area Networks (BAN) and Molecular Area Networks (MAN). Unlike the computer or wireless network systems, molecular communication involves nanomachines and it is hard to apply physical and network layer protocols to those bio-nano machines. There is a need to first put together the standards for these protocols and then start implementing this type of communication models [11]. It also includes security, information loss and bit error correction trials to be tested on early stage molecular networks. This field is still under development and researchers are working to overcome those challenges [12].

**Conclusion**

This paper has highlighted the characteristics and features of molecular communication with open research issues associated in this area. This field and area is very robust as per the theoretical progress due to small size of bio-nanomachines and their mobility. But this field still requires simulations and empirical results under the assumptions that would consider the bio-chemical and bio-medical constraints. The empirical studies have been limited to individual components such as molecular motors but needs to be extended to address system level approach of molecular communication.

**References:**

S.Hiyama,Y. Moritani, T. Suda, R. Egashira, A. Enomoto, M. Moore, & T. Nakano,“Molecular Communication,” in Proc. 2005 NSTI Nanotechnology Conference, vol.3, pp. 392-395.

M. Moore, A. Enomoto, T. Suda, T. Nakano, & Y. Okaie,“Molecular Communication: New Paradigm for communication among nano-scale biological machines,” in The Handbook of Computer Networks. Hoboken, NJ: Wiley, 2007, vol. 3, pp. 1034-1054.

T. Suda, & T. Nakano,“Biological Cell Communication Technology: An Architecture Overview,” in Sixth International Conference on Networked Computing and Advanced Information Management (NCM), 2010, pp. 488-490.

M. Moore, T. Nakano, W. Fang, A.V. Vasilakos, & S. Jianwei,“Molecular Communication and Networking: Opportunities and Challenges,” in IEEE Transactions on NanoBioScience, 2012, vol. 11, Issue. 2, pp. 135-148.

H. Kitano,“Biological Robustness,” Nature Review Genetics, 2004, vol. 5, pp. 826-837.

K. Kinosita Jr., R. Yasuda, H. Noji, & K. Adachi,“A rotary molecular motor that can work at near 100% efficiency,” Philos. Trans. R. Soc. Lond. B Biol. Sci., 2000, vol. 355, pp. 473-489.

J. Oyekan, H. Hu, & D. Gu,“Exploiting Bacteria Swarms for pollution mapping,” in the Proc. IEEE Int. Conf. Robot. Biomimetics (ROBIO), 2009, pp. 39-44.

L. Marques,& A. T. De Almeida, “Electronic nose-based odour source localization advanced motion control,” in Proc. $6^{th}$ Int. Workshop Adv. Motion Control, 2000, pp. 36-40.

Y. Moritani, S. Hiyama,& T. Suda, “Molecular Communication for health care applications,” in Proc. $4^{th}$ IEEE Int. Conf. Pervasive Comput. Commun. Workshops, 2006.

N. Farsad, A. Eckford, S. Hiyama,& Y. Moritani,“A simple mathematical model for information rate of active transport molecular communication,” in Proc. 2011 IEEE INFOCOMM Workshop Mol. Nanoscale Commun, pp. 473-478.

M. Moore, A. Enomoto, T. Suda, & T. Nakano,“Recent research and development in molecular communication technology,” Journal of the National Institute of Information and Communication Technology, 2009, vol. 55, no. 4, pp. 75-93.

I. F. Akyildiz, F. Brunetti, & C. Blazquez,“Nanonetworks: a new communication paradigm,” Computer Networks, 2008, vol. 52, no. 12,pp. 2260-2279.