論 文 の 内 容 の 要 旨

論文題目　Study on Diffusion-Based Molecular Communication
（拡散型分子通信に関する研究）

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Molecular communication (MC) is a recently proposed paradigm which aims at enabling the communication among nano-machines. Dissimilar to the conventional communication techniques using electromagnetic wave as the information carrier, the molecular communication applies molecules to modulate signals to solve the diffraction problem of currently in use electromagnetic waves at nano-scale. In MC, the physical or chemical characters of molecules can be used to modulate signals. The modulated signals propagate through the medium via the physical displacement of the information molecules. Therefore, the channel has different features from the conventional communication techniques. Among all schemes that implement molecular communication, the diffusion-based channel is considered as the most promising way because of its simplicity and low extra energy cost. This dissertation focuses on the diffusion-based molecular communication (DBMC) and is composed of three components addressing three prominent problems of diffusion-based molecular communication: (1) communication distance measurement; (2) inter-symbol interference; (3) low channel capacity.

Communication distance measurement is always a crucial problem in wireless communications. It also plays an essential role in DBMC. A distance measurement approach based on the arrival time difference (ATD) of two molecular signals is proposed. The ATD approach utilizes two types of molecules with different diffusion coefficients. Thus, when the node to be measured transmits the signals with the molecules simultaneously, there is an arrival time difference. Applying the arrival time difference, the distance between the two nodes can be estimated based on the channel model. The ATD approach avoids the complicated synchronization of the nodes, and at the same time overcomes the error accumulation and inefficiency of using a round trip signal. Besides, the ATD is a time-based approach so that it barely relies on accurate measurement of signal amplitude, namely the concentration in diffusion-based molecular communication.

Inter-symbol interference (ISI) is one of the most crucial problems of diffusion-based molecular communication. The ISI is the interference of the information molecules remaining in the transmission medium of the former bits on the later ones. It is an unavoidable phenomenon if diffusion-based molecular communication because of the diffusion features. It has a severe impact on the bit error rate, especially for a system consists of mobile nodes. We propose two protocols to mitigate the influence of ISI. The first one is a retransmission protocol. When the receiver sensed the signal quality becomes weaker due to the node movement, it transmits a simple acknowledgment to the transmitter. Based on the acknowledgment, the transmitter calculates the current channel condition, estimates the bits transmitted during the weak connection period and retransmits them. Another one is an adaptive code width (ACW) protocol. This protocol is based on the fact that the communication distance influences the ISI. In the ACW protocol, after the connection is established, the receiver transmits distance feedback to the transmitter periodically. The transmitter estimates the communication distance and adjusts the code width accordingly. At the same time, the receiver knows the code width of the next bits using the estimated communication distance from the currently received signal. Consequently, the communication quality is guaranteed. Moreover, the ACW can reduce the redundant code width when the nodes are close to each other, to increase the transmission rate.

Due to the uncertainty and the long-delay character of the diffusion process, DBMC is considered with an extremely low channel capacity compared with the conventional communication techniques. We propose a novel MC utilizing DNA as the information packets. A simple modulation scheme is proposed in which the two types of nucleobase pairs are used as different bits. Therefore, a series of binary bits can be encoded onto a single DNA molecule. Additionally, the diffusion coefficient of DNA molecule is negatively correlated to the base pair number. By applying an observing window and focus slot scheme, we design a diffusive DNA based molecular communication model. Furthermore, the channel capacity of the proposed system is also analyzed. However, the diffusion leads to the disordered arrival of the DNA packets. To this problem, we propose a method using multiple duplicated packets and a buffer in the receiver to compare the number of received packet DNA molecules. The proposed method does not only reduce the probability of disordered arrival, but also increases the effective transmission rate of the diffusive DNA based MC.

Overall, this dissertation makes contributions to the theoretical research of DBMC. Three crucial problems are addressed. In particular, we propose an ATD approach to measure the communication distance to increase the accuracy and efficiency. Two protocols are proposed to mitigate the ISI in DBMC. DNA is adopted to design a novel DBMC as packets to increase the possible transmission rate.