論文内容の要旨

〔 題　　名 〕 On Noise-Induced Adaptive Network Control in Ad Hoc Networks Based on Biological Models
(アドホックネットワークにおける生物モデルにもとづいたゆらぎを活用する適応型ネットワーク制御)

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Computer networks have become highly complicated and less flexible to handle emerging problems which often occur nowadays. In order to cope with unpredictable problems, the concept of biologically inspired networks has been introduced to provide a high degree of robustness and adaptability to computer networks. In this thesis, we focus specifically on studying the role of randomness or fluctuation in biological systems. In conventional engineering systems, the randomness---usually referred to as *noise*---is normally seen as an undesirable factor for control mechanisms to the extent that there are efforts on removing and filtering noise to achieve higher signal to noise ratio (SNR) for strict control. On the contrary to artificial systems, biological systems adopt the concept of noise as a part of their mechanisms instead of eliminating it. By utilizing noise internally, biological systems are able to achieve high robustness and adaptability against external noise. Inspired by the concept of utilizing noise, we propose two adaptive noise-induced network control methods for wireless ad hoc networks in this thesis.

The first network control method is a routing protocol for mobile ad hoc networks (MANETs). Routing in MANETs is not a trivial task since it is greatly affected by external influences such as mobility/failure of nodes, unreliability/instability of wireless communication, arbitrarily initiated/terminated sessions, or uncontrollable joining/leaving of nodes. Such adverse and changing environment conditions can also be often observed in biology, where biological systems show a remarkable ability to survive and adapt to these changes. In this thesis, we further improve our previously proposed *MANET routing protocol, called MARAS*, which is based on *attractor selection*, a biological adaptation mechanism that is applied to the next hop selection process. In attractor selection, noise plays an essential role in coping with the uncertainties and variations of the system, which is network dynamics in our case. We will show that by utilizing noise to a certain extent, MARAS is capable of being more adaptive than other well-known protocols. Especially in the presence of large traffic volume and high node densities, generally considered as the worst case scenarios for MANET routing, MARAS retains its superiority as it is capable of still delivering a certain portion of traffic when the other mechanisms fail.

Through the study of the first network control method, we found that the limited bandwidth is one of the biggest challenges in MANETs and ad hoc networks in general. Therefore, we try to improve the available bandwidth in ad hoc networks by using multiple paths concurrently. However, since the quality of each path frequently changes in ad hoc networks due to its dynamic nature, a new challenge of appropriate traffic distribution over multiple paths arises. Unfortunately, traditional traffic distribution methods often rely heavily on the detailed knowledge of each network component and the preconfigured, i.e. fine-tuned parameters. Such detailed knowledge is difficult to obtain with the limited bandwidth, and preconfigured values are usually useful for considered situations but may not be suitable in case of unforeseeable changes. Therefore, we introduce a new concept, called *attractor perturbation* (AP), which enables an adaptive network performance control using only end-to-end statistical information. Based on AP, we propose the second network controlling method, a *concurrent multipath traffic distribution method*, which aims at lowering the average end-to-end delay by only adjusting a sending rate on each path. We demonstrate through simulations that by utilizing the noise-based attractor perturbation relationship, the proposed method achieves a lower average end-to-end delay compared to other methods which do not take fluctuations into account.

Finally, we summarize our observation of noise-based model behavior through research and implementations. Based on our experience, we present advantages and constraints of both models. Furthermore, we also provide guidelines of using our models in other applications with examples of existing implementations. Finally, we proposed a novel concept which combines both models to achieve a multi-objective application.

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論文審査の結果の要旨及び担当者

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論文審査の結果の要旨

Computer networks have become highly complicated and less flexible to handle emerging problems which often occur nowadays. In order to cope with unpredictable problems, the concept of biologically inspired networks has been introduced to provide a high degree of robustness and adaptability to computer networks. This thesis focuses specifically on studying the role of randomness or fluctuation in biological systems. In conventional engineering systems, the randomness -usually referred to as noise- is normally seen as an undesirable factor for control mechanisms to the extent that there are efforts on removing and filtering noise to achieve higher signal to noise ratio (SNR) for strict control. On the contrary to artificial systems, biological systems adopt the concept of noise as a part of their mechanisms instead of eliminating it. By utilizing noise internally, biological systems are able to achieve high robustness and adaptability against external noise. Inspired by the concept of utilizing noise, two adaptive noise-induced network control methods for wireless ad hoc networks are proposed in this thesis.

The first network control method is a routing protocol for mobile ad hoc networks (MANETs). Routing in MANETs is not a trivial task since it is greatly affected by external influences such as mobility/failure of nodes, unreliability/instability of wireless communication, arbitrarily initiated/terminated sessions, or uncontrollable joining/leaving of nodes. Such adverse and changing environment conditions can also be often observed in biology, where biological systems show a remarkable ability to survive and adapt to these changes. This thesis proposes a MANET routing protocol, called MARAS, which is based on attractor selection, a biological adaptation mechanism that is applied to the next hop selection process. In attractor selection, noise plays an essential role in coping with the uncertainties and variations of the system, which is network dynamics in our case. By utilizing noise to a certain extent, MARAS is shown capable of being more adaptive than other well-known protocols. Especially in the presence of large traffic volume and high node densities, generally considered as the worst case scenarios for MANET routing, MARAS retains its superiority as it is capable of still delivering a certain portion of traffic when the other mechanisms fail.

Through the study of the first network control method, it is found that the limited bandwidth is one of the biggest challenges in MANETs and ad hoc networks in general. Therefore, an attempt to improve the available bandwidth in ad hoc networks is made by using multiple paths concurrently. However, since the quality of each path frequently changes in ad hoc networks due to its dynamic nature, a new challenge of appropriate traffic distribution over multiple paths arises. Unfortunately, traditional traffic distribution methods often rely heavily on the detailed knowledge of each network component and the preconfigured, i.e. fine-tuned parameters. Such detailed knowledge is difficult to obtain with the limited bandwidth, and preconfigured values are usually useful for considered situations but may not be suitable in case of unforeseeable changes. Therefore, a new concept, called attractor perturbation (AP), is introduced to enable an adaptive network performance control using only end-to-end statistical information. Based on AP, the second network controlling method, called a concurrent multipath traffic distribution method, is proposed to lower the average end-to-end delay by only adjusting a sending rate on each path. It has been demonstrated through simulations that by utilizing the noise-based attractor perturbation relationship, the proposed method achieves a lower average end-to-end delay compared to other methods which do not take fluctuations into account.

As described above, this thesis achieves useful research results on the adaptive control methods based on biological systems employing fluctuation in MANET. Accordingly, the evaluation committee admitted valuable research advancements as Ph. D thesis in Information Science and Technology.