Chapter X
Immune Based Bio-Network Architecture and its Simulation Platform for Future Internet

Yong-Sheng Ding
Ministry of Education, China

Xiang-Feng Zhang
Ministry of Education, China & Shanghai Dianji University, China

Li-Hong Ren
Ministry of Education, China

ABSTRACT

Future Internet should be capable of extensibility, survivability, mobility, and adaptability to the changes of different users and network environments, so it is necessary to optimize the current Internet architecture and its applications. Inspired by the resemble features between the immune systems and future Internet, the authors introduce some key principles and mechanisms of the immune systems to design a bio-network architecture to address the challenges of future Internet. In the bio-network architecture, network resources are represented by various bio-entities, while complex services and application can be emerged from the interactions among bio-entities. Also, they develop a bio-network simulation platform which has the capability of service emergence, evolution, and so forth. The simulation platform can be used to simulate some complex services and applications for Internet or distributed network. The simulators with different functions can be embedded in the simulation platform. As a demonstration, this chapter provides two immune network computation models to generate the emergent services through computer simulation experiments on the platform. The experimental results show that the bio-entities on the platform provide quickly services to the users' requests with short response time. The interactions among bio-entities maintain the load balance of the bio-network and make the resources be utilized reasonably. With the advantages of adaptability, extensibility, and survivability, the bio-network architecture provides a novel way to design new intelligent Internet information services and applications.

INTRODUCTION

The development of Internet technologies enables more and more man-made devices to access Internet and act as its components, which shows us a bright prospect of Internet. The future Internet will be the core of the worldwide

information infrastructure and the general service platform with computation, communication, entertainment, e-business, and so on. So future Internet should configure and reconfigure its network services dynamically to satisfy demanders, and Internet applications can adapt to the change of different network environments. Internet nodes also should be secure and can survive failures and attacks. Obviously, the future Internet should be capable of extensibility, survivability, mobility, and adaptability to network environments. It is necessary to optimize the current Internet architecture and its applications to address the challenges of the above requirements.

Biological systems such as human beings can be regarded as sophisticated information processing systems, and can be expected to provide inspiration for various ideas to science and engineering. Artificial immune systems (AIS), one of biologically-motivated information processing systems, have recently received much attention of researchers (Castro & Timmis, 2002; Ding & Ren, 2000). Immunized computational systems combining a prior knowledge with the adaptive capabilities of immune systems can provide a powerful alternative to currently available techniques for intelligent systems. AIS are adaptive systems based upon the models of natural systems in which learning takes place by evolutionary mechanisms similar to biological evolutions. AIS do not precisely model the human immune system or provide an explanation of how the immune system works. They provide problem-solving methods to some complex problems. However, the recent studies of AIS are mainly focusing on the intelligent control, fault diagnose, optimization, pattern recognition, associative memory, computer security, and so on. All of these models are referred to one or two aspects of biological immune system, and its complex behaviors and systemic intelligence have not been developed yet.

Inspired by the resemble features between future Internet and the immune systems, we can introduce some key principles and mechanisms of the immune systems into the design for future Internet. So we can apply these theories and mechanisms, particularly the emergent behaviors, to design a novel bio-network architecture (Ding & Ren, 2003), which provides for future Internet application environments. And we can further build a bio-network simulation platform which has the capability of service emergence, evolution etc. (Gao et al., 2004; Ren & Ding, 2002). The platform can be used to simulate some complex services and applications for Internet or distributed systems.

In this chapter, we discuss the design and implementation of the bio-network architecture and its simulation platform, particularly, how the bio-entities, the society-entities, and the interactions among the society-entities are designed to emerge some complex services and applications for Internet or distributed systems. We also provide two examples of bio-network simulators to generate the emergent services from the immune network computation models to demonstrate the feasibility of the bio-network architecture through computer simulation experiments on the platform.

BACKGROUND

The Requirements of Future Internet

Future Internet should exhibit a strong sense of automation: 1) Support for survivability from massive failures and attacks; 2) Ability to configure and reconfigure system dynamically; 3) Awareness of Internet system environment; 4) Seeking of behavior optimization to achieve its goal; and 5) Requirement to detailed knowledge of system components and status.

The requirements of future Internet resemble the self-organizing and the self-healing properties of biological systems. There is a strong similarity between the complex interaction of organisms in biological systems and that of components in a networked system (Bhalla & Lyengar, 1999; Girvan & Newman, 2002). This makes us to study the relationships among components in the Internet environment by associating it with biological systems, especially with some key concepts and principles in biological immune systems. As such, we can introduce some immune mechanisms to study evolutionary Internet systems with those desirable properties.