

## **The Bio-Networking Architecture** **Bi-weekly report #5 (Aug. 5, 2002): Adaptation and Evolution**

PI: Tatsuya Suda (suda@ics.uci.edu)  
University of California, Irvine  
<http://netresearch.ics.uci.edu/bionet/>

### **Introduction:**

Adaptation and evolution by natural selection are among key biological concepts that the PI applies in the Bio-Networking Architecture. Analogous to a biological entity in the real world biological systems, service components (referred to as cyber-entities) in the Bio-Networking Architecture follow simple behavior rules (e.g., replication, reproduction and migration). A cyber-entity invokes its behavior based on local information (such as resource availability) and interactions with other nearby cyber-entities. These autonomous behaviors of cyber-entities in the Bio-Networking Architecture result in network applications that adapt to changing environment.

A cyber-entity also evolves in its behaviors. When a cyber-entity replicates or reproduces with another cyber-entity, diverse behavior policies are created through mutation and crossover in their behavior policies. Since an inefficient cyber-entity exhausts energy quickly and eventually dies in the Bio-Networking Architecture, only beneficial cyber-entities are retained in the system, enabling network applications to adapt to changing environments.

### **New Achievements:**

In the area of evolution and adaptation aspects of the Bio-Networking Architecture, the PI has recently published works regarding the preliminary simulation results:

- In a presentation entitled “Evolution Simulations for the Bio-Networking Architecture” at the IEICEJ Next Generation Networks workshop [SS01], and
- As a book chapter entitled, “Preliminary Simulation Study of the Bio-Networking Architecture,” [TS02].

To investigate the potential benefits of adaptation and evolution in the Bio-Networking Architecture, the PI has developed a simulator and, through simulations, demonstrated emergent behaviors such as scalability, adaptability and survivability in a variety of network environments.

### **Evaluation of Natural Selection and Evolutionary Mechanism**

Natural selection mechanism in the Bio-Networking Architecture is designed to improve network-wide performance by removing cyber-entities that are not suited for network environments. Natural selection is performed based on the concept of energy where inefficient cyber-entities exhaust energy and eventually die, resulting in well adapted cyber entities retained on the network. With the evolutionary mechanism that can generate diverse cyber-entities in behavioral policies with possible mutation and crossover, cyber-entities gradually increase their fitness to the environment in changing network conditions.

In the preliminary simulations, the PI has evaluated the natural selection and evolutionary mechanism in a static environment. A network is configured as a 5×5 grid topology. 8 users are assumed in the simulated network with different request generation rates ranging from 5 to 30 requests per second. One cyber-entity can process 5 requests per second and receives 10 energy units from a user in return for processing a request. Each platform node charges cyber-entities 1 energy unit for computing resources (e.g., CPU, memory, bandwidth), and also 100 energy units for platform services (e.g., replication, reproduction, migration supports).

In the simulation results shown in Figure 1, one of the following four types of cyber-entities are assumed. The first type referred to as PR (primary) in Figure 1 is a cyber-entity without any bias in its behavior. The second type (referred to as PD (productive) in Figure 1) tends to produce offspring more often than other types of cyber-entities. The third type, ES (energy seeker), tends to migrate towards a node that hosts a user with high request generation rate and stay at that node. The fourth type, WA (wandering), randomly migrates in the network.

Deploying one of the four types of cyber-entities, Figure 1 shows the simulation results with and without the evolutionary mechanisms. In this figure, the horizontal axis indicates simulation time (in seconds) while the vertical axis indicates energy gain (= acquired energy – consumed energy) per cyber-entity. As time progresses, cyber-entities with the evolutionary mechanisms gradually achieve higher energy gain than those without the evolutionary mechanisms, showing that cyber-entities successfully evolve by optimizing their behaviors.

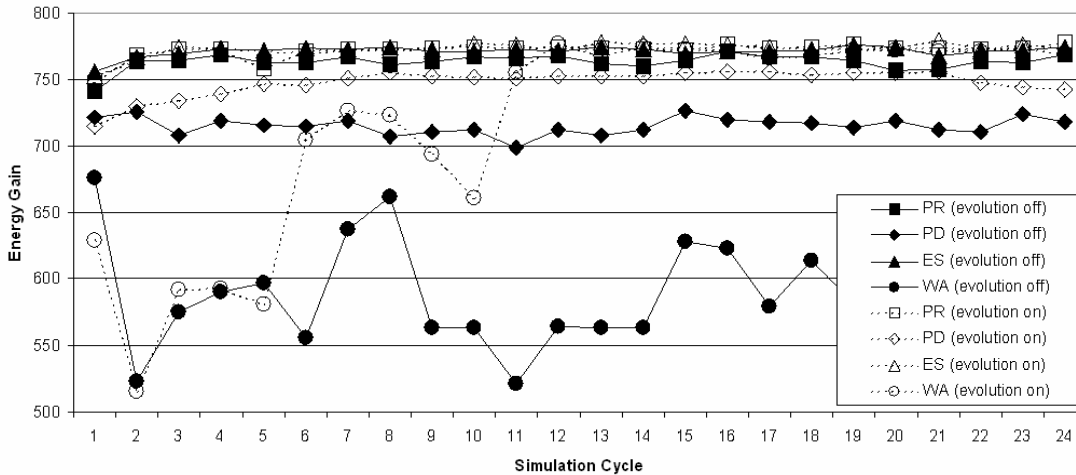


Figure 1: Energy Gain

Figure 2 shows the response time as a function of time for the same set of simulations shown in Figure 1. This figure shows that cyber-entities with the evolutionary mechanisms keep small response time.

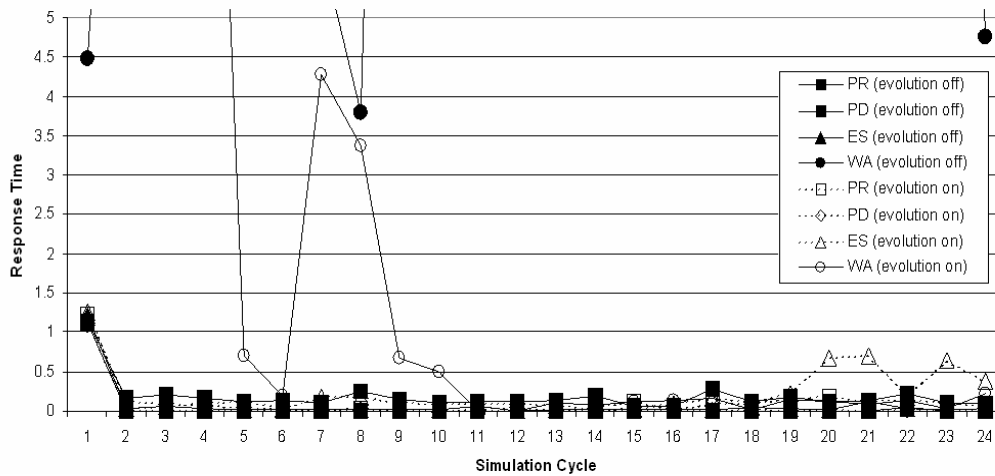


Figure 2: Response Time

## **Reference**

[TS02] T. Suda, T. Itao, M Matsuo, “The Bio-Networking Architecture: The Biologically Inspired Approach to the Design of Scalable, Adaptive, and Survivable/Available Network Applications,” *The Internet as a Large-Scale Complex System*, Ed. K. Park, 2002.

[SS01] S. Sugizaki and T. Suda, “Evolution Simulations for the Bio-Networking Architecture,” *IEICEJ Next Generation Networks workshop*, December 2001.