The Bio-Networking Architecture
Bi-weekly report #3 (July 8, 2002): Bio-Networking Platform

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Introduction

The Bio-Networking Architecture is a new framework for developing large-scale, highly distributed, heterogeneous and dynamic network applications. It applies biological concepts and mechanisms in network application design and provides scalable, adaptive, and survivable/available network applications through autonomous interactions of objects.

In the Bio-Networking Architecture, a network application is implemented as a decentralized collection of autonomous objects called *cyber-entities*. This is analogous to a bee colony (a network application) consisting of multiple bees (cyber-entities). Each cyber-entity implements a functional component related to their service or application and follows simple behavior rules (e.g., replication, reproduction and migration) similar to biological entities. Cyber-entities store and expend *energy* for living. They gain energy in exchange for providing their services, and expend energy for receiving services from other cyber-entities, performing their biological behaviors, and utilizing resources (e.g. CPU cycles and memory space).

With support from DARPA, the PI has designed and implemented the Bio-Networking platform, namely, a middleware system that provides reusable software components for deploying and executing cyber-entities. These components abstract low-level operating and networking details (e.g. I/O, concurrency, messaging and network connection management) and provide a set of runtime services that cyber-entities frequently use for performing their services and invoking their biological behaviors.

New Accomplishments

In the area of the Bio-Networking platform, the PI has recently submitted and published works regarding the design, implementation and measurement results of the Bio-Networking platform:

- In a paper entitled "The Bio-Networking Architecture: Its Architectural Design and Platform Implementation," submitted to the International Symposium on Distributed Objects and Applications 2002 [SS02], and
- In a standard proposal document entitled "The UCI Initial Proposal to SDO PIM," presented at the Object Management Group technical meeting [SFS02].

The PI's recent accomplishments include (1) design of all components in the Bio-Networking platform, (2) preliminary implementation of the Bio-Networking platform, and (3) preliminary measurements of the Bio-Networking platform to examine its efficiency and scalability [SS02]. The PI also proposed the key design of the Bio-Networking platform to the Object Management Group (OMG), the largest standard making body for object oriented software technologies, as a reference architecture for Super Distributed Objects specifications [SFS02, SAS01, SSS02].

Design of the Bio-Networking Platform

The Bio-Networking platform runs on a network node and provides execution environment for cyber-entities. It consists of three components; bionet services, bionet message transport, and

bionet container.

Bionet services provide a set of runtime services that cyber-entities frequently use, and major runtime services that Bionet services provide are listed below.

- *Bionet lifecycle service*; allows cyber-entities to change their internal state, replicate, and reproduce.
- *Bionet relationship management service*; allows cyber-entities to establish, examine, update and eliminate their relationships with other cyber-entities.
- *Bionet resource sensing service*; allows cyber-entities to inquire the type, amount and unit cost of available resources (CPU cycle and memory space).
- *Bionet energy management service*; keeps track of energy levels of cyber-entities running on a local platform, and allows the cyber-entities to pay energy for receiving services from another cyber-entity, utilizing resources (CPU cycle and memory space), and performing their behaviors.
- *Bionet discovery service*; allows cyber-entities to search for other cyber-entities on a remote node through their relationships. This is discovery at the cyber-entity level, as discovery queries are (logically) exchanged between cyber-entities over their relationships.
- *Bionet cyber-entity sensing service*; allows cyber-entities to search for other cyber-entities running on a local and neighboring platforms. This is platform level discovery, as discovery queries are exchanged between platforms over the platform connectivity.
- *Bionet pheromone emission service*; allows cyber-entities to emit their pheromones (traces) and to sense pheromones emitted by other cyber-entities.
- *Bionet topology sensing service*; allows cyber-entities to sense the existence of remote platforms within N hops.
- *Bionet migration service*; allows cyber-entities to migrate to another platform.

Bionet message transport abstract low-level networking details such as network I/O, concurrency, messaging, and network connection management. Bionet container dispatches incoming messages to cyber-entities running on a local platform.

At the time of this writing, the PI has implemented bionet message transport, bionet container and four bionet services (lifecycle, relationship management, energy and resource sensing).

Preliminary Measurement Results

Figure 1 shows a result of preliminary measurements of the Bio-Networking platform that the PI implemented. The measurement examined the latency for message exchange between two cyber-entities. In this measurement, a cyber-entity randomly chooses a remote cyber-entity and sends a message. The Bio-Networking platform runs on a Java 2 virtual machine (version 1.4) atop of a Windows XP with an Intel Pentium 3 processor (1 GHz) and 256 MB RAM. Figure 1 shows that the message exchange latency with the Bio-Networking platform is comparable with existing distributed object platforms (Jac ORB, Java IDL, Zen). Figure 1 also shows that the message exchange latency remains relatively constant as the number of cyber-entities grows (0.18 msec in average), indicating that the Bio-Networking platform scales.

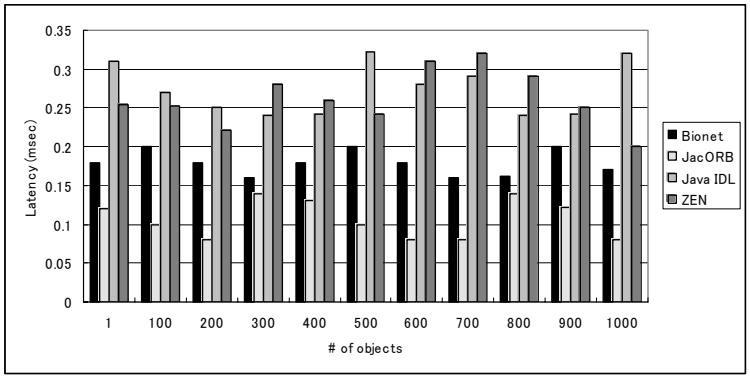

Figure 1. Message Exchange Latency between two cyber-entities

Reference

[SS02] J. Suzuki and T. Suda, "The Bio-Networking Architecture: Its Architectural Design and Platform Implementation," submitted to the International Symposium on Distributed Objects and Applications 2002.

[SFS02] J. Suzuki, K. Fujii and T. Suda, "The UCI Initial Proposal to SDO PIM," Super Distributed Objects Domain SIG, Object Management Group, OMG document number: sdo/2002-06-01, presented at the OMG TC meeting at Orlando, June 2002.

[SSS02] S. Sameshima, S. Steglich and J. Suzuki (ed.), "PIM and PSM for Super Distributed Objects," Request for Proposal, Super Distributed Objects Domain SIG, Object Management Group, January 2002.

[SAS01] S. Sameshima, S. Arbanowski and J. Suzuki, "OMG Super Distributed Objects White Paper," Super Distributed Objects Domain SIG, Object Management Group, July 2001.