Migration Control of Bio-entities in the Bio-network Middleware

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Abstract. Future Internet applications and services should be autonomous, self-evolutionary, and adaptable to the change of different users and network environments. Inspired by the resemble features between biological neuroendocrine-immune system and future Internet, we introduced some key principles and mechanisms to design a bio-network architecture and its middleware. In this paper, asynchronous migration mechanism is discussed based on the bio-network middleware. A credit-based migration control scheme is proposed. The simulation result shows that the scheme decreases the response time of service bio-entities and reduces the migration frequency. As such, it can ensure that the service bio-entities migrate effectively to provide services for users and minimize their cost. And the desirable requirements of future Internet are further satisfied.

1 Introduction

Internet is evolving into the core of the worldwide information infrastructure and a single integrated platform for computing, data storage, communication, entertainment, e-business, and so on [1]. Future Internet applications and services should be autonomous, self-evolutionary, and adaptable to dynamic network environments. Adopting mobile agent technology is a prospective solution to design the applications and services [2, 3].

Large-scale biological systems have formed a great deal of mechanisms, which can adjust themselves to adaptive and survivable environments. Biological systems are composed of dispersive, autonomous, and mobile biological individuals with self-regulation, adaptability, evolution, and survivability. The biologically inspired information systems have been applied widely to engineering fields. Recent researches in biology show that the biological neuroendocrine-immune system (NEIS) establishes an intelligent system through complicated regulation [4, 5]. We have abstracted an integrated computation framework from the NEIS and developed the NEIS-based bio-network architecture that provides future Internet application environments [6]. The agent-based simulation platform for the bio-network has also been presented [7]. The bio-network can act as a network middleware for complex services and applications on Internet and distributed networks.

Y. Shi et al. (Eds.): ICCS 2007, Part III, LNCS 4489, pp. 74–81, 2007.

In this paper, we discuss migration scheme of bio-entities in the bio-network. Section 2 introduces simply a bio-network middleware and discusses its asynchronous migration mechanism. Section 3 proposes a credit-based migration control scheme. Section 4 simulates the response time and the migration frequency of the bio-entities with or without credit management service. Finally, Section 5 concludes the paper.

2 Macro Migration Model

2.1 Bio-network Middleware and Its Migration Service

The bio-network middleware consists of the bio-network platform, bio-entities and their survivable environment. The bio-network platform is a software framework fully implemented by Java language. The bio-network platform includes bio-network core services and bio-network low-level functional modules established in a network node. The bio-network core service layer provides a set of general-purpose runtime services that are frequently used by bio-entities, such as lifecycle, bio-entities migration, evolution state management, credit management, sustainability management, and security authentication service. The low-level functional modules manage low-level network and system resource and allocate resources to bio-entities. A bio-entity is an autonomous mobile agent and analogous to an individual in the biological system. The bio-entity survivable environment deploys and executes bio-entities and protects the node from being attacked with some security policies.

The bio-network platform runs in an asynchronous distributed system on a network node. Thus an overlay network environment is formed with wide-area bio-network platforms [8]. Several nodes can form a community niche and the niche is a logically defined area where the bio-entities in a community can learn from their surrounding environment. A bio-entity can sense which bio-entities are in the community niche, what services they perform, and which resources it can access to. This helps it create a new application or join an existing community. Physical proximity among network nodes is used to define a community niche in this study.

The bio-network platform provides the bio-entity migration service, which supports the migration behavior of the bio-entities. The migration behavior involves determining where and when to migrate through considering the cost/benefit tradeoff of migrating towards an adjacent community niche. The migration will be used to find useful partner bio-entities and acquire new relationships.

2.2 Asynchronous Migration Mechanism

The bio-network platform reduces network communication throughput and enhances the flexibility, extensibility, and tolerance of the network through a migration mechanism controlled by credits. A bio-entity migrates to another platform in order to provide services to meet user requests. It utilizes network resources after it pays some credits. This method can reduce network delay and provide efficiently network services to obtain more credits from users. A bio-entity also establishes new relationships with other bio-entities after it migrates to another platform and these bio-entities emerge some new services.

The system transfers a bio-entity to a bit-blob using the object serialization method and then sends it to other nodes. The bio-entity may be resumed by the object de-serialization method when the system wants to reuse it. The sustainability management service allows a programmer to store the bio-entity's state into a storage device so that the bio-entity is executed later. It is responsible for storing the serialized codes and states of the bio-entity into the storage material, such as hard disk, to support non-sustainable connection. When a bio-entity waits for non-connection resources, the sustainability management service ensures the lowest costs.

A bio-entity autonomously distributes on a bio-network node. Its behavior is not controlled by network users or other bio-entities. Its migration behavior includes where to migrate, when to migrate, and costs and benefits. It must pay credits for migration and it will die if it has not enough credits. The migration service adopts synchronous or asynchronous migration mechanism (AMM). The bio-entity calls migration service and chooses the migration mechanism. As to synchronous migration mechanism, the platform will immediately execute the migration request from the bio-entity. It will send error information to the bio-entity if the destination node is unreachable. The bio-entity decides how to do next. As to AMM, the platform does not immediately execute the migration request, but insert it into the sequence. The

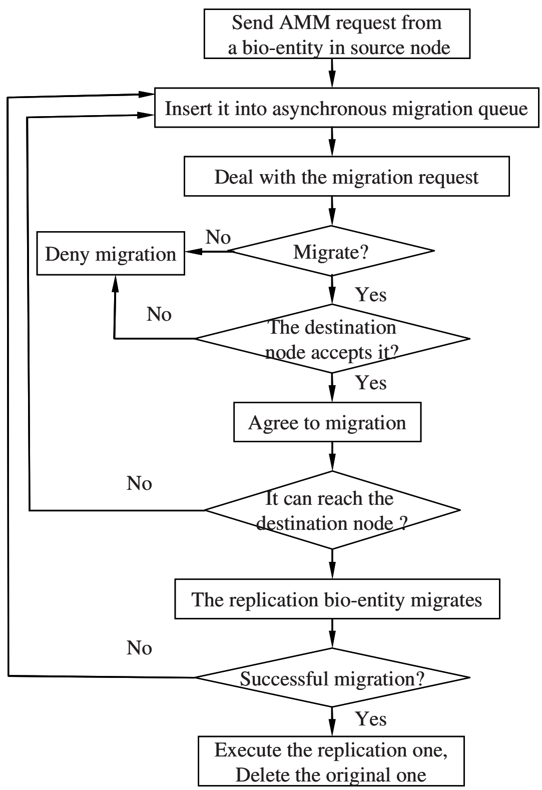

Fig. 1. AMM for a bio-entity

cost of credits is different using these two mechanisms. AMM is adopted when the following case happens:

(1) The chosen destination node is not reached;
(2) The bio-entity is off-line mobile user;
(3) The bio-entity waits a return off-line user on ever-connective node.

Taking AMM as an example, we discuss the migration mechanism based on the credit as shown in Fig. 1. After a bio-entity migrates to asynchronous migration request queue and its migration request is dealt with, the migration service decides whether the bio-entity can migrate according to credits information and migration control algorithm, see section 3.1. Then the migration service judges whether the destination node accepts the request. If the destination node agrees to migration, the platform judges whether it is reached. This causes network delay and reduces quality of service, and thus the bio-entity has to pay many credits for the system resources. Hence, it should balance its cost and benefit. If the destination node is reachable, a replication one migrates to it. After its successful migration, the platform executes the replication one in the destination node and deletes the original one.

3 Credit-Based Migration Control Scheme

Each bio-entity and network resource, such as CPU, memory, and bandwidth, has its own credit-control scheme. A service request (such as a user or a bio-entity) has its own payment scheme, including reward or punishment for acquired service based on quality of service. One or more algorithms implement a bio-entity's state transfer. A set of parameters, such as weights, and a threshold, are included in an algorithm. Take migration operation as an example, we consider how a bio-entity changes from *Dangling* to *Migrating* state. The parameters of migration behavior include:

1) *MigrationBenefit* (*MB*). *MB* is the benefit achieved by a bio-entity when the bio-entity provides service with lower cost and network delay. It is usually a position value.

2) *MigrationCost* (*MC*). *MC* is the cost for either network resource used by the bio-entity or higher resource cost of the destination node. It is a negative value.

3) *MigrationRisk* (*MR*). *MR* includes some uncertain factors. It may be a negative value.

4) *MigrationAsynchronous* (*MA*). *MA* means that the bio-entity adopts the AMM. It may be a negative value.

5) *MigrationThreshold* (*MT*). *MT* determines whether a bio-entity migrates or not.

The bio-entity executes migration operation if the inequation (1) can be met,

$$(MB\ \ MC\ \ MR\ \ MA)\cdot(w_1\ \ w_2\ \ w_3\ \ w_4)^T \geq MT \tag{1}$$

where w_1, w_2, w_3, and w_4 are the weights of MB, MC, MR, MA, respectively. The bio-entity has to pay credit units for environment sensing when the AMM is adopted. The above migration behavior is an incomplete list and a programmer can add other behaviors to it.

A request user gives credits to the bio-entities after it evaluates the acquiring service. This method helps him to decide which bio-entity is worth trusting. We can decide if a bio-entity is reliable based on *TrustCredit*.

The request user return a defray message with a collaboration record and a trust value α ($-\frac{1}{2} \le \alpha \le 1$). The trust value α increases for a reward or decreases for a penalty. A bio-entity adjusts the value with its interaction partners based on the level of user satisfaction or preference. Suppose a value α, the *TrustCredit* value V is updated according to the formula (2),

$$V^{+} = \begin{cases} V^{-}(1-\alpha^{2}) + \alpha^{2}, & \alpha \ge 0 \\ V^{-}(2 - \frac{1}{1+\alpha}), & \alpha < 0 \end{cases} \tag{2}$$

where, V^{-} and V^{+} are the former and new *TrustCredit* value, respectively ($V^{-} \in [0,1]$). *TrustCredit* value increases with a reward for a high preference and decreases with a penalty for a low preference. The formula (2) ensures that the decrement is faster while the increment is slower. The value α belongs to the interval $[0.5, 1]$. Hence, V^{+} belongs to the interval $[V^{-}, 1]$ when α is larger than or equal to 0, and V^{+} belongs to the interval $[0, V^{-}]$ when α is less than 0.

4 Simulation and Analysis

4.1 Simulation Model

In our previous work [7], we have implemented the prototype of bio-network service simulation platform, including software, general objects and simulators using Java language. It supports pluggable functions and provides a general easy-to-use programming API. It contributes to implement our approach in real deployment with minimal modifications. The simulation experiment is constructed on Windows 2000 operation system with Intel Pentium 4 processor (2.4 GHz) and 512 MB RAM.

(1) Initial network topology and user requests: A simulated network is a 18×12 topology network with 216 network nodes, and bio-entities are deployed on the platforms. The platforms are initialized on each network node. There are two kinds of bio-entities in the simulation: users request bio-entities and service bio-entities. Request bio-entities do not execute biological behaviors and are arbitrary on the platform. A user sends a request per second. Service bio-entities who are close to user requests have priority.

(2) Behavior mechanisms and credit parameters: In our simulation, a bio-entity has some behaviors, such as creation, service provided, replication, migration, and death, while it has not mutation and crossover behaviors. A user request pays 20 credit units for a service bio-entity. And a service bio-entity can provides 10 services per second

towards a user request. But it need pay 150 credit units for using the resources on the platform, such as CPU, storage, and bandwidth. It should pay its platform 100 credit units for replicating itself and transfer 20,000 credit units to its child bio-entity. It also should pay its platform 200 credit units in order to migrate from the platform to another one.

4.2 Results and Analysis

The bio-network produces initially 60 user requests and 20 service bio-entities. Every service bio-entity has 20,000 credit units. Credit management service asks community niche sensing service to check the resource cost. It also checks resource utilization of each bio-entity on the same platform. And it deducts resource cost from the current credit card of a bio-entity. If the card has not enough credits for resource utilization, credit management service notifies evolution state management service will destroy the bio-entity.

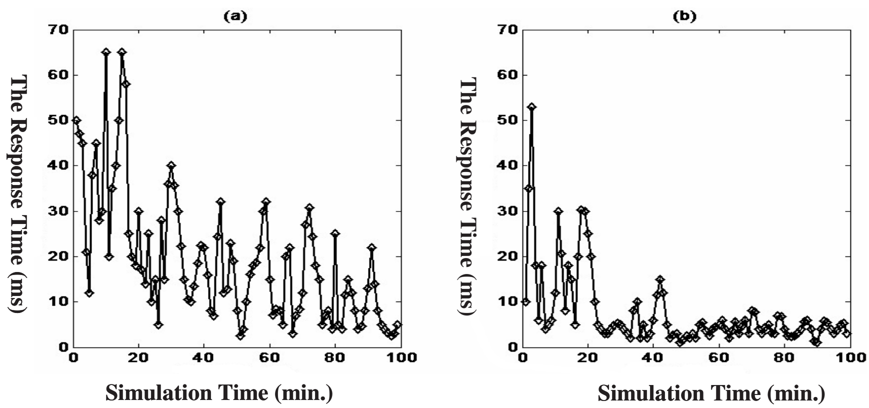

Fig. 2. The response time of the service bio-entity with different environments. (a) without credit management service; (b) with credit management service.

We simulate two kinds of environments with and without credit management service. The request response time and migration frequency of service bio-entities change with the simulation time are as shown in Fig. 2 and Fig. 3.

Without credit management service, the credit flow does not exist among bio-entities so that a request can only be handled by its nearest bio-entities. The bio-entities can only provide service and migrate. The requests are executed more quickly with credit management service than without credit management service in Fig. 2. Credit management service optimizes resource allocation and ensures that service bio-entities are responsible for their behaviors, migrate and replicate according to the number of user requests. The response time decrease quickly with credit management service. From Fig. 3, we can see that the useless migration decreases with credit management service because the service bio-entities will execute carefully their behavior in view of their cost.

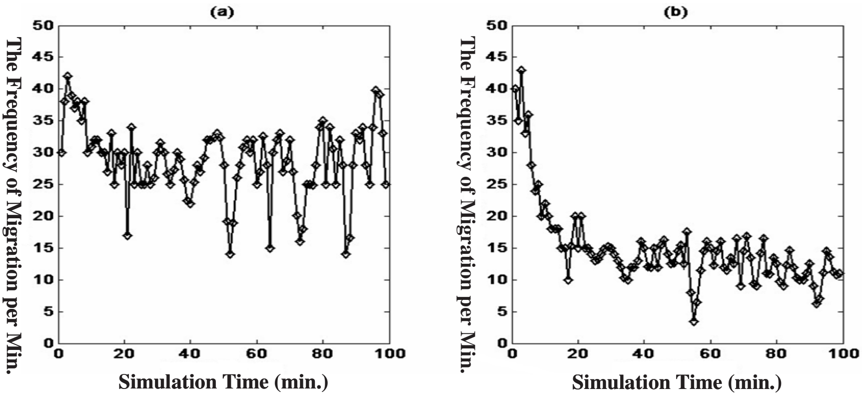

Fig. 3. Migration frequency of the service bio-entity under different simulation environments. (a) without credit management service; (b) with credit management service.

5 Conclusions and Future Work

Inspired by mobile agent technology, we discuss asynchronous migration mechanism of a bio-entity on the bio-network. We propose the migration control scheme based on credit mechanisms. Experiments results show that the proposed scheme ensures that the bio-entities migrate to a neighbor platform to provide services effectively and use their credits reasonably. Network services can adapt and evolve to meet user requests.

The next work is on issue about implementing other services of the bio-network middleware to perfect the bio-network architecture. In addition, in terms of network services and applications, more experiments will be designed to evaluate the performance of the middleware.

Acknowledgments

This work was supported in part by Program for New Century Excellent Talents in University from Ministry of Education of China (No. NCET-04-415), the Cultivation Fund of the Key Scientific and Technical Innovation Project from Ministry of Education of China (No. 706024), International Science Cooperation Foundation of Shanghai (061307041) and Specialized Research Fund for the Doctoral Program of Higher Education from Ministry of Education of China (No. 20060255006).

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