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A novel service-oriented intelligent seamless migration algorithm and application for pervasive computing environments

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HIGHLIGHTS

- We present the architecture of the service migration system for dealing with various kinds of service resource failures.
- We propose two judgment theorems of triggering a service migration activity and completing a successful service migration activity.
- We propose the service-oriented intelligent seamless migration (SOISM) mechanism and algorithm for pervasive computing environments.

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ABSTRACT

How to improve the reliability and efficiency of a system is one of the most important issues in the pervasive computing domain. Fault tolerance and process migration are the effective methods of improving system's reliability and efficiency. In this paper, we propose a service-oriented intelligent seamless migration (SOISM) mechanism and algorithm for pervasive computing environments. We introduce the architecture of the service migration system, design and implement a service fault detector and a service fault manager. We propose two judgment theorems of triggering a service migration activity and completing a successful service migration activity. We also adopt a method of optimizing service migration route among the service resource networks by scheduling to minimize average completion time. We have implemented the SOISM mechanism in an intelligent service selection prototype (ISSPS) system which provides the pervasive web services for users for pervasive computing environments. We have fulfilled various simulations and the results show that the proposed service selection and migration mechanism is not only reliable but also efficient.

1. Introduction

The dawn of the 21st century has seen explosive interest in Ubiquitous/Pervasive Computing. Coming roughly a decade after founding manifesto by Mark Weiser [1], much of this research addresses issues that may seem exotic relative to mainstream computing. Promoters of this idea hope pervasive computing embedding the integration of computer, communication and digital media technology makes it possible to integrate the physical world we are living in and the virtual world in the information space together as the whole, which would enable people to move around and interact with computers more naturally than they currently do [2,3].

In pervasive computing environments thousands, or even hundreds of thousands of concurrent entities, i.e. clients and services, may frequently interact with each other [4]. To support such large-scale applications, a distributed server infrastructure is used. However, neither the interaction of clients nor the dynamic of context's environments in the distributed server infrastructure is predictable [5]. This causes low reliability of system performance [6]. The current trend towards achieving high QoS of pervasive computing services requires integration of a variety of fault tolerance technologies such as service migration to support seamless pervasive computing environments.

The service migration in pervasive computing environments is a kind of the process migrations. It is a capability that allows a running service program or date to be paused, relocated to another node of network, and continued there. Relative to virtual machine migration [7] and connection migration [8], process migration has been a hot topic in system research and several distributed operating offer the capability of migrating processes. Previous related studies have yielded several approaches. V-System

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[9], Amoeba [10], Mach [11], Sprite [12], and MOSIX [13] are some of the examples. Furthermore, BLCR [14] is an open source checkpoint–restart library for Linux, which can be used for migrating processes. Zap [15] implements a thin virtualization layer on top of the operating system which provides the facility of migrating a group of processes, called pods. Incremental checkpoint/restart of process migration has been proposed by several recent studies [16,17]. These efforts show that service migration must implement seamless migration, namely, implementing seamless computing. One of the important requirements of seamless migration is that services are allowed to not only move freely between heterogeneous networks but also maintain application continuity. The issue is particularly difficult because that pervasive computing system is heterogeneous network environments, which has quite stringent requirements with QoS [18], delay [19], jitter [20] and performance [21]. The traditional migration methods cannot meet the seamlessness requirements of service-oriented migration of pervasive computing paradigm because pervasive computing environments have some different traits from the traditional distributed computing environments.

Therefore, in this paper, we firstly discuss the extension definition and formal description of service, then and propose architecture of service migration system. We adopt a novel ANN-based (Artificial Neural Network) service selection model to select optimal service for user in pervasive computing environments by using an improved artificial neural network algorithm [22]. We propose an intelligent service-oriented seamless migration (SOISM) algorithm in pervasive computing systems. The idea is that when the service failure happened, a service migration activity should be trigged. We implemented the service migration mechanism in an intelligent service selection prototype system (ISSPS), which provide the pervasive web services for users in pervasive computing environments. We estimate our approaches through simulations experiment and obtained promising results. The results show that the proposed service migration scheme is not only reliable but also efficient.

This paper is organized as follows: In Section 2, we propose problem statement. In Section 3, we describe extended definition and formal description of service. In Section 3, we explain the framework of service migration system. In Section 4, we propose an intelligent service-oriented seamless migration mechanism and algorithm. The detailed description of evaluation method and judgment theorems of triggering a service migration activity is proposed. Section 5 describes the simulation experiment and discusses our experimental results. Finally, we present conclusions and further work.

2. Problem statement

From certain point of view, pervasive computing systems are the personal computing system. The most valuable part of the personal computing system is a rich collection of services or applications from spreadsheets and word processors to CAD tools and medical imaging aids and so on. We refer to them as personal productivity services or applications because their primary goal is to provide an optimal service for user from all the usable service candidates. They share certain traits:

(a) Users customize each service according to own demand. These customizations can help users tune the service to their specific cognitive preferences and thus improve his productivity.
(b) They have quite stringent requirements with Quality of Service (QoS), and are affected by dynamic context of system environments.
(c) They usually need integrated services composed of different kinds of signal service.

Thus, the pervasive computing environments satisfied these requirements are dynamic and heterogeneous environments, which result in the provided service may be changed and no longer meet the user's requirements. Therefore the unsuitable service has to be migrated to else service provider that has same or similar function, namely implementing service-oriented seamless migration. That is what we research in this paper.

Seamlessness is an important attribute of service-oriented migration in pervasive computing environment. Usually, low distraction is the defining characteristic of seamlessness. A classic example of this is cell phone handoff between two access points—the user is never aware of the migration. Another example is the migration between connected and disconnected operation in a system such as Coda [13]. A few of service-oriented seamless migration activity belongs to horizontal handover. However there is more to seamlessly migrate than vertical handover [15,23] between heterogeneous network in the GPRS or UMTS network and cell phone handoff between two access points in the wireless communication network [24]. Although the mechanism of seamless migration is very complicated, a minimal set of key problems of service-oriented seamless migration activity is the "three W's and one H":

Who: Who trigger and carry out the judgment theorem of triggering service-oriented seamless migration activity?

What: What content should be migrated (namely deciding migration granularity)?

Where: Which service provider is the most suitable destination to migrate (namely deciding destination of migration activity)?

How to optimize performance: The main objective is to how to optimize performance by minimizing the total completion time over all migration activity.

3. Framework of the service migration system

3.1. Extended definition and formal description for service

Within pervasive computing environments, service is regarded as service component which is the most fundamental and important conception. Services can be implemented as either hardware devices, software programs, or a combination of the two, and can be found by human and computational clients. The definition of service in existed distributed or grid system [25] is not appropriate for pervasive computing system because:

(a) The connotation of service is different from traditional distributed system. In pervasive computing system, a service is an entity that can be used by a person, a program or another service. A service may be a computation, storage, a communication channel to another user, a software filter, a hardware device or another user;
(b) In pervasive computing system, all kind of attributes of service are varying according to the context environments;
(c) The description approach for service is different from the description approach of traditional distributed system.

So we expand the traditional definition of service [15,23] to a new service definition by adding new items for pervasive computing environments.

Definition 1. Service is defined as an entity which can provide certain functions and be composed of a set of atomic services AS_j ($0 \leq j \leq n$) which is a description for certain subunit with self-governed function. A service can be used by a person, a program or another service. A service may be a computation, storage, a communication channel to another user, a software filter, a hardware device or another user.

Our formalized description of service can be expressed as:

$$S_i = \left\{AS_j\langle ID, T, K, P, V, C, Z, A\rangle | 0 \leq j \leq n\right\} \quad (1)$$