

A Context-aware Handoff Management for Seamless Connectivity in Ubiquitous Computing Environment

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Abstract - Despite the importance of seamless connectivity in ubiquitous computing, research for seamless connectivity is not considered properly. To provide seamless connectivity, this paper proposes intelligent context-aware handoff management scheme and middleware architecture. In this paper, we defined our own profiles about various contexts like user intentions as well as issues of network layer and designed modules for efficient vertical handoff (VHO) management and continuous service. Consequently, proposed context-aware handoff management scheme prevents unnecessary handoff cases and eventually maintains optimal network configuration in ubiquitous computing environment. And also simulation results show about 40% enhanced performance in the number of VHOs and about 20% enhanced performance in throughput compared with conventional schemes.

Keyword: seamless connectivity, vertical handoff, context-aware, profile, and ubiquitous computing.

1. Introduction

Recently, ubiquitous computing is regarded as one of the most attractive research area in computer science and thus both academic and industrial sectors conduct research in many relevant areas. One of the major premises for ubiquitous computing is that all components should be connected to the networks [1]. For this reason, seamless connectivity is an important research issue in ubiquitous computing, and to provide seamless connectivity, a handoff management scheme between heterogeneous network interfaces, called VHO, considering different characteristics of each interface is required. However, existing approaches only assume that all components are connected with networks seamlessly, and do not consider how seamless connectivity is provided. Also in vertical handoff schemes, handoff operation only occurs based on network factors, such as signal strength and latency, and does not consider any context information, e.g., user intentions.

To provide seamless connectivity, this paper proposes intelligent context-aware handoff management scheme and middleware architecture based on the profiles in ubiquitous computing environment composed of heterogeneous network interfaces. We defined our own profiles, application profile reflecting some important application requirements, user profile reflecting any specific user information and requirements, work profile which is context information inferred from context engine, and abstracted profile which is abstracted based on

work profile from application manager for supporting multi-applications. And based on these profiles, we propose a VHO decision manager that performs effective VHO and an application agent that manages application's service mode for continuous service. Consequently, the proposed context-aware handoff management scheme considering context information, such as user intentions as well as the issues of network layer, prevents unnecessary handoff operations and enables optimal network configuration in ubiquitous computing environment. And also simulation results show that about 40% of performance can be enhanced in the number of VHOs and about 20% enhanced performance in throughput can be achieved, compared with conventional schemes. The remaining part of this paper consists of four parts. In section 2, related work is introduced. In section 3, proposed schemes, middleware architecture and algorithms, are presented. Section 4 shows evaluation result and, lastly, conclusions are presented in Section 5.

2. Related Work

Pervasive computing infrastructure, GAIA, allows applications to specify different behaviors in different contexts by gathering of context information from different sensors, delivering appropriate context information to applications, and providing a powerful context model that allows complex reasoning to be done on contexts [2]. An architectural framework, AURA, allows user mobility and adapts computing environments proactively to a given situation by using models of tasks consisted of inferred service information and user information [3]. Especially, Context Toolkit [4] presents conceptual model for context-aware applications and enables the construction of prototypes for context-aware applications. Another pervasive computing infrastructure that exploits Semantic Web technologies to support explicit representation, expressive querying, and flexible reasoning of contexts in smart spaces, Semantic Space, enables applications to run proactively [5]. But, these approaches are about techniques for ubiquitous computing, like sensor abstraction, context reasoning, and etc., based on the assumption that seamless connectivity is guaranteed. They did not consider any interaction mechanism between changing environment and network status [2] [3] [4] [5].

In [6] [7] [8], VHO scheme between heterogeneous network interfaces is studied. But, they only consider the issues of network layer, such as signal strength, network latency, cost, and so on. Also in [9], active application oriented (AAO) scheme performs VHO, based on application requirements rather than the issues of network layer, so it provides more efficient VHO. But the AAO scheme assumes that only one application runs on mobile terminal and it does not take into account context information like user intention.

3. Context-aware Handoff Management

In this section, we present a context-aware handoff management scheme that can configure the optimal network environment for providing seamless connectivity. Middleware architecture and modules for this scheme are shown as in Figure 1. In Section 3.1, middleware structure and major algorithms are explained for each module and in Section 3.2, overall operation flow is presented.

3.1 Middleware Architecture

To support effective seamless connectivity, optimal network configuration should be guaranteed. Thus, the proposed middleware architecture consists of application profile manager, user profile manager, context engine, application manager, application agent and VHO decision manager shown in Figure 1. Those components are explained in following subsections.

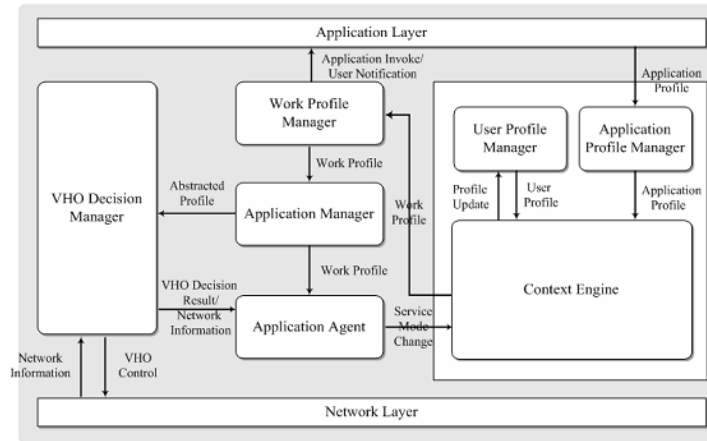


Figure 1. Handoff management middleware architecture.

3.1.1 Application Profile Manager

Application profile manager manages application profiles reflecting some important application requirements. Application profile consists of several service modes which can provide continuous service by changing service quality and minimum required values for bandwidth, packet error rate (PER), and latency to run applications smoothly in each service mode as shown in Table 1. Thus, a specific service mode is selected depending on network parameters for continuous service.

Table 1. Example of application profile.

Application Name	Service mode	Bandwidth (kbps)	PER (%)	Latency (ms)
Navigation	1 (video-based)	192	5	8
	2 (audio based)	64	8	12
	3 (text based)	16	10	15

3.1.2 User Profile Manager

User profile manager manages user profiles reflecting any specific user information and requirements. User profile is composed of using time, transferred data volume and priority in each work. Using time is the average time spent for a given work process completion in the previous work process and transferred data volume is the average amount of transferred data during the same process. Priority is the degree of preference for any specific application in each work. Its example is constructed as in Table 2.

Table 2. Example of user profile.

Application Name	Work	Using Time (s)	Transferred Data Volume (Kbytes)	Priority
Navigation	Navigation	1920	8192	1

3.1.3 Context Engine

Context engine is an inference module based on application profile, user profile, and information from various sensors. In this paper, context engine is a simple rule-based module, and generates work profile. Work is a group of applications in some given situations, and work profile is the information related to the applications of work. Work profile consists of using time, transferred data volume, priority, current service mode, bandwidth, PER, and latency in each service mode of any application as in Table 3.

Table 3. Example of work profile.

Work Name								
Navigation								
Application Name	Using Time (s)	Transferred Data Volume (Kbytes)	Priority	Current Service mode	Service Mode	Bandwidth (kbps)	PER (%)	Latency (ms)
Navigation	1920	8192	1	1	1 (video-based)	192	5	10
					2 (audio based)	64	8	12
					3 (text based)	16	10	15

3.1.4 Work Profile Manager

Work profile manager manages work profile and requests application invocation or the change of service mode and notifies application suspension to the application layer.

3.1.5 Application Manager

Application manager generates abstracted profile from the work profile. The abstracted profile consists of bandwidth, packet error rate, latency, and work bandwidth. Bandwidth is the sum of all application's required bandwidths. Packet error rate and latency are determined according to a value satisfying all application's requirements, which may be the minimum value among all application's values. Work bandwidth represents a permitted bandwidth based on user pattern and is used to prevent unnecessary handoff during VHO decision procedure. Its example is shown in Table 4. Work bandwidth is a bandwidth calculated as follows:

$$\text{Work bandwidth} = \frac{\text{sum of all application's Transferred Data Volume}}{\text{Using Time of Work}}$$

Table 4. Example of abstracted profile.

Work Name	Bandwidth (kbps)	PER (%)	Latency (ms)	Work bandwidth(kbps)
Navigation	160	5	8	120

3.1.6 VHO Decision Manager

VHO decision manager decides whether it should perform handoff and requests the network layer to change network interface if necessary, based on the abstracted profile and network information. In this paper, we assume that network layer provides the information about other available network interfaces as well as current network interface through control channel. Detailed VHO decision algorithm is described as in Figure 2.

```
check current network whether bandwidth, PER, latency of Abstracted Profile are satisfied
if satisfied all factors then
    stay in current network
else
    check current network whether work bandwidth, PER, latency of Abstracted Profile are satisfied
    if satisfied all factors then
        stay in current network
    else
        check available network whether bandwidth, PER, latency are satisfied
        if satisfied network exist then
            handoff to satisfied network
        else
            check available network whether work bandwidth, PER, latency are satisfied
            if satisfied network exist then
                handoff to satisfied network
            else
                handoff to nearest network to requirement
                request Application Agent for Service mode change
```

Figure 2. Pseudo code of VHO decision algorithm.

Also, application agent manages application's service mode. When VHO decision manager requests service mode change, the application agent changes application's service mode based on each application's priority of work profile in the order of lower priority. If a problem is not solved by changing service mode, then the application agent suspends the application also in the order of lower priority and notifies this to user.

3.2 Operation Flow

The overall operation progress is performed based on the proposed scheme as in the following steps. In the first step, context engine generates work profile and delivers it to the work profile manager. In the second step, work profile manager requests application invocation to the application layer. In this step, work profile manager requests the change of service mode and notifies application suspension to the application layer when work profile is regenerated from context engine in the sixth step. In the third step, application manager generates abstracted profile based on work profile and delivers it to the VHO decision manager. In the fourth step, VHO decision manager decides whether it should perform handoff and if necessary requests network layer for VHO if necessary based on algorithm described in Section 3.1.6. In the fifth step, application agent checks application's service mode and decides service mode change or application suspension when VHO decision manager requests service mode change. And go to the first step for regenerating work profile based on result of the fifth step.

4. Evaluation

In this section, we present simulation results to compare the proposed scheme with some other VHO schemes,

conventional VHO scheme that only concerns network issues, and AAO scheme that concerns network issues and applications requirements.

4.1 Simulation Model

Simulation proceeds with three network interfaces, seven applications, and four works. The three network interfaces are WWAN, DMB, and Wibro, and network factors about each interface are based on [10] [11]. While simulation is proceeded, network factors of these network interfaces, bandwidth, PER, and latency, are randomly changed based on each interface's characteristics and the list of available network interfaces are randomly changed too. Seven applications refer to applications for navigation service, broadcasting service, data transmission service, Instant Messaging Service (IMS), online game service, explorer service, music service, and four works are shown in Table 5. In every simulation, each work's applications have different using time and transferred data volume, which are randomly generated.

Table 5. Example of simulation scenarios.

Work	Applications
Entertainment	Broadcasting Service, IMS, Explorer Service
Online game	Online Game Service, Explorer Service
Business	IMS, Data Transmission Service, Explorer Service
Navigation	Navigation Service, Music Service

4.2 Simulation Result

Evaluation is based on two aspects, i.e., the number of VHOs and throughput reflecting handoff delay.

In Figure 3, proposed scheme represents the smallest number of VHOs and shows about 40% enhanced performance compared with conventional scheme. This result is caused by the difference between algorithms adapting to continuously changing environment. In Figure 4, throughput that is calculated based on total transferred data and total using time reflecting delays caused by VHO is presented and also proposed scheme shows highest throughput compared with conventional VHO and AAO schemes. The enhanced throughput compared with conventional scheme is about 20%.

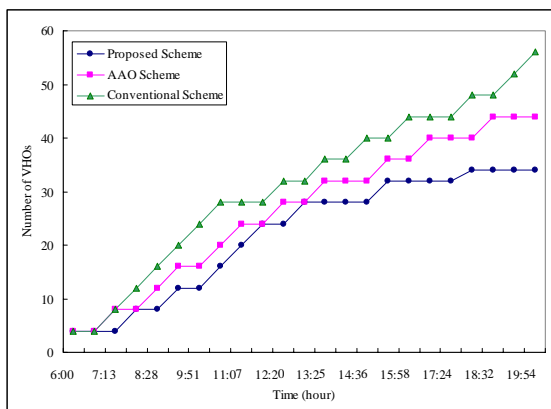


Figure 3. Number of VHOs.

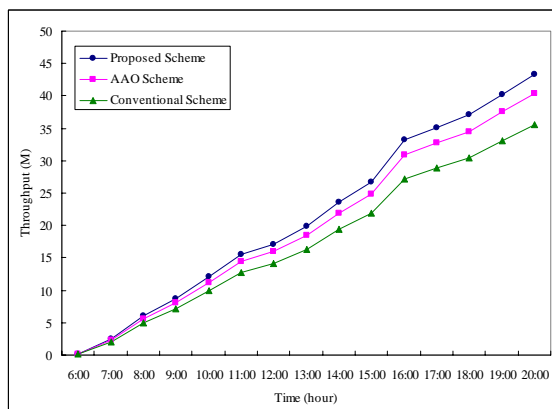


Figure 4. Throughput.

5. Conclusion

Seamless connectivity is an important research issue in ubiquitous computing. However, existing approaches only assume that all components are connected with networks seamlessly or are only concerned about factors of network issues. The provision of seamless connectivity requires an intelligent handoff management which builds up the optimal network environment. In this paper, we proposed a context-aware handoff management scheme for seamless connectivity in ubiquitous computing environment, based on profiles reflecting various context information and efficient VHO management algorithm. And simulation results verify that our proposed scheme provides optimal network environment that copes with continuous changing environment effectively and prevents unnecessary handoffs.

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