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Larry Korba
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Preface

It is becoming quite clear that there will be important technological advances in mobile and wireless connectivity, known as third-/fourth-generation (3G and 4G) mobile telecommunications systems. As a result we will be surrounded by ever-growing multidomain (technical and administrative) heterogeneous communications in both wired and wireless networks. This resulting environment deals with communication in multizoned networks, where people, devices, appliances and servers are connected to each other via different kinds of networks. Networks will be pervasive, ubiquitous, multiservice, multioperator and multiaccess. The mobility trend will also be spurred forward by the growing availability of mobile-enabled handheld devices.

Mobile systems are expected to provide mobile users with cost-effective, secure, yet ubiquitous service access anywhere and anytime. Users will then continue to enjoy the new-found freedom mobile access provides and will have increasingly high expectations of mobility-aware applications that should be capable of seamlessly supporting the mobile lifestyle.

The papers in this volume discuss issues from models, platforms, and architectures for mobility-aware systems to security, mobile agent technologies, sensitive communications, context awareness, mobile applications and management. They cover both practical experience and novel research ideas and concepts.

We would like to express our appreciation and thanks to the authors for their contributions to preparing and revising the papers as well as the technical program committee and the reviewers who helped put together an excellent technical program for the workshop. Special thanks are due to Hamid Harroud and Mohamed Khedr who kindly contributed their time and effort to help with the organization of the review process and the technical program.

October 2004

Ahmed Karmouch

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Mobility Prediction for Mobile Agent-Based Service Continuity in the Wireless Internet

Paolo Bellavista, Antonio Corradi, and Carlo Giannelli

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Abstract. New challenging deployment scenarios are integrating mobile devices with limited and heterogeneous capabilities that roam among wireless access localities during service provisioning. This calls for novel middleware solutions not only to support different forms of mobility and connectivity in wired-wireless integrated networks, but also to perform personalized service reconfiguration/adaptation depending on client characteristics and in response to changes of wireless access locality. The paper proposes the adoption of Mobile Agent (MA) proxies working at the wired-wireless network edges to support the personalized access of limited wireless clients to their needed resources on the fixed network. In particular, the paper focuses on how to predict device mobility between IEEE 802.11 cells in a portable lightweight way, with no need of external global positioning systems. In fact, we claim that mobility prediction is crucial to maintain service continuity: MA-based proxies can migrate in advance to the wireless cells where mobile clients are going to reconnect to, in order to anticipate the local rearrangement of personalized sessions. The paper proposes and evaluates different mobility prediction solutions based on either client-side received signal strength or Ekahau positioning, all integrated in the SOMA platform. Both simulation and experimental results show that SOMA can predict the next visited cell with a very limited overhead and enough in advance to maintain service continuity for a large class of wireless Internet services.

1 Introduction

The increasing availability of public wireless access points to the Internet and the widespread popularity of wireless-enabled portable devices stimulate the provisioning of distributed services to a wide variety of mobile client terminals, with very heterogeneous and often limited resources. Even though devices and networking capabilities are increasing and increasing, the design of mobile applications will continue to be constrained by several factors, from limited display size to high connectivity costs, from bandwidth fluctuations to local resource availability, also abruptly changing due to client mobility among wireless cells during service provisioning.

Let us focus on the common deployment scenario where wireless solutions extend accessibility to the traditional Internet via access points working as bridges between fixed hosts and wireless devices [1]. An exemplar case is the usage of IEEE 802.11 access points to support connectivity of WiFi-equipped terminals to a wired local area network [2]. In the following, we will indicate these integrated networks with fixed

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Internet hosts, wireless terminals, and wireless access points in between, as the wireless Internet.

Service provisioning over the wireless Internet must consider the specific characteristics of client portable devices, primarily their limits on local resources and their high heterogeneity. Limited processing power, memory and file system make portable devices unsuitable for traditional services designed for fixed networks and require both assisting wireless terminals in the service access and downscaling contents to obey resource constraints. In addition, portable devices exhibit extreme heterogeneity of hardware capabilities, operating systems, installed software, and network technologies. This heterogeneity makes hard to provide all needed service versions with statically tailored contents and calls for on-the-fly adaptation of service provisioning.

We claim the need of middleware solutions to dynamically adapt service results to the specific properties of client devices and to the runtime resource availability of the provisioning environment [3-6]. Middleware components should follow client roaming in different wireless localities and assist them locally during their service sessions. Moreover, client limited memory suggests deploying middleware components over the fixed network, where and when needed, while portable devices should host only thin clients, loaded by need and automatically discarded after service.

By following the above solution guidelines, we have recently designed and implemented application-level middlewares, based on Secure and Open Mobile Agent (SOMA) proxies, to support the distribution of context-dependent news and video on demand to wireless devices with strict limits on on-board resources [5, 7, 8]. The primary design idea is to dynamically deploy SOMA proxies acting on the behalf of wireless clients over the fixed hosts in the network localities that currently offer client connectivity. In particular, this paper focuses on a crucial challenge for MA-based middlewares for the wireless Internet: how to predict the client movements among wireless cells, making unnecessary any external Global Positioning System (GPS). Mobility prediction permits to migrate personalized SOMA proxies in advance with regards to the client roaming. Thus, SOMA proxies have the time to proactively reorganize user sessions in the newly visited network localities, by rebinding to needed resources and local middleware components for service adaptation, with the ultimate goal of supporting session maintenance and continuous service provisioning [5].

We propose three different mobility prediction solutions, all exploiting a first-order Grey Model (GM) [9]. The first approach uses only the client-side monitoring data about Received Signal Strength Indication (RSSI) in a decentralized, lightweight, and portable way (we call it RSSI-GM for shortly). The other two solutions take advantage of the positioning data provided by the commercial Ekahau Positioning Engine (EPE) [10]. Ekahau Cell Probability (ECP) exploits the EPE-provided probabilities of being located in a cell, both currently and in the recent past, as the input for GM-based mobility prediction. Ekahau Distance (ED)-GM bases its prediction on the current/recent distances of client nodes from the borders of IEEE 802.11 cells of base stations in their visibility.

We have evaluated the performance of the three mobility prediction solutions both via a simulator, which can model nodes randomly roaming among IEEE 802.11 lo-

calities, and by exploiting a system prototype deployed over WiFi-enabled PDAs with MS Windows CE.NET. Both experimental results show that the simplest and completely decentralized RSSI-GM approach outperforms the others. In addition, notwithstanding the portable and application-level approach, RSSI-GM has demonstrated to be capable of predicting the next cell location enough time in advance to permit SOMA middleware to rearrange personalized sessions before the client connects to the new wireless locality. This permits to provide adapted services to limited wireless devices without any interruption in the case of client roaming.

2 Motivating Mobility Prediction in MA-Based Middlewares

Service provisioning in the wireless Internet usually calls for downscaling service contents to suit the specific limits of client devices. For instance, dynamic content negotiation and tailoring are crucial for multimodal services providing resource-consuming multimedia in Web pages. In addition, device mobility requires other support operations that are too expensive to be performed by severely limited devices, e.g., context-aware local/global resource retrieval and binding. On the one hand, local discovery operations may consume non-negligible client resources to explore the execution environment and to negotiate with available services. On the other hand, the global identification and retrieval of user-related properties, such as user/terminal profiles and security certificates stored in directories, may require long continuous connectivity, difficult to be handled directly by portable devices.

We claim that wireless Internet service provisioning can significantly benefit from distributed and active infrastructures of mobile middleware proxies working in the fixed network on behalf of portable devices [6]. Proxies can decide the best adaptation operations to perform on service results and can be in charge of any additional management operation, such as supporting connectivity and discovering the needed resources/service components. Moreover, proxies can act, locally to the client, as distributed cache repositories for successive service requests. In addition, if proxies are mobile, they can follow device movements during service provisioning by supporting session migration between the different network localities visited, and install automatically only where and when needed [6].

For all above reasons, the primary design choice in SOMA-based middlewares for the wireless Internet is to provide any wireless device with one SOMA-based companion entity, called *shadow proxy*, which run in a wired node (place) in the same wireless network locality that currently provides connectivity to the device [5, 8]. Wired/wireless terminals in a locality can be grouped into logical domains, as depicted in Figure 1; domains are disjointed, even if they include wireless access points with coverage areas that partially overlap.

Shadow proxies are in charge of determining the applicable context for their clients and of consequently retrieving and binding to the needed local/global resources. Proxies solve the issues related to receiving, caching, and coordinating the tailoring of service contents by taking context-dependent decisions based on profile metadata that describe device characteristics and user preferences [6].

In the following, the paper concentrates on the crucial issue of how to predict the client movements between SOMA localities in order to migrate in advance the proxies to the next domain of attachment of their associated clients. A detailed description of the implementation of the different SOMA middleware components that support the distribution of context-dependent news and video on demand to wireless devices is out of the scope of the paper, and can be found elsewhere [5, 8].

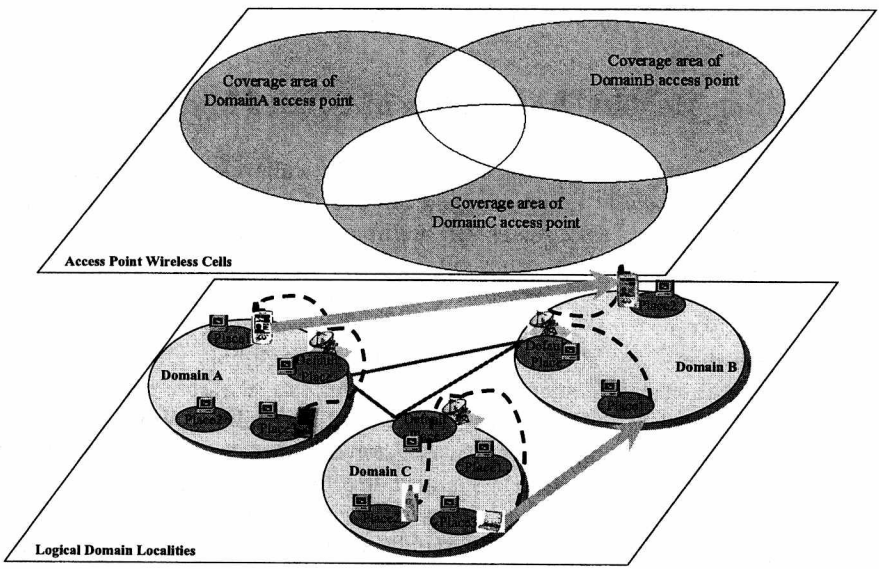

Fig. 1. Portable devices roaming among SOMA wireless access localities.

To better understand the need for mobility prediction, let us describe the service management operations that the SOMA-based middleware performs in response to a client change of locality. Let us suppose a user roams from DomainA to DomainB in Figure 1 while she is receiving her personalized location-aware service contents. Note that user movements also produce the user change of access point coverage area, since in location-aware services clients should typically associate with their closest base station. Depending on the (usually configurable) handoff strategy of the underlying communication layer, the user device is transparently de-associated from the origin wireless cell and associated to the destination one i) when the client no more receives the origin signal, ii) when the destination RSSI overcomes the origin RSSI (handoff hysteresis = 0), iii) or, more generally, when the destination RSSI overcomes the origin RSSI of a specified threshold t (handoff hysteresis = t), also to reduce bouncing effects.

Once notified of the communication handoff, the middleware should migrate the shadow proxy to the destination domain. There, the proxy should instantiate and configure the needed local middleware components and reconnect to the server (or to an equivalent local replica of it) before being capable of serving its client again. This

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