Creating an Open Agent Environment for Context-Aware M-Commerce

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Abstract. In this paper, we introduce MyCampus, an agent-based environment for context-aware mobile services, which we are in the process of developing and validating on Carnegie Mellon University's campus. The environment revolves around a growing collection of customizable agents capable of (semi-) automatically discovering and accessing user personal resources (e.g. calendar, location tracking functionality, food preferences) and Web services as they assist their users in carrying out different tasks such as planning an evening out, organizing a study group or filtering incoming messages.

The openness of the MyCampus architecture directly derives from a set of ontologies for describing personal resources, contextual attributes, user preferences and web services. Contextual information and other personal details about a user are accessed via a ***Semantic e-Wallet***, subject to access privileges set by the user. Over time, the user can pull new agents into her context and assume that these agents will automatically be able to discover and access relevant contextual information and personal details. Similarly, service ontologies facilitate the introduction of new Web services by allowing agents to (semi-)automatically discover and access them. Such openness could one day play a key role in helping create a more leveled playing field for producers of Web services. It could also open the door to new markets for a wide variety of simple, task-specific agents capable of automatically adapting to their user's context and preferences.

1 Introduction

With tens of millions of Internet-enabled mobile devices, the mobile Internet is opening the door to a slew of new mobile applications and services that will assist users as they engage in time-critical, goal-driven tasks. Yet today, the mobile commerce landscape is dominated by relatively simple infotainment services [1]. Moving beyond these simple services requires overcoming the inherent input/output limitations of mobile devices through higher degrees of automation and the development of services that understand the context within which their users operate – e.g. their locations, the activities they are engaged in, who their friends and colleagues are as well as a number of other contextual attributes and preferences.

Today, however, information about a user's context is distributed across a number of heterogeneous resources. Her location might be stored in the Home Location Register of her mobile phone operator, her activities in her calendar, the list of her colleagues in a company database, etc. To make matters worse, this information is gener-

ally represented in an ad hoc fashion, making it prohibitively expensive to develop and maintain applications capable of leveraging it.

The same is true for Web services, which all rely on idiosyncratic ways of representing information and interacting with the user. Amazon's product information and the forms it uses to interact with customers are different from those found at Barnes and Noble. As a result, today's comparison shopping agents, for instance, are hard-wired to access predefined websites and are dependent on information being represented according to specific formats at each site (e.g. as soon as a particular website changes its location or format, the agent will fail).

MyCampus is a semantic web environment for context-aware services that we are in the process of developing and validating on Carnegie Mellon University (CMU)'s campus. The environment revolves around a growing collection of customizable agents capable of (semi-)automatically discovering and accessing personal resources and Web services as they assist their users in carrying out different tasks (e.g. planning an evening, organizing a study group, looking for a place where to eat, filtering incoming messages). The power and scalability of the environment directly derives from a set of ontologies for describing personal resources, contextual attributes, user preferences and web services, making it possible to easily accommodate new task-specific agents, new personal resources and new Web services.

2 Literature Overview

Prior efforts to develop context aware applications are many. Early work in context awareness includes the Active Badge System developed at Olivetti Research Lab to redirect phone calls based on people's locations [2]. The ParcTab system developed at the Xerox Palo Alto Research Center in the early nineties relied on PDAs to support a variety of context-aware office applications (e.g. locating nearby resources such as printers, posting electronic notes in a room, etc.)[3,4]. Other relevant applications that have emerged over the years range from location-aware tour guides to context-aware memory aids. More recent research efforts in context awareness include MIT's Oxygen [5], CMU's Aura [6] and several projects at Berkeley's GUIR (e.g. [7]) to name just a few.

While early context-aware applications relied on ad hoc architectures and representations, it was quickly recognized that separating the process of acquiring contextual information from actual context-aware applications was key to facilitating application development and maintenance. Georgia Tech's Context Toolkit represents the most significant effort in this direction [8,9]. In the Context Toolkit, widgets act as wrappers that provide access to different sets of contextual information (e.g. user location, identity, time and activity), while insulating applications from context acquisition concerns. Each user (as well as other relevant entities such as physical objects or locations) has a context server that contains all the widgets relevant to it. This is similar to our notion of e-Wallet, which serves as a central repository of all personal resources relevant to a given user (e.g. relevant location tracking functionality, relevant collections of preferences, access to one or more calendar systems, etc.). Our Semantic eWallet however goes one step beyond Dey's Context Toolkit, as it supports much richer models of personal resources - what personal information they give access to, how to go about accessing this information along with access control functionality. This richer model is key to supporting automated discovery and access of a user's personal resources by agents. In other words, while the Context Toolkit focuses mainly on facilitating the development of context-aware applications through off-line, re-use and integration of

context-aware components (i.e. widgets), our architecture emphasizes real-time, on-the-fly instantiation of context-aware agents through automated discovery and access of relevant personal resources subject to access control privileges – you would not want any agent to be able to access all your personal resources.

Our work builds directly on recent efforts aimed at moving the Web from an environment where information is primarily made available for human consumption to one where information is annotated with semantic markup that makes it understandable to computers (and intelligent agents). These efforts are part of a long-term vision generally referred to as the *Semantic Web* [12, 13]. They have already resulted in a succession of semantic markup languages [14,15] as well as more specialized attempts at defining ontologies of Web Services in the context of a language known as DAML-S [16]. In our work, we rely on the use of DAML+OIL to represent user preferences and contextual information (e.g. location, calendar activities, social and organizational relationships, etc.) and on concepts developed in DAML-S to represent both Web Services and personal resources.

3. MyCAMPUS Architecture

Like many other campuses, CMU's can be viewed as an everyday life microcosm. Members of the community engage in a broad range of activities from working and studying to socializing, practicing sports, attending a variety of events, shopping, eating, etc. MyCampus users access personalized, context-aware agents from their PDAs over the campus's wireless LAN.

Specifically, in our architecture (see Figure 1), each user has an e-wallet that acts as a semantic directory of personal resources (e.g. calendar, location tracking functionality, preference repositories, service subscriptions, etc.) enabling agents to automatically discover and access a user's personal resources, while controlling access to these resources according to profiles set by the user. Users can over time pull new task-specific agents into their personal environment – in a way reminiscent of today's mobile phone users who download new ring tones and caller group icons on their handsets - except that our agents may very well reside on servers rather than on the mobile device itself. As users pull individual copies of task-specific agents into their personal environments, these copies are instantiated, taking into account relevant contextual attributes and preferences accessed via the user's e-wallet. Access to a user's personal resources is not necessarily restricted to the user's own agents but can include agents working for other users (e.g. allowing your colleagues and their agents to see where you are between 8am and 8pm or allowing your girlfriend and her agents to schedule activities in your calendar on Friday night). Access privileges are set by the user and specify who can access what, under which conditions. In general, access to a user's personal resource may involve:

- Requesting the value of a contextual attribute at a particular time (e.g. where is the user right now, or does the user already have a meeting between noon and 1pm today?)
- Requesting regular updates about the value of one such attribute (e.g. send me updates on the user's location every 5 minutes)
- Requesting updates as the value of a particular attribute changes (e.g. let me know each time the user enters or exits a building)
- Modifying the value of an attribute (e.g. scheduling a meeting in the user's calendar)

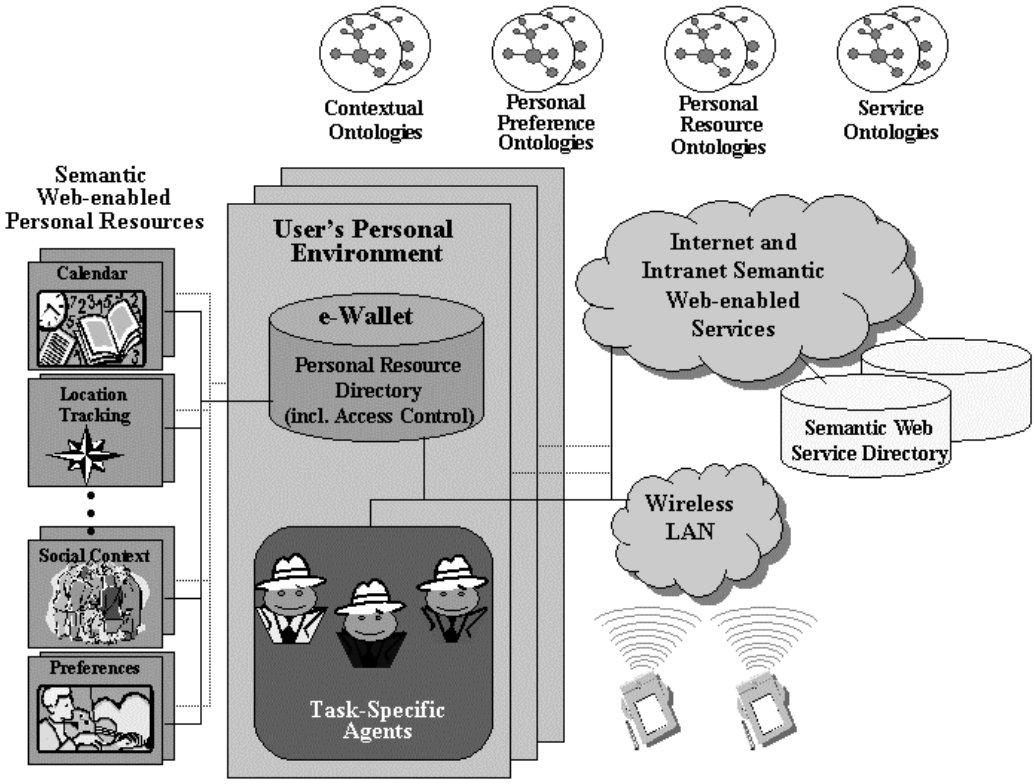

Fig. 1. Overview of MyCampus Architecture

Current contextual attributes include the user's location on campus, her calendar, social relationships (e.g. friends and classmates), a number of preferences (e.g. food preferences, message filtering preferences, etc.) as well as information about the weather. Location information is currently obtained using location tracking functionality deployed by local startup PanGo Networks on top of CMU's WiFi (IEEE802.11) Wireless LAN, though one could easily envision multiple types of location tracking functionality (e.g. WLAN location tracking when on campus and cellular network location tracking provided by one's phone operator when outside). Weather information is obtained by connecting to an outside Website.

4 MyCAMPUS Agents

An example of a simple agent implemented at the time of writing is a "restaurant concierge" that gives users suggestions on where to have lunch, depending on their food preferences, the time they have available before their next meeting or class, their location on campus and the weather. For instance, when it rains, the concierge will look for places that do not require walking outside and, if the student only has say 20 minutes before her next class, it will limit its recommendations to nearby fast food places.

Other agents our group is currently experimenting with include context-sensitive message filtering and message routing agents, context-sensitive reminder agents, as well as more sophisticated agents endowed with planning and automated Web service access functionality. Context-sensitive message filtering agents are used to filter push messages such as announcements about events on campus (or promotional messages companies could be sending you). Our system relies on a taxonomy of messages (e.g. promotional messages versus seminar announcements) and on context-sensitive preferences (e.g. "when in class, I don't want to be disrupted by promotional messages) to decide which messages to show to the user.

Our group is also experimenting with other message filtering agents and message routing agents in the context of projects with Alcoa and with the Department of Defense (e.g. to decide how to reroute important messages if their intended recipient is not available). Context-sensitive reminder agents remind students of tasks they have in their to do list such as buying milk as they get close to the local grocery store or picking up a homework assignment when they approach the right building on campus.

5 Concluding Remarks

MyCampus is an ambitious project that aims at leveraging the power of recent Semantic Web concepts in support of mobile, context-aware services. Our work revolves around the development of a growing collection task-specific agents that users can pull into their personal environments. Thanks to the use of ontologies for representing personal resources, user preferences, and contextual attributes, agents can automatically access and exploit relevant contextual information. Declarative Web service descriptions also make it possible for agents to automatically discover and access Web services as they assist their users. Through its use of semantic annotations of Web Services and personal resources, the MyCampus architecture provides for an environment where it is particularly easy to introduce new agents, new Web services as well as new contextual resources. We believe that such openness could eventually pave the way to a more leveled playing field for producers of Web services and could also open the door to new markets for a wide variety of downloadable, task-specific agents capble of automatically adapting to their user's context and preferences (e.g. services to help you filter messages, plan an evening out, etc.).

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