INTEGRATING MOBILE AGENT AND CONTEXT-AWARE WORKFLOW ANALYSIS FOR M-COMMERCE APPLICATIONS

Jiazao Lin[1], Xining Li[2] and Lian Li[1]
[1]*Department of Computer Science & Department of Mathematics, Lanzhou University, Lanzhou, Gansu, P. R. China*
[2]*School of Computer Science, University of Guelph, Guelph, Ontario, Canada*

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Abstract: Mobile commerce (M-commerce) is an attractive research area due to its relative novelty, rapid growth, and great potential in business applications. Unfortunately, there are a number of constraints effecting both performance and usability of mobile devices and network bandwidth. In addition, existing M-commerce applications are lack of fully automated business processes and still require significant manual effort. In this paper we present a general solution of integrating mobile agent and context-aware workflow to implement automated trading task and compose services dynamically in real time to create a highly personalized assistant. Furthermore, the proposed context-aware model derives from a set of ontology of descriptive contextual attribute for knowledge sharing and logical inference. Instead of executing a fully defined process description, the composite workflow can be executed with forward or backward selection of services determined at run time. We have carried out an evaluation experiment. The results show that our proposed solution is feasible and viable.

1 INTRODUCTION

With the development of Internet and its related technologies, the most significant change of our daily lives is the way of conducting business. There is no doubt that Electronic commerce (E-commerce) is the most successful model to explore opportunities and expand business into global commercial market. It offers new channels and business models for buyers and sellers to effectively and efficiently trade goods and services over the Internet （Laudon and Traver, 2006）. However; the traditional E-commerce is based on the client/server approach, which requires a stable connection between client and server. Such a requirement makes some restrictions on the spatial and temporal activities. With various types of Internet-enabled mobile devices, such as PDA's, mobile phones, pocket PC's, etc., the mobile Internet is opening the door to numerous new mobile applications and services that will assist mobile users to engage in time-critical, goal-driven tasks (Sadeh, 2002). M-commerce has emerged and attracted a growing number of research efforts recently. The basic idea of M-commerce is to conduct business transaction with mobile devices and telecommunication/wireless networks, either directly or indirectly (Bai and et al., 2005). It can help nomadic users to roam a wide range of services and products over the Internet on an anywhere and anytime basis. Due to the mobility, personality and flexibility, M-commerce is likely to become the main business model in the near future (Ngai and Gunasekaran, 2007).

One issue which must be considered in the design of M-commerce applications is the limitation of mobile environment and interface between users and applications. In the mobile environment, it is impossible to retain a long connection between the client and service providers (Qiang and Hin, 2002) and it is also unreliable to transfer a huge amount of data between client and server. Comparing to applications based on desktop, the mobile handhold devices have some physical constraints, such as small screen size, limited battery capability, limited storage and computing capacity, and low-bandwidth links with a speed which is slow and varies for different periods of time. In addition, the nomadic users need to frequently check trading opportunity (Mihailescu and et al., 2002), as well as carry out fuzzy and complex information exchange and decision-making tasks. Therefore, it leads to the raise of revenue and creates the risk of missing trade opportunities if the trade time is constrained by the

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limited availability of physical access to the service (Kowalczyk and et al., 2003).

Furthermore, It is well-known that an M-commerce transaction involves a sequence of activities, such as negotiation, purchasing, shipment, payment and logistic services. These activities demand additional features of automation and optimization. Existing M-commerce applications are lack of fully automated business processes and still require significant manual effort.

In order to solve the problems mentioned above, we propose the concept of integrating mobile agent and context-aware workflow to implement automated trading task, and compose services dynamically in real time to create a highly personalized assistant. A mobile agent is a self-contained executable entity which is capable of autonomously roaming the Internet to access computing and information resources to carry out user specified tasks. Deploying mobile agents in M-commerce could add automatic and intelligent capabilities to conduct a business transaction (Bădică and et al., 2005), and offers mobile users the freedom of connection or disconnection/reconnection functionality to reduce network cost and power consumption. Workflow is the process within a system and the rate at which that happens. Through workflow analysis, we could observe and extract how this process takes place and improve it for efficiency and effectiveness. To achieve user desired goals, a management mechanism can be used to aggregate different business steps into workflows, and automatically chain multiple services together by using planning (Chakraborty and et al., 2005). However, existing workflow management systems lack an appreciation of the content of a business process and do not make decisions based on the nature of information being gathered, that is, many decisions are traditionally made in the process description at design time. In our system, we propose to extend workflow systems to integrate and utilize contextual information relevant to nomadic user to enhance a higher level of automation. For an M-commerce application, the contextual information refers to nomadic user profile and preference which plays a crucial role in the simplification of the interaction between human and the virtual digital world. A general sense of context awareness refers to the ability of an application to discover and take advantage of contextual information (Dey and Abowd, 1999). In our work the context information involves the Person Profile, Environment Profile, Current Activity and Context History. The context-awareness and adaptability accommodated into the workflow is called Context-aware workflow, which is defined as the process of autonomous and adaptive constructing from atomic services to form a specific, complex task with contextual information. The objective of our research is to design a flexible, adaptable mobile infrastructure to accommodate M-commerce applications.

The reminder of this paper is organized as follows. In Section 2, we will discuss some highlight concepts and methodologies involved in our system, such as mobile agent, context model and context-aware workflow. Section 3 will present our proposed solution and the layered system architecture. In Section 4, we show an experiment to testify the feasibility of the proposed architecture. Finally, we conclude our work and indicate future works.

2 HIGHLIGHT CONCEPTS AND METHODOLOGIES

The dramatic evolution of wireless/telecommunication technologies and mobile computing devices has attracted many researchers to migrate their interests from E-commerce to M-commerce. Several M-commerce platforms have been proposed which use either traditional client-server model or agent-based architecture, such as eAuctionHouse (Sandholm and Huai, 2000) and MAE (Mihailescu and et al., 2002). Other M-commerce researches involve mobile advertising, mobile stock trading, mobile marketing, mobile content distribution, etc. On the other hand, in order to explore automation and optimization of business processes, a number of context-aware applications have been developed to support service composition, such as CAWE (Ardissono and et al., 2007) and CACS (Luo and et al., 2006). However, due to the varity of mobile devices, evolving wireless and telecommunication technologies, heterogeneous platforms and existing and emerging business models, there is still a long way to go in terms of developing the user friendly M-commerce applications. Therefore, in our proposed infrastructure, it will incorporate the concepts of mobile agent, context aware computing, web services, workflow, as well as their related models and methodologies. We will present a brief overview of these researches, and discuss their relevance with our system.

2.1 Mobile Agent Technology

Agent technology is a paradigm for structuring, designing and building systems that require complex interactions between autonomous distributed

components. The agent model has been recognized as a highly effective implementation technique in E-commerce or M-commerce (Kotz and Gray, 1999). Especially the mobile agent paradigm has been deployed as a good candidate to overcome the limitations of connectivity, latency and bandwidth of wireless and telecom networks (Hagen and et al., 1998). For example, a nomadic user can dispatch mobile agents from a handhold device to perform an M-commerce application. Once the application has been launched, the user may disconnect from the network. The execution results can either be sent back by mobile agents through SMS/email, or be collected when the user receives a notice and reconnects to the network. In order to ease the access and participation, reduce costs and improve trading efficiencies, support for automation of decision-making, our proposed system adopts the agent technology and deploys two kinds of agents, namely, stationary agent and mobile agent. A stationary agent always resides at its host and be classified as a home agent or a vendor agent. A home agent is responsible to accept requests from a mobile user and dispatch corresponding mobile agents to invoke a trade transaction, whereas a vendor agent acts as the representative of the vendor to keep track of all transactions, inquires, and possible trade negotiation. A mobile agent represents the "runner", who roams the Internet to carry out the assigned task. Obviously, mobile agents must be lightweight in order to swiftly move across the network. Mobile agents are initialized and dispatched by its home agent to migrate to multiple provider sites and communicate with vendor agents to perform their tasks. Having finished their assigned work, mobile agents may move back to the home server to deliver the execution results.

2.2 Context Model

M-commerce applications have a great demand for context awareness, that is, a need to exploit various information in order to adapt application behaviors. Most existing applications focus on location awareness, i.e., to provide personalized services based on the customer's current position in physical space. Generally speaking, context could be any information that is helpful to characterize the situation of an entity, where an entity can be a person, a place, a physical or a computational object (Dey, 2001). In addition, context could be either explicitly indicated by the user or implicitly extracted from other information sources. Certainly, mobile customers want to find the best deal in an M-commerce environment. The best deal can only be obtained by appropriately combining information gathered from various shopping services in the physical vicinity. To facilitate the development of extensible and interoperable context aware applications and make contextual data usable and sharable by M-commerce applications, it is essential to have a set of principles for specifying any given context from any domain. To achieve this, a set of well-defined, uniform context models and protocols is required. As a formal representation of entities, ideas, and events, along with their properties and relations within a system of categories, ontology allows sharing a common understanding of information and deriving additional information from what is already known (Uschold and Gruninger, 1996).

Derived from above discussion, we consider the context as the entire collection of entities and their properties that can form a meaningful relationship between mobile users and M-commerce applications. As a result, we define the context dimensions which have to be considered in our system. It consists of a set of elements along four axes, namely, Person profile (Name, Sex, Nationality, Birthday, Social Role, Address and Phone, Friend List), Environment profile(Current Time, Date, Longitude, Latitude, Weather, Temperature, Light, Noise), Context history (Visited Webs and Shopping History) and Current activity. It is worth to note that we only listed a portion of context in our system, the content will extended along with the progress of system development.

2.3 Workflow Management

In M-commerce applications, it is desirable that business activities to be completed quickly with high quality and low cost. A well-designed workflow management system can provide potential competitive advantage to manipulate a series of tasks within a business transaction to produce a final result. In recent years, web services are growing and evolving rapidly in M-commerce applications. The development of new service composition by integrating existing services is generating considerable interests in business communities. There are several typical approaches to the web services composition (Milanovic and Malek, 2004). However, these conventional workflow management models and systems do not provide sufficient characteristics such as automatic composition and adaptability verification. It is therefore important to study how to design a workflow management system which can integrate and utilize context information in the analysis process and activity enactment.

For this purpose, we propose a context-aware workflow management system, as an autonomous

and adaptive process which is able to construct a complex service from atomic activities to achieve a specific task with contextual information. The composition service should be executed with the freedom of forward or backward selection and the service selection is determined at run time instead of executing a fully defined process description. Therefore, we introduce an abstract hierarchy whose higher-level elements describe the tasks to be performed in a generic way. The hierarchy consists of two layers, namely, Abstract Activity and Activity Flow Description (AFD).

An Abstract Activity is a high-level description of the capabilities and categorization of an atomic service with similar functionality. The service functionality is specified in terms of its inputs, outputs, preconditions and effects. Each abstract activity has an associated set of context-dependent implementations representing the alternative courses of the action which the service management model should actuate, depending on the context states. Each Abstract Activity is associated with a service type. There are two types of concrete services in our system, namely, E-service and A-service. An E-service represents a common web service which includes the service provider, the purpose of the service and the method of invocation. On the other hand, an A-service indicates an agent-based service which includes the remote agent host, name of the vendor agent, and the method of agent communication. To invoke an A-service, a mobile agent must migrate to the remote agent server and communicate with the named vendor agent. A vendor agent is a persistent agent acting as the representative of the vendor. It provides services interactively with the mobile agent to implement authentication, query, negotiation, etc.

An AFD indicates the order of a collection of activities without the details of execution. It may contain one or more abstract activities. An abstract activity is replaced by one of the concrete implementations at run time. An AFD can also be predefined, to customize the services requested by the nomadic users. It is the responsibility of workflow management system to determine the actual implementation at execution time based on the context information. Therefore, it is necessary to deploy a conceptual level specification language to describe process product, service and information flows, including the tasks, the dependencies between the tasks and the required roles. In our system, we will employ XML to describe a logical business transaction. The primary reason is the flexibility offered by XML in terms of structured multi-object documents, compact message construction as well as the wide acceptance of XML as the communication standard for wireless-based applications.

2.4 Service Discovery

Service discovery has been widely studied to allow automatic detection of services, especially web services offered by various service providers. A web service can be invoked by using a specified protocol, such as Simple Object Access Protocol (SOAP), and has an interface described by Web Service Description Language (WSDL) and its related information is published to the Universal Description, Discovery and Integration (UDDI). A service discovery protocol mainly involves dynamically discover and select the best currently available service that fits the need of a specific requirement from user. At this stage, we do not consider the selection rules and selection policies, instead, we focus our attention on a novel approach to discover and select service on the basis of Abstract Activity and contextual information. To get the benefits of the web service standardization and to avoid the redesign of another lookup service we adopt UDDI registry with some extension. Concretely speaking, a new tag <AgentService> is added to a UDDI service registry if the service is an A-Service, that is, the service is implemented by agent-agent interaction.

In this stage, we will illustrate a typical control flow of service discovery and service selection during execution of an M-commerce transaction. To begin with, a lightweight mobile agent is dispatched by the mobile device to deliver a XML-based AFD message to the Home server. Having received the AFD message, the Home Agent will transfer the message to the workflow management system for further processing. The Service Discovery and Selection module extracts atomic activities from the AFD message and uses system defined selection rules and contextual information to search available services from the UDDI server. Based upon the search results, the workflow management system will hook up a concrete implementation to each atomic activity, that is, to invoke a web service if the result returned by discovery module is of type E-service, or to create a mobile agent if the result is of type A-service. An E-service will be invoked by the standard SOAP protocol, while an A-service is carried out by a mobile agent who migrates to one or more remote hosts and communicates with various vendor agents to obtain required services.

3 OVERVIEW OF PROPOSED SYSTEM ARCHITECTURE

To support our proposed approach, we are now in the stage of developing the workflow management prototype system. The main characteristics of the prototype design are adaptability and flexibility. Adaptability is achieved by the context awareness mechanism embedded in the system. Flexibility is obtained by the layered architecture, as presented in Figure 1, where each layer will be wrapped by web service interface. The top layer consists of two function modules which reside in the mobile device.

Portal: This module constitutes the interface of the mobile user and the handhold device. It mainly encompasses different GUI facilities where the user can customize tasks by setting preferences, permission profile and personal information. There are three major functions in this module: Service Information model aggregates a series of abstract activities with similar functions in M-commerce applications. Activity Design GUI is a tool for the mobile user to customize an M-commerce application by setting requirements, preferences, and permission profile. User Information Panel offers functionality to manage user's personal information and contextual information.

Abstract and Connection: This module serves as the communication and operation bridge between the mobile user and the home server and includes two major functions. Abstract Composition Engine is responsible to extract abstract activities from user's specification and transforms the abstract activities to an AFD message. Transform Model Engine is used to transform concrete services into abstractions which are cached in Abstract Activity Centre.

The middle layer is the core of our system, that is, the Context-aware Workflow Management, which involves three main modules:

Service Composition Engine: This module provides the function of translating the well-defined abstract Description Level flow into a concrete workflow in which the required resources will be bound. It manages, controls the workflow, and designates the appropriate service to accomplish the task. Workflow Translation function interprets and decomposes the AFD message came from the top layer into a workflow. Logic Control Repository specifies the business logic of the workflow. XML parser is used to parse the AFD message. Service Management maintains service patterns and templates which are frequently used in M-commerce applications. Service Discovery and Selection communicates with UDDI servers, evaluates application conditions for each candidate service

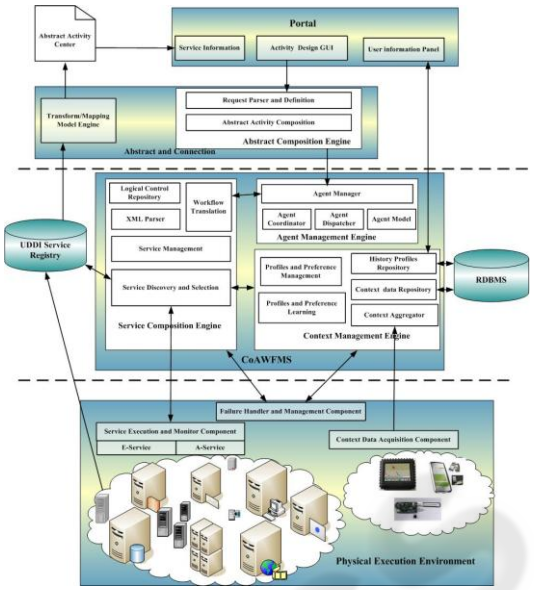

Figure 1: Overview of the System Architecture.

instance and matches appropriate service to an atomic activity.

It will consult Context Manager to bind the context-dependent information to each concrete service implementation.

Agent Management Engine: This module is supported by the IMAGO system [X. Li, 2006].

Context Management Engine: The major function of this module is to gather and process contextual information. History Profile Repository handles every activity performed by the nomadic user across a time span. Context Repository stores all information related to the mobile user and the user's environment. Context Aggregator is used to create new context space based on the existing knowledge and updates. Profiles and Preference Management provides the function of managing the explicit user profile and interest information in a canonical method. Profiles and Preference Learning automatically checks and updates context information through a learning algorithm, such as services and web sites visited frequently.

The bottom layer constitutes the Physical Execution Environment of the home server. In fact, it is a virtual machine specially designed for M-commerce applications.

4 A PROTOTYPE EXPERIMENT

The design methodology and system architecture discussed in previous sections are our ongoing

research project. In order to verify the feasibility of our design, we have conducted some preliminary experiments of system components and functions that are considered to be critical to the viability of our approach. We will use a simple example to demonstrate our experiment. Suppose that a mobile user wants to arrange a trip from Beijing to Shanghai. The trip schedule contains booking a one-way flight ticket, arranging airport pickup, making a hotel and a restaurant reservation. The trip reservation starts at the handhold device of the mobile user. At this stage, we have a simple GUI portal. It should be noted that the prototype at current phase is neither complete nor user friendly. It only serves as a meaningful means with visual representation and guidance to the mobile users for initiating an M-commerce application. In order to cope with context information and context reasoning, we adopt Jena Semantic Web Toolkit to simulate the workflow management module. In the prototype experiment, we defined four classes to simulate and verify the service discovery and activity execution.

Through this experiment, we believe that our proposed approach is capable of adapting existing techniques, such as web service, service discovery, etc., and generating sufficient information for context-aware workflow analysis.

5 CONCLUSIONS

In this paper, we presented the design and architecture which integrates mobile agent technology and context aware workflow to accommodate M-commerce applications. The novelty of our proposal is that it uses an ontological context model to provide personal and environmental contextual information and supports the composition of context-aware services. As a consequence, it not only utilises existing web service and service discovery protocol, but also employs mobile agents to achieve flexible network roaming for interactive services.

Even though we have completed a few critical experiments, the whole research project is still in its very early stage. Our next steps are to complete the workflow management system and to integrate the system with a mobile agent infrastructure. In addition, there are some aspects that should be further investigated. First, we shall study how to model user behaviour though data mining and reasoning, and how to predict the user's actions based on various profiles. Secondly, we will redesign the mobile portal in order to manage the limited computational resources of handhold devices and provide a user friendly interface. Thirdly, we will investigate the development of M-commerce agents with more intelligent decision-making and learning capabilities in the context of automated business transaction.

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