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## An Approach to Providing a Seamless End-User Experience for Location-Aware Applications

**Sastry S. Duri, Alan G. Cole, Jonathan P. Munson, James E. Christensen**
IBM Research Division
Thomas J. Watson Research Center
P.O. Box 704
Yorktown Heights, NY 10598

**Research Division**
**Almaden - Austin - Beijing - Delhi - Haifa - India - T. J. Watson - Tokyo - Zurich**

# An Approach to Providing a Seamless End-User Experience for Location-Aware Applications

Sastry Duri, Alan Cole, Jonathan Munson, Jim Christensen
IBM Thomas J Watson Research Center
30 Saw Mill River Rd., Hawthorne, NY 10532
{sastry, colea, jpmunson, ibmjim}@us.ibm.com

## ABSTRACT
With an increasing number of businesses considering the possibility of launching location-aware, mobile commerce applications, the quality of the end-user experience will become more and more critical. We propose *dynamic bookmarks* and *location domains* as mechanisms to give consumers simple and straightforward access to a dynamically changing set of location-based services. Dynamic bookmarks are descriptions of services, which are bound to actual, registered, services as a user's location changes. Location domains provide meaningful location context for location-aware services. We discuss the motivation and background of our work in progress, describe the key concepts involved, and present a system architecture we have adopted.

## Keywords
Dynamic bookmark, location domain, location-based services, location-aware applications, mobile computing, mobile commerce

## 1. INTRODUCTION
Location-aware applications or services are those in which the location of a person or an object is used to shape or focus the application or service. At this time, perhaps the greatest enabling force behind the growth of such services is the FCC mandate that wireless carriers in the United States be able to determine the approximate location of mobile phones making emergency calls. Another enabling factor is the growing worldwide deployment of GPS devices, both in automobiles and elsewhere.

As the technology to determine a device's location becomes more mature and more widespread, there is growing pressure—driven also by the need to recoup the investment in the wireless network required to satisfy the FCC mandate—to use it to benefit mobile commerce in the form of location-aware applications and services.

One of the essential characteristics of this new class of location-aware applications is a convenient and seamless end-user experience. This is especially true for mobile commerce, where the end-users are discretionary participants, and where they have the freedom to try other approaches or services.

### 1.1 Motivating Scenario
As a motivating example, we imagine a web-based, mobile-commerce application making use of location-aware services. We assume that a consumer has previously received a digital coupon from the national office of a retail chain (via e-mail, or perhaps as a notification through their wireless portal), and that this coupon is available on a handheld device such as a mobile phone or PDA. We then imagine that the consumer has an application that offers a set of services related to the coupon, and is aware of the consumer's location and the location of the retail locations where the coupon may be used. The consumer, if interested, may ask for driving directions from his or her current location to the nearest store, perhaps located in a nearby shopping mall.

Upon arriving at the mall, the shopper is given more detailed directions about which entrance is best and where the store is located within the mall. As the shopper enters the store itself, further details of the promotional offer are transmitted to the handheld device, together with directions to the aisle and shelf where the featured item may be seen.

Afterwards, the shopper may wander into other stores in the mall. As each store is entered, the shopper may request to see specials and featured items offered by the establishment, together with other information about the store and its services and products. If the consumer has, for example, a special interest in gardening and woodworking, then stores offering services or products in these interest areas will perhaps offer special incentives to the consumer. Within each store, the handheld device may be used to access a *Store Guide* providing not only general information about the store, but also information specifically tailored to the specific potential customer.

### 1.2 An Exploratory Simulation
In the above scenario, the consumer is offered a variety of services based both on the consumer's location and on the consumer's preferences. We constructed a demonstration application, with a Palm™ PDA running a small, custom-built browser as the handheld client. The server portion consisted of a set of Java servlets running on a desktop machine. In this demonstration, two location technologies were simulated, one assumed to work outdoors and the other indoors. In the simulation, as a consumer entered or left a building, a different simulated location technology would take over, and would cause customized web pages to pop up on the handheld device.

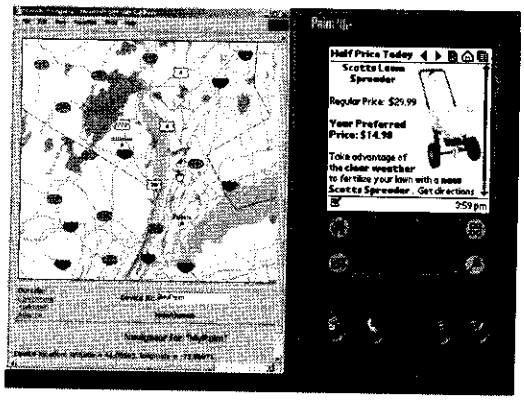


**Figure 1. Mobile commerce simulation.**

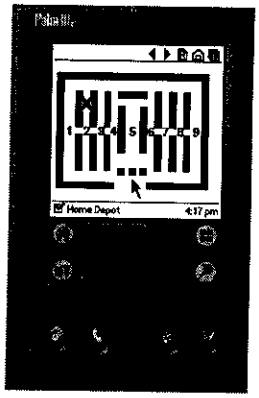


**Figure 2. Inside the store.**

Figure 1 shows a screen shot of the demo. On the left is a map used to simulate the user's geographical location; on the right is the digital coupon on the consumer's PDA. The consumer may request directions to the nearest store. Upon entering the store, the user's PDA displays a personalized welcome page listing the consumer's coupons. Tapping a link leads to a display showing both the user's and the product's locations on the store's floor plan (Figure 2).

Demonstrations of this mock-up to co-workers and clients were received with enough interest to encourage us to develop mechanisms through which such a scenario could be implemented in the real world, with real location technologies. This paper describes our progress to date.

### 1.3 Project Challenges

The development of an actual system to support the scenario above presents a number of significant challenges. At the technology level the challenges include session portability across different wireless technologies, availability of good indoor location technologies, and seamless transition between different location technologies. At the system level the challenges include registry structures for efficient lookups, new architectures to support service composition, and interoperability of constituent services such as map drawing and route computing. At the semantic level the challenges include development of extensible vocabularies that are machine understandable and expressive enough to provide meaningful descriptions of services. Finally, at the usability level, the challenge is to provide a seamless end-user experience—across different wireless technologies, location technologies, and organizational boundaries.

In this paper, our focus is on application and infrastructure issues involved in a mobile user accessing similar services when crossing organizational boundaries. Specifically, we are developing: (1) a *dynamic bookmark* mechanism to capture end-user service requirements, and (2) the *location domain* as an abstraction that will provide meaningful location context to services.

The rest of the paper is organized as follows. Section 2 gives some background on location technologies and location-aware applications. In section 3, we discuss issues contributing to the end-user experience. In section 4, we present a brief description of our approach. Section 5 describes the architecture we have adopted. In section 6, we present our conclusions, and detail possible future extensions.

## 2. BACKGROUND

In this section we provide some background to the current activity in location-based services. We briefly describe location technologies and some example applications.

### 2.1 Location Technologies

Location technologies may be roughly divided between those that work outdoors, and those that work indoors.

Outdoors (and with a good view of the sky), GPS has been available since the early 1980's. More recently, much work has been done on locating mobile phones with the aid of the wireless networks. Angle of Arrival (AOA), Time Difference of Arrival (TDOA), and location pattern matching are several techniques that are currently being explored.

Indoors location technologies are not yet as mature. The GPS receiver may not work indoors at all, and, even if the mobile phone does work indoors, a location accuracy of 100 meters or so may not be particularly useful in most indoor settings. Wireless micro-cells, wireless LAN access points (e.g., 802.11b), Bluetooth Local Positioning beacons, or Assisted-GPS [16] may all provide eventual answers, but none is widely deployed at the current time.

### 2.2 Example Applications

The number and variety of location-aware applications is growing rapidly. Here we give just a few examples.

*Localized yellow pages* are now commonplace on the web. These services allow a consumer to search for businesses of a certain type near a certain location. In most cases, the location is now entered manually, but providing the location automatically could make use of these services easier and more efficient, especially if the consumer is in an area that he or she does not know well.

Another increasingly common location-aware application is the *automotive navigation/routing system.* Based on GPS, these systems typically provide driving directions from a start point (or the current location) to a desired destination, and can show maps of the current area.

*Personal locator services* such as finding a mentally impaired relative, a lost child, or a criminal are becoming commercially available [9]. In general, such services equip the individuals to be

located with a device that is capable of reporting the individual's whereabouts back to a monitoring station almost instantaneously.

*Location-based advertising* is another service which is just beginning to be technically possible, and which has seen some early test marketing. If the location of a mobile phone can be detected, then it is possible to make special promotional calls (or send messages to WAP phones) when the consumer is in proximity of a particular business.

So far, there are few commercially deployed location-aware applications that use indoor location. One example of such an application is *asset tracking*, in which RF tags are applied to items (shipping containers, pallets, or cartons). Inventories can then be updated and packages tracked, all automatically.

## 2.3 Related Work

The past decade has seen a steady increase in research efforts in the area of context-aware applications, and in the special case of location-aware applications. An overview of this work is provided in [5], and [3] provides a categorization of some "compelling" applications in this field. A survey of context-aware applications is given in [8]. The GUIDE project [4] has also influenced our thinking on application structure.

The work of Narayanan on realms and states [11] has helped to shape our view of location domains, and [10] also emphasizes the importance of integrating various location technologies.

In [15] Varshney *et al.* present a mobile commerce framework to simplify the design and development of mobile commerce applications.

The work of Manuel Román *et al.* [13] focuses on enabling access to services from many different devices. This they achieve by having a single XML file describe both the service functionality and the user interface in a device independent manner, and using a device specific XSL style sheet to map user interface components to platform-dependent resources.

The PIMA project [1] addresses issues in mobile application sessions, specifically in handling sessions that are transferred from one device to another. The project focuses on, for example, how to transfer the session of an application running on a WAP phone outdoors to a corresponding application running 802.11b-enabled PDA indoors.

# 3. ENHANCING THE END-USER EXPERIENCE

One of our goals is to be able to provide location-aware applications which continue to function as the handheld device is carried from work to home, to the mall, in the automobile, on trips, and wherever the end-user goes. There are at least four aspects to providing this seamless end-user experience.

## 3.1 Wireless Communication Mobility

As the device is carried from one wireless access point to another, whether of the same or different type, IP sessions should be handed off transparently. This is outside our scope of work, and is being provided in any case by other efforts.

## 3.2 Integration of Location Technologies

As the device is carried from outdoors to indoors, or from one indoor establishment to another, it is quite possible that the underlying location technology will change. Outdoors, a Bluetooth-enabled mobile phone might be a device whose position is determined by the wireless carrier's network. Indoors, the device may become self-positioning through Bluetooth local positioning protocols. In any case, location information should be available to the application through the same methods and APIs.

A location service, such as the one proposed in [10] addresses this issue.

## 3.3 Seamless Roaming across Organizational Boundaries

Yet another barrier to the ability of a location-aware application to operate seamlessly is presented by the boundaries among organizations. When a shopper wanders from one store to another, or leaves work for an airline trip, a number of organizational boundaries are being crossed. If a commercial establishment wishes to offer promotions, specialized directions, or e-coupons to shoppers within its boundaries, and if this is to be done smoothly, then the infrastructure must help to make this possible. For a seamless end-user experience it is desirable to preserve the user's interests across organizational boundaries.

## 3.4 Automated Service Discovery

We expect a tremendous growth in location-based service offerings. In the future, at a given location, there may be multiple overlapping location-based services at any one time, each offered by different organizations. There may be an overall Mall Guide, individual Store Guides for each establishment within the mall, a City Guide for tourists, a Traffic Guide offered by the Department of Transportation for motorists, and an Office Guide provided by an enterprise for the internal use of its employees. Each of these many Guides would offer a variety of services in the spirit of [4]. Therefore, there is a need for automated discovery of services.

# 4. APPROACH

To provide a seamless end-user experience across organizational boundaries we need to detect when a mobile user crosses such boundaries, and to be able to determine automatically the identities of organizations and entities within whose boundaries they are currently located. In this way, a much smaller menu of currently relevant information sources, based on current location as well as other attributes such as time and user profile, can be offered to the consumer.

One approach we have been investigating is the use of what we call *dynamic bookmarks* and *location domains*. Mobile users specify their requirements for services using dynamic bookmarks. Services describe their characteristics in terms of user specifiable requirements. A location domain serves as a unifying frame of reference for deploying related, inter-operable services. In addition, it captures the geographic characteristics of the services deployed in it. As a device enters one of these location domains, it can use service discovery to find a proximate location-aware service and connect to it for local information.

We are currently in the process of building a system to explore these ideas.

## 4.1 Dynamic Bookmarks

A dynamic bookmark is very similar to a regular browser bookmark. Just as a regular bookmark provides access to a web resource indicated by the associated URL, so too a dynamic bookmark provides access to a web resource associated with its

**Table 1. Sample dynamic bookmark entries**

| Bookmark Name | Attributes | Preferences | URL |
|---|---|---|---|
| Garden Center | Type = Nursery and Garden Centers<br>Services = product reservation<br>Capabilities = routes, store locator | Profile release = no<br>Partial match = yes | http://gardenworld.com |
| Store Guide | Type = Nursery and Garden Centers<br>Services = store guide<br>Capabilities = product locator | Profile release = yes<br>Partial match = yes | NONE |

URL. There are a few important differences, however. The URL associated with a dynamic bookmark may vary from location to location. The application detects location changes and updates the URLs associated with dynamic bookmarks. Also, each dynamic bookmark is associated with a set of attributes that are used to find matching URLs at a given location. Finally, the process of matching dynamic bookmarks with corresponding URLs is triggered by changes in the user's location.

Table 1 shows sample dynamic bookmark entries. Each of these entries includes a dynamic bookmark name and dynamic bookmark attributes. For each bookmark a user may specify preferences to indicate whether to release personal profile information, or to accept partial matches, and the order in which attributes should be matched. The URL field could be empty if no URL matching the attributes of the dynamic bookmark is found.

Services describe their functionality, and other characteristics in terms of user specifiable terms. We believe initiatives such as the one proposed in [7] to facilitate seamless B2B and B2C electronic commerce will yield the standard vocabulary needed for attributes and their values. For illustration purposes, consider an attribute set consisting of {type, capabilities, services} which may be adequate to characterize a consumer's m-commerce needs. The attribute type specifies the type of establishment in which the consumer is interested; its values could range over the category descriptions found in North American Industry Classification System [12], for example, "Nursery and Garden Centers." The attribute capabilities specifies location-based capabilities of the service. These, for example, could include a nearest store locator, product locator, facility locator, directions, and route planning. The attribute services describes available customer services. These include, for example, product reservations, special promotions, online checkout, and remote purchase.

Table 2 shows sample entries in a service registry. Each entry in the table includes a URL, and its attributes. The attributes shown in Table 2 are examples of attributes that may be associated with a service entry. Further, an entry may optionally contain service preferences, and coverage. A service preference enables a service to express its preference for the requester of its services. Service preferences include criteria such as credit rating, financial worth, employment status, educational qualifications, marital status, customer status, health status, driving history, etc. Coverage specifies the geographical region of coverage for the URL.

Two emerging trends bode well for the above scenario. First, the web community is shifting its focus from producing content for human consumption to programmable web, i.e., delivering services over the web through service discovery, and ad-hoc composition of web services [17]. Second, there is a growing realization that machine understanding of web content is a must for intelligent service delivery. Multi-disciplinary efforts, drawing researchers from the fields of knowledge representation, ontology, and agents, are underway to facilitate machine understanding of web content [1].

The full potential of the dynamic bookmark abstraction can only be realized when the bookmark-matching process is initiated in response to a change in the user's location. In order to be effective and meaningful, the location changes should be represented by higher-level abstractions.

## 4.2 Location Domains

Cyberspace has no boundaries. But real businesses do. For example, a restaurant's delivery service delivers food to certain areas in its neighborhood. This information is important to consumers in making choices. Thus, our notion of location-based services is that location context is bi-directional information between service providers and consumers—that is, it is important both in how a service serves consumers, and in how consumers choose their services. Hence, in our approach, services describe their location and, optionally, coverage area in addition to the

**Table 2. Sample service registry entries**

| URL | Attributes (Mandatory) | Service Preferences (Optional) | Coverage (Optional) |
|---|---|---|---|
| http://gardenworld.com | Name = Nursery and Garden Centers<br>Type = appliances-household<br>Services = special sales<br>Capabilities = routes, store locator | User type = generic | "All" |
| http://gardenworld.com/storeGuide | Name = Store Guide<br>Type = Nursery and Garden Centers<br>Services = store guide, online checkout, special sales<br>Capabilities = product locator | User type = preferred | "Inside store" |

characteristics of their service. To serve this need in the context of the scenario above, we developed the construct of *location domain*.

In the scenario, the consumer travels from his or her home to the mall, aided by driving instructions from a guide service received through their PDA. The consumer then enters the mall and is again aided by a mall-specific guide service in order to get to a particular store. Once in the store, another, store-specific, guide service directs them to the product of interest. In our approach, the store, the mall, and the larger world are each a *location domain*. Specifically, a location domain:

1. Has a well-defined geographical area;
2. Hosts a set of resources related to that area;
3. Provides a frame of reference in which each resource locates itself;
4. Offers core services related to the frame of reference, such as computing distance between points and determining routing from one point to another;
5. May contain other location domains.

The mall domain is located in the *world* domain, which is the root domain—the domain that contains all other domains. An organization would create a subdomain in order to offer services that are specific to the subdomain and are only relevant within it. Medical centers and universities may wish to do this, for example. This hierarchical relation of domains is illustrated in Figure 3.

Domains may use different means of describing location. The *world* frame of reference will use a geographically-based system such as latitude and longitude, while a store may use aisle number. A resource's description of its location within a domain may be a point or a region. A bus service, for example, may describe its location as the region it serves, while a bookstore may use a point location.

We believe that, in the future, the concept of location domains may be extended to a more powerful construct that would allow arbitrary relations to be established. This would facilitate more sophisticated reasoning about services, in the manner of the *realms* mechanism described in [11].

## 5. SYSTEM ARCHITECTURE

The architecture for the system we are building is shown in Figure 4. The *Client* is a standard browser, and may use either HTTP/HTML or WAP/WML. The *Wireless Gateway* provides wireless connectivity, authentication, and subscriber and device management. We are currently using IBM's WebSphere

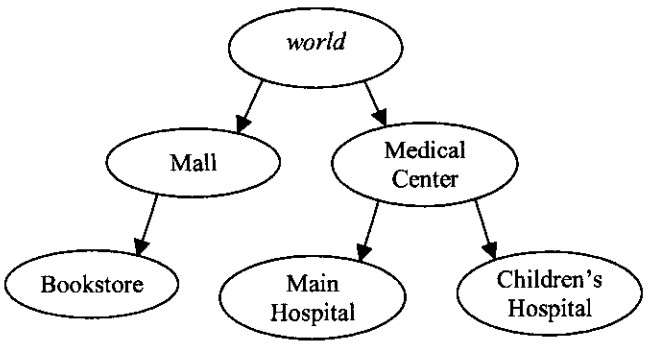


**Figure 3. Hierarchical location domains.**

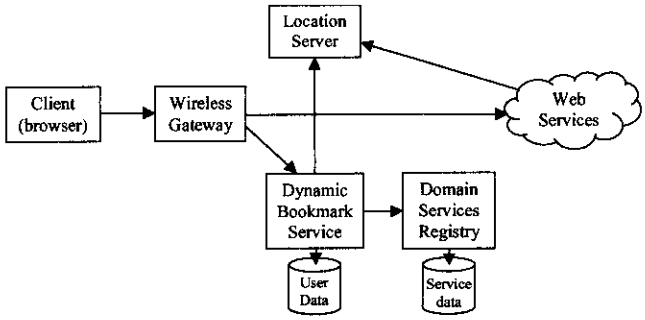


**Figure 4. Architecture for location-aware services.**

Everyplace Suite™, which also provides content transformations to HTML or WML, including image adaptation. The *Location Server* provides a single, uniform interface to the various location technologies mentioned earlier. The location server we are using is an IBM Research effort and is not described in this paper.

We are building the *Domain Services Registry* (DSR) using an implementation of a UDDI registry [14], which is included with the Web Services Toolkit from IBM Alphaworks [6]. The registry contains a descriptor for each service registered within it. The descriptor specifies a service's location, coverage area, and characteristics, as described above. We are currently evaluating suitable vocabularies for these names and values.

*Web Services* are implemented with a SOAP interface, and are also built with the Web Services Toolkit. Accessing a service may require authorization, which is supplied by an *Authorization* service (not shown). Services that require the consumer's location request it from the *Location Service*. Services are responsible for maintaining the address of a consumer's location service in their own subscriber records.

The *Dynamic Bookmark Service* (DBS) executes dynamic bookmark lookups on the Domain Service Registry on behalf of the user. A subscriber's set of dynamic bookmarks are stored by the DBS and are re-evaluated, using name/value matching as described above, as the subscriber's location changes. The DBS determines a change of location by periodically querying the Location Service. If the location has changed, the DBS then re-evaluates the user's dynamic bookmark set via queries to the DSR, using the new location as part of the query.

The location element of matching is based on proximity. The DBS looks for matching services within a rectangular area around the user's location. Users may choose the size of the area through a "zoom" control.

A dynamic bookmark may not match anything within the most immediate (innermost enclosing) domain. The DBS will then query the DSR of the parent domain, until either a match is found, or the *world* domain has been reached.

## 6. CONCLUSIONS

In this paper, we have presented a dynamic bookmark mechanism that enables users to express their needs as attributes of a dynamic bookmark. Later, these attributes are matched against a service registry to find the URL of a matching service, which is then bound to the dynamic bookmark. This way the user can focus on

characterization of his/her needs, which is a one-time process, and leave the burden of finding services to the application.

Motivated by our earlier simulation, we are currently in the process of implementing these ideas. Our approach relies heavily on the efforts of others to standardize vocabularies for service description and discovery.

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