A Testbed for the Exploration of Novel Concepts in Mobile Service Delivery

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***Abstract*—This paper describes an open, extendable, and scalable system that supports the delivery of context-dependent content to mobile users. The system enables users to receive content from multiple content providers that matches their demographic data, active profiles, and context such as location and time. The system also allows users to subscribe to specific services. In addition, it allows users to provide their own content and services, by either using the system's publicly available interface or by filling out one of the service-configuration templates.**

I. Introduction

The Internet has recovered from the dot-com crash of the early 2000's and is now bustling with activity. New and innovative technologies and services appear at a rapid rate. For example, services that cater to our needs for factual information include Wikipedia and a host of news sites. For images, there are services such as flickr.com, photo.net, and plazes.com. For music, there is last.fm, pandora.com, and The Hype Machine. For video, youtube.com is probably the most visible. Many services utilize a variety of community concepts. Wikis, blogs, and RSS feeds are everywhere. Many services are fueled by Google-like business models where services are made available on a global scale and are free to their users, being paid for instead by means such as advertisement [10].

It is time for the conventional Internet to go mobile. In particular, new generations of Internet-enabled mobile devices are emerging that will offer an attractive infrastructure for the deployment of the mobile Internet.

The positions of current mobile phones are often known with considerable inaccuracy—only the location of the base station in the cellular infrastructure being used may be known. In contrast, current navigation systems use quite accurate GPS-based positioning, but lack Internet connectivity. We expect the next generations of these types of devices to melt together, yielding navigations systems with Internet connectivity and phones with GPS-based positioning. The boundaries between Personal Digital Assistants, mobile phones, and navigation systems will increasingly become blurred, and we will simply use the term "mobile phone" to represent these devices.

Whereas, e.g., YouTube and Flickr, support the sharing of video and photos, we envision a system that supports the sharing and delivery of services in a mobile setting. In particular, the system described in this paper aims to serve as a testbed for the exploration of data management techniques that are needed in order to fuel a portal that supports the sharing and delivery of context-aware mobile services. In part because the system needs to evolve as it is being used, the system is designed to be open and extendable.

The system supports the matching of content that is known to the system against the users' demographic data, active profiles, and dynamic context, such as time and location.

In addition, the system enables publish/subscribe scenarios. Users can supply their content streams to the system using a publicly available interface, or by using one of the templates supplied with the system. These templates also allow easy setup of output streams that utilize the available input streams. Examples include email, RSS and blog push.

The context-dependent delivery of services to mobile users is the subject of numerous papers. Most papers study specific aspects of the overall task of service delivery. Such aspects include stream management [5], [8], context matching [2], [11], information delivery, publish/subscribe functionality [11], spatial tracking [4], route management [1], and support for specific queries such as Nearest Neighbor queries [9].

The system proposed here is unique in how it provides a complete set of components for the context-dependent delivery of content, rather than a subset or a specialized solution. The components are exchangeable, e.g., the system's context-matching component can easily be exchanged and new content delivery methods can be added.

Section II briefly describes the rationale for the proposed system. Sections III and IV cover the system's functionality and architecture. Finally, Section V concludes and identifies research directions.

II. Outlook

This section offers our views on the near-future conditions for the deployment of mobile services, including mobile content delivery.

Most new mobile phones are Internet-enabled, i.e., they have built-in data communication capabilities. The bandwidth is currently limited to well below 100 kbit/s for GPRS and EDGE [3] networks and below 400 kbit/s for 3G [12] networks. With the introduction of HSDPA [13], with up to 14.4 Mbit/s, and Wimax [6], with realistic speeds of up to 10 Mbit/s, this is slated to change.

The current pricing for mobile Internet access, often in excess of 1€/MB, remains quite high. Flat-rate subscriptions are possible with some mobile providers, but again at a relatively

high price. We expect this to change in the future—flat-rate subscriptions probably will be priced near today's wireline broadband subscriptions. However, substantially cheaper mobile Internet access may still be some years away.

Next, we also expect support for navigation to find its way into mobile phones. Some such devices already exist, e.g., the HP iPAQ hw6915, and others have been announced, e.g., the Nokia E95, which is expected to be available by the first quarter of 2007. These are high-end phones that will have a quite modest market penetration for several years to come.

In step with the proliferation and increasing sophistication of the infrastructure for mobile services and content delivery, we anticipate an increasing demand for up to date content. This may be due to business or professional reasons, but other reasons such as social identity and status are also likely to play important roles. Users will require much more advanced features than simple RSS-based subscriptions.

We also expect users to demand convenience. Users do not want to use multiple systems in order to retrieve the desired information, as is the case today.

Finally, information overload will remain a trend in society. People are exposed to increasing amounts of information, and there are no signs of a slowdown.

Based on an outlook as described briefly above, we aim to design and prototype platform technologies for mobile service delivery that:

- Works at low bandwidth and enables low-cost communication.
- Works with low-end mobile phones, e.g., offering alternatives to GPS-based geo-positioning.
- May serve as the foundation for an open and regulated portal for the sharing delivery of mobile services.
- Enables the filtering and push-based delivery of content based on the user's context.

The system described in this paper aims to serve as a testbed for exploring such technologies.

III. Platform System Functionality

Figure 1 illustrates the overall functionality of the system. The system takes as input content streams from a number of service and content providers. To avoid spam and illegal content and services, the providers are screened before they can publish to the system.

The system also permits its users to subscribe to third-party services. Such services are expected to deliver specialized content to the framework, e.g., corporate news, sensor readings, or surveillance information. The platform system has a public interface that enables the creation and delivery of such services via the platform. Users must explicitly subscribe to the individual subscription services available.

The portal that exposes the system's functionality to its users contains a number of templates that allow the users to create subscription services that they can subsequently use themselves or share with other users. This enables easy creation of useful services. For example, one template allows users to define their own email services that pushes their email to their mobile phones.

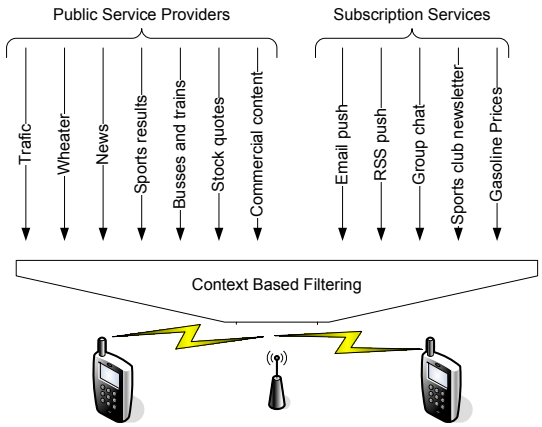

Fig. 1. Overall System Functionality

The system also allows service providers to plug their own templates into the portal. The portal then allows users to create, and subsequently use and share, services that are delivered by the service providers. For example, it might be natural for a company to supply a more functional version of the email service to its employees by using this functionality. Another example is a service that pushes information about discounted gasoline prices to users based on their locations. A user can specify both a discount and a distance threshold, e.g., a 10% discount compared to the list price and a distance of 5 km. Whenever the user is within 5 km of a gas station that sells gas with at least a 10% discount, the user is notified and, possibly, directions are given. This kind of service is enabled by allowing service providers to subscribe to the current position of a user.

The framework uses push technology [7] for the delivery of information in real time. (The next section offers some detail on the implementation of this.)

The content delivered to a phone is simple and flexible: it consists of a headline and either a piece of text or a URL specifying the location of additional content. This allows for inexpensive delivery of text-based content such as emails, stock quotes, or RSS feeds, while also supporting rich content such as photos, formatted text, and other HTML-based content. On the phone, the headlines of incoming content are shown in a list. When selected, the content is shown in a browser. Text is simply displayed, and URL content is fetched and displayed in the browser. This simple message-based approach has shown to be very useful.

While we believe that the use of list-based navigation fits well with the mobile use situation, user-interface design is orthogonal to our focus.

To enable users without GPS to use location-based services, the system makes it possible for the users to manually specify their current locations. The portal allows a user to define a number of locations on a map, e.g., home and work. The user can then choose among these locations when mobile.

IV. Platform System Architecture

Figure 2 offers a high-level illustration of the system's component architecture. The components communicate using sockets, which contributes to obtaining a decoupled architecture where components may easily be replaced. The use of sockets also allows for more flexible scaling of the system in comparison to the use of ordinary object-oriented message passing.

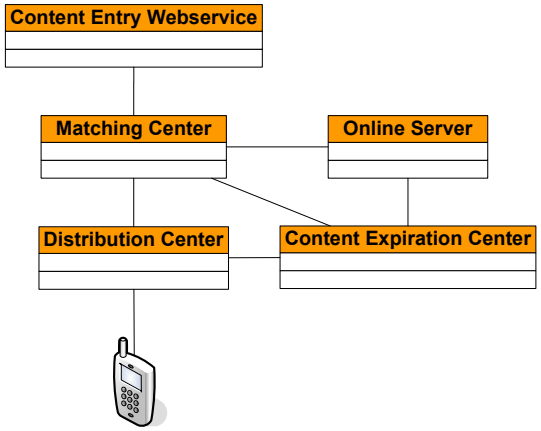

Fig. 2. System Architecture

Users can choose between several connectivity options when using the system. Content arrives though the *Content Entry Web-service* component at the top. The content is passed to the *Matching Center* component, which accesses a list containing the online users, including their active profiles and current locations, from the *Online Server* component. Demographic data are retrieved from a user database. Based on this information, the *Matching Center* determines which users should receive which content. The *Matching Center* is only concerned with the users that are currently online.

The content and a list of the users who should retrieve the content are sent to the *Distribution Center* that then sends the content to the users specified. Users have several connectivity options, including pull and push-based content retrieval. In most cases, push-based delivery is superior with respect to both cost (the average number of bytes sent per message) and delivery time (the time between arrival at the server and delivery at the client). Push-based delivery can be handled in two ways: by running a server application on the clients or by keeping an open connection to the clients. Due to firewall constraints imposed by mobile-service providers, only the latter solution works in most real scenarios.

With the pull-based solution, the clients regularly query the server for new content. This implies serious overhead on the server because most requests do not return new content. The solution is also more expensive for the user in most scenarios. If a user has a "pay as you go" subscription, which most GPRS users do, the solution is approximately 2 orders of magnitude more expensive than the push-based solutions.

In addition to directly delivering content to online users, the system includes a *Content Expiration Center*. This component caches incoming content and delivers it to suitable users when they come online. The content providers can provide a time-to-live attribute in the content meta-data (defaults to immediately) specifying the time frame in which the content is relevant.

V. Conclusions and Research Directions

This paper presents a demonstration of a platform system for the context-dependent delivery of content to mobile users. The system is intended to serve as a convenient testbed for the experimentation with novel concepts in mobile-service delivery. The system is unique in its support for user setup and customization. It offers novel interfaces for service providers and subscription services, and it employs novel push-based delivery mechanisms.

The platform system is an evolving system, and several directions for future research exist. It is relevant to improve the context matching component, to allow for more advanced matching. In conjunction with this, we are integrating efficient tracking of a user's current location into the system, as well as a route prediction solution that allows the system to use a user's anticipated route and destination as context. Concerning context matching for subscription services, support for new and advanced stream queries that will allow users to retrieve very specialized content are desirable. These include aggregates, time dependent, and multi-stream queries. To achieve widespread use of advanced stream queries, a high-level, or even graphical, context matching language is desirable.

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