Mobile Computing, Web Services and the Semantic Web: Opportunities for M-Commerce

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Abstract. This paper focuses on the intersection of mobile computing, the Semantic Web and Web services, and examines how these technologies serve as a foundation for an architectural framework that provides new opportunities for mobile commerce and services within organizations. Mobile technologies introduce several advantages that cannot be attained through conventional wired connectivity. These include localization and personalization, which allows the delivery of customized information to users based on locale, identity or a user role. Two technology initiatives that hold promise in helping realize the potential of mobile computing are the Semantic Web and Web services. The Semantic Web is an initiative supported by the W3C intended to support semantic meaning and context for Web resources. Key technologies include RDF and DAML for data categorization and inference. Web services represents an approach for applications to communicate with each other automatically over the Web using standard Internet protocols. Collectively, these technologies open up new possibilities for leveraging the capabilities of mobile computing where the Semantic Web supports contextual meaning and Web services technologies allow registration and discovery of services based on mobile context.

1. The Web and Mobility

Mobile computing is moving into a phase driven by high-speed bandwidth and increasingly powerful device technologies. The auctioning of global spectrum to support new, high speed third generation (3G) wireless networks is now giving rise to high speed, multi-media Internet access to cell phones and wirelessly-enabled PDAs. The rollout of 3G technologies and the emergence of wireless LAN technologies are now important drivers for mobile commerce.

At the same time, device capability is increasing. Devices capable of increased processing power are coming to market and the availability of Java on wireless devices is opening new possibilities, not only for delivering data to mobile devices but for using those devices to deliver information to the enterprise in new ways. The Java 2 Micro Edition (J2ME) [1] allows developers to use Java to develop applications for mobile devices including cell phones and PDAs. Companies making use of J2ME include Research In Motion (RIM), with its Blackberry two-way handheld devices; Korea's Lucky Goldstar, with its J2ME-based CDMA mobile phones; Sega with Personal Java for its Dreamcast consoles; Nokia with its EPOC-based mobile phones; and Sony with its mobile phones.

1.1 Localization and Personalization

Among the unique features of mobile computing are localization and personalization. Localization is the ability to locate wireless devices using either global positioning (GPS) or through cellular technologies that pinpoint location to within several feet. The ability to locate subscribers, coupled with the delivery of personalized information, is viewed as an important aspect of wireless service for both consumers and employees.

From a consumer perspective, localization provides opportunities to deliver information to travelers about nearby restaurants and hotels. For businesses, localization allows companies to track workers across a wide region and improve company efficiencies. But the real impact is expected when mobile data sources serve as data providers to organizations.

The other unique aspect of wireless is personalization. Because wireless network providers already track user identity for billing purposes, applications can leverage this information to personalize content based on user preferences and/or patterns of usage. While technology forecasts predict significant revenues from wireless technologies, the caveat is that the mobile Internet will succeed only if applications are developed that can take advantage of the unique characteristics of wireless.

Work by Hjelm [2] has focused on the importance of context in accessing data from wireless devices. In a mobile environment, users do not have the time to conduct extensive searches while on the move. Mobile users require that supporting systems understand who they are, where they are located and to deliver appropriate information on demand. Solutions centered around Composite Capability/Preference Profiles (CC/PP) [3] allow parameterized requests to be sent to servers that contain both documents and user profiles that can help systems transform data for relevant and efficient delivery over wireless networks.

2. XML and Mobile Commerce

One of the foundational building blocks of the Web is XML [4]. Most IT departments have at least been tracking the Extensible Markup Language (XML) over the past several years. During that time XML has emerged as the primary technology for building bridges between different systems. XML's successes include its use as data exchange language between brokerage firms' account systems and various stock exchange order systems.

XML is finding increased utility in the wireless world. It is the basis for WAP, the Wireless Markup Language and is also used as the basis for XHTML, the next generation XML-compliant HTML that both WAP and i-Mode will be transitioning to in the near future, thus strengthening the connection between wireless and XML. In addition XML also is playing a major role in the middle tier through XML data storage that is used as the source for a wide variety of clients and display types. It's common to expect a wireless strategy to support many different types of clients that expect HTML, WAP, i-Mode, Palm Query Applications, AvantGo, Text, SMS, Paging, or even XML content.

One key technology supporting XML for wireless devices is XSLT, the Extensible Stylesheet Language Transform [5]. XSLT supports the Model-View-Controller architectural style [6] where application data may be separated from specific display requirements. As illustrated in Figure 1, XSLT templates can be used to store the markup language-specific content (i.e. HTML, WML, etc.) and are 'applied' to the XML using an XSLT processor.

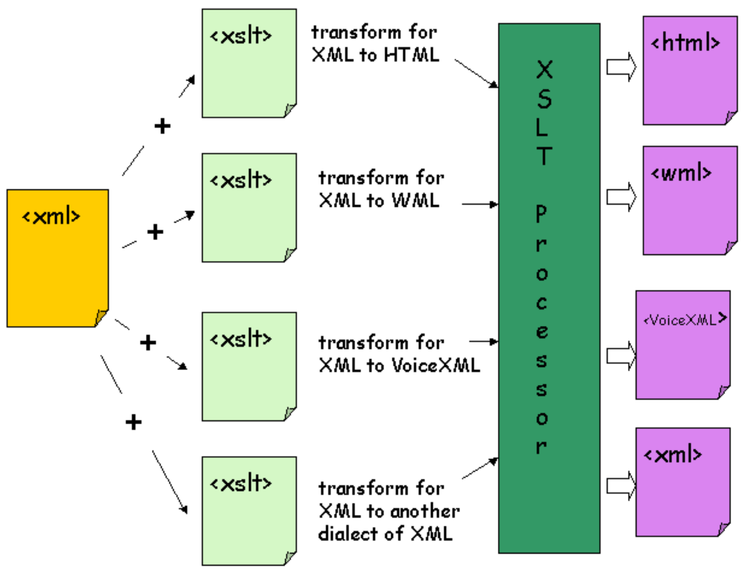

Fig 1. XML maybe used to generate output for a variety of different wireless platform through the use of XSLT

However, XML alone has limited capability to describe the relationships (schemas or ontologies) with respect to objects. This is where the use of ontologies provides a powerful way to describe objects and their relationships to other objects and has opened up new ways of thinking about ways to integrate mobile computing with conventional web access. One such initiative is the Semantic Web.

3. The Semantic Web

As wireless networks extend the reach of the Web, there is increasing need to add meaning to the data that is both delivered and generated. This fact has not been lost on the W3C which has been pursuing the concept of a Semantic Web - an extension of the current web in which information is given well-defined meaning, better enabling computers and people to work in cooperation. [7]

The goal of the Semantic Web is to support the mapping of existing and future systems onto the Web, preserving the universality of the Web while supporting localized domains. Organizations, for example, should be able not only to search the vast wealth of resources available across the Web but also to restrict search among partners and suppliers. To accomplish this requires an understanding of context. One of the important technologies for providing flexible, context-sensitive data descriptions on the web is RDF, the Resource Description Framework [8].

3. 1 RDF

RDF is an XML-based technology for managing context on the Web. It accomplishes this through the expression of constraints whereby all objects, relationships, types, and assertions are treated as first class objects. First class objects means that both objects and relationships have their own URIs and are thus not constrained in how they may be combined with each other. By giving first class identifiers to types, relationships, and assertions, it is then possible for a Semantic Web to permit context to determine the trustworthiness of the statements. Thus, it is not the intent of the Semantic Web to codify truth but rather to provide structures that allow truth to be evaluated in the context of each application. These are not new issues. The commerce and financial communities have evolved techniques to manage exchange of information without requiring perfect trust [9] with the same issues reappearing on the Web.

However, RDF is only a starting point for representing semantic information that can be used to support the exchange of knowledge on the Web. Key research questions include how to generate semantic descriptions, how software agents can discover these descriptions, and how agents integrate information from different sites. Efforts to address these issues may be found in the work of Heflin and Hendler [10] and Frankhauser [11] who have developed tools for using RDF to describe computer science knowledge and the role of semantic annotations for reusable fragments of course material.

Recent work has used RDF as a base technology to extend RDF descriptions to allow new inferences. DAML, the DARPA Agent Markup Language, [12] has been developed as an extension to XML and the Resource Description Framework (RDF) with the goal of enabling the generation of new information-based descriptions of entities.

3.2 DAML

DAML opens up the possibility of making inferences over limited domains. For example, using DAML descriptors, one can assert that "Parenthood is a more general relationship than motherhood." and "Marge is the mother of Bart" which taken together allow a DAML processor to conclude that "Marge is the parent of Bart" even though the explicit fact is not declared anywhere in a database. The latest release of the language, DAML+OIL, [12] provides a rich set of constructs with which to create ontologies and to markup information so that it is machine readable and understandable.

4. The Emergence of Web Services

While a Semantic Web offers the possibility of supplying context for mobile computing, the unique character of mobile networks opens up new opportunities to leverage the emerging Web services frameworks centered around asynchronous, message-based middleware [13]. Web services represents a shift in distributed computing from tightly-coupled networks to a more loosely-coupled architecture that is well suited to the addition of mobile networks and devices.

There are three major aspects to Web Services:

- A ***service provider*** *who* provides an interface for software that can carry out a specified set of tasks.
- A ***service requester*** who discovers and invokes a software service to provide a business solution. The requestor will commonly invoke a remote procedure call on the service provider, passing parameter data to the provider and receiving a result in reply.
- A ***broker*** or ***repository*** that manages and publishes the service. Service providers publish their services with the repository and request access to those services by creating bindings to the service provider.

The Web services technical infrastructure ensures that services even from different vendors will interoperate to create a complete business process. Web services accomplishes this by defining new ways of interacting through the registration, discovery, and connection of software packaged as Web services. While still in its early stages, Web services holds the promise of extending the Web from an infrastructure that provides services to humans to one that provides services to software looking to connect with other software. For IT organizations and end users, Web Services makes possible new ways of thinking about the enterprise, working with partners and suppliers and doing business over the Web. For mobile users these opportunities include the following.

Corporate Intranets. The Web Services model of discovery and connection makes it possible to use standard web technologies to promote communication and information distribution within the organization.

Partners and Suppliers. Web Services opens up similar opportunities for connecting between partners and suppliers. For example, by defining an interface that describes how to access inventory data and publishing that interface on a server available to trusted partners, a company can make timely information available to other companies without requiring that partners share a common network. All that is needed is an Internet connection and an agreement to share data on controlled access servers.

Internet-based e-commerce. By publishing a Web service interface on publicly available server repositories, companies can tap into a global base of Web services-aware clients who will be scouting repositories for matches to their needs. This ability to describe functionality as a service interface also opens the door to new uses for legacy systems.

4.1 Web Services and Mobile Commerce

Understanding the implications of Web Services for companies looking to leverage mobile computing technologies, means realizing that Web services is at once an architecture-driven technology and a process. As a technology it represents a set of protocols that builds on the global connectivity made possible by the Internet and open Web standards such as XML. As a process, it's an infrastructure that supports software discovery and connection over the Web and that is part of a growing realization that the decentralized, loosely coupled, synergistic nature of the Web can't be ignored.

4.2 Technology and Architecture

The technology driving the Web Services revolution is the web itself. Until now the web has acted primarily as an information resource for human users connecting to servers around the world and following links to resources and information. Web Services means taking this capability to the next level so that software can search for services and obtain desired service functionality just as simply as users click on web links. The potential of such connectivity is enormous since it means a move away from reliance on network-limited systems and makes it possible to build systems more reliably so that requirements such as robustness and maintainability may be addressed [14].

Behind the move to Web Services are three main technical drivers:

1) XML - the tag-based language for supports the creation of industry-specific data vocabularies and that is itself supported by numerous auxiliary technologies for display, data typing and transformation.
2) HTTP - the web protocol used to deliver documents, pictures and all forms of media across the web. HTTP's role in Web Services is that it can be used to pass XML data while ignoring details of programming language, platform or operating system.
3) SOAP – the XML-based protocol that can be carried by HTTP to any web server. SOAP is the XML glue that lets clients and providers talk to each other and exchange XML data using HTTP, or even file transfer (FTP) or mail (SMTP) protocols. SOAP also brings to the table a set of rules for moving data through a network so that multiple recipients can contribute to the data flow.

The cumulative effect of these technologies is a fundamental change in how we now think about distributed computing. Prior to SOAP, doing distributed computing interaction options meant choosing from a palette that consisted of either Microsoft's Distributed Component Object Model (DCOM), Java's Remote Method Invocation (RMI), or the Object Management Group's Common Object Request Broker Architecture (CORBA). While these technologies are still in widespread use today, their primary drawback is that they limit the potential reach of the enterprise to network nodes that share the same infrastructure. With SOAP, however, the potential space of interconnection is the entire Web itself. This is why there is such intense interest in XML and SOAP. It is out of this new capacity for interaction that Web services emerges and opportunities for M-services arise.

4. 3 The Process

While the various technical forces (XML, HTTP, SOAP) lay the groundwork for platform independent software interconnection, there still remains the problem of how software systems can actually begin to communicate with other software systems written in different languages and running on the different platforms.

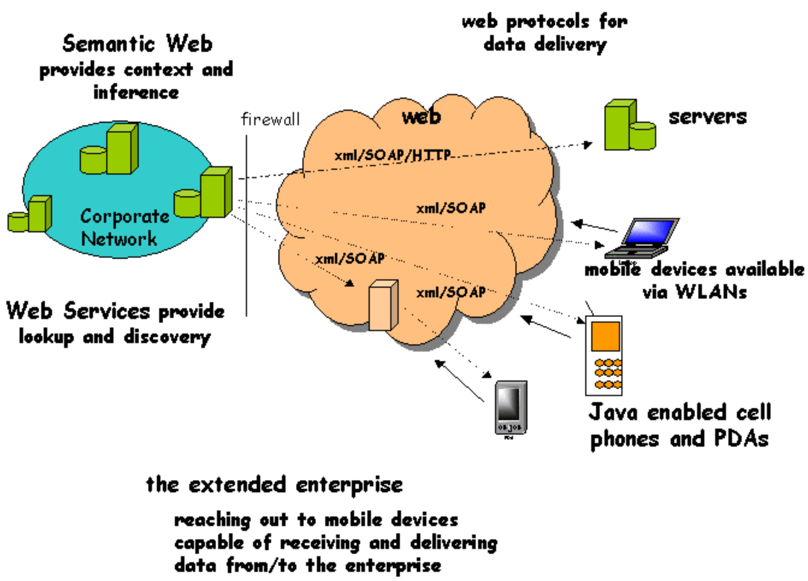

Fig 2. The Semantic Web and the Web Services' XML-based protocols opens up new opportunities for mobile commerce.

To make the possibility of interconnection a reality requires an agreed upon process for one system to find another and begin communicating. The Web Services vision is that systems with no prior knowledge of each other can begin to communicate despite internal differences. Web Services addresses this problem by defining rules of engagement that build on HTTP, SOAP and XML. These new rules of engagement provide:

•**Description:** The Web services model specifies white pages that list the identity of a service provider, yellow pages that categorize services and green pages that describe how to connect and use a service. Providers are responsible for defining this information.

•**Exposure:** Web services repositories host the white, yellow and green pages. Potential clients query repositories and to download descriptors that tell a client how to connect and use the services.

•**Invoking:** Downloaded descriptors tell clients how to invoke a service. The common method of communication is SOAP over HTTP. XML-RPC, a SOAP capability, allows language independent remote procedure calls to be sent to a Web services supplier.

•**Delivering data/services:** When the service has been invoked, XML-RPC returns the any requested data back to the initiating application.

4.4 Protocols Support the Process

As illustrated in Figure 2, the process behind the Web Services model is supported by XML and SOAP. Built on top of these two protocols are UDDI and WSDL. UDDI provides a uniform way to describe and discover services and to obtain details of how to connect and interact with Web services providers. UDDI stems from a cooperative agreement among Microsoft, IBM, and Ariba on an XML-based specification for establishing a registry of businesses and services on the Internet. Since the initiative began in August 2000, the project has expanded to over 260 UDDI community members and is one of the main drivers behind the acceptance of Web Services.

However, as UDDI is evolving, it is clear that many of the initial uses of the repository idea will occur behind corporate firewalls where private registries will be available internally or among a closely knit family of trusted partners and collaborators to facilitate enterprise wide sharing and application integration. By starting small on less critical projects, managers and developers can gain the experience needed to migrate to more ambitious projects beyond their corporate boundaries.

WSDL is an XML-based protocol used to describe the specifics of accessing a Web service. Details include the type and number of parameters passed to a service and the type and structure of the result returned. Once a Web service has been discovered (via UDDI), WSDL provides the details of how to actually bind and interact with that service. WSDL supports direct client interaction with a Web service over standard Web protocols rather than requiring special networking software installed on each machine.

5. The Semantic Web Meets Web Services

Mobile computing is undergoing the same growing pains experienced by other emerging technologies. After an early period of inflated expectations fueled by over active and aggressive marketing, mobile computing for the enterprise appears to be moving to a more mature phase where we are beginning to understand how to deploy wireless applications.

The big challenges facing IT managers is how to position, manage and leverage wireless technology within the organization and to manage the data for delivery to and receipt from mobile devices. To date, the focus has been on:

1) business-to-consumer (b2c) – using wireless technology to reach out directly to consumers.
2) business-to-employee (b2e) – using wireless technology to make corporate data available to mobile workers
3) business-to-business (b2b) – using wireless technology to create new efficiencies in dealing with business partners and suppliers

For these approaches, the most important technology driving a wireless web has been XML. Although not a wireless technology, XML is widely used to represent data in a simple, standardized way and to deliver data for wireless networks. It is also the basis for two important initiatives – Web services and the Semantic Web.

Both the Semantic Web and Web Services provide synergies that open up new possibilities of software interconnection. Web services protocols such as UDDI and WSDL allow software to interconnect without the burden of requiring a common underlying proprietary network. Now add to this capability new dimensions of context and ontology based on Semantic Web technologies such as RDF and DAML and we may well be on the verge of new ways of thinking about mobile computing. First, as a means to direct localized and personalized data to mobile devices, but perhaps more importantly, to offer context and deduction to the new text, audio and visual input collected from mobile devices. This combination of semantics and data has the potential to revolutionize the web as we know it today.

6. Summary

The intersection of mobile computing, the Semantic Web and Web services technologies provides a fertile ground for creating new opportunities for mobile commerce and services within organizations. The Semantic Web initiative, supported by the W3C, supports semantic meaning and context for resources on the Web. Two of its key technologies, RDF and DAML, enable data categorization and inference. For data delivery to and from mobile devices, requirements for semantics and context are critical. Coinciding the increasing capabilities of mobile networks and devices, Web services technologies are emerging to help automate communication between software entities over the Web. At the center of both Web services and the Semantic Web is XML and XML technologies.

Together, both the Semantic Web and Web Services open up new possibilities for leveraging the capabilities of mobile computing with the Semantic Web supporting contextual meaning and Web services technologies allowing registration and discovery of services based on mobile context.

References

1. John W. Muchow, *Core J2ME Technology*. Sun Microsystems Press, 2001
2. Johan Hjelm, Semantics for the Wireless Web. Keynote presentation. IST Semantic Web Technologies Workshop, Luxembourg, November, 2000
3. The World Wide Web Consortium, Composite Capability/Preference Profiles (CC/PP): A user side framework for content negotiation. W3C Note 27 July 1999. http://www.w3.org/TR/NOTE-CCPP/
4. The World Wide Web Consortium, Extensible Markup Language (XML) 1.0 (Second Edition). http://www.w3.org/TR/2000/REC-xml-20001006
5. World Wide Web Consortium, XSL Transformations (XSLT) Version 1.0. http://www.w3.org/TR/xslt
6. Mary Shaw and David Garlan, *Software Architecture. Perspectives on an Emerging Discipline*. Prentice Hall, 1996
7. Tim Berners-Lee, James Hendler and Ora Lassila, The Semantic Web, *Scientific American*, May 2001.
8. The World Wide Web Consortium, Resource Description Framework (RDF) Model and Syntax Specification. W3C Recommendation 22 February 1999. http://www.w3.org/TR/1999/REC-rdf-syntax-19990222
9. Joseph Reagle, Trust in Electronic Markets. First Monday. Vol 1, No. 2, August, 1996
10. J. Heflin and J. Hendler, A Portrait of the Semantic Web in Action. *IEEE Intelligent Systems*, 16(2):54-59, 2001
11. Peter FrankHauser, Teachware on demand – the role of semantic annotations. *IST Semantic Web Technologies Workshop*. Luxembourg, November, 2000.
12. The World Wide Web Consortium, DAML+OIL (March 2001) Reference Description. W3C Note 18 December 2001
13. Frank Coyle, *XML, Web Services and the Data Revolution*. Addison Wesley, 2002.
14. Jan Bosch, *Design and Use of Software Architectures*. Addison Wesley, 2001