A FRAMEWORK FOR PROVIDING MOBILE WEB SERVICES

S. El-Masri
School of Computing and IT, University of Western Sydney, Locked bag 1797 Penrith South DC NSW-1797, Australia
B. Suleiman
School of Computing and IT, University of Western Sydney, Locked bag 1797 Penrith South DC NSW-1797, Australia
Email: s.elmasri@uws.edu.au

ABSTRACT

Web services are moving towards mobile world as a new emerging technology for applications communication. Mobile devices can operate as service consumers or service providers. Most approaches nowadays support consuming web services from mobile devices. This paper introduces a new framework called "Mobile Web Server" for providing mobile web services for not only mobile devices but also web applications. The proposed model is based on the existing web service and mobile technology standards in order to provide software and platform independent mobile services. As well, it reduces the overhead on mobile devices and the wireless network, as they are resource constraints, by presenting a web server which hosts and manages all mobile services. The mobile web server communicates different mobile applications that belong to different mobile network operators to enable services exchange between various types of mobile and web applications. It also addresses the security issues of provided and consumed mobile services through mobile network operators. Moreover, the framework supports the provision of both static as well as dynamic mobile services. Some practical applications for the framework are also introduced to show how the framework works.

Keywords: Mobile web services, mobile devices, mobile web service providers, XML, WSDL, UDDI

1. INTRODUCTION

Over the past decade, there has been a rapid growth in Internet technology and its impact on the way that human beings communicate. In particular, Internet technology has quickly becoming a popular means for consuming products and services, accessing various types of information as well as communicating through E-mail. As a response to this growth, a huge amount of applications and services have emerged in the market in order to provide various types of services and information.

More specifically, most organizations have moved their business to the Web as an efficient way of providing simple, quick, flexible and up-to-date services for large numbers of companies and people. With this dramatic growth of several types of application, a way for communicating these services and information together to achieve their functionality is required. This communication, in fact, had been a strong challenge to the computing world due to the diversity of not only the implementation of organizations' applications but also their platforms as well as the network protocols adopted by these organizations [3], [11]. To address these challenges, web services technology has been developed and adopted by many IT and communication industries such as Microsoft, IBM, Java Sun and World Wild Web Consortium (W3C) [28], [29].

Web services technology is about providing a standard mechanism for communication between applications. This standardization is independent from the implementation of applications, platforms and operating systems under which they operate. It also does not depend on a particular communication protocol that may be used by applications [3]. To do so, several standards have been introduced and supported by a wide range of IT and communication organizations. These standards include eXtensible Markup Language (XML), Simple Object Access Protocol (SOAP), Web Service Description Language (WSDL) and Universal Description Discovery and Integration (UDDI). Based on these standards, web services are software components that can be described, searched, and integrated by any web application. So, web applications can

communicate with as many data sources as possible regardless of the platform or computing environment in which they are hosted [28], [29].

Meanwhile, mobile telecommunication has also evolved and become popular during the past few years, since it provides anytime-anywhere communications. As well, it allows people to manage time more flexibly. With the increase in the number of wireless personal communications and the number of electronic services provided by the Internet, people tend to prefer the use of mobile devices for achieving all their work. Such preference is because mobile devices are simple, light, small, easy-to-use and any-time-anywhere information providers. Therefore, mobile network operators started providing their customers with a diverse range of services presented by other parties.

Along with the growth in mobile and networking technologies, access to web data services from mobile devices has been growing in popularity. For instance, mobile network operators have expanded their services to the third-party applications market such as SMS business in Europe to allow their clients to receive a wide range of instant services, such as share prices, sport scores and ring tones to their mobile devices. Thus, the need for accessing more services and applications that reside on the Web and other mobile devices has led to a mobile web services technology [10].

The Mobile web services idea is about enabling mobile applications to search access and integrate various services and information provided by web applications and/or mobile applications [19]. To be successful, mobile web services require the adoption of existing web service standards, Internet protocols and wireless standards. In addition, some challenges and constraints need to be addressed such as wireless network and mobile devices constraints. Wireless Application Protocol (WAP) and Wireless Markup Language (WML) are two important standards that have been introduced to support mobile web services standards. WAP has been introduced as a standard way for enabling access to various types of services from wireless devices. WML is a standard language for representing services and information according to mobile devices constraints such small screen display and processing power [33].

With the emerging technology of mobile web services, it is essential to differentiate between both consuming and providing web services from mobile devices. Intensive efforts have been spent on providing web services to mobile devices. These efforts include introducing and implementing different architectures that provide a wide range of services accessed by mobile devices.

On the other hand, until now, less effort and work has been spent on the area of mobile web service providers. It is essential to recognize the role of mobile web service providers with the emerging technology of mobile telecommunications. Mobile users could be services' carriers and these services could be required to be accessed from other mobile or Web applications. Moreover, mobile and/or Web applications may at a particular time need to find access and use some up-to-date services that are provided by mobile users to achieve their tasks. Such interaction of providing and consuming mobile services must be achieved automatically between applications. To do so, a mechanism to perform such task is really required.

The idea providing and consuming mobile web services should consider several significant issues. First, searching, accessing and integration of required services should be on the application level. Secondly, existing standards like web service, Internet and Wireless standards should be used to allow a wide variety of applications that reside on different computing platforms, including mobile platforms, and execute on different computing environments to benefit from these services. Thirdly, mobile devices constraints such as memory, processing power and battery life as well as wireless network constraints like bandwidth should be addressed as well. Fourthly, security and authentication issues of mobile service providers and consumers should also be considered.

The main goal of this paper is to introduce a mobile web server framework which enables mobile devices to be service providers to not only mobile devices but also to Web application clients. The model is based on presenting a web server called 'mobile web server' to host and manage mobile services among mobile and Web applications. The model also considers the issues described above, since it uses the existing web service, Internet and wireless standards as well as reducing the overhead on mobile devices and wireless network by allowing the mobile web server to host, process and manage provided and consumed mobile services. As well, it addresses security issues of provided and consumed services through communicating with different mobile network operators.

This research paper is structured as follows. In section 2, essential standards and definitions for mobile web services are introduced. A summary of most important related work to mobile web services is presented in section 3. Section 4, introduces and discusses mobile web server architecture. Practical applications for a mobile web server framework are presented in section 5 as well. Finally, section 6 draws out some conclusions and recommendations for further work.

2. RELATED TECHNOLOGY STANDARDS

To be successful and widely adopted, mobile web services should utilize existing standards of web services, Internet and wireless technology. In this section a brief description of core technology standards are introduced as a context for mobile web services.

A web service is a software component that encapsulates a set of operations to achieve particular functionality (service) and can be registered, searched and used by any application through a set of predefined standards and Internet Protocols. Examples of web services include: a credit card service that processes and verifies credit card transactions for a given credit card number, and an airline service that provides flight time table and reservation functionality [11], [17].

Web services are essentially founded upon four major technology standards: XML, SOAP, WSDL and UDDI. XML provides a standard data representation that can be transmitted and exchanged to any platform regardless of used network and transport protocols. Specifically, XML provides a common and standard way for exchanging information between different applications and systems [7], [8]. SOAP introduces a standard messaging format for exchanging XML documents (i.e. it is the communication channel between applications) [15]. WSDL is a standard meta-language that provides a mechanism to describe the functionality of web service. UDDI provides a standard mechanism to register and locate web services. In particular, UDDI defines a standard set of protocols that are used to store and real-time look up information about other web service applications. It looks like "Yellow Pages" that provides a full listing of all services available on the web. Used together, these technologies make web services interoperable with any application as well as software and hardware independent [17].

WAP and WML are the other essential standards for mobile web services which are related to mobile technology. WAP is the open standard specification that enables mobile users to easily access and interact with information and services from their wireless devices. WAP has been defined, coordinated and developed by WAP Forum as a standard framework for wireless application development. It is compatible with any operating system and with most well-known wireless networks [22], [32]. The main purpose of WML is to provide content and user interface for specific wireless devices that have small displays, limited user-input capabilities, a restricted bandwidth connection, limited memory resources, limited browsing capabilities and limited computational resources [33]. Besides WAP and WML, Subscriber Integrity Module (SIM), which is one of the most secure modules that are used for mobile customer authentication, is another core component for mobile web services. It provides a strong secure link between a mobile client account and a mobile network operator for verifying the identity of clients.

Working together, these technologies form the infrastructure for mobile web services technology. Mobile web services are about the convergence between mobile and Web applications. Such convergence includes data communication and information exchange between applications running on mobile platforms and on the Web. Mobile devices can be either service consumers or providers. Consuming web services from mobile devices means an application executed on a mobile device needs to access and use services provided by other web applications, whereas mobile service providers allow mobile or web applications to access and integrate services provided by mobile applications.

3. RELATED WORK

Several research studies have focused on the view of providing services to mobile devices. Many frameworks were suggested to extend Web services to mobile devices [18], [5], [25]. In [18] Web service standards (XML, SOAP, WSDL and UDDI) were used along with Web Service Flow Language (WSFL) to first, provide an interoperable, flexible and easy to implement framework for building and deploying mobile Web services and secondly, to provide dynamic workflow management of mobile clients. On the other hand, the suggested framework in [5] takes the advantage of mobile agents and location information and integrates them with SOAP, UDDI and WAP standards to reduce the required effort by mobile users to search for Web services and to provide more convenient and intelligent mobile services.

While these two frameworks consider the convenience and simplicity factors for providing or creating mobile Web services, the framework which has been introduced by Morioka *et. al* .[25], on the other hand, highlights the security issues of mobile web services by suggesting a framework with open Application Programming Interfaces (APIs) that can be applied when mobile devices are used in web services payment systems. Based on existing web service standards and other standards, this system considers the context of the mobile service such as time constraints, the amount of payment and network connection status to provide appropriate Authentication, Authorization and Accounting (AAA) charging procedure for mobile payment services.

In the meantime, other research studies have addressed performance issues in mobile web services [4], [23], [1], [14], [13] through using proxy servers. Many research studies [1], [4], [13] have proposed transcoding proxy servers to minimize the delay in accessing web services from mobile devices. The key purposes of these proposed proxy servers are compression and caching. Furthermore, they intended to reduce the amount of traffic travelling through the wireless network when mobile clients access web services.

However, all these proxy servers share one problem which is a bottleneck of service. A distributed proxy server system for mobile web services has been suggested [14] to address the drawback in such servers. The proposed system cashes Pre-requested mobile web services on multiple proxy servers distributed in two different geographical regions and provides mobile services by performing “Handoff Message Protocol” as mobile clients move to different areas. While the author [14] has suggested a distributed proxy server system, Hadjiefthymiades and Merakos [23] have proposed not only mobile web service proxy server architecture but also a Path Prediction Algorithm (PPA) as a service location predictor for caching purposes. The PPA is based on artificial intelligence techniques for machine learning and it predicts mobile user locations. Furthermore, this PPA manages the service caching process by predicting mobile user location and then relocating the services that this user may request on the nearest mobile cell caches.

Accessing the Internet from mobile devices is an area of interest that has been covered in mobile Web services research work [26], [12]. Both studies addressed the problem of navigating and accessing Internet services from mobile devices, but Matt *et al*. focused in their study on improving Web search services on mobile devices, while Kaasinen *et. al.* [12] have proposed two

approaches in order to bring Web-based services to WAP devices. Based on WML and WMLScript, Kaasinen *et al*. have suggested their framework for building Web applications that are specially tailored to mobile clients.

The HTML/WML proxy converter, on the other hand, is a proxy server which performs an on-line conversion of HTML-based pages to a WML contents which are a suitable format for mobile browsers. In addition, the proposed proxy server performs a caching and content adaptation of HTML Web services which includes modification of Web-based services based on a user's preference, channel throughput and/or capabilities of mobile device [12].

The use of middleware for wireless communication is another field of research in mobile Web services which is highlighted in the literature [2], [30]. Reflective middleware architecture has been proposed as a solution for interoperability of mobiles applications with Web services that are advertised and implemented upon different types of middleware [2]. Elsewhere, two compression techniques have been proposed for XML middleware communication messages called GNU ZIP (GZIP) and Wireless Binary XML (WBXML) [30] to overcome the verbose problem of XML messages which used as intermediate data representation for mobile middleware communication.

A different study in mobile Web services [27] has introduced a new data mining technique for predicting appropriate mobile Web services. The two-Dimensional Multi-Level (2DML) association rules mining predict the most possible Web services for particular mobile client in terms of location and service characteristics.

However, the research studies that have been discussed above highlight only one issue of mobile Web services which is consuming Web services from mobile devices. Enabling mobile devices to be service providers is the other new issue that has not been addressed yet. In contrast to other studies [26], [12], Kehr and Zeidler have suggested architecture to bring mobile information to the Web [16]. They extend the SIM to be a small personal Web server that hosts up-to-date information about mobile users. This Web server can be accessed through the Web using URL like http//mhp.net/+61410983800. Furthermore, they indicate that mobile clients can configure their own information from their mobile devices and give some permission and privileges to several groups of people such as their family members, friends and/or work colleagues to access these services from the Web. However, this system does not address providing mobile web services problem for many reasons. First of all, it does not allow application-to-application communication and data exchange, secondly it allows access to mobile information only from the Web, and thirdly it does not use Web services standards to provide services. What is actually required is to access mobile services via applications execute on both mobile devices and on the Web through set of adopted standards and protocols.

4. A NEW FRAMEWORK FOR PROVIDING MOBILE WEB SERVICES

When thinking of mobile devices as Web service providers, a variety of different frameworks are possible. A good framework considers several essential issues that are simple, flexible, interoperable and independent of any platform, software and/or network to provide mobile Web services. The proposed model in this paper for providing mobile Web services is an attempt to address these issues through first, using existing web services, mobile technology and wireless networking standards in order to allow a wide variety of applications to exchange information. These applications, in fact reside on different computing platforms which include mobile platforms, and execute on different computing environments. Secondly, the model considers mobile devices constraints such as memory, processing power and battery life and tries to reduce processing overhead on them. It also takes into account the constraints of wireless network like bandwidth. Thirdly, it addresses security and authentication issues of mobile service providers and consumers, and fourthly, the process of searching, accessing and integrating required services are achieved on the application level. Figure 1 depicts the overall details of the suggested framework with all possible parties.

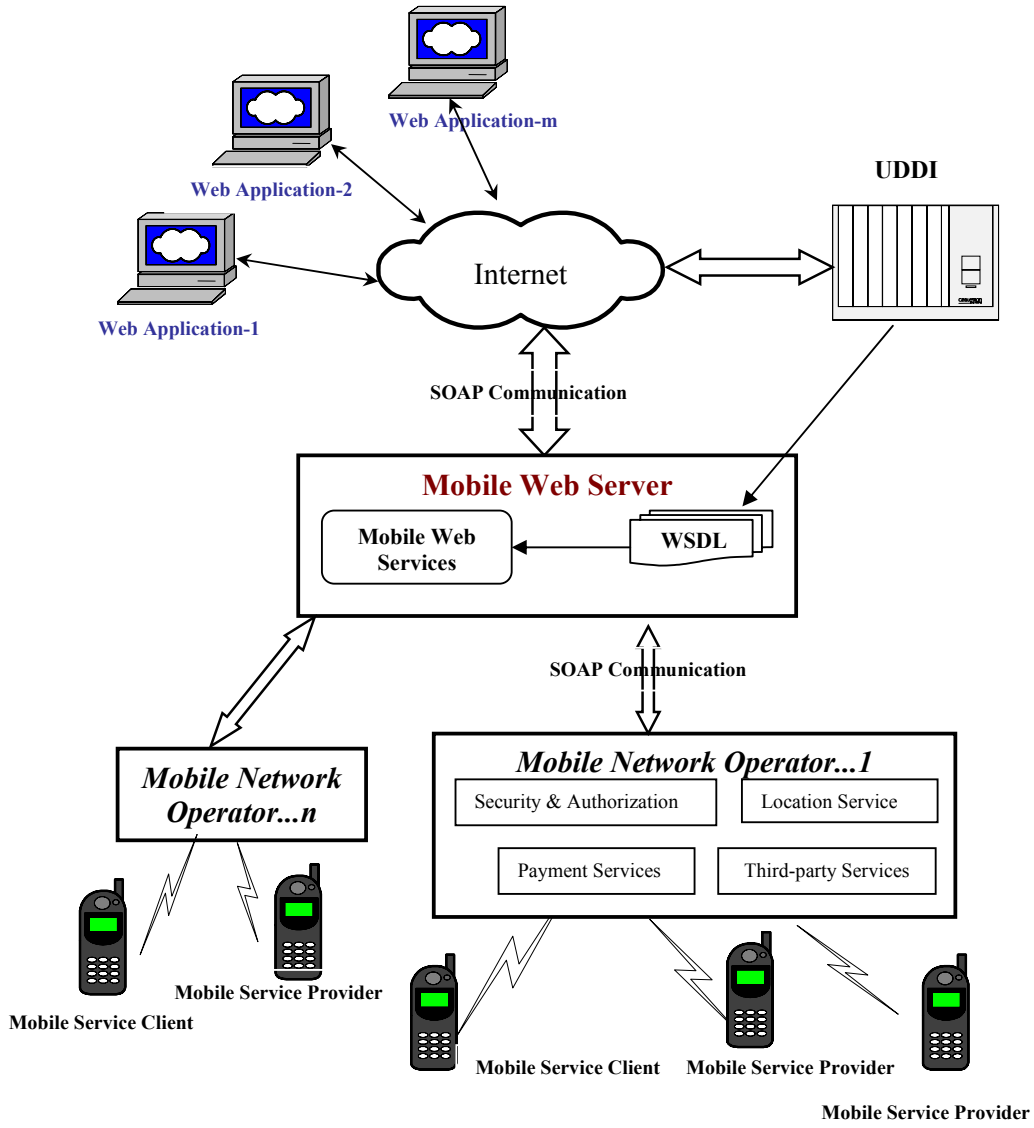

Figure 1: Mobile Web Service Provider Framework

According to the above figure, mobile service providers and mobile service clients have a direct wireless connection with their mobile network operators. They communicate with the mobile web server through their network operators in order to provide and request mobile Web services. Using a simple mobile application developed by any framework language such as Microsoft .NET or Sun J2ME, mobile Web service providers can configure their mobile services on the mobile Web server. They communicate with the mobile Web server through their mobile network operator using SOAP messages in order to provide the configuration of their Web services. In particular, they provide the description details of their mobile Web service (i.e. WSDL document) and the service itself. As well, they register their services on the UDDI registry via their mobile network operator to be available for both mobile and Web applications. So, mobile Web services and their description reside on the mobile Web server and they are registered in the UDDI, which means it can be searched by any application wherever it executes.

The UDDI is used by the Internet and mobile network operators to find particular mobile services. As well, it points to the description details of mobile Web services which live on the mobile Web

server. Such mobile Web services are considered a static mobile Web service. It considered as static, since these services are rarely changed and they do not depend on the context in which the mobile users are in. For example, a manager could configured their schedule as a service on their mobile and allow their employees to access this service. In this case, the manager needs to configure their mobile services for one week and they may change it when new situations come up. On the other hand, other services such as location services are considered to be a dynamic mobile Web service (or real-time mobile Web services), since as mobile users move, the location service need to be updated so that when other service clients try to access their location service they can get the up-to-date location. Such dynamic services are provided by mobile network operators via the mobile Web server.

Mobile network operators, on the other hand, enable mobile clients to communicate with the mobile Web server. It is an important component in mobile Web service provider models, since they provide several services to their subscribers such as security and authorization services, location services, payment services and other services provided by other service providers like SMS and MMS services. Therefore, in this framework it is supposed that all provided and consumed mobile Web services should be carried out through the mobile clients' network operator. The framework supports providing and consuming mobile Web services through several mobile network operators. Thus, it connects all mobile operators to the mobile Web server and through that server the access to the provided services is achieved by a variety of applications that may reside on mobile platforms or on the Web. In this way, mobile and web clients can benefit from a variety of mobile services regardless of the network operator that mobile service providers belong to. The communication between the mobile web server and mobile network operators is achieved using SOAP messages.

As a central connection between all parties, the mobile Web server hosts the static mobile web services as well as it manages the access to these services from any platform. At the same time it is connected to all mobile network operators in order to get access to dynamic services like location services. To keep security and privacy, these services are only provided and accessed from and through mobile companies which are the only parties they have access to such services. In addition, the mobile Web server needs to access security services in order to ensure the identity of mobile service providers and consumers. As well, it can benefit from other services provided by third-parties which may need a mobile application to access them.

The mobile Web server also allows mobile network operators to access services provided by other mobile network operators since all mobile services and their implementations live on the mobile Web server. The mobile web server usually communicates with required applications and components and it processes the required web service to reduce the overhead on mobile device and on the wireless bandwidth. It also adapts the result of the required service according to the capabilities of the mobile device client by using appropriate technology such as WML. Moreover, the mobile web server communicates with all parties through SOAP message which are XML implementation. The XML data representation, in fact, makes the provided services independent of any software or hardware.

Web applications can also consume mobile Web services through accessing them from the Web. Web applications access the UDDI to search particular mobile service; if found the UDDI points to the WSDL document of that services (which exist on the mobile Web server) and the WSDL document give the details about the required service along with its implementation (i.e. functionality).

5. PRACTICAL APPLICATION OF MOBILE WEB SERVICES FRAMEWORK

Now according to this framework, consider the following situations that show how mobile Web services are provided and consumed by both mobile and Web applications. Assume that Adam is

a manager of particular organization and he spends most of his time outside the organization but he needs to schedule his calendar on his mobile phone to be accessed by the secretarial of the organization in order to know his daily meetings and tasks. At any particular time the secretary needs to access his schedule to arrange meeting with a particular party. By requesting this service from the web application running on their organization, the application searches the UDDI to get the address of WSDL document of that service, which exists on the mobile web server. The WSDL provides details about the service and how to communicate with it. The mobile web server uses these details and communicates with the mobile network operator to ensure the privileges and permission of the service client. Once the service client is allowed to use that service, the mobile web server communicates with that application via SOAP and provides access to the functionality of the service. Moreover, the secretary could update their manager schedule and a notification could be sent to the manager to tell him that his schedule has been changed.

In another situations consider that Adam would like to sell his home. With this framework, he can use a mobile web service application to configure details of this service. This includes communication of Adam's mobile application with the mobile web server through the mobile network operator to provide the implantation of the service and its description. As well, the application connects to the UDDI in order to publish that service. Adam can give public access to this service or he can give access for mobile users who live in particular area. On the other hand, assume that John would like to buy a home with specific details. He accesses his mobile web services application on his mobile and goes to the selling section and provides details of the required home. The application connects to UDDI through John's mobile network operator to search that service and find out if it is available. Then the UDDI gives the mobile application the address of that service to the mobile web server where the description of the services and its implementation live. After that, the mobile web server processes the service and forwards the result to the mobile application to combine it with other results if needed. Notice in this situation there is no need to check the authority access to the service since it is declared as public access or the mobile network operator could check the location of the service client if Adam determines the area to which the service should be published.

In a commerce situation, consider a shopping centre that would like to send a special offer to all people near their centre at rush hours. Through their web application, they initiate their request and determine a set of conditions to find people who are close to their centre. The application interacts with the mobile web server and requests a location service for all persons near the centre. In this case there is no need to access the UDDI since the location service is a real-time service and needs to be accessed from mobile network operators. The mobile web server, in turns, forwards the request to all mobile networks operators connected to it and requests that service. Each mobile network operator determines the location of all mobile users who previously gave permission to that centre to provide them with special offer services. Then each mobile network operator can send the shopping centre's offer to their user as an SMS or allow the shopping centre to do so by sending mobile numbers of all persons close to that shopping centre.

CONCLUSION

Mobile devices could be either service providers or service consumers. While intensive research work has focused on providing web services to mobile devices, until now there is no particular research study has addressed the problem of providing mobile web service. In this paper a new framework for enabling mobile devices to be Web service providers for both mobile and web applications has been introduced. The framework is based on existing Web service and mobile technology standards. It also reduces the overhead on mobile device and wireless bandwidth, since they are resource constrained, by adopting a mobile Web server. The mobile Web server hosts all mobile Web services and manages access to them through communicating with required parties to provide mobile Web services for both mobile and Web applications. The mobile Web server communicates with different mobile applications that belong to different mobile network operators to enable services exchange between various types of mobiles and platforms. The

security and authenticity of provided and consumed mobile services have been addressed as well through mobile network operators.

To be successful, the mobile Web services framework needs to be adopted by mobile network operators. Also an implementation for mobile Web service applications to access provided mobile services is required to be developed by leading IT industry. Furthermore, it would be essential in the future to allow other mobile Web servers to be integrated with this framework as a mobile services caching to reduce the overhead on the mobile Web server and increase response time for provided and consumed mobile Web services.

REFERENCES

[1] Fox, A., Gribble, S.D., Brewer, E.A., Amir E., Adapting to Network and Client Variability via on-demand Dynamic Distillation. *Operating Systems Review*, 1996. 30(5).

[2] Grace, P., Blair, G., Samuel S., A Marriage of Web Services and Reflective Middleware to Solve the Problem of Mobile Client Interoperability. *Proceedings of the 1stInternational Symposium on Information and Communication Technologies.* 2003.

[3] *An Introduction to the Web Services Architecture and Its Specification*, available at:http://msdn.microsoft.com/webservices/understanding/advancedwebservices/default.aspx?pull=/library/en-us/dnwebsrv/html/introwsa.asp. [Online]. Access date: March 27, 2004.

[4] B. House1 and D. Lindquist, Webexpress: A System for Optimizing Web Browsing in a Wireless Environment. *In Proceeding of the Second ACM/IEEE International Conference on Mobile Computing and Networking,* 1996.

[5] *Cheng, S. T., LiuJ. P., Kao, J. L., Chen, C. M. A New Framework for Mobile Web* Services. Applications and the Internet (SAINT) Workshops, 2002, p. 218-222.

[6] Chatterjee, S., Webber, J., *Developing Enterprise Web Services: An Architect's Guide*, Prentice Hall PTR, November 14, 2003.

[7] Core Standards Extensible Markup Language, available at: http://xml.coverpages.org/xml.html#overview. [Online]. Access date: March 30, 2005.

[8] *Extensible Markup Language*, available at: http://www.w3.org/XML/. [Online]. Access date: March 30, 2005.

[9] Graham, S., Simeonov, S., Boubez, T., Davis, D., Daniels, G., Nakamura, Y., Neyama, R., *Building Web Services with Java™: Making Sense of XML, SOAP, WSDL, and UDDI*, Sams, December 12, 2001.

[10] GSM Europe, available at: http://www.gsmworld.com/gsmeurope/index.shtml. [Online]. Access date: March 29, 2005.

[11] *IBM's Web Services Site*, available at: http://www.alphaworks.ibm.com/webservices. [Online]. Access date: April 2,2005.

[12] Kaasinen, K., Aaltonen, M., Kolari, J., Melakoski S., and Laakko T. Two Approaches to Bringing Internet Services to WAP Devices. *Computer Network*, 2000. 32(1-6):p.231-246.

[13] Ham, K., Jung, S., Yang, S., Lee, H., Chung, K., Wireless Adaptation of WWW Content over CDMA, *Sixth IEEE International Workshop on Mobile Multimedia Communications, 1999.*

[14] Kim, K., Lee, H., and Chung K. A Distributed Proxy Server System for Wireless Mobile Web Services. *In Proceeding of 15th International Conference on Information Networking,* 2001. p. 749 – 754.

[15] *Latest SOAP Versions*, available at: http://www.w3.org/TR/SOAP/. [Online]. Access date: April 1, 2005.

[16] [16] Kehr, R., Zeidler, A., Look, Ma, My Homepage is Mobile!. *Personal and Ubiquitous Computing archive,* 2000. 4(4): p. 217– 220.

[17] *Microsoft's Web Services Site*, http://msdn.microsoft.com/webservices, [Online]. Access date: March 30, 2005.

[18] Mnaouer, A. B., Shekhar, A., Liang, Z.Y., A Generic Framework for Rapid Application Development of Mobile Web Services with Dynamic Workflow Management. *In proceedings of IEEE International Conference on Services Computing,* 2004. p. 65 -171.

[19] *Mobile Web Services Roadmap*, available at: http://www.microsoft.com/serviceproviders/resources/bizresmwsroadmap.mspx Access date: March 30, 2005.

[20] Monson-Haefel, R., *J2EE Web Services*, Addison Wesley, October 24, 2003.

[21] *New to SOA and Web services*, by IBM, available at: http://www.alphaworks.ibm.com/webservices/newto. [Online]. Access date: March 28, 2005.
[22] Patil, B., Saifullah, Y., Faccin, S., Sreemanthula, S., Aravamudhan, L., Sharma, S. and R. Mononen, *IP in Wireless Networks*, Prentice Hall PTRP, January 31, 2003.
[23] Hadjiefthymiades, S., Merakos, L., Proxies + Path Prediction: Improving Web Service Provision in Wireless-Mobile Communications. *Mobile Networks and Applications. Archive*, 2003. 8(4): p. 389-399.
[24] Tian, T. Voigt, T. Naumowicz, H. Ritter and J. Schiller. Performance considerations for mobile web services. *Computer Communications*, 2004. 27(11):p. 1097-1105.
[25] Morioka, M., Yonemoto, Y., Suzuki, T., Etoh, M., Scalable Security Description Framework for Mobile Web Services. In Proceeding IEEE International Conference of Communications, 2003. 2: p.804-808.
[26] Jones, M., Buchanan, G., Thimbleby, H., Improving Web Search on Small Screen Devices. *Interacting with Computers*, 2003. 15(4): p.479-495.
[27] Tseng, S. M., and Tsui, C. F. An Efficient Method for Mining Associated service Patterns in Mobile Web Environment. *Proc. of the 2003 ACM symposium on Applied computing*, 2003. p:455-459.
[28] *The World Wide Web consortium W3C*, available at: http://www.w3.org/. [Online]. Access date: March 30, 2005.
[29] *Web Services Interoperability*, available at: http://www.ws-i.org/. [Online]. Access date: March 30, 2005.
[30] Hanslo, W., Macgregor, K., The Efficiency of XML as an Intermediate Data Representation for Wireless Middleware Communication. *In Proceedings of SAICSIT*, 2004. p.279–283.
[31] *Web Service Description Language WSDL1.1*, available at: www.w3.org/TR/wsdl. [Online]. Access date: April 1, 2005.
[32] Wireless Application Protocol White Paper, available at: http://www.wapforum.org/what/WAP_white_pages.pdf. [Online]. Access date: April 5, 2005.
[33] Wireless Markup Language Specification Version 1.1, available at: http://www.wapforum.org/what/technical.htm. [Online]. Access date: April 5, 2005.