Towards Intelligent Wireless Web Services for Tourism

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Summary
The vision of Intelligent Wireless Web (IWW) goes beyond just connecting mobile devices to the Internet. It includes the creation of a pervasive, user centred mobile environment, which has the ability to provide highly specific data and services to users on as-needed basis, by intelligent interpretation of the user context. IWW services could provide mobile tourists highly precise data and services on an as-needed basis, with flexibility of use for the user. With the emergence of high-speed wireless networks, such as Wi-Fi, Bluetooth and 3G, and analogous developments in Internet technologies such as the Semantic Web, Web Services, Agent based technologies and Context Awareness, the realisation of the vision of the IWW has become a possibility. The realisation of the IWW will enhance the value proposition of mobile communications in tourism. Delivering context-relevant and personalised information to mobile tourists will save valuable time and will improve efficiency and productivity. Moreover, there is a need to integrate technology innovations in other areas, such as multimodal interfaces and speech technologies, to enhance the usability of the mobile devices. However, a key challenge is to link various technological enabling elements with methodological, cultural, social and organisational aspects specific to the tourism industry. This paper presents a state-of-the-art review of the enabling technologies and discusses how, by exploiting the convergence and synergy between different technologies, it has become possible to deliver IWW support to mobile tourists.
Key words:
Intelligent Wireless Web; Semantic Web; Web Services; Agent technologies; Context awareness.

Introduction

The convergence of Internet technologies and wireless communications has the potential to open new avenues of mobile collaboration, thereby minimising the impact of the physical dispersion of tourists and of travel agents. Lately, a wide range of portable wireless devices has emerged based on personal area networking (e.g., Bluetooth), Local Area Networking (e.g., IEEE 802.11) and Wireless Wide Area Networking (e.g., GSM, GPRS, 3G). Analogous advances in other Internet technologies such as Web Services (WS), the Semantic Web, Agent Technologies, joined with the improved wireless bandwidth and the ability to better capture context information, can efficiently be used to support mobile tourists.

In this paper we explore the vision of the intelligent wireless web based services and its significance for the tourism industry. We review various enabling technologies for the IWW and discuss their interoperation for the realisation of intelligent wireless web services. Next, we discuss key issues that need to be addressed, in order to realise the vision of the IWW.

2. Towards the Intelligent Wireless Web

Nowadays the tourism industry makes efforts to implement techniques that can reduce travel cost and improve performance. In this view, there has been a movement towards the use of collaborative processes that influence the Internet platform, thereby allowing participation of the mobile tourists, from the very early stages of the travel. However, these collaborative traveling solutions are customized primarily towards the requirements of desktop-based fixed network client. The collaboration requirements of travel agents and other mobile tourists are not well addressed. Existing deployments of mobile communications in the travel industry have some highlighted limitations:

- The support for mobile tourists is currently seen as a "simple" delivery of the relevant information. Information delivery is mainly static and is not able to take into account the mobile tourist changing context and the changing travel conditions. The need for dynamic mixture of contents and context sensitive information provision for mobile tourists is not adequately addressed. This can lead to differences between what the application does and what the actual data requirements of tourists are.
- Existing mobile communication applications in tourism lack cohesion with the current desktop based ICT (information and communication technology)

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infrastructure. This problem is being addressed through the use of proprietary or open standard APIs (Application Programming Interfaces), resulting in tightly coupled and inflexible systems. Most of the commercially available mobile applications for the travel industry are designed mainly for internal off-line use, centering around batch-oriented cradle synchronisation. The need of the mobile tourists to have real-time access to multiple information resources is not adequately addressed. In addition, the application of mobile communications in the travel sector is done in a piecemeal fashion. For example, mobile applications are often designed to support a specific high-end client (e.g. travel management, quality assurance, health and safety etc.) This selective application of mobile communication technologies often results in mixed handling of data, where a set of manual and semi-automated processes work together. Frequently, this mixed handling has a negative impact on the process workflows.

- There has been incomplete work to integrate emerging Internet technologies (e.g. Web Services, the Semantic Web, Agents, Context Aware computing) with the travelling environment. The existing travel processes require mobile tourists to sift through huge amounts of travel data to determine the information relevant to their current context. In such a case, mobile tourists' effectiveness to make a particular travel depends on their ability to remember the relevant information and documents and their relationships to one another. The relationships among documents become even more complex as travelling tasks become more complex. Moreover, given the limited display size of mobile devices, undertaking extensive searches is a difficult task. At the same time, full of activity travel agents are involved in several tasks. Keeping track of all the tasks and related dependencies has become a frightening challenge. The application of technology to address such issues remains limited.

The above factors affect the value proposition of mobile communications in the travel industry. They also point towards the need for an IWW support infrastructure, which can intelligently interpret the user context, and through the semantic description of travel data, can deliver information relevant to the current context of the user.

Alesso and Smith (2001) define IWW as a "network that provides anytime, anywhere access to information resources with efficient user interfaces and applications that learn and thereby provide increasingly useful services whenever and wherever needed" [5]. The key feature of the IWW is the separation of data from presentation and applications. This separation allows the reuse of the existing desktop ICT infrastructure for service delivery to both wired and wireless users.

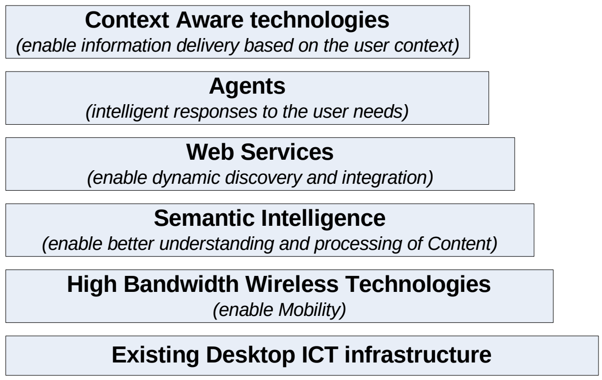

Fig. 1 Building blocks of the IWW

The key building blocks of the IWW (Fig. 1) are the following ones:

- *High bandwidth wireless technologies* that provide the fundamental communication link between the wired back-end and the wireless front-end.
- The *Semantic Intelligence layer* enables knowledge description (using ontologies) and knowledge access (by supporting information retrieval, extraction and processing).
- The *Web Services layer* ensure dynamic discovery of resources and resource integration. Adherence to web services standards would allow mobile tourists or their software agents an ability to share data and dynamically invoke capabilities from other applications in a multi-domain, multi-technology, heterogeneous environment.
- The *Agent layer* plays the key role in addressing issues such as security, negotiation, personalisation and web service procurement.
- *Context Aware* technologies play a key role by intelligent interpretation of the user context, based on various parameters such as location, time, profile, user task etc.

2. Enabling Technologies of the IWW

2.1 Wireless communication technologies

Recently there have been significant advances in wireless networks in terms of technology, protocols, standards, quality of service (QoS) and user acceptance. Various portable devices, such as PDAs, mobile phones and other wearable equipment are emerging, supporting W-WAN (wireless wide area networking), W-LAN (wireless local area networking) and PAN (personal area networking) capabilities. The opportunities for enhancing collaboration between distributed tourists are increasing with the emergence of high-speed wireless data transmission technologies, incorporating broadband and multi-media support. Besides, intelligent transport systems and location-based services (LBS) provide context aware information to mobile tourists. Examples of LBS are city guide systems (e.g. http://www.Wcities.com) and wireless aggregators (e.g. http://www.Kizoom.com/). Basic mobile services for tourists are: *car navigation, on trip information, parking information, public transport information, security and emergency, tracking services and mobile e-Commerce services* [13]. Frequently, tourists on the move are supported by means of LBS using mobile tourism guides, which have been proposed providing a wide range of functionalities with respect to context awareness and adaptation. Schwinger et al. [31] give an in-depth survey of existing mobile tourism guides and evaluate these guides using criteria for context and adaptation.

2.2 Web Services

Web Services are self-describing, self-contained, modular applications that can be published, located, and invoked across the Web. Once a *Web Service* is deployed, other applications (and other Web Services) can discover and invoke the deployed services regardless of operating system or programming language [21]. As identified by [14], the key to Web Services is on-the-fly software creation through the use of loosely coupled, reusable software components. Therefore, Web Services allow for low cost integration, by the adherence to various common standards [11]. A typical Web Services architecture consists of three entities: a) *service providers*, b) *service users* and c) *service brokers* (or *service registries*).

- *Service registry* enables an enterprise to describe its businesses, services and rules. Through a registry, businesses describe how they wish to undertake transactions, search for other businesses that provide desired services and integrate with these to undertake a transaction. The API (Application Programming Interface) for registering services is called *Universal Discovery and Description Interface* (UDDI).
- *Service providers* publish their services through brokers who maintain registries that clients can look up.
- *Service users* (human users or agents) search services in registries and invoke these services using a Web Interface. *Simple Object Access Protocol* (SOAP) is used to pass object information between applications.

Web Services technology can play a key role in the realisation of the IWW, because of its key features such as interoperability, dynamic service discovery and reusability. Resently, there is growing interest in making mobile devices capable of accessing Web Services over wireless networks [28].

2.3 The Semantic Web

The Semantic Web is an extension of the current Web in which information is given well defined meaning, better enabling computers and people to work in cooperation [6]. It allows the data to be defined and linked in a way that it can be used by machines not just for display purposes but also for automation, integration and data reuse. The Semantic Web technologies provide intelligent access to heterogeneous distributed information, enabling software applications to mediate between user needs and information sources [14]. Fig. 2 illustrates the layers of the Semantic Web Architecture as defined by W3Consortium (http://xml.coverpages.org/xmlAndSemanticWeb.html).
These layers are described below:

- *XML+ NS+ XML schema layer*: XML provides the common syntax, while *Namespace* (NS) and *XML Schema* define contents and rules;
- *RDF and RDF schema layer:* RDF (http://www.w3.org/RDF) is a conceptual data layer on top of XML. It is application and domain neutral, and defines a metadata layer and domain specific vocabulary. RDF model can be used to describe anything that has a Universal Resource Indicator (URI);
- *Ontology vocabulary layer*: This layer is the backbone technology for the Semantic Web. It provides a common language on the human and machine level to enable knowledge exchange. An ontology provides machine-processable semantics of data and information sources that can be communicated between different agents [14], thereby facilitating knowledge sharing and reuse. Web Ontology Language (http://www.w3.org/2001/sw/WebOnt) is used as an ontology definition language;
- *Logic layer*: This defines rules for dynamic inference and definition of hierarchies and processing of schemas and instances;

- *Proof and trust layers*: They involve rating of sources and processes and monitoring of logical steps.

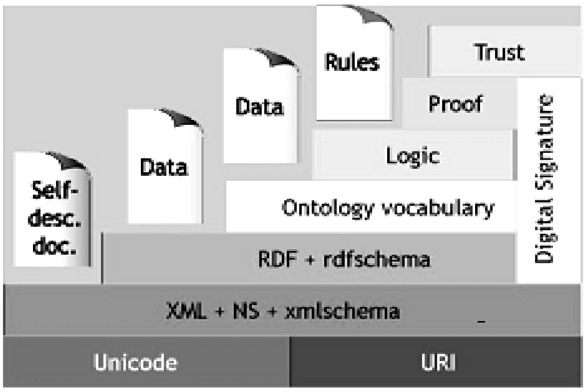

Fig. 2 The Semantic Web technologies

In the travel industry, the Semantic Web technologies offer considerable benefits in terms of travel management, content and document management, knowledge management, supply chain management and integration of distributed applications and services [20]. The Semantic Web technologies help in the realisation of the vision of the IWW in the following ways:

- Deeper understanding of the semantics of document content and travel task structure using ontologies, will help the mobile tourist in intelligent information retrieval, extraction and processing, thereby helping him to accomplish elements of a travel plan;
- Through the introduction of ontological reasoning, Semantic Web techniques are suitable for flexibly discovering abilities in using information that was not specifically designed or intended for a particular use case [22]. Given the dynamic nature of travel processes, this would help in on-the fly resource discovery and integration. Mobile tourists will be able to dynamically locate highly specific data and services on an as-needed basis.
- Travel enterprises very often undertake their processes in different ways. Differences in the meanings of terms make collaboration difficult. The use of shared ontologies and semantic standards will ensure increased interoperability across devices, platforms and applications [27].
- Separation of presentation and data, as ensured by the Semantic Web technologies, will ensure the use of the same middleware tier for both mobile and fixed network clients.
- The Semantic Web technologies can provide a standardised way to interpreting context, enabling both human and software agents to infer new context knowledge and consequently take intelligent actions.

2.4 Agent based technologies

A *software agent* is a self-contained program capable of controlling its own decision-making and acting based on its perception of its environment, in pursuit of one or more objectives [34]. In many systems, several agents are required to work in concert, resulting in a multi-agent system (MAS). A typical travel collaboration scenario is inherently distributed in terms of geography, knowledge, function, expertise and information. The notion of a (multi) agent-based system provides a natural metaphor to match such distribution. In a collaborative travel environment, agents will be essential in addressing the issues of security, negotiation, personalisation and Web Service procurement. The concept of intelligent agents is also being considered in a diverse range of sub-disciplines of information technology, including human computer interaction, computer supported cooperative work, computer networks, software engineering, distributed and concurrent systems, mobile systems, and telematics. Agent technologies are central to the concept of IWW and are vital to the realisation of the Semantic Web vision.

2.5 Context aware computing

Burrell et al. [7] define *context-aware computing* as "*the use of environmental characteristics such as the user's location, time, profile, identity and activity to inform the computing device so that it may provide information to the user that is relevant to the current context*". The application of context awareness has been demonstrated in a large number of tourism applications [1][23], museums [16] and route planning [26]. Basic projects that have specifically focused on location-based data delivery are the Mobile Shadow Project (MSP) [15] and the GUIDE project [10]. The MSP approach is based on the use of agents, to map the physical context to the virtual context. The Ambience Project (http://www.extra.research.philips.com/euprojects/ambience/) has adopted a different approach by focusing on creating a digital environment that is aware of a persons' presence, context, and sensitivity and responds accordingly.

Context-aware computing plays an instrumental role in realisation of the vision of the IWW by allowing tourism applications to better understand user context and adapt services to the interpreted context, thereby ensuring that the busy tourist gets highly specific data and services. Using context aware services delivery, it is possible to eliminate distractions for mobile tourists, related with the volume and level of information. Also, user interaction with the system can be reduced by using context as a filtering mechanism to put context relevant information to the users. This has the potential to increase the usability, by decreasing the level of interaction required between the mobile devices and the end users. The emergence of complementary technologies such as *ubiquitous computing*, *user profiling*, and *sensor networking* enables the capture of many other context parameters.

2.6 Ubiquitous computing technologies

The vision of IWW is to integrate ever-increasing intelligence in the mobile tourists' environment. *Ubiquitous computing* is an emerging paradigm of personal computing, characterized by the shift from the dedicated computing machinery (requiring user's attention e.g. PCs) to pervasive computing capabilities embedded in our everyday environments [33]. Realisation of the vision of the ubiquitous computing has become possible because of advances in different technologies including sensors, wireless and wired communications, memory, processor architectures, software technologies and communication systems such as mobile phones, Internet and WWW [3]. Over the past decade, several projects have focused on ubiquitous computing. These projects include IBM's pervasive computing (http://www.research.ibm.com/thinkresearch/pervasive.shtml), Xerox PARC's ubiquitous computing (http://www.parc.com/about/default.html) and MIT's Oxygen initiative (http://oxygen.lcs.mit.edu/Overview.html).

Ubiquitous computing technologies can play a key role by bridging the gap between the physical world of travel operations and the virtual world enabled by the ICT infrastructure. Although many tourism collaboration applications make extensive use of virtual project environments, in reality, a significant working time of the mobile tourist is spent on activities in the physical environment. Ubiquitous computing technologies have the potential to make collaborative processes and services sensitive to the data available in the physical world.

2.7 Profiling technologies

A key feature of context awareness is to adapt various data and services to the needs of the users. Also the data need to be transformed as per the device capabilities. Profiling technologies allow delivery of personalised information to users, based on their profile and device capabilities. Initiatives for the description of personalised information such as preferences have already been studied by a W3C working group and propositions such as CC/PP (Composite Capability/ Preference Profiles) (http://www.w3.org/2001/di/Activity) have been made. The goal of the CC/PP framework is to specify how client devices express their capabilities and preferences to the server that originates content. The information that the terminal provides, using CC/PP, can be used not only to tag information that is being collected but also to enable selection and content generation responses, such as triggering alarms or retrieving information relevant to the task at hand.

2.8 Wireless sensor networks

Recent advances in wireless sensor networking technology have enabled the development of low cost, low power, multifunctional sensor nodes, capable of sensing, data processing, networking with other sensors and data communication to external users [4]. These advances promise a much wider range of applications for tourism processes. Sensor networks can be used to monitor a wide range of environments and in a variety of applications, including wireless data acquisition, tourists monitoring, smart highways, environment monitoring, site security, automated tracking of expensive products on a tourism destination, safety management and many others.

2.9 Location based services for Tourism

CRUMPET (CReation of User-friendly Mobile services Personalized for Tourism) is a mobile application that uses multi-agents to construct a context-aware system. Its use is mainly limited to providing query and recommendation services. Schmidt-Belz et al. [30] analysed CRUMPET implementing tourism-related value-added services for nomadic users across mobile and fixed networks and evaluating agent technology in terms of user-acceptability, performance and best-practice as a suitable approach for fast creation of robust, scalable, seamlessly accessible nomadic services. To evaluate the usefulness of CRUMPET they conducted a research about what kind of information the tourists need during their visit in a destination. Regarding the information that a mobile tourism service should supply, transportation, maps, tour information, and sites of interest are the kind of information that tourists consider as the most useful. Ghandour and Buhalis [13] based their research on secondary data and primary data collected through qualitative and quantitative methods. They analysed the market for location-based tourism services (e.g. what LBS the mobile travelers need, when and in what form they would like to receive it, and how much are they willing to pay for it). Moreover, they analysed the impact of the new mobile services on destination information providers and destination management systems. The major initiative that has been developed within a European IST project is the *Mobile Tourist Guide* prototype [19], which promotes the use of 2.5/3G cellular networks with LBS.

3. TECHNOLOGY CONVERGENCE

The technologies discussed above constitute the building blocks for the realisation of the futuristic vision of IWW services, which would allow intelligent access to highly specific and customised information on as-needed basis. Application of the semantic Web technologies, based on creation and use of common ontologies provides a mechanism for integration and shared use of information and resources. The Web Services-based solutions provide low cost service discovery and application integration opportunity, both within the enterprise, as well as with external project partners and suppliers. Web Services open standards-based dynamic discovery and integration is starting to get wide support from the tourism industry. Agent based technologies provide a useful means of integration and coordination of services, while context aware computing provides a key filtering mechanism to deliver relevant data to users. The vision of IWW services strongly links the aforementioned enabling technologies. Alongside the technology convergence, improvements in wireless communication technologies allow enhanced connectivity, allowing for anytime, anyplace connectivity. Together, these technologies provide a comprehensive approach to support mobile tourists.

A recent research project has focused on the application of semantic Web and peer to peer (P2P) technologies in tourism destination management systems (DMS). This project (called LA_DMS) provides semantic-based tourism destination information by combining the P2P paradigm with semantic Web technologies [24]. It proposes a metadata model encoding semantic tourism destination information in an RDF-based P2P network architecture. This metadata model combines ontological structures with information for tourism destinations and peers, and takes of P2P technologies and semantic web services, interoperability, ontologies and semantic annotation.

The vision of the semantic Web combines the key technology elements of the Semantic Web, Web Services and Agents. While Semantic Web technologies provide ontological definition of the resources and their relationship, Web Services ensure dynamic discovery and integration**.** This enables intelligent access to heterogeneous, distributed tourism information, enabling software products to mediate between user needs and the information sources available. It will also provide mechanisation in service identification, configuration, comparison and combination, enabling the realisation of intelligent Web Services**.** Agent based technologies also play a key role in the realisation of the Semantic Web vision by collecting web tourism content from diverse sources, processing the information and exchanging the results with other applications [18]. Also the application of the semantic Web technologies enable automated software agents to reason about the Web content, and produce an intelligent response to unforeseen situations.

Sadeh et al. [29] created a Semantic Web environment that revolved around a collection of customisable agents capable of automatically discovering and accessing Intranet and Internet services as they assist their users in carrying out different tasks. Dogac et al. [12] developed an infrastructure to describe semantically-defined Web Services available to mobile devices through agent technology and service registries. Cheng et al. [9] developed an architecture to make Web Services more convenient and efficient to use on mobile devices. This architecture integrates mobile agents with Web Services to make use of location information in the Web Service architecture. Maamar et al. [25] investigated techniques and solutions that could support stationary and mobile users in a secure wireless e-commerce environment using agents and other Semantic Web technologies. In a mobile tourism environment, agents can play a critical role by helping the tourist on the move use highly specific data and services on as needed basis. For instance, delivering answers to short term queries, such as travel related tasks, and yet still being aware of long-term travel goals to be satisfied. The convergence of the Semantic Web and Agent based technologies also ensure a semantics-based linkage to data resources, thereby increasing the level of knowledge identification. Agents can also help in preventing the user from being overwhelmed by irrelevant information, using rule based filtering and adaptation of information to individual context and preferences. Correspondingly, there is a considerable interest in the application of Semantic Web-based technologies for context aware applications. Semantic Web technologies provide an independent way to interpret context, thereby enabling both humans and software agents to infer new context knowledge and consequently take intelligent actions. In *Konti* Project [32], an ontology was developed for expressing the properties required for constructing contextual profiles. Chen H. et al. [8] applied the Semantic Web technologies for modelling ontologies of context and for supporting context reasoning. Adler [2] has investigated the convergence of the ubiquitous computing infrastructure and the Semantic Web to enable explicit representation of device capabilities and service functionality, individual addresses for everything (using URIs) and the Semantic Web as the basis for "semantic interoperability".

4. CONCLUSION

The realisation of the vision of the IWW is within reach and will enhance the value proposition of mobile communications in the tourism industry. Delivering context-relevant and personalised information to mobile tourists will save valuable time and will improve efficiency. Also there is a need to integrate technology innovations in other areas, such as multimodal interfaces and speech technologies, to enhance the usability of the mobile devices. However, a key challenge is to link various technological enabling elements with methodological, cultural, social and organisational aspects specific to the tourism industry. This would require input from different scientific fields, including computer science, telecommunications, system design and ergonomics. This holistic multi-disciplinary approach is essential to address the relationship between component technologies, end users, business processes and wireless technologies. To encourage widespread adoption, there is a need for successful case studies. There are numerous potential benefits and the tourism industry needs to make the necessary investments to realize these.

References

[1] Abowd, G., Atkeson, C., Hong, J., Long, S., Kooper, R., Pinkerton, M. (1997) Cyberguide: A Mobile context-aware tour guide. *Wireless Networks,* 3, pp. 421-433.

[2] Adler, M.R. (2001) Ubiquitous Computing and the Semantic Web: Connectivity, Representation and Reasoning http://weatherhead.cwru.edu/pervasive/2001/content/adler-UbiComp.doc.

[3] Ailisto, H., Kotila, A., Strommer, E. (2003) Ubicom applications and technologies. Espoo 2003, VTT Tiedotteita-Research Notes, 2201 (54 pp.).

[4] Akyildiz, F., Su, W., Sankarasubramaniam, E., Cayirci, E. (2002) Wireless sensor networks: a survey. *Computer Networks: The International Journal of Computer and Telecommunications Networking,* Vol. 38, No. 4, pp. 393–422.

[5] Alesso, H.P., Smith, C.F. (2001) *The Intelligent Wireless Web*, Addison Wesley ISBN: 0201730634.

[6] Berners-Lee, T., Hendler, J., Lassila, O. (2001) The Semantic Web. *Scientific American*, Vol. 279, No. 5, pp. 34-43.

[7] Burrell, J., Gay, G.K. (2001) Collectively defining context in a mobile, networked computing environment. Short Talk Summary in CHI 2001 Extended abstracts, May 2001.

[8] Chen, H., Finin, T., Joshi, A. (2004) Semantic web in the context broker architecture. *IEEE Conference on Pervasive Computing and Communications*, Orlando, March 2004, IEEE Press, 2004, pp. 277– 286.

[9] Cheng, S., Liu, J., Kao, J., Chen, C. (2002) A New Framework for Mobile Web Services. *Symposium on Applications and the Internet (SAINT) Workshops*, Nara, Japan, pp. 218–222.

[10] Cheverst, K., Davies, N., Mitchell, K., Friday, A. (2000) Experiences of developing and deploying a context-aware tourist guide: the GUIDE project. *Proceedings of the 6th International Conference on Mobile computing and networking*, August 2000, Boston.

[11] Dahlem, D., Jahnke, J.H., Onabajo, A., Wang, O. (2002) The challenges of implementing web services on small devices. *Proceedings of the Workshop on Pervasive Computing, Going Beyond Internet for Small Screens, OOPSLA 2002*, Washington, USA, November 4th, 2002.

[12] Dogac, A., Laleci, G., Kurt, G., Kabak, Y., Acar, A. (2002) A platform for semantically enriched mobile services. *Proceedings of the First International Conference on Mobile Business*, Athens, Greece, (July).

[13] Ericsson, O. (2002) Location Based Destination Information for the mobile tourist. *Proceedings of ENTER 2002 Conference*, Innsbruck, Austria.

[14] Fensel, D. (2001) Ontologies: silver bullet for Knowledge Management and electronic-Commerce, Springer-Verlag, Berlin.

[15] Fischmeister, S., Menkhaus, G., Pree, W. (2002) MUSA-Shadows: concepts, implementation, and sample applications; a location-based service supporting multiple devices. In J. Noble, J. Potter (Eds). *Proceedings of the Fortieth International Conference on Technology of Object-Oriented Languages and Systems* (TOOLS Pacific 2002). Sydney, Australia. Conferences in Research and Practice in Information Technology, Vol. 10, pp. 71-79 ACS.

[16] Fleck, M. Frid, M. Kindberg, T., O'Brien-Strain, E. Rajani, R., Spasojevic, M. (2002) From informing to remembering: ubiquitous systems in interactive museums. *IEEE Pervasive Computing* 1, pp. 13–21.

[17] Ghandour, R., Buhalis, D. (2003) Third-Generation Mobile-Services and the Needs of mTravellers. *Proceedings of the ENTER International conference*, 2003, 29-31 January, Helsinki.

[18] Hendler, J. (2001) Agents and the Semantic Web. *IEEE Intelligent Systems*, Vol. 16, No. 2, pp. 30-37.

[19] Kamar, A. (2003) Mobile Tourist Guide (m-ToGuide). Deliverable 1.4, Project Final Report. IST-2001-36004.

[20] Kanellopoulos, D., Kotsiantis, S., Pintelas P. (2006) Intelligent Knowledge Management for the Travel Domain. *GESTS International Transactions on Computer Science and Engineering*, Vol. 30, No.1, pp. 95-106.

[21] Kreger, H. (2001) Web services conceptual architecture [Online:] http://www-3.ibm.com/software/solutions/webservices/pdf/WSCA.pdf

[22] Lassila, O., Adler M. (2003) Semantic gadgets: ubiquitous computing meets the semantic web. In: D. Fensel, J.A. Hendler, H. Lieberman, W. Wahlster (Eds.) *Spinning the Semantic Web: Bringing the World Wide Web to Its Full Potential*, MIT Press, 2003, pp. 363– 376.
[23] Laukkanen, M., Helin, H., Laamanen, H. (2002) Tourists on the move. *In Cooperative Information Agents VI, 6th International Workshop, CIA 2002*, Madrid, Spain, Proceedings, Volume 2446 of LNCS, Springer, 2002 (July), pp. 36– 50.
[24] Kanellopoulos, D., Panagopoulos, A. (in press) Exploiting tourism destinations' knowledge in an RDF-based P2P network, *Journal of Network and Computer Applications* (Elsevier).
[25] Maamar, Z., Mansoor, W., Yahyaoui, H. (2001) E-commerce through wireless devices. *Proceedings of IEEE 10th Int. Workshops on Enabling Technologies (WETICE'01)*, IEEE Press, 2001, pp. 328–333.
[26] Marmasse, N., Schmandt, C. (2002) A user-centered location model. *Personal and Ubiquitous Computing*, Vol. 6, Nos.5/6, (January) pp. 318– 321.
[27] Missikoff, M., Werthner, H. Höpken, W., Dell'Ebra, M., Fodor, O. Formica, A., Francesco, T. (2003) HARMONISE: Towards Interoperability in the Tourism Domain. *Proceedings of Information and Communication Technologies in Tourism 2003, ENTER 2003*, pp. 58-66, Helsinki: Springer.
[28] Pilioura, T., Hadjiefthymiades, S., Tsalgatidou, A., Spanoudakis, M. (2005) Using Web Services for supporting the users of wireless devices. *Decision Support Systems.*
[29] Sadeh, N., Chan, E., Van, L. (2002) Open agent environment for context aware m-commerce. *Challenges in Open Agent Systems Workshop*, (AMAS, 02), Bologna, Italy.
[30] Schmidt-Belz, B., Laamanen H., Poslad S., Zipf A. (2003) Location-based mobile tourist services – First user experiences. *Proceedings of ENTER Inter. Conf.*, 29-31 January, Helsinki.
[31] Schwinger, W., Grun, Ch., Pröll, B., Retschitzegger, Schauerhuber, A. (2005) Context-awareness in Mobile Tourism Guides – A Comprehensive Survey. Technical Report, July 2005. [Online]: http://www.wit.at/people/schauerhuber/publications/contextAwareMobileTourismGuides_TechRep0507.pdf
[32] Toivonen, S., Kolari, J., Laakko, T. (2003) Facilitating mobile users with contextualized content. *Artificial Intelligence in Mobile System 2003*, Workshop, Seattle, 2003 (October 12th).
[33] Weiser, M. (2003) The computer for the 21^{st} century. *Scientific American*, Vol. 265, No. 3, pp. 94-104.

[34] Wooldridge, M., Jennings, N.R. (1995) Intelligent agents: theory and practice. *The Knowledge Engineering Review* Vol. 10, No. 2, pp. 115-152.

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