Challenges for Semantic Grid based Mobile Learning

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Abstract

Recent advances in mobile and ubiquitous computing and wireless communications and networking have paved the way for a new learning paradigm called Mobile (e)Learning (or m-learning). Over the same period there has been an increasing interest in Semantic Web technologies and Service-Oriented Architectures such as Web Services and the Grid. In this paper we discuss the potential benefits and key challenges of integrating these two trends. Such a combination takes advantage of semantic metadata, large scale resource sharing and mobility to enable novel learning scenarios and improve the pervasiveness of e-learning. However, there are key challenges in the areas of managing semantics throughout the Knowledge Life Cycle, supporting Grid services on reduced capability devices and developing new pedagogical models with domain experts that may not understand the capabilities of mobile and ubiquitous systems.

1. Introduction

Mobile and wireless devices such as mobile phones, Personal Digital Assistants (PDAs), Tablet PCs and laptop computers are increasingly popular. These devices allow mobile communication and facilitate access to information anytime anywhere. The investigation of the educational use of these mobile technologies has led to a new learning paradigm called Mobile Learning (also known as m-Learning) which is broadly about learning on the move. In the future it is expected that learning activities will gradually be moved away (or extended) from the usual classroom into the learner's environment [13]. This will help make learning a more personal, collaborative, situated and lifelong process.

Mobile learning research is steadily progressing. Several large scale initiatives (e.g. MOBilearn [16], mlearning [15], from e-Learning to M-learning [17]) have been investigating the potential benefits of this new pervasive approach to learning. A recent UK survey in the use of mobile devices in schools and higher education suggests that young adults (16-24) are switched onto learning by mobile phones and PDAs [11].

The uptake of Mobile learning has so far been mostly hampered by a number of social and technological issues including telecommunications costs [13]; device-related limitations such as low computational power (with exception for laptops), low storage capacity, reduced screen size and display quality, short battery life; and wireless network-related constraints such as low bandwidth and instability or unreliability [2, 3, 14]. However most of these problems are being addressed by the rapid spread and continuous development of ubiquitous, pervasive and mobile technologies such as handheld devices (mobile phones, PDAs), portable computers (laptops, tablet PCs) or wireless networks (WI-FI, 3G/UMTS, Bluetooth, WLAN or GPRS, Mobile broadband).

The other major obstacle for m-learning is the difficulty of developing m-learning applications themselves and in particular the problems of expanding the types of e-learning activities available into the mobile arena so that there is genuine added value, rather than just providing existing applications on a reduced device.

There is therefore a need for software tools and technologies that can ensure the development and provision of lightweight, secure and distributed learning resources and services to learners on the go. Key technologies that can help achieve such a goal include the Semantic Web, and Service-Oriented Architectures such as the Grid. For instance the Semantic Web can support semantic interoperability of distributed learning resources and services, and the Grid is an ideal infrastructure for flexible, secure and large scale sharing of these learning resources in a distributed setting.

Together these approaches are known as the Semantic Grid [12]. In this paper we build on our previous investigations into Mobile Grid [25] by investigating the main challenges involved in supporting semantic rich services, in the spirit of the Semantic Grid, in the m-learning domain.

The remainder of the paper is structured as follows: section 2 defines and presents our view of m-learning, section 3 argues the case for Service-Oriented Architecture (SOA) and semantics by introducing the key technologies (Grid and SOA, Semantics, Semantic Grid) and their benefits to Mobile Learning. Section 4 discusses the main challenges for Semantic Grid Mobile learning and section 5 concludes the paper.

2. Mobile e-Learning

Mobile learning has emerged as an educational application from advances in mobile computing and handheld devices, intelligent user interfaces, context modelling, wireless communications and networking technologies (WI-FI, Bluetooth, GPS, GSM, GPRS, and 3G) [19, 21, 22]. It is a direct impact of these mobile and pervasive technologies on learning, initially used to support lifelong learning [20].

There are many views on the definition of Mobile learning [8,9,10,20,21,24]. A key aspect to be taken into account is mobility which can be associated to the technology or to people. From a technological perspective, it is defined as learning that takes place via the use of mobile and wireless devices [21]. From a learner (or teacher)'s perspective it involves any form of learning that takes place while people are on the move. These two views are combined in the following definition from the MOBilearn project by O'Malley et al.[21]:

"Any sort of learning that happens when the learner is not at a fixed, predetermined location, or learning that happens when the learner takes advantage of the learning opportunities offered by mobile technologies".

The key principle of Mobile learning is to promote a more pervasive approach to learning by allowing it to happen anytime and anywhere. In this regard Paul Harris' defines mlearning as "The point at which mobile computing and eLearning intersect to produce an anytime, anywhere learning experience"[10].

From a pedagogical view point there is a paradigm shift from the current transmissive mode of teaching/learning which is content-based and teacher-centred, towards a more constructivist or socio-cognitive approach which is communication-based and learner-centred [18]. A similar approach of knowledge construction is adopted by the ELeGI project with the use of collaborative and experiential-based learning in a contextualized, personalized and ubiquitous manner [23]. Learning in this context is seen as a social activity taking place in a social environment through individual or collaborative group work and knowledge sharing. The ultimate objective being for learning to become an integrated part of our daily life, that is no longer recognized as learning at all [13]. Figure 1 shows some of the key dimensions of mobile learning.

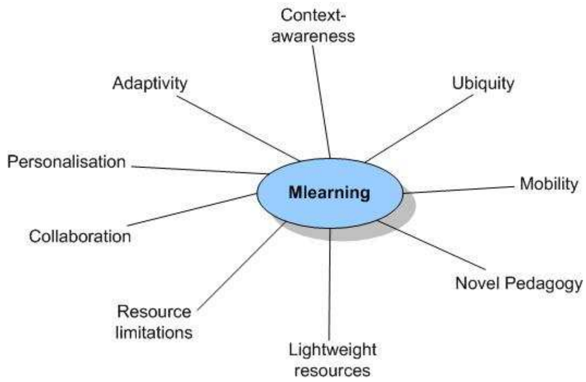

Figure 1: Mobile learning dimensions

In more concrete terms we believe that there are three types of m-learning application currently being explored:

- *Access*: Desktop applications or resources made accessible from mobile devices (providing existing content on the go).
- *Field*: Applications supporting existing pedagogical activities that already occur beyond the classroom. For example, laboratory or field work.
- *Novel*: Applications supporting pedagogical activities that are prohibitively difficult or impossible to achieve without mobile technology and therefore not currently practised.

Access applications are easy to implement as they draw on existing software and systems but there are needs to a good case for extending access before they add any real value (such as using push technologies like SMS to prompt small chunks of regular revision [28]).

Field applications are more challenging as they generally require more sophisticated technology that understands some of the context of use of the mobile device. In the same way that existing e-learning tools make classroom activity easier to organise and access, field m-learning tools make existing field practise easier to orchestrate or record (for example, using image matching techniques on photographs taken with a mobile device to look up species in a digital guidebook [29])

Novel applications are the most challenging of the three as they not only require new technology but also new thinking about how the activities made possible by m-learning could be applied in a pedagogical context [30]. This is so challenging because the technology is alien to many practitioners and an extensive process of co-design between technologists and practitioners is necessary to create satisfactory new activities [31].

3. The Case for SOA and Semantics

The overall success of mobile learning relies on the ability to efficiently model and provide access to context-aware, personalised and flexible learning resources and services to learners on the move using different types of mobile devices. Yet these devices have inherent limitations, and the mlearning pedagogical approach also raises new technological challenges.

We believe that emergent technologies such as the Semantic Web, and Service Oriented Architectures such as the Grid, can help address most of these mobile learning issues. This section introduces these technologies and discusses their potential for Mobile learning.

3.1. The Grid and Service-Oriented Architecture

Currently the trend in the distributed computing and middleware areas of computing is towards Service-Oriented-Architectures, and in particular the GRID is evolving as a SOA for securely orchestrating and sharing stateful services and resources across distributed virtual organisations [1]. There is a great potential for Mobile Grid-based e-learning. Mobile learning is distributed by nature and would benefit from using a SOA such as the Grid. The main advantages of such integration are as follows:

- *Modularity*: as the services are dynamically coupled at runtime.
- *Interoperability*: due to standardisation of the service interfaces.
- *Extensibility*: due to the relative ease with which new services can be incorporated.
- *Security*: is inherent to the Grid and very useful in a wireless network context for authentication.
- *Collaboration*: resource sharing which is a key factor of the Grid, can efficiently support the sharing of learning resources/services and mobile device capabilities.

Loosely coupled secure Grid services would be particularly useful in a mobile leaning context as mobile devices change their networks and neighbours far more frequently than ordinary computer installations, and would therefore benefit from being able to find and use services that were local to the device (for example, to utilise a nearby screen to show information that couldn't be crammed onto a handheld display). Mobile devices also usually have much less computational power than desktop computers, and could benefit from the Grid's ability to offload computation to a more powerful device.

3.2. Semantics

In recent years efforts such as the Semantic Web have emphasised the utility of describing meta-data with explicit semantics (by attaching consistent meaning to meta-data via the use of typed classes and constrained relationships, formally defined in an ontology).

Having formal semantics for meta-data has a number of advantages:

- *Well-formed*. The process of mapping a domain to an ontology helps to ensure that the meta-data has been holistically designed, and therefore is internally consistent and an appropriate model of the domain
- *Semantically Interoperable*. Because ontologies can be formally described it is possible to check if a particular set of meta-data is valid. It also means that two systems that subscribe to the same ontology can guarantee a level of interoperability, particularly if they are also using the same syntactic mark-up.
- *Higher Order Reasoning*. Because the meta-data is described according to a common ontology the relationship between the meta-data instances is well understood.

This means that systems can reason over the meta-data and derive new relationships and connections.

However there are also costs to using rich semantics. These can be summarised by the need to manage semantics throughout the Knowledge Life Cycle [26]. In particular the first phase of the cycle, Knowledge Acquisition, where the ontologies are developed, requires significant effort and preferably the input of domain experts. In addition there is a later Knowledge Maintenance phase, where the ontology is updated (and expanded if necessary) and meta-data annotated with the earlier ontology may need to be changed.
Nevertheless, we believe that rich semantics help to develop more powerful information systems, which directly benefits Field and Novel m-learning applications. This is because these types of applications need to manage a great deal of context information about where and how a device is being used and this can be more easily managed with consistent and explicit semantics.

3.3 Semantic Grid

The Semantic Grid is "an extension of the current Grid in which information and services are given well-defined meaning, better enabling computers and people to work in cooperation" [12]. By analogy, the Semantic Grid is to the Grid what the Semantic Web is to the Web. The key idea of the Semantic Grid is to apply Semantic Web technologies to the Grid, including the use of those technologies to describe Grid services [27].

The benefits of the Semantic Grid for the e-learning domain in general are already being investigated by number of research initiatives. Samaras et al. provide Semantic Grid services for managing Learning Objects (LO) metadata [33]; whereas Bachler et al. use collaboration in the semantic Grid as a basis for e-learning [32]. Mobile learning can have similar benefits, providing that lightweight middleware are available for mobile devices.

The Semantic Grid brings to Mobile learning the combined advantages of the Semantic Web and the Grid. As well as enabling semantic interoperability and high-level reasoning, it also allows large scale sharing and reuse of distributed and secured learning resources and services.

In a mobile learning environment, the use of semantics, semantic annotations and Grid technologies can significantly leverage the usefulness of interoperable lightweight learning resources and services. These resources can be easily understood, queried and reasoned over by mobile and ubiquitous applications, which facilitates the automatic and dynamic service discovery and composition needed to provide targeted learning activities to mobile learners. Semantic interoperability can be achieved for learning resources, device functionalities and capabilities, user profiles and the mobility context. Less powerful devices can take advantage of resources advertised by more powerful devices, to perform complex learning activities.

Table 1: Benefits of the Semantic Grid for mobile learning.

Mlearning / **Semantic Grid**	Context awareness, Personalisation & Adaptivity	Social collaboration	Mobility, limitations & lightweight resources	Ubiquity & pervasiveness	Security
Modularity & loosely couples Web Services		✓	✓		
Distributed Resource sharing & collaboration		✓	✓	✓	
Security					✓
Semantic Interoperability	✓	✓	✓	✓	✓
Knowledge life cycle & reasoning	✓	✓	✓		✓

As mentioned above, mobile learning is also a collaborative process that takes place through social interactions. A Semantic Grid infrastructure for mobile learning can provide a distributed platform for developing; sharing and reusing loosely coupled and semantically annotated learning resources.

Most of the mobile learning dimensions shown on Figure 1 can benefit from the integration of Semantic Grid technologies. The summary on Table 1 shows the dimensions and the Semantic Grid features they are likely to benefit from.

4. Challenges for Mobile Semantic Grid

In the light of the preceding discussion, the Semantic Grid has a great potential for Mobile learning. However there are also challenges to be addressed for a successful integration of these technologies into the Mlearning domain. At a high level the main challenges include the following:

- From a Semantic Web perspective, the management of the semantics in Mobile e-learning applications using the knowledge life cycle.
- Supporting the Grid infrastructure on Mobile and handheld devices
- Developing and promoting the new mobile learning pedagogical models which extend the standard transmissive or classroom-based approach with a constructivist and collaborative approach of learning anytime-anywhere.

Developing, using and maintaining lightweight ontologies for mobile and pervasive devices, performing mobile semantic annotations, as well as engaging in semantic negotiations and learning service discovery in a mobile context are among the topics to be addressed at the semantic level.

Although there is growing interest for Mobile Grid with initiatives like the Mobile OGSI.NET [2], there is still a lack of proper lightweight Grid infrastructure or middleware. Current middleware have mostly been mobility-unaware which makes it difficult to provide similar services to businesses and users on the move.

Beside the technological challenges, it is also crucial to develop adaptive and context-aware mobile learning resources and services that meet the needs of learners on the go and the limitations of mobile devices.

Addressing these challenges will accelerate the development and deployment of fine-grained, dynamic, adaptive and semantically enriched learning components or services that can be used by learners on the move. It will also enable the development of novel learning applications specific to mobile devices.

9. Conclusions

E-Learning has so far been mostly delivered from desktops via wired and stable network connections. With ongoing advances in mobile, wireless and ubiquitous technologies such as Mobile phones and PDAs, WI-FI, Bluetooth, GPS, 3G, Broadband; a new e-learning paradigm called mobile learning is emerging. Mobile learning promotes a pedagogical shift from a formal, classroom-based and teacher-centred approach towards an informal, constructivist, collaborative and learner-centred approach where learning can happen anytime and anywhere.

However the expansion of mobile learning heavily requires the availability of tools and technologies to support the development and deployment of lightweight, secure and distributed learning resources and services to learners on the go, taking into account device limitations.

This paper has argued that emergent technologies such as the Semantic Grid, which is a combination of Semantic Web and Grid technologies can help fulfil such a requirement, and allow novel mobile-exclusive learning applications to emerge. The Semantic Grid provide an ideal infrastructure for developing lightweight, secured and loosely coupled, adaptive and context-aware, and semantically-enriched mobile learning resources and services. For instance the Semantic Web can support semantic interoperability of, and reasoning over distributed learning resources, and the Grid can support flexible, secured and large scale sharing of these learning resources. The paper has discussed the potential advantages and key challenges of Semantic Grid-based Mobile learning.

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