PEER-TO-PEER FRAMEWORK FOR MOBILE LEARNING WITH CONTEXT-AWARE SERVICES

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ABSTRACT

Peer-to-peer (P2P) and mobile technologies enable the integration between face-to-face and virtual communities, allowing users to experiment new models of learning and to contextualize them to their physical space or time. In this work we describe our view of a P2P e-learning community (PEC), and propose a taxonomy for context-aware e-learning services. Moreover, we illustrate how P2P mechanisms can be used to enhance the quality of such services when their consumers are equipped with mobile devices. We finally illustrate SP2A, our middleware solution for building P2P service-oriented applications, which has been recently ported to J2ME in order to add support for mobile devices.

KEYWORDS

Peer-to-Peer, Mobility, Learning Paths, Context-aware Services, Middleware

1. INTRODUCTION

The spirit of P2P is going to extend over Web 2.0 as the ever increasing user-generated content may contribute to information sharing and growth. In general, P2P is useful where shared resources and services lie at many endpoints. In the context of education this trend may enable each user to be much more proactive in the creation of paths for his/her own training and in communicating with other members which share some interests to build new group knowledge.

Given that nowadays technology is mobile, students turn "nomad" [Bryan04], *i.e.* they overcome the boundaries of a classroom or a course to organize themselves in mobile groups which can quickly change their members and their goals. Especially in higher education, an institution should provide an IT infrastructure to involve learners in making meaningful connections to resources or other people.

In this work we introduce a P2P framework for mobile learning. Section 2 describes our view of a P2P e-learning community (PEC), with particular emphasis on technical issues arising when members act in a mobile environment. Section 3 proposes a taxonomy for context-aware e-learning services, and illustrates how P2P mechanisms can be used to enhance the quality of such services when consumers are equipped with mobile devices. Section 4 illustrates SP2A [Amoretti05], *i.e.* our middleware solution for building P2P service-oriented applications, which has been recently ported to J2ME. Section 5 describes real-world experiments which have been conducted with the GUI-based network explorer, a useful tool for e-learning service retrieval based on our middleware. Finally, conclusions and future work are proposed in section 6.

2. PEER-TO-PEER E-LEARNING COMMUNITIES

A P2P e-learning community (PEC) is an unmoderated environment in which informal knowledge exchange, rather than formal training, takes place. As peers join the network, opportunities increase for more information to be stored, accessed, exchanged, and learned. A community of practice (CoP) is made by people who have a common interest in some subject and collaborate over an extended period to share ideas, find solutions, and build innovations [Wenger98]. The CoP concept refers as well to the stable group that is formed from such regular interactions. On the contrary, a PEC is a highly dynamic collection of *peergroups*, whose members collaborate over short periods to exchange knowledge.

Mobility introduces some additional uncertainties on the stability of learning groups: mobile devices can have some limitations of computational and storage resources, or a low quality of achievable data connections, causing mobile peers to become unexpectedly unreachable. To provide learning tasks without service interruptions the system infrastructure should be able to discover other peers able to support the learning activity. Moreover, the learning framework should be able to adapt service provision on the base of user context, both in term of his/her physical space and time and in terms of user's device and network capabilities. The service-oriented P2P learning framework proposed in this paper supports PECs in which users adopt different devices and perform different kinds of learning activities.

2.1 Related work

Since a few years the research community has been investigating the opportunities offered by P2P technologies to support CoPs and PECs. Edutella is one of the most well-known projects targeting P2P learning applications [Edutella]. Edutella is a P2P network for exchanging information about learning objects, yet as it does not support content exchange, it cannot be seen as an infrastructure for developing a virtual learning environment. P2P architectures can support interoperable and ubiquitous learning environments, but the efficiency of a learning activity strictly depends on the context. [Yang06] illustrates a mechanism for context acquisition at run time, in a P2P based learning space. In [Chen06] P2P mechanisms, together with instant messaging (IM), are applied to provide a seamless integration of learning resources. Contents shared in the P2P network are sources of explicit knowledge, such as lectures, while discussions recorded in the IM are used to share personal experience among the users.

3. CONTEXT-AWARE E-LEARNING SERVICES

A context-dependent service for mobile consumers is a service whose behaviour and output can be adapted to user preferences, location, and resources (*e.g.* device capabilities, negotiated bandwidth).

In this section we illustrate which kinds of e-learning services can be provided in a context-aware fashion, using the P2P paradigm. We already referred to P2P as the synonym of e-learning services offered both by institutional actors, i.e. teachers, and by informal actors, *i.e.* students. At the infrastructural level, P2P means a set of mechanisms supporting user connectivity and, exactly, context-awareness.

User-to-user services like *videoconference* are highly demanding in terms of bandwidth and resilience to network shortages. To cope with their requirements, P2P streaming techniques (bandwidth sharing, etc.) are a meaningful solution. With respect to centralized solutions, P2P streaming models are characterized by the lack of single points of failure, which is an advantage, but also by the topological mismatch between the overlay network and the physical network, which leads to non-optimal resource exploitation.

On-demand services, which are not characterized by user-to-user live interactions, may be based on P2P discovery mechanisms and content-adaptation and replication techniques. We consider here two examples: on-demand streaming, and on-demand learning path construction.

On-demand streaming applications with distributed providers of multimedia objects can be realized by means of traditional P2P architectural models for file sharing. But, with respect to this kind of application, on-demand streaming requires more guarantees on data flow continuity and delays. For this reason, data chunks scheduling must consider a broader range of parameters, which are often related to the characteristics of the underlying physical network. Moreover an efficient recovery mechanisms must be provided in order to guarantee the continuity of the data flow.

The *on-demand learning path construction* service accepts queries and searches for related learning objects (LOs), building a learning path which can be dynamically rearranged during the process if the owners of some LOs leave the network. By definition LOs encapsulate both learning content and appropriate descriptive information (metadata). As illustrated by [Kotzinos05], semantic relationships of LOs have essentially two spaces: the inner space, which implies the LO structure, and the outer space, which delivers the learning value of LOs within specific context of use. Both kinds of relationships enable the specification of learning paths, as sequences of semantically interrelated LOs. The e-learning architecture proposed by [Kotzinos05] consists of a portal, in which instructors publish LO descriptions and define semantic relationships between published LOs. Learners can browse or query the LOs of the portal, but also insert new LOs or enrich the descriptions of existing LOs in order, for example, to extend the available learning paths for a course. Our approach considers an even more dynamic environment, in which LOs are frequently

updated (*e.g.* a mathematics student may publish her/his exercise solutions day by day) and their availability depends on their replication degree (RD) in the overlay network (since there is no central repository).

For example, we assume that a learner is interested in "Computer Science" for a half-day learning session. The learning path constructor suggests the following LOs:

Current time: 9AM
Proposed learning path:

1. **"Information theory (basics)" – OD – lecture slides - [RD=2] – time: n/a**
2. **"From finite state automata to Turing machine" – OD – lecture video – [RD=5] – time: 1h**
3. **"Algorithms and Data Structures" – U2U – live lesson – [RD=n/a] – time: 11AM-12AM**

It is important to observe that user-to-user services can figure as steps of a learning path. Their position in the LO sequence depends on the declared availability of the service provider.

4. MIDDLEWARE SOLUTION FOR SERVICE-ORIENTED PECS

SP2A [Amoretti05] is our middleware solution enabling service-oriented applications for virtual communities. SP2A is distributed as a set of Java interfaces and both J2SE and J2ME class implementations. The API includes four packages: `group`, `rps` (*i.e.* resource provision service), `security` and `state`.

SP2A currently supports three state-of-the-art technologies: Web Services [WS02], OWL-S [Paolucci02] and JXTA [Traversat03]. These technologies complement each others: Web Services provide a framework for service interface description and invocation; OWL-S supplies service providers with a core set of mark-up language constructs for describing the properties and capabilities of their services in unambiguous, computer-interpretable form; JXTA operates at the lower level providing P2P functionalities.

4.1 Peergroup management

PECs are particular types of peergroups: communities of peers organized for specific knowledge sharing. At the middleware level, the creation of subspaces is also motivated by the need to create scoping environments which restrict the propagation of query messages, thus improving the performance of discovery algorithms. Moreover, content exchange and service interaction often require the creation of secure domains. Currently SP2A allows user-driven subgrouping (but not yet self-organization), which means that when a peer joins the network it searches for peergroups which match its interests, and it is allowed to create a new one if necessary. It is quite evident that providing security to peergroups is rather a difficult goal, because interactions are not just user-to-service, but also service-to-service on behalf of the peers, thus requiring delegation of rights from peers to services and dynamical instantiation of services. SP2A provides a `SecurityManager` interface for security policy enforcement in peergroups. Peers can have different ranks, corresponding to the actions they are allowed to perform within the group. A partial list of ranks is:

- admin - the peer is a member trusted by the group founder; the actions it is allowed to perform are: service sharing/discovery, group monitoring, voting for changing member ranks;
- newbie - the peer is a new member; it only can search for an admin peer, to ask for a promotion;
- searcher - the peer is allowed to search for services and to interact with them;
- publisher - the peer can search for services but also publish its own services in the peergroup.

4.2 Service deployment, publication and discovery

To use a resource, a consumer must know if the related Resource Provision Service (RPS) exists and is available; if it operates under a specified set of assumptions, constraints, policies; and if it can be invoked through a specified means, including inputs that the service requires and outputs that will form the response to the invocation. Service deployment is transparent to the user, which only has to invoke the shareRPS method of the RPSManager.

```
//// [1] Service construction
MathService math = new MathService();
rpsManager.addToRPSList(math);
//// [2] Service activation and publication
```

```
rpsManager.shareRPS(math);
```

The previous example refers to a case of "local" RPS, *i.e.* a service whose instance is intended to be running in separate thread of the SP2A-based peer application. SP2A also allows to share in the P2P network the descriptions of "external" RPSs, *i.e.* services deployed in traditional containers (*e.g.* Axis servers) and addressed by simple URLs.

Using the math service example, we illustrate how a SP2A-based peer performs attribute/value search and service interaction, using the RPSManager and the methods which all RPSs have in common.

```
rpsManager.findRPS(mainGroup, "Name", "MathService");
... // search results filtering
ResourceProvisionServiceImpl math =
(ResourceProvisionServiceImpl) rpsManager.getDiscoveredRPSVector().getElementAt(..);
String WSDLbuffer = math.getInterfaceDescription("WSDL");
... // interface parsing
Integer a = new Integer(..);
math.invokeOperation("add", new Object[] { a });
```

5. GUI-BASED PEC EXPLORER

Using our middleware, we developed a GUI-based application that can be executed both on PCs and PDAs or Smartphones. It is very useful for learners to have a graphical interface that shows all the session steps and helps them to correctly manage the learning material.

The application is composed of tab panels, making it is very easy to switch from one to the other even using a mobile device; in particular, in the case of mobile users, it is the application itself that recognizes the type of selected LO and runs the corresponding program. When the execution is completed, it is possible to come back to the list of available LOs, and select another step of the learning path.

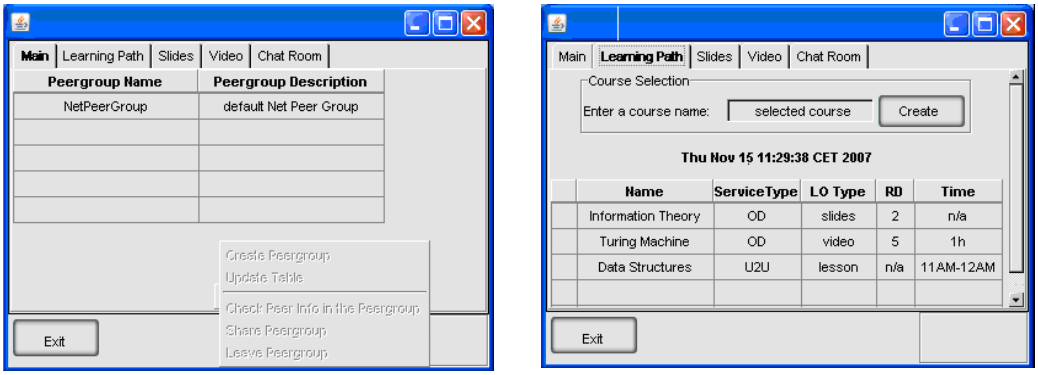

Figure 1: *left*- Main panel, for peergroup management, *right*- Learning path management panel.

Figure 1.*left* shows the main panel, listing available peergroups that the user can join to collaborate in exchanging knowledge and learn with other members.The Learning Path panel (Figure 1.*right*) allows to select a topic and shows the corresponding learning material. For example, a learner who is interested in "Computer Science" for a half-day learning session can type the course name in the learning path panel, and start the search. The learning path constructor suggests some LOs depending on the current time of request, and the GUI-based network explorer shows them within a table with all the information the learner needs to use them. The LO table shows if the service is on-demand or user-to-user, and what is the type of the LO, *e.g.* a presentation, a live lesson video, etc. The replication degree is also provided, to inform the learner about the resource availability in the overlay network. The last information provided is related to the time dimension: for on-demand services it may provide the duration of a lesson or a video, while for user-to-user services it may show the availability of providers. For example if a teacher is available in the chat room at a particular time, the corresponding LO is scheduled depending to the time shown in the table.

Finally, the learner can select a LO and switch to the corresponding tab panel. From each panel it is possible to perform actions depending on the LO type: for example, the slides panel lists all the downloaded presentations, and it is possible to select one of them and show the slides. If a mandatory step in the learning

path is jumped, a dialog will suggest the user to go back to the LOs list and select the right activity to successfully complete the learning path.

6. CONCLUSIONS AND FUTURE WORK

The framework proposed in this paper enables P2P e-learning communities (PECs) in which members collaborate over short periods to exchange knowledge by means of user-to-user services, and consume LOs provided by on-demand services. The P2P approach also allows to cope with mobility requirements and to provide services in a context-aware fashion.

From theory to practice, we used our SP2A middleware to develop a GUI-based PEC supporting application that can be executed both on PCs and PDAs or smart phones. The application accepts queries and searches the P2P network for related LOs, building a learning path which can be dynamically rearranged.

Further work is required to add distributed reputation mechanisms for securing both service selection and PEC membership management. Moreover, we are interested in the design and implementation of mechanisms for proactive construction of context-aware learning paths based on user interests.

ACKNOWLEDGMENT

This work has been partially supported by the Italian Ministry for University and Research (MIUR) within the project PROFILES under the PRIN 2006 research program.

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