Peer-to-Peer: an Enabling Technology for Next-Generation E-learning

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Abstract In this paper, we explore new directions for future e-learning tools. Our idea is to use peer-to-peer technologies to create collaborative learning communities. We start by analyzing the limitations of current e-learning tools. Then, we present an overview of peer-to-peer technologies to show how they can be used for better e-learning tools. Finally, we propose a framework for collaborative communities based on enhanced peer-to-peer networks. This position paper presents initial results of our work and we continue to work on the detailed specification of the proposed framework and its prototype implementation.

1 Introduction

The advent of the Internet and the Web has enabled a rapid grow of information and communication technologies used in the learning process, typically referred to as "*e-learning*". We can distinguish between two main kinds of e-learning technologies. In the first one, traditional lectures given in a classroom are delivered to learners through "*on-line multimedia streaming*". Such process allows learning even if teachers and learners are at different places. A multimedia stream can also be recorded and replayed later to make learning possible at any time, thus enabling "*off-line*" delayed courses. Other material such as slides can augment the image and the sound of the lecture to form structured multimedia presentations in which different media are synchronized in time. Several tools support this kind of technology, e.g. products by RealNetworks [7] or the SMIL standard developed by W3C [11]. Still, multimedia streaming oriented e-learning remains focused on the traditional model of a lecturer transmitting knowledge to learners.

The second kind of e-learning technologies is more focused on teaching material and aims at providing rich learning content offered to learners through Web portals. A teacher creates a complex document composed of learning units (lesson, course, exercise, quiz) on which learners can work at any place or at

any time. The advantage of this technology is its off-line nature—a learner can learn when it is well-timed and make progress at her own pace. However, in this process a learner sometimes requires some help from the teacher, which can be achieved via mail exchange, forum messages, chat, or more rarely via audio or video-conferences. Learning objects are usually documents with complex structure that require standardized formats for using and exchanging them (we can cite standards like SCORM [2] or IMS [5]). Searching for relevant content may be a problem so that usually a learning object includes some metadata for precise indexing. Several standards exists for specifying metadata such as Dublin Core [8] and RDF [12].

Even if a considerable amount of tools and products is largely available, e-learning has not yet gained wide popularity and it is not clear if it is beneficial for all actors: learners, teachers, and teaching institutions. In this paper, we will try to identify some reasons for this state and sketch some new directions to follow, if we want to make e-learning happen. Our idea is to explore how peer-to-peer technologies (P2P) can be used for e-learning and what they can bring to this domain.

2 Limitations of the current e-learning technologies

We have identified several problems with current technologies and tools for e-learning:

- any technology follows the traditional hierarchical learning model involving a teacher and a group of learners,
- in the case of on-line technologies, a teacher and a group of learners need to be present at the same time,
- learners in a group usually work in isolation without coordination or close communication,
- the cost of investment in e-learning may be prohibitive, for instance the professional video and audio equipment for multimedia distribution is expensive and requires highly qualified staff; running off-line e-learning portals relies on qualified personnel and requires constant maintenance,
- using complex learning objects and advanced communication tools is not easy for all learners, because it requires some level of computer literacy and initial instruction, which can be a barrier for large adoption.

In our view, we can overcome all these problems with a new approach based on peer-to-peer networking. We observe that existing e-learning tools have followed the development of the Internet and the Web, but widely deployed peer-to-peer tools have not been yet considered as a source of possible enhancements of e-learning technologies. We think that peer-to-peer technologies may

- enable wide and easy distribution of learning objects,
- change the traditional hierarchical teaching model into a flat one,

- support via a distributed learning object the formation of collaboration groups with learners having common objectives,
- provide an anchoring point for easy interactive communication between learners.

To better assess the possibilities of P2P technologies, we briefly introduce the principles of their operation.

3 Principles of peer-to-peer technologies

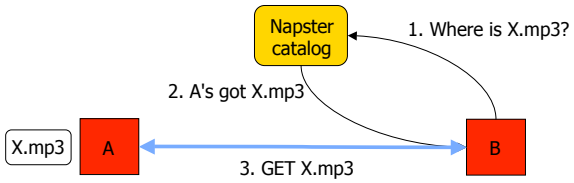

Fig. 1. Principle of Napster

In peer-to-peer technologies, communication follows a different model from the traditional client-server one widely used in current distributed systems [1]. In the client-server model, the roles of communicating entities are asymmetrical: a server waits for incoming connections or queries from a client and provides some service. A *peer* system may act as a client and a server depending on what operation it needs to perform, for example it can respond to a search query as if it were a server and forward it to other systems as if it were a client. At the beginning, peer-to-peer systems have appeared as technologies for sharing audio or video files. More recently, they also provide any kind of large scale distributed services: television broadcasting [6] or handling a directory of VoIP subscribers (e.g. Skype [3]).

The first peer-to-peer system designed for sharing MP3 files was Napster that provided a centralized catalog of files available on personal computers. Figure 1 shows the principle of its operation: when system B wants to find file X.mp3 held at system A, it queries the catalog that returns A as the holder of the file. Then, B directly contacts system A to request the file. The main drawback of this scheme is the centralized catalog of files on which depends correct operation of the system.

Gnutella proposed another way of operation, which is completely distributed. Every node in the Gnutella network knows several *peers*, e.g. system B knows systems C and D in Figure 2. When it receives a query for a file (operation 1), it checks whether it holds the file and forwards the query to all its peers, which

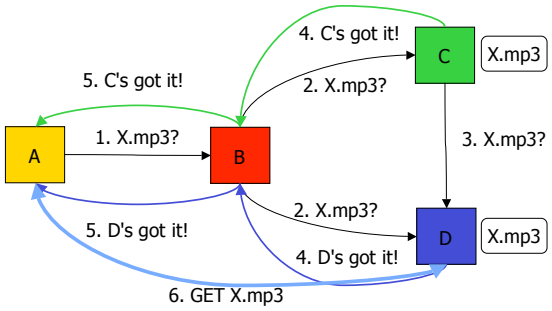

Fig. 2. Principle of Gnutella

is called *flooding* (operation 2-3). Nodes that hold the desired file, reply with a message that returns back on the path followed by the query (operation 4-5). The node at the origin of the query chooses one node and downloads the file. The system may increase the download performance if the node downloads different chunks of the same file from different nodes. One drawback of this scheme is related to flooding—the propagation of queries based on this principle in a large scale system may take a lot of time.

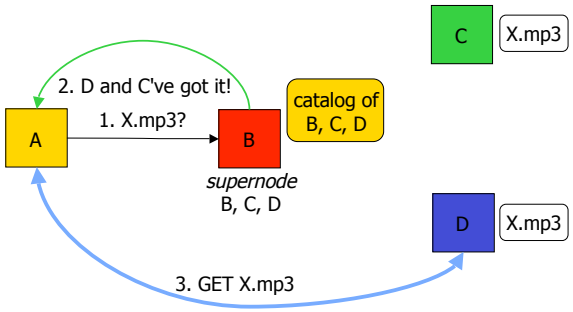

Fig. 3. Principle of FastTrack

FastTrack is a hybrid architecture in between Napster and Gnutella. Popular P2P systems such as Kazaa and Grokster are based on the Fast Track software library. In FastTrack, some nodes in the network play the role of *supernodes* that maintain parts of the catalog needed to find a file. This is the case of node B in Figure 3 that knows which files are held on nodes B, C, and D. When A tries to find a file, it sends a query to its supernode (operation 1) that looks up the

catalog to find the holder. It then returns the placement of the file and A can download the desired file. In a large scale network, there are a lot of supernodes and a query is flooded to all of them to find the required file.

Many other P2P systems exist and their operation slightly differ according to what functionality they want to optimize. We can cite BitTorrent, Freenet, JXTA, and some research prototypes such as Chord, Pastry, CAN, OpenDHT.

From the point of view of e-learning systems, P2P technologies present some interesting features, but by now their application to this domain just begins. We will propose some new ideas on this subject in the next section.

4 Peer-to-peer technologies for e-learning

Some work has already pointed out the importance of applying P2P technologies to education. Edutella has proposed a peer-to-peer architecture for exchanging RDF-based metadata [9]. It builds upon Semantic Web techniques and the JXTA middleware. Its purpose is to make the reuse of globally distributed learning resources easier. Berman and Annexstein has considered P2P technologies as crucial in future educational systems [4]. In particular, they propose to integrate them in a new *personal knowledge management* paradigm, which is useful for students and educators in many activities encountered in everyday teaching, researching, and learning.

Our idea is to use P2P technologies for easy and large scale distribution of learning objects that will enable the creation of collaborative learning communities. A P2P network may provide easy access to educational resources without the need for third party Web servers, which often require considerable management and maintenance effort—P2P networks operate in an autonomous and spontaneous way with minimal management overhead. Moreover, users can use P2P systems almost without any initial training.

In current distance learning systems, educational resources are usually conceived for a single learner that works on her own, in most cases in isolation from other learners (however, some interaction between learners is usually provided via fora or chat). Imagine that we distribute an enhanced learning object through a P2P network to a group of learners. The enhancement consists of adding a means for anchoring a community of users interested in the content of a learning object: each learner that uses the object can easily communicate with other users or with the author/instructor related to the object. In such a dynamically formed community of learners, the learning process may become more efficient, because its members apply the principle of *"learning by teaching"*: the learners that understand different parts of the learning material can explain difficult matters to others. Usually it works well, because we start to understand a given problem sufficiently well, if we are able to explain it to somebody else. Thus, the whole group can make considerable progress even without referring to the author/instructor. In some cases though, more help will be needed and the learners can interact with the author/instructor.

To specify the details of a framework that operates along these lines, we need to address several issues. The first problem is related to a wide and easy distribution of learning objects. We have seen in the previous section that P2P technologies present many advantages with respect to this objective—they offer a search functionality in a large scale network of nodes and a possibility of efficiently download desired objects. However, we have also seen that to precisely identify relevant learning objects, we need to enhance learning objects with some metadata to support more advanced search functionalities, the feature addressed in the Edutella project. So, our learning objects need also to include metadata and the supporting P2P network has to use them for precise searching. We need also decide which format should be used for representing the contents of learning objects, we can think about SCORM or IMS, and integrate it with a suitable metadata standard.

Next issue concerns the formation of collaboration groups with learners having common objectives. In current P2P systems, there is no communication between users exchanging files. In our view, we need to enhance a learning object with a sort of a *"communication handle"* that will enable easy interactive communication between learners. This can be achieved by forming a communication overlay between involved nodes similar to what is done in recent VoIP networks such as Skype [3] or Gizmo [10], or TV distribution applications such as PPLive [6]. When an object appears on a node, it leaves a piece of information that will be used later for creating the audio or video communication overlay. At any time later on, a learner can contact other learners that use the object. Any other interested person such as an author or an instructor can be included in the overlay since its beginning. In this way, a learning object acts as a catalyst for a collaborative learning community. Still many other issues remain concerning the implementation of such communication overlay, for instance, how to leverage a considerable amount of existing tools and deployed VoIP or video distribution systems.

We believe that such a P2P learning network will contribute to changing the current teaching model: instead of a traditional hierarchy between the teacher and the learner, we will enable a much more egalitarian mode of operation, in which every person is able to learn and teach according to her needs and abilities.

5 Conclusion

This paper outlines some new directions for future e-learning tools. Our idea is to use peer-to-peer technologies to create collaborative learning communities. For precise searching, we plan to associate metadata with learning objects. In this way, learners will be able to search a peer-to-peer network for relevant learning objects. Moreover, we will enhance learning objects with communication handles to create a communication overlay between the learners interested in the common contents. At any time, a learner will be able to contact other learners that use the same learning object. The resulting collaborative space may change the traditional learning model into an egalitarian community enabling mutual

teaching and learning. Although we are at the initial stage of our work and many open questions remain, we believe that such ideas are original and worth of exploring. We continue to work on the detailed specification of the proposed framework and its prototype implementation.

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