An Approach for Supporting P2P Mobile Collaborative Communication to Suggest Learning Objects Based on Learning Profile

Abstract: The growth of small devices using as cell phones and smartphones has requested for the development of applications in different areas. The users may perform different tasks in these devices as read e-mails and magazines, make financial transactions, share physical resources, software and data, access multimedia content, and enjoy a variety of other applications. The diversity of mobile communication scenarios brings up the needs for applications to access not only Internet services but also local applications. This kind of application demands for a local communication, called collaborative communication, between the devices without the usage of Internet infrastructure. This scenario represents a peer-to-peer (P2P) network, which allows the sharing and the exchanging of hardware, software and content. The content includes not only objects as musics, texts and videos, but also data about interests of the user. In the e-learning area this is not different and these applications potentially attract the students’ attention. Considering the user preferences and interest, the application may suggest suitable content to the student, motivating him during the learning-teaching interaction. The goal of this work is to propose a mobile P2P collaborative communication approach to allow the sharing and the exchanging of learning objects comparing their metadata to the student learning profile. The learning profiles are split into dimensions based on Felder and Silverman model to attend different student preferences. A prototype based on the proposed approach was developed to validate our architecture. We performed the architecture evaluation with 20 students of an undergraduate course. An evaluation using different message protocols was conducted to verify the proposal and suggest the best communication technology. The communication technology has an impact on the time spent during the exchange of objects which may interfere in the student motivation.

Keywords: learning profile, collaborative communication, P2P mobile communication.

1 Introduction

The miniaturization of computational devices for personal use along with recent advances in communication technologies has significantly expanded the access possibilities to a wide range of applications in several fields. Nowadays, it is possible to read e-mails, make financial transactions, share resources (hardware, software and data), access multimedia content and enjoy a variety of other applications through a small cell phone or a sophisticated smartphone, either the
user is stationary or moving, whether at home, on the street or at work. In this vision, technology is immersed in the environment so that information can be accessed naturally from any device at user’s disposal regardless of his physical location (Weiser, 1999).

Although the mobile devices have resources to communicate through the Internet, there are scenarios where communication is more localized, without the need of the Internet infrastructure. The daily interactions between people at work, university and where they live are much more evident when compared to global interactions. The common scenarios include collaborative peer-to-peer (P2P) interaction to share and download files, interaction to exchange data such as music and videos, and opportunistic communication (Costa and Fialho, 2008; Nicolai et al., 2006). In these scenarios, there is no need to use the infrastructure of the Internet in terms of domain name service (DNS), routing and addressing. It is enough to have local modules dealing with the discovery and advertisements for supporting the communication process. All these aspects could and should be solved locally through local services, allowing the collaborative communication (Ferraz et al., 2011; Santana et al., 2008; Pelusi et al., 2006).

The student’s learning style is one of the way to highlight the features that belong to him, such as: personal and social preferences, learning profile, and subject knowledge level. The exchange and sharing of materials between two students can further enrich the learning process when they use contents which are adherent to their learning profiles. By considering the learning styles during the learning process it is possible to provide users with different teaching strategies, meeting the student’s individual needs. In this sense, it is important to highlight that the student learning style should be observed through different dimensions achieving diverse aspects of their preferences, such as media format and participation in group activities (Zaina et al., 2011). The student’s learning profile reflect their learning style.

The dynamic linkage between contents and student’s learning profile may enhance the adequacy of the learning objects that will be exchanged and shared between the students. The use of metadata standards adds quality to learning systems in the task of handling learning objects, improving their reuse and retrieval (Devedžić et al., 2008). Learning objects are specified by fields that describe their general data (e.g., title, description, keywords), technical details (e.g., media format, size, software and hardware requirements), learning features (e.g., concrete and abstract approaches, visual and verbal elements), and other relevant metadata (Zaina and Bressan, 2009).

The motivation of students in an e-learning may arise from different roots including the acceptance of the tool used in the learning process. Considering the network communication, the response time of a request can interfere in the student motivation (Pelusi et al., 2006). In some cases the student’s lack motivation, caused by technological problems, may make him to give up the interaction.

Due to the restriction of mobile device resources, the protocol used in the P2P communication can directly influence on the building and in the exchanging of messages. Different protocols for composing and exchanging mobile messages have been adopted including Protocol Buffers, JSON (JavaScript Object Notation) and Thrift, aiming at improving the local communication and making the best use of the mobile devices’ resources. These protocols have been developed in order to
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decrease the message size and to boost the time of the message building. The goal of this work is to present an approach for supporting P2P mobile collaborative communication to suggest learning objects (LOs) based on learning profile. The main research questions for our work are:

- Is it possible to relate the LO metadata to learning profile features?
- Have the technologies for small devices supported the communication to LO exchange?
- Have the different communication technologies interfered in the size and in the time of the data exchange on the proposal architecture?

Aiming to answer the research questions, we proposed an approach that considers the learning profile and topics of interest of the students involved in the process. Upon successful connection, the student who requested the communication will view LOs of other devices and then he can request the transference of the LOs. Metadatas are adopted to describe the learning objects and the learner profile (Devedžić et al., 2008). A prototype has been developed in the Android platform (Android, 2012) using Bluetooth technology to evaluate the proposal. Another auxiliary application was developed to permit the population of devices’ local repository from an Amazon cloud to the device, providing a diversity of materials to the evaluation of the model. We also used different communication technologies aiming at the verification of message size and communication time and, consequently, optimize the time spent in the exchange of messages. The design of learning and teaching’s processes are not considered in this work.

The remainder of this work is structured as follows: Section 2 explores related concepts (mobile collaborative communication, learning profile and learning objects) and related works; Section 3 presents the proposed approach; Section 4 reports the evaluation of the approach; and Section 5 discusses the conclusions and outlines future works.

2 Theoretical Background

This section introduces the main concepts on which the developed work is based. Section 2.1 briefly presents the concepts related to the mobile collaborative communication and Section 2.2 presents the definitions of learning profile and learning objects employed in this work.

2.1 Mobile Collaborative Communication

A Peer-to-Peer (P2P) network is composed by elements which share hardware and software to provide services and content in a decentralized way. The peers, network elements, perform both server and client roles, providing and consuming services and content (Kurose and Ross, 2007).

In the communication side, the collaborative communication between two network devices can be classified into two types. The first one considers a collaborative communication when the most of the features to support
collaboration occurs at local level. Functions such as routing, name service, finding context and message forwarding are performed without the use of a global network infrastructure (Costa and Fialho, 2008). The second one uses a global infrastructure (Internet, for example) adopting the services provided by such infrastructure. There is also the possibility of a hybrid model that takes into account the two types of communication (Jung et al., 2007). The collaborative communication is provided by different technologies with a variety of features such as autonomy, interoperability, availability to share data, context sensitive, and the appropriate use of hardware resources.

Among the features mentioned above, context sensitivity has become a key element in collaborative applications. A context-sensitive application is able to adapt its operations without explicit intervention of the users, providing information and services that are relevant for users to perform their tasks using information taken out of the interaction context (Vieira et al., 2011). In this sense, context plays a key role to enable applications to refine the available information into relevant information, to choose appropriate actions from a list of possibilities, or to determine the optimal method of information delivery (Baldauf et al., 2007).

Different elements may interfere in the context of user interaction. Among them, we can consider the profile of users who are interacting and sharing objects as an important context element (Kobsa, 2007). The media format may be another contextual element concerned in the user interaction which can directly interfere in the time of exchanging messages.

Different protocol communication models have emerged for supporting the messages exchanging as an alternative of XML messages (W3C, 2012b). Among them, we can highlight JSON (Website, 2012), Protocol Buffers (Google, 2012b) and Thrift (Thrift, 2012) as solutions that improve the performance of the communication. These protocols and their features are presented in Table 1.

Considering the conditions to establish a P2P communication, the protocols discussed above are important alternatives to optimize the exchanging and the building of messages. This may directly influence the students’ motivation during his interaction.

### 2.2 Learning Profile and Learning Objects

The learning profile has an important role to support the e-learning systems. Understanding the learning preferences of the student is useful for assisting him with more meaningful objects. Each individual fits into a specific learning style, what makes him to adopt attitudes and behaviors that are repeated in different moments and situations (Felder and Brent, 2005). Learning styles refer to highly individualized tastes and trends of a person, that influence their choices during the learning process. The student motivation can be improved when an e-learning environment supplies the student with elements that are in accordance with the individual’s learning style. The learning profile of a student may take into account his learning styles aiming at supplying the e-learning system with the learning preferences of the student.

The definition of what is an important information for the learning profile depends on the application’s goal. Some applications work with generic profiles that report only the fundamental information to support the application perform.
Others are more specifically providing the application with different adaptation process (Al-Hmouz et al., 2010). A learner model can help in the information arrangement through a formal and explicit representation of a learner profile. The creation of a learner model involves the organization of data that identifies the learner profile so that they can be interpreted by an electronic environment (Brusilovsky and Millán, 2007).

There are several models used in the characterization of learning profiles and learning styles, each of which is suitable for a different learning scope: the Myers-Briggs Type Indicator – MBTI, Kolb’s Experiential Learning Model, the Hermann Brain Dominance Instrument (HBDI), the Honey-Mumford’s Learning Styles Questionnaire (LSQ), and the Felder-Silverman Model.

Coffield et al. (2004) conducted a critical review of 13 models, which includes the models cited previously, used for identification and classification of learning styles. The authors report that there are different visions related to the use of learning styles. The first one argues that the use of learning styles may impose a label in the student. The second one reports the idea that learning styles allow the teacher to offer the student materials that are adherent to their preferences. However, it should be clear that the use of learning styles must be flexible so that the learner may have their own choices.

Graf et al. (2008) presents another methodology aimed at the identification of learning styles based on student behaviour. In their work, a LMS (Learning Management System) (Zaina et al., 2001) is the source for the collection of student interaction data, which are compared to behaviour patterns previously defined in conformance to the Felder-Silverman learning style model. The authors applied the Felder and Silverman questionnaire (Soloman and Felder, 2008) in order to identify students’ profiles. The focus of their work is to evaluate their results with a technique of behaviour patterns matching, verifying the convergence of their experiments.

Among the possibilities of leaning style modelling, the Felder-Silverman model (Felder and Brent, 2005; Felder and Silverman, 1988) was chosen to be used in this work since it has the strongest emphasis on the relationship of learning styles and teaching strategies. Besides, the model is largely employed in computer and engineering courses that are important areas for us (Zaina and Bressan, 2008). This model uses the concept of dimensions and, therefore, describes learning styles in different perspectives. The dimensions also facilitate the association of learning objects with learning profiles. Table 2 presents the model’s dimensions adopted in this work. Nonetheless, it has not proposed how to realize a dynamic linkage between the content and the profile. In another work, Zaina and Bressan (2008) relegates Felder/Silverman’s orientation dimension, proposing an alternative approach that splits the student learning profile into three categories: perception, presentation format and student participation. Its goal is to detect clusters of preferences that reflect different data perspectives caught during the tracking of learning styles.

Learning environments have different goals and one of them is to offer educational material, usually called learning objects (LOs). In this context, LOs must be selected so as to correspond to the students’ preferences. One of the ways to organize learning objects so that they can be used and reused systematically is
through the use of descriptive metadata, that is, a set of attributes that describes learning objects (Devedžić et al., 2008).

The LOM (Learning Object Metadata) standard (LOM, 2002) of the Institute of Electrical and Electronics Engineers (IEEE) is the most commonly metadata specification used for e-learning. The LOM standard has a structure that describes learning objects through descriptor categories. Each category has a specific purpose, such as describing general attributes of objects, and educational objectives. Table 3 shows the LOM categories adopted in this work.

2.3 Related Works

There are e-learning application examples found in the literature that works with learning profile, learning objects and P2P communication. We focused in the follows which have relationship with our approach.

Honey and Mumford’s learning styles questionnaire was employed by Lowery (2009). The assessment phase was conducted with the offering of activities, and with the identification of students’ styles. The author reports the problems in assisting some styles in disciplines with practical nature, bringing new challenges to future on-line lectures planning.

Milošević et al. (2007) proposed the adoption of a learning style that allows the system to build learning workplaces, bounding learning content and learning styles through the SCORM (Shareable Content Object Reference Model) (Devedžić et al., 2008). Although this proposal adopts a standard to support the concept specification, it does not consider the learning profile according to dimensions.

Stash et al. (2004) presents an authoring tool to design the relation between instructional content and medias by building a graphical model that was incorporated by the AHA! platform. The learning style conceptions of the tool were based on the Honey and Mumford model. A variety of learning object options, related to specific contents, was linked to the students’ possible styles; this linkage guided the sequence of content visualization (prerequisites). The tool translates the graphical design to rules that reflect what actions should be performed according to the student learning needs. Although the work presents the use of learning styles for content suggestion, the relationship between learning objects and learning profiles is not done automatically, what demands that the tutor be responsible for linking objects and profiles.

Mobilis Project (Fonseca et al., 2008) presents a service-oriented middleware architecture which focus on dynamic composition of services. The main goal is to support an automatic and portable offering of services according to the user context parameters. The middleware has two layers, the core services and the Mobiles services. The first one is responsible for providing context information, collaboration services, data and events sharing to mobile applications. The second one is composed of services which provide or not a graphical interface to the user. Our proposal is similar to Mobilis but also takes into account the capability of using different communication technologies to exchange data across the network.

EduSHARE (Angelaccio and Buttarazzi, 2010) e-learning application proposes an e-learning application that allows the data sharing in a P2P communication between student and teacher, and student and student. The main feature is to support the feedback on understanding of what is being discussed in the class
through questions sent to the student by the teacher. The student response may be sent to other students sharing the impressions and doubts. Nevertheless, the proposal does not provide a flexible architecture. We focus on the modularity providing the architecture extensibility which supports different technologies and allows the addition of different elements in the profile’s matching to attend learning demands.

3 The mobile collaborative communication approach

The student’s satisfaction with the materials offered by an e-learning system is fundamental in order to achieve the user approval. For the intent of offering quality, the relationship between the student and the system is built upon the tracing of personal preferences, reproducing the users’ expectations. Hence, learner profile is one of the most important components of e-learning systems, storing the relevant data about user preferences (Soloman and Felder, 2012).

Based on concepts of learning profile, learning objects and mobile collaborative communication, this work describes a model to supply the sharing and the exchanging of learning objects through a mobile P2P communication, concerning on the student’s learning profile, their relationship with the learning objects and the protocol used in the communication. The learning objects are offered to the students according to the results of the matchings of keywords describing the students’ interests, the learning object metadata and students’ learning profiles. The next subsections will report the elements of our proposal.

3.1 Requirements

For the proposed approach to be adopted, some requirements must be attended. The first one is that the learning objects available in the mobile collaborative communication must be catalogued using LOM standard. The proposal adopts only the LOM categories and fields described in Table 3.

Another requirement is that the learner model must be the student learning profile using dimensions based on Felder and Silverman (Table 2). A learner model contains relevant information to attend a system needs to automate tasks. The learner model adopted in this work contains the student identification, keywords that represents his learning interests and learning profile split into three dimensions: perception, presentation format and student participation. Two local repositories of objects, their respective metadata and the learner’s profile must be in the devices. These repositories can be updated when the users change their search and/or interests.

3.2 The approach

In this paper it was considered the mobile collaborative communication with local support of network functions without the use of the Internet infrastructure. The devices involved in a P2P communication can perform both roles in different situations: client and server. The roles are dependent on who starts the communication request.
The interaction starts after two devices have been found and one recognizes the other. When the wireless communication mechanism of the device is active it scans for other active devices. The student selects the device he wishes to connect and then the requesting device becomes the client and the other the server. As the result, the communication is established and the collaborative process begins automatically. The scan and the connection process can be developed according to the technology adopted in the communication. The different technologies supply the developers with APIs (Application Programming Interfaces) to provide these implementations.

The proposed approach contains four main components Context Manager, Forwarding Manager, Object Sharing Manager, and Naming, Routing and Identification Manager, which are composed of other subcomponents as shown in Figure 1.

The Context Manager is responsible for providing the communication and the interaction between both P2P elements of the application, client and server. In the server side it deals with the matching and retrieval procedures whilst in the client side it shows the objects retrieved from the server. To enable the collaborative communication, the Context Manager must be running on both devices: the client and the server. In the server, the matchings processes consider the learning profile of the client and the server’s learning object metadata to suggest the learning objects to the client.

The Forwarding Manager deals with the building and the forwarding of the messages to the client and/or server. It is supported by the Naming, Routing and Identification Manager during the message exchange. This module has flexibility for adopting different protocols to build the messages in the server and to parse the messages in the client.

The Object Sharing Manager manages the learning object sharing between applications and devices, wraps and unwraps objects and saves and requests objects. Like the Forwarding Manager it is support by the Naming, Routing and Identification Manager during the learning object transference.

The Naming, Routing and Identification Manager provides the mobile applications with the infrastructure communication basic services, allowing the application to search and to find services, objects and other network devices, to apply the domain name service and to forward messages. It is important to highlight that the module does not use any Internet services. All the discovery and advertisement services are supported by this local module. Once communication is set up, the client’s Context Manager requests to the Forwarding Manager the creation and the sending of a message to the server’s Context Manager (1). The message contains the student learning’s profile (split in dimensions) with the keywords of his interests (2). The Forwarding Manager may adopt different protocols to encapsulate the message. When the message is delivered to the server, the server’s Context Manager invokes the Matching Keywords (Context Manager subcomponent) (3) which looks for learning objects metadata in the LOM local repository which looks for learning objects metadata in the LOM local repository. The method seeks for learning objects whose metadata fields (title, description and keywords) match with the keywords sent by the client. The method returns a set of learning object metadata (LO metadata) that fits with the keywords.
Considering only the learning objects’ references that were retrieved in the previous step, the server’s **Context Manager** performs the next step based on the criterion learning profile. In the **Matching Learning Profile** (3), the dimensions of the student’s learning profile (Perception, Presentation Format and Student Participation) are compared to the Interactive and Learning Resources fields of the Educational category of LOM standard (Table 3).

Table 4 presents the binding between the fields of the LOM standard (describing the learning content – Table 3) and the students’ Preference Categories (Felder-Silverman – Table 2). The method returns to the server’s Context Manager a set of metadata that fits the dimensions of the client’s learning profile and the LO metadata (4). Then the server’s Context Manager requests to the **Forwarding Manager** to send the response message (compose of the retrieved metadata) to the client (5). The **Forwarding Manager** encapsulates the message using the same protocols and dispatches it to the client (6).

As soon as the client’s **Context Manager** receives the server message, it invokes the **Object Viewer** (7) which shows to the user the server objects according to the metadata retrieval (keywords, titles, media format, etc). When the user chooses one or more objects, the client’s **Context Manager** sends the selected references to the client’s **Object Sharing Manager** (8).

The server’s **Object Sharing Manager** receives from the client the object identifiers (9). The **Object Retriever** retrieves the respective object in the **LO Local Repository** (10). After this, the object files are wrapped by the **Object wrapper** (11) and dispatched to the client by server’s **Object Sharing Manager** (12). In the client, object files are unwrapped, catalogued and stored in the device’s **LOM** and **LO Local Repository**, respectively performed by **Object Unwrapper** (13) and **Object Cataloguer** (14). After that, the client can view the physical file of the retrieved objects.

The objects retrieved from the server are now available in the client local repository. The client would provide the new objects in a future collaborative communication.

4 Implementation and Evaluation

In order to validate our proposal we developed a mobile application prototype to share and exchange objects using Bluetooth technology. We performed experiments with different communication protocols to compare the performance of them. Section 4.1 presents the prototype implementation and its evaluation and Section 4.2 reports the protocols evaluation.

4.1 Mobile Prototype Implementation

Based on the proposed architecture we developed a mobile e-learning application that allows devices to share and exchange objects considering the profiles of the users involved in the communication. The mobile application was developed in an Android platform and used the Bluetooth API for implementing the communication functions such as forwarding messages, service names and routing.

Although our architecture is Internet-independent, we used a cloud application to create the initial local repositories in the devices. Besides, this application may
aid the updating of learner model or/and the improvement of the local repository with new learning objects. The cloud application, called Web Collaborative Learning (WCL), allows users to download the objects, their respective metadata and the learner’s model previously registered. The learner model available by the application is composed of the keywords, reported by the user which states his preferences in the learning area and his learning profile. The user’s learning profile was extracted from the outcomes of the questionnaire of Soloman and Felder (2012) that the user answered in his first access to WCL. By using the WCL, the student may look for learning objects in the Web, select ones that he has interest, and register the object keywords creating the object metadata. Besides the keywords, the object metadata contains its media format (video, sound, etc.) and the object URL. WCL application is hosted in an Amazon cloud (Amazon, 2011) and uses the SQLite database 3.6.20(SQLite, 2011).

It must be clarified that the WCL application has been used by students of our campus for some time and, as a consequence, we could benefit from such a database for implementing our approach. Our mobile module connects to the cloud database and before the objects be downloaded to the mobile device it shows the description of the catalogued objects. The user chooses the objects and the mobile module performs the download, storing the objects and their metadata in a local repository on the mobile device. The user can also download from the cloud his user profile. After that, the user does not need the Internet infrastructure to connect and to share the objects with other devices.

4.1.1 Mobile Prototype Evaluation

We have conducted an experiment with the mobile prototype of our proposal that was applied during the second semester of 2012 in two regular college courses: Distributed Systems and Software Engineering. The courses are part of the computer science under graduation curricula of Brazilian universities. The experiment was used as a supplement to traditional lectures and was divided into two steps. The first one was the identification of learning profiles based on Felder and Silverman questionnaire and the cataloguing of learning objects by the student using WCL. The second one was the use of learning objects and the students’ profile in the mobile application.

First, the students (a total of 170 students) have used the WCL, cataloguing learning objects according to the subjects that they have been studied in the classes. The students answered the Felder and Silverman questionnaire during the WCL register. Figure 2 presents the profile types identified after the application of the questionnaire. Felder and Silverman point out that a student fit in a dimension when the dimension’s value is greater than 7. When a dimension has a value between 5 and 6 it is considered that the student does not have a concrete value defined. We have noted that the sensing, visual and active were the highlighted values in the dimensions when we observed the dimensions whose values are greater than 7. We have supposed that these results were consequence of the students area: Computer Science. However, in the dimension sequential-global we noted that there were a high number of students whose profile value is between 5 and 6, showing that there were not a absolute value in this dimension.
After the previous step, we invited 20 volunteers' students of the two courses to test our mobile prototype. Our goal was to answer the first and the second research questions:

- Is it possible to relate the LO metadata to learning profile features?
- Have the technologies for small devices supported the communication to LO exchange?

Some students have used their own Android devices and others used our devices. The Android 2.0 and 2.1 were the system versions used in the experiment. Before starting the communication with the devices, we have asked to the students for downloading from WCL in the Amazon cloud a set of learning objects, catalogued by the students and their respective learner model composed by the elements report in 5. We have advised the students to select objects based on two relevant topics of the courses: functional tests (Software Engineering) and cloud computing (Distributed Systems). After downloading the data from the cloud, the devices were disconnected from the Internet, being enabled to start the P2P communication. We explained to the students about the profile dimensions aiming at them to be aware of the objects' suggestion performed by the system.

The students performed tests connecting the devices and exchanging the learning objects during a week. The students have reported problems with the learning object exchange when the connection failed. In this exception scenario, they have had to start the exchanging process again, because the architecture did not work with fault tolerance. In the end of the experiment, we applied a questionnaire to the student for supporting our conclusions versus the research questions. The students have reported questions as the frequency that they share files with other colleagues using only the device connection, their preferences fitted with the learning object suggested to them, and the technological problems happened during the objects exchanging. Most students (75

4.2 Protocols Evaluation

In this paper, we also aimed to evaluate technologies that could be used by mobile collaborative applications to provide the communication between various mobile devices. Our goal was to answer the third research question:

- Have the different communication technologies interfered in the size and in the time of the data exchange on the proposal architecture?

The technologies and communication processes used in our evaluation boost the development of applications in the high levels of the proposed approach. Our intention is to suggest the best communication technology for the mobile P2P communication, because we understand that the communication throughput can interfere in the student motivation to use the application.

Starting from the legacy of the web servers technologies, HTTP (HyperText Transfer Protocol) (Kurose and Ross, 2007) is the widely used protocol which works with both: the delivery of documents from server to devices and the receiving of requests from the devices. Due to the maturity and the capability for carrying different message types, the HTTP became a good option for P2P
communication. It is fundamental to highlight that from now on, the term server refers to a mobile device performing the role of serving data to a client mobile device.

We divided our evaluations into two groups. The first one takes into account the usage of HTTP where, in this case, two HTTP servers were implemented, one using Java and other using Node.js (Node.js, 2012). Both were used to exchange HTTP messages between the mobile devices. We evaluated different structures of messages over HTTP: XML, JSON, JSONH, Protocol Buffers and Thrift messages.

The second evaluation was to implement our client/server application using RPC (Remote Procedure Call) (Comer, 2007) technologies. On this approach, we used the Protocol Buffers RPC, Thrift RPC, DNode with a JSON message and DNode (GitHub, 2012) with a JSONH message.

The final goal of our evaluation was to compare two different communication technologies, HTTP and RPC, having different type of messages being carried inside each technology and then suggest which is the best one to use for collaborative communications. It was established that each implementation should send to the server one learner model used on the prototype application with one thousand fields and waits for the server response. Each test was performed one thousand times in a row and then the average of all these tests was used on the comparison.

4.2.1 Analyzing the Size of the Messages

First of all, we analyzed the message size (see Figure 3) considering the communication between the mobile devices and the server. Note that our evaluation did not concern the time to build these messages. Nonetheless, this is an important point in a real application. As described above, we are dealing with XML, JSON, JSONH, Protocol Buffers and Thrift messages in this evaluation.

Based on the results, we have some observations to point out about each technology adopted in the experiment. We consider the message size in a decreasing arrangement.

Although the XML technology is widely implemented in many programming languages and is easy to parse, the verbosity (W3C, 2012b) of XML makes it the biggest message with 177.1Kb.

JSON comes next with 161.1Kb. As explained before, JSON is an alternative to XML since it produces a simple message and does not bring to humans the difficulty to understand and interpret its structure. Even though it is 10% smaller than XML, this is not an enough percentage to make it the best one. In our particular message, we realized that many fields are repeated labels, hence the usage of an homogeneous compressor would fit perfectly. JSONH was the solution with the smallest message size (77.1 Kb). It is exclusively implemented with JavaScript, therefore it can only be used with Node.js. Despite the message being only generated by Node.js, it was adopted by other communication technologies since the technique used by JSONH is really simple and this could be translated to any programming language easily.
4.2.2 Analyzing the Communication Time

We performed the experiment concerning the comparison of HTTP and RPC implementations.

Figure 4 shows the HTTP implementations. We can observe that most of the messages sent over HTTP reached times very close. Nevertheless, the Node.js implementations were better than Java, demonstrating the potential of Node.js for network applications. The exception using Node.js was the Thrift over HTTP that, unexpectedly, had a better performance than others on Node.js.

On Node.js, JSONH got the lowest time, but the serialization and the parsing of the message spent a relevant time as with Protocol Buffers. Then, we concluded that JSON is the best technology to use with Node.js due to its low time for generating messages and low time for communication.

On the other hand, JSON on Java did not achieve the best performance. As a conclusion, on the Java scenario, Protocol Buffers and Thrift should be adopted to develop the collaborative network application. Figure 5 depicts the tests run with different RPC solutions. Although the worst communication time was performed by Protocol Buffers, it managed to build a message in a very small size, which can improve the performance in situations where Internet bandwidth is really limited.

In relation to Protocol Buffers, Thrift achieved a communication time four times smaller, and a message that, despite being greater than Protocol Buffers, almost does not vary in size.

DNode (using JSON message) got a better performance when compared to the other RPCs, even sending a message whose size is far superior to other implementations, demonstrating the potential of Node.js in networking applications. Using the implementation of DNode, we also tested the homogeneous compressor JSONH, which got a really compact message, smaller even than the Protocol Buffers. But the performance of this implementation was nearly twice as long compared with DNode JSON, since the compression and decompression consume a remarkable time.

Finishing the tests and the analysis, we consider that DNode is the best solution in case of choosing the RPC technology for communication among mobile devices. On the other hand, all HTTP implementations presented an outstanding performance. At the same time, Node.js has been used by several developers for easily and fast implementing HTTP applications and, in this work, the evaluation pointed out that Node.js performance is higher when compared with Java HTTP implementations.

5 Conclusions and Further Work

In this work we have raised up an approach for supporting P2P mobile collaborative communication to suggest learning objects (LOs) based on learning profile, without the usage of the Internet infrastructure. The focus concerns in the student’s learning profile and its linkage to learning objects for automatic content offering. To do so, we used matching’s processes to select the learning objects according to the student keywords that report the interests defined in the learner model. Upon successful connection, the student who requested the communication
will view LOs of another device that he has interest and then he can request the transference of the LOs. The proposed approach allows the adoption of widespread high level protocols and communication process, such as HTTP and RPC.

In order to evaluate our proposal, a prototype of an e-learning application was developed and experimented with 20 undergraduate students. A mobile module, which connects to a cloud application database was developed to help students to download the requested requirements of the proposal (learning objects, metadata and learning profile). The devices’ P2P communication was performed without the cloud intervention. After the experiments we concluded that our architecture achieved their goals previously planned.

We also evaluated different communication protocols for P2P communication. We concluded that the implementations with HTTP are better than the ones with RPC. Also, when we look into the HTTP implementations, we observed that the Node.js is well indicated for implementing HTTP applications. Such solution has getting attention recently and the evaluation done in this paper showed that it has better communication times as well as message sizes than other approaches. Further works include adding new features to the matching process to consider other context elements. Such new features include user physical localization and device resources as screen size, features that must be considered when choosing the most adequate learning objects. Besides, we have developed a fault tolerance module which may be used when the devices are not connected. This problem was related by the students during the prototype experimentation.

References


An Approach for Supporting P2P Mobile


W3C (2012b). Xml technology. [http://www.w3.org/standards/xml/](http://www.w3.org/standards/xml/).


Table 1  Communication Protocols.

<table>
<thead>
<tr>
<th>Protocol</th>
<th>Description</th>
<th>Main Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>JSON</td>
<td>JavaScript Object Notation, is a lightweight text-based open standard designed for human-readable data interchange. Although JSON has its backgrounds in the JavaScript Programming Language (W3C, 2012a), it is not exclusive of JavaScript.</td>
<td>The main goal of JSON is to provide resources to ease the message parsing and building by any machine (Website, 2012). The JSON protocol is often used for serializing and transferring data over a network connection, sending data between web applications.</td>
</tr>
<tr>
<td>JSONH</td>
<td>JSON Homogeneous Collections Compressor was developed to compress homogeneous collections (messages where the contents are repeated many times in different tags) (WebReflection, 2012). JSONH provides the best performance, cross programming language, and resources to pack and unpack generic homogeneous collections.</td>
<td>Considering an overall performance and the simplicity of the message, JSONH is three times faster than JSON in compression and two times in parsing. In some cases, bandwidth size used in the message exchange may decrease in thirty percent of original size.</td>
</tr>
<tr>
<td>Protocol Buffers</td>
<td>It is an open source technology developed by Google (Google, 2012a)</td>
<td>It defines a neutral platform and language with an extensible mechanism for serializing structured data. Its resources are available in a variety of languages such as Java, C++, and Python (Google, 2012b).</td>
</tr>
<tr>
<td>Apache Thrift</td>
<td>It is a software framework to implement scalable and distributed services.</td>
<td>The framework is originally developed by Facebook (Facebook, 2012) and, as well as in Protocol Buffers, many languages may support the Thrift resources (C++, Java, Python, PHP, Ruby, Erlang, Perl, Haskell, C#, Cocoa, JavaScript, Node.js, Smalltalk, OCaml, and other languages) (Thrift, 2012).</td>
</tr>
</tbody>
</table>

Table 2  Adapted dimensions of the Felder and Silverman model.

<table>
<thead>
<tr>
<th>Dimensions Categories</th>
<th>Features</th>
<th>Learning Styles</th>
<th>Teaching Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perception</td>
<td>The focus is in the best way through which the student can obtain information: contents, exercise type, for instance.</td>
<td>Sensing, Intuitive</td>
<td>Concrete, Abstract</td>
</tr>
<tr>
<td>Presentation</td>
<td>It is related to the input. Content preferences chosen by the student such as media types.</td>
<td>Visual, Verbal</td>
<td>Visual, Verbal</td>
</tr>
<tr>
<td>Participation</td>
<td>It describes the student attitude either as active or reflective.</td>
<td>Active, Reflective</td>
<td>Active, Passive</td>
</tr>
</tbody>
</table>

Table 3  Description of the LOM categories.

<table>
<thead>
<tr>
<th>LOM Category</th>
<th>LOM Field</th>
<th>Characterization</th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
<td>Identifier, Type, Title, Language, Description and Keywords.</td>
<td>General description of the learning object.</td>
</tr>
<tr>
<td>Technical</td>
<td>Media Format (video type, sound), Size, Physical location, Requirements (object use: software version, for example).</td>
<td>Technical features description.</td>
</tr>
<tr>
<td>Educational</td>
<td>Interactive type (active, expositive), Learning Resource Type (exercise, simulation, and questionnaire), Difficulty.</td>
<td>Educational functions and pedagogical characteristics of the learning object.</td>
</tr>
</tbody>
</table>
Table 4  Link between the LOM fields and the preferences dimensions.

<table>
<thead>
<tr>
<th>LOM Field</th>
<th>Field Values</th>
<th>Preference Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interactive</td>
<td>Active, Expositive</td>
<td>Sensing</td>
</tr>
<tr>
<td>Learning</td>
<td>Figure, Video, Film, and others</td>
<td>Auditory</td>
</tr>
<tr>
<td>Resource</td>
<td>Practical Exercise, Experiment, and</td>
<td>Active</td>
</tr>
<tr>
<td></td>
<td>others; Questionnaire and Readings</td>
<td>Reflexive</td>
</tr>
</tbody>
</table>

Table 5  Proposed learner model - specification of the students' learning profiles.

<table>
<thead>
<tr>
<th>Component</th>
<th>Attributes</th>
<th>Characterization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal Information</td>
<td>Student identification, Name, School level, and Course</td>
<td>Personal information includes student data that is rarely modified.</td>
</tr>
<tr>
<td>Preference Categories</td>
<td>Perception, Presentation Format, and Participation</td>
<td>Holds the learning profile in different dimensions through the Preference Categories specification.</td>
</tr>
<tr>
<td>Interests</td>
<td>Keywords</td>
<td>This aspect describes the keywords that the student has interested in search.</td>
</tr>
</tbody>
</table>

Figure 1  Mobile P2P collaborative communication approach.
Figure 2  Profiles identified from the questionnaire.

Figure 3  Message sizes.
Figure 4  Time of the HTTP implementations.

Figure 5  Time of the RPC implementations.