AN ARCHITECTURE FOR SUPPORTING DISTANCE LEARNING IN AN ENVIRONMENT WITH LOW-BANDWIDTH INTERNET CONNECTION

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ABSTRACT

Distance learning is an alternative for mass education without dependencies on physical education resources. This approach is very important for developing countries like Indonesia. Unfortunately, these countries usually have limited Internet bandwidth required to deliver distance learning materials effectively, so the challenge is to implement distance learning over such limitations. We developed an architecture and tools to cope with Internet limitation and share learning resources. The architecture consists of a learning management system as the engine for the distance learning system, a set of metadata to help disseminate information about learning materials, an e-mail-based query tool, and a web browser that works based on the principle of user-oriented quality of service. Collectively, these tools provide students with low-bandwidth Internet connection access to learning materials, either using online or offline mechanism.

Keywords: distance learning, software architecture, low-bandwidth Internet connection

INTRODUCTION

One of the biggest problems in developing countries is provision of proper education for school-age people throughout the country. There are at least two issues that must be addressed to achieve the goal, namely, spread distribution of the target people and scarcity of good-quality education resources (e.g., qualified teachers, up-to-date learning materials, and appropriate facilities). One promising approach to address these issues is to use Internet technology in delivering education through distance learning. Using distance learning, education materials can be delivered to a large number of people in short time. Also, precious education resources can be developed by good teachers and then shared without much difficulties.

Effective distance learning requires high-capacity communication network infrastructure and efficient management and organization of learning materials. Unfortunately, this has become the main obstacle for most developing countries. Disparity of distribution of Internet facilities and expensive telecommunication costs have been preventing people in developing countries from gaining access learning resources offered by the Internet. As the case of Indonesia for example, our national average teledensity number is 36.8 out of 1000 (P3TIE, 2003), and according to the Indonesian Association of Internet Service Providers (APJII), there are only 11 millions Internet users by the end of 2004 (out of more than 200 million people). It should be noted, however, that 95% of this figure are people who live in Java island where communication and Internet infrastructure is better than the other parts of Indonesia.

Even for those with Internet connection, high-speed access is still a luxury due to limited bandwidth and connection quality. The Indonesian Internet Exchange (IIX) recorded only 3.9 Gbps bandwidth usage for the whole country in January 2005 (APJII, 2006). Internet access tools such as Web browsers do not help much since the design of their underlying technology assumes high-quality networks as the operating environment. Network latency, jitters, and other disturbances are treated as exceptions, but for most people in developing countries, these “exceptions” sets out as the normal operating condition.

DESIGN AND IMPLEMENTATION

For most developing countries, it is difficult to expect massive investments on communication infrastructure in a short period of time, so for a short-term solution, the option is to optimize existing infrastructure to deliver distance learning. We propose an architecture for optimizing Internet access in environments with low-quality network connection. The architecture, shown in Figure 1, is based on the concept of user-oriented quality of service (QoS) (Wardani, 2003).

User-oriented QoS is a subjective measure of network services (Vouk et.al, 1999). Its working is not dictated by network performance, but instead is defined by users. In our proposal, user-oriented QoS is used to compensate the limitations of network infrastructure with freedom and flexibility on the user

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side in accessing the network. Access behaviour is completely defined by users, instead of by the network. For example, if a user is willing to wait longer for a download operation, he or she has the full control to command the browser to do so (i.e., instead of surrendering to the “connection time out” restriction imposed by the browser). Allowing a user to set up his or her QoS requirement provides more opportunities to express his or her access specification. It should be noted that the use of user-oriented QoS does not improve access performance, however, it can optimize access in environments with limited network resources.

![Diagram of Repository Model](image)

**Figure 1. Architecture for optimizing access in distance learning environments with limited Internet connection**

Referring to Figure 1, the repository layer is where learning materials are stored. It is implemented using database schemas that model a structure of learning material organization.

The presentation and management layer implements the above structuring concept. It allows composition of learning materials to form a course structure.

Once a structure is created, users can define how a course is to be presented. Course presentation defines the learning pattern that should be pursued by students. Different types of subjects require different patterns for best pedagogical results. For example, a course subject containing modules with strong sequential nature would be best delivered using a strict serial pattern. This means students are not allowed to jump into the middle of the course before completing the preceding modules.

Another issue that must be handled by the presentation and management layer is scalability of distance learning services. Distance learning can be conducted in formal learning environments (e.g., in departments where students must register formally for subjects they intend to take), as well as in wider environments such as open-learning programs where any individual can register to the system and access its content without being constrained to academic formalities. To accommodate the need for greater flexibility, we designed different ways to access the distance learning system. We provide both direct access to the learning management system via web, or indirectly via e-mail mechanism. The latter provides non-intrusive access for users who do not need to involve in formal learning activities.

The fundamental architecture shown in Figure 1 is then implemented. We developed three software components to realize the architecture: a learning management system with metadata properties, a user-configurable browser, and an email processor. The implementation used Open Source tools:

- Apache web server
- PHP programming language
- MySQL database system

The system is run on standard PC computers connected to a FastEthernet LAN.

**RESULTS AND DISCUSSIONS**

We have described the architecture for supporting distance learning in environments with low-bandwidth Internet connection in Figure 1. Details of each component described in Figure 1 are explained below.

**Learning Management System**

The learning management system (LMS) is a web-based tool for managing learning materials. It is implemented as a server-side application that communicates with the learning object repository through a set of SQL commands. Lecturers can use it to upload learning materials to the repository, structure them, and remove them.

Once learning materials have been put into the repository, they can be structured to mimic course material organization in the real world. A course is collection of modules, which define a chunk of cohesively related topics. A course topic defines a specific, focused subject of discussion, from which learning materials are developed. This organization is composed hierarchically and the LMS tool allows mix-and-match composition of objects in the structure. It promotes the concept of reuse; a lecturer can use other lecturers' materials to develop his or her course. Composition of learning materials is done interactively through object structure manipulation within the LMS. This is illustrated in Figure 2.
Metadata

The role of metadata is to export information about learning materials in the repository for non-intrusive access (i.e., without having to enter directly into the system) (Dwiyantri, 2004). The structure of learning materials, as well as pertaining information about individual objects, are represented using XML format.

Each learning material has its own metadata. The metadata describes the object’s ID, owner, title, access permission, hierarchical position, and course-specific information such as goals, objectives, and references. It also specifies an access link that can be used by users to retrieve the object.

A learning material’s metadata is created or updated automatically upon the material’s creation or modification.

E-Mail-Based Query

For users with very poor Internet connection, we developed an offline access tool using e-mail mechanism (Tentu, 2004). A user specifies his or her access through a simple access language written in the body of e-mail, which is then delivered to a server-side email processor. The e-mail processor extracts and reconstructs the message and passes it to the learning management system.

There are two types of query messages: those for getting information about learning materials or course structure, and those for retrieving learning materials. Reply to the first type of messages comes from the metadata associated with the requested materials, including an access link to get the materials. A reply is sent back to the user via e-mail. A reply to a retrieving query includes attachments containing files of the requested materials.

Since this application is intended to distribute learning resources, no strict security measure is implemented to control external access. Users are only requested to register to get a free account. User authentication is solely based on this account, and grant to access depends on the permission set by the owner of the material.

User-Configurable Web-Browser

For online access, we designed an Internet browser that allows users to define their own quality of service specification. A user can define the behaviour of the browser to adjust to the performance of the network (Lisica, 2003). For example, instead of giving up upon long network delays, the user can command the browser to wait longer or to search for alternative web sites during a download process.

The user-defined behaviour of the browser is based on the subjective QoS concept. The model defines access parameters that are used to compare user’s expectation and the actual performance of delivery of a service (Wardani, 2003). Subjective QoS is measured around this comparison: if the user’s expectation is better than the actual performance, he or she perceives that the system can provide good QoS, or vice-versa. This measurement can then be used to trigger actions associated with the user’s judgement on the system’s QoS. For example, to override a browser’s default behaviour for time outs and insist on trying downloading, the following code can be programmed into the browser.

```java
settime x := 300; // expectation: 5 minutes
repeat
    y := gettime(connect("http://singau.mtl.ugm.ac.id/");
    until (y < x);
    display("http://singau.mtl.ugm.ac.id/index.html");
```

In the previous code, when the underlying network transport mechanism fails due to time out, the browser takes over control by repeating the process.

DISCUSSION AND FURTHER WORK

IT-based distance learning is one of important areas in education. This fact is demonstrated by the numerous computer applications addressing different aspects of digital learning. WebCT (WebCT Inc, 2006) is a commercial package that focuses on general course management aspects such as course presentation, teacher-student interaction, and assignment and assessment.

Attention to the organization of learning objects is shown by Ilia, an open source learning management software (Ilias Team, 2006). Ilias proposes the concept of “category” to group learning objects. However, category is a generic unit that has little association with the real condition (i.e., how
teachers actually organize their lecture materials). Furthermore, it does not explicitly support reuse of learning objects.

Blackboard is another commercial package targeting for a “networked learning environment” (NLE) (Pitinsky, 2004). It uses extensible architecture that allows multi-mode interaction involving learning actors and resources with their respective roles. Furthermore, as a software package designed to work with NLE, Blackboard's existing features can be extended using the provided software development kit (SDK).

NLE is an integrated and comprehensive approach for digital learning. However, its ideal implementation is only possible when supported by sufficient network infrastructure. For people with limited network connection, a more crucial problem is not about the learning environment; it is about providing access to learning resources. Unfortunately, research in this area is more focused on new frontiers in network technology (e.g., web browsing optimization in wireless environment (House and Lindquist, 1996; Rodriguez et al, 2004)), rather than making network mechanisms to be more efficient and tolerant to low-bandwidth and unreliable environments.

A challenging idea is to implement NLE in environments with limited Internet connection. To overcome constraints on Internet connection, closely related learning actors and resources must be organized into “clusters” and managed by “learning centers”. A cluster implies frequent interactions among its members, therefore a learning center must be served by sufficient network connection. A learning center implementation could be a learning management system used in a specific department. Furthermore, clusters can be networked to form distributed learning centers. Communication between learning centers can be facilitated using the architecture and tools proposed in this paper.

CONCLUSIONS

Access to online learning resources is available to only a small fraction of people in developing countries. Even for these people, the cost is expensive due to lack of Internet bandwidth. Our effort attempts to improve accessibility by providing an distance learning architecture that optimizes Internet access in environments with limited bandwidth and encourages sharing and reusing learning materials.

Our approach in access optimization focuses on the user (user-oriented), not on the network system, because it is the user who experiences poor network performance. We feel it is the user who finally has to make the judgement for his or her access.

Sharing and reusing of learning materials are facilitated by an hierarchical structure of learning objects that resembles actual structuring of course materials. The structure allows mix-and-match course composition, thereby encouraging the quick development of good-quality course materials.

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