The Next Generation Mobile Classroom
Server-Side Implementation

by

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Submitted to the Department of Electrical Engineering and Computer Science
in partial fulfillment of the requirements for the degree of Master of Engineering in Electrical Engineering and Computer Science at the

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Abstract

The Next Generation Mobile Classroom (NGMC) project is a system of integrated wireless devices developed to enhance the learning experience in large university lectures. Based on advanced technologies, such as 802.11b networking and wireless Pocket PCs, the system enables learning features typically missing in traditional lecture halls such as mini-quizzes, nondisruptive questions, online collaboration tools, and media distribution. Development of the system was driven by research and experience in online pedagogy, with the primary goal being an increase in the interaction between members of a large classroom. This thesis chronicles the development of the system, from the early research and design, to the final implementation and deployment in an MIT classroom. The author focuses on the implementation of the central software component of the NGMC, the application and database server.

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Acknowledgments

The Next Generation Mobile Classroom is a large endeavor, and I would never have completed my portion without the help from many individuals and groups offering their support. First, I would like to thank the iCampus group [9], in particular Hal Abelson and David Mitchell, for offering much guidance and support for the project. Much thanks must be given to Ed Barrett for allowing the NGMC group to pilot the project in his class, 21w.785, in the fall of 2002 [20]. I must also acknowledge and thank the other members of the NGMC team, Mark Tompkins, Raj Dandage, Manuel Centeio, Dr. W. John Dickerson, and Greg Dennis, who provided their time and expertise through the entire project. Finally, I owe special thanks to Dr. Nishikant Sonwalkar for supporting me since my sophomore year and being the perfect thesis adviser throughout the lifetime of this project.
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Chapter 1

Introduction

1.1 The Next Generation Mobile Classroom Project

The Next Generation Mobile Classroom Project (NGMC) is a technical solution to the goal of bringing the small classroom learning experience into large university-level lectures. The project enables greater interaction, faster feedback, and increased multimedia distribution through the use of the latest technologies. The NGMC consists of a network of full-featured wireless handhelds integrated through custom software geared for use in the classroom. The system enables learning features never realized in a large lecture hall before. Instant quiz reports, nondisruptive questions, electronic scheduling, and automated media distribution are all realized by the system. Smart client programs run on the individual handhelds and connect to a substantial server application and database. This thesis details the design and implementation of the software running on the centralized server.

Development of the project started in the spring of 2002 with the application for a MIT/Microsoft iCampus grant to develop the project. The grant was won by the team and design of the project began immediately. Many architectures and features were discussed, eventually settling on those described in this document. By the end of the 2001-2002 school year, a prototype was completed and presented to the iCampus team. Further development proceeded during the summer. In the fall of 2003, the team purchased the production hardware and deployed the Next Generation Mobile
Classroom in the MIT class 21w.785, Communicating in Cyberspace. In the spring of 2003, the Next Generation Mobile Classroom was used in 21w.765, Nonlinear Narrative.

1.2 Chapter Notes

Chapters 1 and 2 describe the motivation and objective for the project. Chapter 3 details the educational research that has guided the project. Chapter 4 discusses projects developed by others that are related to the Next Generation Mobile Classroom. Chapters 5 through 9 describe the system at the different levels of functionality, and follow the progression of development of the system, starting at the educational goals and finishing with coding the system. Chapter 5 deals with the educational features of the system. Chapter 6 covers how the educational goals were achieved on a technical level, but does not go into specifics, such as hardware and software platforms. Chapters 7 and 8 describe the actual software and hardware architectures, respectively. Chapter 9 covers in detail the server-side architecture of the NGMC.

1.3 Contributions

This is a large project and requires the efforts of many individuals. As a key director of the project, my contributions involve the architecture and implementation of the server application, as well as general motivation and design. This task covers the implementation of the display protocol, the many functional components of the system, authentication, and data storage. Basically, this includes the software running on the three servers shown in figure 8-1. I also configured the server hardware and software components running on the system. Other members of the project are contributing other components to the system. Raj Dandage implemented the software that runs on the client machines. His masters thesis covers this development [5]. Mark Tompkins coordinated the PDA distribution and usage in the classroom.
Chapter 2

Project Motivation

2.1 Background Information

Throughout our careers at MIT, the members of the NGMC team have worked much on educational technologies. We have done research on campus as well as worked at outside companies that focus on education and technology. We feel that, executed correctly, technology definitely has a place in education. For example, online research databases such as LexisNexus [13] are now an essential tool for performing any type of technical research. As technology improves, and more of our information becomes digitized, technology will continue to have a greater role in education. Eventually, we see it taking an essential role in the classroom. The NGMC project was designed to provide a taste of this future.

2.2 New Technologies

A major motivation for creating the NGMC was to integrate many new technologies appearing on the market and at MIT. At the time of writing, to our knowledge, we are the only project to use PocketPCs [15] running custom software over 802.11b networking in a flexible, centralized system for the classroom.
2.2.1 Portability

For the first time ever, extremely portable, powerful, pen-based computers with color screens are appearing on the market. While we could have designed a system where students carry a laptop to class, or take class in a computer cluster, we wanted the system to be more personal, but not greatly interfere with students’ lives or established lectures. In addition, portable, pen-based devices are typically less expensive than a full-fledged laptop or desktop computer. We distributed tiny PocketPCs to students and expected them to have the devices whenever on campus. These new devices allowed students to always have a powerful technological interface with them, an important step in bringing technology into forefront of education.

2.2.2 Centralization

The NGMC project could have consisted of a suite of applications that ran on the portable devices and provided the functionality we desired. Much of this functionality is already provided by the PocketPC in the form of an embedded address book and calendar. However, we wanted a centralized system, so that all information relevant to the system is stored centrally, so students and teachers can access this information using various devices, at any time. For example, if a student forgot his PocketPC at home, he can still access class materials using a PC in a computer cluster. This feature required us to write most of the software of the NGMC to be run on a centralized server.

2.2.3 Wireless Campus Network

Recently, MIT and many other universities have been deploying 802.11b wireless networking on campuses [23]. Most large lecture halls have this technology deployed. As this technology is widespread on campus, well supported by manufacturers, and is high-bandwidth, it is the perfect means of communication from the student’s devices to the server. Fortunately, at the time of development, PocketPCs with wireless functionality were just appearing on the market.
2.3 Pedagogical Motivation

The core motivation in creating the NGMC was to improve the learning experience. In this iteration of the project, we focused on higher-education, particularly large lectures. The following sections, as well as chapter 3, explain various areas of the classroom where technology can take a role in improving the experience. The interactions between teacher and student in a large classroom can be significantly improved by wireless devices.

2.3.1 Related Research

My thesis adviser, Dr. Nishikant Sonwalkar, has performed extensive research into the area of computer-based educational facilities. I have worked with Dr. Sonwalkar at various MIT labs, integrating electronic teaching methods into the classroom. The Next Generation Mobile Classroom is the culmination of my work into this area of educational research. Chapter 3 focuses on his research and its relation to the Next Generation Mobile Classroom project. Dr. Sonwalkar’s pedagogical research indicates that interaction is a key dimension for improving the learning experience and to reach learning goals.

2.3.2 Personalized Communication

During a large lecture, almost all the information exchange is from the lecturer to all the students. It is very rare for there to be individualized communication between a teacher of the class and an individual student. If questions are asked by students, they disturb the flow of the lecture, and usually the question’s answer is relevant to only a few students at the lecture. This is because students have varying knowledge of the material, so a question asked by one will be too advanced for some and too basic for others. As will be seen, the NGMC provides a means of personalized communication between students and teachers during lecture. A student can ask a question during lecture and receive an answer, without disturbing the class.
2.3.3 Student Progress Feedback

In a traditional lecture, it is very difficult for professors to gage students’ understanding of material during the course of the lecture. The professor can pose a question to the entire class, and some students can nod their heads or raise their hands, but it is unlikely that a student that is falling behind will let this be known to others. Thus, an anonymous means of asking questions to the class is needed. It must be very simple for the students and professors so to not be a big distraction in lecture. The mini-quiz functionality of the NGMC allows professors to quickly and easily determine students’ understanding of the material in the middle of lecture. The feature also ensures that students will pay attention through the entire lecture.

2.3.4 Scheduling and Contact Management

In a large class, it is convenient to have a centralized database of student and teacher contact information, as well as a centralized scheduling system. Most universities have these databases in place, but they are often inaccessible to students. If they are provided to students, they are usually in the form of a Web page [21]. Of course, a student would need to be at a computer connected to the Internet to view this information. In addition, study groups are an effective way of helping students learn course material. It would be very helpful if there existed a central study group management server, where students could meet other students to form groups and set meeting times. If all these systems were integrated, maintenance and modifications would be simplified. It would also be convenient if students had access to these systems, especially the group management database, while in class. As will be seen in chapter 5, the NGMC provides all these features, and is always available to students in the classroom. During lecture, if a student feels he or she needs to understand the material better, he or she can sign up for a study group right then and there.
Chapter 3

Related Educational Research

3.1 Background Information

The primary goal of the Next Generation Mobile Classroom is to improve the classroom learning experience through the use of new technologies. One cannot blindly bring computers and PDAs into a classroom and expect students to learn better by using them. Much research has gone into the proper use of technology in a classroom, and has guided us in the development of the Next Generation Mobile Classroom.

At the forefront of pedagogical research is Dr. Nishikant Sonwalkar, my thesis adviser for this project. The former Director of the Hypermedia Teaching Facility and current Principal Educational Architect at the Academic Media Production Services at the Massachusetts Institute of Technology, Dr. Sonwalkar is regarded as a leading expert in the application of computers in education[3][10]. In my workings with him over the past four years, I have developed a greater understanding of the place for technology in education.

During my time at the Hypermedia Teaching Facility, Dr. Sonwalkar and I developed online courseware for various institutions and corporations, ranging from college freshman physics tutorials to corporate training sites. We would emphasize the use of the latest technology, which at the time was multimedia: video, audio, automated slideshows, etc [33]. The Next Generation Mobile Classroom is a natural progression from my past work, focusing on the current new technologies: wireless, XML, and...
3.2 Learning Styles and the Learning Cube Model

Given that the Next Generation Mobile Classroom is aimed at enhancing how students learn in a college-level class, it is helpful to observe that different students learn differently. In his research, Dr. Sonwalkar has quantified the wide variety of presenting material to students into five distinct "Learning Styles." The different Learning Styles all teach the same information to students, but vary in the methods of presenting the information. For example, the Apprenticeship Learning Style presents content in a step-by-step fashion, the style of most text books. On the other hand, the Discovery Learning Style presents content in a much more exploratory method, letting students see the results of their lesson usually before they learn the theory behind it. More information on the various Learning Styles can be found in the referenced articles of this thesis [31].

Much of Dr. Sonwalkar's research revolves around what he calls the "Learning Cube." The Learning Cube is a convenient way of showing how the many elements of the classroom fit into the realms of Interaction, Learning Style, and Media [32]. Figure 3-1 shows the various learning styles, and how they relate to various levels of different types of media and student/teacher interaction. By focusing on a discrete number of learning styles, and by examining the makeup of the instructional materials in an online course, we can get a rating on the applicability of a given course for certain types of students [34].

The Learning Cube describes the learning experience as having three principle dimensions: multimedia presentations, learning styles that suggest a particular content sequencing, and interactivity that ensures connecting students with teachers and students with students. The pedagogical success of a course within the classroom, and asynchronously on the technology enabled educational space, depends in the utilization of all three elements. The NGMC project's focus is to enhance the interactivity dimension of the learning cube by providing a wireless means of interaction. The
other important aspect is the instant feedback from students to “adaptively” improve presentations in the classroom to meet the needs of students.

3.3 Relation to Next Generation Mobile Classroom

The Next Generation Mobile Classroom is a means of presenting information to students in a way that has not been realized in a classroom before. Chapter 5 will go into detail about the various educational functionality, but the major improvements to the classroom that the project realizes are an increased level of interactivity between students and professors, and the better integration of multimedia elements into the classroom. It is clear how these improvements relate to the Learning Cube. While the traditional classroom presents information with text and graphics, and varying levels of student/teacher interactivity, the interactivity drops dramatically in large classrooms. At the university level, lectures can be enormous, greatly limiting this interaction. The Next Generation Mobile Classroom restores this interactivity, and
brings the other media elements more easily into the lecture hall.

Figure 3-2 shows the flow of information for the creation of a textbook-based online course. It shows the steps needed to move from a traditional textbook-based class to one that supports the various Learning Styles. The upper half concerns the manipulation of information to be put in the various display formats, and the lower half shows the means of presenting this information to students. The Next Generation Mobile Classroom is a way to realize the lower half of the diagram.
Chapter 4

Related Projects

4.1 Overview

Other universities and corporations have developed or are in the process of creating similar systems to the Next Generation Mobile Classroom. These projects have been in development for a longer time than the NGMC system, but do not use as advanced technology, are not as convenient to use, nor as integrated into the classroom. This chapter will detail a few of these related projects, and explain how we used the experiences of others to guide the development of the NGMC project. The chapter focuses on three leading systems for integrating the classroom electronically: The PRS system from EduCue, the Classroom Communicator, and the ActiveClass system at UCSD.

4.2 PRS from EduCue

The PRS, or Personal Response System, is a system composed of many infrared transmitter devices and a receiver. The transmitters are given to students, and are used to submit information to the lecturers during class. The transmitters resemble television remote controls, and the students must aim them at the receiver and press the appropriate buttons. The system is mainly used for quizzing students during the lecture. The professor displays a multiple-choice quiz using a projector, and the
students submit their answers using the handheld transmitters[4]. The system is relatively easy to deploy, and accomplishes its goal of allowing professors to quickly receive feedback from students in lectures. The system also includes an “I am lost” button, that anonymously signals to the professor to slow the lecture.

The PRS system does have some serious drawbacks, though. It is usable only for multiple-choice questions, so it may not be appropriate for some quizzes or surveys given in classes. The information flow is in only one direction, from student to teacher, so the system does nothing to improve communication from teacher to student or from student to student. While the system is relatively simple, the transmitters each cost around $50, which is inexpensive when compared to the hardware used in the NGMC project, but is expensive when you consider that the system does not provide much more functionality than what can be accomplished with students raising their hands in class. Finally, it relies on proprietary hardware, so the receiver and computer backend must be transported to every classroom where it is to be used.

In developing the Next Generation Mobile Classroom, we wanted to provide all the functionality of the PRS system. Basically we wanted an easy means of students to anonymously send information to the professor. We also wanted to enhance this functionality, so to include the answering of other types of questions, such as short-answer text questions. We desired to use different hardware from the PRS system, on both the client and server side. First, we wanted the hardware used by the students to be useful for other purposes. Laptops would work, but we wanted the clients to be extremely portable. This decision lead use to the use of PDAs for the students. We also wanted any classroom to be able to support the NGMC. Thus, we took advantage of the wireless deployment at MIT and located the server offsite, but accessible from anywhere through the Internet.

4.3 Classroom Communicator

The Classroom Communicator is a logical step from the PRS system. It provides the same functionality, but in a more elegant way. Instead of using specialized in-
frared transmitters, the system uses WAP-enabled mobile phones[6]. The server is also Internet-based, so that any classroom could use the system, as long as it received mobile phone coverage. Other advanced features that the Classroom Communicator provides are greater question flexibility—question types beyond multiple-choice are supported—and Internet-based administration[2]. The system also supports very simple sending of information from teachers to students.

The Classroom Communicator provided many powerful integration features and was the first system to truly enhance the communication between students and teachers. Using a Java-based interface, the professor would create quizzes before class, and during class, would send them to the students’ phones. The results would instantly be recorded and displayed on a classroom projector. While the provided functionality was limited, the Classroom Communicator proved that an integrated wireless system could provide enhanced features to a lecture with minimal modifications to the classroom.

The primary drawback to the Classroom Communicator was the reliance on a third-party for the data transmission—a wireless phone company. Special phones were needed, which at the time were extremely expensive. Each phone also required a wireless account with a phone company, which for data transmission is very costly. The phones also had small, black and white displays and numeric keypads, making alphanumeric data entry difficult, though not impossible.

The Classroom Communicator provided a good example on which to base the educational features of the Next Generation Mobile Classroom. We wanted to provide the wireless features of the Classroom Communicator, but did not want to rely on a commercial third-party. We wanted the students’ devices to be usable for other purposes, but desired them to be more powerful and with a better human interface. After several conversations with the creator of the Classroom Communicator, Eric Brittain, it became clear that usability was extremely important in the success of the project. This fact guided us in making the interface a top priority in the development of the NGMC[36].
4.4 ActiveClass

Of the related projects examined during the development of the NGMC, the UCSD ActiveClass project is the newest and most advanced. The system is a substantial technological step up over previous projects, using PocketPCs and 802.11b wireless networks. The advanced system permits full two-way communication, and advanced interfaces. The ActiveClass system provides quizzing, as well as the ability for students to ask questions during class. In addition, the system can display class documents on the students’ PDAs[35].

While it uses more elegant technologies than the Classroom Communicator, the ActiveClass system does not provide a large functional step up from the previous project. The usability and cost-effectiveness of the ActiveClass is much greater, due to the use of different devices and integration with classroom wireless access points.

The project was designed to use as many well-known standards as possible, and the communications and display mechanism is purely Web-based. The client software is simply the integrated Web-browser on the PDA. While this fact allows the system to support many types of client hardware, it limits the degree of interaction between users of the system. For example, the client software does not instantly know of new information from the server. Instead, it has to reload a Web page every 30 seconds. This design causes a large load on the server, and drastically delays the speed of information being shown to students. In addition, because it is purely a Web application, the system does not integrate with the convenient and powerful built-in features of the PocketPC such as the address book, calendar, and media devices.

We desired to produce a system that had at least the functionality of the ActiveClass project, but removed the restrictions of relying on a basic Web-browser as the client program. Since PocketPCs and 802.11b networks were becoming widespread at the time, and they fit the goals of the system better than any competing options, it made sense to use them in the NGMC project. Their interface was easier to use than other projects, and we strove to achieve a similar level of usability. Our biggest
enhancement over the ActiveClass project was the development of the “smart client” program running on the PocketPCs. While our system uses Web-based protocols to exchange information, the client software removes the drawbacks of relying on a basic Web browser as the client program. Using our own client software on the PocketPC, we could provide instant communication in both directions from student to teacher, and take advantage of the features built into the PocketPC.
Chapter 5

Educational Functionality

5.1 Goals

The Next Generation Mobile Classroom project has the primary goal of using technology to enhance the learning experience in university lectures. The NGMC project plans to provide three main improvements over the current university classroom: 1) better interaction between the professor and student; 2) increased feedback given to the professor concerning students’ progress; and 3) increased communication between students to enhance their collaborative learning efforts. When brainstorming the project, we came up with a list of goals for the project. These are listed in table 5.1.

For the pilot version of the project, we settled on a diverse feature set, suitable for many lecture-based classes. Many of these features, such as question routing, had never been deployed in a class, especially using handheld wireless technologies.

The following section explains the functionality of the major features of the system.

5.2 Feature Discussion

5.2.1 Overview

Table 5.2 gives a brief description of the major educational components of the NGMC. The following sections give an in-depth description of each feature. The screen-shots
Table 5.1: Functional Goals of the NGMC

- Allow professors to easily gage students’ understanding of material during class.
- Improve the distribution of class materials.
- Allow individual student feedback in large lectures.
- Be easy to use, so that student and professors will easily adopt it.
- Not be intrusive to classes.
- Handle a wide variety of classes, size-wise and content-wise.
- Be useful outside class, for correspondence and material distribution.
- Record usage data for later analysis and to assist in pedagogical enhancements.
- Use newly-deployed technologies at MIT.
- Ensure student privacy.
- Be secure against network-based attacks.

pictured in these sections are from the deployed NGMC system and demonstrate the fully-functional system. Most are screens from a PocketPC accessing the system, but PC screens are shown where noted.

5.2.2 Message of the Day

The message of the day feature allows professors to enter a message into the system that is displayed when students first log on to the system. Professors can use this feature to display lesson plans, class news, or any other short-term information. Figure 5-1 shows the student home page with a message of the day. Past messages are remembered, and the students can easily look through them. In addition, it is simple for professors to enter the day’s message. Figure 5-2 shows a screen shot of the professor’s entry screen for a message of the day.
Table 5.2: Educational Features of the NGMC

- **Message of the Day:** A message, lecture outline, etc. for all student at beginning of class.

- **Question Routing:** Allows students to ask questions during lecture without disruption of class.

- **Mini-Quiz:** Allows professors to quickly gage students’ understanding of material during class.

- **Scheduling:** Sets up reminders for professors and students about class meetings, group meetings, tests, etc.

- **Contacts Management:** Manages student and teacher contact information and sets up study groups.

- **Media Management:** Allows students and professors to exchange learning materials and assignments.

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Figure 5-1: NGMC Student Home Page Showing Message of the Day

![NGMC Student Home Page Showing Message of the Day](image)
5.2.3 Question Routing

The question routing feature allows students to anonymously ask questions in class, without disturbing the flow of the lecture. The process is as follows. From the home page on the student’s PDA, the student clicks on the “Ask a Question” link and a text field appears. Figure 5-3 shows this screen. The student enters the question to be asked and submits the page. Many students can ask questions during a lecture, and they get queued for the professor. When the professor desires to answer the asked questions, he pulls up a screen that lists the questions in the order asked. See figure 5-4. The professor can “deactivate” questions, which makes them disappear from the easily-accessible queue page, but does not permanently delete them. Later he or she can delete questions on another administrative screen.

5.2.4 Mini-Quiz

One of the most innovative features of the Next Generation Mobile Classroom is the “mini-quiz” function. This flexible feature allows professors to gain information from students in real-time to be displayed immediately, or selectively archived. One use of the mini-quiz feature could be to gage students’ understanding of material midway
Figure 5-3: Student Asking a Question

Figure 5-4: Professor Viewing Question
through lecture. Using his or her PDA, the professor would send a premade quiz to all students, and it would appear on all of their devices. Figure 5-5 shows an example student quiz. After students finish answering the questions, the professor can show the results in graphical form on the classroom projector, or the students can individually view the results on their PDAs through the Next Generation Mobile Classroom software. See figure 5-6. Both multiple-choice and text-entry questions can be used to create quizzes of any length, as shown in figure 5-7.

The mini-quiz mechanism can be used for more traditional quizzes as well. The professor has full control over who can take quizzes and who can see the results, so many styles of quizzes can be created. For example, a quiz may be taken by the entire class, but only the professor can see the results. Or, as was done often in the project’s pilot program, a presentation feedback survey can be created that can be taken by the entire class, but only the presenting group can see the results.

5.2.5 Scheduling

The Next Generation Mobile Classroom has a powerful scheduling mechanism for managing class events. Professors and students can create events, and dictate who can see the event. The choices are any combination of: individuals, project groups,
or the entire class. The calendar of events is easily accessible from the student and professor interfaces. In addition, the client software running on the PDA is integrated with the calendar of the PocketPC, so that events created by the NGMC system can take advantage of the built-in notification system and calendar of the PDA.

Figure 5-8 shows the main events screen on the user's PDA. The user can view events for various time periods, or create a new event. Figure 5-9 shows one of the screens used when the student or teacher is creating an event. The individual selects a date on the calendar, and the system brings the user to a screen where he or she can enter information about the event and indicate who can view the event's information.

5.2.6 Contacts Management

The NGMC software includes a fully-featured contact management system. In the system, each user can be in one or more classes. In each class, the user is either a professor, teaching assistant, or student. There is also a special user type called 'admin' that has complete control over the system. The system allows the same user to be a student in one class and a TA in another. Thus, the same person does not have to remember multiple login names and passwords.

Within a class, each user can be in one or more groups. These groups can be used
Figure 5-7: Professor Editing a Quiz on a PC
Figure 5-8: Viewing and Creating Events

Figure 5-9: Viewing and Creating Events
for any purpose: study groups, project groups, tutorial sections, etc. The system can store contact information about each user such as email address, office address, phone number, and student ID. To ensure users’ privacy, all information is not publicly available. The user does have the control to dictate which users or groups can see his or her personal information. Like the scheduling feature, the contact management functionality is also integrated with the PocketPC software, to allow a user to easily add class or project group members to his or her address book.

Figure 5-10 shows a screen from the contact management section of the NGMC. From this page, the user can see the information about the people in the group that he or she belongs to, as well as view other groups’ information, if they chose to make it available for viewing by others.

5.2.7 Media Management

The Next Generation Mobile Classroom includes a powerful multimedia distribution mechanism. The system allow users to share media such as video, audio, pictures, and documents with specific groups or individuals. The feature is very easy to use. The user navigates to the media section from their home page. From there they can view available media, or upload their own. For example, a user can record an audio
Figure 5-11: Uploading a Media File

file using the integrated microphone in the PocketPC. This file can be easily shared with specific project groups, certain individuals, or the entire class. Figure 5-11 shows the interface for uploading media into the system via the PDA.
Chapter 6

Technical Specification

6.1 Overview

This section covers the technical components of the NGMC at a high level. The previous chapter described the functional goals of the system, and this chapter will go over how these goals can be achieved using today’s technology. We leave low-level details such as the choice of hardware and software platforms to later chapters. First, the technical goals of the NGMC are discussed, then the final technical specification is presented, with discussion.

6.2 Goals

Since the NGMC project is a long-term venture, it should accommodate changing technologies through a modular and flexible architecture. Table 6.1 lists the goals that we wish the NGMC architecture to achieve. These targets mainly revolve around flexibility and robustness. The system was designed as a Web-based application so to easily accommodate various client devices and operating systems as well as minimize the complexity of the software running on the client devices.

We defined a specific feature set for the NGMC in the previous chapter, and we want the system to accommodate these features, but also have the flexibility to support more features and even hardware not available at the time of development,
Table 6.1: The Goals of the NGMC Technical Architecture

- The system supports various types of devices (PCs, PDAs, Tablet PCs[18]).
- The code for the logic of the system is not specific for certain devices.
- The system is modular so that components can be added and removed with minimal effort.
- The system does very little to restrict the flexibility of future components.
- The complexity of the programs running on the client computers is minimized.
- The maximum amount of data is stored on the central server so that users can access the system through various means and perform similar functions.
- The system uses existing standards and APIs whenever possible.
- The system uses existing MIT classroom infrastructure (such as 802.11b).

such as Tablet PCs. In addition, we want to use as many existing APIs and standards as possible to ensure the system can be easily adopted and modified. We also want to not place many restrictions on the hardware which is used to access the system, especially on the client side. We envision a future NGMC-enabled lecture hall where the professor uses a laptop, the TAs use Tablet PCs, and the students use PDAs of various makes and models. The system should allow all present to have the same usability and functionality. Finally, many universities such as MIT are deploying wireless networking technologies on campus and in lecture halls[22]. We believe it makes sense to use such existing technologies so we do not have to supply our own hardware to connect the computers in a lecture.

6.3 Final Specification

After much debate, design, trial, and error, we settled on the technical features outlined in table 6.2.

Figure 6-1 gives a good overview of the major hardware and software components of the system. These will be further described in later chapters.
Table 6.2: Final NGMC Technical Feature Set

- All communication is routed through a server connected to the Internet.
- System built with interfaces for PDAs and PCs.
- Primary student interface is through PDA running PocketPC 2002[17].
- Professor interface is through PDA in class and PC at home.
- A specialized client program is used for accessing the system on PDA.
- Any HTML4-compliant[30] Web Browser can be used to access the system on a PC.
- All communication between client and server is over HTTP.
- SSL is used to encrypt all information transferred between client and server[24].
- Definitely use MIT’s Internet infrastructure, and use the classroom 802.11b access points if possible.

Figure 6-1: NGMC Hardware and Software Component Communication
6.4 Discussion

Because we wanted students and teachers to be able to access the system using various hardware and always have the same information available, we decided to use a client-server architecture. All information and most functionality is provided by the server. The use of a server for data-storage and information processing, and the fact that we planned to use Internet-based networking hardware naturally lead to the use of Web-based technologies for the information exchange.

However, a purely Web-based system would not satisfy all our functionality goals. For example, we cannot easily and smoothly have a teacher redirect all students’ devices to a specific mini-quiz or URL using simple HTTP. Thus, a specialized client program was written to access the system. Raj Dandage’s thesis details the client component[5]. HTTP provides most of the functionality needed to access the system, so the client uses a Web-browser as a foundation, but adds many enhancements to improve usability and functionality.

Because we wanted a full-featured Web-browser-enabled client, we chose PDAs running PocketPC 2002 as the primary client hardware for students accessing the system. We also allow PCs running standard Web-browsers to access the system, since it is often easier to enter information into the system using a keyboard and mouse rather than a pen. Lanky. Professors used this mode of accessing the system to easily input text into the system for features such as the mini-quiz.

Because we wanted to ensure the privacy and security of individuals using the NGMC, we chose to use SSL to encrypt all communication between client and server in the system. This was a logical security protocol choice since we use HTTP for information exchange. The use of unencrypted wireless technology also encouraged the use of an end-to-end encryption protocol such as SSL.

Several circumstances out of our control helped to refine the final technical specification. First, some hardware components were not available for use at the time of development. We were unable to acquire Tablet PCs for our pilot deployment, so we designed the system for PCs (including laptops) and PDAs. MIT had deployed
802.11b networking infrastructure across their classrooms, so we chose this as the wireless networking technology.
Chapter 7

Software Architecture

7.1 Overview

The NGMC is a complex system, with various software programs running on different pieces of hardware at different locations. This chapter details the various software components of the NGMC. It discusses the software architecture of all pieces of the system, from the client program on a PocketPC to the database program running on the server. I discuss our architecture choices and why we picked them over the many alternatives. Overall, the NGMC must be reliable, flexible, powerful, and secure. I believe our architecture choices help us achieve these goals.

7.2 Clients

There were two major areas of software development in the NGMC project. First was the client side. The only way a user can access the features of the NGMC is by using a supported client software application. The system is flexible enough to support basic Web interfaces, customized Web-based applications, or customized applications using an XML interface. These software applications are shown as the software components for the NGMC Clients in figure 6-1. For the initial deployment of the NGMC, we designed for PocketPCs and standard PCs, though the system is flexible enough to allow extremely varied software clients.
7.2.1 PC Clients

Standard PC Web browsers have reached a very mature level, and allow flexible communication with a Web server. For this reason and for portability reasons, we intend for PC users to access the NGMC using a Web browser such as Microsoft Internet Explorer or Netscape. Since PCs use a standard Web browser to access the system, we did not need to develop any software on the client side for those users. We did, of course, need to develop the software on the server side to interface correctly with the standard HTML4 protocol that these Web browsers use.

7.2.2 PocketPC Clients

Because the Web browser for the PocketPC are not as full-featured as those for the PC, and because we desired to take advantage of many of the Operating System components of the PocketPC platform, we performed significant development on the client side for the PocketPC. We developed a specialized program called the NGMCBrowser (see figure 7-1) and also wrote software to interface with the PocketPC 2002 OS components such as the Address Book, Calendar, and sound recording hardware. This work was performed primarily by Raj Dandage, another member of the NGMC team, and is described in his masters thesis[5]. The NGMCBrowser and NGMC server communicate using a specialized protocol running over the HTTP protocol. The details of this communication is further described in appendix C.

7.2.3 Other Clients

At the time of writing the NGMC officially supports only standard PC and PocketPC clients, but the system uses standard Web-based protocols for communication between client and server, and hardware that can use these protocols can access the system. In some cases, the server software would be modified to support the client software, but because of the XML-based[29] server architecture, this is relatively easy. For example, Java-based mobile phones[27] are appearing on the market at the time of writing and these could definitely be used as a client for the system. A Java-based client program
would have to be written for the phone, and it would use standard Web protocols to communicate with the server. On the server side, the only modifications would deal with interface issues, such as screen size and text input. These modifications would be in their own module, and would not modify any program logic.

### 7.3 Servers

The central “brains” of the NGMC are the server programs running on a computer connected to the Internet. These include the NGMC Server, which is a large set of program objects that perform the customized functionality for the system. An application server executes these programs when a client makes a request. The application server also establishes the connection between client and server and encrypts the communications using SSL. The NGMC Server additionally uses a separate database server for data storage and manipulation.

In developing the NGMC, the Microsoft .Net architecture[16] was chosen for the NGMC Server. This involved using Microsoft Internet Information Services (IIS) for the application server and Microsoft SQLServer for the database server. After completing about 75% of the server development, I ran into many problems mainly
related to the immaturity of the platform. Thus, in the summer of 2002, I switched
software architectures to an open-source system using Apache[7] as the application
server, MySQL[1] as the database server, and PHP[8] as the language for the NGMC
Server components. While the .Net architecture may have a greater feature set than
the PHP/Apache/MySQL architecture, it is not as mature in terms of performance,
reliability, and debugging (at least at the time of development).

7.3.1 Preliminary NGMC Server Platform

I initially chose to use a Microsoft .Net architecture since it is well supported, provides
respectable performance, is object-oriented, and allows code to be easily written and
maintained through the Visual Basic language. A major goal was to separate the
logic of the functions of the system as much as possible from one another as well
as isolate the logic from the user interface mechanisms. The strictly object-oriented
approach of the .Net platform fit my goals well. However, during development using
this architecture I ran into many problems that made debugging tedious. The XML
classes were extremely complicated for the tasks I was performing, and were very
restricting in terms of debugging. In addition, Visual Basic is an older language with
a too-simple syntax. A better language, C#, was developed for the architecture, but
this was also too immature at the time of development. Though I developed much
code for this architecture, I felt it necessary to switch to a platform that was easier
to develop for.

7.3.2 Preliminary Application Server

The .Net architecture used IIS as the application server. This is a powerful Web-
server that is very easy to configure. While it is infamous for its security holes, any
competent systems administrator would keep up with the software patches released for
the application. IIS also integrates well with the database server and development
tools for the platform. The server is designed to only run on Microsoft operating
systems, but this was not an issue for our uses.
7.3.3 Preliminary Database Server

The initial database server for the NGMC was Microsoft SQLServer. This is a full-featured, stable database server that is easily configured. Its performance is respectable, but is slowed because of some advanced features that the NGMC did not take advantage of initially. It worked well in the initial development, but I switched to MySQL since it is better integrated with the Apache Web server.

7.3.4 Final NGMC Server Platform

I chose to use the PHP/Apache/MySQL development platform for the final NGMC development. While these applications are typically used for pure Web development, their usage is spreading into other areas of development like graphical programs and shell scripting. PHP is a flexible, easy-to-learn language with many advanced feature such as object-oriented development and powerful text parsing. It also runs extremely fast on both Linux and Windows systems. While not required for PHP development, I chose a strictly object-oriented architecture that shared the same object model as the .Net application.

7.3.5 Final Application Server

The final application server was the open source Web server Apache 1.3. This is a secure, mature, and fast program that runs on many different hardware platforms. While PHP is a separate product from Apache, they are integrated very well. Its configuration is somewhat more difficult than that of IIS, but I had prior experience with the system. Apache's primary purpose is serving HTML Web pages (along with supporting images, files, etc.), which we use when standard Web browsers access the system, but we use this functionality to send the specialized data to the NGMCBrowser.
7.3.6 Final Database Server

I also changed the database server to MySQL. This was primarily for performance reasons. MySQL has a much smaller feature set than that of SQL Server or other database servers, but as a result its performance is better. It is also very well integrated with PHP. The performance advantage is important since the system gets hit with many requests in a short period of time when used in a classroom of many students. Only in a few cases did the feature restrictions of MySQL cause any trouble. For instance, the server does not support SQL subselects, and this slightly complicated the display of quiz results. In the future, it would be relatively easy to change the database server to a more powerful one, as PHP supports all major database servers (Oracle, SQL Server, PostgreSQL).
Chapter 8

Hardware Architecture

8.1 Overview

Figure 8-1 shows how the hardware of the NGMC is coordinated. We have a few central servers, and clients—students, professors, and TAs—communicate wirelessly using various devices (laptops, PocketPCs, etc.). The Client Server is the application that communicates directly with hardware clients of the system—PCs, PDAs, Tablet PCs. The Client Server communicates with the Application Server, which contains the logic of the system. The Application Server uses a separate Database Server for data storage and manipulation.

A major goal of the system is to allow the use of various devices to access the system; students and professors can use their own laptops to access the system, or if they happen to own a more-portable PocketPC, they are provided with the same functionality. This flexibility allows the system to be used with devices that are not yet widely used, such as Tablet PCs.

In the project’s first iteration, we intended students to access the system using Toshiba e740 PocketPCs. This intention is described below. We also designed the system so that professors would primarily use PCs to access the system, because of the superior methods of inputting data. Because of the flexibility of the server architecture, as will be seen later in the document, this intention did not bar professors from using PDAs to access the NGMC or students from using PCs to access the
system. We also contained all three server programs (Database Server, Application Server, Client Server) on a single hardware server on the MIT Internet network.

8.2 Client: Toshiba e740

Perhaps the most important component of the NGMC is the wireless devices that students use to access the system. At the time of initial design of the NGMC (Spring 2002), there were a few options for wireless devices that would be suitable for use in a classroom. We could have used mobile phones, pagers, Palm-based PDAs (Personal Digital Assistants), PocketPC-based PDAs, laptop computers, or specialized hardware developed for the student-to-teacher communication, such as the PRS system by EduCue. Though we contacted many manufacturers, we were unable to obtain any Tablet PCs. First, we wanted the client hardware to be extremely portable and relatively inexpensive, thus, we eliminated laptops from the list of possible client
Table 8.1: NGMC Client Hardware Options

<table>
<thead>
<tr>
<th>Device</th>
<th>Means of Communication</th>
<th>Used in NGMC?</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobile Phone</td>
<td>3rd Party Cellular</td>
<td>No</td>
<td>Not MIT Wireless Network</td>
</tr>
<tr>
<td></td>
<td>Network</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pager</td>
<td>3rd Party Cellular</td>
<td>No</td>
<td>Not MIT Wireless Network</td>
</tr>
<tr>
<td></td>
<td>Network</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Palm-Based PDA</td>
<td>802.11b/Cellular</td>
<td>No</td>
<td>Not flexible OS</td>
</tr>
<tr>
<td>PocketPC-Based PDA</td>
<td>802.11b</td>
<td>Yes</td>
<td>Fit requirements</td>
</tr>
<tr>
<td>Laptop PC</td>
<td>802.11b</td>
<td>No</td>
<td>Too bulky and expensive</td>
</tr>
<tr>
<td>PRS</td>
<td>Local IR</td>
<td>No</td>
<td>Only 1-way communication, not flexible</td>
</tr>
</tbody>
</table>

We wanted the system to allow communication in both directions between lecturer and student, so we chose not to use the PRS system. Next, we wanted to use the newly-installed wireless access points installed in MIT classrooms, so mobile phones and pagers were eliminated. We were left with PDA devices. When comparing the Palm and PocketPC systems, it was clear that the PocketPCs suited our purposes well. The wireless hardware was well-integrated into the operating system, the devices were small, but had high-resolution screens, and we could embed a full-featured Web-browser into a custom application running on the PDA. The various options for client hardware are described in table 8.1.

At the time, there were a few types of PocketPCs available. We obtained samples of the HP Jornada and Compaq iPaq, and while these were well-designed devices, they required an expensive wireless adaptor to be able to use the MIT 802.11b network. In the Spring of 2002, Toshiba released the e740 PocketPC, which included an embedded wireless card. It also cost less than the HP and Compaq options. After successfully testing a sample e740 with our software, we ordered 30 for the pilot program of the NGMC project. See figure 8-2 for a picture.
Figure 8-2: Toshiba e740 [28]
8.3 Server

In the initial deployment of the NGMC, the three servers shown in figure 8-1 are present on the same computer. This computer is a standard x86 PC server in a desktop case. The Client, Application, and Database servers are relatively demanding on the resources of the computer in the NGMC application, so the server is a relatively powerful machine in terms of RAM and hard drive performance. Appendix A contains detailed specifications of the configuration of the server.

The server is housed on the MIT network and connected by standard 100base/T Ethernet. Figure 8-3 shows the path of data on a typical connection between client and server. Data travels through the Internet between client and server. The client is connected to the Internet through MIT’s wireless access points. The server is connected through a local Ethernet network. End-to-end SSL encryption is used to secure the data traveling through these potentially-unsecure networks.
Chapter 9

Server-Side Implementation

9.1 Overview

The server is the functional heart of the NGMC architecture. It receives all requests by clients, coordinates data storage and manipulation, performs the various functionality features of the NGMC, and builds output tailored for the particular client hardware. At 20 thousand lines of PHP code, the implementation is the largest piece of software in the system and was my major contribution to the project. This chapter outlines the goals for the architecture, presents an overview of the implementation, and describes the various functional units in the system.

9.2 Goals

Table 9.1 lists the goals I desired to satisfy when designing the server-side architecture of the NGMC.

I feel that all these goals have been reached in the final implementation of the NGMC server. The following discussion demonstrates this belief.
Table 9.1: The Goals of the NGMC Server-Side Implementation

- Easily allow new types of devices to access system without serious coding.
- New functional models can be added easily.
- Separate functional logic from the display mechanisms.
- Allow specialized interfaces to client software.
- Allow Web-based access.
- Be secure against network-based attacks and protect users’ privacy.
- Use standard protocols and coding procedures.

9.3 Component Model

The server-side implementation is divided into four main types of classes. Each type of class has a standard interface and provides a distinct function in the system. Figure 9-1 gives a good overview of the various types of classes and how they communicate. A central advantage of this type of implementation is that the client interface classes are separate from the classes that implement the logic of the system. This allows one to later add a new client module for a device such as a Tablet PC, but not have to modify any application classes in order to allow the Tablet PC to access the system. In addition to the client and application classes, a central executive class controls the exchange of data between the modules and separate “service” classes provide extra functionality for all the modules in the architecture. See figure 8-2 for a picture.

9.4 Code Details

The following sections describe the various class types in the server-side implementation. Appendix E gives a full list of the classes used in the system according to the following categories.
9.4.1 Executive

The executive is the central class of the system. It controls the exchange of data throughout the system. When a request comes into the server from a client, the executive calls on the client’s specific class to translate the request into XML according to a schema defined for inter-module communication. I use XML as the major means of exchanging data in the system for many reasons: it is a supported standard, it is flexible, and it deals with data, not the look and feel of an application. Once the client’s request is translated into XML, the executive forwards the XML to the appropriate application modules. The applications return new XML to the executive, which it then forwards to the client module that made the request. The module then translates the XML into the correct client format and returns it to the device.
9.4.2 Clients

The client modules provide an interface between specific devices and the XML used in the system. While the system is Web-based and most devices that will be used to access the system can interpret standard HTML, I want to provide specific functionality when certain devices access the system. For example, I want to return only necessary information as well as minimal graphics to PocketPC devices because of their small screens. The architecture allows this functionality, since we can control the translation of the system’s XML for each device. Furthermore, the architecture allows new devices to access the system with minimal effort. One simply needs to write a client class for the device; no other code would need modification.

9.4.3 Applications

The application modules are the most complex in the system. On the surface, they can be seen as black boxes that take in XML and output XML based on the input. These modules dictate what users can see and do with the system. For example, the quiz application module provides the functions for professors to give mini-quizzes to students during lecture. Each module is separate, yet based on the same abstract class, so that it is easy to implement new modules or modify old ones without affecting other application modules.

9.4.4 Services

The final type of class in the system is the service modules. The methods in these classes provide miscellaneous functionality, and can be called by any of the types of modules. For example, the database service provides the interface to the database server. Applications send the service SQL queries, and the service responds with arrays of data (if applicable). To promote speed and flexibility, the interface to these modules is through method calls, not XML.
9.5 Database Schema

I use a standard SQL database in the NGMC server-side implementation. Figure 9-2 shows a brief overview of the various tables I use in the database. Appendix B contains the full database schema.

As is seen in figure 9-2, the data is centered around a user table and class table. These are separate, so that the system can be used simultaneously for different classes, allowing the same user to assume different roles in different classes. For instance, a single person, using the same username and password, could be a TA of one class, but a student in another. The system ensures that one class will never see another class’s data, even if both are simultaneously using the NGMC.

9.6 XML Schema

As stated above, I use a standard XML schema for all communications between the modules of the NGMC server. Figure 9-3 shows an example XML file of the data sent
from the Client module to the Executive module during the start of a request to the system. This example is a simple one; the user is asked to view the quiz main page. This request was made by a user on a PC, so the returned data will be in HTML format. Note that this fact is not shown in the XML, since the functional units do not need to know what type of client is accessing the system; they will work for all, as long as there is an appropriate client class present in the system. Figure 9-4 shows an example XML file of the data sent from the Executive module back to the Client module during the end of a request to the system. This example is of the same quiz page request, and the output is mainly XHTML, which is interpreted by the client class on the way back to the client. Appendix D contains full details of the XML schema.
Figure 9-4: Example XML Schema: From Executive to Client
Chapter 10

Conclusions

The Next Generation Mobile Classroom project is a flexible system that is designed to enhance the classroom experience for both students and professors. By enabling greater interaction and easier information distribution over conventional classrooms, the NGMC project brings the small class experience to large university lectures. This thesis focused on the initial development of the project and detailed the implementation of the heart of the system—the centralized application server and database.

The motivation for the project stemmed from research into enhanced methods of learning through electronic devices. Years of experience in online education by both the developers of the project and advisers to the project guided the feature development and interface design. Much research on similar projects for integrating electronic devices into the classroom also guided us in the design and deployment of the Next Generation Mobile Classroom.

Among the many educational features the Next Generation Mobile Classroom provides are the message of the day, question routing, mini-quizzes, scheduling, contact management, and media distribution. The message of the day effectively distributes news to students. The question routing feature allows students to anonymously ask questions without disrupting the lecture. The mini-quizzes allow professors to instantly gauge students' understanding of lecture material. The scheduling feature integrates class events with students' calendars. The contact manager controls the distribution of personal information. The media manager easily allows class members
to distribute various types of multimedia. All these components are tightly integrated and easy to use.

The initial deployment of the system is based on the client-server model. Client computers consisting of Toshiba e370 PocketPCs running a custom client program wirelessly connect to a centralized server. The system uses newly-deployed wireless technologies on the MIT campus. Standard APIs, protocols, and server software was used to ease development, speed customization, and ensure security. The development of the heart of the NGMC system, the server software and database, was the focus of this document.

Design and implementation of the Next Generation Mobile Classroom was complex, but proceeded smoothly. We created the first system of advanced wireless devices to successfully enhance the learning communications in university lectures. The system was piloted in the MIT class 21w.785, Communicating in Cyberspace, in the fall of 2002. In the Spring of 2003, the system was successfully used in 21w.765. We plan to continue the project in the fall of 2003, adding features and increasing usability. As with any new complex electronic system, there were bugs to work out, but the software clearly achieved its goal of bringing class members and materials together to improve the learning experience.
Appendix A

Server Configuration

The following tables detail the configuration of the hardware and software used in the final deployment of the Next Generation Mobile Classroom.

Table A.1: NGMC Server Configuration: Hardware

- Computer Model: Dell
- CPU:
- RAM:
- Hard Drive:
- Network Connection: Standard 100/baseT Ethernet to on campus MIT T1
Table A.2: NGMC Server Configuration: Software

- Operating System: Microsoft Windows 2000 Server
- Web Server: Apache 1.3
- Programming Language: PHP
- Database Server: MySQL
- Remote Access: VNC[12]
- IDE: Dreamweaver MX[14]
Appendix B

Database Schema

NGMC Database Schema in SQL format. Exported by phpMyAdmin.

# phpMyAdmin MySQL-Dump
# version 2.3.2
# http://www.phpmyadmin.net/ (download page)
#
# Host: localhost
# Generation Time: Jan 28, 2003 at 11:50 PM
# Server version: 3.23.53
# PHP Version: 4.2.3
# Database: 'ngmc'
# --------------------------------------------------------

# Table structure for table 'tbl_class'
#
CREATE TABLE tbl.class
  id int(11) NOT NULL auto_increment,
  name varchar(255) NOT NULL default '',
  title text NOT NULL,
  number varchar(255) NOT NULL default '',
  PRIMARY KEY (id)
) TYPE=MyISAM;
# --------------------------------------------------------

# Table structure for table 'tbl_event'
#
CREATE TABLE tbl.event
  id int(11) NOT NULL auto_increment,
  ownerid int(11) NOT NULL default '0',
  eventdate date NOT NULL default '0000-00-00',
  classid int(11) NOT NULL default '0',
  eventtype varchar(255) NOT NULL default '',
  title text NOT NULL,
  description text NOT NULL,
  PRIMARY KEY (id)
Figure B-1: Full NGMC Database Schema
CREATE TABLE tbl_group (  id int(11) NOT NULL auto_increment,  groupname varchar(255) NOT NULL default '',  grouptype varchar(255) NOT NULL default '',  datecreated datetime NOT NULL default '0000-00-00 00:00:00',  ginfo1 text NOT NULL,  ginfo2 text NOT NULL,  ginfo3 text NOT NULL,  PRIMARY KEY (id),  UNIQUE KEY groupname (groupname) ) TYPE=MyISAM;

CREATE TABLE tbl_log (  id int(11) NOT NULL auto_increment,  userid int(11) NOT NULL default '0',  classid int(11) NOT NULL default '0',  datetime datetime NOT NULL default '0000-00-00 00:00:00',  remotehost varchar(255) NOT NULL default '',  infol text NOT NULL,  info2 text NOT NULL,  info3 text NOT NULL,  info4 text NOT NULL,  info5 text NOT NULL,  PRIMARY KEY (id) ) TYPE=MyISAM;

CREATE TABLE tbl_media (  id int(11) NOT NULL auto_increment,  filepath text NOT NULL,  userid int(11) NOT NULL default '0',  createddate datetime NOT NULL default '0000-00-00 00:00:00',  description text NOT NULL,  PRIMARY KEY (id) ) TYPE=MyISAM;

CREATE TABLE tbl_motd (  id int(11) NOT NULL auto_increment,  classid int(11) NOT NULL default '0',  showdate date NOT NULL default '0000-00-00',  PRIMARY KEY (id) ) TYPE=MyISAM;
CREATE TABLE tbl_permission (  id int(11) NOT NULL auto_increment,  ownerid int(11) NOT NULL default '0',  grouptype varchar(25) NOT NULL default '',  groupid int(11) NOT NULL default '0',  resourceid int(11) NOT NULL default '0',  datestart datetime NOT NULL default '0000-00-00 00:00:00',  PRIMARY KEY (id) ) TYPE=MyISAM;

CREATE TABLE tbl_question (  id int(11) NOT NULL auto_increment,  userid int(11) NOT NULL default '0',  classid int(11) NOT NULL default '0',  datecreated datetime NOT NULL default '0000-00-00 00:00:00',  active tinyint(4) NOT NULL default '0',  question text NOT NULL,  PRIMARY KEY (id) ) TYPE=MyISAM;

CREATE TABLE tbl_quiz (  id int(11) NOT NULL auto_increment,  datecreated datetime NOT NULL default '0000-00-00 00:00:00',  name varchar(255) NOT NULL default '',  comments text NOT NULL,  classid int(11) NOT NULL default '0',  creatorid int(11) NOT NULL default '0',  PRIMARY KEY (id) ) TYPE=MyISAM;

CREATE TABLE tbl_quiz_answer (  id int(11) NOT NULL auto_increment,  quizid int(11) NOT NULL default '0',  questionid int(11) NOT NULL default '0',  userid int(11) NOT NULL default '0',  answer text NOT NULL,  PRIMARY KEY (id) ) TYPE=MyISAM;
```sql
CREATE TABLE `tbl-quiz-question` (
  `id` int(11) NOT NULL auto_increment,
  `quizid` int(11) NOT NULL default '0',
  `ordernumber` int(11) NOT NULL default '0',
  `type` varchar(255) NOT NULL default '',
  `questiontext` text NOT NULL,
  PRIMARY KEY (id)
) TYPE=MyISAM;

CREATE TABLE `tbl-quiz-question_choice` (
  `id` int(11) NOT NULL auto_increment,
  `quizid` int(11) NOT NULL default '0',
  `questionid` int(11) NOT NULL default '0',
  `ordernumber` int(11) NOT NULL default '0',
  `choicetext` text NOT NULL,
  PRIMARY KEY (id)
) TYPE=MyISAM;

CREATE TABLE `tbl-quiz-question_text` (
  `id` int(11) NOT NULL auto_increment,
  `quizid` int(11) NOT NULL default '0',
  `questionid` int(11) NOT NULL default '0',
  `rows` int(11) NOT NULL default '0',
  `cols` int(11) NOT NULL default '0',
  `prefill` text NOT NULL,
  PRIMARY KEY (id)
) TYPE=MyISAM;

CREATE TABLE `tbl-session_user` (
  `id` int(11) NOT NULL auto_increment,
  `username` varchar(255) NOT NULL default '',
  `password` varchar(255) NOT NULL default '',
  `sid` varchar(255) NOT NULL default '',
  `datecreated` datetime NOT NULL default '0000-00-00 00:00:00',
  `studentid` varchar(255) NOT NULL default '',
  `firstname` varchar(255) NOT NULL default '',
  `lastname` varchar(255) NOT NULL default '',
  PRIMARY KEY (id)
) TYPE=MyISAM;
```

email varchar(255) NOT NULL default '',
homephone varchar(255) NOT NULL default '',
workphone varchar(255) NOT NULL default '',
mobilephone varchar(255) NOT NULL default '',
address varchar(255) NOT NULL default '',
city varchar(255) NOT NULL default '',
state varchar(255) NOT NULL default '',
zip varchar(255) NOT NULL default '',
classviewable tinyint(4) NOT NULL default '1',
lastaccess datetime NOT NULL default '0000-00-00 00:00:00',
lastclassgroupid int(11) NOT NULL default '0',
refresh tinyint(4) NOT NULL default '0',
refreshparams text NOT NULL,
lastquerystring text NOT NULL,
lastlastquerystring text NOT NULL,
rememberme varchar(255) NOT NULL default '',
comments text NOT NULL,
PRIMARY KEY (id),
UNIQUE KEY username (username)
) TYPE=MyISAM;

# --------------------------------------------------------
# Table structure for table 'tbl-sitecomment'
#
CREATE TABLE tbl-sitecomment
(id int(11) NOT NULL auto_increment,
datetime datetime NOT NULL default '0000-00-00 00:00:00',
type varchar(255) NOT NULL default '',
comment text NOT NULL,
email varchar(255) NOT NULL default '',
contact tinyint(4) NOT NULL default '0',
PRIMARY KEY (id)
) TYPE=MyISAM;

# --------------------------------------------------
# Table structure for table 'tbl_user_group'
#
CREATE TABLE tbl_user_group
(id int(11) NOT NULL auto_increment,
userid int(11) NOT NULL default '0',
groupid int(11) NOT NULL default '0',
uginfo1 text NOT NULL,
uginfo2 text NOT NULL,
uginfo3 text NOT NULL,
PRIMARY KEY (id)
) TYPE=MyISAM;
Appendix C

Client/Server Communication Protocol

Over standard HTTP, the NGMC server and NGMCBrowser can send special commands. This allows the server to perform a wide range of actions on the PDA, such as updating the user interface, manipulating a users' PocketPC address book and calendar, up updating the version of NGMCBrowser. These commands are described below.
Table C.1: Client/Server Special Commands over HTML

- Controlling NGMCBrowser's menu bar:
  \[\text{\texttt{\textit{imeta http-equiv="ngmc-url" content="link,Displayed Name"}}} \]
  Example (in PHP):

```html
<meta http-equiv="ngmc-url" content="[##internal-link app-portal##] ,Home">
<meta http-equiv="ngmc-url" content="[##internal-link app-question##],In-Class Questions">
<meta http-equiv="ngmc-url" content="[##internal-link app-quiz##],Surveys & Results">
<meta http-equiv="ngmc-url" content="[##internal-link app-events##],Lectures & Events">
<meta http-equiv="ngmc-url" content="[##internal-link app-courses##],People & Groups">
<meta http-equiv="ngmc-url" content="[##site_comment_page##] ,Contact Admins">
<meta http-equiv="ngmc-url" content="[##logout##] ,Logout";>
```

- Communicating a user's session ID:
  \[\text{\texttt{\textit{imeta http-equiv="sid" content="session ID"}}} \]

- Adding/Updating Address Book Entry:
  \[\text{\texttt{\textit{imeta http-equiv="ab" content="ID,content"}}} \]

- Adding/Updating Calendar Entry:
  \[\text{\texttt{\textit{imeta http-equiv="cal" content="ID,title,date,content"}}} \]

- Update NGMCBrowser Version:
  \[\text{\texttt{\textit{imeta http-equiv="version" content="latest version,url"}}} \]
Appendix D

Complete NGMC Server Internal XML Schema

<ngmc>
    <request>
        <querystring value="sdfgsdfg"/>
        <form_elements>
            <element name="name" value="value"/>
            <element name="name2" value="val2"/>
        </form_elements>
    </request>
    <session>
        <userinfo sid="sid" userid="2345" username="name" firstname="first" lastname="last"/>
    </session>
    <course>
        <courseinfo classid="2345" name="classname" number="21w.785" usertype="ta"/>
    </course>
    <output>
        <redirect url="complete querystring"/>
        <page_properties>
        </page_properties>
        <output_sections>
            <section name="sdfgsdfg" appname="session" priority="toploadlow">
                <!--
                    Inside <section> is pure xhtml, you may use FTS tags though:
                -->
                <a href="[## internal_link app=appname querystring=sadfgsdfg#app=defg ##]">
                </a>
                <img src="[## media app=common filename=name.jpg #]"/>
                <form action="[## thispage ##]">
                </form>
            </section>
        </output_sections>
    </output>
</ngmc>
Appendix E

Complete NGMC Server Class File Listing
Figure E-1: NGMC Class Files (viewed from an IDE)
The following figures show the class hierarchy in the Next Generation Mobile Classroom server-side implementation.
Figure E-2: NGMC Class Files (continued)
Bibliography


