

Practical Programming: Android Development in the Laboratory

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Abstract

This paper presents a novel laboratory project where final year undergraduate students are tasked with developing Bluetooth mobile applications for the Android platform. The challenges that arise in assessing a project where students' acquisition of a good practical understanding of Bluetooth technology may be easily overtaken by the programming difficulties encountered are discussed, along with ways in which this effect can be mitigated. We detail the learning environment created, describe the assessment methodologies adopted and analyse the course outcomes.

1. Introduction

One cannot imagine learning to swim without entering the water or learning to play the violin without access to an instrument to practice on, similarly one cannot imagine an undergraduate program without practical interaction with technology in a laboratory environment. One secondary benefit of these hands-on laboratory experiences is that they shape the students' appreciation of the ancillary challenges to be faced in a real-world development environment. While much care is taken to shield freshmen students from such challenges, it is essential that final year students gain a greater appreciation of these secondary considerations as they begin the transition towards professional practice in the workplace. This creates a challenge for those faced with the creation of suitable laboratory experiences for final year students and in this paper we discuss how these considerations shaped the design and implementation of a final year laboratory assignment for Computer Science students taking a module in Mobile Communications.

The laboratory assignment brought two mobile technologies that students are very familiar with from everyday life into the classroom – the Bluetooth wireless standard and the Android development platform. Android has previously been incorporated in student learning efforts [1, 2, 3] and offers rapid application development in a real-world environment through its application framework and emulator [4]. Students were tasked with developing an application within the constraints that it should utilize Bluetooth and must run on an Android device. They were encouraged to be as innovative as possible while also taking into account the time available to them for this work. Students were encouraged to be realistic about what they could expect to develop and to set out a clear timetable for the work they proposed to carry out.

The assignment included a programming element and a design element. The programming element aimed to build on the students' familiarity with the Java programming language while giving them a deeper practical understanding of its use in the development of applications for use on Android devices. Programming in a mobile environment exposes raw core functionality to the students and allows them to develop an appreciation how this functionality can be integrated into their own designs and other applications. The design element aimed to increase student motivation and interest in the assignment by encouraging them to be creative and to put forward their own ideas for a mobile application. While this left the lab quiet open as to what the application could be, it also gave students freedom to think about exactly what Bluetooth could be used for. This bottom-up approach to the utilisation of the wireless technology helped students to develop an appreciation of how to scope practical solutions around which they can then build their application development work.

This paper describes how programming on a mobile platform presents an environment with new constraints and programming nuances. Although students had a previous background in programming using the Java programming language, this new environment presented a new Application Programming Interface (API) to students. For many students the learning curve associated with understanding this development environment consumed a large amount of their time-on-task. This proved surprising, and frustrating, to many of them; however they gained a much greater appreciation of the learning curve involved when working within an environment with which you are unfamiliar.

The paper details our assessment methodology for this assignment. This sought to capture all aspects of possible student learning and engagement: from their understanding of Bluetooth and its applications to codebase functionality. Some of the student application designs are presented giving an insight into the level of sophistication achieved and the challenges encountered. Student comments provide qualitative feedback which allows for further discussion on student experience and engagement with the lab.

In the next section, previous work on the creation of laboratory assignments for mobile communications modules is presented. We consider the mobile development platforms employed in educational lab assignments and discuss how they impact on student learning. An overview of the mobile communications module that provides the setting for the laboratory assignment detailed in this paper is given, the motivation for, and the description of, the laboratory work is provided. The assessment methodology is outlined and the project outcomes discussed. Finally we detail the lessons learned about the design and delivery of a laboratory assignment involving both wireless technologies and application development.

2. Mobile Communications in the Classroom

The pervasive integration of mobile communications technology in our daily life underlines the importance of Mobile Communications modules for the formation of a final year student in Computer Science. When considering the approaches to adopt in the teaching of wireless concepts it is useful to describe what these concepts are and to ask if they are sufficiently different to warrant investigation into teaching methodologies specific to the area. The main concepts that underpin wireless communications are that by its nature the wireless medium is a shared medium and that signal strength is not as constant and easily predicted as in wired communications [1]. Having to deal with signal fading and a shared medium produces a more uncertain and less dependable environment where the boundaries of performance are harder to specify and guarantee. The resulting solutions are complex and have an impact on design across multiple layers.

There are a number of teaching approaches for introducing these concepts to students across the different layers. At lower layers some suggested classroom assignments focus on teaching wireless transmission characteristics [5, 6]. While these projects appear successful at demonstrating lower layer concepts, their outcomes do not produce functional high-level applications and so may appear rather abstract to students. However, understanding the nature of wireless communications in this detail may help students appreciate the concepts that can be used to produce a functional module for a larger system. Approaches that focus on signal propagation at the physical layer do not usually describe how these concepts can be accessed and interacted with using standard programming modalities [7].

From the number of platforms created to teach in these environments it seems the design of these environments is an interesting topic in itself and could be used as a basis for the teaching of mobile communications [8]. The platforms reviewed describe environments at a certain layer of abstraction. Many describe how the low-level nuances of programming and hardware considerations on mobile environments can be hidden allowing the rapid development of applications [9]. While this may be desirable for students in their freshman years, it is of

questionable merit for those nearing the transition from university into the workplace. Understanding mobile and wireless communication requires knowledge across a number of layers and programming can be adopted as the single metaphor for teaching concepts at the different layers. However, little research exists into how to expose concepts at different layers in the mobile software stack in a simple and easily accessible form.

Mobile and wireless communications are constantly, and rapidly, evolving and while students are often earlier adopters of such technologies [10] they are generally not familiar with the range of Operating Systems and the API's that are available for these environments [11, 12]. Becoming familiar with a new development environment is not straightforward and can take a considerable amount of time.

The time available to students to devote to an assignment impacts on what can be achieved by a student or group of students. If a concept at a lower layer is chosen, then development of a fully functioning application may not be feasible within the allotted time frame. To achieve detailed low-level knowledge while producing a self-contained application a larger-scale team effort is needed which requires work across multiple assignments [13]. One part of this approach is the provision of a constructed lab "setup" which provides some of the necessary elements for the successful completion of the assignment. Alternate approaches limit the students to technologies that operate within environments with which they are very familiar. For example the Sun Microsystems/Oracle SunSPOT wireless sensing devices [14] are programmed through Java/J2ME and so may be easily integrated into laboratory assignments for students familiar with Java [15].

A more lightweight approach to lab assignments is to utilise an existing mobile development environment to provide a programming task [3]. One benefit of this approach is that it appears that the more infrastructure that is provided for the student, the quicker they can produce a fully functioning application [16, 17]. However, the provision of this infrastructure can mask the challenges a student may encounter if faced with a similar task in the professional workplace.

A wide array of platforms for teaching mobile application development concepts exist [18, 19, 20]. Approaches in this area include the extension of existing Application Programming Interfaces (APIs) [16] to the introduction of entirely new platforms that overlay existing APIs [18]. An alternate approach is to use simulated networks to teach students about mobile networks [21]. Another approach to teaching mobile communications is to use a concept such as location as the central theme of the assignment [22]. This approaches the area by giving the student a broad view of the technologies and leaves the question of technology and programming platform more open for discussion by the students.

3. Laboratory Work: Bluetooth-based Android Development

The laboratory assignment outlined in this paper forms part of the Mobile Communications module offered to final year Computer Science students at Trinity College Dublin. This 12 week module covers all aspects of mobile communications from the fundamentals of wireless transmission to cellular and wireless communications technologies such as Bluetooth, ZibBee, Wifi, WiMax and LTE-A. Routing protocols, Mobile-IP, security and ethics are also considered. As part of the module, a set of three laboratory projects are given to the students to augment their practical understanding of some of the mobile communications technologies encountered during the course. The third and last assignment is the one outlined in this paper. This is the most complex assignment of the three as it combines the theoretical understanding of a mobile communications technology with the practical aspect of developing a mobile application utilizing such technology.

The module seeks to encourage students to develop their analytic understanding of the applicability and limitations of a range of mobile communications technologies. Following this line of thought, a practical laboratory assignment was designed such that the students apply

their knowledge of Bluetooth technology through the development of a mobile application. The chosen mobile application development platform was Android which is programmed using Java. Final year Computer Science undergraduates are expected to be capable of planning and implementing simple applications for mobile devices written in Java.

As part of the assignment students are encouraged to develop their critical understanding of the applicability of the mobile technologies involved. They look to move from a theoretical understanding of the Bluetooth communications mechanisms to a more practical appreciation of its function and features, including the profiles and protocols implemented in the Bluetooth stack which they employ in the development of their application. The students also look to extend their programming capabilities into more real-world applications through the development of applications for Android devices.

3.1 Laboratory Work Description

The students worked in self-selected groups of two. The assignment description was given as a set of requirements and outcomes while decisions on the nature of the application were left to the students. The first milestone in the project was the creation and presentation of a proposed mobile application using the selected mobile technology, i.e. Bluetooth. This tested the students' understanding of the applicability, limitations and underpinnings of the Bluetooth technology. It also allowed for possible intervention and direction for groups that were struggling with the creative and technological aspects of the project.

A master class in Android, the Linux-based development platform, was given to the students which covered the basics of Android mobile development. This covered the main features and architecture of Android alongside the main building blocks involved in the creation of a simple application. The four application components: Activities, Services, Content Providers and Broadcast Providers were introduced and the asynchronous messages which trigger components, known as Intents, were addressed. The manifest file "AndroidManifest.xml" and the user interface layout structures were also explained. Finally, students were referred to the Android's developer guide, for further reading, specifically to the section on Bluetooth.

Assignment Statement:

"You are requested to implement an application which makes use of a Bluetooth profile for inter-device communication. A brief description of the application, and the appropriate Bluetooth profile(s) employed, should be initially reported. As a proposed development platform, a tutorial on Android has been given and an HTC Dream/G1 Android phone has been provided to each group. For testing purposes, the use of Bluetooth enabled devices or the collaboration between groups might be required. The HTC Dream/G1 phone is running Android v1.6 and supports Bluetooth 2.0+EDR; it also comes with a 3.2 megapixels camera and an Assisted-GPS.

You can use this link as a good starting point for the use of Bluetooth in Android, (comes with a sample chat app): <http://developer.android.com/guide/topics/wireless/bluetooth.html>

A report must be submitted containing a description of the work (introduction, specifications, implementation and difficulties), Bluetooth profile selected, user case scenario, and instructions on how to build and execute your solution. The code should be attached. A quick functional demo of the application running must be presented."

The mobile application needed to be implemented and demonstrated on physical mobile devices. Depending on the networking requirements of each application, the students required more than two mobile devices for development and testing. While a limited number of Android HTC Dream/G1 mobile phones were available, many students were willing to use their own Android mobile phones for further testing in the project.

3.2 Development Environment

The students employed the Android Development Tools (ADT) plug-in for the Eclipse IDE to handle project creation and management, which greatly speeded up the development process. ADT gives access to the Android Debug Bridge (ADB) and the Dalvik Debug Monitor Server (DDMS), which provides, amongst other features, port-forwarding services, screen capture on the device, thread and heap information on the device, logcat (viewing system debug output), and radio state information. The students familiarised themselves with the Bluetooth API and its available methods for communications, the ADB command line interface for debugging, the Android SQLite database, and an understanding of the artefacts needed to create an Android application. A major difficulty was that the students could not use the Android mobile device emulator as Bluetooth is not supported; therefore testing had to be done in the devices using the ADB command line.

The HTC Dream/G1 provided to the students came with Android 1.6 installed however this was not released with an official Bluetooth API. So the students were required to upgrade the HTC Dream/G1 device to Android version 2.2 which officially supports Bluetooth. The HTC Dream/G1 had to be rooted, a custom flash recovery ROM loaded, a Second Program Loader in the SD flashed, and Android 2.2 installed. Android 2.2 integrates the Linux BlueZ stack and offers the Generic Access Profile (GAP), Service Discovery Protocol (SDP), and Radio Frequency Communication (RFCOMM) profiles, this gave students ready access to features such as Bluetooth device discovery, piconet formation and secures communications.

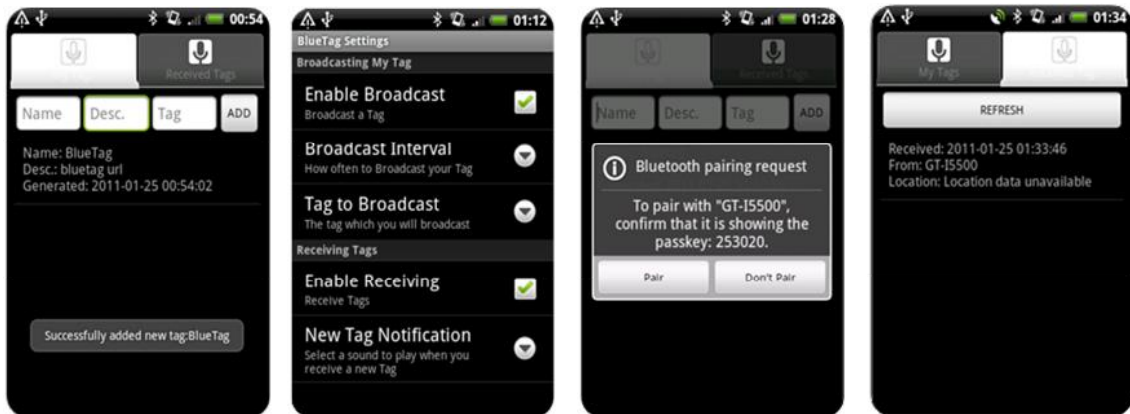
3.3 Student Engagement

From the start it was clear that students were extremely taken with this assignment. The fact that they would be working in the real world Android development environment appealed to them greatly. This was evidenced by their motivated and enthusiastic discussions on the project during assigned laboratory classes and also in their constant emails to instructors during the course of the assignment. Two samples of the applications developed our detailed below.

One group took the sample Bluetooth chat application provided in the Android developers guide as the basis for their project. They gained a full understand of how it operated and then they proposed to extend it so that discovery and message relay could be achieved between devices on different piconets within a scatternet. The application, named "PicoChat: Chat over multiple Bluetooth Piconets", allowed a master node in one piconet to discover Bluetooth devices in another piconet, and route messages to them. Routing tables at master nodes are periodically populated by receiving broadcast chat messages containing the list of devices known to other master nodes. Contactable devices are displayed and are stored in the masters' local database. Routing of chat messages is then performed by forwarding packets according to the masters routing table. This group encountered difficulties in testing the application in terms of networking as the Android emulator does not support Bluetooth and at least three mobile devices were needed for testing.

Another group opted to develop a QRtag-based Bluetooth Social Network application, which they called "BlueTag" (see Figure 1). They used the File Transfer Profile, built on top of the OBEX communications protocol, to send objects (files or folders) containing BlueTag files to Bluetooth devices in the neighbourhood which were willing to share interests. A user interface offered the option to create, delete and modify BlueTags, which contain QRtags, a timestamp, GPS position and extra descriptors. The initial goal was to broadcast Bluetag information to devices in range to create a social profile. However, the current Android Bluetooth API's requires devices to be paired before an RFCOMM connection can be established. Therefore the application allowed the user to select which devices in range to connect to.

Figure 1: BlueTag: QRTag Bluetooth Social Networking Android Application.



3.4 Assessment Methodology

The maximum mark achievable for the laboratory was 100%. The assessment took into consideration (i) initial project planning and the final project report (45%), (ii) the codebase (20%) and (iii) the demonstration of the mobile application and exit interview on their work (35%).

The marks awarded for the demonstration including assessment of the initial planning phase of the project, evaluation of the (ideally) working prototype and the group's ability to communicate technically about their work. The code produced was assessed in terms of both its clarity and its functionality. The students' application was assessed in terms of its originality, features and relevance with respect to the Bluetooth technology. The quality of the user interface was also considered. The report was assessed in terms of the detail provided on the initial idea proposed and the final application developed. The report was expected to contain a description of Bluetooth in terms of the requirements of the project including the profiles or protocols employed and their use. It was expected that the report would include a technical discussion of the implementation in Java and a description of the possible usage scenarios considered. The student discussion of the difficulties they encountered during the project and the solutions given was also considered.

4. Evaluation, Reflection and Conclusions

The students engaged with, and were very enthusiastic about, this project; collaborating amongst them to solve common difficulties and even sharing mobile devices for testing purposes. Almost all of the students were interested in this type of assignment and classified it as being very useful and relevant. However most groups commented on the fact that the devices provided ran an older version of Android e.g. "The mobile device model provided was old".

In their reports all the student groups acknowledged the steepness of the initial learning curve involved in the development of Android applications with statements such as "Learning Android took away most of the time of the project". Any groups that required more than two mobile devices commented on the problems they faced, e.g. "The lack of Bluetooth support in the emulator made the development and testing of the application quite difficult" or "The number of mobile devices provided to each group was not enough". All groups were happy with the starting code samples they had to work with e.g. "The sample chat application at the Android's developers guide was very useful".

In addition, a survey was taken with respect to the module and the presented assignment using a 5 step grading system from “Strongly Disagree (1)” to “Strongly Agree (5)”. All the students “Agree (4)” and “Strongly Agree (5)” that “The laboratory work was useful as part of the Mobile Communications course”. Also all of them “Strongly Agree (5)” that “Learning Android and Bluetooth technology is useful” and they also “Agree (4)” that “The introduction to Android class was useful as a starting point”.

4.1 Reflection on the Learning Environment Created

The mobile devices chosen for this lab were the ones most readily available in the host institution; however these proved slightly problematic as the version of Android on them needed to be upgraded to obtain full Bluetooth support. While this provided a learning opportunity for the students, this had not been one of the original intended outcomes of the project.

A major challenge students experienced was the lack of Bluetooth support in the emulator, this meant that they could not test networking applications before their deployment on physical devices. This had on a knock-on effect on the number of mobile devices required for testing as it had been envisaged that most of this work would take place using the emulator. One of the upsides of this lack of devices was that it fostered a spirit of collaboration amongst the students and many used their own Android devices for development and testing.

The learning curve for Android development consumed much of the students’ time and effort. Students had to utilize all the basic mechanisms of Bluetooth communications through the API, which gave them a general and practical understanding of the technology. In addition, the Bluetooth chat sample application at the Android’s online guide proved a very useful starting point. One possible way to reduce the learning curve would be to ask the students to work at a specific layer of the Bluetooth stack (BlueZ), developing some enhancement which requires an understanding of the Bluetooth underpinnings. Working at lower layers of the stack definitely gives the student a deeper understanding of the technology, but the complexity of the assignment needs to reflect the student learning curve, the available time and the potential difficulties.

4.2 Conclusions

The laboratory outlined above details the development of mobile applications for Android devices that make use of the Bluetooth technology. The learning environment and challenges encountered have been described and discussed, both from the perspective of the student and the module instructor. Mobile applications developed by some of the students have been described and the assessment methodology detailed. Finally, qualitative feedback received from the students has been analysed and reflections on the learning environment provided.

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