Course Design for Internet of Things Using Lab of Things of Microsoft Research

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***Abstract*—The emergence of Internet of Things (IoT) has created great changes and innovations in the related industries. With various applications and services regarding IoT, there has been a big leap in real life of human beings. However, there is big discrepancy between industries and educational program of universities regarding recent trend of technologies. Lab of Things (LoT) platform is an IoT platform, which is easy-to-learn and easy-to-develop. It is appropriate for a semester course in the universities. Considering all these facts, in this paper, we present our experience in designing a course on IoT application development using LoT of Microsoft Research, which is a one semester (15 weeks) course in universities. As the results of the course, students developed application easily applicable for real life and demonstrated them in the showcase.**

***Index Terms*— Lab-of-Things, IoT, Sensor Network, Course Design.**

I. Introduction

Internet of Things (IoT) has become one of the emerging topics for human life and technologies [1-4]. IoT indicates the interconnection of sensors, devices in an internet existence infrastructure with efficient computational techniques. Typically LoT system consists of four layers, i.e., sensing, networking, service and interface layers [3]. Sensing layer is integrated to hardware to sense and control the physical world. Networking layer supports network connection and data transfer. Service layer creates and handles services. IoT creates more opportunities to improve efficiency, accuracy and benefit of cyber-physical systems. IoT has been applied to various areas such as healthcare, smart shops, intelligent transportation, smart cities, etc.

IoT is rapidly increasing its social impacts. According to Gartner Inc., there will be nearly 26 billion devices for the IoT by 2020, and IoT product and service suppliers will generate incremental revenue exceeding $300 billion, mostly in services, in 2020. Meanwhile, ABI Research mentioned that more than 30 billion devices will be wirelessly connected to the IoT by 2020. A large amount of IoT related products has been researched, developed, and performed. In recent exhibitions, the importance of IoT on the modern technology trend was significantly emphasized. Many IoT related products were presented in these exhibitions. Giant companies in SoC (Intel, Qualcomm, and ARM), Big-data (CISCO, IBM), Wearable (Samsung, P&G) and Telecom (AT&T, SKT) clearly showed their interest in IoT technology through their displayed products. IoT-related various applications and services have made a big leap in real life of human beings.

On the other hand, there came out a big gap between industries and educational program of universities regarding recent trend of technologies. Regarding IoT, since it is an initial phase of the growth, it is somewhat difficult to offer a course to design IoT services and applications. In order to make students accustomed to the concept of IoT and develop applications easily, it seems that a platform architecture is essential.

Lab-of-Things (LoT) platform is an IoT platform which is designed not only for home handling, but also for conducting researches on a large scale [5]. LoT provides system designers an advantageous method to handle connection and to manage attributes clearly and control connected devices in their systems. Using LoT platform, researchers can easily build applications and services on the top layer of the system to conduct experiments on both small and large scales.

Recently, a large number of engineering courses has been presented to reduce the gap between university and industry. A capstone course of software production creation has been proposed in [6] to help students integrate and apply knowledge into practice. The author divided students into teams of three to six students to apply their educational approach. The approach includes templates for work products, iterative development, and interim deliverables with fixed schedule deadlines, project tracking and examples for key word product. In [7], authors presented a course to help student learn the product development process by projects that require practice on both hardware and software. In [8] and [9], we present our experience in designing basic and advanced courses on mobile software development. Feedbacks from students showed that these courses were valuable for industry careers.

Considering all these facts, in this paper, we present a course on IoT application development using LoT platform of Microsoft Research, which is organized in a semester (15 weeks) course in universities. The main goals of this course include 1) exposing students to recent trends of IoT applications on smart home, smart city and smart car, etc. 2) providing easy ways to design various IoT applications using LoT 3) leading the students to design and experience various IoT applications

through the course 4) enhancing students' programming skills to satisfy engineering requirements.

Based on this model, we developed and offered a course titled "IoT with LoT" with multidisciplinary capstone design in spring semester 2015 at Kookmin University, Korea. Various applications were developed by 25 students. At the end of the course, there was a showcase for the students to make a demonstration of their works which follows local industrial companies' requirements. The showcase is sponsored and hold by Microsoft Research Asia, National Research Fund, Korea and IoT research center@Kookmin University, Korea. In the showcase, the local industrial companies joining with the university to evaluate the work results of the teams.

The remainder of this paper is organized as follows. In Section II, background and motivation is briefly introduced. In Section III and IV, course design and course related project results are investigated respectively. Conclusion are provided in Section VI.

II. Background and Motivation

IoT has undergone a big evolution in the industry [4]. This has led to a huge gap between universities and industry. Hence, it is necessary for both parties, universities and industry, to get involved in curriculum development as partners.

Recently, Microsoft Research has released a new IoT platform named Lab of Things (LoT). This platform facilitates design and management of sensors and devices in IoT systems. Therefore, design and implementation of IoT systems and applications can be easier to conduct. LoT platform is basically developed in C# environment. LoT provides drivers and scout components for corresponding devices so that developers can use to design and develop their applications easily. Figure 1 shows the interconnection of sensors and devices in a LoT system.

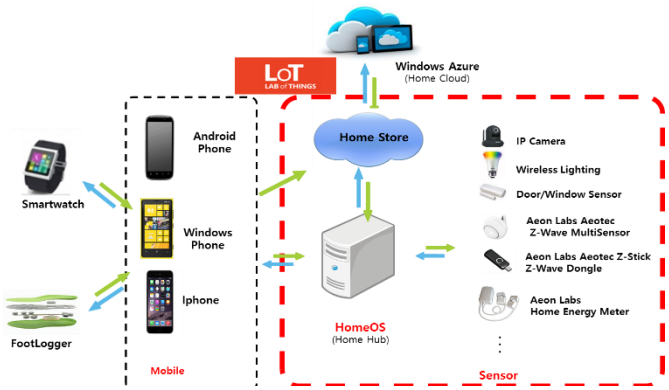


Figure 1. Interconnection of a LoT system

In LoT systems, a server PC runs LoT platform to connect and centralize all devices through Wi-Fi connection. This server PC, which is called "HomeHub", manages and controls all devices in the systems. Using this architecture, sensors and devices in systems can be easy to manage, and therefore, large-scale research can be facilitated to conduct. Figure 2 depicts a scenario of conducting large-scale researches in various geographical locations. Two researchers can connect their large-scale researches in two different locations together using LoT, thus, researches can be shared to each other and a research can be expanded into different environments.

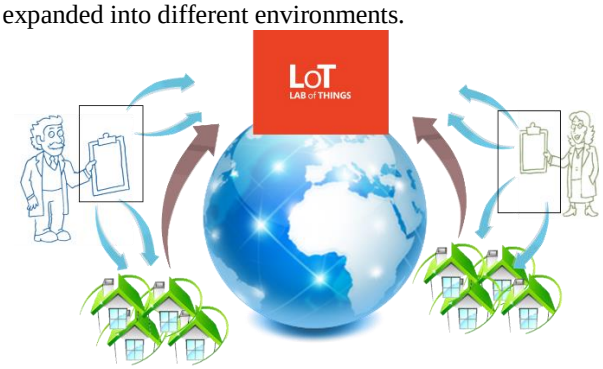


Figure 2. Conducting research using LoT

In our capstone course, we organized students in groups and help them practically address challenges of engineering system design and implementation. The course on developing IoT systems and applications using LoT platform significantly considers practical implementation and includes practical materials to let students approach to recent technology trends and be well-prepared for industry transition. The course also covers the explosive growth of IoT sensors, devices, platforms and systems

III. Design of the IoT with LoT Course

In this section, we explain our key objectives in designing the course and describe in detail the main content of the course. We also present our grading rubrics to evaluate students' performance during the course.

A. Main Objectives

A capstone course on IoT applications needs to balance between industry needs and the limitation of university course, while challenging them with lectures and course materials that foster innovation and creativity. In the industry perspective, the following issues are important to take into account.

- Summarizing trends of IoT applications and released IoT platforms for development
- Clear explanation for specific APIs of a platform
- Robust methods to connect sensors and devices in a system
- Data synchronization and access in server

The university course should also regard the following pedagogical issues:

- Course design with limited time and resources
- The lecture should be helpful for knowledge enhancement, system design and programming skill development
- Many sample applications should be provided

The final design of the course needs to strike a good balance that trades off the needs of industries and the limited resources available in a semester university course. Our main directions for the course design are as follows:

- Providing helpful surveys of recent trends in IoT growth and its development
- Supporting enough IoT application examples which can be used directly for the students' application design,
- Preparing sufficient practice examples and homework materials to ensure that students have hands-on, and detailed experience in various aspects of IoT system development.

B. Course design for IoT with LoT offering at Kookmin University

Logistic factors for the capstone design course is depicted in Table I. Our offering course was design for EE students at Kookmin University who have fundamental background on embedded systems and possess basic programing skills to follow the course. The target students of the course is juniors and seniors.

TABLE I. COURSE LOGISTICS

Prerequisites	Embedded system, basic programming skills
Target students	Juniors and Seniors
Required time	3 hours in class 2 hours in homework
Programming language	C#, JavaScript
Platform	LoT, HomeOS, Windows Phone
Type of course	Project-oriented

The "IoT with LoT" course offered at Kookmin University consists of 4 hours of regular lectures, i.e., 2 lectures per week and 1.5 hour teaching for each lecture. Figure 3 shows the overall structure of the course. The course is divided into 3 core parts: concepts, hands-on training and project tracking. On the first lecture of a week, we explain concepts, summarize trends and provide basic programming skills to students. On the latter lecture of a week, we focus on practical skill through Hands-On-Tutorials (HOT) by analyzing applications examples developed by LoT and SESL Lab teams. After the HOT lecture, homework exercises are provided to help student follow the lecture contents easily. The course contents can be summarized in Table II.

TABLE II. SCHEDULE FOR THE TERM PROJECTS

Week	Content
Week 1	• Introduction to multidisciplinary capstone design 'IoT with LoT' • Running sample LoT application with example source code
Week 2	• Basic concept of LoT and recent trend of IoT in various exhibition • Running LoT application using Arduino
Week 3	• Introduction to various service concepts by merging WP, LoT and Azure • Basic C# programming
Week 4	• Basic UI programming(such as button, check box) for Windows Phone
Week 5	• Windows Phone programming for Graphic, Multimedia, Sensing, Networking, etc.
Week 6	• Basic concepts of Windows Azure cloud service • How to create a simple Windows Azure cloud service app from scratch
Week 7	• Introduction to Azure mobile service • Development of simple application using Azure Stream Analytics service
Week 8	• Basic concepts of HomeOS • How to develop a HomeOS app using web-camera and IP camera
Week 9	• Introduction to Lab of Things • Development of Camera Viewer application with Azure
Week 10	• How to connect and Arduino board to HomeOS using serial connection • How to store collected data in Azure using Azure API
Week 11	• How to remotely update Hubs using FTP connection • LoT EventHub
Week 12-15	• Term project • Application implementation

C. Evaluation

Table III shows the grading rubrics for evaluation of students' performance in the lecture. We divide the evaluation into 3 categories, i.e., homework, examination and project, which credit 30, 30 and 40 points for overall score, respectively. The homework exercises are built based on HOT sessions to help student practice programming skills and system desire. The examination mainly focuses on concepts, understanding of Windows phone, HomeOS, LoT platforms and tests on some particular scenarios of programming IoT applications.

TABLE III. COURSE EVALUATION RUBRICS

a) Grading

Rubric	Score
Homework	30
Exam	30
Project	40
Total	100

b) Project evaluation

Criterion	Percentage	Score
Creativity	20%	8
Research	30%	12
Technology	20%	8
Usability	20%	8
Total	100%	40

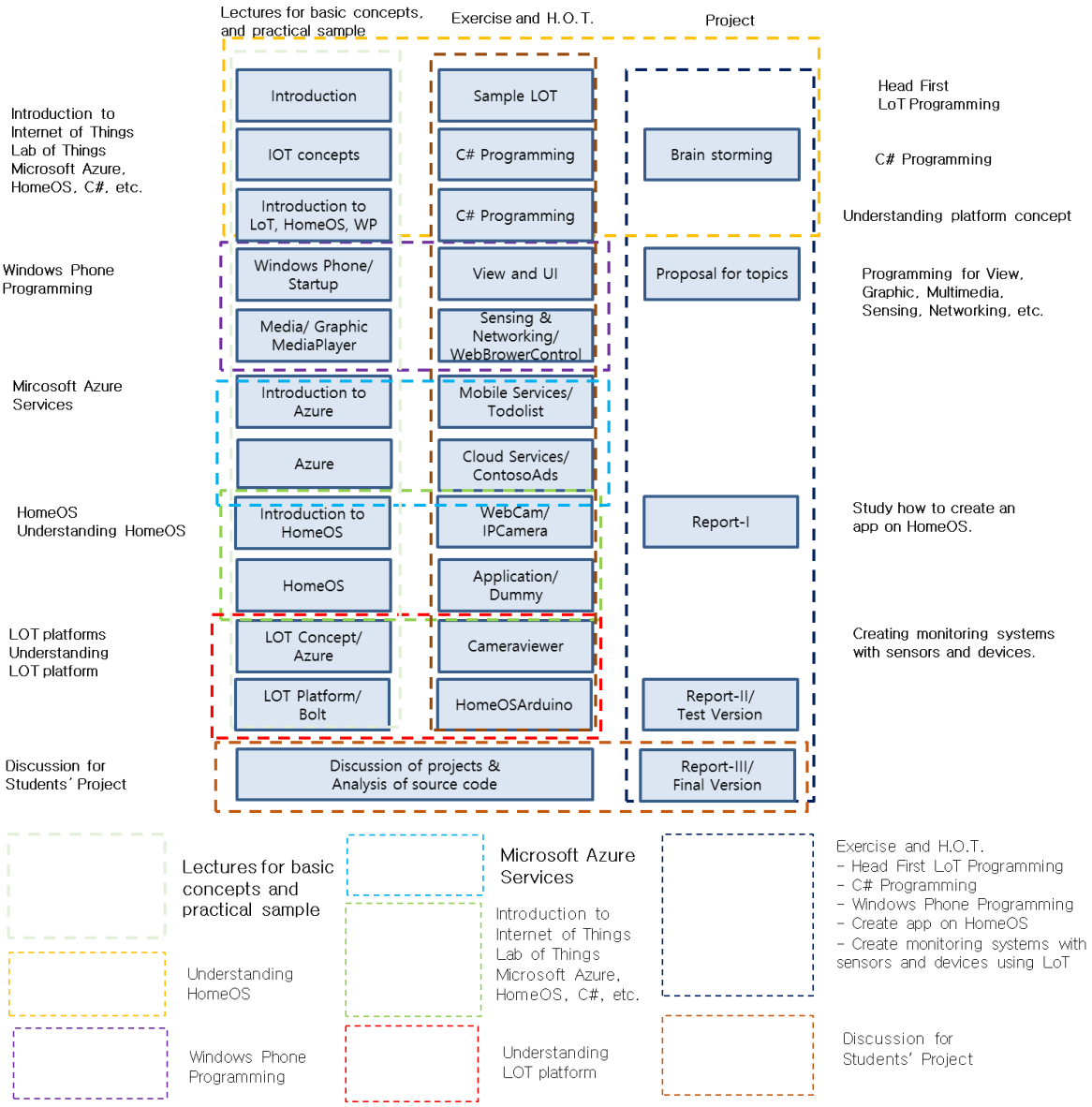


Figure 3. A course design for advanced Android programming

In the capstone design, we fundamentally emphasize the grading on the project conduct of teams. The project grade is about 33% higher than grades of homework and exam parts. The projects are assigned to teams at the beginning weeks of the course (Week 1-3) and progressed during the course. The evaluation for projects is based on four criterions: creativity, research, technology, and usability.

IV. Course Final Projects

As described earlier, a major outcome of the course was a final project developed by teams of 3-4 students. A total of 7 teams completed the course projects and participated in the project showcasing event [10-11].

Table IV shows the detailed schedule for the team projects. These project were progressed in parallel with the lectures and HOT sessions.

TABLE IV. Schedule for the Term Projects

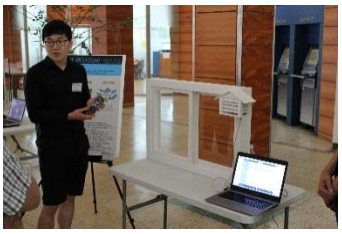
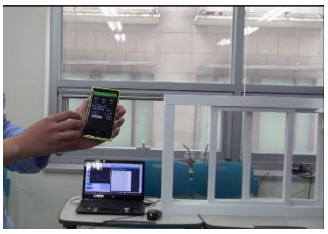
	What to do	***Due date***
Team	Making teams (3-4 students per team)	Week 1-3
Project plan	Detailed project plan Final project plan (Week 5)	Week 4-5
Development & discussion	Progress reports – first app	Week 8
Final report and presentation	Project report - test version Final reports - papers and presentation (Week 13)	Week 10-13
Showcase	Showcase and presentation	Week 15

Table V shows the term projects of the students. At the end of the course, we organized a showcase event [10] to encourage students to present their project results. Figure 4 shows examples of some presented projects.

TABLE V. TERM PROJECTS

Team name	***Contents***	***Categories***
Smart Window	Obtain weather data of specific area Remotely control window	Remote control Monitoring Smart Home
Light follows you everywhere	Monitoring of human life pattern during sleep to control devices Control of light and fan based on collected data	Machine Learning Automation
Green House	Remote Monitoring and automatic control of greenhouses' environment conditions (temperature, humidity, and etc.)	Remote monitoring Automation
RFID System	Personally control of devices in offices	Automation Smart Home
Health Helper	Tracking of exercising data of users'	Remote monitoring Healthcare
Smart Elevator	Elevator instalment Smart indication of current number of people in elevator based on light illuminant	Automation
Smart Home	Remote control of home devices	Remote control Smart Home


a) Health Helper

a) Smart Window


b) Smart Elevator

Figure 4. Examples of term projects

In the showcase, we also invited experts from IT companies, i.e., Microsoft Research, Samsung Electronics and Limei Inc., to together evaluate team projects. Each company provide a grade for each team respect to their industrial requirements. Finally, we summarized all results and combined with our academic evaluation to rank the teams. Three teams out of seven teams won prizes in the showcase event. The first, the second and the third awards were assigned to 'Health Helper', 'Smart Window' and 'Smart Elevator' teams, respectively, following the evaluation of both academic and industrial sides. Moreover, each company has a presentation at the showcase to expose their thoughts and introduce their own trends in the IoT field.

V. DISCUSSION

A. Student feedback

We received excellent feedbacks from the students in the "IoT with LoT" couse, which is gathered from the lecture management system at Kookmin University. Generally, we received an overwhelmingly positive evaluation from the course participants. Specifically, they graded the course 4.2 over 5-scale. Students acknowledged that the course challenged their demands for time for practicing and programming, especially, in a quite new programming language for them (C#), but the students appreciated the course offering and enjoyed designing the final projects. The students also appreciated the contribution of teaching assistants (TAs) in leading discussions and holding interactions during the course.

B. Teaching paradigm

One of the most popular approaches in teaching engineering is Classroom Presenter [12] which uses technology in classrooms to enhance teaching and learning. In this method, lecturers can easily interact with students at the classroom based on high-end devices. Another well-known pedagogical method is Classroom Response Systems [13], where students' responses are aggregated. To develop technical skills, capstone designs are usually preferred [6, 8, 9] because of its significance in hands-

on training exercises. We think that each method has a potential impact in classroom and syntheses of these methods possibly provide better designs. Considering these ideas, to apply into the IoT area, we designed the course in a capstone class form combining with the Classroom Presenter approach. Specifically, lecturer utilizes devices such as tablet, projector, and computer with boards, pen, and e-pen to offer students interactive lectures, meanwhile, we provide student useful hands-on tutorials to practice in the classroom. Homework is designed to help student recap lectures, review hands-on trainings, and develop their technical skills, whereas, the final project is for evaluating their performance in both academic and industrial views. Results of the showcase and student feedbacks prove that the designed course model is appropriate for effectively increasing practical technical skills of students, and possibly reducing the gap between universities and industries in a specific area.

VI. Conclusion

In this paper, we presented a course design for IoT application development using the LoT platform of Microsoft Research. The target of the course is to 1) introduce recent trends of IoT and its applications, 2) provide students sample systems and codes using LoT platform to analyze IoT applications, 3) lead students to design and implement IoT systems, 4) train students for engineering environment. The presented course was successfully offered at Kookmin University in Spring 2015. The students' term projects have been demonstrated in the showcase which was organized at the end of the course. For future offerings, we intend to insert machine learning applications into the LoT-based systems. We also encourage conducting of large-scale researches.

Acknowledgment

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