MAKER: A Maker Space Smart Badging System

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Making a Maker Space Smart Badging System

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As a capstone design project a team of students from Bucknell University created a "Smart Badging System" to monitor use and control access of various Maker Space resources, including 3D printers, a Vacuum Former, Industrial Chiller, Laser Cutter, Vinyl Cutter, and others. This paper reports on the development of the smart badging system that will be installed in summer, 2016 in Bucknell's 7th Street Maker Space and MakerE. The smart badging system is intended to replace the current system which uses paper sign up sheets and cardboard IDs. The intent of the project is to give each user of the campus network of MakerSpaces an RFID badge that will allow them to access equipment they have been trained to use, allow them to request training for on equipment they have not yet been trained on, and allow administrators to monitor equipment use. The system is based on a user web interface developed in WordPress that allows both makers and administrators to access different features. While makers can submit training requests, search users and resources, and view recent projects, administrators have all the same features with the added ability to view usage logs, add makers or resources, and add student technicians that supervise the maker spaces. The student team designed the system to be based on widely available, open source software with custome hardware components that are based on popular platforms so that expansion of the system can server as a source of Maker projects. This paper briefly outlines the project and the capstone course in which it was developed; the system will be demonstrated at the ASEE conference.

Introduction

The purpose of the "Smart Badging System" is to replace the login/monitoring system that is currently in place in the maker spaces on campus here at Bucknell. The current system has studentsscan their campus ID card when they enter the space and then put on a cardboard badge with stickers indicating the equipment they have training on. The intent of this project was to replace this simple, low-tech system with a similarly cost effective method capable of limiting access to resources to authorized users, enabling individuals to request training on resources they are not yet authorized to use, and log when resources are being used. The system design was given to a team of senior electrical and computer engineering students as their capstone design project. As of the writing of this paper the system has passed a system integration test that demonstrated overall functionality; the conference presentation will report on installation of the system.

The smart badging system has gone through several iterations from the initial conception of the project. The problem statement devised by the team is:

> *"Create a smart badging system that monitors usage and controls access of various Bucknell Makerspace resources. The system will allow users to easily set up training to utilize resources and create a safe working environment. Additionally, the system should be easily scalable and maintainable by support systems on campus. Admins and Student Technicians will be able to configure the system with an easy to use web interface."*

The MakerSpace Badging System has three major subsystems: a card reader and control hardware at each resource that connects to the internet and controls resource power, a MySQL database running on a campus server that logs all users and use of resources, and a secure web interface that draws information from the database that is implemented using the popular WordPress software and freely available plug-ins. The system authenticates users based on a unique User or Maker ID (UID) coded into an RFID card to identify a particular maker and a Resource ID (RID) that uniquely identifies a particular type of resource. Note that the Resource ID is for a type or model of resource rather than a specific device so that a user who is trained to use a MakerGear 3D printer, for example, may use the resource at any MakerSpace on campus. A level zero block diagram of the current system iteration is shown below.

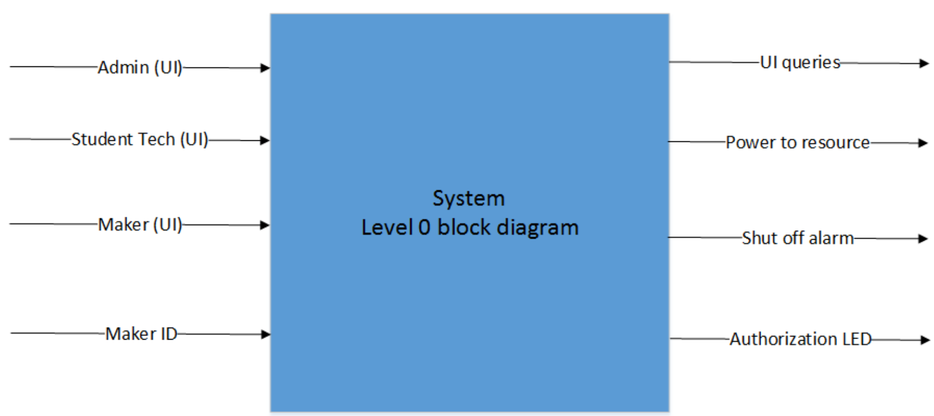

Figure 1: Level 0 block diagram showing major inputs and outputs of the overall system. A more detailed description is provided subsequently.

Development Process: the Capstone Design Course

The MakerSpace Badging System was developed a team project in a senior capstone design course in electrical and computer engineering. This section describes the course in which the system was developed. The highly structured capstone design course stretches over an entire year with a half credit fall course focusing on student team creating multiple representations of their design followed by a full credit spring course where the design is realized. At Bucknell one credit corresponds to four credit hours. The year is structured into twelve milestones with specific deliverables from the team due at each milestone. The course milestones are: (1) project exploration, (2) team formation, (3) problem identification, (4) conceptual project representation, (5) technical and logistic representations, (6) second iteration and reflection, (7) fabrication and unit test, (8) system integration and test, (9) finalize representations, (10) system acceptance test, (11) client delivery, and (12) final reporting and reflection.

The rationale for creating a much more structured design course was the observation that students were often not sufficient familiar with the design process to exhibit good design habits. While students were exposed to a cornerstone design experience in their first year, it has been shown that the knowledge from such "bookend" courses does not persist [1]. The more structured format was designed to introduce novices to elements of good design. To support learning of the various stages of design the course is based upon a theory of social construction of knowledge known as the Vygotsky cycle [2-4].

Unlike capstone teams in other departments at Bucknell and many other universities that have nominally three or four students, the design team for the MakerSpace Badging System project consisted of six students. On this larger team three defined roles were created: one project manager, one system engineer, and four design engineers. The project manager and system engineer were chosen by consensus of the team and also approved by the instructors. The role of project manager was to manage all communications and project logistics including coordinating the work of the other students on the team. The project manager was also responsible for project documentation. The project managers of each team met weekly with the instructors and lab director. Since the project manager serves as the point of contact for all instrumentation and components requests for the team, these meetings made it relatively easy to ensure communications are consistent. Another major role of the project manager is to document the team's progress on the project. The project manager creates a team archive that consisted of a poster size copy of the project block diagram and Gantt chart; current and past versions of the team's project reports and documentation; datasheets of all components used by the team; and copies of schematics, layouts, and project reports. One goal of creating the project manager role was to enable one student with the capacity to document the overall evolution of the project and student team's design process.

The role of system engineer has the responsibility of developing and maintaining an overall, high-level system view of the project the team was designing. The system engineer created and modified the team's technical block diagram and was instrumental in defining the interconnection protocols between various project elements and the interface with users or outside systems. This was a difficult role for most students to take on since many lacked either the experience or training to think in systemic terms.

The remaining members of the team were design engineers and were responsible for building and testing one or more subsystems of the overall design project. They also had responsibility for overall project fabrication in the later milestones. Design engineers worked closely with the system engineer to ensure their portions of the project could be integrated and the project manager to communicate issues and needs to the rest of the team.

To reflect the different responsibilities each role had a separate grading scale. The project manager was weighted towards reviews of the team logistic model, maintaining project documentation and regular communication with the client. The system engineer's grade is weighted towards system integration and functional decomposition milestone. The design engineers have the heaviest point weighting on developing individual subsystems for integration into the overall project. Points were, however, shared between all three roles in every milestone so that inter-dependence among team members is maintained.

There were several rationales to increase the team size. In the past when smaller teams were the norm students who were not sufficiently prepared or who chose not to engage with the design course had a strong impact on the course outcomes since one students reduces effective team size by a third or a quarter. In addition teams without defined roles and assignment of responsibilities tended to be amorphous, which caused frequent breakdown in communications between team members and between the team and instructors.

The course was team taught by one faculty from electrical engineering and one from computer engineering. All materials submitted by the teams at the conclusion of a course milestones were scored by at least two faculty using rubrics followed by comparison of scores from raters. In most cases scores were in good agreement; where differences existed the instructors compared notes and arrived at a consensus scores. The rubric scoring categories were also mapped to assessment of ABET outcomes [5].

Overall the use of structured milestones and defined team roles with different grading criteria have led to an increase in the success rate of projects. Qualitative evaluation of written end-of-semester reflections indicate that that the course succeeded in creating a professional environment. This is an important element since research shows that students often dissociate academic experiences from what they see as "real world" engineering [6]. From the perspective of the instructors, the regular milestones, chance to meet with project managers weekly and individual milestones made it easier to track the progress of both teams and individual students.

Smart Badging System Design

The team of six students went through the process outlined above to develop the Smart Badging System. At the time this paper is being written the team is preparing for Milestone #10, the system acceptance test. As designed by the student team the system is composed of three major subsystems: a resource access point with a badge reader and resource controller, a MySQL database which serve as the system backbone, and a WordPress web site that serves as the primary user interface. In initially designing the system there was considerable discussion as to whether to use existing campus ID cards or use low cost, commercially available RFID cards. Ultimately inexpensive RFID cards were chosen rather than existing campus ID cards for several reasons. First, the intent is to leave the ID card on the scanner to keep a resource active, and since some resources such as 3D printers can take a considerable period of time to complete a user job, the team did not wish to "freeze" use of the campus ID card down for that length of time. Also the low frequency scanners used for RFID cards were considerably less expensive than the 13.56 MHz campus ID system, and data security concerns were minimized by having a stand-alone system.

An overall system diagram is shown below in Figure 2. This diagram is the design team's conceptual solution description that shows overall function of the system.

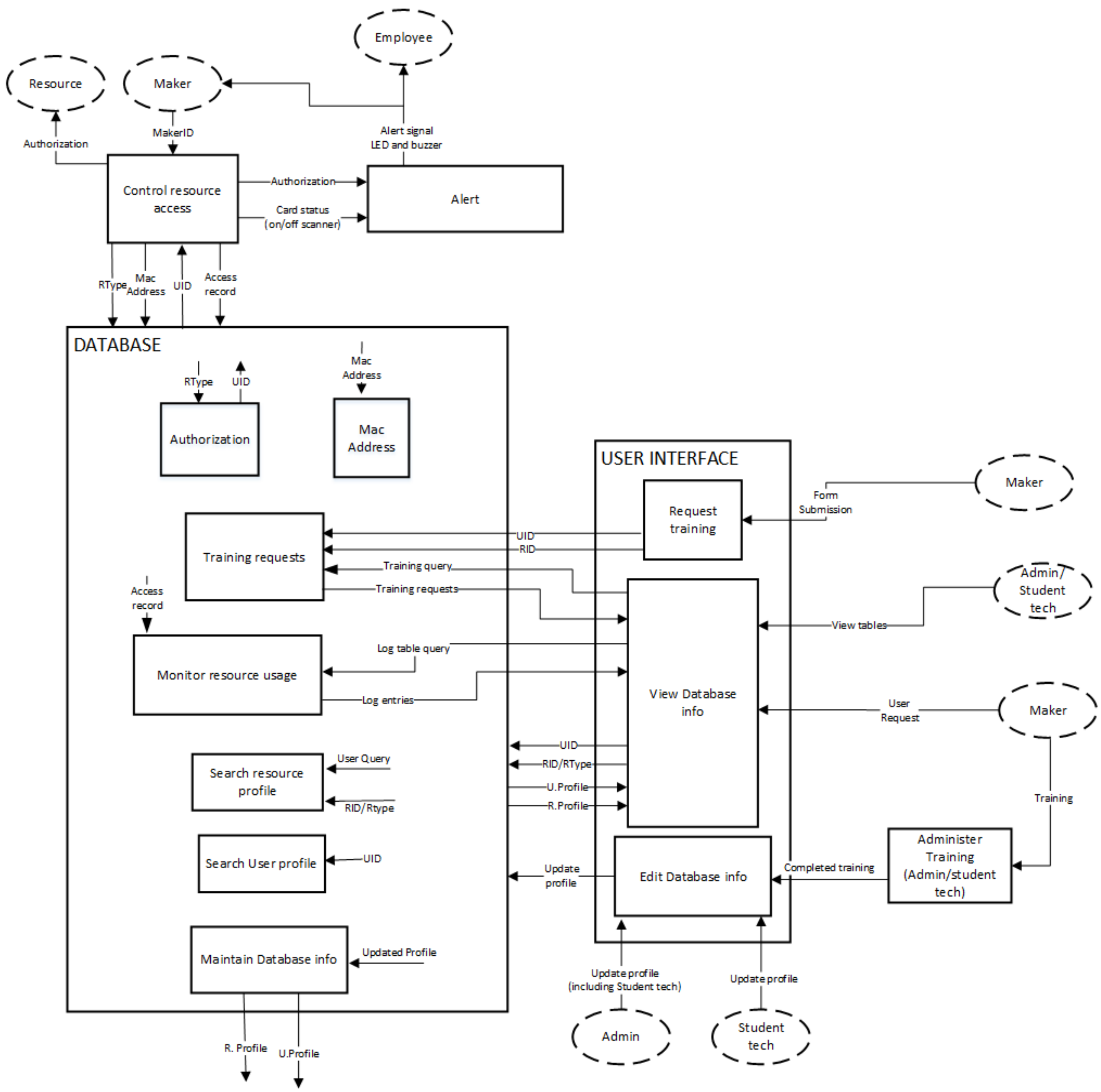

Figure 2: MakerSpace Badging System conceptual solution description which provides an overall view of the system operation. External agents are shown as ovals that interact with the three major system elements: resource access point (upper left), Web UI (lower left), and the database (lower right).

A resource access point is located at each piece of equipment in the MakerSpaces that needs access control or use logging. For this reason a primary design consideration was to keep the cost to a reasonable level. Each resource access point has an RFID card scanner connected to a Raspberry Pi II (RPi) computer that manages the resource through its GPIO pins. The RPi was chosen due to the relatively low cost, large support community, and to stay within the Maker ethic. The intent is to create each resource access point as a Maker Project available to students. The RPi is connected either via the Wi-Fi campus network or wired Ethernet to the database that determines whether the MakerID scanned is either allowed or restricted from using the desired resource. Access is controlled by either shutting off AC line power to the resources through the use of a solid state relay or using a small mechanical relay to connect to the equipment interlock (if available). The Raspberry Pi II both checks whether or not a maker is authorized by reading the maker's RFID card (UID) and references the database as to whether the scanned UID is authorized for the resource attempting to be accessed. If the maker is authorized, power to the resource will flow through the SSR, allowing access to the resource. The system has been designed with a card slot since the RFID card must remain on the scanner in order for the resource to remain operable. If the UID were to be removed, intentionally or accidentally, there is a period where an alarm sounds before the resource is shut down so that a student tech's ID can be placed on the scanner to continue use of the resource if shutting down would cause a safely concern or impact operation. Figure 3 below shows the preliminary design of the resource access point which will be made from laser-cut lexan so operation is visible in the Maker spirit. Not show are LED lights which will cause the case to glow red when access is denied and green when the resource is on.

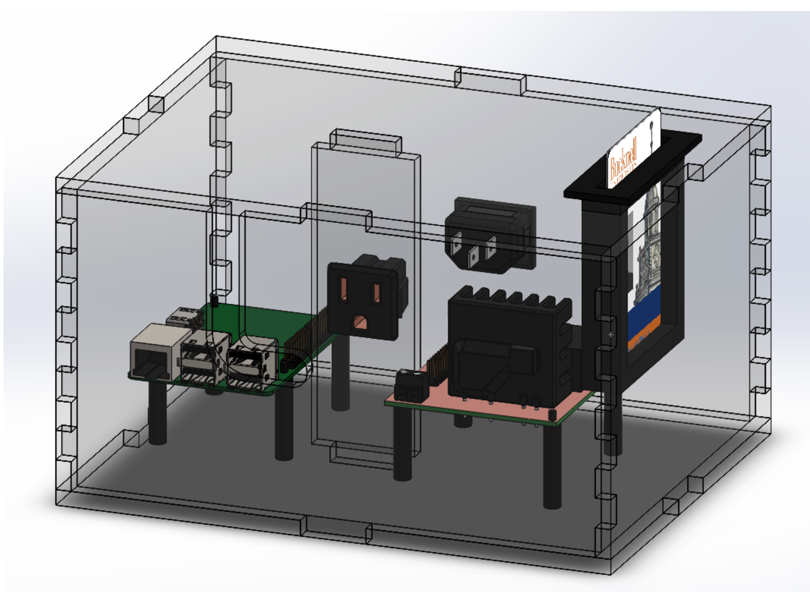

Figure 3: Initial design of the MakerSpace Badging System resource access point The card holder is shown on the right, the SSR in the middle, and the RPi is mounted on the right. The case will be made from laser-cut lexan.

The other part of the system accessed by users is the web based user interface system that is used by users of the space, student technicians, and faculty space administrators. The system is developed in Wordpress using available plugins that interface with the MySQL database. The entry to the site is at www.eg.bucknell.edu/makerspace which gives the user an option to log on as a maker or as a technician/administrator. If the user logs in as a maker, the user is given the option to request training for any resource type, which will notify technicians that a training request has been submitted, search users to find if any those authorized on the resource, and allow connection between the user seeking access and other uses who can access the piece of equipment in question. Users may opt out of being tagged in search results should they wish to remain anonymous. Users can also query which resources they are authorized to use and search through the various types of resources throughout the maker spaces on campus.

If the login is made as a technician or as an administrator the above functions are still available along with the ability to add new resources, add new makers, and view resource usage. Student technicians who work at the maker spaces have all of the previously listed capabilities, while maker space administors are also able to add student techs. The website also provides links, available to anyone, to separate sites that display maker profiles, the maker spaces on campus, and the recent projects that Bucknell's makers have worked on. The project gallery is supported through a WordPress Instagram plugin. A screenshot of the web site user interface (UI) is shown below as would be seen by student technicians and administrators following initial log in.

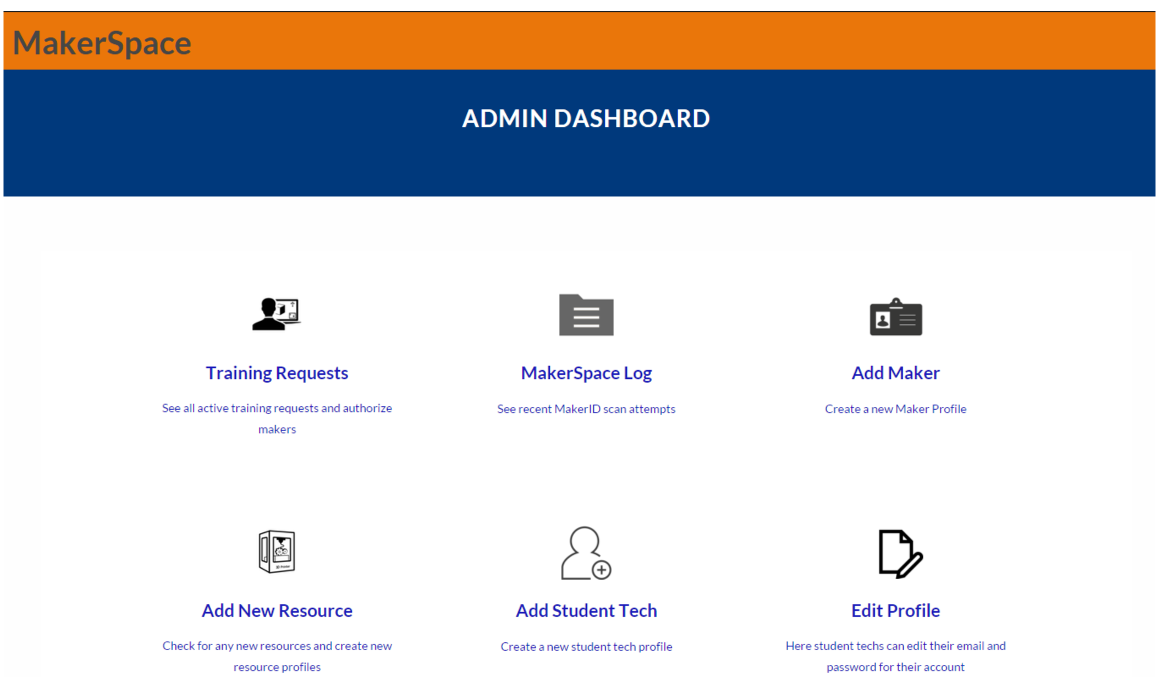

Figure 4: A partial screenshot of the MakerSpace Badging System WordPress based web user interface (UI) for the student technicians and space administrators. This site is used to handle training requests, view resource usage, etc.

At this writing the overall system has undergone a first round of integration testing to demonstrate that the overall concept is functional from end to end. On the software side some testing has been done to determine the effects of system scaling. At this point there are only two MakerSpaces at Bucknell, but several more spaces may potentially come online in the near term. To better understand system scaling the student team simulated an increasing number of requests and found the scaling behavior shown in Figure 5. Overall the system should be able to handle hundreds of requests with reasonable lag which is more than are anticipated. On-site testing has demonstrated significantly more lag using WiFi than wireless, particularly when there are a large number of concurrent users on the network. For this reason the intention is to use wired internet connectivity whenever possible.

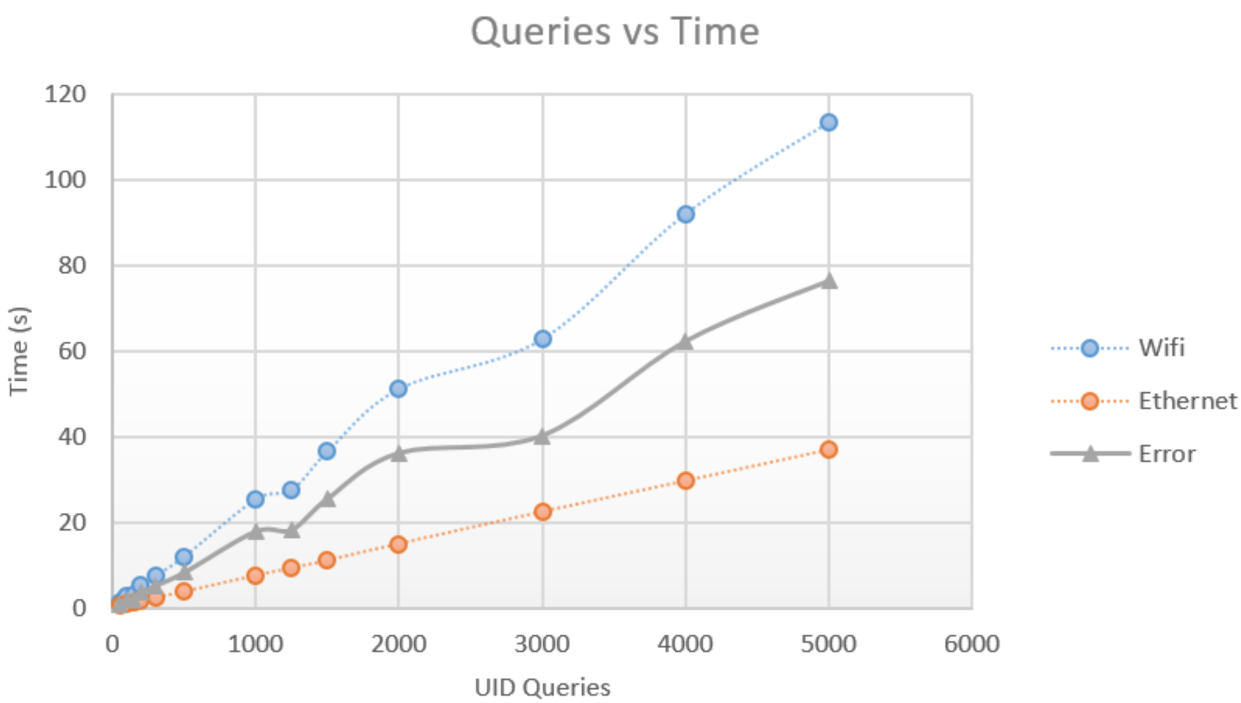

Figure 5: Simulation of execution time for continuous queries simulating checking UID when resource is on.

Demonstration at the ASEE Maker Exhibition

The intent of the Bucknell MakerSpace Badging System is to provide an open-source resource for other campus Makerspaces that may be interested in controlling access to some equipment and logging equipment usage. A demonstration system will be available at the ASEE conference with functionality determined by successful completion of the project by the capstone design team and the vagaries of internet access. The complete plans and code for the project will further be made available on a public website at the conclusion of the project in early May 2016.

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