April 21st 2010

Dr. Andrew Rawicz
Simon Fraser University
Burnaby, British Columbia
V5A 1S6

Re: ENSC 440 Post Mortem for Microflow's Networked Water Faucet System.

Dear Dr. Rawicz:

The attached document is intended to describe the team's experiences and technical issues related to the prototype design, development and demonstration of Microflow's networked water faucet system. Included in the document are four sections in which each team member has described their own experience with the semester long project. Also included are several general sections covering the major components of the prototype development. In each section we have attempted to address issues that were faced and notable issues that were overcome.

In parallel with the development of Microflow's networked water faucet system, individual team members also achieved personal development through academic success. The team members were quickly able to recognize where and how they could contribute to this Engineering project which will help us in future team project situations.

Microflow Systems Incorporated is a start up technology company made up of the following four members: Kwang-young Lee (CFO), Sonca Teng (CEO), Micheal Hou (COO) and Aaron Marcano (CTO). The post mortem document is intended to summarize our team project and team member experiences.

Sincerely,

Sonca Teng
Chief Executive Officer
Microflow Systems, Inc.

Enclosure: *Post Mortem for a Networked Water Faucet System*

Microflow
Systems Inc.

Post Mortem for Microflow's Networked Water Faucet System

Submitted to: Dr. Andrew Rawicz – ENSC 440
Steve Whitmore – ENSC 305
School of Engineering Science
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Capstone Engineering Project
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1. Introduction

The networked water faucet system is a system that achieves smart metering by monitoring, updating a storing water usage for faucets and showerheads. One key component of the project is the feedback that a user gets when he or she is using water at sinks or faucets, as well as to see the total amount of water used around the household for the day so he or she may use water accordingly. This feature is what makes this technology a green product with an objective to help people use water more efficiently at home and at work.

1.1 Scope

This document is primarily intended to record the issues, problems, and achievements of the Microflow team and the individuals that made up the team. As we reflect on the project for ourselves we are also communicating with peers and professors to help them achieve higher success with Engineering Science 440 and 305.

1.2 Intended Audience

The main audiences are ENSC 440 and 305 professors, TA's and future students of these courses.

2. Overall System

2.1 Current State

The Microflow Faucet and Showerhead system design has been completed. The system, composed of an LCD screen for a user interface, a microprocessor to control other components, a wireless transceiver to communicate with other systems, and a flow sensor to measure water usage, is performing as specified by the design specification document.

The microcontroller is connected to the LCD screen using a 6 I/O pins, and can use the connection to display characters and numbers onto the screen. Software development has been completed so the microcontroller can initialize, display characters, and reset the screen.

The flow sensor is connected to the microcontroller via an interrupt input pin. This enables the microcontroller to measure the water used while performing other tasks. With this, the water usage can be measured and calculated.

The microcontroller has an internal clock that can keep track of time and give out an alarm in every specified time span. This feature has been enabled to allow the microcontroller to reset its water usage values every 24 hours, at 12AM. However, this feature was not enabled for the presentation, for demonstration reasons.

All system functionalities have been tested and verified. Water measurement accuracy and precision has been also tested, and well exceeds our 3% accuracy benchmark.

2.2 Issues

One of the major issues encountered during the project was the battery life and how long the battery can power the system. Currently, one 9V battery will power the system for 5 hours, and becomes very warm. The voltage regulators we use also get very warm. This is an issue with the fact that we were using linear voltage regulators. We decided to make a change to our design to incorporate a set of switching regulators later on, which are over 90% efficient vs 50% efficient, but our supplier did not come through in the end and we did not manage to get these incorporated in time.

Another issue with the system was the water measurement inaccuracy. This was due to the inherent inaccuracy of the selected flow sensor. The flow sensor model selected had high lower flow rate limit and low pulse counts per litre. The reason the flow sensor model was selected is because when ordering the flow sensor, due to the long turnaround time (2+ weeks), the team decided to use a high flow rate limit unit, therefore not risking the potential failure when the sensor cannot keep up with the flow rate of the water. Even so, the accuracy comes within our specified range of 3%.

2.3 Future Work

To reduce power consumption and improve power efficiency, the linear voltage regulators have been replaced with a switching type, which is significantly more efficient (3.3V), and generate less, if none at all, heat. This alone will double the usable time, but this is not enough. Other power saving features, such as putting the microcontroller to sleep mode when the system is not in use, therefore reducing the power consumption from 0.3W to less than 1mW, scaling down the microcontroller's clock speed to reduce power consumption by sacrificing the processing strength and tapping into the XLP mode (eXtra Low Power), and turning the LCD backlight off when not needed, is currently being explored and/or implemented. Finally, the transceiver will also be shut off in times of inactivity, only to be activated at predetermined times. All these initiatives together will theoretically extend lifetime of the unit up to two years of continuous usage.

During testing, the flow rate of a normal faucet has been found (~2.5GPM with a flow restrictor), and either by using a more accurate model with lower low-flow limit and higher pulse counts per liter, or designing a new flow sensor with higher accuracy. Although the former approach will be more convenient as it uses pre-made solution, due to its prohibitive cost (~$93.00 CAD per sensor), the latter option is being explored.

3. Transceiver

The transceiver was the critical component that allowed our networked water faucets to communicate with each other over the network. The nature of the project was such that we were faced with the challenging tasks of figuring out how to achieve networking capabilities for our system. There are many companies dedicated to delivering wireless capable devices and fewer that support their customers like Microchip.

This is the company we chose to purchase wireless transceivers from and it was definitely the right choice for our project. We chose Microchip for several reasons with most obvious reasons being that they provided to us software, a development environment and sample devices free of charge. One other reason that we chose Microchip's wireless transceivers is because of the fact that our PIC was also made by Microchip. This decision made the connection and communication between two of the most important components of our system much easier. Development time was significantly reduced because of preliminary research resulting in smart component choices. These decisions proved crucial when our team began to realize just how crunched for time you can be when taking part in a single semester capstone Engineering project.

3.1 Current State

Our transceivers worked quite well and once we made the appropriate programming or hardware changes, they consistently operated as the data sheets and application notes had specified. They currently transmit messages on one of the 16 channels over the RF band between 2.405 GHz and 2.48 GHz. Our system's Microchip transceiver modules, model # MRF24J40MA, have 12 pins and a PCB antenna with a maximum 400 foot data transmission range.

3.2 Issues

One of the notable problems that we overcame with the transceivers was to send messages with the correct content and format that were specific to our project. This may sound easy, however when you are compiling thousands of lines of code that will run on a PIC which communicates with a transceiver through wires, and that transceiver must then communicate wirelessly with another transceiver things did become difficult. Fortunately, our team was always able to overcome even the most challenging issues faced while learning how to achieve wireless communication between multiple devices.

3.3 Future Work

Our messages are currently being passed across the network without substantial security and without data encryption. These are two very important areas that will need to be addressed and implemented properly if this device is ever to hit the market. Future issues also include message hopping so that messages can be passed indirectly from one node to the next. Achieving message hopping communication between multiple nodes will allow messages to be passed outside of the 400 foot maximum transmission range of a single device.

4. Software

4.1 Current State

Software development has been completed to satisfy basic functionalities. Measurements have been implemented so that either metric or imperial units can be selected to display the water usage data, by changing a variable during programming.

Software can also properly control the LCD screen and the wireless transceiver, and receive input from the flow sensor and update its water usage value. After initialization, the microcontroller has been programmed to run in an infinite loop to calculate, display, and broadcast its water usage values, if there aren't any broadcasts to receive.

The software can also save up to 16 network addresses in its memory to keep track of network water usage. That is 16 potential faucet and showerhead systems and their respective water usage data stored in the microcontroller.

4.2 Issues

The biggest issue with the software currently is the network node addressing and identifying. When broadcasting or receiving network messages the messages contain the source address, a 16-byte string to uniquely identify the sender. However, the source address verification method currently used in the software cannot compare a 16-byte string to another 16-byte string properly, continuously overwriting data from other sources. Although the team tried to work out the bug, but in the end, only one byte was used to identify a network sender, therefore limiting the number of potential faucets per system to 16, instead of 16^{16} addresses. Further debugging is under way to address this particular issue.

Another issue with the software is unnecessarily repeated tasks. The LCD screen, even when it is not necessary to change any of the water usage value displayed because the value has not been changed, still gets over written, therefore wasting processing time and power. Some measures have been implemented to reduce repeated processes. More thorough software optimization will likely solve this issue.

4.3 Future Work

Other than addressing the software issues discussed previously, further future work that's being researched is the possibility of computer software or application to increase data storage capability and tracking, as well as better user interface and usability in general. When completed, this software will be able to keep track of overall and particular water usage, the trends, and more.

5. Hardware

5.1 Current State

The assembly of device is complete and is working as intended. The enclosure design for both showerhead and faucet are able to mount perfectly and structure integrity remains intact under reasonable abuse.

5.2 Issues

The enclosure is not totally water proof, as water vapour can still get in through the holes for LCD pin connection. The showerhead enclosure is currently made out of cardboard and is wrapped in plastic to keep the water out. The box is not as strong as it could be.

5.3 Future Work

Both showerhead and faucet will have the LCD embedded into the unit. The whole device should be minimal design but attractive at the same time and still be direct bolt on replacement.

6. Budget and Timeline

6.1 Budget

Proposed budget for this project was $821 Canadian dollar, and the actual spending for this project is $876.56. We are over budget by $55.56 due to failed devices and their replacements. We also spend extra money on obtaining the ZENA network analyzer but which cost is covered by returning the PICDEMZ demo board we didn't end up using. We would actually be under budget if we did not design the extra shower head during the middle of our development phase.

Four hundred of our project cost is covered by ESSEF funding and the rest of the cost will be spitted among company members. We are also going to apply for the Wighton fund on completion of the project.

6.2 Timeline

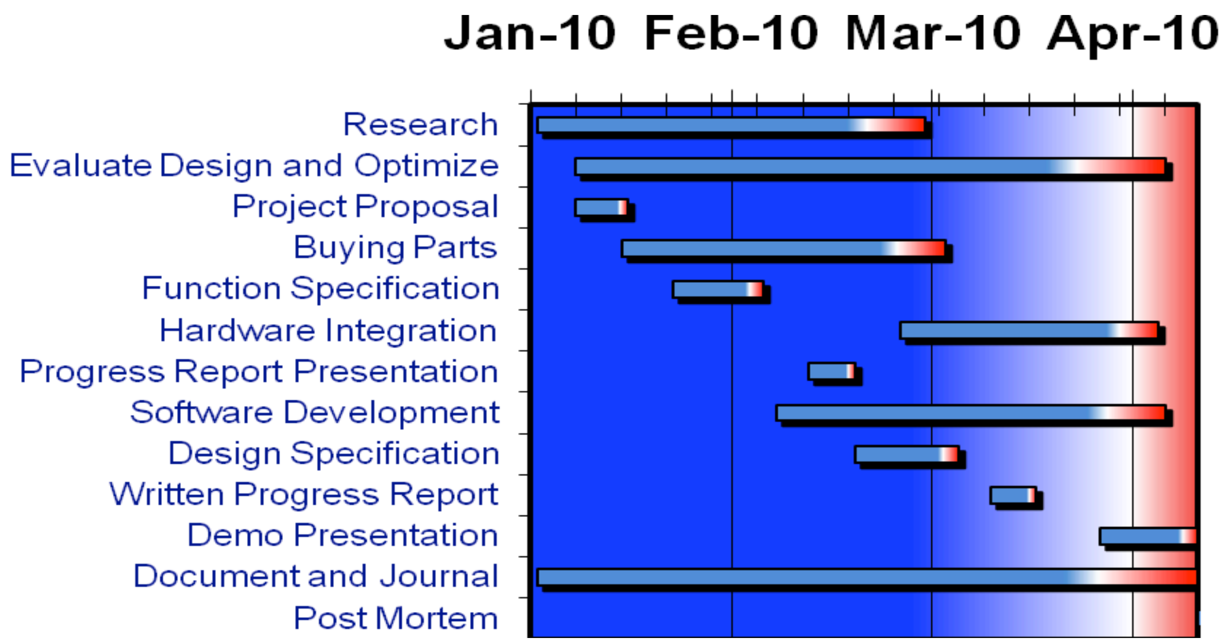

Figure 1 - Project Timeline

This is the actual timeline that we have used to complete the project. The major differences are in hardware integration and software implementation. We knew the software integration will take the longest time so we started early while waiting for the hardware components to arrive.

We have followed our timeline in a weekly order, however, hardware integration took longer than expected because of the extra adapters we need to order and modification to the enclosure is also changing with the development while refining the details. Moreover, in the process of modifying the faucets to meet our needs, one of the faucets had suffered damage beyond repair and a new one has to be bought and modified. Despite all of the setbacks, we have conquered the obstacles and are able to finish the prototype on time.

One of the cosmetic setbacks is due to transaction error. Sonca designed a PCB but the order to manufacture it did not go through. However, with the breadboard setup we are still able to show the intended functions that we designed for the project.

7. Individual Experience

7.1 Michael Hou

Doing this project has taught me a lot. The process to research and develop a product from start to scratch was something I never thought I would be able to do. I have always see myself as a user instead of a designer. However, with the help with my team we can make anything happen with some research and a lot of time.

At the start of the project, we had a hard time deciding on the project topic. A lot of our ideas are either already on the market or patented but not on the market. It was also very difficult to come up with a topic that is feasible and profitable at the same time. In the end, we decided to come up with a product that is both environmentally conscience and socially responsible. That is how the network water faucet system comes to this world.

Once we have decided on the product, I have begun to think of how my years of learning in the engineering field can finally contribute to this project. I then took on the role of being the overall system designer and tester for our project. My main contributions are to design the virtual drawing for our product and simulate it. Once everything looks good on the computer, I start to put everything together in real world and optimize it for practical use and ease of operation. I have also helped out in developing the software and testing to see if there are any bugs. It was also very important to pull us back into reality and look into real world issues while designing functionality and practicality.

I was super excited when I see the whole system assembled and working for the first time and relieved as it was very close to the demo day. When I was figuring out how we are going to showcase the video, I start to real believe we are going to make a difference and change how people treat the most important resource in this world. One thing I have really learnt is that teamwork and communication between the team is the utmost important and will make things work.

7.2 Sonca Teng

This has been a greatly eye-opening experience for me, on two fronts. Being the only electronics engineer in the group among systems engineers, I was charged with performing the electrical system design. This is nothing new to me, as I have taken a good number of advanced electronics design courses at SFU. But I soon found that there were key differences when attempting to design a project from scratch, sourcing components on your own, and trying to build a system for **reliability, power efficiency,** and **cost**, three aspects that have **not** been covered by electronics courses at SFU. Further, I learned a great deal about learning to keep a large scale project on track, how to coordinate efficiently with a team of four on a major project, and how to write professional project documentation. Toward the later part of the project, my team sent me to a business development workshop where I learned how we could potentially go commercial on completion of our project.

There were some key differences to designing for a lab, versus designing for a commercially feasible product. First, ordering components had become part of the process. In labs, the components are all given to you in a bag, and you simply piece them together. In earlier courses, we would be given exactly what we needed, and it was rather like putting together a Lego kit. Later in more advanced courses, they would give us a bag of all sorts of components and we would choose what we needed from there. But now, being left on our own, I had to source parts that would fulfill our specifications. Not only that, but these parts had to be as low-cost as possible, while being as reliable as our design documentation specified, had to be efficient in power consumption, and had to be **environmentally friendly** (targeting RoHS certified devices). Power consumption was probably my biggest challenge. Originally, I had specified use of Linear Voltage Regulators, as this is standard practice in our labs and there have never been any problems of any kind. However, in our labs we do not operate on battery power; we tap into the DC power supplies and take power for granted. We also do not keep our circuits running for more than 15 minutes, and do not operate our circuits in enclosed areas. Consequently, we do not ever experience heating and reliability issues. This is how I learned to use Switching Regulators. A quick consultation with Patrick Leung revealed that though these are more complex and more costly, they are the perfect fit for our project.

This is not the first time I have led a team. Most significantly, I was Team Lead for the ENSC 151 project group where we were given a microcontroller and development board, and we were left on our own to develop, in assembly language, an integrated system based on the hardware. I learned a great many things from that course, things that I was able to apply to ENSC 305/440. Setting down specific goals and milestones for individuals and sub-groups within our team was essential. We needed to be efficient with how we specified work to be done, and when it needed to be done. Motivation was also key. In general, I kept the team going by doing my best to always have a plan for where we were going and how we were going to accomplish it, and maintaining confidence that if we followed the path, we would get there.

As for my team dynamics role within the group, I was the visionary – I would pitch new ideas and concepts at the team and they would give their feedback on whether it was worth pursuing. I was also the one to check up on people and see how they were doing, to give them big-picture feedback on the direction they were taking, and giving them advice for how they could proceed if stuck. I kept them motivated for the most part by setting down milestones and having a plan toward achieving them.

Toward the end of the project, my team sent me to the BC Innovation Council sponsored Entrepreneurship and Technology Commercialization workshop in order for me to gain insight into how we would transform our Capstone Project into a business. I found a few contacts there, and I definitely learned a great deal about setting up a business, marketing, channel acquisition, and financing at the grueling three-day 9-5 workshop. I am confident that we can leverage this newfound knowledge of mine to help put our product on store shelves, especially because we have a project worth being proud of here. We can make a difference.

7.3 Aaron Marcano

In general the team was a pleasure to work with and the project was a very good experience. I think the team benefited from a lower number of members because we each had to take accountability for the progress of the project, I didn't feel as though there was an unbalanced effort by the group. To be able to build team dynamics with members who I was not friends with before the formation of the group was one of the most important aspects of the project for me personally. In life I am sure there will be many instances when a team is formed and they will not know each other prior to the project, so this was good practice. Other important aspects included the additional technical skills that were acquired and the writing skills.

My experience with wireless communicating devices grew considerably throughout the project. I really had no idea how our devices were all going to communicate within the system until I began writing parts of the design specifications. I was only able to write my sections of the design specifications by studying the product data sheets, reading application notes, learning about specific features and deciding which ones to use from those resources.

One of the most exciting parts of the project was when the transceiver messages were first being broadcasted and we were able to visually observe the messages being wirelessly intercepted by our network analyzer. The network analyzer had a display that showed any packets that were sniffed on a specific channel using the MiWi wireless communication protocol. At that point the team's efforts seemed to be paying some dividends; we were now able to wirelessly communicate between the devices in our network.

In conclusion, if I could do this project over again I would still keep the group at four members, to allow pairs to work together. I would also have done extended research about wireless communication before beginning the design specifications. Overall a great project, thanks to the ENSC 440 and 305 professors, the teaching assistants, the ESSS and the Microflow team.

7.4 Kwang-young Lee

I've gained a lot of project oriented experience in this course, both technical and teamworking wise. In technical aspect, I gained exposure to programming and debugging microcontrollers. And by researching on coding and proper way of using it, I was able to program the microcontroller to control and receive data from other components of the project. Sometimes, it took some several trials to make a certain component to work, such as the LCD screen, which took more than 2 weeks of debugging to function properly. In the end, most important lesson I learned is to be patient, persistent, and keep trying until it works. This skill will allow me to further pursue the microcontroller technology, even as a hobby.

Another aspect I've learned was about team dynamics and project documentations. Team discussions and deadlines were very useful at keeping track of progress and splitting tasks among teammates. And documentations enabled us to minimize arguing amongst ourselves when it came to designing user interface and other features for the project. Although some arguments were not settled, such as the product name for the showerhead unit, but most of the important decision making processes and discussions were made with little conflict.

I've also learned that during project development, it's always beneficial to plan ahead and give ample amount of time in case something goes wrong. With good enough preparations and schedule keeping, this may not be necessary, but it helped out in many cases where project development for a certain component, such as the wireless transceiver, took much longer than expected. My new motto after this course is, 'hope for the best, prepare for the worst'.

All in all, the best part about the course is the fact that I can apply what I learned in class and learned during research into a new, practical application, where I can see the results, and every improvement I make makes the end product that much better. That is what really kept me going, knowing that I am making a difference.

8. Conclusion

This has been quite the experience for all of us. Being that it was completely open ended, that we were left on our own to set our schedule and goals, it was a bit like being dropped into the deep end of the pool before really learning how to swim. It seems there is merit to this type of learning though, as we rapidly formed ourselves into a cohesive unit of engineers bent on realizing a common vision.

Technically, we picked up a far-reaching range of skills that we had not come across in our previous courses. Issues such as designing for reliability and cost, manufacturing for cost and environmental conscientiousness, parts sourcing, direct phone/email technical negotiation with suppliers, direct phone/email technical discussion with support engineers of manufacturers, to name a few.

Every person in our team served a major role in not just a technical way, but in a team dynamics regard. Sonca fulfilled a team leadership role and was able organize and reorganize efforts, to keep everyone together toward reaching designated milestones. Aaron was a motivator. Somehow when everything seemed to be falling apart, when nothing seemed to want to work, he could always convince us that the solution was just around the corner, and we were set for a major breakthrough. And somehow, this always managed to be a self-fulfilling prophecy. He was also a mediator and resolver of conflicts. Eddie was the trooper, who kept going and going and going no matter what was going on externally. He was like the clock in our system. And Michael fulfilled the role of being both devil's advocate and enabler, by questioning at first, then wholly supporting when convinced.