TRANSNET RFID SYSTEM

POST-MORTEM

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Introduction

The TransNet RFID System is intended for use by TransLink in detecting fare evaders and improving security aboard SkyTrains in a cost-effective way. It is also a system intended to make fare payments more convenient for passengers by eliminating the need for physical barriers (found in many fare-card systems). This system will count the number of paying and non-paying passengers boarding a public transit vehicle. TransLink can then use this information to find locations where fare evaders are present. By seeing how many people are boarding in certain locations and seeing how many resources, such as buses, are allocated to that location, TransLink can further utilize this data to send more buses as they are needed.

This system is divided into three subsystems. One system consists of integrating battery-assisted RFID tags into fare passes. An RFID reader onboard the vehicle will read these tag's unique codes and securely transmit them to a main server with a database at TransLink's headquarters. The second system will use video cameras and computer vision techniques to count the total number of people boarding each vehicle. The third system is the database server where each passenger's account associated with his/her RFID tag will be stored.

This post-mortem will reflect on the overall experiences of the TransNet engineering team, including comparisons between plans which were set initially in the proposal (i.e. timelines and budgets) and what actually ended up happening, a description of how the team was organized and the project was completed, lessons learned and what would be done differently, individually written sections by each team member of their personal contributions and experiences with the project, and finally some concluding statements regarding future plans for our RFID system.

System Overview

The TransNet RFID System can be modeled at a high-level as shown in Figure 1.

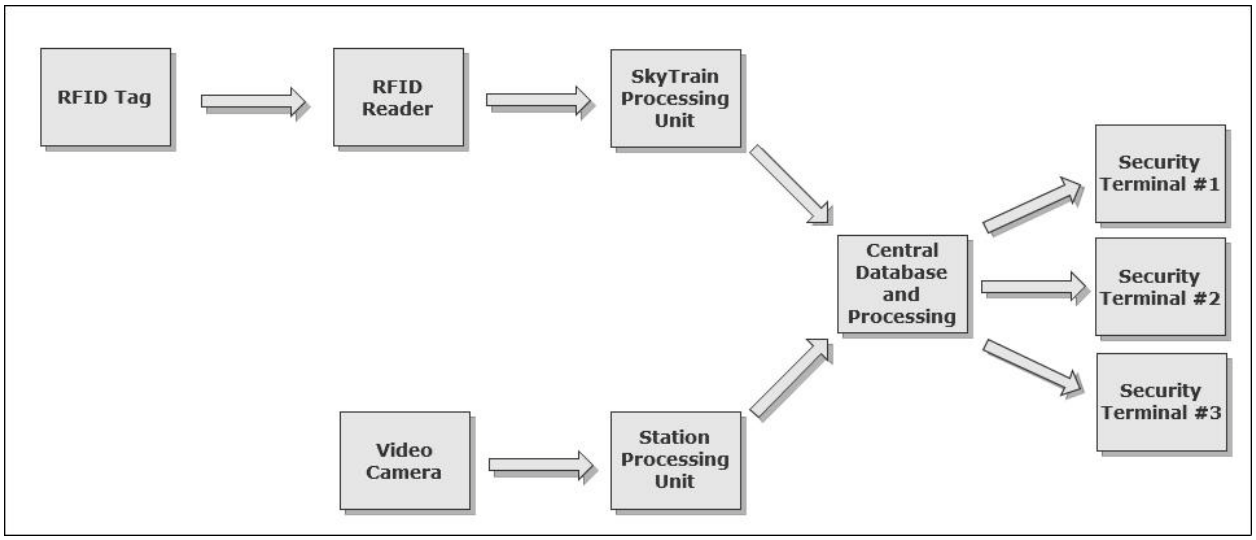

Figure 1: High-level block diagram of TransNet RFID system

All riders will have their own personal transit card with an embedded BAP RFID tag. The unique ID of each rider's RFID tag is directly associated with that rider's transit account, which keeps track of what transit services the rider has been billed for. Billing is retroactively optimized such that the rider is billed the least amount possible. For example, a rider could attain over $200 in SkyTrain fares but should not be penalized for their lack of foresight and would only be billed the cost of a monthly pass.

The embedded RFID tags are scanned by an RFID reader with one to four antennas located in the SkyTrain. The exact number of antennas required to fully cover an entire SkyTrain is not known at this time, but will be tested on an individual basis for any mass transit systems wishing to purchase and implement the TransNet RFID System. Due to budget constraints, only one antenna will be used for the prototype system currently under development. RFID scanning will occur once the SkyTrain has left the station. This is done to ensure that no tags of riders standing on the station platform are inadvertently scanned.

Video cameras are mounted above each SkyTrain door; these cameras point towards the floor and observe all riders entering and exiting the SkyTrain at each station. No rider identification is performed by these cameras to address any privacy concerns. People tracking will be implemented using computer vision and image processing techniques to compute the net number of people entering or leaving a SkyTrain at a given station. This processing is done by computers located at the station platform.

All of the scanned RFID data and the physical count of people in the SkyTrain are then sent through a wireless 3G connection to a central database. The central database serves two important functions. Firstly, it allows any transit system personnel at an authorized terminal to monitor the live transit data in real time. Secondly, it routinely stores (configurable by the transit company) a snapshot of the current transit data and stores it to disk. This allows the transit company to collect, analyze, and manipulate their full transit data history for any desired research purpose, such as determining low or peak usage times and adjusting the number of trains in service accordingly.

There were a few main problems with actually implementing this system. First, we were unable to obtain battery assisted passive tags. Instead, we had to use regular passive tags. This meant that if the tag was too close to the body, or a body was between the tag and the reader, the tag may not be read due to attenuation of the radio frequency signal by the water content of the human body. This resulted in some inaccurate reads during our demo.

Secondly, the image processing part of the project proved to be much more difficult than anticipated. We were able to get some reasonably good accuracy in well lit, uniform areas when we had lots of time to fine tune and customize the processing algorithm for a particular location. However, we were unable to use our standard testing location in the demo, and did not have sufficient time to recalibrate the processing for our demo location. This resulted in many counting errors which was the main problem during our demo.

Budgets and Timelines

Table 1 below compares our original estimated cost and our actual cost.

Equipment List	Estimated Cost	Actual Cost
RFID Reader	$725	$1185
RFID Tags	$100	$50
Camera	$130	Borrowed
Micro-controller	$35	Not used
Contingency	$100	N/A
Taxes/Shipping	N/A	$190
Total	$1090	$1425

Table 1: Comparison of estimated and actual costs for TransNet RFID system

The two main reasons for going over budget was we initially thought we could get away with a cheaper RFID reader, but after more research found we needed to buy a more sensitive (more expensive) RFID reader to take maximum advantage of BAP tags. Secondly, we underestimated the cost of shipping and taxes for all of our components.

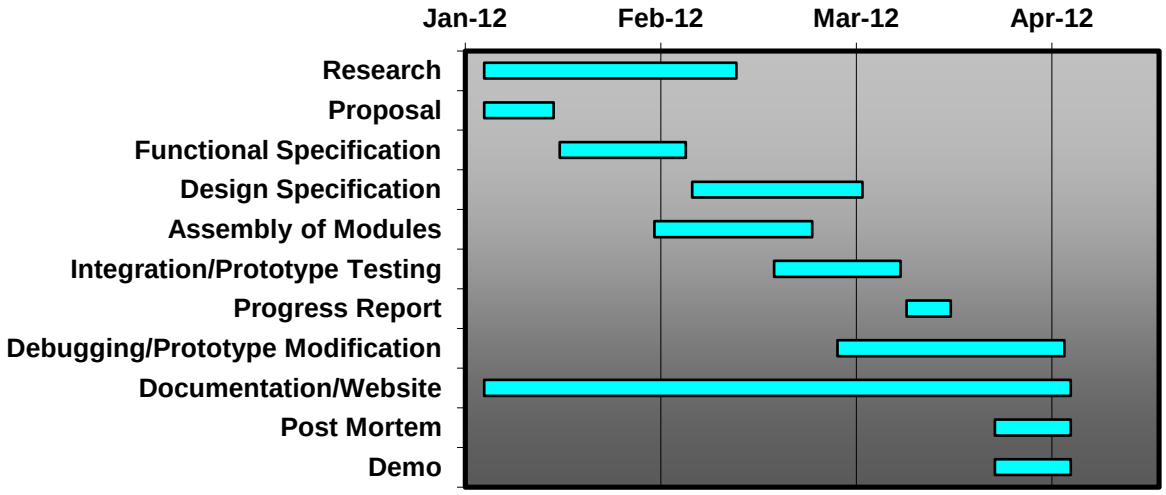

Figure 2: Original Gantt chart found in project proposal

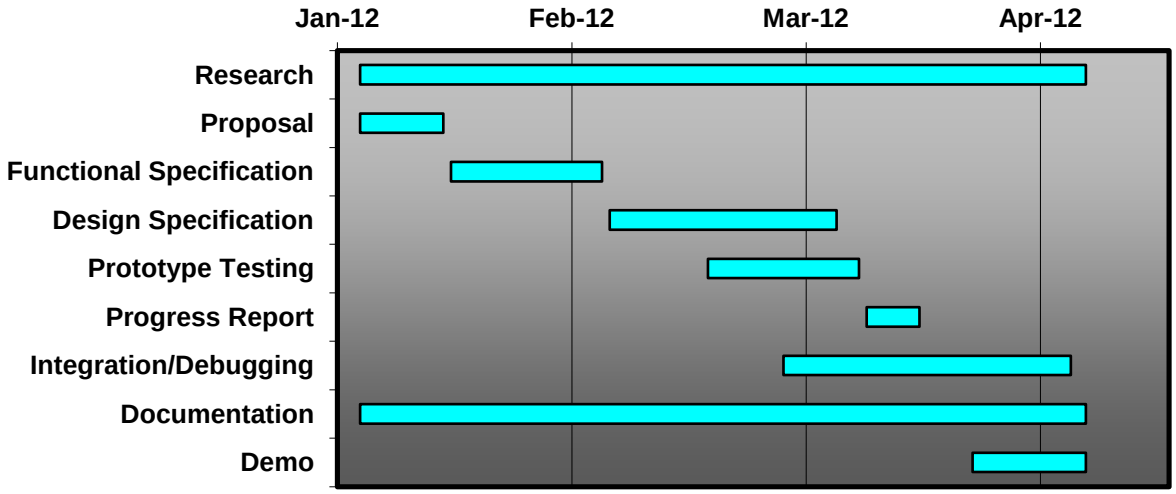

Figure 3: Gantt chart showing actual timeline for our project

It can be seen in figures 2 and 3 that the planned timeline and the actual timeline are quite similar. The main difference is the ongoing research which happened due to our first purchase of

BAP tags falling through and constantly trying to find a new supplier, which we were unable to. Some of the rows disappeared because they merged in with other categories (Assembly of Modules got lumped together with Prototype Testing and Post-Mortem with Documentation).

Team Organization

Since our project had two main components, the RFID/database component and the image processing component, we split up and specialized in one of these two areas. Mohammad and Daniel focused on the image processing, whereas Bilal, Maxim, and Alex dealt with the RFID reader and the associated database storing all of the RFID tag information.

There was still many times where we intermingled and provided suggestions or help solve some problems that the other team was having. Overall this was a good setup because both aspects of the project were quite challenging so being able to focus on just one thing really helped.

Things for Next Time

One thing that really tripped us up was purchasing the RFID tags. Buying non-consumer level products like this can be very time consuming because you often need to get in direct contact with the selling company before you can even find out what the price is. As was the case with these BAP tags, there is also a minimum buy limit in order to be able to make a purchase, so some of the tags we were interested in could not be purchased because you needed to buy 20 or more of them and this would cost us too much money. Next time we need to acquire any kind of components like this, we will definitely be sure to get it done as soon as possible to account for things like parts being out of stock (which happened to us with our first BAP tag purchase).

Another thing was our preparation for the demo. Unfortunately for us, we had to demo in a room which is locked the majority of the time and we did not have access to it. Due to the nature of our image processing part of the project with the camera, changing the position/setting of the camera without being able to adjust for these changes makes the count very inaccurate. If we had some more foresight, we could maybe have tried to start fine tuning our demo as soon as we found out which room our demo was booked in, or have found a separate location that we always have access to that also would have been suitable for the demo. Even if we did a new project that wasn't room/environment dependant, we still see the importance of many, many trial runs of your demo to ensure things run smoothly on presentation day.

Individual Reflections

Alex Moore – Chief Executive Officer

The area of this project which I spent the vast majority of my time was programming the algorithms for database querying, further processing of the RFID tag and physical people count information, and displaying these results such that they could be viewed by security personal. All of this was done in PHP, and completely from scratch. I also programmed the RFID reader in C# to scan the tags, write the data to a text file, then make a connection to an FTP server and upload the text file there. Some sample code was provided by the RFID reader company for programming the reader, but making the connections to the FTP server was researched on my own.

I had never programmed in PHP or C#, or dealt with mySQL for database querying before. This project single handedly strengthened my programming background more than any other course I have taken in engineering.

Aside from software, there were many other things I learned as well. This has been the most serious project I have ever undertaken, counting both individual and group projects. I cannot stress enough how important being able to get along and work together with other group members is. We were always open to each other's ideas/suggestions, and help one another out whenever possible. We had many debates about certain issues throughout the project, for example, how we should handle privacy concerns with regard to our RFID system. Even though opinions varied, the discussion remained civil and no one was stubborn enough to prevent a consensus from being reached. Everyone wanted to see the project succeed, and that is why it did succeed.

Another important detail I learned from this project is the importance of research. Everyone was heavily involved with research early on, and I was surprised to see research was always relevant right up to the final presentation and demo. Taking the time to do solid research, particularly during project idea selection, is basically like front loading the risk on your endeavor so you are protected 2-3 months into the project and don't realize what you have chosen to do is not going to be realizable by the end of the semester.

Daniel Frigo – Chief Operations Officer

Throughout this project I was mainly involved in implementing the people tracking image processing algorithms in MATLAB. I had previously completed a research co-op which involved a heavy amount of programming in MATLAB. For this reason I had very good MATLAB experience prior to starting this project which came immensely helpful in the end.

I quickly found out early on in the project that the image processing part of the project was going to be extremely difficult. Early on, before beginning to write code for the image processing, I did as much research as I could on the topic of using cameras to track people. I came across some very scary complicated advanced research that has been done on this subject, far beyond my expertise. During this early phase I had many doubts about whether we could actually get this part of the project working at all and was constantly considering other easier alternatives to achieve the same purpose. I gave some deep thought and did a lot of research on these alternatives, as well as discussed them with the group, but always came back to the same conclusions. Either these alternatives simply won't work, or they are too expensive to implement. As such, using cameras and image processing was the way to go.

After about a month of intensive research I considered a relatively simple image processing approach to the people tracking problem that seemed feasible to implement in the remaining time that we had to complete the project. After this, me and Mohammad started implementing this approach in MATLAB, while occasionally continuing to do research.

While working on this implementation I learned a lot about image processing that I had no prior knowledge of. I have also discovered a high interest in this subject and hope to do more work related to image processing. In particular I have gained a high interest in the project itself. It has motivated me to continue to research more advanced algorithms regarding the people tracking problem and to implement these algorithms in the code to improve the accuracy of the system. It's a possibility that more work will be done to improve this people tracking system in the future.

In addition, this is one of the most time constrained and pressured projects I had. Working under these conditions has taught me to be organized, to manage time wisely and to be patient with other group members. In addition I have learned a great deal with regards to working in a team environment and co-operating with other team members.

Overall, though incredibly frustrating, I feel this project has been a great learning experience. I feel it has given me an idea of what it's like to be working on a project in a professional work setting.

Bilal Nurhusien – Vice President of Operations

ENSC 440 has been one of the most challenging courses I've taken at SFU. I've learned a great deal about RFID technology, basic database architecture, and team dynamics. We had a difficult time choosing a project idea. As soon as we decided to choose the Smart Translink System for our project, we needed to do a great deal of research in order to learn how we would build such a system.

Purchasing the RFID BAP tags was very difficult since most of the companies we spoke to deal with large purchase orders. Moreover, we couldn't afford the desired RFID reader from Intelleflex because it was outside of our price range. We settled for the UHF reader from Impinj and bought high quality passive tags from Omni-ID as well.

I contributed to the project by helping to program the RFID reader, build the database, and integrate the different modules of the project together. I also contributed to the Proposal, Functional Specification, Design Specification, and Progress Report.

By far the most difficult aspect of this project was the image processing. Two members of our team were assigned to this task and the rest of us were in charge of creating the database and programming the RFID reader. The division of labour in our team was key to successfully finishing the project. Although we had difficulty meeting with all five members of the group at the same time, we kept in regular contact with each other through email.

Team dynamics are important in every project. Our group had its rough patches throughout this term, but I believe we came together at the end to deliver a good quality product. I'm very proud of my group mates and myself for working so hard these past 4 months on such an ambitious project, especially with the limited time we had to finish it.

Maxim Soleimani-Nouri – Chief Marketing Officer

I would consider ENSC 305/440 capstone project course to be one of the most challenging projects through my undergraduate studies. We had a rough beginning as most of the ideas represented were rejected due to various reasons such as lack of expertise and experience in different branches of engineering. Once our Translink RFID system got approved by the instructors, we immediately began the research process. I would have to admit, I learned a lot about brainstorming and research through this course which constructs one of the major parts of any projects life cycle. Almost everything we implemented in this project were new to all of our group members but we all managed to gain a good understand and grasp of the concepts by doing sufficient amount of research.

From the technical point of view, I began by researching proximity sensors as a way of keeping track of the number of people entering and exiting the skytrains. I also, researched different methods of payment and came up with two solutions: Near Field Communication (NFC), and Bluetooth-enabled cell phone along with corresponding application. In addition, I enjoyed assembling the RFID components and conduct tests with RFID tags. Furthermore, I helped with the overall integration and assembly of the TransNet's RFID system. Technical documentation such as functional/design specifications were delivered.

Overall, I was satisfied with most group members' performance and dedication on this project. However, I do think there was a major lack of communication throughout the semester. I do think we could have better communication in terms of meeting dates and times. I strongly believe that all meeting must be set ahead of time and all group members must be notified one or two days prior to the meeting date. Nevertheless, it is very hard to have meeting between 5 engineering students with different schedules and course loads. Moreover, leadership is an essential part of each group and results may not be obtained when there is no clear assignment of tasks between group members and this was very vague in our group dynamics.

In the end, I am very proud that we were able to demonstrate a working prototype of our project. I would like to thank all of my group members along with my instructors and the TA's who have supported us and have provided guidance and feedback on our documentation and people who help fund this project and make it possible to implement.

Mohammad Osama – Head of Development and Design

Through the course of this project, I acquired a large set of skills from both a technical and personal development aspect. In particular, as the team was subdivided to work on particular tasks – I and another team member (Daniel Frigo) were assigned toward developing the image processing system. Interestingly, much of our initial work required extensive research (unlike most other Engineering courses) were solution are not readily available. This particular aspect was strikingly unique as I essentially learnt that the only guide is your own intuitions for what might be the best approach in solving problems where heavy research is required. The abstract and creative thought process for developing techniques (i.e. image processing) were particularly challenging but generated the highest level of interest. Development platform for image processing software was performed using Matlab for ease of implementation and debugging purposes. My personal expertise using Matlab was certainly not the best hence I found it be a gradual climbing curve when implementing different algorithm.

For most of the project, myself and Daniel worked as duo pairs in developing algorithm as well its implementation. Surprisingly, receiving feedback from your partner on your ideas sometimes breaks down complicated problem into simpler solution and served as a motivating factor for me. In addition to coding and developing algorithm for image processing, I was involved in integration of this component to the larger project. To be honest, I naïvely viewed this to be a simple and straightforward task. However, multiple issues arose that were completely unforeseen ranging from simple networking problems to undiscovered bugs in the code that would crash the program at certain instances. This proved to be painstakingly difficult to resolve and required multiple testing phases to ensure stability in the system. Additionally, an important virtue learnt from this project was patience – which I experienced first-hand when I sought to buy appropriate tags for our RFID system; contacting multiple manufacturers and there respective sales departments which sometimes provided contradictory statements turned out to be an interesting exercise.

Lastly, working under the ever omnificent presence of timelines and due dates creates unprecedented amount of stress. It was certainly experienced near the completion of the project, however, as individuals and on the whole as a group we learnt from our experiences and built both the confidence and determination to move forward. I feel very fortunate to work with people who I have…I felt we transcended from being team member to becoming long-term partners and close friends.

Future Plans

If we had more time the first thing we would have liked to do was obtain some high quality BAP tags so we can really see what our system is capable of. Sadly we were quite unlucky and there was not much we could do, we were told more tags would be coming in stock around June, so if we were still working on the project then, we would definitely be able to get them.

With regards to the image processing, there are a few things that we would like to be able to do. Firstly, we could implement real-time processing as opposed to recording the video in its entirety, then processing this video. This is certainly feasible, as our processing time is already faster than the length of the recorded video. We experimented with this a little bit, but simply did not have time to work out all the bugs in time for the presentation.

We also would have liked to improve the accuracy of our image processing algorithm in a couple of ways. First, we could use color image processing as opposed to converting everything to grayscale to make calculations easier. But going even further, there were many more advanced algorithms which were researched which could lead to far better counting accuracy, but again, four months was not enough time to implement these.