Report on Follow-up Work on Wi-Fi RFID Tags in Citywide Wireless Networks

Lars Kulseng, Trondheim, August 2007

Introduction

In the spring of 2007, Henrik Moen completed his thesis work on Wi-Fi enabled RFID tags in a municipal setting [1]. The thesis sought to find out if Wi-Fi enabled RFID tags can be utilized in services provided by citywide wireless networks such as Wireless Trondheim. This document outlines the follow-up work conducted by Lars Kulseng during the summer of 2007.

Background

This section will explain some of the relevant technologies that apply to this project.

Back-end system

Wireless Trondheim is a company that seeks to provide citywide Wi-Fi services in Trondheim, Norway. The back-end infrastructure follows the Cisco Unified Wireless Network (CUWN) architecture. The topology of the network is illustrated in Figure 1.

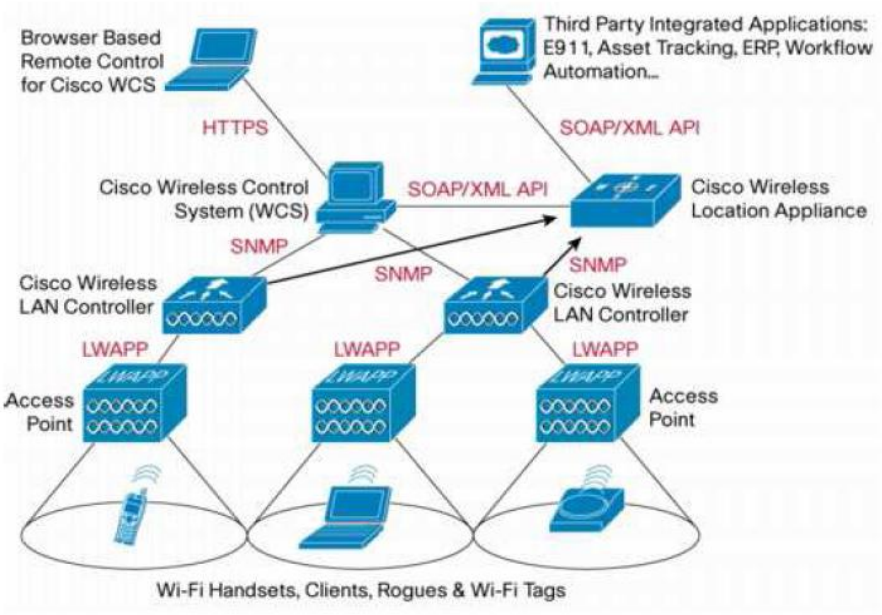

Figure 1. Wireless Trondheim's wireless network is based on the CUWN.

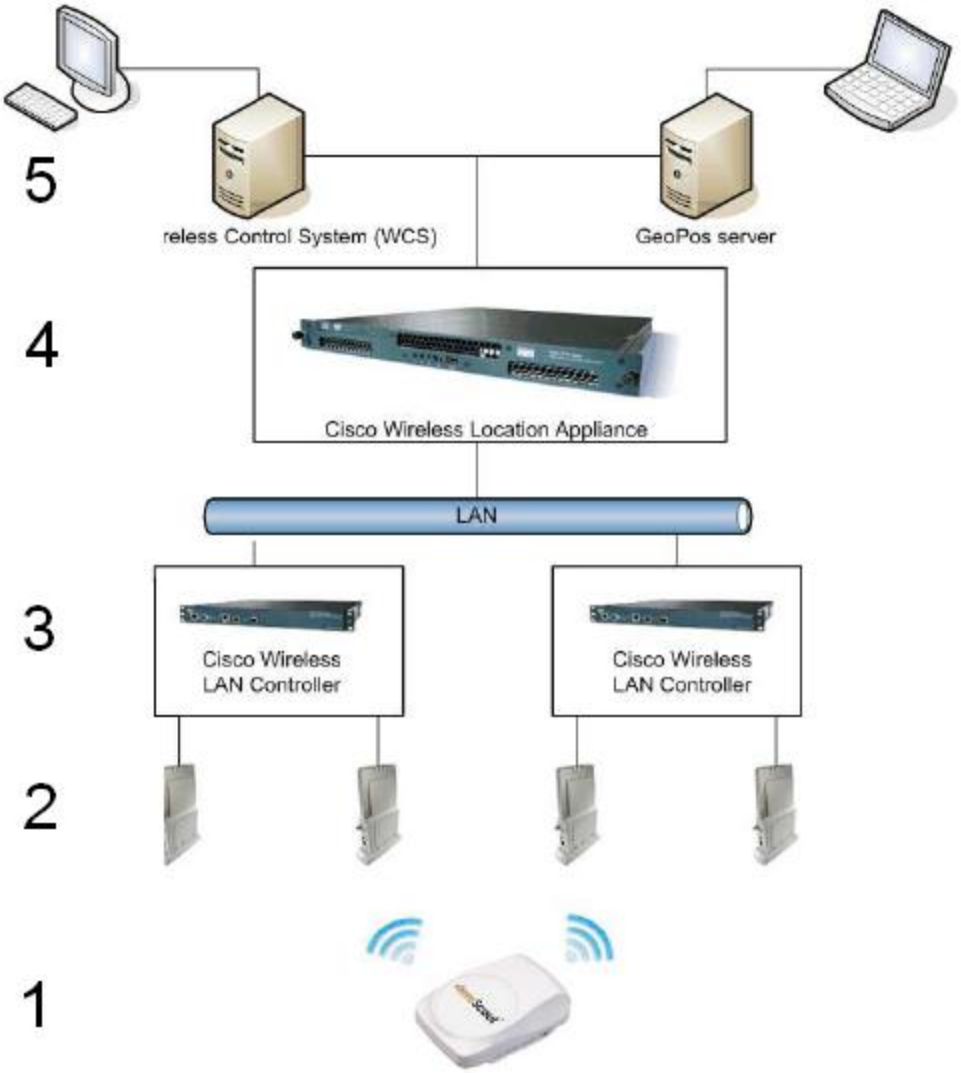

Figure 2. Wireless Trondheim's implementation of the CUWN

As can be seen in Figure 2, wireless devices (1) communicate with access points (2) that are scattered throughout the downtown area. The access points are connected to wireless controllers (3), who feed information to the Cisco Wireless Location Appliance (4). Here, localization data is computed and stored. The localization data from (4) can be extracted using Simple Object Access Protocol (SOAP) and Extended Markup Language (XML).

At Wireless Trondheim, two components use the Cisco Wireless Location Appliance, the Wireless Control System (WCS) and GeoPos (5). The WCS is used to monitor several aspects of the wireless network, including status of access points, and location of devices. GeoPos is a service that utilizes the SOAP/XML interface of the Cisco Wireless Location Appliance to provide position data in a more dynamic way than can be attained through the WCS.

RFID

In Figure 2 above, the device at level 1 of the network model is a Radio Frequency Identification (RFID) device. These devices come in several flavors, as outlined in section 2.3 of Henrik Moen's thesis paper. The RFID devices (or RFID tags) used in Moen's experiments, are called Wi-Fi tags, since they are able to communicate with a Wi-Fi network using the IEEE 802.11 standards and protocols. The Wi-Fi RFID tags send their information to the Cisco Discovery Platform (CDP) multicast address, 01:0c:cc:00:00:00, so all Cisco access points that are listening on channels 1, 6, or 11 can pick up the data. The brand of RFID tags that were tested by Moen is Aeroscout, and Radionor's tags were included in the follow-up work.

Approach

In his thesis paper, Henrik Moen conducted a series of experiments to establish whether certain services were feasible goals for Wireless Trondheim. Many of the services that can be provided though cheap and simple Wi-Fi enabled RFID tags are location based services (LBS). Among these was a real-time localization service where tags could be placed on items to help locate them within the city.

Pertinent to Trondheim is the localization of city bicycles, since Trondheim offers self serviced bicycle rentals in the downtown area. To determine the accuracy of the localization system for bicycles, Moen carried out tests where a specific route was traveled by bicycle. Stops would be made along the path to provide a time reference for later analysis.

Figure 3. Route of the bicycle test, as well as 1 minute stop points.

In the follow-up work, these tests were repeated under modified conditions. The back-end Cisco system was upgraded since Moen authored his thesis. The controllers were actually downgraded from a customized version 4.0.225.5, to a general release 4.0.217.0. One of the variables for positioning of RFID tags ("RFID data timeout") was also altered in the controller. The RFID Data Timeout parameter sets the amount of time that must pass without detection of a tag before that tag is removed from the internal tables of the controller. Since Cisco recommends that this parameter should be set to between 8 and 10 times the value of the beaconing rate [2], which is here 10 seconds, RFID Data Timeout is set from 1200 to 100.

Since part of the purpose of the follow-up was to compare two RFID tag vendors (Aeroscout and Radionor), the power level of the Aeroscout tags was lowered to 13 dBm. This is still not a perfect match, given that the Radionor tags are set at 10 dBm. However, as Moen concluded in his thesis paper, the power levels of the tags had little impact on the variation of his results.

Another attribute that was varied during testing was the repetition of frames coming from the tag. Moen's results bases itself on 1 repetition per data transmission. The hypothesis that results would improve if the amount of repetitions increased would be tested. The number of repetitions would be increased to 3 after performing a test with the original value of 1. For the 3 repetition test, the tags were set to repeat with 512 ms intervals.

A third element of the follow-up was to benchmark the Aeroscout tags against the Radionor tags in their static positioning accuracy. This was carried out by sampling the positioning output of the tags against GPS data for a given position. All the data was then transferred into a highly detailed map of Trondheim, using a program called ArcGIS/ArcMap. Here, the error distance was measured, and recorded.

Results

This section includes results from the follow-up work.

Bicycle Tracking

The outcome of the bicycle tracking experiments was perhaps the most dramatic of the results. The figures below show that a significant improvement was obtained by altering the software of the controller. Figures 4 and 5 show the original traces with and without location smoothing enabled. For the follow-up tests, location smoothing was turned off. Figure 6 shows new results with 1 frame repetition, and Figure 7 shows the new results with 3 frame repetitions.

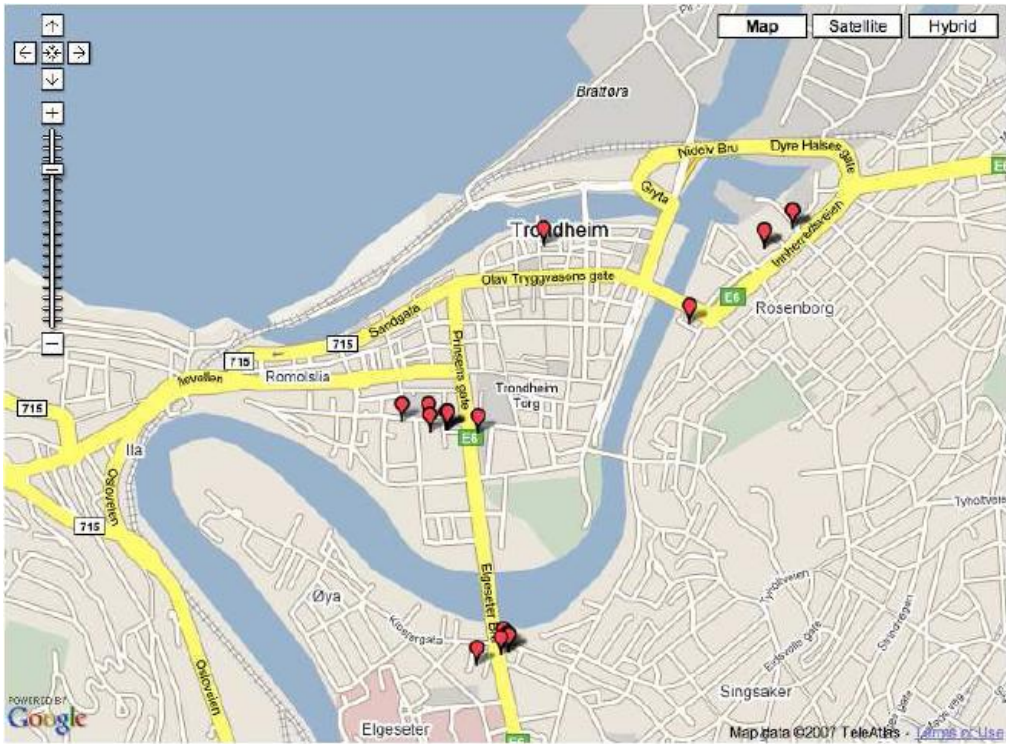

Figure 4. Original result using location smoothing

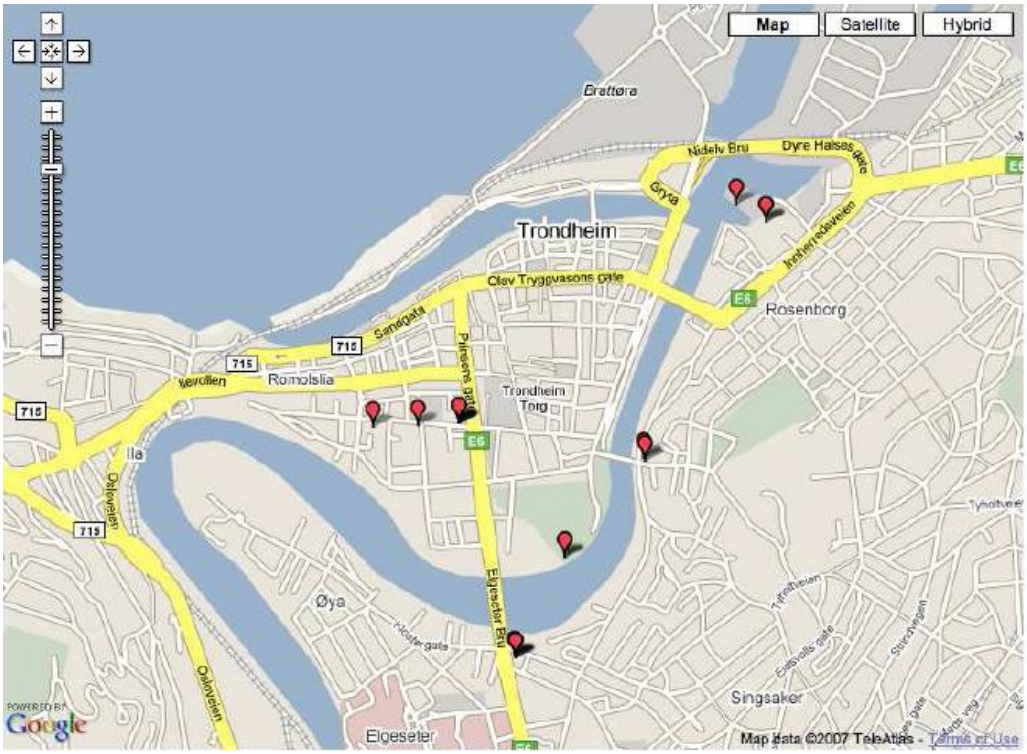

Figure 5. Original results with location smoothing turned off.

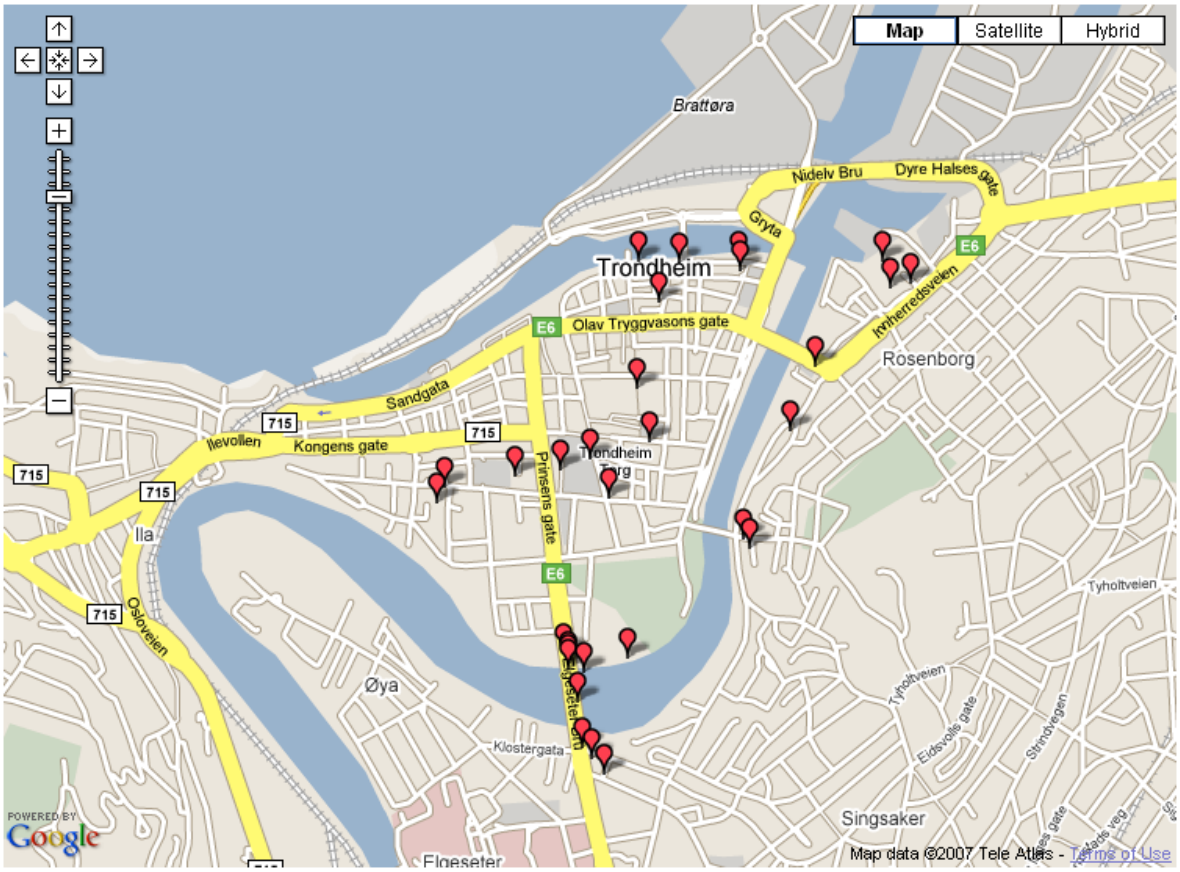

Figure 6. New results with 1 frame repetition.

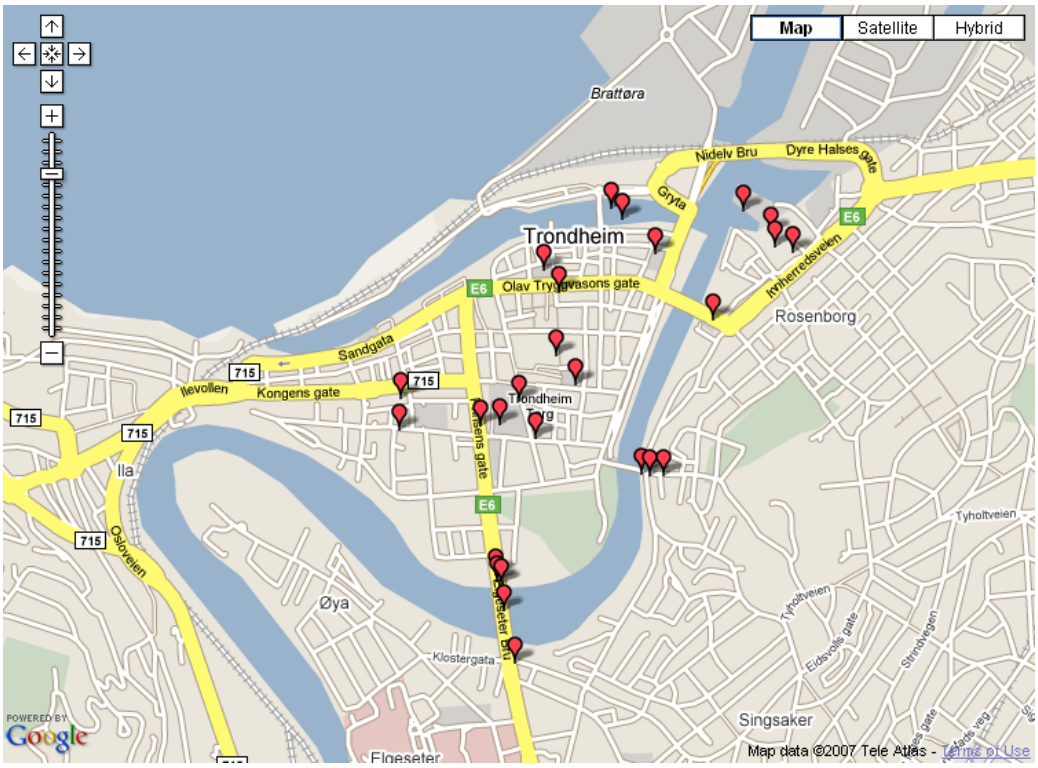

Figure 7. New results with 3 frame repetitions.

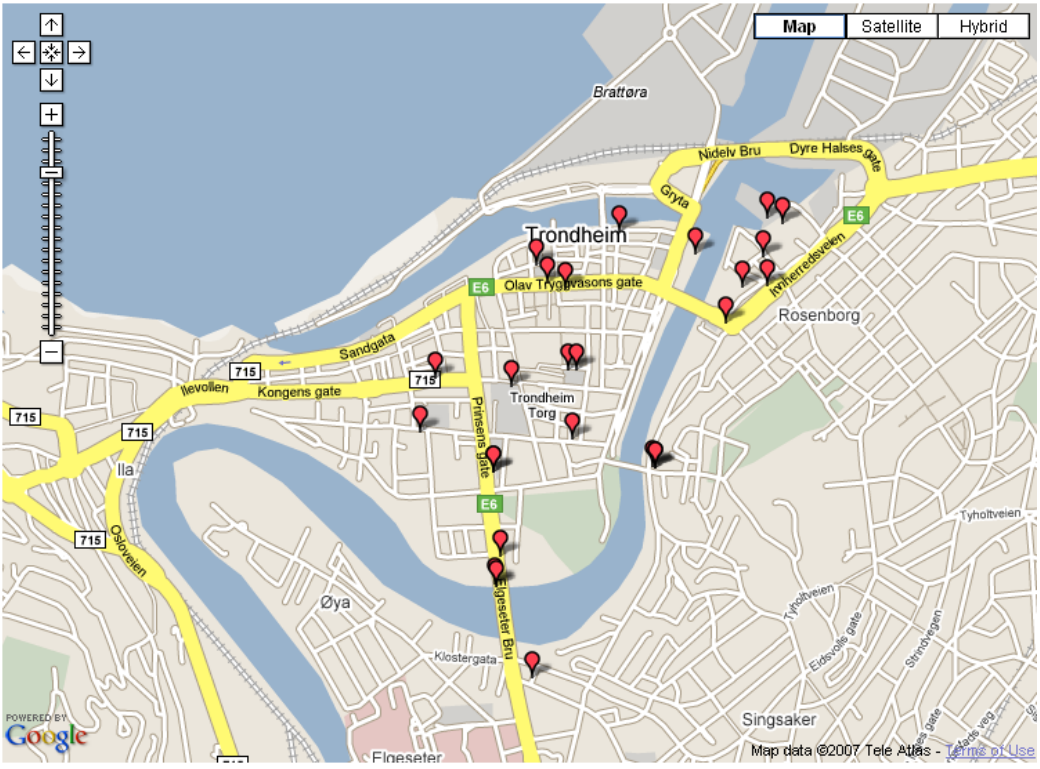

Figure 8. Results from Radionor tag.

As these figures reflect, the altered configuration of the system has significantly improved the traceability of the path. The points are more spread out than in the original experiments, and now cover more of the route than before. For the new results however, it is interesting to note that adjusting the repetition rate to 3 frames per location did not affect the results to a considerable degree. When we add the Radionor RFID tags to the equation we see that these tags show the same marked improvement as the Aeroscout tags.

Aeroscout vs. Radionor in static positioning

The static positioning tests were conducted in two subparts, in a similar fashion as the original thesis paper by Henrik Moen. One test was done at Marinen, where there is only one access point. The second sub part of the test was conducted at Torget witch is covered by several access points. The results of the tests are shown in the figures below. Throughout these figures, the green dot indicates the actual position of the tags; the red dots indicate the GeoPos result for Radionor tag (bright red) and the Aeroscout tag (dark red). The black dot is the position of the nearest access point to the actual position. Many of the dots will not be visible because some of the readings were identical, and hence will be on top of each other.

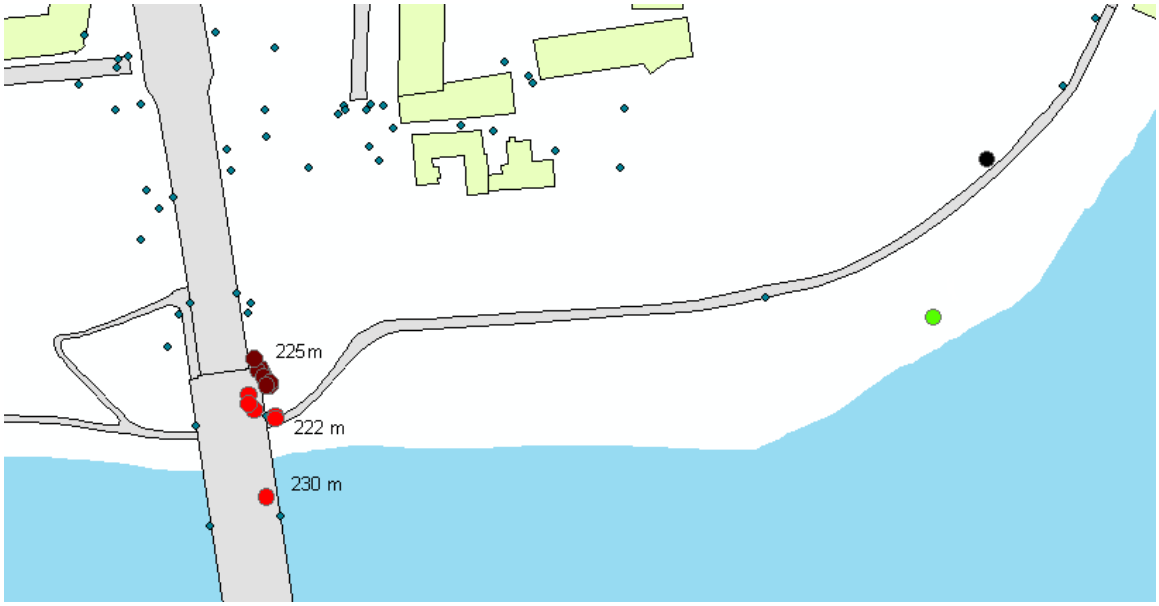

Figure 9. Marinen position 1

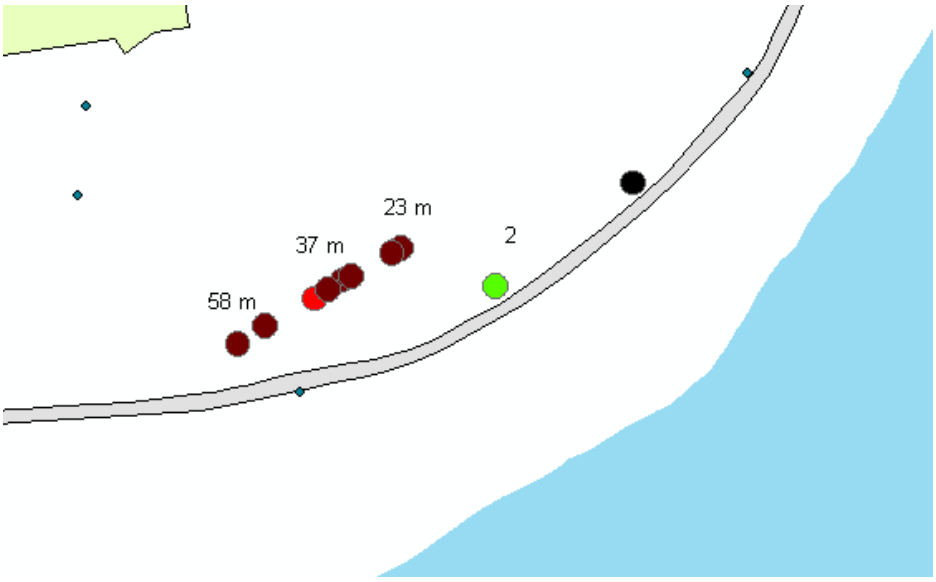

Figure 10. Marinen position 2

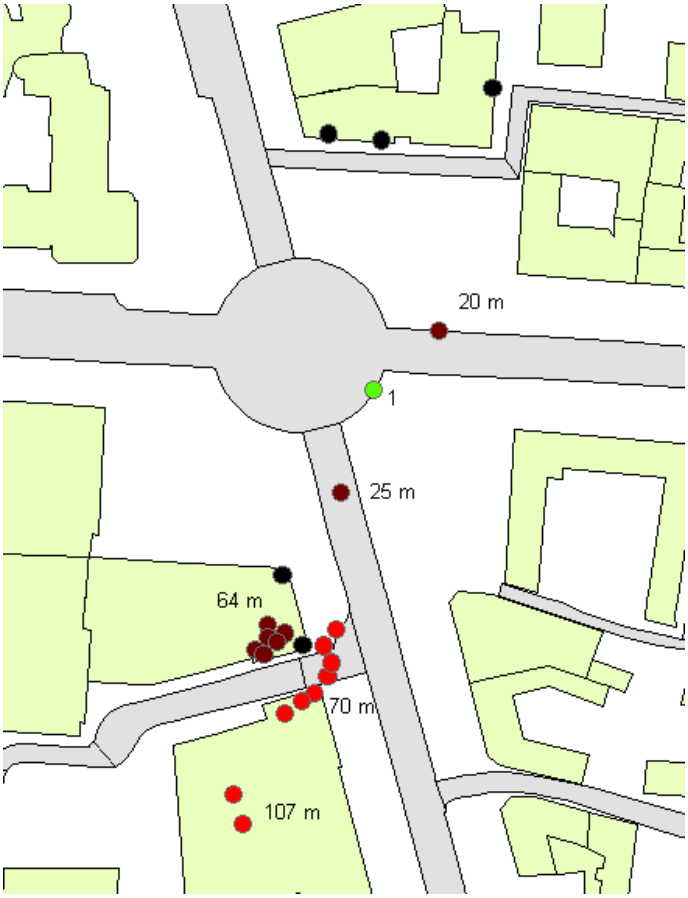

Figure 11. Torget position 1

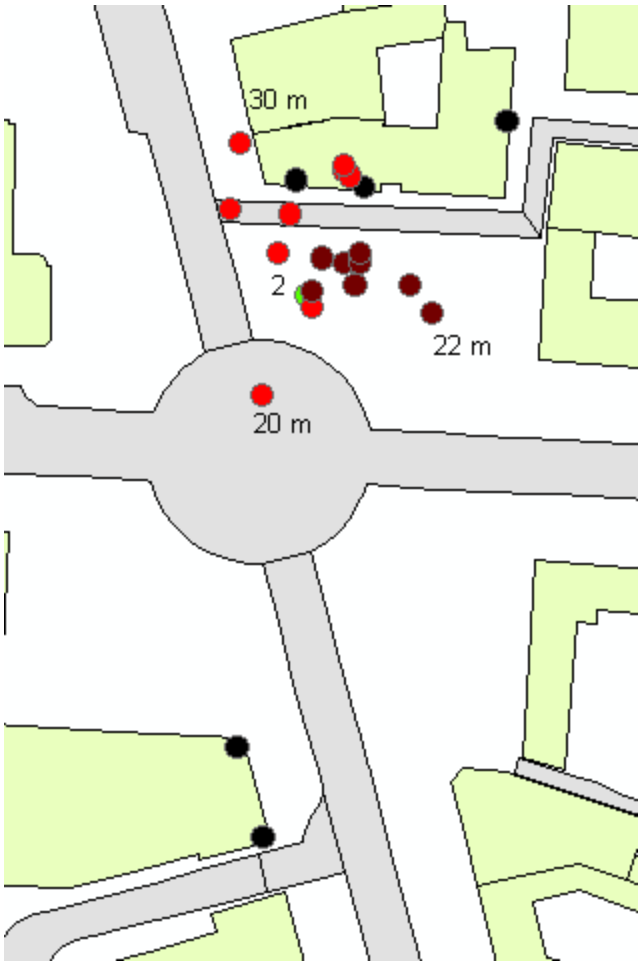

Figure 12. Torget position 2.

We can see from the figures above that the system finds it harder to place the first position than the second position. At Marinen the first position yields an average error of just over 220 meters for both brands of tag. At Torget the first position has an error of as much as 107 meters for the Radionor tag with the average (without outliers) being about 80 meters. The Aeroscout tag gives more sporadic results here, but most of the results are about 64 meters away from the actual position.

For the second position in both tests, the results show a major improvement to the first position. For Marinen, the average error is about 35 meters, with the Radionor tags exerting a tighter span of positions than the Aeroscout tag. At Torget we see the same kind of improvement, with the largest error being 30 meters. Both brands of tag performed equally in this position, with the Aeroscout tag giving slightly tighter results than the Radionor tag.

Conclusion and future work

After altering the back-end system and comparing two vendors of RFID tags, the results can be described as encouraging. New data gathered from experiments show that performance has generally increased without additional cost to the project. Which of the two brands of tags are the most suitable for this service is unclear, as the results are relatively similar.

In the static positioning experiments, the results of the first position for both subtests are likely due to the fact that the tag is sitting closer to the perimeter of the coverage area of the access points. This seems to confuse the system, thus helping it make mistakes. Just as in Henrik Moen's work, the tags close to the access point at Marinen have the unfortunate tendency to compute the location very far away from the actual position. The same conclusion can be made here as Moen made with his experiments, namely that calculation of position is more accurate with more access points.

For further study, the settings can be altered to perform more aggressively to attempt an even more accurate data set. The focus of any changes should mainly be on the back-end system, since pushing the RFID tags to their limits is likely to lower battery life with limited impact on performance. It also seems likely that adding more access points to the network will improve the performance of these services in the future. The Cisco location system in use at Wireless Trondheim does not support external antennas, which are in use in this network. Support for external antennas is expected to arrive Q4 2007 [3].

References

[1] - A Study of Wi-Fi RFID Tags in Citywide Wireless Networks – Henrik Moen, 2007
[2] - Wi-Fi Location-Based Services—Design and Deployment Considerations, Cisco Systems, 2006
[3] – Personal conversation with Thomas Jelle (Managing Director, Wireless Trondheim)