A Feasibility Study into Tracking Wi-Fi Enabled Mobile Devices

M.Dagnall[1] and N.L.Clarke[1,2]

[1]Centre for Security, Communications and Network Research,
Plymouth University, Plymouth, UK
[2]School of Computer & Security Science, Edith Cowan University, Australia
e-mail: info@cscan.org

Abstract

Modern mobile and portable devices such as laptops and smart phones are expensive technologies that are often the target of theft. In the event that they are lost or stolen, it is desirable to recover them and their contents if possible. Whilst existing tracker technologies can often provide a rough geo-location, they lack in providing resolution in the last few hundred meters. This research focuses on the development of a mobile system for locating WiFi enabled portable devices via the WiFi signal emanating from them. A mobile localisation system utilising a combination of a directional Yagi antenna and the received signal strength was developed and shown to be effective at locating WiFi sources at ranges from 45m to 500m away depending on the environment.

Keywords

Mobile, WiFi, Tracking, Localisation, Yagi Antenna, 802.11g, Directional, WLAN

1. Introduction and Background

WiFi enabled portable devices such as smart phones and laptops are regularly targeted by thieves or misplaced by their users with 850,000 mobile phones stolen across the UK in 2007 (Flatley, et al, 2009). In the event of theft of loss, recovery is desirable either to recover the device or its contents. The physical value can be in the region of hundreds or thousands of pounds but its contents such as confidential, commercial or classified information in some cases could far exceed the physical value of the device. During a recent study of major European organisations, the financial loss resulting from a missing laptop averaged €35,000, with the total impact totalling €1.29 billion (Ponemon Institute, 2011). Due to the items portable nature, once it has been stolen in could conceivably be secreted in numerous environments. There is therefore a justifiable need to track and locate WiFi enabled portable devices in the event that they are stolen.

Current solutions employed in the tracking location of lost or stolen devices typically employ a combination of some of the following technologies:

- GSM – The mobile cell can be used to locate the portable device
- GPS – The GPS coordinates can be broadcast by a GSM module
- RF 173Mhz – Localisation via traditional wildlife tracking

GSM cell location cannot always be relied upon to provide sufficient resolution to recover the device on its own. Typically, GPS does not perform well inside buildings (Bakhru, 2005; Bajaj et al, 2002) and in the event that the GPS signal is lost an alternative method of locating the device is required. Even when these technologies do work, they frequently only provide an approximation of the location, rather than a specific location. Traditional RF tracking solutions (i.e. those used for tracking wildlife) can be employed, but this is with a cost penalty as this is additional functionality to be incorporated into the device. Therefore, alternative options need to be researched that are capable of providing a finer granularity of tracking capability for the last few hundred meters. Given the widespread adoption of 802.11 WiFi modules, this research seeks to establish whether this signal can be repurposed in order to locate the box instead of traditional RF methods.

There are existing applications of WiFi for localisation but these are principally focused on some form of triangulation which requires multiple receivers in order to do so. Generally the location of the receiver is known and so are the expected path losses. RADAR is an established tracking system based on RF for locating individuals or object in buildings. It relies on multiple access points with overlapping coverage in order to function. The combination of received signal strength measurement and signal propagation modelling facilitates location (Bahl & Padmanabhan, 2000). Due to the varied environments that mobile devices operate in signal propagation modelling is not viable. The tracking unit should be capable of being used for tracking in isolation so more established triangulation methods are not suitable.

In this paper, we focus on localising 802.11g signal sources using a directional antenna. Section 2 of this paper illustrates how the tracker was developed. The 3rd section summarises the results from a series of experiments with section 4 discussing the implications of the findings. The final section presents the conclusions.

2. Development of the WiFi Tracker

In order to facilitate tracking the WiFi signals back to their source the tracker required 3 basic components:

1. A directional antenna for obtaining a vector to the target
2. A method of obtaining WiFi signal metrics that are suitable for tracking
3. A method of displaying the metrics in a manner usable for tracking

These components were developed and employed as follows:

1. The Pheenet ANT-120YN 2.4 GHz Yagi antenna was used as Yagi antennas typically provide high gain with a narrow focus (Rosham & Leary, 2004). This narrow focus facilitated the directional nature of the antenna.
2. The RSSI (Received Signal Strength Indicator) and the MAC address can be obtained from a WiFi adapter connected to a directional antenna. This allows the strength of the received signal to be captured along with its identity. The output from the Linux command *iwlist scan* provides a list of WiFi sources and their RSSIs available to the WiFi adapter. This output was

programmatically captured and filtered in order to obtain the RSSI for a specified MAC address (i.e. the target's MAC address). The sample rate achieved was 0.3Hz, that is the RSSI and list of WiFi sources to be filtered was updated every 3 seconds. A GUI was developed in Java and a signal strength bar was used to display the signal strength associated with the target's MAC address. This provided a simple hot and cold measure of RSSI VS. Direction.

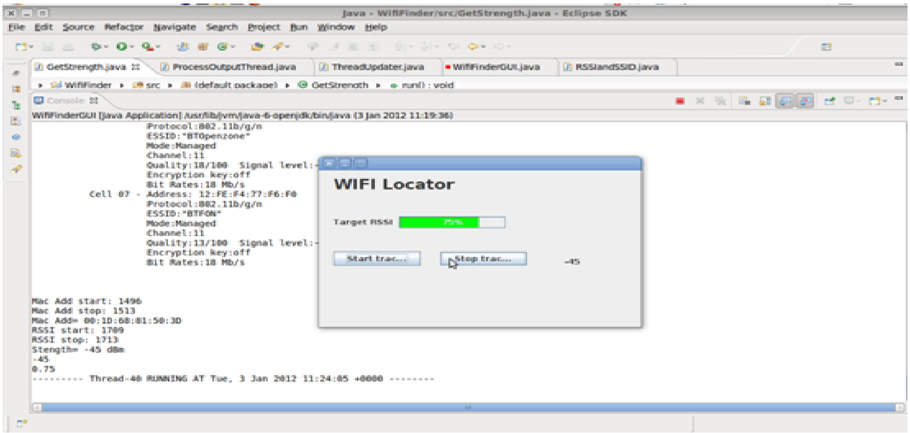

Figure 1: Screen shot of GUI displaying high RSSI

The antenna was connected to a USB WiFi adapter with an external antenna connected. This was connected to a Linux Ubuntu OS laptop which was used to host the RSSI capture and GUI functionality.

Figure 2: System architecture

3. WiFi Tracker Methodology & Results

A range of environments were chosen for experimentation and testing of the WiFi tracker, those discussed in this paper are:

1. Clear countryside
2. Urban terraced
3. Urban City Centre
4. Large building, analogous in layout to a shopping centre

In order to simulate a WiFi enabled target, a simple 802.11g domestic access point (AP) was used.

The RSSI was captured as a power and the units are measured in dBm accordingly. A note on the difference between 0 signal strength (no signal) and 0dBm (1mW power): Where a signal was lost in its entirety, that value has been changed from 0 to -100dBm (effectively no signal). This is because a strength of 0dBm (1mW) was not measured, being high signal strength/power and would have misrepresented the results.

1. Clear countryside

The AP was placed at the edge of an open space and the maximum distance at which the target's signal could be recorded with direct line of sight was 560m

2. Urban Terraced

For this experiment the AP was placed centrally on the ground floor of a double glazed, terraced property with the windows closed. Scanning was initiated and RSSI readings were taken at increasing distances after turning left out of the property until the signal was lost at 45M. Turning right out of the property resulted in a maximum distance of 112M being reached prior to the signal being lost. The experiment was repeated with the windows open but it had no significant impact on the range with identical distances being recorded at which the signal was lost.

3. Urban City Centre

The access point was placed on the 4th floor of an office block in a large city centre. The total area of the 4th floor was 1438 m^2. The maximum distance at which the target's signal could be recorded with direct line of sight was 200m away. The front of the building was surveyed by sweeping the antenna from side to side on each floor. The signal was significantly stronger on the right hand side of the 4th floor, which cut down the most likely search area to 448m^2. Upon entering the building, no further signals could be detected on the preceding floors until entering the 4th floor. Once it was confirmed that the 4th floor contained the target, it was located by sweeping the antenna and following the strongest signal within 3 minutes. In figure 3, the signal strength can be seen increasing as the tracker gets closer to the target.

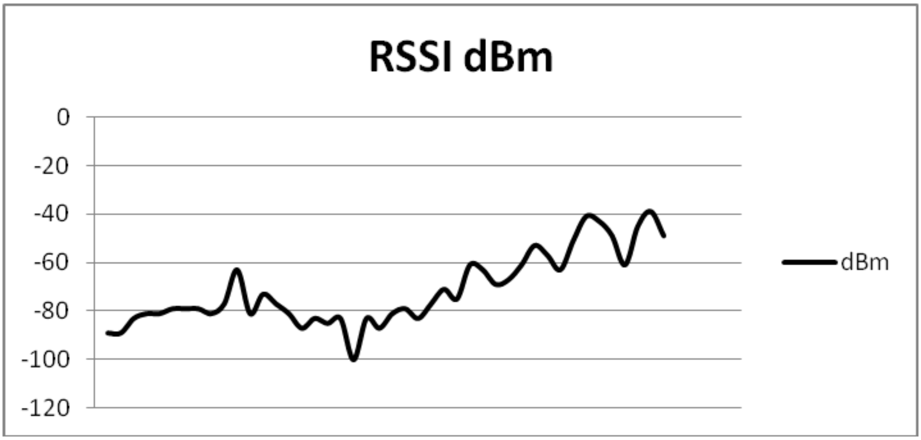

Figure 3: 4th floor RSSI over Time during search

There were 15 windows of the 4th floor and they were coated in a heat reflective film. Two of the windows were open, 20 signal strength readings were taken from the front of the building with the windows open and then closed in order to determine if the open windows were significant. The RSSIs measured are shown in Figure 4.

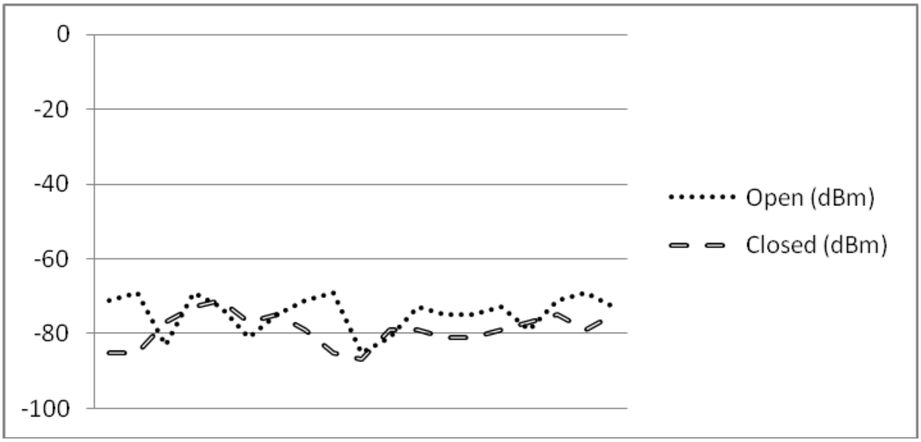

Figure 4: RSSI(dBm) Open heat reflective windows VS Closed

4. Large Building

This site is a large office building with accommodation for 2000 employees and a total floor space of 35,000m^2. It contains a large central atrium with stairs and lifts giving access to floor plates on each side of the atrium, a lay out common to many shopping centres. The AP was hidden by an assistant in an unknown location and locating the target was attempted from outside the building. It took 12 minutes to find the target. After surveying the exterior of the building, the location of the target was approximated to be on the second floor in the west quadrant of the building. Upon entering the building the signal was lost but following the building layout and ascending the stairs resulted in the signal being required and traced back to its source. The AP was found located in a room with an area of 990m^2. The signal was subject to reflections and in places ghosting was encountered. However, this was easily eliminated, by taking readings in other directions and following the strongest RSSI.

4. Experimental Discussion

The objectives of the experimentation were as follows:

1. How far away from a target can the tracking solution start reading the RSSI?
2. Is it possible to locate a target using the tracking solution?
3. Is it possible to locate a target using the tracking solution in a variety of environments?

The maximum range in clear line of sight possible with the equipment used for the research in the environments available was 0.5km. Clear line of sight may be useful in a situation where the target is not in an urban environment. The maximum effective distance achieved was 200m from an elevated position and from between 45m and 112m from at ground level. It is therefore possible to cover a larger area without obstructions to line of sight to the 802.11 scanner than in an urban environment where there are obstructions. However this does not necessarily lessen the effectiveness of the tracker. A range of a 100m or so within a built up area is acutally quite effective. Streets and building layouts can be used as visual guides for the tracker to follow in combination with the RSSI and vector prodivded by the directional antenna.

If the WiFi source is placed in an elevated position, then this range can be at least doubled. Ideally, an environment with a building surrounded by clear line of sight for up to a kilometer would be used for ascertaining the exact range but such a bulding was not available at the time of research. Also from an ideal perspective a range of building types would be used and a range of elevations but there has to come a point where the practical benefits would be outweighed by the logistics of this approach to the research.

During experiment 2, the maximum range was less than expected. The signal propagation was approximately 50% on the west side of the property than the east side. Although such a marked delta is initially surprising, further investigation of the construction of the building may explain the results. The walls on the north and west side of the property are unusual in being in excess of 450mm thick and solid. The wall on the east side is double skinned brick and significantly thinner.

According to (Ohrtman & Roeder, 2003) a window in a brick wall will reduce signal strength by 2dB and the brick wall by 3dB. However the attenuation caused by windows did not prove to be significant when testing the tracker in operation during experiments 2 and 3. The distances maximum tracker range was unaffected by opening of closing the properties windows and doors.

For line–of-sight (LOS) propagation the transmitting and receiving antennas must be in effective line of sight of one another. The qualifier *effective* is used as the atmosphere can refract signals and objects in the signals path may reflect, refract or scatter them (Stallings, 2005). Although reflections may result in false positive readings and could in theory make it very difficult to localise the target, testing has shown that reflection, refraction and scattering actually help the singal propogate. This means it is possible to follow the signal to its strongest source such as in a building where without this propogation, it may not have been picked up at all.

Being in a bulding, with lots of potential for ghosting, was not the issue it was orginally thought to be. This is because by applying a little common sense, the tracker can follow the building layout. By using the building corridors and doorways to guide the tracker, it is possible to locate targets even in larget buildings. This was demonstrated in experiments 3 and 4 when upon entering the building, it was sufficiently large that the signal found outside was lost. However because the signal was strongest when pointing up at a specific part of the bulding from the outside, the tracker can use the layout of the building to guide them to likely places to pick up the signal again.

The environment and its sensitivity/gain, affects the maximum range of the tracker. The environmental factors are not possible to control as the intended target when in use (a mobile device) is by design portable. In order to increase the effective range, the gain could be improved by using a more sensitive WiFi adapter or an antenna with higher gain. However this would need to be balanced against the impact of cost on the tracker and its portability.

5. Conclusions & Future Work

The WiFi tracker developed for this research can be used in order to locate a WiFi enabled targets such as a smart phone or laptop and provides a finer granularity of location tracking in the final few hundred meters.

The effective range of the tracker developed for this research is between 45m and 200m when the target is place in a building. The effective range is affected by environmental considerations such as the thickness of walls. Elevation has a significant impact on range, the range increases with elevation. With uninterrupted line of sight of the target, the range increases to approximately 500m.

Refraction and multipath interference was more of a help than a hindrance. The refraction of the signal around buildings allowed the signal to be followed back to the source by following the path of corridors and stairs.

Due to the limited range of the WiFi tracker, it is highly unlikely that it could be effectively deployed on its own in the field without the help of alternative tracking technologies such as GPS to guide operator to an effective start point.

Future work needs to focus upon the physical constructed for use commercially. It would ideally be as compact as possible. The tracker developed for this research required two hands to operate, which made opening doors and operating lift controls difficult. Weather proofing of the tracker would also be desirable as would some resistance to impact as it is likely that the tracker will be subject to both at some point during day-to-day use.

6. References

Bahl, P., & Padmanabhan, V. M. (2000). RADAR: an in-building RF-based user location and tracking system. *NFOCOM 2000. Nineteenth Annual Joint Conference of the IEEE Computer and Communications Societies. Proceedings. IEEE , 2* .

Bajaj, R., Ranaweera, S. L., & Agrawal, D. (2002). GPS: Location-Tracking Technology. *Computer , 4*, 92-94.

Bakhru, K. (2005). A Seamless Tracking Solution for Indoor and Outdoor Position Location. *International Symposium on Personal, Indoor and Mobile Radio Communications , 3*.

Britsh Retail Consortium. (2011). Cash and Valuables in Transit: Best Practise Guidlines for Retailers. 2, 14. British Retail Consortium.

Flatley, J., Moon, D., Roe, S., Hall, P., & Moley, S. (2009). *Home security, mobile phone theft and stolen goods: Supplementary volume 3 2007/08 - British Crime Survey*. Home Office.

Ohrtman, F., & Roeder, K. (2003). *Wi-Fi handbook: building 802.11b wireless networks*. NY, US.

Ponemon Institute. (2011). *The Billion Euro Lost Laptop Problem: Benchmark study of European organisations*. Ponemon Institute.

Rosham, P., & Leary, J. (2004). *802.11 Wireless LAN fundamentals*. Indianapolis, US: Cisco Press.

Stallings, W. (2005). *Wireless Communications and Networks* (2nd Edition ed.). Upper Saddle e River, NJ, USA: Pearson Education.