# Pinpointing a WiFi-enabled device in 3D using Multipoint Triangulation

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***Abstract*— WiFi has emerged as one of the essential technologies to provide location-based services indoors owing to the rapid proliferation of wireless access points in metropolitan areas and the rising use of smartphones. WiFi-based positioning appears to be a potential option because it does not need a complicated local infrastructure, in addition, user devices (such as mobile phones) can already analyse WiFi signals, and WiFi signals are widespread and powerful. This work proposes using triangulation of angle measurements from WiFi routers based on router access points. The proposed algorithm has little estimation noise and enables for the measurement of angle-of-arrival and angle-of-departure. Multipath propagation can be calculated using the MUSIC technique. The generalised algorithm is not too complicated. Simple triangulation algorithm output measures Time of Arrival (ToA) and Time of Flight (ToF), and considers the signal strength of all the access points hence increases the access points required. Hence, we use Multipath Triangulation to build the first decimeter-level WiFi localization system, which utilises a single access point and a single channel, and does not impose any overhead, data sharing, or complex coordination protocols. The results obtained indicate that Multipath Triangulation provides the capacity to improve localisation by using multipath reflections rather than discarding them. Furthermore, we use decimeter-level localization because it is possible to overcome the negative consequences of multipath interference.**

***Keywords*— Kidnapping, Location, Routers, Triangulation, WiFi**

## I. Introduction

Kidnapping has long been projected to cost the world hundreds of millions of pounds, and international firms are quite concerned about the crime. Around the world the number of kidnapping cases has been rising steadily in recent years, and there is, however, little assurance that trends in abduction in one city or nation can foretell trends in other places.

Frequently police lack the necessary technology to locate the victim of an abduction, especially if that technology id low cost and easy to use. The primary goal of the work was to offer police forces some suggestions for locating a kidnap victim. We offer several concepts, including mobile tracking, WiFi, and wireless communication networks. The objectives were to illustrate the advantages of present tracking systems in use and to propose a tracking system for locating where a kidnapped person is being held, for example, within a block of flats using WiFi routers based on router access points (AP). The proposal is to create an approach for tracking and tracing of a kidnapped person using the concept of WiFi triangulation.

The primary requirement is to provide law enforcement authorities with an approach for locating the victim or suspect using accessible networking technologies. The task of finding kidnapped people has grown more difficult in recent years. Therefore, the work considers any technologies that are accessible and help researchers efficiently combine all the data so that they can develop an appropriate set of guidelines for discovering the kidnapped individual. In this instance, it is presumed that the kidnapped person has their phone with them. As a result, there are several opportunities to track the victim's phone or determine their last known whereabouts, assuming that the device is powered and has WiFi enabled which is the case more often than not.

## II. WiFi Device Location Identification

Knowing where a device is, forms the basis of many mobile device navigation systems, with global positioning system (GPS) as the most common technology [2]. The accuracy of GPS in 3-dimension can vary depending on a number of factors, such as the quality of the GPS receiver, the number and quality of GPS satellite signals received, and the environment in which the receiver is located. In general, GPS is more accurate in the horizontal (x and y) dimensions than in the vertical (z) dimension, because the GPS satellite signals are transmitted from above, and the accuracy of the vertical position calculation is affected by factors such as the signal's angle of incidence and atmospheric effects. In general, modern GPS receivers can provide 3D position accuracy within a few meters, depending on the specific conditions, while device positioning systems need considerably more dependable systems with an accuracy of up to 0.5m. However, more accurate results can be achieved through the use of differential GPS (DGPS) or Real-

Time Kinematic (RTK) techniques, which use additional information to improve the accuracy of the GPS signal. In general, GPS cannot be used to navigate within buildings, such as those found in shopping centres, hotels, and educational institutions. A well-known positioning solution based on the angular technique is Cisco Hyper location routers. However, it is a unique transceiver that was built. They are quite large and are typically equipped with numerous antenna [3].

Indoor localization is an effort to determine location, i.e., to respond to the inquiry, "Where is this specific device?" There are many different kinds of localization procedures, some of which function well outdoors and extend partially within, others of which function only inside, some of which provide centimetre-level accuracy, while others only manage 15 metres at best. The centralised and distributed localization families of approaches are frequently distinguished in the literature on sensors and location using wireless technology [4]. A radio infrastructure gathers data and signal from a mobile object in the centralised approach. In this context, the infrastructure may consist of one or more radio points The location engine uses the centralised elements to determine the location of the mobile object. Because of this, it is not necessary to infer that there is a fundamental technique just because location is calculated by a central system.

An alternative approach to indoor location identification based on using WiFi router access points [5]. There are various approaches that can be utilised to calculate a target device's location using distance measurements from the APs. One common method is to use trilateration, which involves intersecting three spheres centred on each AP and with radii equal to the measured distances. The intersection points of the three spheres give the possible locations of the device, and the actual location can be determined by choosing the intersection point closest to the measured distances. Fig. 1 illustrates three APs with their relative radii, along with intersection points.

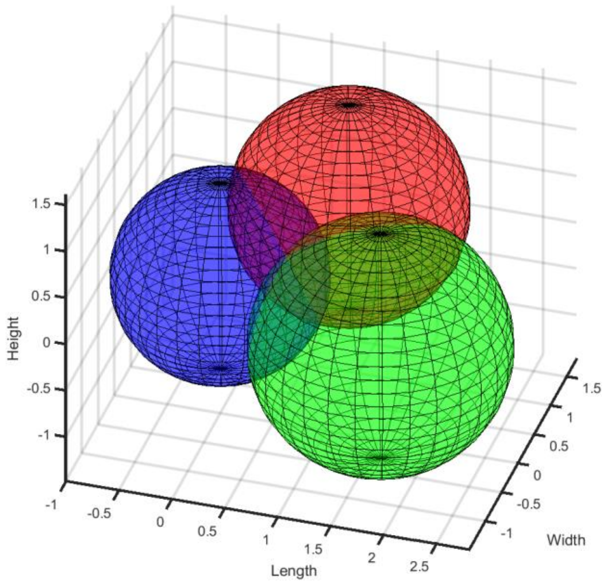


Fig. 1 'Signal' Overlap for Triangulation

Multipoint triangulation can be used to pinpoint the location of a WiFi-enabled device in 3D by measuring the signal strength of the device from several known APs located in the area. The basic principle behind multipoint triangulation is to use the distance between the device and each of the known APs to calculate the device's location within a 3D space. To do this, a particular characteristic of the signal is measured between each of the APs and the target device, and the distances between the device and each of the APs are calculated using an appropriate signal propagation model such as time-based methods, or angle-based methods (Fig. 2).

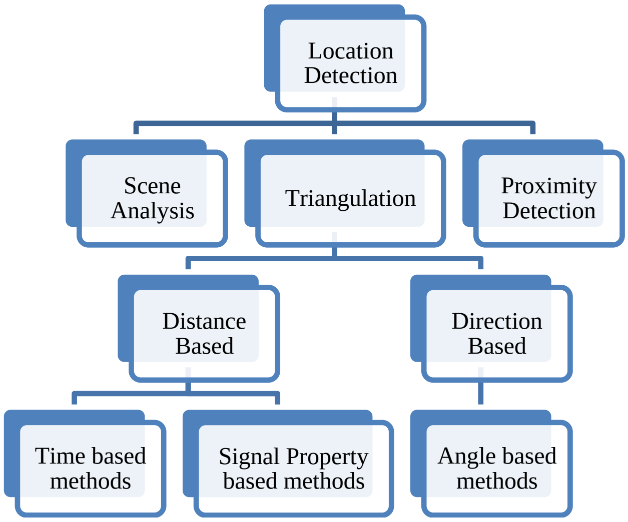


Fig. 2 Location detection methods.

There are several methods to locate a Wi-Fi device in 3D (Fig. 3), but the specific techniques and tools required may vary depending on the type of device and the purpose of the location identification. Some approaches, such as time of flight, angle of arrival, or received signal strength are detailed below.

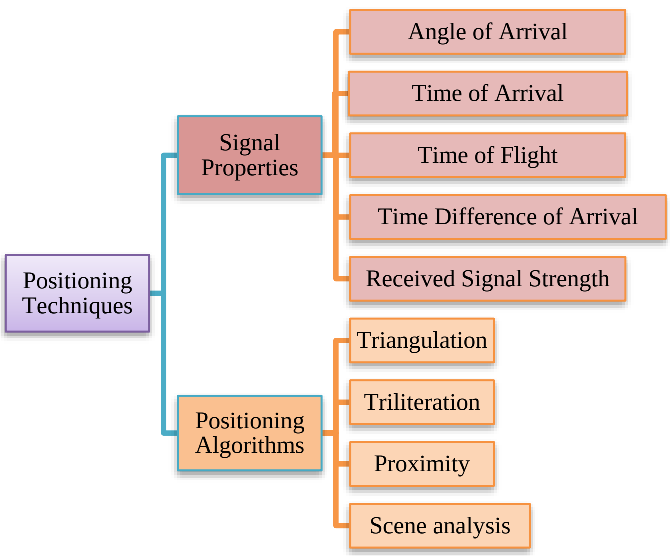


Fig. 3 Device localization approaches

### A. *Time of Flight (ToF)*

ToF is a method for measuring the distance between an AP and the target device by calculating the time it takes for a signal to travel from the AP to the target device and back. By knowing the speed of the signal, the time-of-flight measurement can be converted into distance.

### B. *Time of Arrival (ToA)*

In telecommunications, ToA is used to measure the delay between the transmission and reception of a signal. This can be used to determine the distance between two points, or to synchronize signals in a network.

### C. *Time Difference of Arrival (TDoA)*

TDoA is another way to solve the synchronisation issue. Instead of using absolute time measurements, it uses relative time measurements between many pairs of APs or reference nodes with known positions. A hyperbolic curve is produced for each variation in arrival time data. It takes the TDoA from at least three receivers to locate the junction and, consequently, the transmitter, in the location space. While the transmitter and receiver do not need to be time synchronised for this technique, the APs must be strictly time synchronised [9].

### D. *Angle of Arrival (AoA)*

AoA is used in wireless communication systems to determine the direction from which a signal is coming. Multiple antennas or an antenna array are used to receive the signal from different angles. By comparing the phase and amplitude of the signal received by each antenna, it is possible to determine the angle of arrival of the signal. This information can then be used to determine the direction from which the signal is coming.

### E. *Received Signal Strength (RSS)*

RSS is a measure of the power level of a signal as it is received by a target wireless device. It is typically measured in decibels relative to a reference signal level, and can be used to estimate the distance between the AP and the device. The strength of the received signal can be affected by a variety of factors, such as distance, obstacles, interference, and the characteristics of the transmitting antenna.

### F. *Multi Path Utilisation*

Location determination can be refined by using advanced signal processing techniques employing ToA or TDoA measurements, as well as AoA, RSS and ToF in combination to improve the accuracy measurement by overcoming any inaccuracies of each signal measurement [6] [7].

## III. Proposed Solution Approach

Trilateration is a technique used to determine the location of an object or signal by measuring its distance from three or more known reference points, and is a common method used in GPS systems and other location-based systems.

In trilateration, the distances from the object to each reference point are measured, and these measurements are used to calculate the object's position. The reference points can be either fixed or mobile, and they can be located at any distance from the object as long as their positions are known.

This approach can be further refined by using advanced signal processing techniques such as time of arrival (TOA) or time difference of arrival (TDOA) measurements, which provide more accurate distance measurements and improve the overall accuracy of the location calculation [8].

Trilateration is a technique used to determine the location of an object or signal by measuring its distance from three or more known reference points, and is a common method used in GPS systems and other location-based systems. In trilateration, the distances from the object to each reference point are measured, and these measurements are used to calculate the object's position. The reference points can be either fixed or mobile, and they can be located at any distance from the object as long as their positions are known. In relation to target devices of kidnap victims, we propose that police utilise mobile WiFi hot spot systems which they are then able to place at known positions within a building; the mobile devices can then be relocated as required to close in on the target device.

Any system that the police employ has a number of specific requirements in relation to operational usage. The cost must be low since police forces have limited finances (especially in the UK), also operational use might result in damage to the equipment meaning possible frequent replacement with the associated cost implications. To be of practical use in the field, the system should be easy to use, lightweight, and mobile. It is also advantageous to utilise commercially available equipment since it provides replacement availability, and can be upgraded as needed. This leads to a realistic and sensible set of required resources, while there are a number of possible commercial items available, the ones listed below are for illustration.

*1) Mobile WiFi hot spot Internet Router:* A more than suitable system is a 4G WiFi router with a large capacity battery for example up to 72 hours of standby time, where WiFi access is achieved simply inserting a standard SIM card. The capability to connect multiple users at the same time is advantageous. Fig. 4 illustrates one device which costs under £50 (US$60).

Fig. 4 Portable Mini Portable Wireless WiFi Router.

*2) Data only SIM with monthly plan:* There are various deals available, certainly in the UK, starting at £1 (US$1.20) per month per device. For this proposed application a minimum of 4 devices are required.

*3) Computing devices:* The operational system requires a small sized laptop as the primary device to be used by the senior police officer in charge of the investigation based at a fixed location outside the building of interest. Additionally, at least three tablet devices are required as the units that are moved around the building by the police. A typical low cost laptop is shown in Fig. 5 priced at £100 (US$120), while Fig. 6 illustrates a suitable tablet costing £45 (US$55).

Fig. 5 Mini laptop.


Fig. 6 Mini Tablet.

4) *Internet email accounts specifically linked to each device:* To enable communication between the command unit and the mobile police devices, it seems appropriate to utilise email rather than mobile phone or text, because this allows any police officer to use the equipment knowing that the device will provide instructional messages from the commanding officer regardless of the actual user. This also has an additional benefit of allowing the whole system to be deployed operationally very quickly. This approach also allows for silent communication between the police officers, hence not altering suspects to their activity. The email addresses can be set-up by the Police Force using their own email system, assigning email addresses such as 'wifiDevice1@police.org' and 'CommandUnit@police.org'.

5) *Cloud storage:* Signal data (such as ToA, AoA etc) from each WiFi device needs to be collected and analysed by the command unit, in which case uploading signal data to a cloud-based system offers a simple and reliable approach. Software on the command unit undertakes the triangulation calculations.

For the proposed of a laptop and three tablet devices with each having its own WIFi router and SIM card subscription, the total cost is approximately £480 (US$580). This is considered a very reasonable expenditure for a police force and would allow the police to purchase a number of systems for use across their geographical operational area.

## IV. Discussion

It is important to note that trilateration requires accurate and reliable distance measurements, and that errors in these measurements can result in inaccuracies in the calculated position. Additionally, trilateration can be affected by obstacles, signal interference, and other environmental factors, which can also impact the accuracy of the location calculation.

The system is currently undergoing practical tests.

## V. Conclusions

The aim of this work was to provide a potential approach to WiFi device location suitable for use by police forces. Such a system has been proposed and is currently under test and development prior to deployment with the police.

It is important to note that the use of techniques to locate a Wi-Fi device may have privacy and legal implications, and thus imperative to use them only for legitimate and lawful purposes. Additionally, it is not ethical to use these techniques to locate someone without their consent, and doing so can have serious legal consequences.

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