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**Introducción.**

En este trabajo final de grado (TFG) vamos a ver cuales son las técnicas actuales de posicionamiento de dispositivos móviles, una vez vistas y analizadas vamos a centrar el trabajo en el análisis de datos. Tenemos datos recabados de un sensor colocado en un punto concreto de la Gran Vía de Madrid el cual esta recabando datos de los dispositivos que pasan cerca de él. El trabajo que vamos a realizar va a ser el de limpiado de datos, procesado de datos, análisis de datos, visualizado de datos y posteriormente realizaremos un modelo predictivo de estos datos con el fin de predecir la afluencia de dispositivos en el futuro. También realizaremos un análisis de los datos recabados para elaborar un modelo estadístico de los mismos de cara a un uso corporativo.

**Sistemas de rastreo de señales en exteriores:**

**GPS**

La primera tecnología que vamos a comentar es una con la que estamos todos familiarizados. Dicha tecnología se denomina GPS (Global Positioning System).

En cuanto a su funcionamiento, un GPS para poder determinar la localización de un móvil, el GPS hace uso de satélites, que permitirán establecer dicha ubicación. Aunque este método funciona muy bien en exteriores, como ya sabemos, en interiores es donde tiene claros problemas de funcionamiento, pudiendo ser impreciso en muchas ocasiones o directamente no funcionando.

Aunque el GPS tiene una clara ventaja frente a las antenas, por ejemplo, un GPS es más preciso. En su caso la precisión es de unos 10 metros, lo que permite tener información muy clara sobre la ubicación de dicho móvil. Por eso no es de extrañar que aplicaciones como Google Maps se basen en este método.

Incluso los dispositivos móviles que carecen de GPS pueden ser localizados gracias a la manera en la que se conectan con la red telefónica. Esto es posible gracias a la localización mediante GSM o 2G (segunda generación) un servicio ofrecido por las empresas de telefonía móvil que permite determinar con cierta precisión dónde se encuentra físicamente un dispositivo móvil determinado. Un ordenador o un dispositivo móvil pueden localizarse gracias a tres cosas: [1]

1. la aproximación a las torres de telefonía
2. El tiempo que tarda una señal en ir de una torre a otra
3. Por la fuerza de la señal recibida.

Por otra parte, entre los usos principales del GPS encontramos los siguientes:

1. Ubicación: determinación de una posición.
2. Navegación: desplazamiento de una ubicación a otra.
3. Seguimiento: supervisión del movimiento de objetos o personas.
4. Cartografía: creación de mapas del mundo.
5. Temporización: permite realizar mediciones precisas del tiempo.[2]

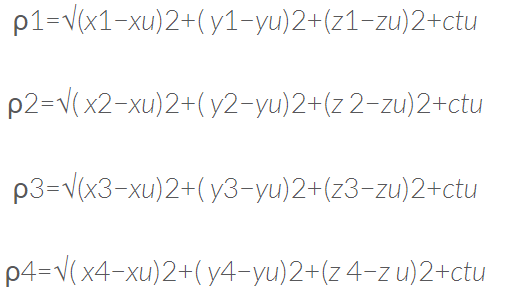
Dentro del posicionamiento por GPS vamos a comentar la localización y posicionamiento por medio de llamadas telefónicas, ya que utilizan de GPS para su localización.

Cuando se realiza una llamada telefónica desde un dispositivo móvil, se asume que el dispositivo se encuentra en un radio de 1km de la estación emisora/receptora a la que se conecta, pero este método no es preciso, ya que no es cierto que el dispositivo se encuentre en un radio de 1km. Para poder concretar su posición con gran precisión necesitaríamos de 4 satélites.

Esto traducido en números nos quedaría de la siguiente manera.

Matemática del problema:

Ecuaciones finales

Texto, Carta

Descripción generada automáticamente

Para llegar a las expresiones anteriores debemos realizar previamente los siguientes pasos:

Matemáticamente obtendríamos la posición de la siguiente forma:

1. Dibujo de una persona

   Descripción generada automáticamente con confianza bajaSabemos el tiempo en el que el satélite envió la señal (t0) y sabemos el tiempo en el que el dispositivo recibió la señal (t1), por lo que para calcular el tiempo que ha tardado en llegar la señal a nosotros, hacemos la diferencia de los tiempos:
2. También podemos calcular la distancia a la que se encuentra el satélite de nosotros, multiplicando el tiempo que ha tardado en llegarnos la señal por la velocidad a la que viaja:

Donde c es la velocidad de la luz y r es la resistencia receptor-satélite, de esto podemos definir también:

1. Se puede dar que la distancia sea errónea por un pequeño error en el reloj atómico del satélite, por lo que **p** no es una medida de distancia exacta. Teniendo esto en cuenta, ahora el **Tiempo del receptor = Tiempo GPS + Tiempo U**, donde Tiempo U es el error.
2. El siguiente paso, suponiendo que **U** es nuestra posición y **S** es la posición del satélite, podemos saber la distancia de receptor-satélite -> **r=s-u**
3. Agrupando las ecuaciones vistas, obtenemos las ecuaciones de la figura inicial:



[3]

**Triangulación de antenas**

Este es un método que permite saber dónde se encuentra un móvil sin necesidad de aplicaciones. Simplemente se consulta a qué antena se encuentra conectado este teléfono. El operador va a poder ver qué móviles están conectados a dicha antena, además de lo bien o mal que reciben la señal. La intensidad con la que se recibe dicha señal ya da información sobre su ubicación en ese momento.

Gracias a esto resulta posible saber la ciudad en la que está. Además, en ciudades grandes como Madrid es posible tener datos sobre la zona o barrio en la ciudad en la que se encuentra dicho teléfono. En función de la intensidad de dicha señal, se puede saber también la distancia a la que se encuentra de la antena en cuestión. Si hay varias antenas en dicha zona, como ocurre en muchas ciudades grandes, se sabe con mayor precisión la ubicación de este dispositivo. Este método es normalmente más efectivo en ciudad que en zonas rurales, aunque no es el más preciso.

¿Pero cómo se realiza la triangulación por antenas?

Imagen que contiene exterior, luz, grande, firmar

Descripción generada automáticamentePara entender mejor la triangulación, vamos a ver una imagen de una antena de comunicaciones:

[4]

En la imagen podemos observar que tiene una forma similar a la de un triángulo y cada lado del triángulo se denomina sector.

Estos sectores son etiquetados por las letras griegas alfa, beta, y gamma (a, ß, Y).

Dentro de cada sector se puede ver la distancia a la que está conectado un teléfono móvil.

Esto permite localizar el teléfono detectando a qué sector está conectado, y la distancia a la que se encuentra.

Mirándolo de una manera más visual podemos fijarnos en la siguiente imagen:

Gráfico, Gráfico radial

Descripción generada automáticamente

Ahora, supongamos que nuestro objetivo está conectado en el sector Gamma, y está en el rango número 4 por la potencia de la señal que hemos obtenido, así sabemos que el teléfono móvil está en algún lugar en el área marcada por el color rojo:

![Gráfico, Gráfico radial

Descripción generada automáticamente](data:image/jpeg;base64,/9j/4AAQSkZJRgABAQEAAAAAAAD/4RCyRXhpZgAATU0AKgAAAAgAAodpAAQAAAABAAAIMuocAAcAAAgMAAAAJgAAAAAc6gAAAAgAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAFkAMAAgAAABQAABCAkAQAAgAAABQAABCUkpEAAgAAAAMwMAAAkpIAAgAAAAMwMAAA6hwABwAACAwAAAh0AAAAABzqAAAACAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA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AAAAAAAAAAAAAwAAAAAAAAADAAAAAAAAACMBAAAAAAAAlt4MAAAAAABQSwYHAAAAALnfDAAAAAAAAQAAAFBLBQb/////////////////////AAA=)

Esto se daría en el caso de que un dispositivo móvil estuviese conectado a una torre de comunicaciones, pero si se diese el caso en el que el dispositivo está conectado aun total de tres torres de comunicaciones, tendríamos lo que se llama una triangulación, en este caso podemos rastrear el teléfono con verdadera precisión, como se muestra en la imagen:

Diagrama, Diagrama de Venn

Descripción generada automáticamente

[5]

Una vez vista la triangulación, existe otro método sustituto llamado Trilateración.

Mientras que la triangulación se basa en ángulos, la trilateración se basa en distancias, usa las localizaciones conocidas de dos o más puntos de referencia (antenas o satélites), y la distancia medida entre el sujeto y cada punto de referencia. Este es un método que se puede aplicar a nivel satelital como a nivel antena de señal.

Para entenderlo mejor vamos a fijarnos en la siguiente imagen:

Un dibujo de una persona

Descripción generada automáticamente con confianza baja

La explicación de la imagen es la siguiente, estando en el punto B, queremos conocer su posición con respecto a los puntos de referencia P1, P2, y P3, pudiendo ser estos antenas o satélites que se encuentran en un plano bidimensional. Al medir r1 se reduce nuestra posición a una circunferencia. A continuación, midiendo r2, la reducimos a dos puntos, A y B. Una tercera medición, r3, nos devuelve nuestras coordenadas en B. Una cuarta medición también puede hacerse para reducir y estimar el error. En cuanto a los radios de las circunferencias hacen referencia ala distancia del receptor con respecto a la antena, por lo que a medida que la posición del receptor se mueva, el radio de cada círculo (distancia) también cambiará

**Wifi**

Las señales Wifi son otro método que se puede usar para determinar la posición de un móvil. Cuando activas el Wifi en tu teléfono, para ver la cantidad de redes que hay disponibles, el listado suele ser amplio. Si bien no te puedes conectar a la mayoría de ellas, porque están protegidas por una contraseña, este listado sirve como un indicador para determinar tu ubicación, porque estás en el radio de todas estas redes.

El rastreo por redes wifi permite tener datos bastante precisos sobre la ubicación. Puede dar datos con una precisión de entre 40 y 50 metros, que es menos preciso que el GPS, pero sigue siendo mejor que las antenas. Además, es un método que consume poca batería. Esta técnica suele emplearse cuando la señal GPS es insuficiente. El rastreo o posicionamiento de dispositivos mediante señales wifi es un valioso recurso para el posicionamiento en interiores.

Los datos de ubicación recopilados por sensores o puntos de acceso, o enviados desde los puntos de acceso a los dispositivos de los clientes, son incorporados por varias aplicaciones de ubicación y se traducen en información que impulsa múltiples casos de uso con reconocimiento de ubicación. Los sistemas de posicionamiento basados ​​en Wifi pueden utilizar diferentes métodos para determinar la ubicación de los dispositivos. La mayoría confía en las técnicas basadas en el indicador de intensidad de la señal recibida (RSSI), señal de la que hablaremos más adelante. Sin embargo, algunas aplicaciones pueden aprovechar métodos de posicionamiento Wifi más avanzados: [6]

1. Posicionamiento Wifi mediante puntos de acceso

El posicionamiento Wifi con puntos de acceso se basa en las infraestructuras Wifi-existentes instaladas en espacios interiores para ubicar dispositivos. Esto permite a las organizaciones aprovechar su infraestructura existente para habilitar aplicaciones con reconocimiento de ubicación, sin necesidad de hardware adicional. Los AP (Access Point) de edificios pueden detectar transmisiones de dispositivos Wifi-cercanos, tanto dentro como fuera de la red. Estos datos de ubicación luego se envían a un servidor y a un IPS (Sistema de Posicionamiento de Interiores) central y se utilizan para calcular la posición de un dispositivo.

1. Posicionamiento Wifi mediante sensores

El posicionamiento Wifi con sensores utiliza sensores habilitados para Wifi que se implementan en posiciones fijas en un espacio interior. Estos sensores detectan y ubican de forma pasiva transmisiones desde teléfonos inteligentes, etiquetas de seguimiento de activos, balizas, credenciales de personal, dispositivos portátiles y otros dispositivos Wifi. Los datos de ubicación recopilados por el sensor se envían a un servidor y son ingeridos por el sistema central de posicionamiento en interiores (IPS) o el sistema de ubicación en tiempo real (RTLS) . El motor de ubicación analiza los datos para determinar la ubicación del dispositivo transmisor. Esas coordenadas se pueden usar para visualizar la ubicación de un dispositivo o activo en un mapa interior de su espacio.

Las técnicas de posicionamiento de Wifi más utilizadas determinan la ubicación mediante el uso de una medida llamada indicador de intensidad de la señal recibida (RSSI. Estos enfoques basados ​​en la intensidad de la señal son fáciles de implementar, pero no logran altos grados de precisión, ya que el entorno que rodea a la señal puede influir en la intensidad de dicha señal, es por esto que en ocasiones las señales RSSI pueden verse afectadas por el entorno, por ejemplo, el volumen de personas alrededor de la señal. La adición de otras técnicas menos comunes y más avanzadas puede conducir a resultados de posicionamiento Wifi más precisos, incluidos el ángulo de llegada (AoA) y el tiempo que tarda la señal en volver(ToF).

A continuación, vamos a ver en que consisten estas técnicas de posicionamiento:

**Multilateración RSSI**

Como bien hemos comentado en el apartado de Triangulación de antena, en las aplicaciones basadas en RSSI, varios puntos de acceso Wifi existentes o sensores habilitados para Wifi desplegados en una posición fija detectarán los dispositivos Wifi que transmiten y la intensidad de la señal recibida del dispositivo. Estos datos de ubicación recopilados por AP o sensores se envían al sistema de posicionamiento interior central (IPS) o al sistema de ubicación en tiempo real (RTLS). El motor de ubicación analiza los datos y utiliza algoritmos de multilateración para estimar la ubicación de los dispositivos de transmisión. Alternativamente, la intensidad de la señal de los puntos de acceso cercanos en relación con un dispositivo inalámbrico se puede utilizar para determinar la ubicación del dispositivo.

El uso de un método basado en RSSI con multilateración es la opción más fácil de activar y de bajo costo para el posicionamiento Wifi. Sin embargo, no ofrece un alto grado de precisión posicional porque está sujeto a la atenuación, absorción, reflexión e interferencia de la señal.

Diagrama

Descripción generada automáticamente

Imágenes Google

**Huella digital RSSI**

La toma de huellas dactilares también es un método basado en RSSI. El posicionamiento Wifi a través de huellas dactilares implica el uso de una base de datos que registra la ubicación y la intensidad de la señal de los AP circundantes, así como las coordenadas de un dispositivo Wifi, como un teléfono inteligente o una etiqueta de seguimiento en una fase inactiva. Para crear la base de datos de huellas dactilares, es necesario un proceso de calibración que requiere mucho tiempo y que puede ser necesario realizar repetidamente. Mientras rastrea activamente un dispositivo, los valores de RSSI se comparan con estas huellas dactilares en la base de datos para estimar la ubicación del dispositivo previamente entrenado.

Al igual que determinar la ubicación a través de la intensidad de la señal y la multilateración, la toma de huellas dactilares no brinda un alto grado de precisión posicional, a menos que el sistema se calibre continuamente para reflejar los cambios ambientales. Este es un método de bajo costo para el posicionamiento Wifi, pero requiere una actualización continua de los patrones de RF entrenados en la base de datos. Los enfoques de huellas dactilares también se ven afectados por la atenuación de la señal (la mayor influencia), la absorción, la reflexión y la interferencia. Es decir, La huella digital es un método muy eficaz para el posicionamiento de dispositivos en interiores, pero se ve muy condicionado por el entorno que rodea al dispositivo, por lo que si se realiza cualquier cambio en el entorno como el movimiento de una mesa o silla, la huella digital deberá actualizarse. [10]

Diagrama

Descripción generada automáticamente

[7]

**Tiempo de vuelo (ToF)**

ToF (time-of-flight) es un método de posicionamiento en interiores de alta precisión, utilizado por tecnologías de precisión como UWB (banda ultra ancha). Esta técnica avanzada puede medir con precisión la distancia entre dispositivos Wifi al calcular el tiempo que tardan las señales en viajar entre dispositivos. Es decir, este método es capaz de posicionar un cuerpo calculando el tiempo transcurrido entre la emisión y la recepción de un haz de luz infrarrojo.

ToF se puede aprovechar para detectar la ubicación precisa de un dispositivo Wifi utilizando múltiples sensores o puntos de acceso. Esto requiere una implementación densa de puntos de acceso o sensores para detectar un dispositivo Wifi, como un teléfono inteligente o una etiqueta de seguimiento. Para que funcionen correctamente, los sensores o AP deben sincronizarse con precisión con el mismo reloj maestro. Las señales del dispositivo Wifi serán recibidas por los AP o sensores en el rango de comunicación y con sello de tiempo. Luego, todos los datos con marca de tiempo se envían al IPS o RTLS central. El motor de ubicación analizará los datos de cada ancla y las diferencias en los tiempos de llegada a cada ancla y utilizará la multilateración para calcular con precisión las coordenadas de la etiqueta.

Un ejemplo de detector de vuelo, son los contadores de centelleo. Un contador de centelleo o detector de centelleo es un detector de radiación que utiliza el efecto conocido como centelleo. El centelleo es un destello de luz producido en un material transparente por el paso de una partícula. [11]

Este fenómeno, puede proporcionar una excelente resolución de tiempo. En cuanto a su funcionamiento, es simple, El primero de los centelleadores activa un reloj al ser golpeado, mientras que el otro detiene el reloj al ser golpeado. Si las dos masas se denotan por m 1 y m 2 y tienen velocidades v 1 y v2, entonces la diferencia de tiempo de vuelo viene dada por:

Un dibujo de una persona

Descripción generada automáticamente con confianza baja

Dónde:

Imagen que contiene reloj, agua

Descripción generada automáticamente

-> La diferencia de tiempo de vuelo entre la masa de las dos partículas m1 y m2.

L -> la distancia entre los centelleadores.

P -> el impulso entre ambas partículas

[12]

El método de tiempo de vuelo es una técnica de posicionamiento de dispositivos en interiores.

**Ángulo de llegada (AoA)**

AoA es un método avanzado que puede ofrecer posicionamiento Wifi con mayor precisión en comparación con técnicas más tradicionales como huellas dactilares y RSSI. Esto es posible gracias a las interfaces Wifi de Entrada Múltiple Salida Múltiple (MIMO). Para poder encontrar la dirección, un activo móvil, como una etiqueta o una baliza, con una sola antena transmite a un sensor Wifi fijo con un conjunto de múltiples antenas. El cambio de fase de las múltiples antenas, como resultado de recibir la señal, se mide y calcula para determinar el ángulo del dispositivo móvil transmisor y crear un área de certeza del objeto a ubicar.

Una ventaja de un enfoque de AoA es que reduce el número de puntos de referencia necesarios. En lugar de un mínimo de tres sensores como se requiere para cualquier enfoque de multilateración, solo necesita dos para crear una determinación inequívoca de la posición. Los puntos de referencia adicionales se suman a la precisión y confiabilidad de las posiciones calculadas.

Diagrama

Descripción generada automáticamente[8]

**Bluetooth**

Los llamados Bluetooth LE Beacon, son dispositivos que cuando se instalan o colocan en una localización envían eventos. Estos eventos permiten a cualquier dispositivo que emplee el protocolo bluetooth ser identificado y responderle de alguna forma determinada. Básicamente lo que hacen es emitir una señal a corta distancia (unos dos o tres metros) y de esta manera se puede establecer la ubicación de los móviles de manera precisa a través de las balizas instaladas en el área en concreto. Además, una de las grandes ventajas es que este tipo de aparatos son baratos, lo que facilita su aplicación para poder determinar la ubicación de los móviles.

Este método es excelente para el posicionamiento de dispositivos en interiores

**Señales RSSI**

La seña RSSI es el indicador de intensidad de señal recibida, es decir, es una medida estimada de lo bien que un dispositivo puede oír, detectar y recibir señales de cualquier punto de acceso o de un router específico.

Este valor de señal se mide en decibelios desde 0 (cero) hasta -120 (menos 120). Cuanto más se acerque el valor a 0 (cero), más fuerte será la señal.

Intensidad de la señal

La medición de RSSI representa la calidad relativa de una señal que se recibirá en un dispositivo. RSSI indica el nivel de potencia que se está recibiendo después de cualquier posible pérdida a nivel de antena y cable. Por lo tanto, cuanto más alto es el valor de RSSI, más fuerte es la señal.

Calidad de la señal

Cuanto más alto sea el número, mejor será la calidad. Estos son sólo números teóricos para condiciones ideales, pero también depende del sistema y del dispositivo utilizado, que puede determinarse de forma diferente.[6]

Ancho del canal

Si el canal es más ancho, normalmente tiene un valor menor de RSSI. Con esto, se recomienda tener los anchos de canal más pequeños en todas las circunstancias excepto en algunas especiales.

Intensidad de la señal aceptable:

Tabla

Descripción generada automáticamente

Una captura de pantalla de un celular con texto

Descripción generada automáticamente con confianza mediaFormula que relaciona la señal RSSI y la distancia:

Donde:

Fm -> margen de desvanecimiento de la señal

N -> tasa de error ( exponente de pérdida por el camino)

Po -> potencia de señal en el inicio (dBm)

Pr -> potencia de señal en la llegada (dBm)

F -> señal de frecuencia en MHz

**Mac**

La dirección MAC es un identificador único que cada fabricante le asigna a la tarjeta de red de sus dispositivos conectados.

Las direcciones MAC están formadas por 48 bits representados generalmente por dígitos hexadecimales. Como cada hexadecimal equivale a cuatro binarios (48:4=12), la dirección acaba siendo formada por 12 dígitos agrupados en seis parejas separadas generalmente por dos puntos, aunque también puede haber un guion o nada en absoluto. De esta manera, un ejemplo de dirección MAC podría ser 00:1e:c2:9e:28:6b.

Otra cosa que se debe tener en cuenta es que la mitad de los bits de una dirección MAC, tres de las seis parejas, identifican al fabricante, y la otra mitad al modelo. Por ejemplo, los números 00:1e:c2 del ejemplo de dirección pertenecen siempre al fabricante Apple Inc. mientras que los últimos seis determinan el modelo de dispositivo.

La secuencia de bits de cada dirección MAC se divide en 4 áreas, cada una de las cuales codifica información diferente.

Ejemplo de dirección Mac: **00110101 01101000 10110100 00000010 00010011 10011000**

Dirección en hexadecimal -> **AC-16-2D-02-C8-19**

* Bit 1 (destinatarios): el primer bit de la dirección MAC indica si se trata de una dirección individual o de grupo. Este bit se llama I/G (abreviatura de Individual/Group). Si I/G = 0, es una dirección unicast para un solo adaptador de red. Las direcciones multidifusión se identifican con I/G = 1 y se dirigen a varios destinatarios.
* Bit 2 (oficina de emisión): el segundo bit de la dirección MAC indica si es una dirección con validez global (Universal) o si la dirección fue asignada localmente (Local). El bit se denomina U/L. Si U/L = 0, la dirección se considera una dirección de administración universal (UAA) válida en todo el mundo. Las direcciones que sólo son localmente únicas se denominan Dirección de administración local (LAA) y se marcan con U/L = 1.
* Bits 3 - 24 (identificación del fabricante): Los bits 3 a 24 codifican un identificador único de la organización (OUI), que es asignado exclusivamente a los fabricantes de hardware por la IEEE. La asignación de las OUI es generalmente pública y puede determinarse a través de bases de datos. La OUI de la dirección del ejemplo (AC-16-2D) fue asignada por el IEEE al fabricante de dispositivos estadounidense Hewlett Packard.
* Bits 25 - 48 (identificación del adaptador de red): Los bits 25 a 48 proporcionan 24 bits para que los fabricantes de dispositivos asignen un identificador de hardware único (Organizationally Unique Address, OUA). De este modo, se pueden asignar 224 (= 16.777.216) OUAs únicas por OUI. [9]

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