ジオファイ：WiFiアクセスポイントのラベリングを用いた位置特定システム

GeoFi™ - A System for Indoor Location Using WiFi Access Point Labeling

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要　旨

屋内でも市街地でもよく動作するデバイスの位置特定のためのシステムを紹介する．このシステムは，人間が識別することのできる802.11ワイヤレスネットワークアクセスポイントの名前の中に，ある特別な位置情報コードを含む．ここでは，この位置情報コードを用いたシステムと簡単な位置推定アルゴリズム，及び使用例を紹介する．

ABSTRACT

A system for location of devices is presented that works well indoors and in urban settings. The system uses special geographic locations codes embedded within the human readable names of 802.11 wireless network access points. A code system, a simple location estimation algorithm, and example usage scenarios are presented.

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1. Introduction

Over the past several years, many forms of geographic location system have been developed. These systems enable a wide array of research and commercial applications, in a wide array of fields. One of the most common of these is the Geographic Positioning System, GPS[1], which was invented for military applications but has found wide adoption in automobile navigation. GPS is widely useful, but has well known problems with indoor operation and operation in urban settings. Office equipment is commonly used in precisely the environments where GPS is least useful.

Many research and commercial systems implement precise location based upon beacons that advertise their position[2]. The problem with such systems is that significant expense must be undertaken to install the beacon devices, locate them precisely, and then keep them supplied with power. As a result, few of them are deployed.

What is needed is a system for producing location beacons that does not involve new hardware deployment by businesses, and works well indoors and in urban office settings.

GeoFi™ is a technique for applying labels to existing 802.11 (WiFi) hardware access points so that they can be used as location beacons.[3]

2. Basic Principles

The basic idea of this GeoFi™ is simple. We encode a precise geographic coordinate into the Service Set Identifier (SSID) of the wireless access point, using a compact encoding.

A WiFi access point broadcasts a human readable name, called a Service Set Identifier (SSID), which helps humans and computers find access points and know which passwords to apply when using the access point. SSIDs are strings that can have alphanumeric characters and spaces, up to 32 characters long.

We construct a code, which we call a GeoFi™ code. In order to construct the code, we encode latitude and longitude into a pair of base 60 numbers with the two highest order bits from each combined into an initial hex digit. The resulting code uses nine characters to encode a position that is precise to a distance of roughly 2.5 feet at the equator.

More specifically, a GeoFi™ code is a 9-character string constructed from a geographic latitude and longitude in the following way:

1. Scale the latitude and longitude to 0<=l<360
2. Represent the latitude and longitude as 5-character strings by multiplying by 144000, rounding to the nearest integer, and converting the result to Base-60 using the "digits" 0-9, A-Z and a-w. To reduce ambiguity if the code is being typed by hand, replace the letter "O" (uppercase o) with the letter "y", and replace the letter "l" (lowercase l) with "z". Otherwise, the replaced characters might easily be mistaken for the digits 0 and 1.
3. Compute the first character of the tag by taking the high-order digit of the latitude, multiplying by 4, and adding the high-order digit of the longitude.
4. The second through fifth characters of the tag are the four low-order digits of the latitude.
5. The sixth through ninth characters of the tag are the four low-order digits of the longitude.

This works because 360*144000 = 360*602*40 = 40000 (base60).

Base 60 notation is particularly convenient because it maps well into the standard degrees-minutes-seconds notation for angles. Clearly one can build other coding schemes to encode this data, or slightly more or less accurate information.

Geographically, a nautical mile is 1 meridian arc minute at sea level, and is defined as exactly 1.852 km. So a second is 30.867m, and 1/40 second, which is the

resolution of a GeoFi™ tag, is 77.1675cm.

By inserting this code as the final nine characters of an SSID, we can alter the access point into a precise location beacon. Note that GPS location is often accurate to no more than 26 feet, which is approximately the range of a wireless access point. However, a given WiFi receiver can often see several access points, with relative signal strength. This may be good enough to allow the device to position itself within 3 or so meters, depending on the number of GeoFi™ enabled access points it can see.

If we wish to include altitude information, we add a two digit additional code, which would include 600 possible height codes by allowing the first digit of the pair to represent a multiplier from 0-9, and the second to represent a base 60 number encoded just as specified above. This allows some structural redundancy to reduce the accidental appearance of a height code as part of an ordinary SSID word. By specifying that this two-digit code represents the number of floors above ground, and allowing it to optionally appear in front of a GeoFi™ 9 digit code, we allow users to encode height information.

Since most access points broadcast SSID information several times a second, whether or not a user can connect to that access point, it can be listened to passively be a radio receiver. This can be done with a very low power cost to the receiving device, because the no radio transmitter power is needed. GeoFi™ receivers should be able to determine location with accuracy similar to a GPS, within a fraction of a second, even in dense urban environments. It thus makes an excellent complementary technology to the GPS system, which works best in open areas free of obstruction.

GeoFi™ codes are designed to work with almost every available access point hardware. As long as a 9 character SSID is supported, and the character range is allowed, then the access point can be configured to broadcast location information without disturbing its utility as a network router.

It is clear that someone can set up malicious access points with misleading GeoFi™ codes. Indeed, it is quite likely that some points will appear to have valid GeoFi™ codes by accident. Simple sanity checks against previously calculated locations, the time that has passed, and other visible access points should mitigate such problems almost entirely. It is very difficult to travel 300 miles in a half second, after all. Combined with accelerometer data, one can get a very good idea how far a device has moved for modest power costs, and check such dead reckoning information against the GeoFi™ data, which can be seen.

Availability of precise geographic information in urban, indoor environments enables many applications. GeoFi™ technology might allow users to find their location from a laptop print driver dialog, for instance, giving a relative distance and direction for a chosen printer or MFP. Mobile devices might find their relationship to other devices for document transfer, or might query location based information or allow location based superdistribution of documents. Devices like smart phones might be able to find the nearest printing kiosk or print shop to allow documents to be printed.

3. Access Point Location

In order to create a GeoFi™ code, a user must precisely specify the latitude and longitude coordinates for the access point. One method is to use a mapping program, such as Google Maps™ mapping service, to allow a user to place a marker precisely on the map, and then calculate the resulting GeoFi™ code. The image below is an example of just this sort of interface, built using the Google Maps™ Application Programmer Interface. The user places a marker on the map, and the page returns a code for them to use.

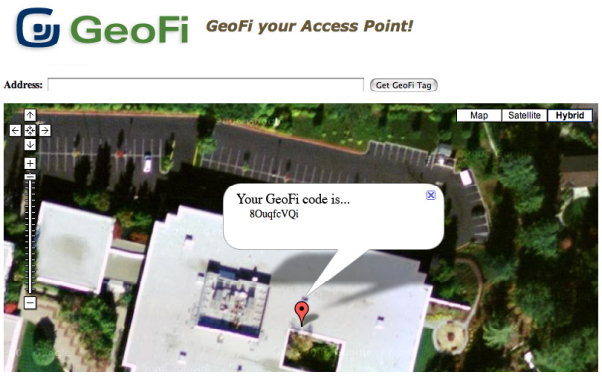

Fig.1 An example of a map-based mash-up for determining the GeoFi™ code for a given location.

Once a code has been obtained, the user would use his ordinary access point management software to insert the code as the final characters of his access point SSID.

4. Location Determination

Once nearby access points have been located and labeled, any device with WiFi reception capability can determine location by the following process:

To determine one's location using GeoFi™, then, simply:

1. Passively listen for the SSID strings of nearby access points
2. List the access points with valid GeoFi™ tags at the end of their SSID strings.
3. Discard any that are too far (e.g., > 100m) away from the centroid of the other points. This gets rid of access points whose SSID accidentally ends in a valid code, or have been intentionally mislabeled.

Interpolate location based on signal strength to locate the receiver.

Fig.2 The relative location is determined based on the signal strength from each access point.

This procedure yields a location with an accuracy of, at worst, the roughly 30m range of a WiFi access point. It may be considerably better, but is constrained by the effect of walls and interference from other WiFi devices. The location computed is always inside the convex hull of a polygon whose vertices are the locations of the visible access points.

5. Advantages

One of the great advantages of GeoFi™ is that it needs no database of access point locations. This means that locations can be derived based on passive reception of beacon frames, even if all the visible access points are closed and no network will allow a connection. This also makes it possible to build location beacons and receivers very cheaply.

A direct consequence of this is that locations do not need to be mapped in advance. Although it is necessary to know where the access points are, it is not necessary to map anything else. Current commercial location products that use WiFi access points have sophisticated data collection methods, where a sensor is moved

through an area on foot or in a vehicle.

On the device side, the advantage is that devices do not need to have an active Internet connection and do not need to store an internal map. Another advantage is that SSIDs are completely under the control of the organization or individual setting up the access point. GeoFi™ can be deployed locally and provides immediate benefits, regardless of how widely it has been adopted.

GeoFi™ devices can determine location very quickly. Within approximately 2/10 second, a given device should be able to detect all available location beacons, and perform the necessary calculation. The device need not broadcast anything in order to calculate location; it just listens to nearby access points. Hence, it can be extremely low power.

GeoFi™ works with all existing WiFi access points and clients. No hardware or software changes are required on the access points and existing WiFi devices like laptops and cell phones can be converted to GeoFi™ clients by installing relatively simple software.

6. Potential applications

Since GeoFi™ tags are nothing but compactly represented geographical coordinates, they can be used as tags or labels in many places beside access points. Examples include computer and printer names (DNS names), and even printed labels on objects. A GeoFi™ tag can easily be represented in a QR-code, RFID, or other machine-readable format.

6-1 Equipment location

An obvious use for this technology in an office setting is to automatically locate equipment. Any object that is equipped with WiFi capability, with some software modifications, can determine its location from GeoFi™ beacons and update a central database. For example, a WiFi connected MFP could determine its location and advertise it though the Simple Network Management Protocol. This would allow a service technician to locate a printer without needing to ask directions from nearby people, who may not know the network name of the printer.

6-2 Advertisement

Another use is to enable mobile printing applications. In this usage case, a central web service would contain maps of local areas, indexed by geographic location. A client would ask the central database for the map of the area closest to the current GeoFi™ location, and display the location and network name of those printers. This would allow a visitor from another facility to locate available printers directly from a program or even from the printer driver dialog box.

6-3 Document geolocation

Another use is to allow devices to automatically label documents with the current location. This capability is already present in some commercial camera-phones, and GeoFi™ could enable it in WiFi-equipped cameras, in laptops when files are saved, and in MFPs when documents are received. A mail server might tag an email with the location where it was received, and a mail client where it was last read.

There are many specific industries, such as law, military, and finance, where detailed records of where documents were accessed or printed is very important. In such cases, the GeoFi™ location system could be combined with hash-chained document logs to provide a tamper-evident record of the use locations of important information.

References

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