

How much of the outside E911 Location Problem in VoIP can be reasonably solved using existing Radio Beacons

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Purpose

The objective of this paper is to evaluate *how much of the outside E911 location problem for VoIP can be reasonably solved using existing radio beacons* with a general analysis and the use of Place Lab as a particular experimental application.

The paper is organized into seven sections. Section 1 introduces various kinds of radio based location systems. Section 2 discusses the concept of Wireless E911 and the FCC E911 Accuracy Specifications and outlines how Place labs and Wireless Geographic Logging Engine (Wigle) work. Section 3 describes the methodology being used for data analysis. The experimental results are presented and discussed in section 4 and 5. Section 6 talks about the conclusion while Section 7 discusses the recommendations.

1 Introduction

Voice over Internet Protocol (VoIP) is a novel technology that allows voice to be sent over existing world wide data network. Numerous soft-phone systems, such as Skype, Pulver, and companies like Vonage provide voice carrier services over a network. Internet Telephony over VoIP has offered customers a remarkably cheaper way of

making calls. However, the service has some issues that need to be resolved. One of them is locating the calling party. Unlike the traditional telephone services, whose numbers are attached directly to the address location, the exact location of the Internet Telephony caller cannot be easily determined. Therefore, locating the source of VoIP call has become a challenge in providing E911 services to the customers.

Wireless network is an alternative in calculating the position of the users. Widespread coverage of Wi-Fi networks throughout the U.S. can be used to locate a user. Radio beacons from Wi-Fi Access Points (APs) can be used to solve the Enhanced 911 (E911) location problem, provided they are ubiquitous and comply with the FCC E911 accuracy specifications.

Currently several radio based location systems exist. However, most of them are not ubiquitous as coverage is either limited to outdoors or indoors and are difficult to implement. The Global Positioning System (GPS) [1] is very accurate but requires a clear view of its orbiting satellites. Location Systems like RADAR [1] only work in limited indoor environments and provide a good estimate of user's location (2-4 meters). However, this accuracy comes at a cost of installing and calibrating equipments in the building. The deployment of this system is only feasible in small environments and requires the user to collect data [1]. RightSpot [2], another positioning system, is implemented on a watch. The system determines the location of the device by using FM signals. Several indoor location systems utilize the Electromagnetic spectrum in the range of ultrasonic, infrared and ultra-wideband [2]. Most of these applications require the installation of expensive hardware, which by itself does not fit with the definition of cost-friendly designs [2].

Most radio based location systems focus more on accuracy and less on wide scale deployment. Place lab positioning software is a location system that could be used for both precision and operation in a wide scale. Placelab shall be used as a particular experimental application for analyzing the problem. The testing involves detailed field measurements of user's device (notebook with Place lab installed) at various geographical areas. The samples collected are then analyzed to determine whether or not Place lab is accurate enough in compliance with the FCC E911 accuracy specifications.

2 Background

2.1 Wireless Enhanced 911 (E911)

Wireless E911 [3] aims to enhance wireless 911 services by adding the 911 dispatchers. E911 shall be efficient and reliable by extending additional information (e.g. location and identification). Wireless E911 consists of 2 phases. The first phase mandates the wireless carrier to provide the phone number of the caller and the location of the antenna that receive the signal from the call. The second phase involved in the accuracy of the location provided by the carrier.

2.2 FCC E911 Accuracy Specifications

The E911 rules require that a location estimate be provided to the Public Safety Answering Point (PSAP) for each 911 call. [4]. The FCC has set the following accuracy and reliability requirements for E911 Phase II operations:

“For network-based solutions: 100 meters for 67 percent of calls, 300 meters for 95 percent of calls; For handset-based solutions: 50 meters for 67 percent of calls, 150 meters for 95 percent of calls. [4]”

Phase I information i.e. the cell site or sector where the call is received, should be reported if Phase II location can not be provided [4].

Any Automatic Location Identifications (ALIs) should operate effectively in moving conditions as well [4]. The compliance testing reports should clearly define the geographical area as well.

2.3 Place Lab

Place Lab [7] is positioning software that locates wireless devices such as PDAs, notebooks, and cell phones. These devices can locate themselves by listening to radio

beacons from existing fixed-location bases such as wireless access points, Bluetooth devices, and cell phone towers. The ALI on the user' device checks the locations of the related beacons on the database and calculates its own position with respect to the beacons.

Place Lab [2] architecture consists of three main elements; radio beacons, beacons' databases, and clients. The relationship among these three components is shown in figure 1.

- *Radio Beacons.* The radio sources, such as wireless access points and Bluetooth devices, are called beacons. Every beacon can be distinguished from each other by an identifier such as MAC address. The access points send beacon frames periodically in the clear (neither encrypted by WEP nor affected MAC address authentication).

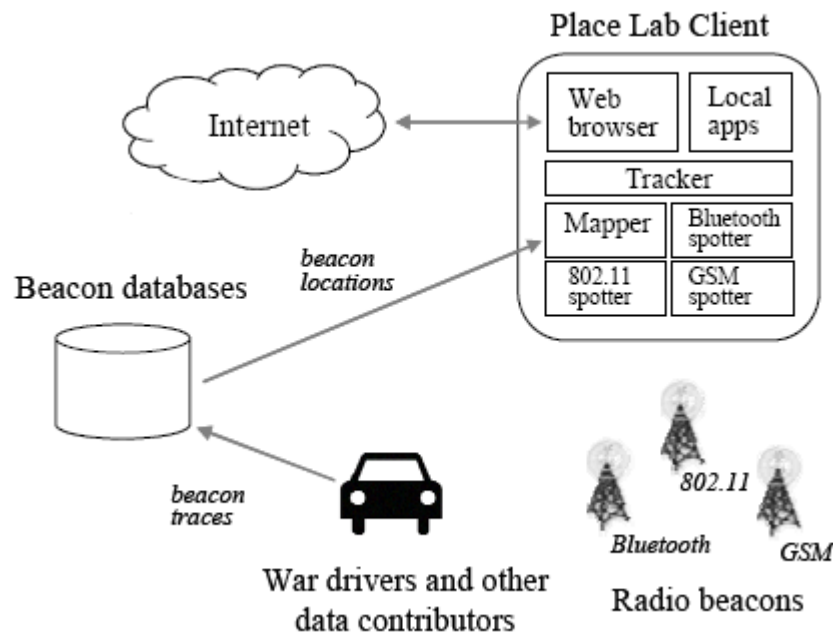


Figure 1: Three main components in Place Lab architecture [2].

- *Beacon Databases* are used to store beacon location information. The databases can be either public or private and are provided by large institutions such as

companies and universities or war-driving [8] (driving in a car with a laptop and war-driving kit to search for wireless hotspots) repository such as wgle.net.

- *Place Lab Clients.* The clients observe the radio beacons and cache the location of the beacons from beacon databases. The clients can then estimate their locations based on this information.

Place labs employs techniques [2,9] known as *Spotting*, *Mapping*, and *Tracking* for calculating the user location. Spotting is employed to detect radio beacons. Wi-FiSpotter, BluetoothSpotter, and GSMSpotter routines are used for detecting beacons from wireless access points, Bluetooth devices, and cell phone base stations respectively.

The next step is mapping. This step maps the locations of beacons from the local cache of beacon data. The access points and devices are mapped in two dimensions (in latitude and longitude format) [9].

Finally, tracking is used to track the user's position. The tracker component in Place Lab estimates the user's location from data provided by spotters' observations and mapper's data [9].

2.4 Wireless Geographic Logging Engine (Wigle)

Wireless Geographic Logging Engine (Wigle) is a world-wide search engine for locating wireless access points. The databases used in Wigle come from war-driving communities. As of today, there are approximately 2,415,327 wireless networks in wigle [10]. To retrieve the access points in the area from the web site, the user has to register and enter a valid address.

Wigle employs triangulation to locate access points. Triangulation is a method that returns “**an average of the latitudes and longitudes gathered using the signal strength (squared) as a weight and assumes that signal strength will change at the inverse square of the distance.** [11]”

Wigle's registered users are not forced to register their access points. If a user does not want its network Service Set Identifiers (SSIDs) to appear in the database,

wiggle.net will remove these entries from the database immediately. Exposing the network SSID makes the network easier to detect, making it less secure.

3 Data Analysis Methodology

The testing for the Automatic Location Identification (ALI) equipments can be accomplished by either predictive methods or the empirical method [4]. Predictive methods verify the compliance with FCC E911 accuracy specifications using lab simulations. The empirical method compares data collected from field measurements directly with those from GPS device. This paper follows the empirical method for testing. The empirical testing method involves the following steps [4]:

- A set of locations are randomly selected.
- An accuracy measurement is made at each of these sample locations. The distance between the actual location and the location reported by the ALI is the error.
- An inaccessible point is replaced by an accessible nearest point not more than three meters away.

“Conclusions derived from test results should be stated for at least a 90 percent level of confidence. A 90 percent level of confidence means that performance can be expected to be at least as good in 9 out of 10 test areas with the same relevant characteristics. [4]”

Order Statistics is used to determine the 90 percent level of confidence on a set of locations [4]. The equation (1) given below is used for this purpose.

$$confidenc(x \leq x_r, y \leq y_s; n, r, s, p_1, p_2) = \sum_{i=0}^{r-1} \sum_{j=i}^{s-1} \binom{n}{i} \binom{n-i}{n-j} p_1^i (p_2 - p_1)^{j-i} (1 - p_2)^{n-j}. \quad (1)$$

p_1 is 0.67 and p_2 is 0.95

n is the number of measurements

x is the percentile point associated with p_1

y is the percentile point associated with p_2

r is the largest measurement for x_r

s is the largest measurement for y_s

“If the r^{th} ordered sample is less than 100 meters and the s^{th} ordered sample is less than 300 meters compliance is established for network based solutions. [4]”

Table 1 shows various sample sizes with the r^{th} and s^{th} ordered sample. We in our analysis have used 50 as the sample size. Therefore, 41st sample is the r^{th} ordered sample and the 50th sample is the s^{th} ordered sample.

Table 1: Identification of Location – Error Samples for Comparison with FCC Required Thresholds for 67% and 95% [4].

Sample Size	Pairs of Test Samples
45	(X_{40}, Y_{45})
50	(X_{41}, Y_{50})
55	(X_{44}, Y_{55})
60	(X_{47}, Y_{60})
65	(X_{50}, Y_{65})
70	(X_{53}, Y_{70})
75	(X_{57}, Y_{75})
80	(X_{60}, Y_{80}) or (X_{63}, Y_{79})
85	(X_{64}, Y_{85}) or (X_{66}, Y_{84})
90	(X_{67}, Y_{90}) or (X_{68}, Y_{89})
95	(X_{71}, Y_{95}) or (X_{72}, Y_{94})
100	(X_{74}, Y_{100}) or (X_{75}, Y_{99})

The analysis involves collecting experimental data in geographical areas in a city representing different testing environments. The following geographical areas in the city of Boulder, Colorado shall be considered:

- Urban exterior setting like the Pearl Street Mall
- Urban/Suburban residential setting like any Boulder residential street
- Rural setting like 5 miles down the diagonal highway

Each set of samples are be randomly located. Each sample is at least five feet apart from any other sample. The samples are then compared with GPS locating device. The 50 samples are then sorted using order statistics. The 41st sample corresponds to the 67% of the calls and 50th sample corresponds to 95% of the calls. Therefore, if the error at the 41st sample is less than 100 meters and the error at the 50th sample is less than 300 meters, compliance is established.

Testing equipment: The testing equipment shall consist of two or three laptops with Wi-Fi cards, one or more GPS devices. The Place Lab positioning software must be installed on the laptop.

4 Experimental Results

(Add equations for calculating errors)

4.1 Urban Exterior Settings: Pearl Street Measurements

Table 2: Location Error between Place Lab and GPS in Pearl Street, Boulder CO

No.	Place Lab		GPS		Error (Meters)	Number of 802.11 APs	
	Latitude	Longitude	Latitude	Longitude		In Database	Total
1	40.01923N	105.27336W	40.01919N	105.27343W	7.4	8	40
2	40.01928N	105.27305W	40.01922N	105.27313W	9.5	6	38
3	40.01905N	105.27393W	40.01912N	105.27400W	9.8	7	35
4	40.01933N	105.27300W	40.01925N	105.27295W	9.9	5	29
5	40.01641N	105.27764W	40.01642N	105.27751W	11.1	7	28
6	40.01725N	105.27637W	40.01729N	105.27625W	11.2	5	35
7	40.01782N	105.27599W	40.01785N	105.27612W	11.6	6	21
8	40.01740N	105.27625W	40.01751N	105.27621W	12.7	5	30
9	40.01765N	105.27644W	40.01769N	105.27630W	12.7	4	25
10	40.01633N	105.27785W	40.01639N	105.27771W	13.7	7	22
11	40.01755N	105.27611W	40.01765N	105.27601W	14.0	3	9

12	40.01941N	105.27278W	40.01929N	105.27290W	16.8	4	11
13	40.01919N	105.27367W	40.01915N	105.27387W	17.6	6	14
14	40.01733N	105.27630W	40.01749N	105.27629W	17.8	4	8
15	40.01707N	105.27635W	40.01720N	105.27621W	18.8	3	37
16	40.01699N	105.27646W	40.01716N	105.27644W	19.0	6	32
17	40.01770N	105.27601W	40.01779N	105.27620W	19.0	4	35
18	40.01898N	105.27405W	40.01895N	105.27427W	19.1	5	25
19	40.01943N	105.27280W	40.01930N	105.27295W	19.3	2	17
20	40.01659N	105.27711W	40.01670N	105.27730W	20.3	5	18
21	40.01667N	105.27703W	40.01673N	105.27726W	20.7	4	22
22	40.01655N	105.27745W	40.01672N	105.27735W	20.8	2	11
23	40.01869N	105.27458W	40.01877N	105.27480W	20.8	3	26
24	40.01755N	105.28176W	40.01736N	105.28178W	21.2	4	8
25	40.01790N	105.27578W	40.01789N	105.27605W	23.0	4	23
26	40.01742N	105.28238W	40.01734N	105.28210W	25.5	4	12
27	40.01690N	105.27657W	40.01713N	105.27659W	25.7	3	21
28	40.01849N	105.27491W	40.01872N	105.27506W	28.6	5	14
29	40.01880N	105.27444W	40.01894N	105.27474W	29.9	3	29
30	40.01968N	105.27595W	40.01991N	105.27614W	30.3	2	14
31	40.01688N	105.27661W	40.01715N	105.27677W	33.0	3	17
32	40.01949N	105.27249W	40.01939N	105.27289W	35.9	4	15
33	40.01670N	105.27697W	40.01699N	105.27723W	39.2	3	19
34	40.01833N	105.27500W	40.01861N	105.27532W	41.4	2	18
35	40.01799N	105.27547W	40.01809N	105.27594W	41.6	1	9
36	40.01675N	105.27682W	40.01711N	105.27699W	42.6	2	5
37	40.01625N	105.27800W	40.01634N	105.27850W	43.8	2	7
38	40.01886N	105.27400W	40.01901N	105.27450W	45.8	3	10
39	40.01753N	105.27888W	40.01748N	105.27949W	52.3	2	7
40	40.01814N	105.27518W	40.01856N	105.27555W	56.4	1	5
41	40.01962N	105.27206W	40.01948N	105.27270W	56.7	2	6
42	40.02013N	105.27022W	40.02004N	105.27094W	62.2	1	5

43	40.01977N	105.27191W	40.01951N	105.27258W	64.0	1	4
44	40.02011N	105.27065W	40.01988N	105.27146W	73.6	1	6
45	40.02009N	105.27378W	40.02080N	105.27360W	80.5	1	3
46	40.02002N	105.27124W	40.01977N	105.27214W	81.6	1	2
47	40.02003N	105.27083W	40.01985N	105.27178W	83.4	1	7
48	40.01998N	105.27156W	40.01958N	105.27247W	89.4	1	3
49	40.02009N	105.27100W	40.01979N	105.27202W	93.1	1	4
50	40.01610N	105.27804W	40.01691N	105.27871W	106.7	1	4

The 41st sample corresponds to an error of 56.7 meters whereas the 50th sample corresponds to an error of 106.7 meters. Since the 41st sample is less than 100 meters and the 50th sample is less than 300 meters, compliance is established for network based solutions.

4.2 Urban/Suburban Residential Settings: 10th, 11th, 12th and 13th Street

Table 3: Location Error between Place Lab and GPS on the 10th, 11th, 12th and 13th Street, Boulder CO

No.	Place Lab		GPS		Error (Meters)	Number of 802.11 APs	
	Latitude	Longitude	Latitude	Longitude		In Database	Total
1	40.00602N	105.27993W	40.00602N	105.27994W	1.00	6	14
2	40.00488N	105.27996W	40.00486N	105.27989W	6.40	4	12
3	40.00798N	105.27866W	40.00804N	105.27863W	7.20	5	11
4	40.00737N	105.27624W	40.00743N	105.27629W	7.90	6	9
5	40.00567N	105.2785W	40.00570N	105.27863W	11.60	5	7
6	40.00738N	105.28565W	40.00748N	105.28556W	13.50	3	8
7	40.00731N	105.27871W	40.00719N	105.27874W	13.60	4	6
8	40.00973N	105.28195W	40.00961N	105.28199W	13.80	5	11
9	40.00937N	105.27862W	40.00941N	105.27878W	14.40	4	9
10	40.00180N	105.28614W	40.00182N	105.28631W	14.70	4	8

11	40.00967N	105.27863W	40.00977N	105.27876W	15.70	5	7
12	40.00942N	105.27863W	40.00954N	105.27879W	19.10	4	9
13	40.00504N	105.27872W	40.00483N	105.27864W	24.40	3	11
14	40.00567N	105.2785W	40.00545N	105.27857W	25.20	4	13
15	40.00885N	105.27605W	40.00862N	105.27657W	27.60	3	10
16	40.00937N	105.27862W	40.00914N	105.27876W	28.20	3	6
17	40.00248N	105.28196W	40.00222N	105.28200W	29.10	3	8
18	40.00732N	105.27871W	40.00707N	105.27856W	30.60	3	9
19	40.00731N	105.27867W	40.00701N	105.27863W	33.60	2	5
20	40.00519N	105.27871W	40.00487N	105.27859W	37.10	4	7
21	40.00858N	105.27967W	40.00840N	105.28004W	37.40	3	8
22	40.00294N	105.27868W	40.00260N	105.27863W	38.10	2	6
23	40.00863N	105.28129W	40.00851N	105.28085W	39.80	2	9
24	40.00932N	105.27861W	40.00896N	105.27862W	40.10	2	5
25	40.00867N	105.27835W	40.00832N	105.27853W	41.90	2	6
26	40.00727N	105.27624W	40.00689N	105.27622W	42.30	2	10
27	40.00747N	105.27625W	40.00785N	105.27623W	42.30	2	5
28	40.00145N	105.28542W	40.00183N	105.28525W	44.70	3	7
29	40.00727N	105.27625W	40.00687N	105.27631W	44.80	2	9
30	40.00148N	105.27993W	40.00188N	105.27987W	44.80	2	6
31	40.00490N	105.27872W	40.00450N	105.27857W	46.30	2	8
32	40.00503N	105.27872W	40.00462N	105.27863W	46.30	3	5
33	40.00733N	105.27871W	40.00779N	105.27866W	51.40	2	7
34	40.00798N	105.27806W	40.00829N	105.27751W	58.20	1	9
35	40.00294N	105.27867W	40.00240N	105.27837W	65.30	1	6
36	40.00937N	105.27863W	40.00878N	105.27860W	65.70	1	5
37	40.00591N	105.27626W	40.00533N	105.27673W	76.00	1	6
38	40.00803N	105.27913W	40.00813N	105.28004W	78.40	1	3
39	40.00932N	105.27861W	40.00859N	105.27857W	81.30	1	5
40	40.00294N	105.27867W	40.00217N	105.27823W	93.60	1	4
41	40.00747N	105.27625W	40.00727N	105.27750W	108.90	1	7

42	40.00947N	105.27990W	40.00980N	105.27861W	116.00	1	2
43	40.00885N	105.27604W	40.00858N	105.27737W	117.30	1	4
44	40.00567N	105.27850W	40.00564N	105.27991W	120.30	1	3
45	40.00944N	105.28041W	40.01036N	105.27964W	121.60	1	4
46	40.00773N	105.28024W	40.00657N	105.27863W	188.50	1	6
47	40.00772N	105.28023W	40.00640N	105.27863W	200.50	1	3
48	40.00802N	105.27989W	40.00792N	105.28000W	202.09	1	2
49	40.01741N	105.28358W	40.01899N	105.29259W	222.02	1	1
50	40.00497N	105.29368W	40.00817N	105.27854W	1334.00	1	6

The 41st sample corresponds to an error of 108.9 meters whereas the 50th sample corresponds to an error of 1334 meters. Since the 41st sample is greater than 100 meters and the 50th sample is greater than 300 meters, compliance is not established for network based solutions.

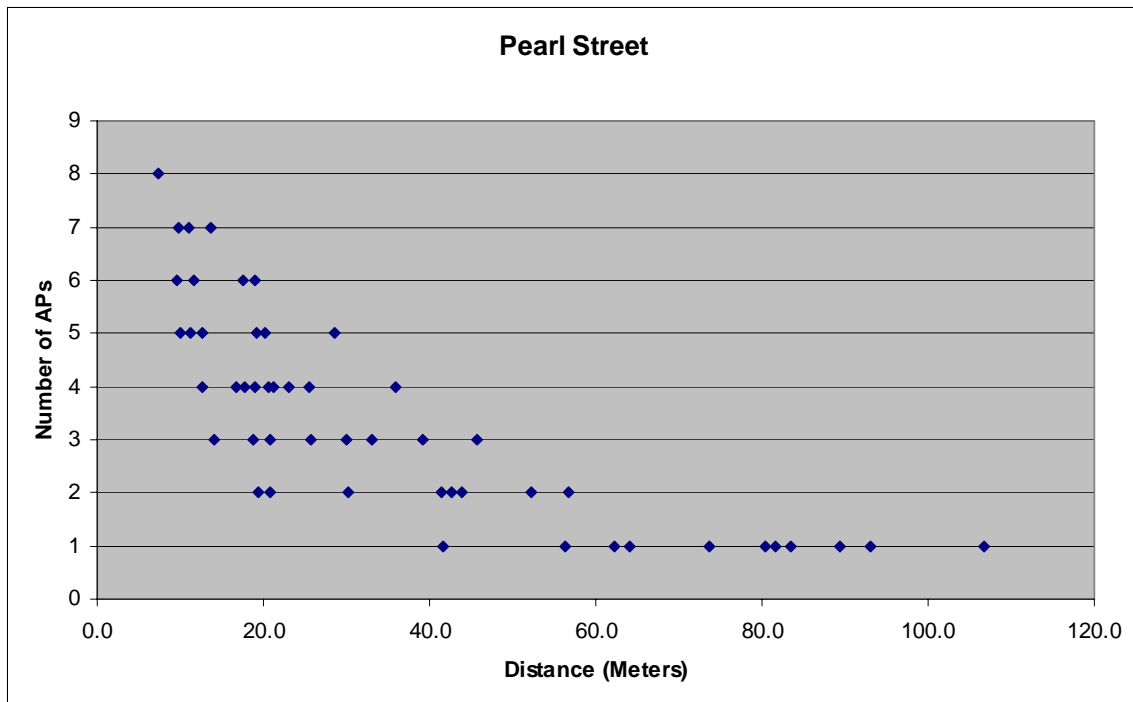


Figure 2: Error vs. Number of APs

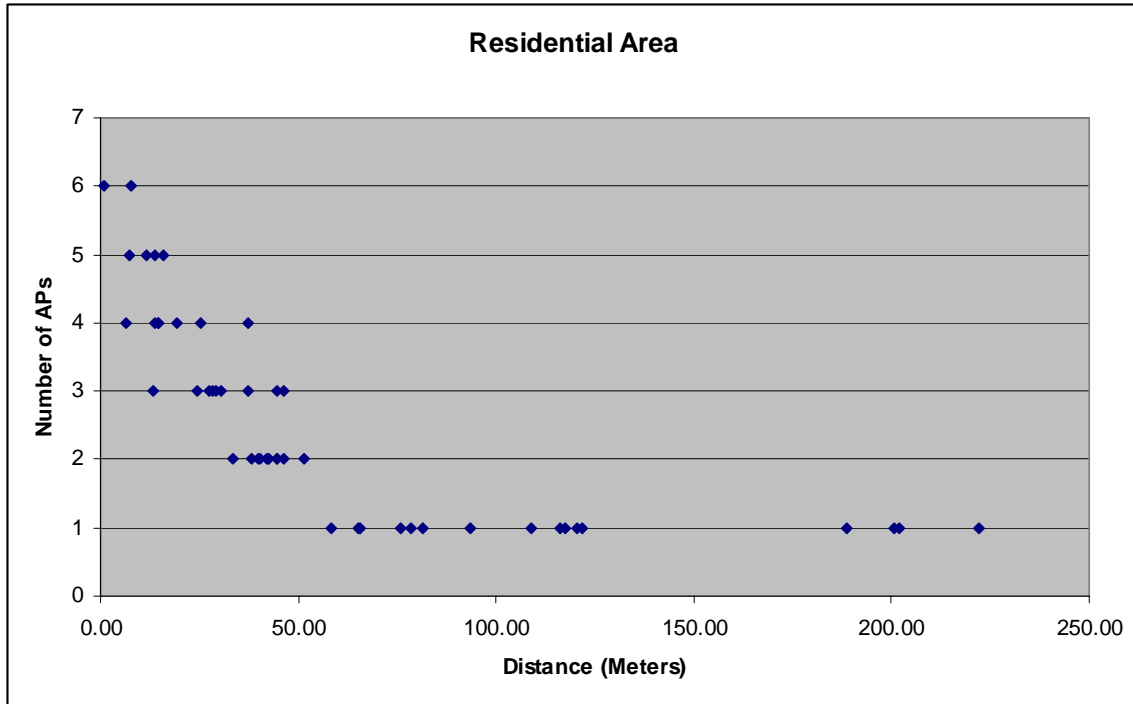


Figure 3: Error vs. Number of APs

Figure 2 and 3 explain the relationship between the number of Access Points and the error calculated. Greater the number of APs in the database lesser is the error. Based on the graph, it can be stated that *the accuracy measurements will always comply with the FCC E911 rules if there are at least three APs in the database*. It is also important to note from the graph, some of the measurements comply with the FCC E911 rules even if there is only one registered AP. This is a special case and happens only when the measurements are taken from a close AP.

4.3 Rural or Semi-Rural Settings: 5 miles down the diagonal highway

No measurements could be taken on the highway because of the lack of Access Points on the highway.

5 Discussion

5.1 Observations

- Accuracy depends on the number of Access Points in the database. The greater the APs in the database, the greater the accuracy is.
- The accuracy measurements will always comply with the FCC E911 rules if there are at least three APs in the database
- In the normal circumstances, only one AP in the database will amount to a large error. However, accuracy is high if the measurement is taken close to a lone registered AP.
- When there are no APs in a site, the data will remain the same from the previous site.
- Works well indoors as well as outdoors.
- After registering on its database, it does not require Internet access to compute new locations; if the user's device is in continuous mobility.
- The Place Labs software computes a location in roughly 5 – 10 seconds.
- Place Labs software relies on two different databases; Place Labs database and Wigle.net database. Some areas of the U.S. are not covered by the Place Labs database; thus, the software relies only on Wigle.net database.

5.2 Advantages

1. Low cost of entry to both users and application developers as it is an open source [2]. The Place Lab software can be downloaded for free from www.placelab.org.
2. Works both indoors as well as outdoors, unlike GPS that needs a line of sight.
3. The software provides user based location rather than provider based location [2].
4. It works with different device types and different wireless technologies; i.e. 802.11, Bluetooth, and GSM.

5.3 Constraints

Place Labs positioning technique has certain constraints for providing an E911 specified location.

Not all Wi-Fi cards work well with Place Labs. PDAs and cell phones that lack Java Virtual Machine (J9) also do not work well with Place Labs [2]. The table shown below illustrates the devices that work well with Place Labs.

Table 4: Place Lab Hardware Compatibility List [5].

Hardware	Wi-Fi Laptop	PDA	Nokia cell phone
Yes	Orinoco Cisco Aironet Prism2 chipset Airport, Airport Extreme Netgear WAG511	iPaq 5450, 5550 iPaq h1940 Dell Axim X30	Nokia 6600, 6620
Partially or Maybe	Intel Centrino Belkin Linksys	Any Windows Mobile 2003 PDA with Wi-Fi and NDISUIO driver model	
No	Atheros chipset Dell WLAN 1450 Mini-PCI		Nokia 3650, 7610

Place Labs scores over GPS as it can work inside the buildings as well. However, large buildings like corporate offices, University buildings, etc. do not want their networks on a public database. Lack of networks in the Place Lab or Wigle.net database implies that Place Labs positioning software cannot work in such buildings.

There is a bug in the software that also needs to be resolved with respect to a mobile user. The mobile user will locate itself if the APs are in the database. Now, if the user moves to a place where the APs are not registered, it will show the same latitude and longitude as the previous one.

Place Labs effectiveness indoors is rather efficient. All it needs is ‘*at least one*’ AP registered in its database in order to compute an estimated location. Moreover, since the user is predicted to be indoors the majority of the time (in his daily routine), a fairly accurate estimate is needed to locate and track his location; based on a 5 – 10 meters error factor [2]. Nevertheless, if no registered AP is around it would be impossible for Place Lab to compute a location; making the techniques and effectiveness of the software exceptionally unreliable.

Place Labs relies on the information from two different sources; Place Labs database and Wigle.net database. Place Labs database does not cover Denver area and its surroundings, but it does cover other important regions of the country, specifically big metro areas i.e. Seattle, WA and California [2]. Therefore, in our own experiments, the software relied primarily on Wigle.net database. Wigle.net is not a 100 percent reliable database. Since it depends on its own war-driving technique and the willingness of users to register their own APs, it does not cover some regions or areas of the country. Regardless of the lack of coverage, it covers most of the Denver area and its surroundings. Nevertheless, its effectiveness in some suburban areas of Denver lack of precision on its location techniques (i.e. triangulation).

6 Conclusion

The accuracy of the Place lab positioning software depends on the number of Access Points in the database. Place lab positioning software also depends on Wigle for information that is not included in its own database. However, Wigle is not entirely reliable. Therefore, the accuracy of the location also depends upon the reliability of Wigle’s database.

Place lab complies with the FCC accuracy specifications in urban settings. This is due to the fact that an urban setting has widespread Wi-Fi deployment. Hence, accuracy is high in an urban environment. Place lab does not comply with the FCC accuracy specifications in semi urban settings. Wi-Fi network is not that widespread in a semi-

urban setting. Place does not comply with FCC accuracy specifications on the highways because of the lack of APs.

Place lab positioning software partially solves the outdoor E911 problem and can play a significant role in Wi-Fi based E911 implementation. However, Place lab faces some challenges that need to be resolved. The numbers of APs, their coverage, the reliability of the database are some of the factors that affect Place lab. The efficiency of Place lab will increase if the hardware/software limitations are resolved.

7 Recommendations

Wi-Fi is now seeing wide spread deployment and with the emergence of Wi-Max in couple of years, the coverage will be maximized. Greater the coverage, greater will be the reliability of the software positioning device.

A software positioning tool needs to be developed that like Place Lab, is user based, has low barrier to entry, and is indoors-outdoors compatible. However, unlike Place lab, the software should have access to a highly reliable database and should work with all kinds of available radio beacons. It should also have minimum hardware constraints. The software should be an open source so that any developer can make improvements and add applications.

The proposed positioning tool can then be embedded in any soft phone application such as Skype and Pulver. The user can click on a button that signifies an emergency call. This can also be used for stolen laptop detection. If a laptop with a wireless card is lost or stolen, the position of the laptop can be detected once it is connected to the wireless LAN.

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