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WIFI ROAMING ACCESS POINT OPTIMUM ASSIGNMENT IN URBAN MULTI-SENSOR NETWORKS

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ABSTRACT

Urban sensor networks produce large amount of data including available WiFi networks information and current GPS location. We work on finding usable information in this WiFi "noise" in urban environments, envisioning the provision of efficient WiFi roaming during travel within the city. We identify the main challenges of such service, and discuss specific issue like finding the optimum sequence of WiFi AP for given route.

KEY WORDS

WiFi sequence, vertical offload, 3G offload, urban sensor networks

INTRODUCTION

In urban multi-sensor environment there is a large amount of gathered data. After that, this data needs to be synchronized with central database at the end of data gathering, but ideally would be the real time data synchronization. However, for the real time synchronization stable and constant Internet access is required. In urban environments there are many open access WiFi access points (hotspots) that provide free Internet access, let us assume that location of those devices is fairly constant, and for the sake of this paper this location is known using GPS technology. Exceptions are mobile hotspots on mobile devices and in special occasions dedicated hotspots for conferences, fairs, exhibitions,...

It is still difficult to make optimum and most efficient WiFi access point (AP) assignment for moving subject. The easiest assignment technique would be using strongest signal. In real life scenario this might not be the optimal assignment because moving object will exit coverage area very soon and new assignment would be necessary. Problem is how to choose optimum WiFi hotspot sequence for given travel path, this sequence should minimize amount of handshakes and maximize availability and path coverage.

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PROBLEM DEFINITION

Mobile object during movement in the urban sensor environment may require stable and constant internet access using existing WiFi infrastructure. Urban multi-sensor networks (UMN) like one described in [1] are usually implemented in the urban environments that do have many WiFi hotspots deployed around the area. Application that may use localization of AP is the assignment of WiFi AP to the roaming object in UMN (or any other network). This assignment would be necessary because of the offloading existing 3G networks with WiFi, is more efficient [2] Every time a moving object is changing its assigned AP it costs time because of authentication process and assignment procedure called handshaking which lasts for about 330ms [3]. During this time vehicle travelling 80km/h can travel up to 7.3m which can be crucial for some applications using urban sensor networks. Sequence of WiFi AP is important because WiFi networks have relatively short range (comparing to GSM network relay stations). Finding the optimum sequence for the given route is one of the problems this paper solves. System that provides environment for the mentioned problem is made of:

- **Server**: Provides service for WiFi roaming objects in the environment. Server problem is that single roaming object may not know the route it is about to undertake, it is up to server to define route. Along with the route, server should provide optimum sequence of WiFi AP roaming object (Client) should be assigned to.
- **Client**: Consumes services provided by the server and assigns itself to the optimum WiFi AP to minimize handovers. Even for the given optimum sequence of WiFi AP, client still has a problem deciding when and where to initiate the physical WiFi switching, because some WiFi AP coverage areas, in a sequence, will overlap. Constant scanning for the available WiFi AP consumes client battery a lot and needs to be minimized.

RELATED WORK

There are several works being done to solve individual parts of the problem defined in section before.

- **3G offloading**
  3G offloading is the technique used to divert some traffic from 3G large networks to localized WiFi AP. "When WiFi is available, it is very likely (roughly 90%) that it outperforms 3G. Such out-performance is significant."[2] Many authors deal with the reasoning for 3G offloading and it is proven that it is better to use WiFi over 3G but there are some issues like WiFi switching (handoff) which may increase network delay [4]
- **WiFi handoff**
  It is referred to switching from one WiFi AP to another, this is called horizontal handoff. Also in scenario where 3G networks are overloaded offloading to the WiFi is considered one of the preferred solutions, this is called vertical handoff: "So, in the ideal case, 3G transfers would be replaced with more energy efficient WiFi transfers whenever possible" [5] The same author defines energy efficiency of WiFi networks that in reality use much less energy than 3G. It is also recognized that handoff procedure is time and resources consuming, so there are many different techniques defining AP assignment strategies/techniques [6]:
  - **RSSI** – strongest signal first
  - **BRR** - highest exponentially average beacon reception ratio first.
  - **Sticky** - client is assigned to AP as long as there is connectivity.
  - **History** - best performance (based on historical measurements).
  - **BestBS** - best performance base station (BS) in future.

- **AllBSes** - uses all BS in vicinity. This technique is a part of special WiFi protocol proposal that is not yet being implemented in any today WiFi standard device.

Analysis using packet delivery measurements proved that the most efficient strategy is AllBSes, followed by BestBS then by History, first one is not applicable for this paper work because it deals with a new WiFi protocol proposal and this paper deals with existing WiFi technology. Regarding BestBS author states: "This method is not practical because clients cannot reliably predict future performance" [6], but analysing the past History strategy seems as most appropriate in the current case.

Another author identifies these baseline handoff policies [7]:

- **Maintain until broken** - client is connected until connection is broken, equivalent to "Sticky" strategy mentioned before.
- **Always Strongest Signal** - equivalent to RSSI strategy mentioned before.
- **Averaged with Hysteresis** - time suppressing frequency of handoffs along with signal strength estimates.

"Driving on familiar routes provides the opportunity to learn and cache the relevant information about APs along a route, which can aid in quick connection establishment." [8] Using this huge amount of data, AP coverage is estimated using the fingerprinting technique to estimate the AP coverage. Later, appropriate AP selection can be made, this strategy is called Scripted handoff. This author also proposes several improvements to the AP handshake procedure at link and network layer to minimize the handoff duration.

PROPOSED SOLUTION

Solution for the problem is a new software system architecture that extends one described in [1].

- **Server**

  Server component of the architecture provides two new web-service methods with multiple overloads. All geographical inputs and outputs for the service methods are represented using OpenGIS standard for textual representation of geographical elements. Problem is that user provides unknown data input format, solution to this problem is providing service methods that require user to synthesize its data input in a structured form. Methods are:

  - ***string GetRoute(string start, string end)*** Method is used to calculate the shortest route for the given starting and ending point. Calculation is done using previous travels. Method returns appropriate OpenGIS compliant Linestring as string, using this simplified procedure:
    1. Find all trip paths(TP) that contain start and end point.
    2. Store TP segments, from start and endpoint on current TP, to a list.
    3. Find shortest TP segment in the list.

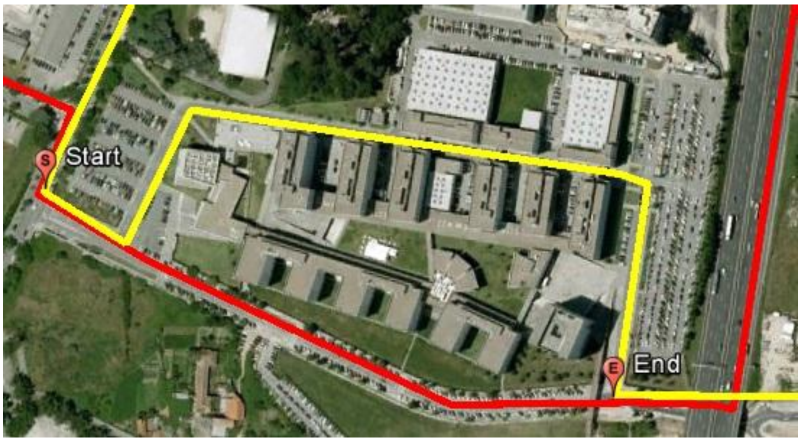

Fig. 1 *Shortest TP segment (Linestring) is the proposed shortest route for given start and end point*

- ***string GetAPSequence(string TravelPath, ReturnMode mode)***
  string GetAPSequence(string start, string end, ReturnMode mode)
  This method has two overloads whose signatures only differ by the input parameters. Methods use *ReturnMode* enumeration that defines available return modes:
  - *ReturnMode.MacOnly*: returns a string that is a comma separated list of MAC addresses.
  - *ReturnMode.MacExtended* : returns a string that is comma separated list of segments: "MAC address:latitude:longitude:radius"
  - *ReturnMode.KML*: returns a KML string that contains MAC address, location and coverage formatted for easy display in the geographical visualization tools like GoogleEarth.

  Other parameter of overloaded methods is input, in first case input is a list of path points *TravelPath*[1]. Path density is irrelevant, it will be taken as is, and all path segments will be represented as a straight line between start and end point of path segment.
  Second overloaded method takes start and end point as input. This means that the caller provides only start and end point for the roaming trip. Path for calculating optimum sequence of WiFi is calculated using the *GetRoute* method previously described. Method return value is a string to maintain easy scalability and compatibility between different clients. JSON or XML is not used to reduce data length by excluding description fields in mentioned data formats.

- **Client**
  Client component of this architecture has a task to call server services de-scribed before. After retrieval of service return data client makes the decision when and where to switch to another AP. As defined before scanning for the available WiFi consumes battery resources and should be minimized.
  There are two scenarios regarding relation between the current and the sub-sequent AP in the retrieved list of AP.
  - Overlapping
  - No overlapping – there is a gap in the returned sequence.

  If there is an overlap, client should begin WiFi scans near the ending edge of the coverage area of the currently assigned AP. If there is no overlapping, client should start WiFi scans near the beginning of the subsequent coverage area of WiFi AP. Definition of *near*: it is a

[1] OpenGIS compliant Linestring

parameter defined inside a client and can be changed by the client user. Its value is in meters and is set by default to 10m. If client is moving relatively fast then this value should increase or decrease in case of slow movement.

All WiFi scans should end after the successful assignment or user intervention (Cancelling)

- **WiFi AP sequence search**

  As defined before, problem is that the proper WiFi AP needs to be selected that way that the moving object remains the most time under coverage of single WiFi AP. This simple task should produce sequence that minimizes handovers between WiFi APs. This strategy is similar to History identified by Balasubramanian [6] Input data for this strategy are scan circles (described before), blue and green circles on Figure 2 and the travel path(TP) - desired route around the city, yellow line on Figure 2.

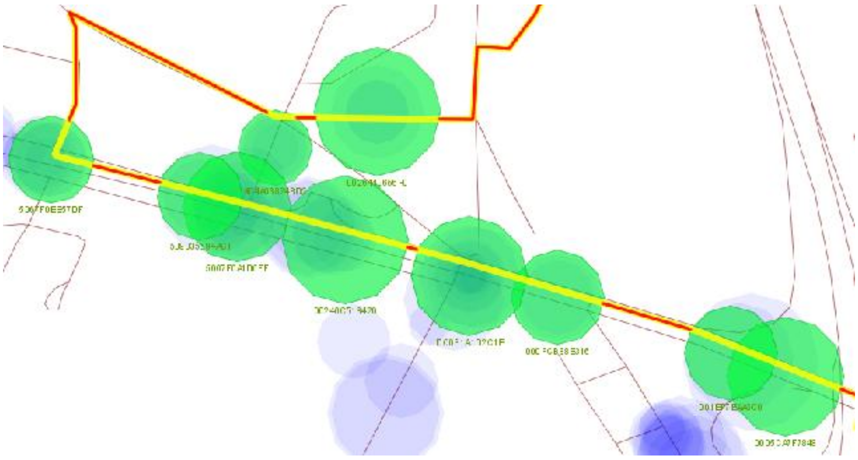

Fig. 2 *AP sequence search result, test case in Porto*

IMPLEMENTATION

This stage takes input TP in a form of Linestring[2]

e.g:

LINESTRING(8:599 41:167; 8:568 41:1788)

and returns the optimum sequence of WiFi AP mac addresses according to the previously described strategy. Order of the points in Linestring is important because it represents the orientation and direction. Each Linestring point is a place on Earth represented by latitude and longitude.

1. Get the list of all *(n)* the WiFi AP location estimation circles that intersect with $TP\text{-}I_n$
2. For each circle *(i)* calculate intersection with TP - (I_i), intersection is a line segment (or curved line segment) that has starting and ending point both on the circle and on TP.
3. Merge each intersection line segment start and end point with TP thus increasing the density of TP Linestring points.
4. Iterate through all the points X of TP and if X is not covered by currently selected WiFi AP then new WiFi AP selection is necessary.

[2] Simple object according to OpenGIS standard

5. Get the list of all intersections from I_n that contain point X = I_x
6. From the list I_x get the intersection that is the longest (length is measured from the point X up to the intersection end) = max(I_x)
7. WiFi AP coverage circle containing the longest intersection (max(I_x)) is the next selected AP.

Figure 2 shows the result of this algorithm. Selected AP are represented by their coverage estimation - green circles. TP is the yellow thick line. Red segments represent parts of TP that are not covered by any AP. Result is the list of WiFi AP MAC addresses according to Server service methods definitions.

ISSUES

While implementing this solution several issues arose that needed extra consideration.

- **Circle approximation**
  Having a circle as coverage estimation is a good for the geometrical approach that this work is using. However, this approach discards data, everything outside a circle is discarded. Alternative is using the probabilistic approach, which uses "fuzzy" circles (that implements channel model) to represent coverage area. Fuzzy means that there is a probability for each point of circle if there is or is not a WiFi AP or anything in between. Geometrical approach says that there is a 100% probability that WiFi is inside a circle, and 0% probability that WiFi AP is outside the circle. This may be an issue if it deals with one (or small number) of scans, if there is large amount of scans this error is averaged out. It is inconclusive which approach (geometric or probabilistic) would give better WiFi AP estimation.
- **GPS error**
  GPS position is imprecise, and GPS measurement is taken as static and correct which is not the case. "When your GPSr tells you the EPE is 40 feet, what it is really saying is "I am pretty sure I know where we are... give or take 40 feet"[3]
  This means that GPS devices provide the information how incorrect GPS measurement is.

STATISTICS ABOUT GPS ERRORS IN THE SYSTEM (in meters)

Table 1

min	max	avg	median	mode
2.0	248.00	110.128	71.92	10

From the Table 1 it can be seen that 10 is the most common value, this means that each measurement does not represent a single point P but a circle with *radius=10m*. Figure 3 shows the distribution of values of GPS error. It can be safely concluded that the error of 10m is appropriate. Assumption is that this small error will average out during time by the large amount of trials.

CONCLUSION

This paper describes solutions to the several specific problems, however there are different approaches that may provide different results. As a part of the future work one such approach is the probabilistic approach; instead of geometric analysis, calculation of probability

[3] http://www.cacheopedia.com/wiki/Estimated_position_error

is done using input data. It would be interesting to see the difference between geometric and probabilistic WiFi AP sequence determination. Part of the future work is a final implementation of this solution; it should be deployed as a web service that can be used in many applications.

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