# OPTIMIZED SEARCHING TECHNIQUE FOR LOCATING MOBILE USERS IN CELLULAR NETWORK

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**ABSTRACT**

*Cellular telephony systems, where locations of a mobile users may be unknown at some times, are becoming more common. Mobile users are roaming in a zone and reports its location only if it leaves the zone entirely. Due to search bandwidth, delay constraints and very often the potential locations of different users overlap, the problem of a concurrent search for many users is different from the problem of searching for a single user. In reality, a cellular network has to serve many competing search requests sharing a limited bandwidth.*

*The system develops a novel method of maximizing the expected rate of successful searches under delay and bandwidth constraints. An approximation algorithm is proposed, that is optimal for most probable cases, and nearly optimal for the worst-case condition.*

*The proposed optimized search strategy outperforms a greedy search strategy, which considers only the users' location probabilities and ignores their deadline constraints. Under certain conditions, the expected rate of successful searches generated by the proposed method is twice the equivalent rate generated by the greedy search strategy. In addition, the proposed search strategy outperforms a simple heuristic algorithm that searches around the user last known location.*

**INTRODUCTION**

Wireless communications have become very pervasive. The number of mobile phones and wireless Internet users has increased significantly in recent years. Traditionally, first-generation wireless networks were targeted primarily at voice and data communications occurring at low data rates.

Recently, I have seen the evolution of second- and third-generation wireless systems that incorporate the features provided by broadband. In addition to supporting mobility, broadband also aims to support multimedia traffic, with quality of service (QoS) assurance. I have also seen the presence of different air interface technologies, and the need for interoperability has increasingly been recognized by the research community. Wireless networks include local, metropolitan, wide, and global areas.

The proliferation of lightweight, portable computing devices and high-speed wireless local-area networks has enabled users to remain connected while moving about inside buildings. This emerging paradigm has generated a lot of interest in applications and services that are a function of a mobile user's physical location. The goal here is to enable the user to interact effectively with his or her physical surroundings. Examples of such interactions include: printing a document on the nearest printer, locating a mobile user, displaying a map of the immediate surroundings, and guiding a user inside a building. As the surroundings change, so does the computing that happens. The interaction between computing and location may also be less direct. For instance, when in the boss' office, pre-fetch facts and figures on business performance and projects for ready access, but while in the cafeteria, turn on the sports score and stock ticker.

In a Cellular Network, when a call to a mobile user arrives, a mobility management scheme is responsible for finding the current cell in which the mobile user resides. Typically, a mobility management scheme constitutes of a location update scheme and a paging scheme.

In the last decade, many location update schemes were proposed. Basically, these schemes were movement-based, timer-based, distance-based, state-based, velocity-based. Schemes that use a hybrid of the above strategies were also proposed. It was proven in that distance-based schemes achieve better performance compared to movement-based schemes and timer-based schemes. A novel information theoretic approach for location update and derivation of probabilistic information about locations of mobile users was proposed in.

A location area is composed of a number of cells. Some researches assumed that a mobile user sends a location update message to the system whenever it enters a new location area and concentrated on the design of an optimal location area. Other researchers assumed that location areas are given and focused on the decision problem of whether a mobile user should send a location update message then it enters a new location area.

Recently, a convex optimization problem was formulated to minimize the costs of location update and paging in the movement-based location update scheme. In a continuous formulation for the problem of one-dimensional location area design is proposed to overcome the computational difficulty associated with the original combinatorial formulation.

In an improved probabilistic location update scheme was proposed. In probabilistic paging is used for contention free mobility management. A survey on location management schemes could be found in.

There is an intrinsic tradeoff between location update and paging. As the frequency of location update increased, the location uncertainty decreases when the frequency of location update decreases both the location uncertainty and paging cost increase. It is possible to see paging as a more fundamental operation than location update. However as pointed out in “Majority of the research on location management has actually focused on update schemes assuming some obvious of the paging algorithm.

The concept of dividing a location area into paging zones was described in. Lyberopoulos proposed to page the cell that a mobile registered with most recently and then page all other cells in the location area if necessary. Rose and Yates proved that given the probabilistic information about the position of a mobile to minimize the average paging cost, the cells with the higher probabilities must be paged before the cells with the lower probabilities are paged. There are three types of methods to obtain the probabilistic information about the locations of mobile users: geographical computation, empirical data, and mathematical models.

All the above works on paging focused on the problem of searching for a single mobile user and assumed that some straightforward strategy of searching for multiple users, such as sequential search is used. I propose an efficient and low-complexity algorithm to concurrently locate mobile users within time slots.

## LITERATURE REVIEW

Previous work in the area of location and tracking system falls into the following four broad categories: (1) IR-based systems (2) indoor RF-based systems (3) wide-area cellular-based systems, and (4) everything else, e.g. ultrasound, magnetic fields, etc.

The seminal work in IR-based location systems is the *Active Badge* system reported in [8], [12]. In this system, a badge worn by a person emits a unique IR signal every 10 seconds. Sensors placed at known positions within a building pick up the unique identifiers and relay these to the location manager software. While this system provides accurate location information, it suffers from several drawbacks: (a) it scales poorly due to the limited range of IR, (b) it incurs significant installation and maintenance costs, and (c) it performs poorly in the presence of direct sunlight, which is likely to be a problem in rooms with windows. Another system based on IR technology is described in [9]. IR transmitters are attached to the ceiling at known positions in the building. An optical sensor on a head-mounted unit senses the IR beacons, which enables the system software to determine the user's location. This system suffers from similar drawbacks as the Active Badge system.

An RF-based location-determination system called the *Duress Alarm Location System* (DALS) [13]. This system uses RF signal strengths to determine user location in a manner similar to our basic system. However, this system differs significantly from our enhanced system, which I describe in this paper. Also, DALS is different from our basic system in that it (a) depends on specialized hardware (b) requires infrastructure deployment over and above a wireless data network, (c) does not take into consideration the effect of the user’s body orientation on RF signals, which our study shows can be significant, and (d) does not take RF propagation into account. Another interesting indoor RF system is the 3D-iD RF tag system built by Pinpoint Corporation [14]. Antennas planted around a facility emit RF signals at 2.4 GHz. Tags, acting like RF mirrors, transmit a response signal at 5.8 GHz along with an identification code. Various antennas receive the signal, and send the results to cell controllers, which triangulate the reflections to determine the tag's whereabouts. The system’s locating ability varies depending on the number of antennas installed in an area but the best advertised resolution is 10 feet. The cost of an entire system is quite high. Once again Pinpoint’s system differs from our system in that (a) it requires specialized hardware to do location determination, (b) they use signal-processing techniques that are significantly different from ours, and (c) their system does not include high-speed data networking capability.

The Daedalus project, a briefly mentions a wireless LAN based system for location estimation. This is a very coarse-grained user location system. Access points (APs) transmit beacons augmented with their physical coordinates. A mobile host estimates its location to be the same as that of the AP to which it is attached. Consequently, the accuracy of the system is limited by the (possibly large) cell size In the wide-area cellular arena, several location determination systems have recently been proposed. The technological alternatives for locating cellular telephones involve measuring the signal attenuation, the angle of arrival (AOA), and/or the time difference of arrival (TDOA). While these systems have been found to be promising in outdoor environments, their effectiveness in indoor environments is limited by the multiple reflections suffered by the RF signal, and the inability of off-the-shelf and inexpensive hardware to provide fine-grain time synchronization. Systems based on the Global Positioning System (GPS), while very useful outdoors, are ineffective indoors because buildings block GPS transmissions.

Researchers have also built systems using alternative technologies. One uses pulsed DC magnetic fields to determine user orientation while another uses ultrasound signals to determine user location. While these technologies and systems are very interesting, they generally suffer the same drawbacks as their IR and RF-tag counterparts. Their specialized hardware is generally targeted at niche markets, tending to make the system cost prohibitive, range limited, and unsuitable for large-scale deployment.

Our work differs from previous work in that I tackle the problem of people location and tracking using the widely available RF-based wireless LANs. With data networking speeds of up to 10 Mbps, wireless LANs have gained rapid acceptance and are widely being deployed in offices, schools, homes etc. Besides the existing wireless LAN our system does not require any additional hardware and can be enabled using purely software means.

## METHODOLOGY

To account for the changes in the environment, I use multiple Radio Maps reflecting different environmental states. This brings up two questions: (1) how many Radio Maps should RADAR construct, and (2) how should RADAR dynamically pick the Radio Map that best represents the current radio environment.

I designed a novel solution to both of these problems by using the access points (APs) to calibrate the environment. The critical observation is that the APs are at fixed and known locations. Each AP listens for beacons (and other packets) from other APs within range and records the corresponding signal strength. The fixed location of the APs implies that any significant change in the signal strength is solely due to a shift in the radio environment.

**Path Discovery**

Every node maintains two separate counters:

Node sequence number – Maintain freshness information of route Broadcast id– Incremented for every new RREQ determine when there has been a significant shift in the radio environment.

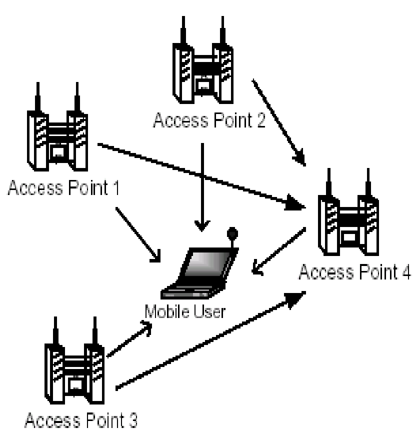


**Fig1 : Access point-based environmental profiling: Beacon packets from neighboring APs are used to estimate (known) ocation of the target AP (AP4) using different Radio Maps.**

RREQ (Route Request packet)

*<Source and destination address and source and destination sequence number, broadcast id, hop count>*

Each node that cannot satisfy the RREQ rebroadcasts to its own neighbours after increasing *hop count.* Each node keeps expiration timers to remove old RREQ and routes from its cache.

RREP (Route Reply packet)

Unicast back to the neighbour from which it received the first RREQ.

*<Source and destination address, destination sequence number, hop count, lifetime>*

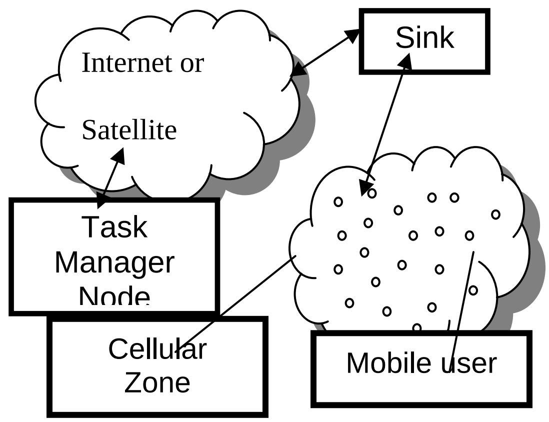


**Fig 2 : Path Identifier in the mobile user domain**

I consider cellular zones with n cells and m mobile users roaming among the cells. The location of the users is uncertain and is given by m probability distribution vectors. The Conference Call Search problem (CCS) deals with tracking a set of mobile users, in order to establish a call between all of them. The search is performed in a limited number of rounds, and the goal is to minimize the expected search cost. In the "unit cost model", a single query for a cell outputs a list of users located in that cell. The "bounded bandwidth" model allows a query for a single user per cell in each round. I discuss two types of protocols; semi-adaptive and adaptive search protocols a semi-adaptive search protocols decides on all the requests in advance, but it stops searching for a user once it is found. An adaptive search protocol stops searching for a user once it has been found (and its search strategy may depend on the subsets of users that were found in each previous round). I establish the differences between the distinct protocol types and answer some open questions which were posed in previous work on the subject. Polynomial time algorithms for finding optimal semi-adaptive and adaptive search protocols for two users

I describe one of our results. I consider the problem of computing an optimal semi-adaptive search protocol for tight instances of CCS. Below I show a polynomial time algorithm for solving this problem for two users.

I describe a fast algorithm to solve the two-users two rounds case (this solution holds for adaptive systems as well). I assume that there are two users and two rounds and $B = 1$. An open question is checked on to decide if computing an optimal adaptive search protocol is polynomially solvable. I note that in this case the semi-adaptive search protocol is equivalent to the adaptive search protocol. Therefore, by computing an optimal semi-adaptive search protocol in polynomial time, I provide a positive answer for this question.

Our algorithm, denoted by *Alg*, guesses $k$ that is defined as the number of cells that an optimal solution pages for the first user in the first round. This guess is implemented by an exhaustive enumeration using the fact that $k$ is an integer in the interval $[0; n]$, and then returning the best solution obtained during the exhaustive enumeration. I next analyze the iteration in which the guess is correct.
Denote by *Ik i* = *p*1*;i* ¢(*n*¡*k*)¡*p*2*;i* ¢*k* the *index* of cell *i* in the *k*-th iteration.

Our algorithm sorts the indices of the cells in non-decreasing order, and then it picks the first $k$ cells (in the sorted list). These picked cells are paged for the first user in the first round, whereas the other cells are paged for the second user in the first round. Finally an optimized search approach to locate multiple mobile users was derived with better performance results compared with adaptive search model.

**CONCLUSION**

I have proposed the optimized search approach to locate a batch of M mobile users in the cellular network within M time slots based on the probabilistic information about the locations of mobile users. I have shown that even when there is only one paging channel in a cell, based on the optimized search approach, it is possible to simultaneously locate a number of mobile users and therefore reduce the average paging cost

As the total number of mobile users increases, the performance difference between the optimized search heuristic algorithm and the simple heuristic algorithm increases. Depending on the total number of cells in the network, total number of mobile users to be located, and the probabilistic information about the locations of mobile users, the reduction of the average paging cost due to the optimized search heuristic algorithm ranges from 40 % to 85%.. As the total number of mobile users to be located increases, the performance of the optimized search heuristic algorithm becomes better. Similarly, as the total number of cells in the network becomes larger, the optimized search heuristic algorithm produces more reduction in the average paging cost. As the decay factor approaches zero, a mobile user tends to appear in a very small set of cells and it takes minimum paging cost to locate the mobile user.

As the cell size in the next-generation cellular network becomes Smaller, the total number of cells in the network increases. Furthermore, the total number of mobile users will continue to increase as well. Therefore, being able to locate mobile users with minimum average paging cost is an important benefit. Our proposed optimized search scheme could be applied in the mobility management protocols in the next-generation cellular network. Proposed algorithm, performs well and does not require high computational complexity.

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