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Locating Mobile Phones on a City Map Using SMS Technology

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Abstract: Finding the location of a mobile phone is one of the crucial challenges in modern telecommunication system. This study proposes a solution of locating a mobile phone on a city map using SMS (Short Message Service). This study intends to help mobile phone users to find out his/her location on a geographical map. The proposed method is GPS-free and it requires no additional technology to be added to existing mobile phones. It uses well-established algorithms to locate a mobile phone on a geographical map and then sends the position-on-a-map to the user mobile by an SMS.

Key words: Direction of Arrival (DoA), Received Signal Strength Indication (RSSI), Radio Direction Finding (RDF)

INTRODUCTION

Pedestrian network is still not financially viable for Third World countries. This leads to lack of proper city navigation for traveling individuals. Cities, that are very crowded and have a complex communication system, are very hard to travel in. Mobile phones can play an important role to solve this problem. As mobile phones are getting cheaper day-by-day, most people have one today. We can use these phones to pin point its owner. Our method will graphically represents the location on a map. This will allow the user to interact using his/her mobile phone and find relevant information about the given location including the location of the user. This will help travelers locate their destinations and reach there faster. This method is a cheaper alternative to current available solutions in the market using Global Positioning System (GPS) since it does not require any additional transceiver (as in the case of GPS system). This method will have an impact on many areas. Some of the possible areas are listed below:

- Courier Service Agencies-Can ask their clients to send their location enabling them to track them easily.
- Door-Door Delivery Services-same as above.
- Personnel Locator-People can find their location using this method and also send their location to their friends enabling them to locate each other.

Our method relies on the following techniques:

- Finding the direction of a mobile phone with respect to a base station.
- Finding the distance of the mobile phone from the base station.
- Sending a small graphical image of a map as SMS.

DIRECTION FINDING

In mobile applications that have continuous data exchange in both directions, such as voice communication in cell phone applications, relative direction information may be acquired continuously and constantly by integrating a Radio Direction Finding (RDF) algorithm in the physical layer, with the use of phased arrays or switched beam arrays (Lehne and Pettersen, 1999). There are many documents discussing how the directional beam of a mobile terminal, can be used to minimize the effect of multipath (Preston *et al*., 1998; Jianxia *et al*., 2000; Yng *et al*., 1994). Most of the proposed algorithms are targeting cell phones and they use phased arrays in the base station. These algorithms are inadequate, since they assume that there is a continuous flow of data in both directions of the communication link. Moreover they are based on phased arrays, which are not easily integrated in a mobile station, due to their cost and size.

Switched antenna arrays are more suitable due to their reduced complexity. Preston *et al.* (1998) have

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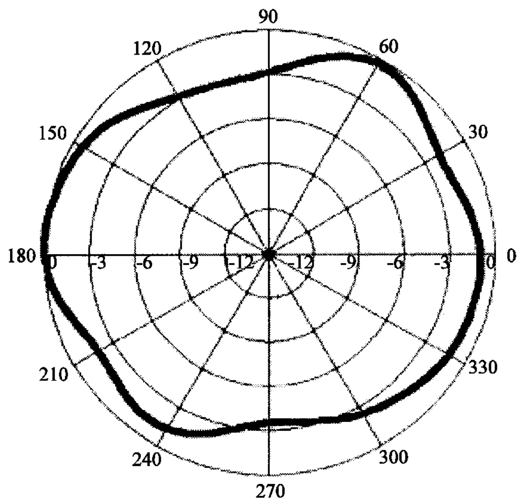

Fig. 1: Switched array radiation pattern-1

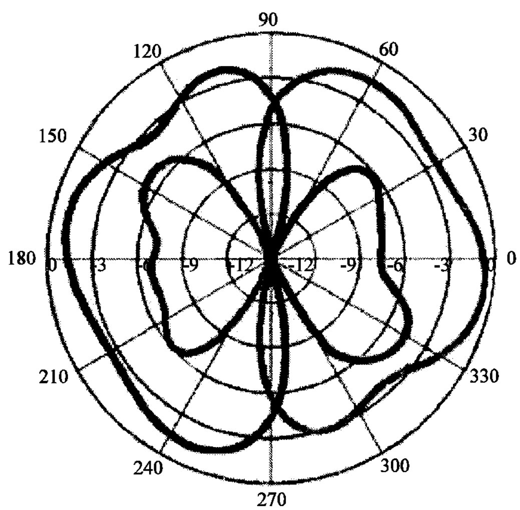

Fig. 2: Switched array radiation pattern-2

proposed a method for determining DoA information using a switched beam array. DoA finding methods are based on the following concept:

The switched beam array produces N different radiation patterns, that divide the azimuth plane in N equal angular sectors. To find the DoA, the receiver scans all these patterns. It then estimates the power of the received signal by measuring the RSSI signal in each sector. By comparing the different RSSI values, the receiver can determine the relative angle of arrival of the incoming signal. The accuracy with which the angle can be determined depends on the comparison method. Since the computational complexity of these methods is low, the time needed to compute the relative DoA is proportional to the total number of the N different array sectors.

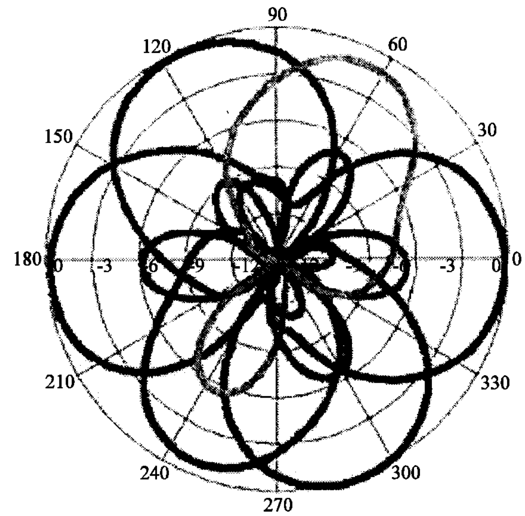

Fig. 3: Switched array radiation pattern-3

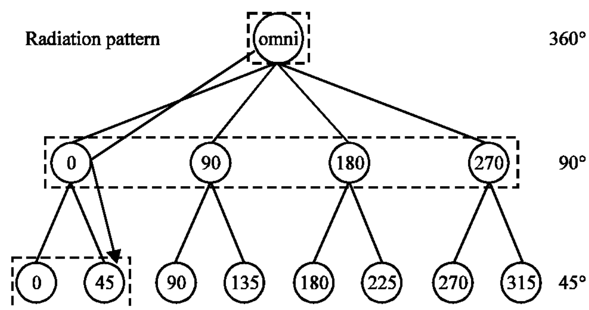

Fig. 4: Tree-like search algorithm for bandwidths of 90 and 45°

The method proposed in this study uses a switched beam array that produces omnidirectional and directional beams. Such switched beam arrays are categorized as patch (Iwasaki, 1999), slot (Kalis, 2000), or monopole arrays.

Figure 1-3 show all the different radiation patterns that are adequate to cover all the azimuth angles by driving a different number of elements. This array either generates an omnidirectional radiation pattern, or divides the azimuth plane in a number of equal angular sectors. There are two types of angular sectors, the wide angle and the narrow angle sectors.

A switched beam array, that can produce the following radiation patterns, is considered here.

- An omnidirectional pattern.
- N1 wide-angle sectors of 360°/N1 each.
- N1.N2 narrow angle sectors of 360°/N1.N2 each.

When the receiver is in idle mode, the antenna is switched to the omnidirectional pattern. Once the RSSI signal exceeds a certain threshold level, meaning that the antenna has received an incident signal, the procedure for determining the transmitter's relative direction is activated. The receiver initially measures the RSSI of all N1 sectors. Once the sector with the best signal is determined, then the receiver repeats the same procedure for all N2 narrower sectors of this sector. This tree-like search algorithm continues until the N_k sector with the best performance is determined and the DoA finding method's accuracy is equal to the beam-width of the narrowest sector. Figure 4 shows how the algorithm evolves in a switched array that has radiation patterns of 90 and 45°. In idle mode, the array operates in the omnidirectional configuration, but when transmission has been detected, the array initially uses four 90° radiation patterns for a first estimate of the direction of arrival and then uses the two 45° radiation patterns that determine the most accurate estimation of DoA. Following this procedure, the proposed RDF algorithm always finds the sector that receives the strongest signal, regardless of the number and strength of the multi-paths received by the antenna (Kalis and Antonakopoulos, 2002). The finer the sectors, the more accurate the direction. But too much accuracy makes the method slow by which time the mobile may change position. Once the direction of the mobile with respect to the base station has been determined, the problem focuses on finding the distance of the mobile phone from the base station. If two base stations are used simultaneously to determine the DoA, then the position of the phone can be determined by triangulation (no distance calculation is needed for this) (Yilin, 2002).

DISTANCE COMPUTATION

There are various methods to calculate the relative distance of a mobile phone from a base station. One such method is Time of Arrival (TOA). It is assumed on the concept that the propagation time of the radio wave is directly proportional to its traversed range. So multiplying the speed of light to the time obtains the range from the mobile phone to the communicating base station (Yilin, 2002) Time is calculated first by sending a beacon frame from the base station to the mobile phone at t_0. On receiving the frame, the phone will response with another beacon frame. When the base station receives the response at t_1, it determines the time-delay by the equation $(t_1\text{-}t_0)/2$. This is carried out repeatedly for obtaining better accuracy.

Another method is concerned with signal energy loss. The attenuation factor (L) is defined by the ratio of the transmitted signal strength to the received signal strength in logarithmic scale. We know the transmitted signal strength. We also calculate the received signal strength. Now from the given formula $L = 10 \log_{10} (4\pi d/\lambda)^2$, we can find the value of d which is the distance of the phone from the base station. Here λ is the signal wave length.

SIMULATED OUTPUT

Using smart antenna the direction of a mobile (requestor) can be found. But its accuracy depends on the number of antennas. The direction of arrival was calculated accurately by simulating the aforementioned technique. The distance of a mobile phone with respect to the base station can be calculated by using two methods-using TOA (Time of Arrival) and analyzing received signal strength.

Using TOA (Time of Arrival): In this method, distance is calculated using d = vt formula, where v = the speed of light = 299792458 meter/s and $t = (t_1\text{-}t_0)/2$. t_0 = the time of sending beacon frame to requestor and t_1 = the time of receiving beacon frame from the requestor. The result obtained from simulation is shown in Table 1.

By analyzing received signal strength: In this method, distance is calculated by the ratio of received signal

Table 1: Result of simulation using TOA

No.	Expected direction (in degrees)	Direction obtained from simulation (in degrees)	t_0 (nano second)	t_1 (nano second)	t (nano second)	d (meter)	Expected distance (meter)
1	30	29.789	0	1334	667	199.96	200
2	30	29.998	0	666	333	99.78	100
3	60	60.021	0	3334	1667	499.89	500
4	80	79.998	0	6670	3335	999.91	1000
5	120	120.012	0	6668	3334	999.51	1000

Table 2: Result of simulation by analyzing received signal strength

No.	Expected direction (in degrees)	Direction obtained from simulation (in degrees)	P_2 (nano watt)	P_1 (watt)	L (ratio)	d (meter)	Expected distance (meter)
1	30	29.789	86.3	5	77.63	199.96	200
2	30	29.998	345	5	71.61	99.78	100
3	60	60.021	13.8	5	85.59	499.89	500
4	80	79.998	3.45	5	91.61	999.91	1000
5	120	120.012	3.45	5	91.60	999.51	1000

strength and transmitted signal strength using the formula $L = 10 \log_{10} (4\pi d/\lambda)^2$ db ,where $L = 10 \log_{10}(P_2/P_1)$, P_2 = received signal strength, P_1= transmitted signal strength, λ = wave length = speed of light / radio frequency. Here we used GSM - 900 MHz as radio frequency. So, λ =0.33 meter was our calculated result. The simulated result is shown in Table 2.

Sending SMS: In response to user request for finding his/her location, the base station first determines the direction (angle in degrees) and the distance (in meters) of the mobile phone using the approaches described above. Each base station maintains a map of its surrounding region, more precisely, the map of the area it covers. The base station then uses this information to point out the user's location in the map. The location of the user on the map is converted into a small graphical image (or logo) and then is sent to the user as an SMS. One thing that is to be noted is that the image format is different for different phone models. So when the user makes the initial request, the phone model must also be sent as a part of the request so that the base station can generate the appropriate image file for that phone.

CONCLUSION

A new technique has been proposed to locate a mobile phone on a city map using existing technology. The proposed method integrates three well known techniques to achieve its purpose. The Direction of Arrival (DoA) has been calculated by using a novel divide-and-conquer algorithm. It has also been shown that the distance of a mobile phone from a base station can be calculated with high degree of accuracy by using TOA or by analyzing received signal strength. Finally, the location of the mobile phone on the city map is sent to the user (requesting mobile phone) by an SMS. The proposed method is cheaper than GPS because GPS requires that every mobile device must have a transceiver. The proposed method, however, requires no change in the existing mobile phones. Most phones support SMS and therefore it is a convenient approach to send small images/logos.

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