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Weather Independent Positioning of MS Using Power Slope Patterning Algorithm via One BS

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***Abstract*—Numerous methods have been applied to accurately determine the location of a mobile station (MS), of which, most of them require weather dependent parameters. An efficient method of positioning and mapping a mobile station in varying weather conditions, without the use of Global Positioning System (GPS); operable using the pre-established infrastructure is proposed. Another advantage of this system is that, only one base station (BS) is utilized. The uplink control channel power from a mobile station received by a base station determines the power to be transmitted to that user. With the change of weather condition, the power data also changes. However, the collective power level changes uniformly; allowing their slopes to remain constant in any case. Extracting the slope of the plot eludes the system from power amplitude dependency, henceforth making this system exclusive to weather change.**

***Keywords*—mobile positioning, slope patterning, single base station, control signal strength**

I. Introduction

Locating a mobile user is a priority task for every mobile operator. In order to perform this task, the most widely accepted method is the use of GPS [1–3]. But the limiting condition of these methods is the need of activated GPS from the user end. Other attempts to locate mobile station (MS) utilized the combination of separate base stations (BS) to triangulate the position of the MS [4]. A better method of positioning is proposed using only one BS.

In order to enable mobile positioning without the need of any internet connection, a novel method is proposed in which the power data of a base station is used. Every modern networking system is equipped with a means to determine the power needed to be transmitted from BS to the MS based on their distance [5]. An example if this is the closed loop system [6, 7], where the power levels of the mobile users are equalized [8, 9]. This change of power is a core data which is used for our positioning system. Extraction of the rate of change of the slope angle of the power data with respect to distance enables us to perform positioning in any weather condition. The extracted data after being compared to that stored in database gives percentage error. The pattern with the least percentage error under a BS resembles the road in which the MS is located. Provided that the correct pattern is successfully determined, the actual location of the MS on the road is determined by comparing its current power data with that of the database.

II. Distance Calculation

An MS always keeps communicating with its nearest BS for the information required for initializing a successful call at any instant of time. This information is conveyed through the control channel (CC). Power level of CC is always constant even if a call is in progress. Control channel's level of power shifts only when the MS is wielded from BS. So, by utilizing power level information provided by the operators, distance between MS and BS can be calculated by using equation (1) given below [10].

$$D = \frac{\lambda}{4\pi}\sqrt{\frac{MP * GC}{BSP}} \tag{1}$$

Here, D is distance, MP is mobile power, GC is gain constant and BSP is base station power. All data were collected from three roads close to Biplob Udyan, CDA Avenue, Chittagong Division, Bangladesh and the roads are shown in Fig. 1 marked with red, blue and black colors.

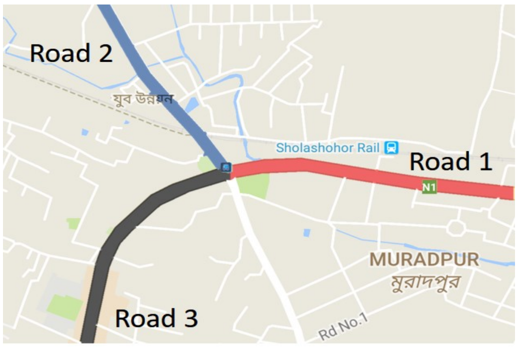

Fig. 1. Roads from which data were collected

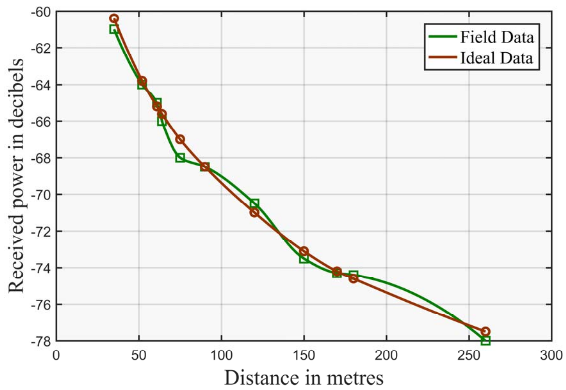

Fig. 2. Field & ideal received MS power vs. distance

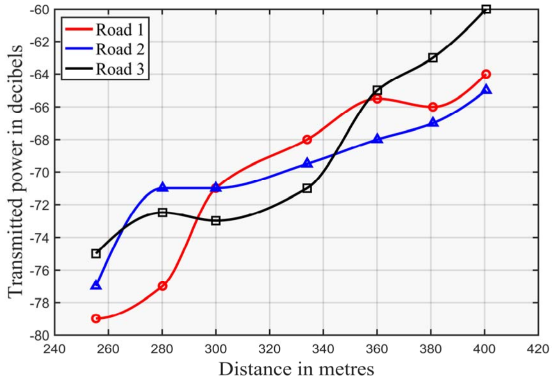

Fig. 3. Power of signal transmitted by BS for each road

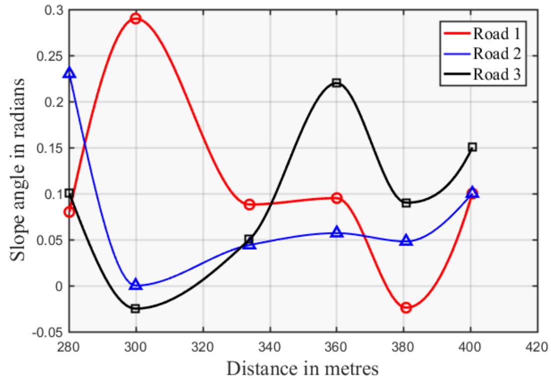

Fig. 5. Slope angle of the transmitted signal power by BS

The relation between field data and ideal received power for a generic road is shown in Fig. 2. It is clear that the field data closely resembles the actual data. So a database of power pattern is built on three roads with one junction. The transmitted power vs. distance relations are shown in Fig. 3.

III. Slope Extraction

The graph of power vs. distance is used to extract a data of slope angle (θ) vs. distance (D) for the given user data. This process relieves our system from the reliance on amplitude of power data because the collective power level changes uniformly. Therefore, for different weather conditions and corresponding power levels, the slopes remain the same. This is shown using field data in Fig. 4. Therefore, the effect of change of weather on power amplitude is bypassed. Equation (2) is used here.

$$\theta(i) = \tan^{-1}\frac{P(i)-P(i-1)}{D(i)-D(i-1)} \tag{2}$$

Here, θ is slope angle, P is power, D is distance and i is any selected data point . The slope angles obtained from the power data are shown in Fig. 5. From this figure, it is observed that the roads show very distinctive patterns which in return yield exclusive results. The use of slope from P vs. D graph has a significant advantage that this method maintains high efficiency even if the weather condition changes. This is due to the fact that for changes in weather condition, the amplitude of power over a region changes more or less at a similar manner. Therefore, the slope pattern of the P vs. D graph ultimately remains the same.

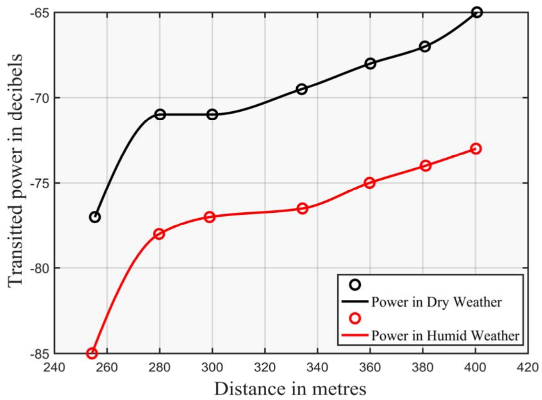

Fig. 4. Transmitted signal power in dry and humid weather

IV. Patterning Data

The rate of change of slope angle is an essential data used for the pattern recognition and error estimation. Every road under a BS footprint yields a unique pattern for the rate of change of θ vs. D. It is determined using equation (3).

$$X(i) = \frac{\theta(i)-\theta(i-1)}{D(i)-D(i-1)} \tag{3}$$

This parameter is finally used to determine the correlation between the data acquired from the user to the base data.

V. Comparison between Base Data and User Data

After collecting the user data and plotting the slope angle versus distance, the system compares the data (X') against previously stored base data. Both scaled by one thousand, of different roads under the range of the closest BS with respect to MS by using root mean square error (RMSE) formula given below:

$$RMSE=\sqrt{\frac{1}{N}\sum_{i=0}^{N}[X(i)-X'(i)]^2} \tag{4}$$

Here, N is the number of points in the graph that to be compared, $X(i)$ and $X'(i)$ denotes the user data and the base data correspondingly at i^{th} point in the graph. Reason behind using *RMSE* is that, the method avoids taking absolute value of the difference and increases with the variance associated with the frequency distribution of error magnitudes increases. After calculating errors using above formula the system concludes that the MS is on the road which has the lowest RMSE value.

For the database values of road 1, 2 & 3 the average of RMSE taken for a MS in road 1 in various weather conditions such as for dry and humid conditions yielded the results shown in Table 1.

TABLE I. Values of RMSE for a User located in Road 1

RMSE / **Roads**	**Dry Weather**	**Humid Weather**	**Average**
Road 1	0.073	0.064	0.0685
Road 2	13.338	13.272	13.305
Road 3	11.321	11.305	11.313

VI. ROAD SELECTION

As there is significantly less line of sight between MS and BS in the rural areas there is always complication in estimating the position of MS using the data of control channel power level. This is because, the power level of CC can be significantly low even if the MS is close to the BS due to different objects that lie between them which cause distortion of power level of CC. But the proposed method eliminates the problem of estimating the position of MS in the rural area as it does not depend on CC power status.

It was mentioned before that the power level of CC in various points on a road is stored in the data base in the BS. Thus, the only real challenge is to identify the road of a MS for the first time, as all roads under a particular BS have to be taken into account. After having the estimation of the road in which the MS is located in real time, the system can easily predict the next position as the power pattern of the road is known. This is possible because each and every road surrounding a BS has to have different CC power pattern because objects surrounding them is different. So, each MS on different road has a unique CC power pattern. Which in turn can also be said that, a single MS on a road also has a particular power pattern on different positions of the road. This is how a MS location is tracked down using CC power pattern.

VII. MS POSITIONING

Following the data obtained from Table 1, it is evident that the system successfully performed the task of predicting the correct road on which the MS was travelling. The next task of the system being, positioning of the MS, was performed via equation (5).

$$\alpha_j = RMSE_j \left| \{ \left| \theta(i) \right| - \left| \theta'(i) \right| \} \right| \quad (5)$$

Where, α_j and $RMSE_j$ are the deviation factor and RMSE value of a specific road and $\theta'(i)$ is the slope angle for i^{th} point in base data. The plot obtained is shown in Fig. 6.

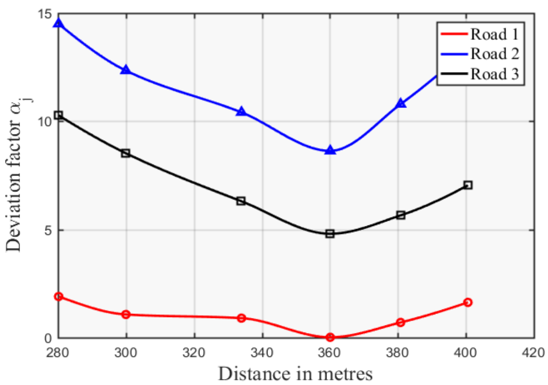

Fig. 6. Deviation factors of points in given roads

As seen from the figure, the deviation factor has the least value corresponding to 360 m in road 1. Therefore, the MS is accurately positioned. In urban areas if there is an open field across a BS and no significant obstacle stands between MS and BS, the position of MS can be found by calculating the distance using equation (1).

A great advantage of the proposed method is that, after locating the MS once, whenever it comes to a junction, the system only needs to check RMSE for the roads across the junction to decide which path the MS has taken. Hence, the calculation time and complexity both are reduced.

Under the condition that a MS transfers from one cell to another, its information can be passed on to the new BS. Thereby avoiding the hassle of comparison with all roads under the new BS.

VIII. CONCLUSION

The model thus ensures a unique and superior method of positioning a MS by a simple yet elegant algorithm which maintains high accuracy of over 90% despite variance in weather conditions, which otherwise lay great impact on existing methods. Following rigorous scrutiny, the results uphold the theory of this method, thereby validating the prospect of materializing it.

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