Mobile Locating Scheme in Cellular System Using Modified TA Range and Base Station Characteristics

Ming-Cheng Liang, Nann-Luh Hwang, Cheng-Yu Chen
Department of Electronics Engineering, ISU
1,section 1,Hsueh-Cheng Rd, Ta-Huu Hsiang, Kaohsiung country, Taiwan, R.O.C

ABSTRACT

In this paper, we study a hybrid scheme that employs time of arrival (TOA), time difference of arrival (TDOA) and other base station information to accurately predict the position of mobile phone is proposed in this paper. Similar to previous studies [1-2], this hybrid technique only makes use of hardware of existing cellular systems, e.g., GSM or PHS, without extra hardware. A modified TA parameter is used to determine the possible range relationship between the base station and the mobile phone. With this scheme, the mobile station will at least be within 100m from the predicted location. More accurate prediction is possible using this scheme.

(Keywords: Mobile Locating, GSM, PHS, GPS, TA Range)

I. INTRODUCTION

To be able to accurately locate the position of a lost vehicle, a lost child or an injured person is important in modern diversified life. Traditionally, a GPS (Global Position System) enabled device is used to report the location of the mobile station [3-9]. The use of GPS device provides a simple way to locate the mobile station, but that is more expensive than use a mobile phone to locate position. Therefore, We need to develop locating technologies that use GSM system’s parameters, the GPS still have many drawbacks now, in general, increase the power consumption, the size of
the mobile station, the cost and the complexity of the devices.

One serious drawback of these techniques based on GPS is that only a small percent of the mobile devices are equipped with a GPS device. For those people with mobile devices, e.g., a PDA or mobile phone, that is not GPS equipped, it is impossible to locate them using the GPS technique.

In the hybrid technique presented in this paper, the TA is treated as a range related to the resolution of the system modified by other environment related factors as shown in Fig. 1. Due to the popularity of mobile phone in cellular system, it will be a very attractive locating technique if one can accurately locate the mobile station using the cellular system parameters with/without modification.

![Diagram showing TA ranges]

TA=1(Blue); TA=2(Green); TA=3(Red)

Fig. 1 The range of different TA

In this paper, a scheme that makes use of the information between the base station (BS) and mobile station (MS) to determine the mobile station is proposed. Depending on the number of
nearly base stations that use GSM parameters to locate the mobile phone accurately.

II. THE HYBRID METHOD

Traditionally, the time of arrival (TOA) information is used to find the distance between the base station and the mobile station. An intersection between the TA range from different base station gives the estimated location of the mobile station. The traditional TA scheme cannot accurately predict the location since the TA can only actually predicts a possible range instead of a possible line.

One advantage of this scheme is that the mobile user will be in the region predicted if the parameters are correctly measured. Therefore, the accurate locating problem has become a way to narrow down the range of intersection. Some base station related data could be used to further narrow down the range of the mobile station. These characteristic data includes the received power distribution, the sectional directivity of the antenna, the height and location of the base station, etc.

A. Time of Arrival (TOA)

TA is a measure for propagation time between mobile station and base station. The TA is used to limit the mobile user to a range as shown in Fig.1. With TA information from more than one base stations and the mobile station, the possible location of the mobile station could be restricted to a narrow region as shown in Fig. 2.
Due to the uncertainty associated with the TA measurement (e.g., 550m for GSM system), it is possible that the possible range of the location is still too large (e.g., 100m away for GSM system) to be accurate. Further reduction is needed in order to give an accurate prediction.

**B. Time Difference of Arrival (TDOA)**

TA is a parameter that measures the time (i.e., distance) between a base station and a mobile station. TDOA is a parameter that measures the TA difference between two base stations. In order to measure the time difference correctly, TDOA requires these two base stations to send out the signal simultaneously.

TDOA provides an additional constrain to restrict the location of the mobile station. The TDOA restriction is a region restricted by two or more hyperbolic curves that is different from TA.
A combination of the TDOA restriction with the TA circles can further limit the mobile location to a smaller region as shown in Fig.3. In the TA and TDOA approach, the location of the base stations should be accurately determined. The accurate location of the base station can be determined using a digital map or using the GPS devices.

Fig.3 Locate the mobile station using TDOA from multiple base stations

The height of the base station antenna might also affect the measurement of TA and TDOA. A study of the effect of antenna height to the effective distance between the base station and mobile station is shown in Fig. 4. The horizontal axis is the distance between the base station and mobile station measured on ground and the vertical axis is the actual distance between the base station and mobile station. There is almost no effect for antenna of 75m or less. The effect is significant only if the antenna is in a very tall building.
Fig. 4 The effect of antenna height to TA

C. Other Related Information

In order to further limit the location of the mobile station, some additional base station parameters, e.g., the received power level and the direction of sectional antenna are used in this study. These parameters could be used to further constrain the mobile station. Due to multiple path effect, the spread of signal could affect the measurement of TA.

In an urban area, the measured TA is usually longer than it should be theoretically. To make up for this excess measurement, the range of the TA will be adjusted accordingly. This adjustment will further reduce the range of possible mobile station location.

D. The Algorithm

In this locating scheme, it is necessary to send and receive signals from more than one base station. Also, it might be necessary to control the sent and received signals from multiple stations simultaneously. The best way to accomplish this control function is to provide a network-wide feature in the mobile network. The architecture is as shown in Fig. 5.
The procedure for this position-locating scheme is as follows:

Step 1: The location-tracking feature for a certain number is initiated at the Service Control Point (SCP).

Step 2: Based on the tracked mobile station’s number, the SCP feature will find the visiting location of the mobile station by sending query to the HLR database.

Step 3: From the VLR database, the SCP feature can determine the current cell for the mobile station and nearby base stations.

Step 4: The SCP feature will determine the location of the base stations from the GIS database.

Step 5: The SCP feature sends request to the mobile switch to ask the base stations to send polling signals to communicate with the mobile station to get the needed information.

Step 6: Based on the received parameters of the mobile station for each base station, the feature in the SCP can draw the TA circles and the TDOA curves according to the GIS base station information. The enclosed region is the possible location of the mobile station.

Step 7: From the enclosed region, choose the geometrical center of the region as the predicted
Step 8: The location of the mobile station could be restricted further. Use other base station parameters to divide the regions into several regions with the mobile station is likely to be in one of the region with certain probability.

Step 9: Find the geometrical center for each region. The center for these regions is the predicted locations for the mobile station with certain probability.

III. EXPERIMENTAL RESULTS

To verify the validity of this scheme, it is necessary to implement the feature in the network of the mobile service provider. In the initial study presented in this paper, we have no access to the network. So, instead of implement the feature in the network, the measurement was done in the mobile station.

A TEMS system is used to assist the mobile station for measuring parameters from different base stations. In this case, TA between base stations and mobile station are measured. However, the TDOA information cannot be obtained correctly in this measurement. So, TA from more base stations are needed to make up for this deficiency.

To accurate locate the mobile station; the TA range is adjusted according to the delay spread of the measured area. A delay-spread pattern is shown in Fig.6 for rural, suburban, urban and bad urban areas. The KaoHsiung metropolitan area has characteristics similar to that of an urban area from previous experience.
Since the TA is an integer value with a resolution related to the system design, the exact range distribution of TA is a range. By measuring more than 200 sites in KaoHsiung area, one has found that a measured TA distribution for different area is shown in Fig.7. Due to the system design, the measured TA value is a digital number which corresponding to a uncertain range near a calculated range. The uncertain range is 550m (about 600m). If there is no error in the measured TA, the measured data should be within 300m from the center that is marked in red in Figure 7. However, from Figure 7, it is found that only about 80% of the measured data is within this range. About 20% of the measured data are shorter than this expected range due to multi-path delay. If one consider the possibility of multi-path delay and slide the range window at different distance, the best case will be the green line case that includes about 90% of the measured data as shown in Figure 7. This is because that the multi-path might or might not occur for the case measured. If we expand the window (the blue one) to include both the case with and without multi-path, we will include more than 95% of the measured data. This data can be reflected in the TA range information. Also, the TA distribution data coincides with the delay-spread prediction.
Fig. 7 Measured TA distance distribution

When we considered the delay spread information, we knew the TA value that could be computed into the range of $R$, as shown follow:

\[
\begin{align*}
TA &= 0 \quad 0 < R < 275(m) \\
TA &= 1 \quad 275 < R < 832.5(m) \\
TA &= 2 \quad 832.5 < R < 1387.5(m) \\
TA &= 3 \quad 1387.5 < R < 1942.5(m) \\
TA &= 4 \quad 1942.5 < R < 2497.5(m) \\
TA &= 5 \quad 2497.5 < R < 3052.5(m)
\end{align*}
\]

With this adjusted TA region, one has randomly select several different mobile locations for calculation. To compensate for the lack of TDOA information, ten stations are used in this test which result is shown in Fig. 8. The horizontal axis in Fig. 8 represents the error between the predict location and the actual location of the mobile user.
From Fig. 8, it was found that the restricted region is less than 50m in diameter for 35% of the cases studied. For the other 65% of the cases studied, the restricted area is between 50m and 100m. From the data found so far, there is no data outside the predicted region found. In all cases studied, it was found that the mobile user is in the confined region predicted for all cases, (i.e., no case with 0m as shown in Fig.8. By using TA range interception technique without TDOA.)

IV. CONCLUSIONS

In this paper, we studied mobile-location scheme that based on TA and TDOA is presented. We knew the TA and TDOA value will be different when we measured it in different terrain and environment. So we need to modify the TA and TDOA range for accurately restricting the mobile users. The result was measured using a mobile station instead of the mobile system. In this case, the TDOA information cannot be obtained. Nevertheless, by using more base stations (i.e., 10 stations in this study), it is still possible to obtain similar results.

From the measured result, one has found that the mobile station is within the predicted area imposed using this scheme for all the cases studied. This result is exciting since the only work needed is to reduce the range of the predicted region if the user is always within the predicted region. In this paper, one uses the propagation delay information to reduce the range of TA. Other base station related information could also be used to further reduce the range. These possibilities are currently under investigation. For all cases studied, the restricted region is less
than 100m in diameters. Also, about 35% of the case, the restricted area is less than 50m in diameter.

If a network measurement feature is implemented and the TDOA information is also included, it is expected that the restricted region can be reduced further. A much more accurate prediction is possible. If the current accuracy is acceptable, it is possible that one can obtain the same result using less base stations.

V. ACKNOWLEDGEMENTS

This research is partially supported by DGT of MOTC and partially supported by the National Science Console, Taiwan, R.O.C. under contract number NSC 91-2213-E-214-038. Their help in this work is much appreciated.

REFERENCES


