TRACKING AND POSITIONING OF MOBILE SYSTEMS IN TELECOMMUNICATION NETWORKS

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Abstract : Mobile positioning technology has become an important area of research, for emergency as well as for commercial services.Mobile positioning in cellular networks will provide several services such as, locating stolen mobiles, emergency calls, different billing tariffs depending on where the call is originated, and methods to predict the user movement inside a region. The evolution to location-dependent services and applications in wireless systems continues to require the development of more accurate and reliable mobile positioning technologies. The major challenge to accurate location estimation is in creating techniques that yield acceptable performance when the direct path from the transmitter to the receiver is intermittently blocked. This is the Non-Line-Of-Sight (NLOS) problem, and it is known to be a major source of error since it systematically causes mobile to appear farther away from the base station (BS) than it actually is, thereby increasing the positioning error.

In this paper, we present a simple method for mobile telephone tracking and positioning with high accuracy. Through this we will discuss some technology used for mobile positioning and tracking.

1. Introduction to Mobile Technology

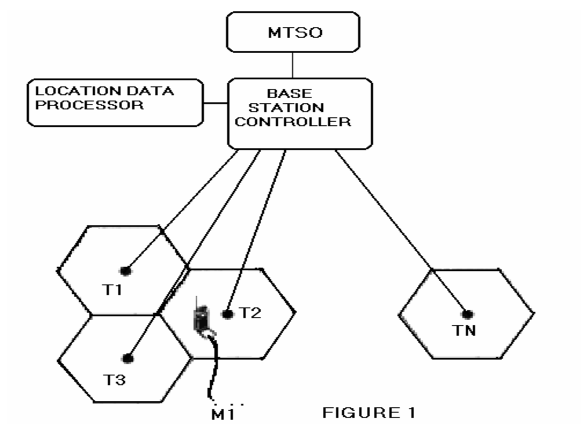


Fig 1 Configuration of a typical mobile telecommunication network.

As shown in Figure 1, the mobile telecommunication network includes a several base stations (BSs) T1 to TN for providing mobile telecommunication service to a mobile subscriber through a mobile telephone M1, a base station controller (BSC) for controlling the BSs T1 to TN, and a mobile telephone switching office (MTSO) for connecting the BSC to another BTS or a PSTN (Public Switched Telephone Network). In a cellular mobile telecommunication network, the whole service area is divided into a several coverage areas having respective base stations (BS). Each BS coverage area is called a "cell." Each BS is provided with a frequency of a range between 900 to 2100 MHz. More than one cells can use same frequency. Only condition is that no two adjacent cells must have same frequencies. An MTSO controls these BSs so that a subscriber can continue his call without interruption while moving between different cells. The MTSO can reduce the time required for calling a subscriber by locating the cell of the subscriber. In case of an emergency like a fire, or a patient needing first aid treatment, the mobile subscriber should be accurately located. Tracking the location of a mobile subscriber within the boundary of a cell in a mobile telecommunication network is known as "location based services Mobile technology includes mainly two functions. They are call fixing and hands-off process. All the BSs are sending a signal of power 25 to 30w to the mobile unit. When a user switches ON his mobile, it will search for the strongest signal and got connected to that BS. Then the mobile unit sends an identification signal to the BS. When he fixes a call, the BS accepts the request and sends the request to the BSC and MTSO. Then the MTSO will searches where the subscriber is and connects the call.When a user moves to another cell the MTSO will change the frequency allotted to it and allots the frequency of the new BS.For both these processes GEOLOCATION of the mobile unit is essential.

2.ARCHITECTURE OF A GEOLOCATION

An example of geo location system architecture [KOS00] is shown in Figure. As we said earlier, in order to fix a call the subscriber we are calling must be located accurately. A geolocation service provider provides location information and location aware services to subscribers. Upon a request from a subscriber for location information about an MS, the service provider will contact a location control center querying it for the coordinates of the MS. This subscriber could be a commercial subscriber desiring to track a mobile device or a PSAP trying to answer an E-100 call. The location control center will gather information required to compute the MS's location. This information could be parameters such as received signal strength, BTS ID, TOA of signals, and so on that we discuss later.Depending on past information about the MS, a set of BS's could be used to page the MS, and directly or indirectly obtain the location parameters. These are sometimes called Geolocation base. stations (GBSs). Once this information is collected, the location control center can determine the location of the mobile with certain accuracy and convey this information to the service provider. The service provider will then use this information to visually display the MS's location to the subscriber. Sometimes the subscriber could be the MS itself, in which case the messaging and architecture will be simplified, especially if the application involves self-positioning.

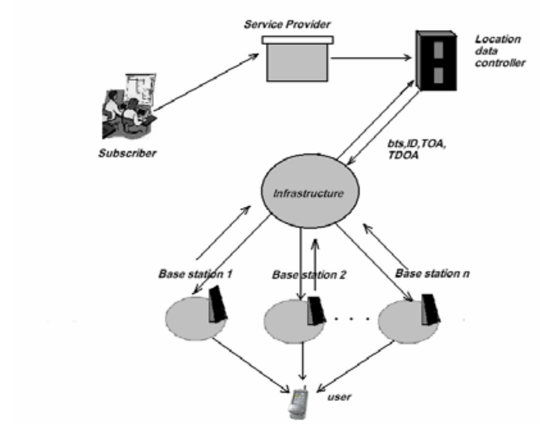


Fig 2.1 Architecture of a general Geolocation system

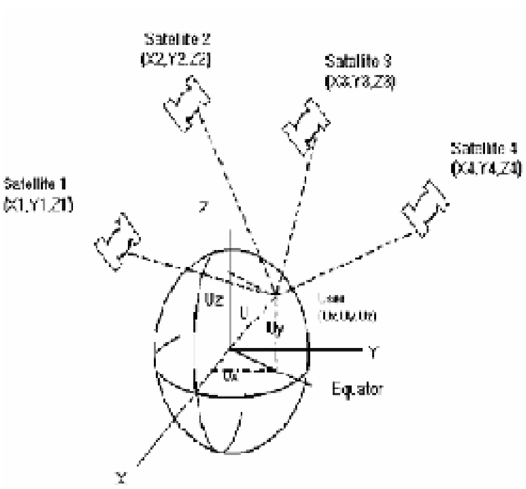
3.TECNOLOGIES USED FOR GEOLAOCATION

3.1 HANDSET BASED MOBILE POSITIONING AND TRACKING

3.1.1GLOBAl POSITIONING SYSTEM (GPS)

A mobile telephone can be located by a mobile telephone itself or through a mobile telecommunication network. To locate the mobile telephone by itself, the mobile telephone is provided with a GPS receiver to calculate its location in latitude and longitude coordinates based on the location information received from a satellite through the GPS receiver.

- Increases the price and the size of the mobile telephone.
- The load on the mobile telephone is increased.
- Power consumption is high.



3.1Global positioning system

3.2 DIRECTION BASED GEOLOCATION

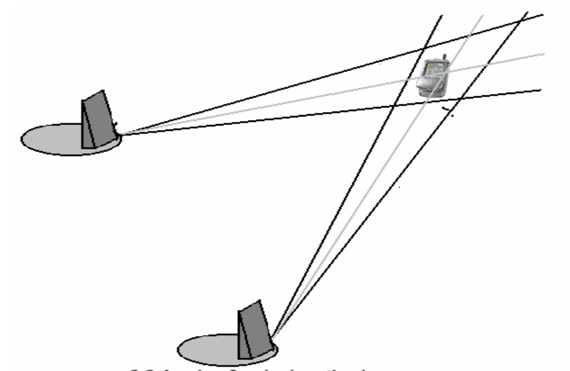
3.2.1 ANGLE OF ARRIVAL METHOD

As said earlier there will be transmission and reception of signals between the mobile unit and BSs. This method calculates the angle of arrival of signal receiving at the BS. When a mobile user switches the system ON it receives the signal from different base stations, may be 3 or 4 or more. The angle of arrival method two or more base station for the determination. It measures the direction of signal falling on the base station and measures the angle of incidence with respect to a normal and determines the position of the system. Angle of arrival method is not an accurate method used for the mobile positioning because of its some disadvantages such as:

• The determination of the system will be in error if the angle of incidence is changed due to any obstacle like atmospheric particles or due to scattering etc.

• The accurate location cannot be determined if the mobile user is in between the BSs, that is in a straight line.

• It cannot be used for the indoor environments.



3.2 Angle of arrival method

The accuracy of the method can be increased by increasing the number of the base stations used for determination. The direction based mobile positioning is not used commonly now a day. It is replaced by the distance based mobile positioning technologies.

3.3 DISTANCE BASED POSITIONING

3.3.1 TIME OF ARRIVAL (TOA)

The TOA method calculates the distance of a mobile telephone and a BS based on the TOA of a signal transmitted from the mobile telephone at the BS. It is assumed that the mobile telephone is located at the intersection point of three circles having the radius of the distances between the BSs and the mobile telephone.The distance is calculated by the following equation,

$R_i = C \tau_i = \text{sqrt} ((x_i – X) 2 + (y_i – Y) 2)$ where,

C – Propagation speed of electromagnetic wave,

τ_i – propagation of time from the mobile telephone to ith base station,

X_i, y_i -- location of ith base station,

X, Y – mobile position.

3.3.2. TIME DIFFERENCE OF ARRIVAL (TDOA)

The TDOA method assumes that the TDOAs of a signal transmitted from the mobile telephone at the three BSs define a set of points on a hyperbola, and the mobile telephone is located at the intersection point of at least three hyperbolas.

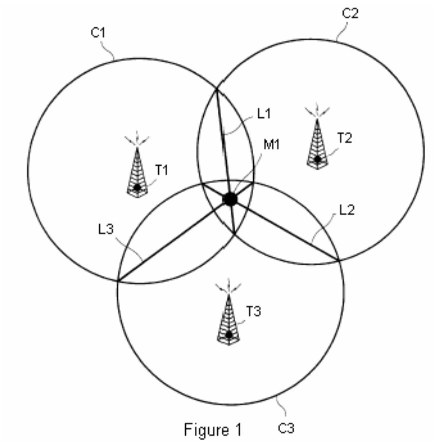


Figure3.3 illustrates a typical TOA method for locating a mobile telephone.

As shown in Figure3.3 ,three circles C1, C2, and C3,whose radii are the distance between the mobile telephone M1 and at least three BSs T1, T2, and T3, are overlapped across an area. The mobile telephone M1 is located in the overlap area. One approach to locating the mobile telephone M1 in the overlap area 1 is to use a common chord, as shown in Figure. 2. When at least three circles C1, C2, and C3 are overlapped over an area without meeting at one point, the mobile telephone M1 is considered to exist at the intersection point of three common chords L1, L2, and L3.The above method using the common chord is not very accurate in locating the mobile telephone except in the case where the mobile telephone is at an approximate equal distance from the selected BSs and in a similar propagation environment to each respective BS.

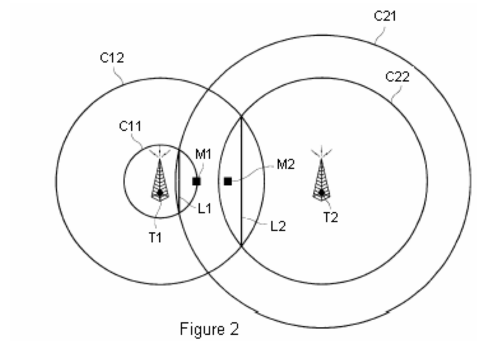
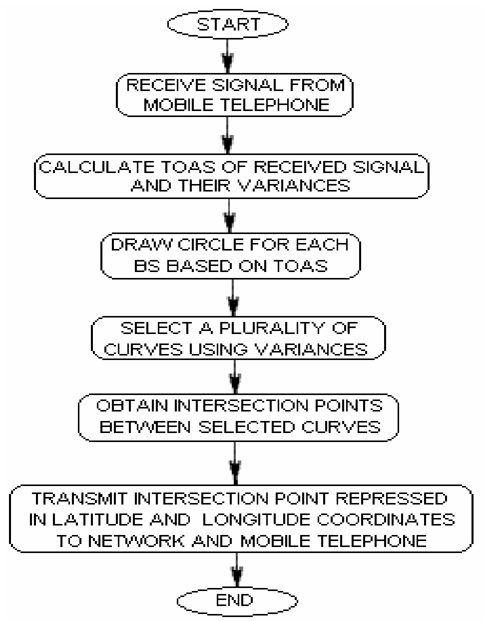


Figure3.4, illustrates the TDOA method of locating a mobile telephone.

In the case that a first mobile telephone M1 is nearer to the first BS T1, as shown in Figure 2, the procedure will be described by a way of example. In Figure 2, two circles C11 and C21 are drawn based on the TOAs of a signal transmitted from the first mobile telephone M1 at the first and the second BSs T1 and T2. A first common chord L1 is defined by the intersection between the circles C11 and C21. But if the path between the first mobile telephone M1 and the second BS T2 is in an NLOS condition and the path between the first mobile telephone M1 and the first BS T1 is in a line-of-sight (LOS) condition, the common chord L1 is positioned far left from the actual location of the mobile telephone M1. The effect is the same in the opposite case. If the path between the first mobile telephone M1 and the second BS T2 is in the LOS condition and the path between the first mobile telephone M1 and the first BS T1 is in the NLOS condition, the common chord L1 is also far right from the actual location of the mobile telephone M1..

4. LOCATION TRACKING CURVE METHOD

The method proposed by us for tracking the location of a mobile telephone using curves connecting the points where circles intersect one another, the circles radii being the distances between BSs and the mobile telephone. The steps involved are:



Flowchart showing the steps involved in locating a mobile telephone

Description: When a location service is requested about a specific mobile telephone by a user or a network, the location data processor draws two circles C1 and C2 with their respective centers set at BSs T1 and T2 based on the TOAs of a signal transmitted from the corresponding mobile telephone M1 or M2 to the two BSs T1 and T2 located near the mobile telephone M1 or M2. The two circles C1 and C2 define a common chord L1.

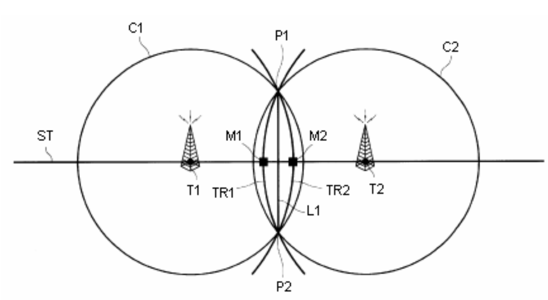


Figure 5

Figure 5, illustrates a proposed method for mobile telephone location.

However,if each mobile telephone M1 or M2 is placed in a different propagation environment with respect to the BSs T1 and T2, the location of the mobile telephone M1 or M2 can not be determined by the common chord L1. Therefore, we use location tracking curves TR1 and TR2 connecting the same two intersection points P1 and P2 of the two circles C1 and C2, instead of the common chord L1. The two curves TR1 and TR2 have their middle points intersecting the line ST, which connects the positions of the two BSs T1 and T2 and the parts of two circles C1 and C2 drawn to connect the two intersection points P1 and P2. Instead of the common chord L1, the location data processor uses the curve TR1 for the mobile telephone M1 and the curve TR2 for the mobile telephone M2. It prevents the location error caused by the multi-path fading or the NLOS path characteristics.

Determination of the location tracking curve

The BS with smaller variances should be selected to draw reference circles based on the variances

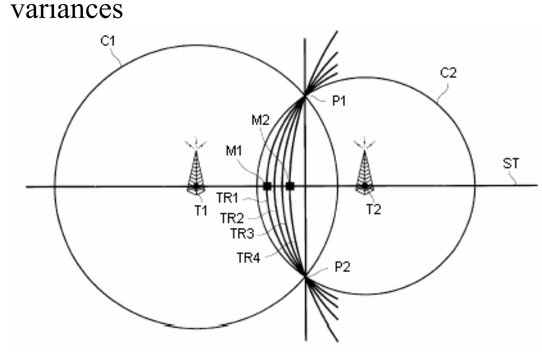


Figure 6

Figure 3.6, illustrates the determination of location tracking curve.

From Figure 6, assuming that the first and the second BSs T1 and T2 selected for use in the location tracking are present at positions (x1, y1) and (x2, y2), respectively, in the second-dimensional coordinates, the location data processor draws the two circles C1 and C2 with the coordinates (x1, y1) and (x2, y2) of the two BSs T1 and T2 at their centers The curve connects the two points P1 and P2 at which the two circles C1 and C2 intersect each other. The coordinates of the intersection points P1 and P2 are (xA, yA) and (xB, yB), respectively.

Since the mobile telephone is near the first BS T1 with respect to the common chord L1, the variances of the TOAs of a signal transmitted from the mobile telephone at the first BS T1 will be larger than those of the signal at the second BS. Therefore, reference circles TR1 to TR4 are drawn with respect to the second BS T2 with smaller variances, as shown in Figure 6.

The coordinates of the reference circle can be obtained (using minimum variance) which has its center on the line ST passing through (x1, y1) and (x2, y2) and passes through (xA, yA) and (xB, yB). Selecting the center of the reference circle is significant as the mobile telephone is located on the reference circle. The location data processor selects the desired curves (reference circles) with respect to the several BSs selected for location tracking.

In Figure 6, as the real location of the mobile telephone deviates farther from the circle C2 with the second BS T2 at its center, the center of a reference circle is farther from the location of the second BS T2. That is, the center of a desired reference circle is farther from the second BS T2 in the case of a third mobile telephone M3 (curve C3) than in the case of a fourth mobile telephone M4.

Reference circle selection

The variances of the TOAs of a signal which arrives at the two BSs T1 and T2 from different paths are used to find the curve on which the actual location of the mobile telephone is determined. If the TOAs of the signal at the first BS T1 from N propagation paths are t1, t2, . . . , tN, the first BS T1 calculates the variances σ of t1, t2, . . . , tN. The location data processor compares the variances calculated by the first BS T1 with the variances calculated by the second BS T2 and considers that the mobile telephone is near to that BS with the larger variances (the first BS T2 in Figure 6). Hence, the reference circle has its center near to the BS with the smaller variances (the second BS T2 in Figure 6) on the line ST.With the larger variances, the center of a reference circle gets farther to the right from the center of the second BS T2. In order to select the desired curve, the location data processor initializes the reference circles with predetermined radii and the variances of TOAs of a signal transmitted from the mobile telephone located on the reference circles, and compare the preset variances with real variance measurements.

The location data processor sets a several reference circles based on the distances between the mobile telephone and the BS with the smaller variances(the second BS T2) In Figure 6, as an example, the first to the fourth reference circles TR1 to TR4 have radii twice, three times, four times, and five times, respectively, of that of BS T2, where all these points of reference circles TR1 and TR4 are located along the line ST The variances of the second BS T2 smaller than those of the first BS T1 are used as a criterion for selecting an optimal reference circle. Therefore, the location data processor predetermines the reference variances for the first to the fourth reference circles TR1 to TR4 to be compared with respect to the second BS T1. It is assumed in the following description that σ 1, σ 2, and σ 3 are reference variances and σ 1< σ 2< σ 3.

The location data processor compares the variances calculated by the two BSs T1 and T2 and selects the base station with smaller variances as a reference point to draw the reference circle. If the selected variances (those of the second BS T2) are σ, the location data processor compares the selected variances σ, with the preset reference variances σ 1, σ 2, and σ 3.

- If σ <= σ 1, the curve of the first reference circles TR1 is selected.

- If σ 1 < σ <= σ 2, the curve of the TR2 is selected.

- If σ 2 < σ <= σ 3, the curve of the TR3 is selected.

- If σ 3 < σ, the curve of the fourth reference circles TR4 is selected.

As we have seen, the location data processor selects the optimal curve (reference circle) for the two BSs among the several BSs, and selects another optimal circle for another BS pair, and so on.

When curves are selected for all selected BS pairs, the location data processor obtains the intersection points among the selected curves as shown in Figure 7. However, as the selected curves do not intersect at one point due to the multi-path fading or the NLOS effects, the midpoint of these intersection points is determined as the location of the mobile telephone.

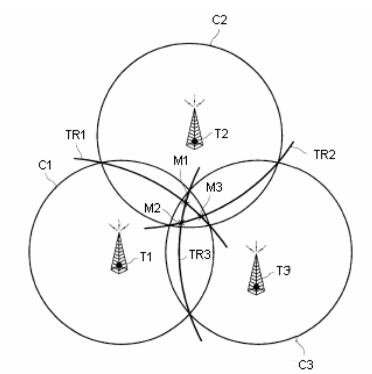


Figure 7

Figure 7, illustrates the positioning of mobile by the proposed method

As the three intersection points M1 (xA, yA), M2 (xB, yB), and M3 (xC, yC) are defined by the three curves TR1 to TR3, the location data processor considers the mobile telephone to be located at (x, y). While the three BSs are selected for the location service using the TOAs of a signal arrived at each BS from a mobile telephone has been described in the embodiment of the present invention, more BSs can be used to increase the accuracy in locating the exact position of the mobile station. If Nth intersection points are defined by location tracking curves obtained according to the present invention and an ith intersection point is at (xi, yi), coordinates (x, y) indicate the location of the mobile telephone.

After the location of the mobile telephone, that is, the intersection points among the curves are obtained, the location data processor represents the intersection points in the latitude and the longitude coordinates and transmits the position coordinates to the network (BS/BSC/MSC) and the mobile telephone.

4. CONCLUSION

Our proposal is advantageous in that the location of a mobile telephone can be accurately tracked even in the multi-path fading and the NLOS environment, by using more accurate tracking curves connecting the intersection points among circles with the radii being the distances between corresponding BSs and the mobile telephone in a cellular mobile communication system. We have described about accurate positioning of mobile telephones, which can be used for several applications. The important considerations to be undertaken while selecting a location based technology are location accuracy, implementation cost, reliability, increasing functionality.

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