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Survey Paper: Location Management in CDMA Network

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Abstract

With the rapid increase in international roaming and highly growing number of cellular subscribers it is important to locate the subscriber both efficiently and accurately not only to reduce the cost but also to decrease the load on MSC and decrease the paging delay. The procedure used by the service provider for both collecting and analyzing the information regarding the subscribers' location is called location management. Location management comprises of location update and paging schemes. This paper tried to highlight the different location management techniques and paging schemes that are used in CDMA network. This paper also compares their features, merits and demerits. Finally the paper discusses various techniques that are used in order to optimize the location update schemes by categorizing them into two broad groups' i.e. static location update and dynamic location update. Each group enlists different techniques that are used to decide the update frequency of MS (Mobile System). This study has tried to summarize their underlying concepts and various pros and cons.

Keywords: *Location update, Angle of arrival, Global positioning system, Location update cost, Enhanced Observed Time Difference (EOTD), adaptive profiling of user*

1. Introduction

CDMA or Code Division Multiple Access was first developed in USSR in the year 1935 by Dmitriy V. Ageev, later it was realized by a young military radio engineer, Leonid Kupriyanovic in the year 1957 [1].The commercialization of CDMA concept happened after a year; as a channel access method. As the name suggests it's a multiple access method i.e. more than one user share the same radio interface to access the channel without getting affected by the presence of others in the network [2]. This becomes possible because, although the interface is shared by more than one user yet the signals are separated from each other in terms of code (pseudo random code) and hence, only the person with the matching code will be able to get the message and for others it will look like noise.

CDMA has travelled a long way since then. Currently, there are two cellular standards of CDMA that are accepted globally and are used in communication purposes the first one is called IS-95 (IS stands for international standard) or CDMA One. It was first developed in North America to compete with Digital-AMPS (Digital Advanced Mobile Phone System) and it became quite popular. It is a second generation mobile phone system and with 1.25 MHz band width it supports a variable number of users [3-5]. It provides voice service along with a data rate of 14.4 Kbps. CDMA 2000 on the other hand is a member of 3G mobile technology. It was first implemented in Korea in October 2000[6]. Since then it had gone through various changes to reach in the 3G stage. The current CDMA 2000 actually denotes a family of standards. Its band width ranges from 1.25 MHz to 3.75 MHz with data speed varying from 144 Kbps to 2 Mbps [7-9]. It is backward compatible with CDMA One.

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CDMA being a wireless cellular technique, the users are not static but dynamic hence for reducing the paging cost and paging delay and for uninterrupted data and voice service [10]. we need location update from the MS. The various techniques and concepts via which location update of the MS can be obtained are discussed in [11]. These location update techniques include Time of Arrival, Angle of Arrival, Enhanced Observed Time Difference, Uplink-Time Difference of Arrival method, Assisted GPS method etc. The study tried to highlight both the advantages and disadvantages of each of the system and how the disadvantages are addressed in the next update.

On the other hand, location update uses the available resources and hence, costs money and as result of which location update needs to be done with efficiency so that it does not occur unnecessarily and should not use the valuable resources erratically. Considering the above mentioned facts, we have discussed some of the basis, based on which we perform the location update namely static and dynamic update, location area concept, reporting cell concept, and threshold and adaptive location update schemes etc. Furthermore, we also tried to analyze the situations and criteria under which a particular system works better than the other. In addition, we also tried to point out some of the existing problems of the scheme.

2. User Location Prediction

User location prediction is a set of technologies that are used to predict the location of a user where predicting the location means pin pointing the geographical location of the mobile used with a minimum possible error without compromising with the performance. This information is then used for various services like emergency response, radio resource management like handoffs or mobile traffic management, etcetera [12-13]. This sector got the largest push when USA telecom authority made it mandatory for mobile service provider to provide the location data of the user for faster E-911 response.

There are various technologies that are used for determining the user's location. It can be broadly classified into two groups,

1. Handset based
2. Network based.

These are further divided into various parts based on different technologies. These technologies are implemented either in combination with other technologies for better precision or implemented alone to save cost with sacrifice of precision. The handset based technology uses the forward DATA channel to give the mobile station the required data (often from more than one base station). Then the mobile station do the necessary calculation. This method suffers from a big challenge of limited amount of available power at its disposal. This results in compromising the accuracy more often than not [14-15].The other method uses the backward DATA channel to get the required information from the MS via more than one BS and then relay this information to MSC where the user location is estimated with precision. As this method uses more than one BS therefore, it becomes inappropriate for rural areas where the BSs are far apart. Generally, the location of the user is decided in comparison to the BSs because, the BSs are equipped with GPS which provide them with absolute geographical location and this in turn helps in determining the MS location [16].

2.1. Handset based Location Techniques

These are the techniques that uses the MS resources (computational and memory resources) to compute the location of the user. So the result is subjected to resource and power constraints of the MS.

2.1.1. Cell ID: The mobile station needs to identify itself over the BS to get the required information to initiate a call or data transfer. So, the MS sends its MPIN over to BS after a fixed time interval in an idle mode. This information is transmitted to MSC and MSC stores that location of the MS in Home Location Register (HLR) for paging when the call comes. This update happens continuously when the user is in a call, so this was initially being used by service provider to get the location data. It was then used to provide roaming services and handoff initiation. This is the cheapest possible way of getting the location information. Also, it does not utilize much of the provided resources and does not need any modification in the MS or BSC as well. But the biggest problem with this technique is that it suffers from high rate of inaccuracy [17]. It only provides the information related to the presence of the MS in a particular cell or which BS is nearer to the given MS. Hence, its accuracy is based on the size of the cell. In remote places, the cell size is big and as a result, the error in location prediction is also high. It also requires an active voice call to locate the MS, failing which it shows the past location of MS. Hence, generally it is used with other location determining techniques to get a better accuracy [18].

2.1.2. Timing Advance (TA) + Cell ID: The radio resources are divided into various time slots for multiple access and therefore, each user is provided with a particular time slot and the Tx signal have to reach the MS at that particular time slot. So the Tx burst takes into account the MS distance from the BS and coordinates its signal transmission with it. Hence, this sense of timing management can be used to estimate the distance of MS from BS. It provides a slight increase in accuracy but this accuracy comes in multiples of 550 meters because the adjustment or advancement of signal burst is made as a multiple of 550 meters [19-20].

2.1.3. Signal Strength + Cell ID: This is another method which is used with Cell ID to determine the user location. The Tx power of the mobile and BS is controlled by the BS depending upon its distance from BS to prevent the near far problem and also to prevent unnecessary drainage of power from handset. So by measuring the Rx signal strength at the MS and by measuring the change of its strength with direction of movement of MS, we can estimate the approximate distance of BS from MS and can predict the user location. This method is useful in case of villages or rural areas because of less obstruction and more availability of line-of-sight path. But in urban areas there is no clear line of sight path and hence, the signal undergoes many reflections before reaching the MS (multipath) and as a result, this method is prone to error for urban areas [21].

2.1.4. Enhanced Observed Time Difference (EOTD): This method is similar to Timing Advance to some extent. Here, the MS listens to the synchronization burst sent by neighboring BSs (a mechanism to pseudo-synchronize the network) and the timing delay between the received signals of various BSs. The MS then uses Multilateration technique to determine its position. In this method, the 2D accuracy is good but it fails to provide any altitude information. In 3G networks, which do not need to synchronize, further data is required to locate the user i.e. the time offset between the Tx of two signals. To get this information, a location measurement unit (LMU) is used on BSs, which is expensive. Also, it requires a software modification in MS to carry out the operation which resulted in its replacement by its counterpart, Uplink-Time Difference of Arrival, which uses MSC resources to carry out the computation [22].

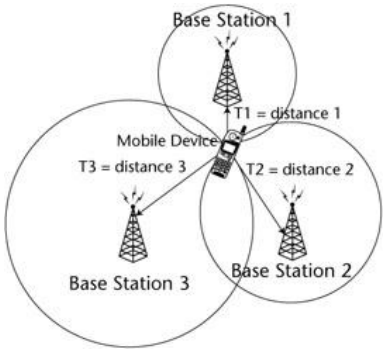

Figure 1. Enhanced Observed Time Difference (EOTD)

2.1.5. Global Positioning System (GPS): GPS is a space based location or position determining system. It uses low earth orbiting satellites to determine the position of any device which is fitted with a GPS receiver. And with increase in number of mobile phones having GPS receiver incorporated with them, finding their location has become very efficient and easy. It uses minimum 4 satellites to pinpoint a user's location with accuracy of few meters and good altitude prediction. The GPS satellite communicates with the GPS receiver in the mobile and uses triangulation to find the user location. It is non-commercial service and hence, the user doesn't have to pay for accessing the satellite. Furthermore, this system works everywhere and also is not affected by weather condition. But it has one problem which is when the user is indoor, due to poor signal strength the accuracy decreases and in some cases, the mobile becomes unable to access the GPS service [23].

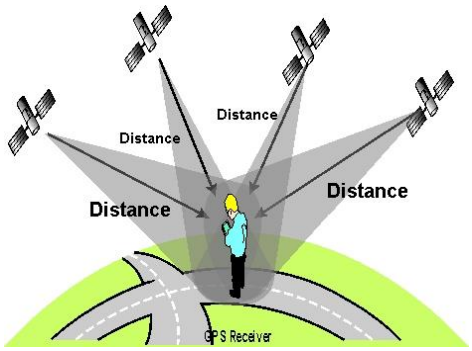

Figure 2. Global Positioning System (GPS)

2.2. Network Based Location Technique

Network based techniques use the available resources of MSC to compute the location of user. This involves more than one BS and the data received are then sent to MSC for calculation. The MSC then use triangulation or other methods to pin point the location. These method is more efficient than the previous methods and are widely used considering the present scenario.

2.2.1. Uplink-Time Difference of Arrival (U-TDOA): It is similar to EOTD except for the fact that the location computation is done in MSC. The Tx signal from MS reaches LMUs placed on different BSs at different time depending upon its distance from BSs. This timing difference from various LMUs is then used to compute the location of MS. This method is quite efficient and it produces results within 50 meter of error [24]. Also, as this method is network based so no software or hardware modification of any kind have

to be implemented on MS. But this method fails to provide any altitude measurement and it, like the EOTD, requires LMUs for accurate measurement.

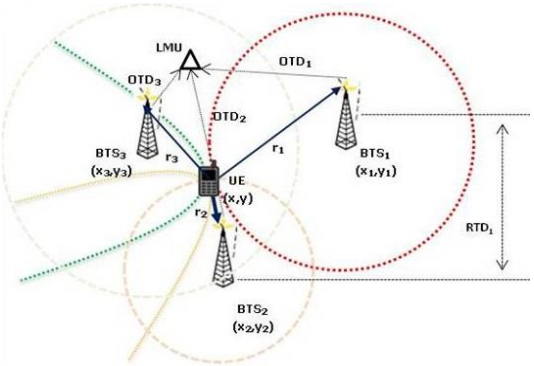

Figure 3. Uplink-time Difference of Arrival (u-tdoa)

2.2.2. Angle of Arrival (AOA): It is one of the classic radio detection technique and is still in use and had gone through various improvements to provide better accuracy. This uses Directional Antenna Array to pinpoint the angle of arrival. The angle of arrival can be calculated in two ways. One way is by calculating the time delay between the signal reaching different elements of the antenna array and the second way is by measuring the phase difference. In either way the result is very accurate. This result can be accompanied with result from other BSs to triangulate the position of the MS or this can be accompanied with the power distribution profile to directly calculate the MS location. While the second method is fast and easy, the second method is more accurate. This system is the oldest method and is widely used in military application. But its use in finding user location in case of CDMA or other cellular services had decreased with time because it requires a line of sight (LOS) path for its accurate measurement and with the ever increasing number of cell phones, LOS path is nearly impossible to find. Hence, it is used in some rural areas or areas with less population density.

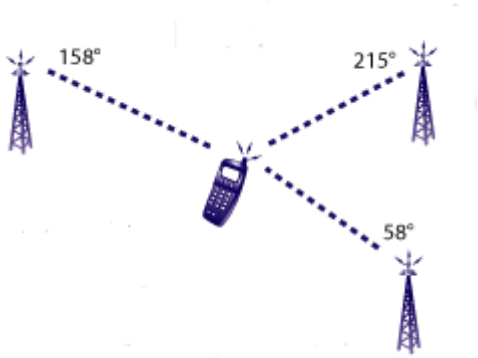

Figure 4. Angle of Arrival (AOA)

2.2.3. Assisted Global Positioning System (A-GPS): It stands for Assisted-GPS which is similar to GPS but with few improvements. When a GPS device is turned on, it takes some time to find the orbit and clock data of the LEO satellites which is known as Time To First Fix or TTFF, in short. This time varies from somewhere between 30 seconds to few minutes. This delay is more in urban areas than in villages or planes. But with A-GPS this time is reduced. As the name suggests, in A-GPS, the GPS receiver is generally assisted to find out the location [25]. This assistance comes from structure like cellular tower that has GPS receiver built into them and they constantly pull the satellite

information hence they provide the required data to the mobile so that the TTFF is reduced. Also, the mobile can send its location data directly to the cellular network via the control channels.

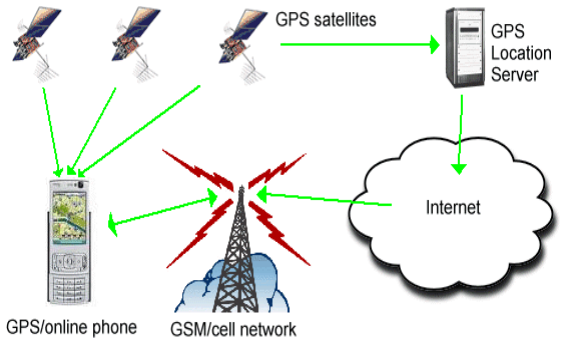

Figure 5. Assisted Global Positioning System (A-GPS)

3. Location Update

The mobile stations are not static and hence, they change their location from time to time so that the location of the user is known and transfer of controls and call requests to that particular cell can be facilitated. But location update needs to utilize the available resources, namely, spectrum and computational ability so that the continuous update will not only result in unnecessary use of these resources resulting in extra cost but will also hamper the user experience as there will be less resource to be used by the user. Also, if the user location is not updated then the paging cost will be very high and the user has to wait for a longer time to get the call connected. Hence, there is a need to optimize the location update process so that these problems will not occur. And to do so we have to update the location of user or the MS based upon certain criteria and depending upon these criteria the location update can be broadly classified into two categories:

1. Static location update scheme
2. Dynamic location update scheme.

3.1. Static Location Update

In this scheme the location update is done based upon certain factors that is independent of the user i.e. the update rules are same for all users irrespective of their movement profile. As this scheme does not requires specific user tracking so the computational requirement is very low and hence, it is very cheap to implement though, it is not efficient like the other scheme. It is further divided into subsections depending upon the parameter used.

3.1.1. Always Update: The MS location is always known to the MSC in real time and hence, it does not require any paging cost as a result it is effective for users with less movement rate and more call arrival rate. But if the case is the reversed then it results in unnecessary location update and hence, proves costly. Therefore, this system is not used in any practical purposes but in AMPS system once the call gets connected the updating scheme used throughout the call is always update type. And this system also forms the base for other update system [26].

3.1.2. Never Update: This is exactly the opposite of the previous scheme. Here, the MS location is never updated. Hence, the updating cost is zero but if the MS changes its location frequently then the paging cost is very huge so it is seldom used

when the subscriber unit is not mobile. Therefore, there is no need to update the location and in those cases this works fine.

3.1.3. The Reporting Cell Concept: The two previous schemes discussed were the extreme ends of location update and so they are not at all optimized. To get an optimized location update this scheme is developed. And this scheme later paved the path for other advanced update schemes. In this system, some of the cells are made reporting cells and by making them reporting cell the MS is instructed to update its location when it enters the reporting cell. This ensures that the MS is most likely to be in the vicinity of the last reporting cell and thus, those cells are paged first and as a result the updating as well as the paging costs are reduced.

The reporting cell can be of two types, namely, bounded and unbounded. The bounded reporting cell makes sure that a mobile phone will cross a given reporting cell before going N cells away from last reporting cell. Whereas, the unbounded reporting cells reduce the number of redundant location updates. However, there is a chance that the user may be far away from the last reporting cell without going through any of the reporting cells. So in that case the paging cost will be high to locate the user. Hence, the MSC have to use an intelligent algorithm to make sure that the user does not go far away from the reporting cell without reporting its location. Also, the reporting cells should be wisely distributed considering the traffic routes and population densities [28].

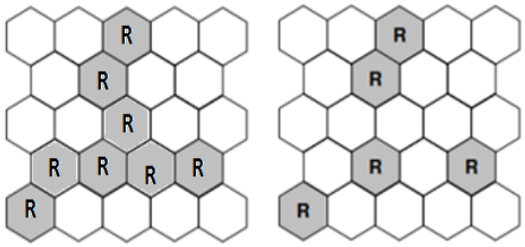

Figure 6. Of Bounded and Unbounded Reporting Cell Strategy

3.1.4. Location Area: This concept groups few cells together to create a location area. Thus, the entire geographical area is divided into a number of location areas. Then the update may be done periodically or based on location area boundary crossing *i.e.*, the MS have to update its location when it leaves its current location area. The periodical location update makes the mobile station to update its location at a particular frequency. And when the call comes, the cells of the last known location area are paged. This system does not take into account of the MS's speed so if the MS moves very fast and crosses the location area before reaching its updating time then in that case the MSC have to page more than one location area so the paging cost goes high [27]. So, the location area boundary crossing scheme provides a more useful aspect in a sense that a mobile station has to update its location every time it crosses the location area so it's sure that the MS will be confined to a particular location area. But it is not devoid of all adversities as there is something called Ping-Pong effect that occurs when a user travels between the cells of neighboring location area, it creates unnecessary location update and hence, costs more money and resources. Though, to overcome this problem many proposals had been put forward but none of them are used widely in particular [29].

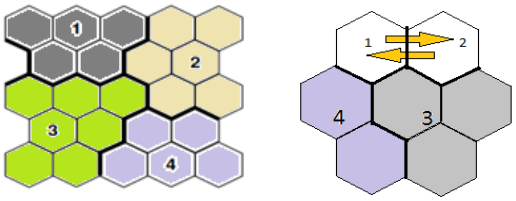

Figure 7. Showing the Concept of Location Area and Ping Pong Effect

3.2. Dynamic Location Update

This location update takes into account the movement and call arrival rate of each user and on that basis sets the threshold of the parameter. The parameter can be distance, time or movement based. This helps in optimizing the location update and paging cost per user. Also, in this scheme, each cell can act as a reporting unit and the location update is independent of cell. This scheme needs special algorithms to decide the location update criteria. Therefore, it needs huge computational power and the installation cost is high too. But the advantages of this system easily outweigh the cost concern. Currently, this area is the hottest topic of research. Considering the parameters, this location update scheme can be divided into various subsections as well.

3.2.1. Threshold: In this a certain parameter is monitored and the threshold value is set depending upon the user's activity. The most commonly used parameters are time, distance and movement.

a) Time based update

It is the most used threshold. The MS have to update its location after the pre-set amount of time. This pre-set or threshold time is user specific. It requires less computational overhead as it requires the mobile device to only maintain a simple timer. This is very useful for user with high mobility and low call rate as it eliminates large part of the overhead that is generated in other two cases [30].

b) Movement based

In this method, the MS updates its location after crossing some predefined number of cells. So in that way the area to be paged is reduced by n-1 number of cells around the last updated cell. Hence, for user with high call arrival rate n is kept small and vice versa. This method outweighs the time based method for users with high call arrival rate and less movement. But this scheme generates large overhead if the user moves continuously in and out of the cell [31].

c) Distance based

This takes into account the distance from its last updated location. Therefore, if it crosses the threshold radius then it updates its location. This frees us from the problem of high overhead that occur in movement based update as instead of cell crossing it takes into account of the actual distance travelled. But on the flip side, this system requires high computational ability as it deals with the actual distance parameters and this is makes it less widely used option.

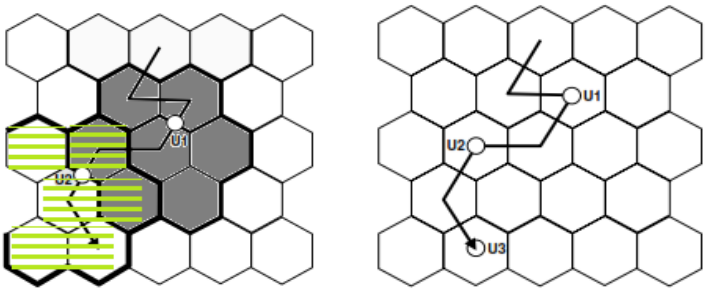

Figure 8. Movement based with n=2 and Distance based Updating Scheme

3.2.2. User Profile: The MSC, based on previous data lists some of the most probable cells that the user will reside in. and in turn the MS will update its location if it moves to any cell other than the mentioned ones.

3.2.3. Adaptive: This method uses adaptive computing for both locating and predicting the user location to minimize the paging and location update cost.

4. Conclusion

Through this paper, the difference location determining techniques and determining a trade-off between accuracy and resource utilization has been discussed. The network based scheme though uses more resources, it provides better accuracy and as result it is being used extensively. It is also discussed about the GPS and A-GPS technologies that are the emerging location determining steps. Also, various location update techniques and update techniques are studied over time are covered. The location update schemes that have taken place via different parameters that can be set per user basis to determine the location update is discussed in detail. The discussion also considers the different aspects of each method and analyzed which method is best suited under what circumstances.

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