# A Novel Distance Based Relocation Mechanism to Enhance the Performance of Proxy Cache in a Cellular Network

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***Abstract:*** *Accessing the World Wide Web with the wireless devices has been the promising technology for the past few years. Interruption in World Wide Web access during handover in a cellular network can be avoided by relocating in advance the proxy cache to the target base station before the handover using the path prediction algorithm. To reduce the cache overhead in the handover, this paper proposes a "distance based relocation" mechanism, in which the cache of the base station is relocated once the mobile unit reaches the relocation point in the cell. This mechanism estimates the time at which the relocation has to be done by keeping track of the distance between the mobile terminal and the base station.*

**Keywords:** *WWW, proxy cache, relocation point, path prediction, distance based relocation.*

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## 1. Introduction

For the past few years, wireless telecommunication has experienced a lot of growth, which brings the interest of "any where – any time computing" also called as "Nomadic Computing". Nomadic Computing refers to mobile users who need access to their e-mail, company data, the Internet etc., at all times no matter where they are at any given moment. In the 1990's, the Internet created a global transport for e-mail and data exchange, but mostly for users at fixed locations. The goal of the 21st century is to provide the same access even to all mobile users. One of the major fields of interest in nomadic computing is to provide efficient access to World Wide Web from the mobile devices in spite of its low hardware and software resources, and its mobility. This enables the mobile users to participate in real time transactions and group communications on the fly [10, 16]. When the mobile device hands off, the new base station may not have the same environment to the mobile device as its old base station. So the mobile device experiences discontinuity in service. To support continuity in service the environment should be created prior to handover in the new base station. This can be achieved by predicting the next target base station. Taking into account these factors, a novel distance based relocation scheme is proposed in this paper. The rest of the paper is organized as follows. Section 2 gives an overview of existing schemes. Section 3 gives the motivation for this paper. Section 4 discusses the proposed approaches for path prediction, cache relocation, and analyses the performance. Section 5 concludes the paper.

## 2. Existing Schemes

The problem of providing World Wide Web service for Wireless has been the most recent research issue addressed by mobile researchers. Proxy based architecture has been proposed in MobiScape [4, 5]. The Mobile Host (MH) uses the Support Station (SS) as a gateway to the WWW. Proxy cache is placed both in the mobile terminal and the support station, which holds the required web pages to reduce the download time. Both MobiScape and Web Express work well without any software changes in the browser and the server. Once a mobile terminal hands off, the base station cache has to be fully reconstructed. In [15], [3], [1], [4], [2], and [7] the constant relocation of the Support Station cache was suggested as an extension of the MobiScape Web Express so that the required environment is made available in the new base station before the mobile user comes to the base station. This avoids the problem of full reconstruction of cache after handover in MobiScape Web Express. To predict the target base station in which the proxy cache has to be relocated, Learning Automaton (LA) path prediction technique is used [15, 3, 1, 4, 2, 7]. But the LA path prediction technique does not consider from where and how the mobile reached the current base station. Prediction accuracy of the LA is low [15, 3, 1, 4, 2, 7]. Time Scheduling for relocation proposed in [11], and [12] better utilizes the cache of the target base station by relocating the cache based on the cell residence time. Even though this scheme is better than immediate relocation [11, 12, 13] the relocated cache in the target base station is unused till the handover. So a better scheme is needed to relocate the cache just before the occurrence of the handover and this has been the motivation for the work proposed in this paper.

## 3. Motivation

Performance of proxy cache relocation schemes depend on the accuracy of the path prediction and relocation algorithms. So to enhance the performance in terms of accurate prediction and better utilization of cache, both the prediction and relocation algorithms must be improved. Pattern Matching (PM) [8, 9] and LA [15, 3, 1, 4, 2, 7] approaches have been proposed for path prediction. The problem with PM is that it does not handle the situation in which the user enters the cell through a new path and the problem with LA approach is that it does not consider the path through which the user enters the cell, which leads to low prediction accuracy. To overcome these problems, a combined approach using PM for users coming through regular path and using LA for other users is proposed to provide better prediction accuracy.

Time scheduling for relocation based on the Cell Residence Time (CRT) and immediate relocation [11, 13] approaches have been proposed for cache relocation. The problem with immediate relocation is that it relocates the cache immediately after the prediction of the target base station. It results in a huge cache overhead on the target base station. The problem with CRT based approach is that it relocates the cache after the elapse of half of the CRT and not just before the occurrence of handover. Relocated cache should be held in the predicted base station unutilized till the occurrence of the handover. Moreover, as the relocation is done well ahead of handover, the relocated pages might be obsolete. To overcome these drawbacks, a distance based relocation scheme is proposed in this paper.

## 4. Proposed Approaches

The algorithm for the proposed approach when the Mobile Terminal (MT) enters the cell is given in algorithm 1.

*Step 1: /* Path Prediction */*
*If the arrival path pattern matches with any of the patterns in the user's profile Then*
*Use the PM Algorithm for Relocation*
*Else*
*Use the LA Algorithm for Relocation*

*Step 2:/*Distance Based Relocation */*

*2.1. Start a timer with an initial value of CRT/2*

*2.2. If distance between MT and BS > Relocation Distance ($d_R$) Then*
*If timer expires Then*
*Perform Relocation*
*Else*
*Goto Step 2.2.*
*Else*
*2.2.1. Discard Timer*
*2.2.2. If distance between MT and BS < Relocation Distance ($d_R$) Then*
*Goto Step 2.2.2.*
*Else*
*Perform Relocation*

*Step 3: End*

### 4.1. Proposed Combined Approach for Path Prediction

When the MT enters the cell, its arrival path pattern is compared with the patterns in the user profile maintained by the base station by using the 'movement circle / movement track detection algorithm' [8, 9].If the arrival pattern matches with at least one of the patterns in the profile, the PM algorithm [13, 14] is used for Relocation. If the arrival pattern does not match with any one of the patterns in the profile, the LA [15, 3, 1, 4, 2, 7] is used for relocation. So, this combined approach of path prediction proposed in this paper works well for regular users and also for users taking a new path. The algorithm for this combined approach is given in Step 1 of Algorithm 1. This approach considers from where and how the mobile terminal reaches the cell and also it handles the case in which the mobile terminal enters the cell in a new path.

### 4.2. Proposed Distance Based Relocation Scheme

The distance based relocation scheme proposed in this paper is given in step 2 of algorithm 1, which keeps track of the distance ($d$) between the base station and the when $d$ exceeds relocation distance ($d_R$), which may lead to handover.

Relocation distance ($d_R$) is defined as the fraction of the maximum possible distance (radius of the cell) between the mobile terminal and the base station, where $x$ is the boundary parameter ($0 \leq x \leq 1$).

$$d_R = x * \text{radius of the cell} \quad (1)$$

Distance based Relocation mechanism has 2 states, viz., Low Signal Strength Region (LSSR) and High Signal Strength Region (HSSR). The state diagram of distance based relocation scheme is shown in Figure 1. Once the MT enters the cell, there are two possibilities for the movement of MT inside the cell namely the MT traveling towards the BS and MT traveling along the boundary.

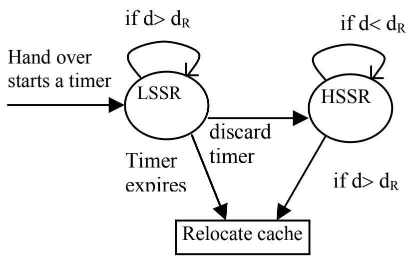


Figure 1. Functionality of instances based.

#### 4.2.2. MT Travelling Towards the BS

When the mobile terminal enters into the cell, initially it will be in 'LSSR'. As it moves inner into the cell towards the BS, d gets reduced to less than $d_R$. This switches its state to 'HSSR'. When the mobile terminal moves away from BS, it reaches relocation point as shown in Figure 2. The proxy cache is relocated to the predicted base station at this point of time.

#### 4.2.3. MT Travelling Along the Boundary

In some peculiar cases, the mobile terminal may travel along the boundary of the cell as shown in Figure 3. To handle this case a timer based approach is used. When a MT enters the cell, a timer is started with a value of CRT/2, calculated as in [11, 13]. When the mobile terminal is traveling along the boundary, it will not switch over to 'HSSR'. So relocation is carried out on the expiry of the timer.

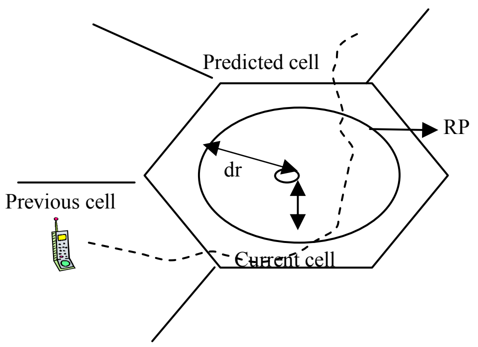


Figure 2. MT Traveling towards the BS.

### 4.3. Simulation Results and Performance Analysis

To evaluate the effectiveness of the above suggested technique, a simulation is carried our institute network using a simulation tool developed by us in JAVA, which includes a virtual cellular network with 100 cells. The results of the simulation model are given below.

#### 4.3.1. Path Prediction Accuracy

To accurately predict the path of the user, the simulation is carried out for the three different algorithms, learning automaton, pattern matching, and combination of the both. The accuracy of path prediction is defined as the ratio of the number of cells correctly predicted to the number of cells actually visited and it is calculated as follows:

$$\% \text{ of } pp \text{ accuracy} = \frac{N1}{N2} \times 100 \tag{2}$$

where *pp* is path prediction, $N_1$ is the no. of cells correctly predicted and *N2* is the no. of cells actually visited The results of percentage of prediction accuracy for the three prediction schemes are tabulated in Table 1. From the first ten rows of Table 1 it can be inferred that the entries are same for all the three schemes as there is no pattern with which the path of the user can be compared with and hence only LA is invoked. As the user travels further, there exists a path pattern with which the profile can be compared and so for the remaining rows, the entries are different as the three different schemes give different results. Also, a similar trend has been observed for different set of simulation inputs. The plot of Percentage of Path prediction accuracy versus the number of cells visited for the proposed approach is given in Figure 4. From the graph, it is seen that the combined approach gives more accurate results compared to LA and PM techniques.

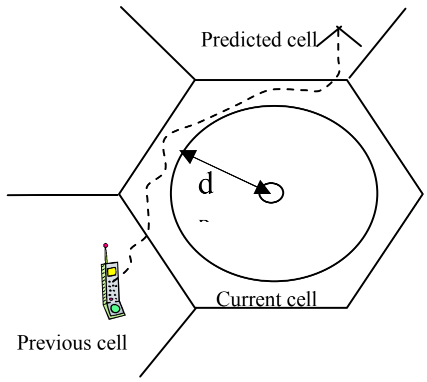


Figure 3. MT Traveling along the boundary.

#### 4.3.2. Cache Overhead

Cache overhead is defined as the ratio of the amount of time the cache remains unutilized/ unexcused by the corresponding MT to the total amount of time the cache resides in the BS, which is calculated as follows:

cache overhead = $\frac{A1}{A2}$ , where *A1* is the amount of time the cache remains unutilized by the corresponding MT and *A2* is the amount of time the cache resides in the BS. Cache overhead depends on the time of relocation. Simulation is carried out for the three different cache relocation schemes, viz., immediate relocation, relocation using CRT, and relocation using Distance based relocation scheme. For the simulation of CRT based relocation scheme, the relocation algorithm is invoked at β*CRT where 0<β<1. A value of β=0.5 is used in our simulation. For Distance based relocation scheme a value of x=0.75 is used in equation 1. The cache overhead in the three schemes is tabulated in Table 2. The plot of cache overhead in the predicted base station before handover Vs the number of cells visited is given in Figure 5, it is inferred that the cache overhead in distance based relocation scheme drastically reduces compared to immediate relocation and CRT based relocation. In the Table 1, $N_v$ represents the number of cells visited, LA represents LA and PM the PM technique.

Table 1. Percentage of path prediction accuracy.

| $N_v$ | LA | PM | PM +LA |
|---|---|---|---|
| 1 | 0 | 0 | 0 |
| 2 | 50 | 50 | 50 |
| 3 | 66.66667 | 66.66667 | 66.66667 |
| 4 | 75 | 75 | 75 |
| 5 | 80 | 80 | 80 |
| 6 | 83.33333 | 83.33333 | 83.33333 |
| 7 | 85.71429 | 85.71429 | 85.71429 |
| 8 | 87.5 | 87.5 | 87.5 |
| 9 | 88.88889 | 88.88889 | 88.88889 |
| 10 | 90 | 80 | 90 |
| 11 | 81.81818 | 81.81818 | 90.90909 |
| 12 | 83.33333 | 75 | 91.66667 |
| 13 | 84.61538 | 76.92308 | 92.30769 |
| 14 | 85.71429 | 78.57143 | 92.85714 |
| 15 | 86.66667 | 73.33333 | 93.33333 |
| 16 | 87.5 | 75 | 93.75 |
| 17 | 88.23529 | 76.47059 | 94.11765 |
| 18 | 88.88889 | 72.22222 | 94.44444 |
| 19 | 89.47368 | 73.68421 | 94.73684 |
| 20 | 90 | 75 | 95 |
| 21 | 90.47619 | 71.42857 | 95.2381 |
| 22 | 86.36364 | 72.72727 | 95.45455 |
| 23 | 86.95652 | 73.91304 | 95.65217 |
| 24 | 87.5 | 70.83333 | 95.83333 |
| 25 | 88 | 72 | 96 |
| 26 | 88.46154 | 73.07692 | 96.15385 |
| 27 | 88.88889 | 74.07407 | 96.2963 |
| 28 | 85.71429 | 71.42857 | 92.85714 |
| 29 | 86.2069 | 68.96552 | 93.10345 |
| 30 | 86.66667 | 70 | 93.33333 |
| 31 | 87.09677 | 70.96774 | 93.54839 |

The Cache overhead in the predicted Base station before handover is tabulated in Table 2. In Table 2, $N_V$ represents the number of cells visited, IR for immediate relocation, CBR for CRT based relocation, and DBR for distance based relocation technique.

## 5. Conclusion

As the number of mobile users increase day-by-day, number of mobile terminals handled by a base station also increases. Base station contains a limited amount of cache resources, which has to be efficiently utilized for providing access to WWW to the mobile user. As the mobile user moves, the cache is relocated to the next base station so that the service is not disrupted.

This is possible only by predicting the path of the user accurately and by deciding the time of relocation. In this paper, the path of the user is predicted by using a combined approach of LA and PM techniques.

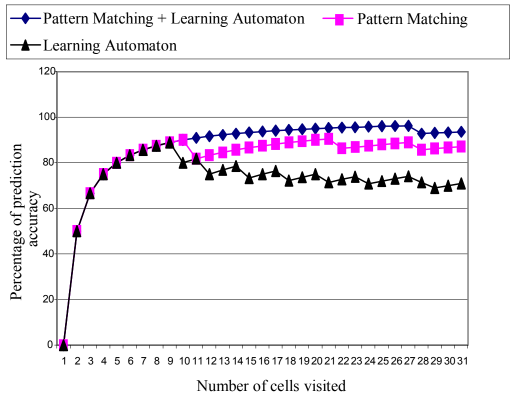


Figure 4. Percentage of path prediction accuracy vs. no. of cells.

Table 2. Total cache overhead in predicted base station before handover.

| $N_v$ | IR | CBR | DBR |
|---|---|---|---|
| 1 | 22 | 14.6 | 2.75 |
| 2 | 26 | 16.375 | 3.25 |
| 3 | 32 | 20.375 | 4 |
| 4 | 34 | 20.725 | 4.25 |
| 5 | 39 | 25.175 | 4.875 |
| 6 | 41.999 | 26.125 | 5.2499 |
| 7 | 45.999 | 28.625 | 5.7499 |
| 8 | 48.999 | 28.725 | 6.1249 |
| 9 | 50.999 | 28.775 | 6.3749 |
| 10 | 56.999 | 33.775 | 7.1249 |
| 11 | 72.999 | 42.575 | 9.1249 |
| 12 | 77.999 | 45.425 | 9.7499 |
| 13 | 80.999 | 46.375 | 10.125 |
| 14 | 84.999 | 48.875 | 10.625 |
| 15 | 87.999 | 49.649 | 11 |
| 16 | 92.999 | 52.249 | 11.625 |
| 17 | 94.999 | 53.1 | 11.875 |
| 18 | 99.999 | 56.65 | 12.5 |
| 19 | 103 | 57.6 | 12.875 |
| 20 | 107 | 58.749 | 13.374 |
| 21 | 113 | 62.749 | 14.124 |
| 22 | 128 | 70.519 | 15.999 |
| 23 | 133.999 | 73.069 | 16.749 |
| 24 | 136.999 | 74.869 | 17.124 |
| 25 | 142.999 | 78.019 | 17.874 |
| 26 | 144.999 | 78.819 | 18.124 |
| 27 | 150.999 | 82.019 | 18.874 |
| 28 | 154.999 | 84.819 | 19.374 |
| 29 | 157.999 | 86.269 | 19.749 |
| 30 | 160.999 | 86.719 | 20.124 |
| 31 | 165.999 | 89.619 | 20.749 |

The simulation result shows that the combined approach provides accurate results than LA and PM techniques. Also in this paper a distance based relocation scheme, which estimates the time at which the relocation has to be done by keeping track of the distance between the mobile terminal and the base station is proposed. The simulation result shows that the cache overhead in the target BS using the distance based relocation scheme is very less compared to immediate relocation and CRT based relocation. This mechanism is very useful in present day scenario where there is an exponential increase in the number of mobile users.

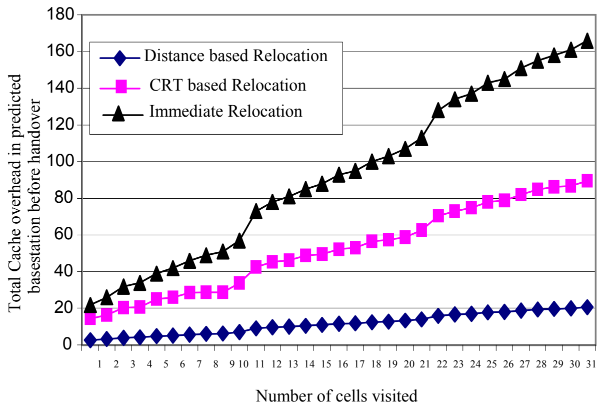


Figure 5. Cache overhead.

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