Time Dependent Resource Reservation Scheme for Cellular Network

Md. Nazmul Hasan[†]

Stamford University Bangladesh Computer Science dept, Dhaka, Bangladesh

S. M Didar-Al- Alam[††]

IUT, CIT dept, Gazipur, Bangladesh, Bangladesh

Summary
Cellular network offers services with diverse quality-of-service supports users to access telephony, paging, instant messaging, and trivial web browsing, video conferencing, voice chat on the same single device. The Portability of communication devices and channel imperfection makes the service offerings much more challenging with limited resources. Resource reuse factor is used in different cluster for efficiently manage the resources. However resource reservation plays a very important role in cellular communication in terms of availability of services as for managing the handoff. There are various schemes present to manage the resources in an efficient way. In this paper, we have tried to analysis several resource management schemes and their drawbacks. We have proposed a time dependent resource reservation scheme which has significant advantages over other schemes.

Keywords:
Mobility Management, handoff, Call Admission Control (CAC), Call dropping probability (CDP), Call Blocking Probability (CBP), Cell Visiting Probability (CVP).

1. Introduction

In a cellular network MU is connected with base station (BS), which uses a dedicated frequency Spectrum. The BS is connected with the BSC by microwave antennas that are again connected with MSCs for controlling purpose. MSCs are interconnected using the optical fiber backbone in most of the cases except some conditions where wireless connectivity is needed that acts as a gateway to the external links. Bandwidth [8] reuse principle is used on the limited available radio frequency spectrum that divides it into smaller spectrums for maximum uses. Smaller sized cells required by the next generation cellular networks to support higher transmission rates of multimedia applications that create increasing handoff problems in the cellular network. That's why resource management becomes a major concern in the perspective field. There are three major aspects to deal with. These are Call Admission Control (CAC), Resource reservation, and Resource Allocation. The paper is organized as follows. Introduction, Different past policies and difficulties with them, Our contribution, Our proposed scheme, Mathematical Relations, Conceptual backend database design, Comparison with old schemes, Conclusion and Future works.

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2. Different Policies for Resource Reservation

2.1 Elementary guard channel (GC)

This GC policy [3] reserves fixed portions of the cell capacity causing huge wastage of resources & higher call blocking probability. Instead of resource reservation, controlling new service admission random walk model decreases CDP below a threshold [1], [3],[5] level. Shadow cluster is formed with neighboring cells likely to be visited by an MU. Resources are reserved estimating the CVP for an MU relying on historic information rather then current mobility information. Initiating a new service is done on basis of resource limitation by giving priority to the existing call. Most of the CAC [1], [5] & resource reservation schemes are designed by reserving a certain bandwidth in each cell or by keeping CDP less than threshold value.

2.2 Non-Mobility Based Resource Reservation Schemes

A fixed portion of bandwidth is reserved in each cell for handoff services in conventional resource management schemes (Ex: Guard channel scheme). Unused channels are shared by handoff and new services. If we say CH_i^T is the number of total channels,

CH_i^u number of unused channels,

CH_i^a allocated channels,

CH_i^r reserved channels,

CH_i^f and number of free channels, then according to this scheme a new service is admitted if and only if

$$CH_i^f = CH_i^u - CH_i^r ,$$

the free channels can support it. Distribution is shown in Fig.1. Handoff is functional when it is supported by unused channels. Handoff service queuing (HQ) model on top of the GC scheme was introduced by Hong and Rappaport.

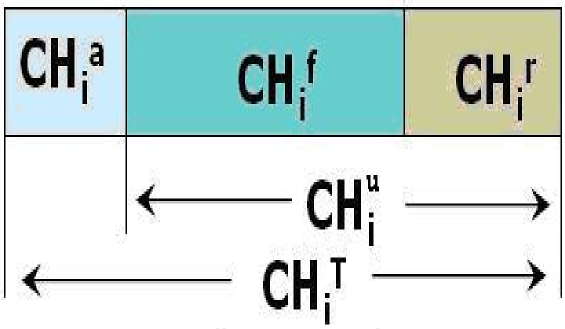

Fig. 1. Cell Capacity Distribution

In this model they assume that a MU can simultaneously communicate with more than one cell; Received Signal Strength Indicator (RSSI) level is used for handoff decision. For a MU the handoff procedure is implemented if RSSI level is less than the handoff threshold signal strength level and also less than the RSSI of any neighboring cell's BS. For unavailable channels of the next cell service are queued until the RSSI of the current BS drops below an acceptable received threshold. Tekinay and jabbari introduced in HQ model measured based priority-queue scheme (MBPS) to maintain priority in the queue, higher priority is given to the services with lower RSSI level. Performance of this HQ model has been studied both experimentally and analytically using the birth-death queuing model [4]. This scheme though can detect handoff situation perfectly but resource reservation part has not been given much concern. Fixed amount of resource is reserved in all the neighbouring cells costing a huge amount of resource wastage.

2.3 Symmetric Random Walk Model Based Schemes

SRWM [7] estimates CDP and/or CBP using different statistical measures & keep them below some threshold values for new/handoff services admission decision.

2.3.1 Threshold Bounded New Service Admission Control Models

In threshold bounded new service admission control schemes [1], [2], [5] new services are accepted if the number of new services or CDP in a cell is below a given threshold. Handoff service is admitted by the remaining unused channels in the cell.

2.3.2. Diffusion Equation Based Models

The properties of the diffusion equation are used to predict the mobility of MU. The influences of MU from the neighboring cells are taken into consideration. Diffusion equation based models takes the CAC decision that expected CDP is kept below $P_{i\,D}$ (a certain limit). No resource is reserved for this purpose. Principles of the diffusion process cannot explain freewill motion of MUs in a cellular environment guided by geographical features.

2.4 Handoff Profiling Based Schemes

This schema predicts future mobility of an individual MU based on the mobility history stored in profiled databases. Path segment or mobility, route & timing information of the visiting MU is recorded in the database.

2.4.1. Path Segment Based Schemes

For dynamic location tracking Tabbane used user specific handoff mobility profiling database based on the quasi-deterministic mobility behavior. Liu and Maguire further pursued the model by tracking repetitions of movement patterns. Location of the MU estimated based on these movement patterns, using pattern matching/recognition-based mobile motion prediction (MMP). Random movements cannot be classified by the simple mobility patterns. MMP algorithm is high sensitive to this is its main drawback. To solve the problem Liu et al. proposed inter-cell mobility predictor. Here routine routes of the user are identified from mobility profile database by using an approximate pattern matching technique. For each user's mobility patterns (UMPs) are recorded and indexed by the occurrence time. It is much less sensitive to small deviation from the user's actual path (UAP).In UMP it is assumed that the direction of MU is not changed within a path segment like within a cell. For a cellular network with micro-cells or Pico-cells using UMP is meaningless. It has high computational complexity and huge storage requirements that is not suitable for realworld situations.

2.4.2. Mobility Route Based Schemes

Levine et al. proposed the scheme where route based user mobility information is profiled at regular intervals. That estimates handoff, cell residence time for each cell and cell-independent call duration. It gives us the time-dependent" CVP for the MU considering all possible routes to visit neighbouring cells. This technique is very expensive as it requires constant updating for each MU in profiled databases. Again the number of possible routes could be infinite. Recording individual or aggregated mobility history is time and space consuming task. Reducing complexity by distributing database demands extra memory and processing power. As aggregated mobility history must be kept centrally, distributed database cannot resolve the problem too.

2.4.3. Route Independent Traffic Flow Based Schemes

This scheme profiles up handoff histories in the form of quadruplets. It has the departing time from the current cell, the index of the previous cell the MU resided in before entering the current cell, the index of the cell the MU entered after departing the current cell, and the current cell dwelling time. CVP is then estimated. Profiling each handoff for a large period of time (at least 24 hours) is space consuming. Here from all the handoff profiling based schemes we found that a major common problem is cost. These models cost huge time and money. Different models records different topics like Movement patterns, Route based mobility information, Handoff histories etc for taking resource reservation decision. But among this Route Independent Traffic Flow Based Schemes are better as they records handoff, though it is very much costly**.**

2.5 Cell Topography Based Schemes

Zhou [6] extended cell topography knowledge to predict CVP directly from the location road-map. From its current position an MU takes the next path with equal probability from the paths ahead. At location *A*, MU can turn left or turn right or take a U-turn. CVP for cells 1, 3, and 5 are 1/3 from cell 4. It is shown in Fig 2. Information of road networks is taken into account ignoring mobility information. It is highly complicated in a city with complex road-networks.

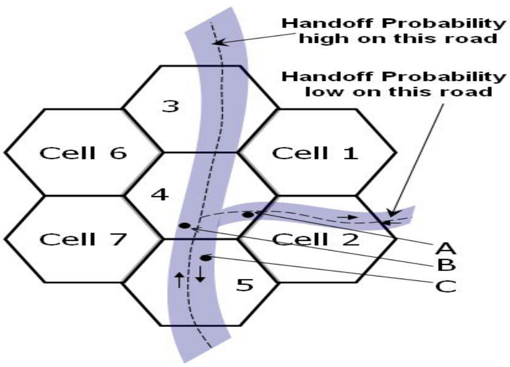

Fig. 2. Cell Topography based on CVP estimation

In this model road networks and environment are taken under consideration. Surely this knowledge helps to handle handoff situation perfectly.

2.6. Parametric Mobility Support Schemes

In this scheme key mobility parameters are used. They are position, direction, and speed. This information is used for CVP estimation, shadow cluster formation technique, solitary resource reservation policy, complete resource reservation and CAC policies.

2.6.1. Shadow Cluster Formation without Explicit CVP Estimation

Using the direction and speed information of the MU this scheme proposed an elliptical shaped (Fig 3)
shadow cluster formation technique [6], [10]. It does not estimate any CVP. MU is the focus of the ellipse and direction is the axis.

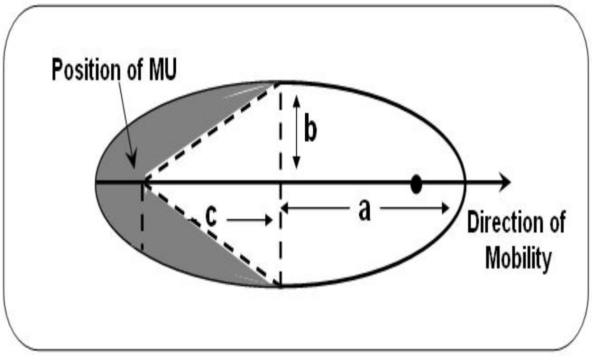

Fig. 3. An elliptical shaded shadow cluster is formed.

In the shaded region which is the backside of the MU's current position, visiting probability is extremely low. Elliptical cluster reserves resources unnecessarily for the area. From the position of the MU the radial span of the cluster should be equal. This should be irrespective of the direction. Next, CVP has no bearing. So the shape and size of the cluster remains same irrespective of the MU current cell. As there is no CVP estimation [11], so resource reservation policy is not effective one. Direction of MU has no influence on the amount of reservation.

3. Our Contribution

As far as we know the database based schemes are mostly not applicable because of there high cost and maintenance problems. Again these database based schemes can not give an optimally efficient performance for the whole network at a time. They actually focus on giving optimal performance for most of the cells. We have proposed a new database based scheme that is able to reserve resources much more effectively. We tried to find out the causes behind performance problems and proposed the new idea with some specific improvements. In this paper we also tried to find out the problems of the previous well established schemes and then show how we can overcome the problems with the help of this theory.

Our scheme would take decision for each and every cell separately. This would be effective for having a constant efficient performance for whole the network.

3.1 Identify the Problems with previous schemes:

Our proposed scheme can be categorized as a Handoff profiling based scheme. Many of the schemes already proposed that profile the mobility history of MU and from that record try to predict the mobility in future. So there are different schemes like-

- Path Segment Based Schemes
- Mobility Route Based Schemes
- Route Independent Traffic Flow Based Schemes

We have already discussed about these schemes in details previously. Now we specially focus on the problems that why these schemes failed to offer an optimum solution.
Problems with the Path Segment Based Schemes are:

- User specific handoff mobility profiling database is used.
- Pattern matching for motion prediction is very much sensitive.
- High Computational Complexity
- Huge storage requirements.

Again problems with the mobility route based schemes are:

- Infinite number of possible route calculation.
- Huge amount of data stored in the database and need constant updating
- CVP estimation technique is computationally highly expensive.
- Unnecessary computational complexity occurs in the system.

With Route Independent Traffic Flow Based Schemes the problems are like:

- It profiles up handoff histories in each cell in the form of quadruplets.
- It exploits an important mobility characteristic like traffic flow.
- Handoff profiling for a large period is very much space consuming.
- Unnecessary handoff records are also profiled.

3.2. Our Motivation

Our motivation for proposing Time Dependent Cell Database Based is described with the aid of a figure 4.
So from the diagram it is clearly visible that how we were motivated to offer this Time Specific Cell Database Bases Scheme. Here in our scheme not only we tried to offer some benefits but also tried to minimize the drawbacks that the previously proposed schemes faced and failed. In the next section we will find out the benefits we get from our scheme. Here the drawbacks we tried to minimized are given.

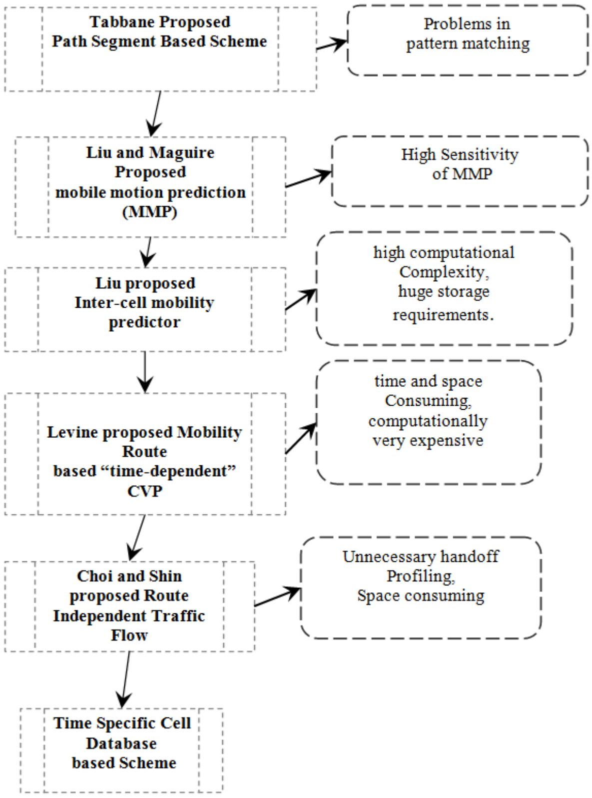

Fig. 4: Motivation for Time Specific Cell Database Based Scheme

3.3. PROPOSED SCHEME

3.3.1. Time Specific Cell Database Scheme

In the proposed time specific cell database scheme a database is maintained for each and every cell. Now the cell database is created by watching the MUs' movement for a period of time. It then takes the decision depending on the database. It updates its database after a defined period of time to notice the change in the cell area. In the Fig. 5 we can see how the cells are using the database to take the reservation decision. Suppose, a city is divided into two parts which are Residential area and office area. Now the cell observer finds out that during the 7am-10am period of time the handoff is happening very frequently in these cells because of the movement of people from home to office. So, for this period the handoff probability is very high in these cells. So the larger portion is reserved for handoff managing to control the handoff rush properly. Then from 10am-5pm cell observer finds a static situation within the cell and that's why use larger portion of its resources for call initiating. Again from 5pm-9pm again rush on road causing same situation during 7-10am because of rush on the road. On the highway, as all the vehicles are moving fast and handoff probability is much higher so always handoff portion should be more for highway cells. Again for weekends we should have different strategies as there is no rush for office area in that period. For amusement & market areas the rush would be higher & handoff should be managed just as before.

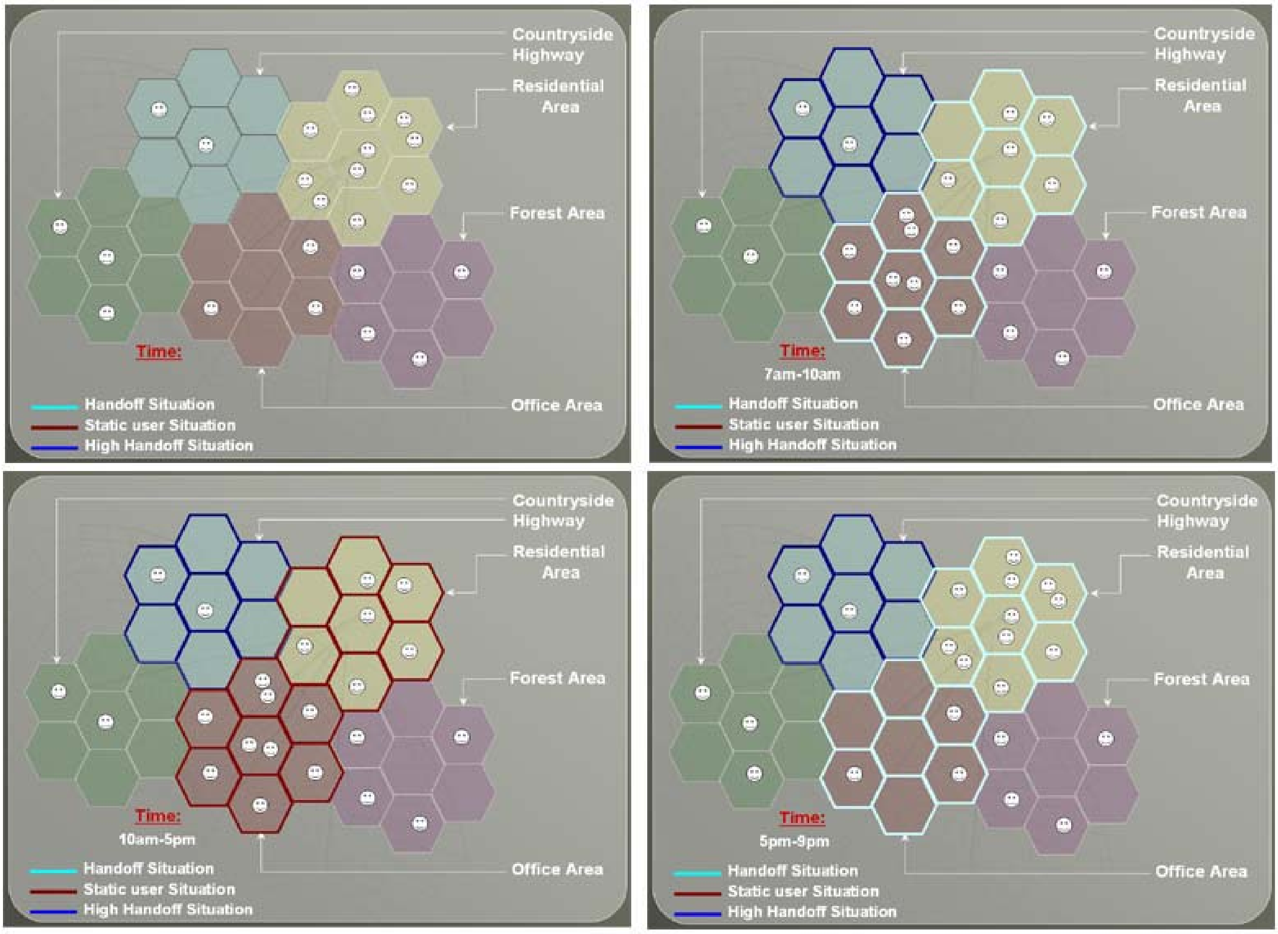

Fig.5. Time specific cell database scheme

3.3.2. Mathematical relationship

Here we are actually trying to give a basic idea how different parameters are related with the handoff probability and how they change its value. To give the relations mathematically we assume

H_p = Handoff Probability for the cell

R_h = Resource reserved for handoff

R_i = Resource reserved for call initiating

Then the relation would be:

$$H_p \infty \quad R_h \qquad (1)$$

$$H_p \quad \infty \quad 1/R_i \qquad (2)$$

As considering only equation **1** we can take our threshold value decision we are only focusing on this

$$H_p \infty \quad R_h$$

$$\Rightarrow H_p = k \,.\, R_h \qquad (3)$$

Here K depends on the factors like,

U= Number of user resident at the moment.

C= Number of call initiated

N= Number of users in neighboring cells

P= Probability of users to move in this cell

T= Average time period for the initiated calls.

And K is dependent on this factor in the following way-

$$\frac{NP}{UCT}$$

So equation 1 can be written as

$$Hp \propto \frac{NP}{UCT} R_h \qquad (4)$$

3.3.3. Conceptual database design for Cell Database Scheme

Suppose we store data in the database for a 2 hour time gap for all 7 days in a week. Observer observes the cell for a specific period of time and stores the handoff percentage for the cell happened in each slot of time. From database if we find handoff probability for a cell more than 40 % then we reserve larger portion of the resource so that we can minimize the CDP. Again if handoff probability is less than 40 % then resource portion is smaller to minimize the CBP.

	6-8 am	8-10 am	10-12 am	12-2 pm	2-4 pm	4-6 pm	6-8 pm	8-10 pm	10-12 pm	12-2 am	2-6 am
Fri	20	25	30	40	40	70	60	30	20	10	10
Sat	20	50	40	30	30	40	60	30	20	10	10
Sun	20	70	55	30	40	55	60	30	20	10	10
Mon	20	70	55	30	40	55	60	30	20	10	10
Tue	20	70	55	30	40	55	60	30	20	10	10
Wed	20	70	55	30	40	55	60	30	20	10	10
Thu	20	70	55	30	40	55	60	30	20	10	10

Fig. 5 Database model view for the proposed scheme

So, for the database schema design we have to have one database in the MSC and one in the BSC because it is difficult to maintain bulky data at BSC. This costs much. To reduce the cost and to gain speed in retrieving we use a distributed database. A sample view of database for a Time Specific Cell Database Scheme is shown in Fig 5.The schema design for the backend database is shown.

3.3.4. Assumptions & Specifications

3.3.4.1 High data retrieving rate

Data retrieving rate is high in this scheme as we are storing data in the BSC database. So the data can be retrieved in a much shorter time than other schemes where others are retrieving data from the OMC. From the graph (Fig. 7) we can see that data size with respect to time is growing up. Though the rate of it low in other schemes in spite of that the time limit is higher. On the other hand the growing scale takes a high jump after 2GB as we consider more than 2GB of data should be retrieved from the MSC. But the graph clearly shows us that high growing rate does not make it ineffective but still it is effective in time savings and high rate data retrieving.

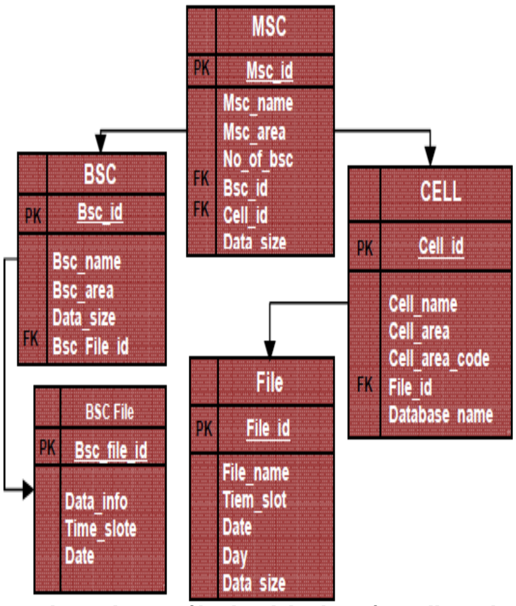

Fig. 6. Schema design of backend database for Cell Database Scheme

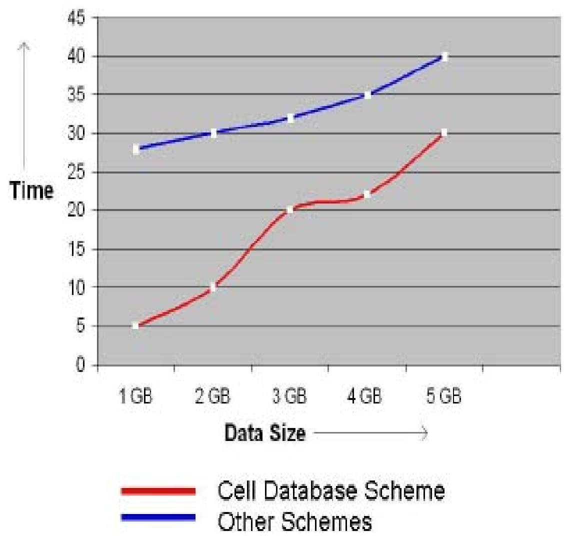

Fig.7. Data retrieving rate graph

3.3.4.2 Constant & Efficient CBP & CDP Management

As in other schemes frequency is managed for whole network at a time depending on historic movement of MU. Though this is applicable for most of the cells but for some cells it may cause hazardous situation. From the graph (Fig. 8) given we can see the effect of this situation. From 7am-10am MUs' much movement causing heavy handoff rushes. For this reason, larger portion of frequency is reserved for managing this handoff situation in the whole network. But it is not efficient for all of the cells. Cells like residential area may need higher portion of frequency for call initiating while much frequency is reserved for managing handoff situation. This causes high CBP. Again form 10am-5pm frequency is reduced for handling handoff situation now which is given for call initiating. But this also causes problems for highway as handoff is occurred frequently in highway.

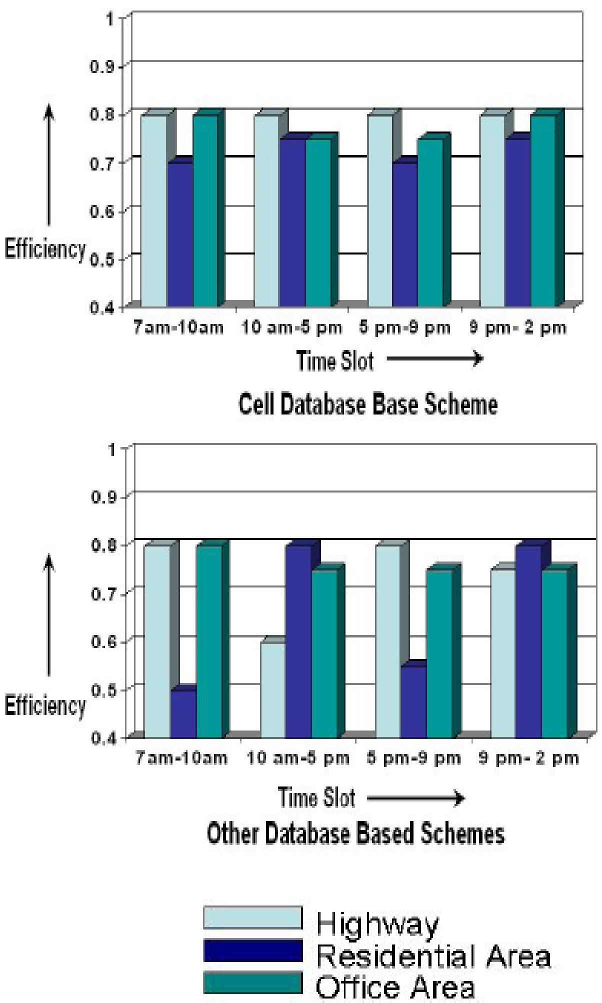

Fig. 8. Efficient management of CBP & CDP\

Some other situations are also given in the graph. In our schema as we maintain cell database, it helps us to take decision on a specific cell that what level of resource it should have for managing the handoff. So here we can ensure that while we are giving high reservation in most of the areas that may not cause high CBP in the residential area. As we are serving it with a low resource reserved, this gives us a constant efficiency Fig. 8) all the time in all the cells. From the graph we get some more situations where CDP & CBP is managed efficiently.

3.3.4.3 Cost Effective data storage

In Mobility Based schema path movement for each MU is taken into consideration & movement of each MU is stored in the database. So here database is huge which causes high cost for managing as well as for storing & retrieving.

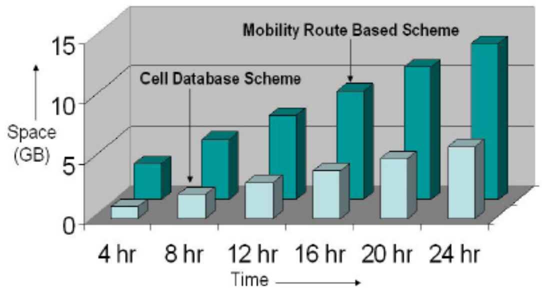

Fig. 9. Cost effective data storage

But in Cell database schema number of handoff per cell is calculated with respect of time. As here we don't calculate each MU's movement other then handoff condition. So, database is small. It is also easy to manage the database as it is distributed. So, our scheme has less costly data storage than Mobility route based scheme (Fig. 9).

4. Working Procedure for The Cell Database Scheme

This flow chart (Fig. 10) is given for showing the working procedure of Cell Database Scheme. From the flow chart it is visible that each time it is taking the decision that it is now going to get new data to store or it is going to take decision on stored data. If it needs to take decision it then checks for the data size. If it is smaller than a fixed amount it looks for the data in the BSC database else it looks in the MSC database which is more time consuming. After gathering of data it takes the decision of the amount of resources to be reserved. According to the decision it reserves the resources. Or it finds out that it is going to gather new data to store. Then it starts by checking out when last database was updated. If it is more than four months ago then the observer gathers new data and stores it. If it was updated within four months then it takes the decision that data is valid for use.

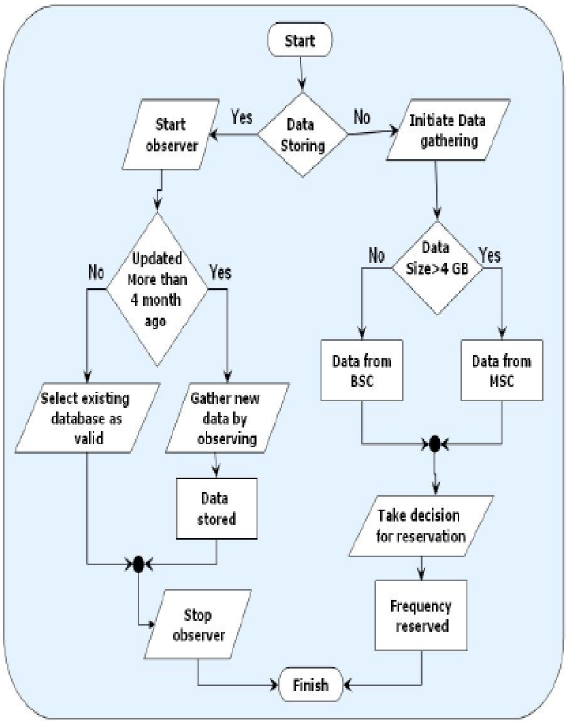

Fig. 10. Cell Database Scheme Flow chart

5. Benefits Achieved from Our Scheme

Our proposed scheme offers some benefits in resource reservation field for cellular network. These benefits are listed below in brief:

- Each and every cell has its own database that helps minimizing the data retrieving time and faster thresh hold updating becomes possible.
- Only the number of mobiles visiting and number of mobiles initiating quitting is recorded in the database instead of storing all path of the MU.
- In our scheme we found out that the database size is minimized and that's why it is much more cost effective.
- Cells are independent units that can take its decisions itself so one cell decision is not affected by some other neighboring cells.
- Resource Reservation is done in some specific time slots. That's why the scheme always gives a consistent performance.

6. Conclusion & Further Work

Above we have discussed some related schemes that contributed a lot in the telecommunication evaluation. But none of them are the optimal one. We have proposed a new concept of resource reservation, where we have taken under consideration the problems of the previous schemes. But we have some further improvements to do in it like:

1. Call duration should be taken into account. That means a database should be maintained for ongoing calls for each cell to limit its excessive holding of a channel. If a call duration limit exceeds then its CDP would be higher and new initiating calls will be given much priority. That means whenever one call takes more than a threshold amount of time then his priority of holding that call is deceased in compare of newly initiated call; if a new call is suffering for getting available channel then that ongoing call will be dropped get giving the priority of new call. Over here CDP will be sacrificed in course of limiting CBP.

2. Mobility and Non mobility based issues should be merged. Previous schemes discussed only with one of those aspects completely ignoring the other one in most of the cases. Schemes those considers both of the aspects actually focuses only one aspect in practical use. Schemes concerned about both the aspects practically will be much more effective.

3. As cell database is used, the database would be a distributed one, which makes it hard to manage. So database management should be taken under consideration.

4. Threshold value for CBP and CDP would be dependent on the cell size. For bigger cell size, for less density area, forest area etc place frequency reserved for the handoff would be very less & vice versa.

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Md. Nazmul Hasan has completed his graduation from Islamic University of Technology (IUT) in November 2008. After his graduation he has joined in Stamford University Bangladesh as lecturer of Computer Science department and till now he is working here. He is also been working as a part time faculty member of Islamic University of Technology (IUT). From the begging of his undergraduate thesis to till now he is involved in several research topic like sensor network, cellular network, Artificial Intelligence etc.

S. M. Didar-Al-Alam has completed his graduation form Islamic University of Technology (IUT) in November 2008. Just after his graduation he joined Islamic University of Technology (IUT) as a Lecturer in Department of Computer Science and Information Technology (CIT) and till now he is serving IUT. His major research interests are related to the field of Artificial Intelligence, Wireless Communication & Networking, Ubiquitous Computing.