

## Improving the Performance of Handoff Calls using Frequency Sharing

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**Abstract:** In this paper, a two-tier cellular wireless network is characterized by overlapping the service area for managing the new calls users having different mobility speed. The overlapping property of the two-tier system provides the advantages that share the traffic load to improve the efficiency of new calls subscriber with guard channels in cell to handle the handoff calls. Using Guard channels, our strategy have the prioritization to the handoff calls. Micro cells are used to provide the services to slow-speed, high-intensity traffic area users and macro cells are overlaid over more than one micro cell cater mainly to lower density, high-speed users. The two-tier of micro cells and macro cells provide the secondary resource to provide the service for new calls as well as handoff calls with guard channels as overflow the slow speed users in macro cell by sharing the frequency in vertical direction as well as sharing the frequency in horizontal direction in the upper layer. The call lose probability of aggregate calls are developed through numerical analysis. The results justify the advantages of proposed strategy.

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**Key words:** cellular network, two tier communication system, load redirection, guard channel, Micro cell, Macro cell.

### 1. Introduction

In order to provide the efficient services against increase of demand for the wireless cellular communication networks is the challenging issue. The radio spectrum range is limited and can't be catch up with increase of users demand for the wireless cellular communication networks. To release that stress one way is to design micro cells moreover, micro cells are not advantageous in the service area where user population is sparse with slow and high speed subscribers. Small cell systems induce an increase the handovers by the high speed mobile subscribers. Micro-macro cell overlay structures can overcome with these difficulties. The overlapping property of the two-tier structure provides the advantages that share the traffic load to improve the efficiency of call admission control. Call admission control (CAC) schemes are critical to the success of future generations of wireless networks. It provides the users with access to a wireless network for services. On the other hand, they are the decision making part of the network carriers with the objectives of providing services to users with guaranteed quality and at the same time, achieving as much as possible resource utilization. It is therefore conceivable that CAC policy is one of the critical design considerations in any wireless networks. CAC schemes provide the services for both users, one of them are new call users and other types of users are on going old call users. New call users are those users who make the new

connection in current cell for communication and therefore required the channel/frequency for connection establishment and on the other hand on going old call users are those users who's connection is already established but due to mobility they required to change the cell for continuous communication therefore further they required the channel/frequency in another neighboring cell for connection establishment to facilitate the users for continuous communication without breaking the connection. Previous type of CAC scheme is called New Connection Establishment (NCE) or in short New Calls and on the other hand latter type of CAC scheme is called Handoff calls. Therefore CAC schemes are categorize in two parts: one is for new calls and the second is for on going (old) calls.

A two-tier cellular network is characterized by macro cells and micro cells overlapping in the service area. Resident on the top layer are larger cells called *macrocells*, while resident on the bottom layer are smaller cells called *microcells*. Subscribers are assigned to micro cell or macro cell based on their mobility speed. In [4, and 5] it is proposed to direct a new/handoff to the appropriate tier based on its previous speed. However, when there are no available channels on the preferred tier, the call will be directed to the other (un-preferred) tier. This is called an *overflow*. In our research, we restricted the fast speed user to overflow in microcell and if slow speed user overflow to un-preferred tier than not return

automatically until it forced to overflow to service the new/handoff calls.

Systems employing multitier cells have been considered in a number of publications. Several methods for handling new calls and handoff traffic of the defined mobile subscriber speed classes are proposed, and performance measures such as the probability of new call blocking, probability of forced termination, and traffic capacity have been determined. In the case of a speed-insensitive selection mechanism, call originations are assigned to a default cell layer which is, in most cases, the lowest (microcell) layer [1, and 2]. If a speed sensitive selection mechanism is used, arriving calls can be directed to the specific cell layer dependent on the speed class of the mobile station. Examples are given in [3, 4 and 5]. Many works also directed in the direction to the optimize the performance of the system based on the factors such as roaming speed of users, level of cloudiness of an area, location management, and channel management etc in the papers [6, 7, 8, 9, 10, 11, and 12]. Two-way overflows are considers in between both tier [13]. In this paper a take-back scheme is also proposed in which call is redirect from an un-preferred tier to the preferred tier at the time of handoff take place. On the other hand a channel rearrangement scheme is a proposed in the reference [14] by forcing a handset in the overlapping area to take a early handoff permanently.

In our research a two-tier system is proposed with Guard-Channels that are reserved to handle the handoff calls only. In this paper our scope is to improve the performance of new calls by using overlapping property of the two-tier system provides the advantages that share the traffic load with frequency sharing techniques in between micro-

macrocell. By using the overlapping property of two-tier system the load of the call may be transferred from lower-tier to upper-tier and vice-versa. Let us assume that a macrocell is overlapping with  $n$  microcells, and a macrocell is neighboring to  $k$  macrocells. When a channel request arrives at the macrocell and if the macrocell has no free channels than the system force one of the slow calls on the macrocell to move to one of the other  $n$  overlapping microcells to vacate a channel on the macrocell. On the contrary, when a channel request arrives at a microcell, if the microcell has no free channels, we can either overflow this call to the macrocell, or force one of the calls on the macrocell to move to one of the other  $n-1$  overlapping microcells to vacate a channel on the macrocell. Then the new call can be overflowed to the macrocell. We observe that such channel-sharing provides a lot of flexibilities to shift the load among the cells on the two tiers in vertical direction, so the scheme is called the **Vertical-Direction Frequency Sharing (VDFS)**. In this system a fast moving calls can't shift to microcells to avoid the more handoff, so that the system can avoid the more call dropping probability. We also take the **Horizontal-Direction Frequency Sharing (HDFS)** only in upper tier with  $k$  neighboring cells similar to the reference [14]. In the proposed system Guard Channels are used only for provide the services to handoff calls and therefore can't be used to overflow the new calls or sharing the channels to provide the services to new calls. The proposed system used VDFS scheme prior to HDFS scheme to share the frequency in both tier for handle the traffic load.

Table 1 shows the redirection of load in different schemes. Numerical analysis shows the performance comparison in between different schemes and proposed scheme.

**Table 1: Redirection of load in different schemes**

| Scheme Reference | Strategy                 | No. of redirect |
|------------------|--------------------------|-----------------|
| 13               | Overflow+Take Back       | 1               |
| 14               | Rearrange+Overflow       | $k+1$           |
| Proposed VDFS    | VDFS with Guard channels | $n$             |
| Proposed HDFS    | HDFS with Guard channels | $n+k$           |

## 2. Proposed VDFS and HDFS Strategy

Let us consider that there is a channel request arriving at the macrocell  $M$  or one of  $n$  microcells microcells  $m_i$ . If there is no channel is available in the cell to satisfy that request than proposed *VDFS* or our *HDFS* strategy will take place, trying to find a channel to serve the said request. The VDFS strategy tries to find a channel by shifting calls in the vertical direction, i.e., from one tier to the other tier. The HDFS strategy tries to find a channel by shifting calls in the vertical direction first. If this fails, it will try to shift calls in the horizontal direction on the higher tier.

In the following two sub-sections, we will discuss channel sharing in vertical and horizontal directions. The first sub-section is for the VDFS strategy, while the combination of the two sub-sections is for the later strategy i.e. for HDFS strategy.

### 2.1 Vertical Direction Frequency Sharing

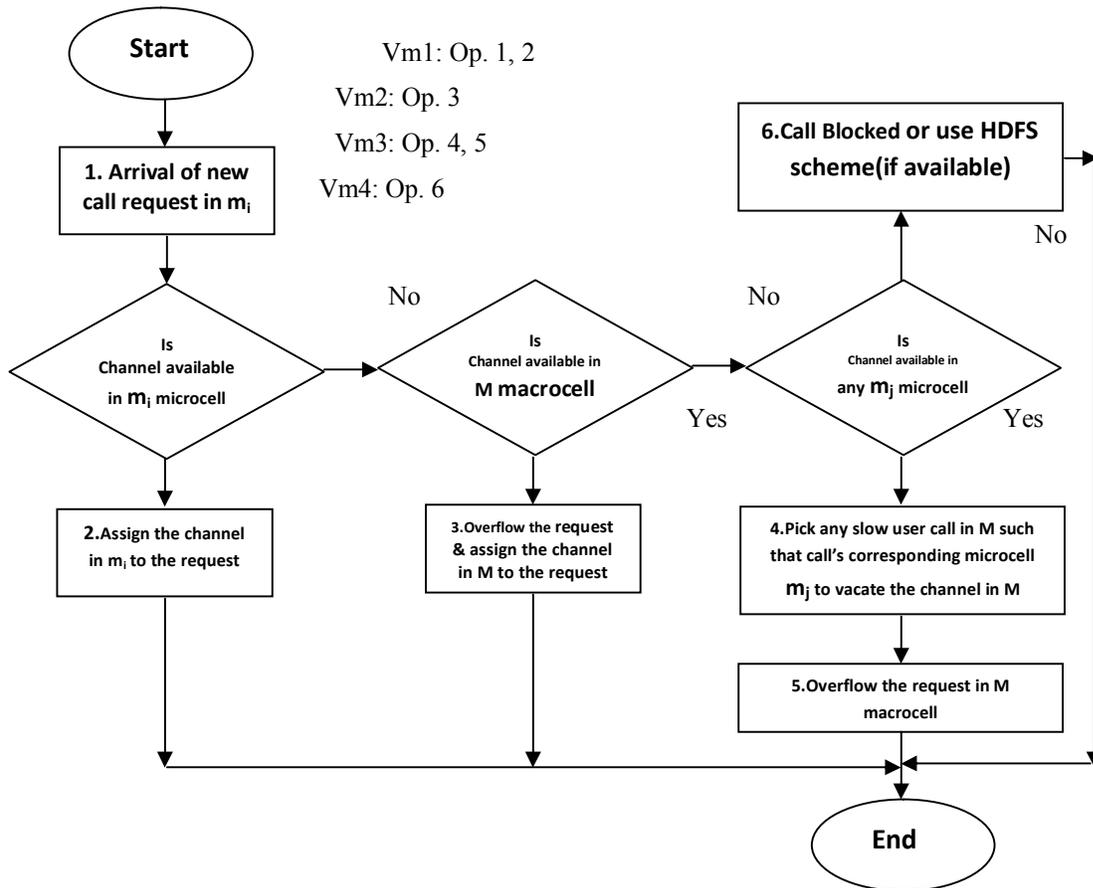
In VDFS strategy, the system does transferring the calls between the two tiers. The tiers may be either homogeneous or heterogeneous. In our discussion the tiers are homogeneous. In the following, we separate our discussion into calls arriving at the low tier and at the high tier. When there is a channel request arriving

to microcell (lower tier)  $m_i$ ,  $1 \leq i \leq n$ , the following operations will be encountered shows by the flowchart 'A' and on the other hand flowchart 'B' shows the operations encountered during the request arriving to macrocell M.

As shown in figure 1, a slow new subscriber S1 arrives at **microcell  $m_1$**  that has no free channel (**Free channels means the number of channels are available greater than Guard Channels for handoff requirements in a cell for proposed schemes**).

Therefore as per flowchart 'A' the operation 3 is applied and subscriber will be overflowed to macrocell

M. But we see that the M is also full therefore the frequency sharing in vertical direction is required and try to pick the slow subscriber as operation 4 which is currently served in macrocell M and that can be handoff to microcell with a free channel. In our example as shown in figure 1 the user P1 can be shifted to a channel in microcell  $m_2$ . After performing the operation 4, the channel is released by P1 user in microcell M can be used by S1new subscriber in macrocell M (operation 5).

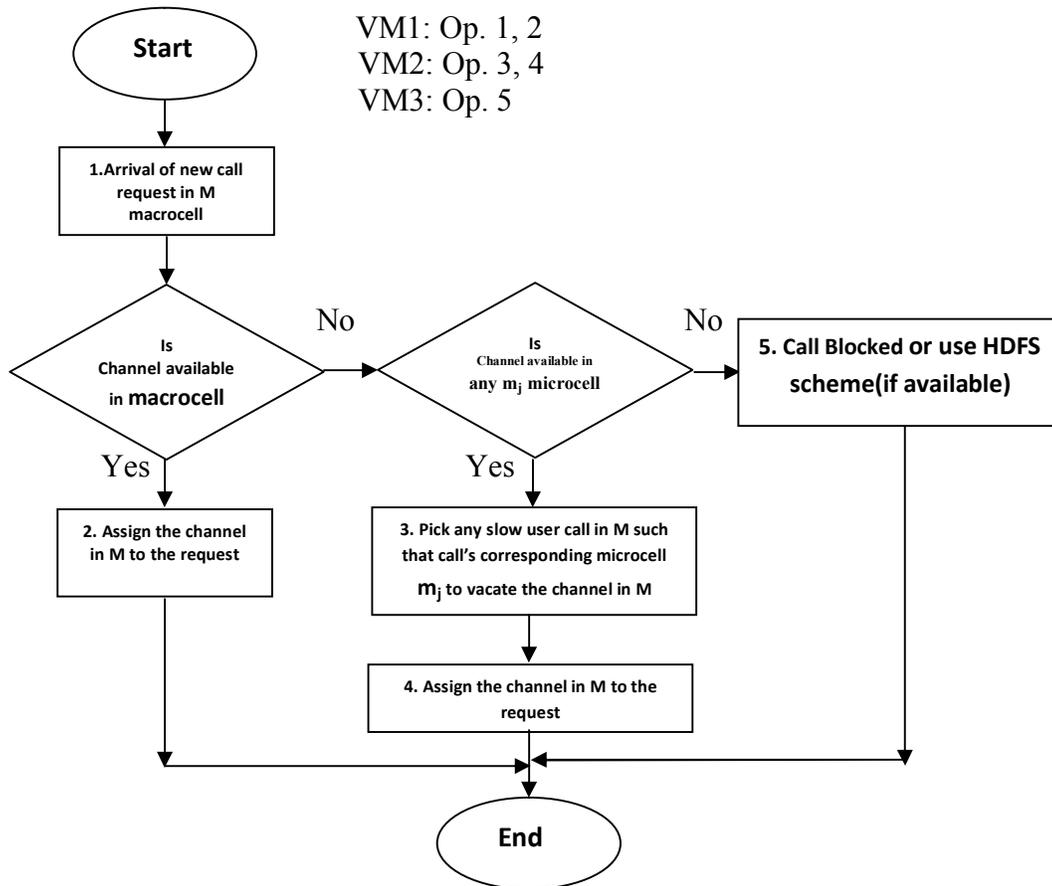


**Flowchart 'A': Operations occurred on Call request arrived to microcell**

**2.2 Horizontal Direction Frequency Sharing**

In this strategy the calls are transferred horizontally in between upper tier. If above VDFS fails than HDFS take place. This kind of sharing taken place by forcing the subscriber on macrocell  $M_i$ ,  $1 \leq i \leq k$  to early handoff in neighbor cell as shown in flowchart 'C':

Example as shown in figure 2, two new subscribers S1 and S2 arrive at microcell  $m_1$  and macrocell M respectively, which have already run out of channels. Subscribers P5 and P6 are two possible candidates that can take early handoff to M3, and M2 macrocells respectively.



**Flowchart 'B': Operations occurred on Call request arrived to macrocell**

Suppose that user S1 arrive first to microcell  $m_1$  that has no free channel(s) therefore vertical handoff occurs to upper layer macrocell M, which is also run out of channels. But in figure 2, we have seen

that all corresponding microcell to macrocell M also goes to out of channels, so operation 4 and 5 of flowchart 'A' is not possible.

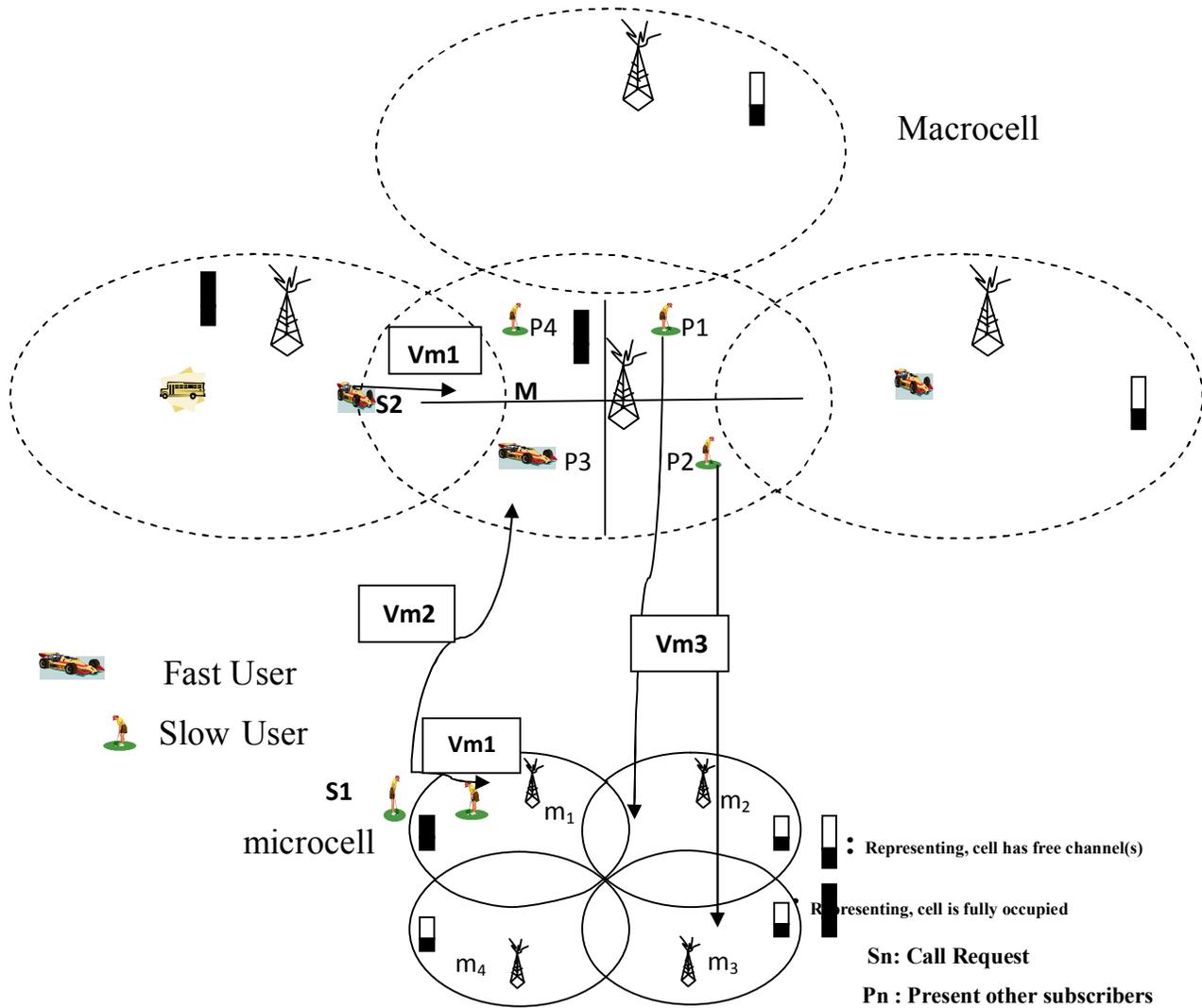
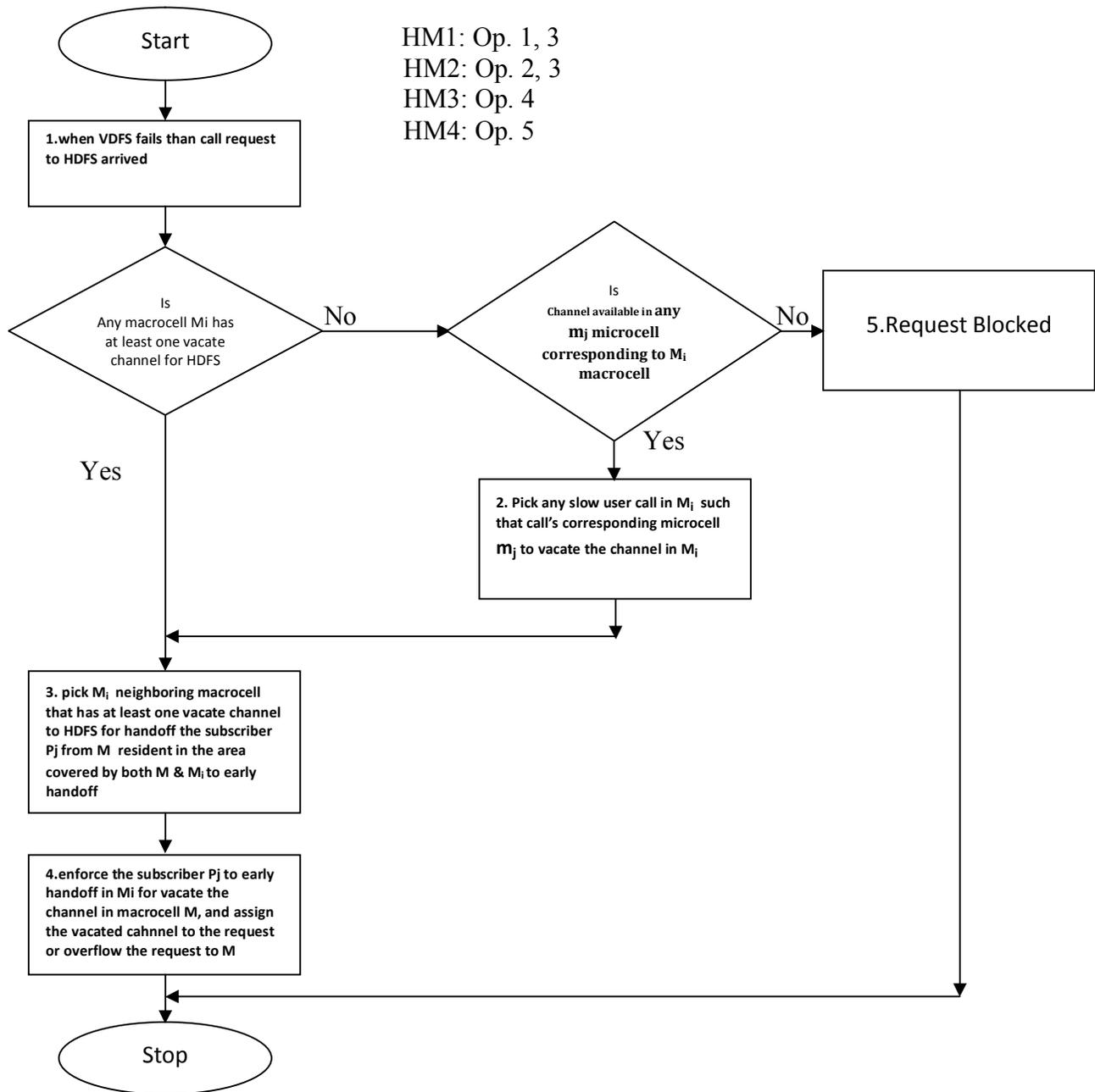


Figure 1: Channel sharing in the vertical direction for slow users

Also, the failure of our VDFS implies that there are no free channels in microcells  $m_1, m_2, m_3, \dots, m_n$  covered by macrocell M. In such situation a HDFS

is required only in upper tier. The subscriber P5 now takes early handoff to macrocell M3 to vacate the channel and may be allocated that channel to user S1.



**Flowchart 'C': Operations occurred on Call request to HDFS**

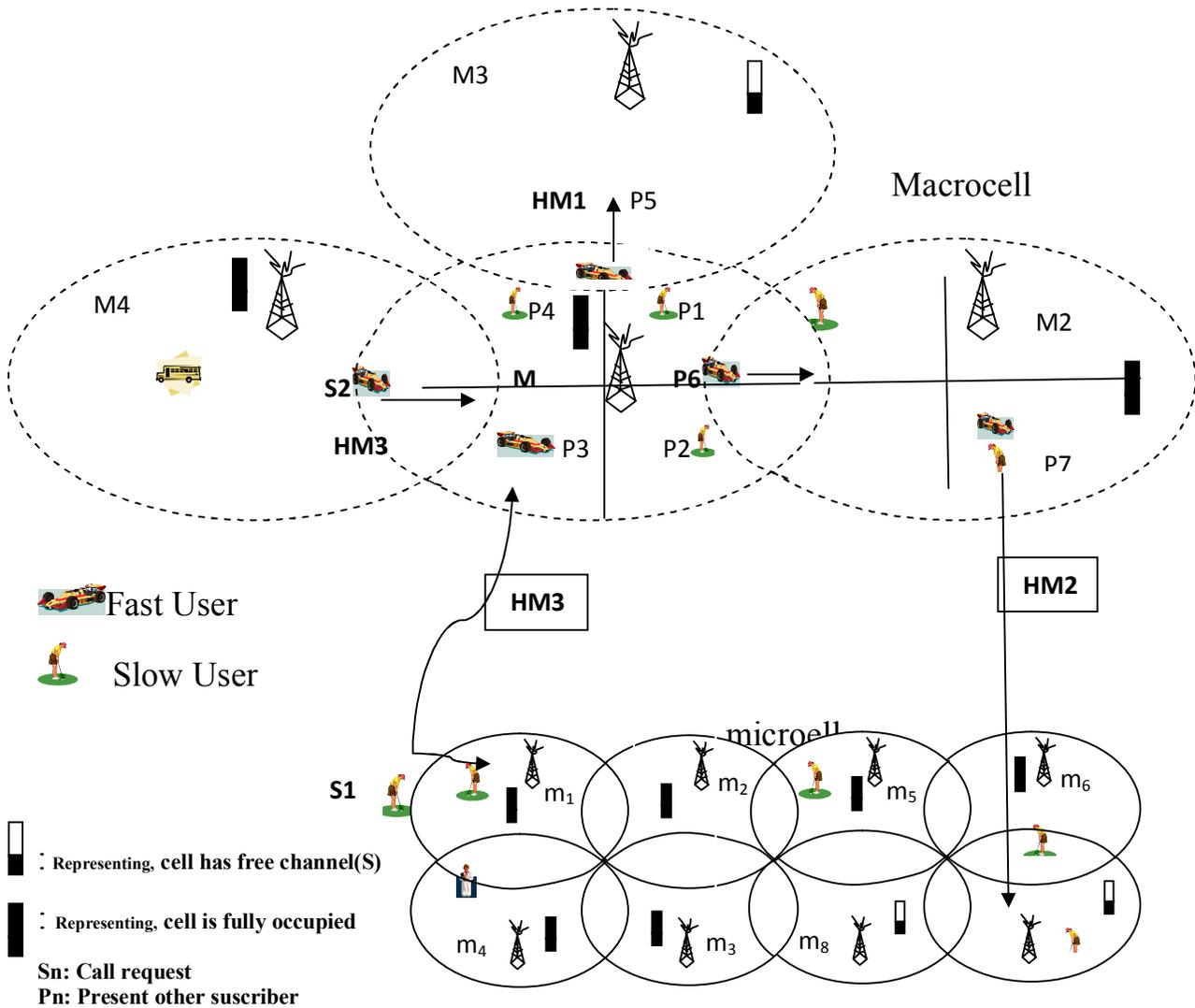


Figure 2: Channel sharing in the horizontal direction for slow subscribers and fast subscribers

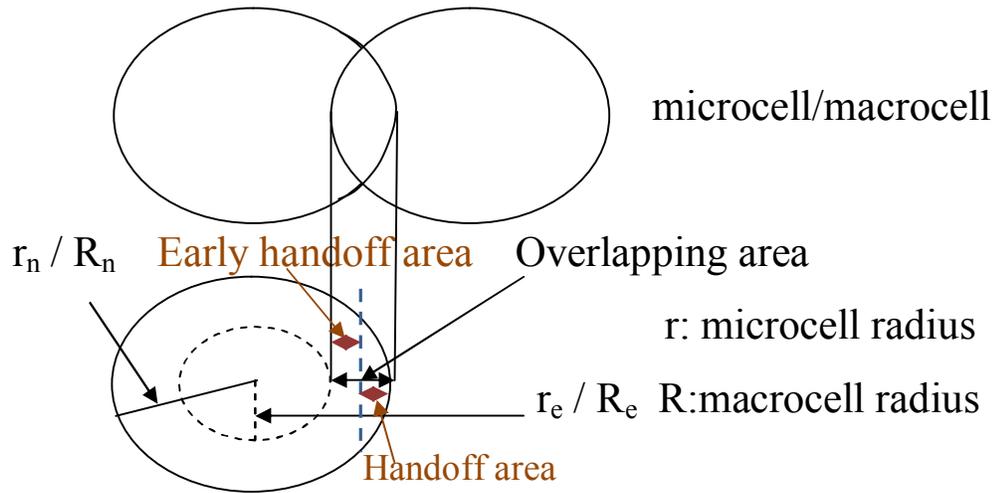
### 3. Analysis Model Description

We assume that cells are circular in shape and each macrocell covers ‘n’ microcells. We assume that all cells in the same tier are statistically identical, and thus we can focus on the behavior of only one cell and its interaction with neighboring cells.

The radius of the circle for a subscriber to take a normal handoff on a macrocell is  $R_n$ , and that on a microcell is  $r_n$ . However, since there will be some

overlapping between two macrocells/microcells, the radius of the circle for a subscriber to take an early handoff on a macrocell is  $R_e$ , and that on a microcell is  $r_e$  as shown in figure 3.

The arrival rates of new calls and handoff calls for both low and high speed users are assumed to be Poisson processes. The Poisson distribution is a suitable approach to represent handoff calls as indicated in [15].



**Figure 3: Radii of the circles for the subscribers to take normal handoff and an early handoff**

Handoff calls have burst characteristics; therefore they occur at different rates. **The cell dwelling time (CDT)** is the time a mobile user spends in a cell before it is handed off to another cell. It

depends on the speed of the mobile user and the size of the cell. The cell dwelling time can be calculated as shown in [13] as follows:

$$\frac{1}{\mu_d} = \frac{\pi r}{2V}$$

Where V is the velocity of subscriber and r is the radius of the cell.

**Note: Subscript s and f are used for indicating slow and fast user respectively and superscript m and M are used to mentioned microcell and macrocell respectively.**

The inverse of the cell dwell time is the **cell cross-over rate (CCOR)** is, therefore for slow and fast subscribers in macrocell are  $\mu_{ds}^M$  and  $\mu_{df}^M$  respectively as follows:

$$\mu_{ds}^M = \frac{2V_s}{\pi R_n}$$

$$\mu_{df}^M = \frac{2V_f}{\pi R_n}$$

The handoff probabilities [16] for fast and slow subscribers in a macrocell are respectively

$$P_{hf}^M = \frac{\mu_{df}^M}{\mu_e + \mu_{df}^M}$$

$$P_{hs}^M = \frac{\mu_{ds}^M}{\mu_e + \mu_{ds}^M}$$

that the call may remain in progress if it could continue to complete without being dropped, and it also follows a negative exponential distribution. According to [16], the mean **channel occupancy time (COT) / session duration** is the mean of minimum of unencumbered call duration and cell dwell time, which should be

$$\frac{1}{\mu_{ef}^M} = \frac{1}{\mu_e + \mu_{df}^M}$$

Where  $\mu_e$  is the inverse of the mean unencumbered call duration time. The **unencumbered call duration (UCD)** of a call is the amount of time

$$\frac{1^M}{\mu_{es}} = \frac{1}{\mu_e + \mu_{ds}^M}$$

for fast and slow subscribers respectively.

All the derivations that are discussed above for macrocell can be recalculate for microcell and represented by replace the superscript M by m as follows:

$$\mu_{ds}^m = \frac{2V_s}{\pi T_n}$$

**A. For macrocell**

- |   |                  |                  |
|---|------------------|------------------|
| Description                                   | fast subscriber  | slow subscriber  |
| 1. Traffic rate of new calls                  | $\lambda_{nf}^M$ | -                |
| 2. Traffic rate of handoff calls              | $\lambda_{hf}^M$ | $\lambda_{hs}^M$ |
| 3. Traffic rate of overflow calls             | -                | $\lambda_{os}^M$ |
| 4. Traffic rate of vertical direction calls   | -                | $\lambda_{vs}^M$ |
| 5. Traffic rate of horizontal direction calls | $\lambda_{zf}^M$ | $\lambda_{zs}^M$ |
| 6. Aggregate traffic rate                     | $\lambda_{tf}^M$ | $\lambda_{ts}^M$ |

**B. For microcell**

- |   |                 |                  |
|---|-----------------|------------------|
| Description                                   | fast subscriber | slow subscriber  |
| 1. Traffic rate of new calls                  | -               | $\lambda_{ns}^m$ |
| 2. Traffic rate of handoff calls              | -               | $\lambda_{hs}^m$ |
| 3. Traffic rate of overflow calls             | -               | -                |
| 4. Traffic rate of vertical direction calls   | -               | $\lambda_{vs}^m$ |
| 5. Traffic rate of horizontal direction calls | -               | -                |
| 6. Aggregate traffic rate                     | -               | $\lambda_{ts}^m$ |

**4. Performance Measures and Analysis**

In this section we analyze the proposed model as described above. The traffic flows include new calls, handoff calls, and those incurred by vertical and vertical-horizontal direction frequency sharing. These traffic flows are all assumed to follow the Poisson process. The parameters related to our analysis are already discussed in section 3. We assume that  $C_T$  and  $C_R$  are the total number of channels available and guard channels for handoff calls in each cell respectively. Therefore, number of channels remaining to handle the new calls only is  $C_A=C_T-C_R$ . If the number of channels free in a cell are greater than  $C_R$  than performing operations both handoff and call set up of new calls can't be problematic. But if any cell has less or equal number of channels than  $C_R$ , a free channels performing only handoff and therefore new calls, or overflow the slow speed user/forced handoff

$$P_{hs}^m = \frac{\mu_{ds}^m}{\mu_e + \mu_{ds}^m}$$

$$\frac{1^m}{\mu_{es}} = \frac{1}{\mu_e + \mu_{ds}^m}$$

Some more traffic parameters that are used in performance analysis of VDFS and HDFS are as follows:

in upper tier are handled by proposed VDFS and/or HDFS schemes.

**4.1 Performance of Using Vertical Direction Frequency Sharing**

In this section we analyze the proposed vertical direction frequency sharing scheme. Our target is to give the efficient scheme to handle the new calls therefore system able to reduce call lose probability of new calls. Therefore drive the *call lose probabilities*  $P_{lf}$  and  $P_{ls}$  for fast and slow subscribers respectively. This is the probability for a channel request being refused after the vertical direction frequency sharing.

Therefore call loss probabilities are:

$$P_{lf} = P_b^M P_{vs}$$

$$P_{ls} = P_b^m P_b^M P_{vs}$$

Where  $P_{vs}$  is the failure probability of vertical direction sharing.

$$P_{vs} = 1 - P_{sv} (1 - P_b^m) \tag{1}$$

Where  $(1 - P_b^m)$  is the probability that microcell has at least one free channel and  $P_{sv}$  is the probability that there exist a slow subscriber that is currently served by the macrocell and also covered by the microcell to served them.

$$P_{sv} = 1 - \left(\frac{n-1}{n}\right) \Xi^{CM} [(1 - P]_s) \tag{2}$$

Where  $\left(\frac{n-1}{n}\right) \Xi^{CM} [(1 - P]_s)$  represent the probability that all slow subscriber served in macrocell are not located in this particular microcell and  $P_s$  is the probability of slow subscribers located in the macrocell for the same area.

The  $P_b^M$ , and  $P_b^m$  is the probability that a mobile subscriber sees no free channel in a macrocell and microcell respectively, in the system where no guard channels are reserved to handle the handoff calls on prioritization basis (for TB and CR schemes):

$$P_b^M = \frac{\left(\frac{\lambda_{tf}^M}{\mu_{ef}^M} + \frac{\lambda_{ts}^M}{\mu_{es}^M}\right)^{C_A^M}}{C_A^M!} \frac{1}{\sum_{l=0}^{C_A^M} \frac{\left(\frac{\lambda_{tf}^M}{\mu_{ef}^M} + \frac{\lambda_{ts}^M}{\mu_{es}^M}\right)^l}{l!}} \tag{3a}$$

$$P_b^m = \frac{\left(\frac{\lambda_{ts}^m}{\mu_{es}^m}\right)^{C_A^m}}{C_A^m!} \frac{1}{\sum_{l=0}^{C_A^m} \frac{\left(\frac{\lambda_{ts}^m}{\mu_{es}^m}\right)^l}{l!}} \tag{4a}$$

These probabilities are worked to the system, when no channels are reserved as the guard channels for handoff calls in the system in which prioritization is not given to handoff calls. When prioritization to the

handoff calls are given than call lose probabilities for macrocells and microcells are as follows (for proposed schemes VDFS, and HDFS):

$$P_b^M = P_{bk}^M + P_d^M \tag{3b}$$

$$P_b^m = P_{bk}^m + P_d^m \tag{4b}$$

$$\lambda_t^M = \left(\frac{\lambda_{tf}^M}{\mu_{ef}^M} + \frac{\lambda_{ts}^M}{\mu_{es}^M}\right), \lambda_t^m = \frac{\lambda_{ts}^m}{\mu_{es}^m} \text{ and } \lambda_h^M = \left(\frac{\lambda_{hf}^M}{\mu_{ef}^M} + \frac{\lambda_{hs}^M}{\mu_{es}^M}\right), \lambda_h^m = \frac{\lambda_{hs}^m}{\mu_{es}^m}.$$

Let us assume that

$$\left(\frac{\lambda_{tf}^M}{\mu_{ef}^M} + \frac{\lambda_{ts}^M}{\mu_{es}^M}\right) \text{ and } \left(\frac{\lambda_{ts}^m}{\mu_{es}^m}\right)$$

Here we regard  $\left(\frac{\lambda_{tf}^M}{\mu_{ef}^M} + \frac{\lambda_{ts}^M}{\mu_{es}^M}\right)$  and  $\left(\frac{\lambda_{ts}^m}{\mu_{es}^m}\right)$  as the traffics contributed by the subscribers on macrocell and microcell respectively for available channels.

$$P_d^M = \frac{(\lambda_t^M)^{C_A^M} * (\lambda_h^M)^{C_R^M}}{C_T^M!}$$

$$\frac{\sum_{l=0}^{C_A^M-1} \frac{(\lambda_t^M)^l}{l!} + \sum_{l=C_A^M}^{C_T^M} \frac{(\lambda_t^M)^{C_A^M} * (\lambda_h^M)^{l-A}}{l!}}{1}$$

$$\Pi_0^M = \frac{1}{\sum_{l=0}^{C_A^M-1} \frac{(\lambda_t^M)^l}{l!} + \sum_{l=C_A^M}^{C_T^M} \frac{(\lambda_t^M)^{C_A^M} * (\lambda_h^M)^{l-A}}{l!}}$$

For computing the blocking probability states,  $(C_{A+1}^M, C_T^M)$ , will block any new incoming call since  $C_R^M = C_T^M - C_A^M$  channels are reserved for handoff only.

$$P_{bk}^M = \sum_{l=C_{A+1}^M}^{C_T^M} \Pi_j^M$$

$$\Pi_j^M = \Pi_0^M \{$$

$$\text{Similarly, } \frac{(\lambda_t^m)^{C_A^m} * (\lambda_h^m)^{C_R^m}}{C_T^m!} \frac{(\lambda_t^m)^l}{l!} ; l \leq A$$

$$P_d^m = \frac{(\lambda_t^m)^{C_A^m} * (\lambda_h^m)^{C_R^m}}{C_T^m!}$$

$$\frac{\sum_{l=0}^{C_A^m-1} \frac{(\lambda_t^m)^l}{l!} + \sum_{l=C_A^m}^{C_T^m} \frac{(\lambda_t^m)^{C_A^m} * (\lambda_h^m)^{l-A}}{l!}}{1}$$

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For computing the blocking probability states,  $(C_{A+1}^m, C_T^m)$ , will block any new incoming call since  $C_R^m = C_T^m - C_A^m$  channels are reserved for handoff only.

$$P_{bk}^m = \sum_{l=C_{A+1}^m}^{C_T^m} \Pi_j^m$$

$$\frac{(\lambda_t^m)^l}{l!} ; l \leq A$$

$$\Pi_j^m = \Pi_0^m \{$$

Let variables  $\lambda_{tf}^M$ ,  $\lambda_{ts}^M$ , and  $\lambda_{ts}^m$  denotes the arrival rates and  $\mu_{of}^M$ ,  $\mu_{os}^M$ , and  $\mu_{os}^m$ , denotes the service rates.

Next, we need to calculate the aggregate traffics  $\lambda_{tf}^M$ ,  $\lambda_{ts}^M$ , and  $\lambda_{ts}^m$  by following the analysis model in [17].

These traffics are composed of new calls, handoff calls, overflow calls, and channel sharing calls. Variable  $\lambda_{tf}^M$  is aggregate traffic rate incurred by new calls and handoff calls into macrocell by the fast subscribers:

$$\lambda_{tf}^M = \lambda_{nf}^M + \lambda_{hf}^M$$

Where

$$\lambda_{hf}^M = \lambda_{tf}^M (1 - P_b^M) P_{hf}^M$$

means the handoff rate is the aggregate traffic rate itself successfully stays in the macrocell  $\lambda_{tf}^M (1 - P_b^M)$  times the handoff probability  $P_{hf}^M$ . Similarly,  $\lambda_{ts}^M$  is the aggregate traffic rate incurred by overflow calls and handoff calls into a macrocell by slow mobile subscribers:

$$\lambda_{ts}^M = \lambda_{os}^M + \lambda_{hs}^M$$

Where

$$\lambda_{os}^M = n \lambda_{ts}^m P_b^m$$

means the overflow rate incurred by overflow from the n microcells covered by the macrocell and  $\lambda_{hs}^M$  is the handoff calls into a macrocell by slow mobile subscribers, which equals the slow subscribers successfully staying on the high tier  $\lambda_{ts}^M (1 - P_b^M)$  times the handoff probability  $P_{hs}^M$ , that is

$$\lambda_{hs}^M = \lambda_{ts}^M (1 - P_b^M) P_{hs}^M$$

The traffic rate of  $\lambda_{ts}^m$  is incurred by new calls, handoff calls, and calls caused by channel-sharing for slow subscribers:

$$\lambda_{ts}^m = \lambda_{ns}^m + \lambda_{hs}^m + \lambda_{vs}^m$$

Where  $\lambda_{hs}^m$  is the handoff calls equals the slow subscriber successfully handoff on lower tier

$$\lambda_{hs}^m = \lambda_{ts}^m (1 - P_b^m) P_{hs}^m$$

and  $\lambda_{vs}^m$  is caused by vertical direction frequency sharing strategy,

$$\lambda_{vs}^m = \frac{\lambda_{vs}^M}{n \left( \frac{\lambda_{ts}^M}{\lambda_{ts}^M + \lambda_{tf}^M} \right) P_{cvs}}$$

Here  $\lambda_{vs}^M$  is the load caused by the vertical direction frequency sharing by slow subscriber in the physical area covered by a macrocell (including one macrocell and n microcell) and  $P_{cvs}$  times the

$$\lambda_{vs}^M = n (\lambda_{ns}^m + \lambda_{hs}^m) P_b^m P_b^M,$$

which equals the new call arrival rate and handoff call rate of slow subscribers into the n microcells  $n(\lambda_{ns}^m + \lambda_{hs}^m)$ ,  $P_b^m$  times probability that they see no free channel in the local microcell, and  $P_b^M$  times probability that they see no free channel in the macrocell.

$$\left( \frac{\lambda_{vs}^M}{\lambda_{ts}^M + \lambda_{tf}^M} \right)$$

Finally the term is the ratio of vertical direction frequency sharing flows by slow subscribers into microcells.

#### 4.2 Performance of Using Horizontal Direction Frequency Sharing

In this section we analyze the proposed Horizontal Direction Frequency Sharing scheme. A mobile subscriber call request when found no free channel in its local cell then previously discussed VDFS take place first. If VDFS fails than HDFS can be taken place. Again our goals is to drive the *call lose*

probability that a subscriber in macrocell can be rearranged to a microcell but only a fraction 1/n of the load will be injected to the microcell. The rate  $\lambda_{vs}^M$  can be derived as follows:

probabilities  $P_{lf}$  and  $P_{ls}$  for fast and slow subscribers respectively.

The call loss probabilities are:

$$P_{lf} = P_b^M P_{vs} P_z$$

$$P_{ls} = P_b^m P_b^M P_{vs} P_z$$

Where probability  $P_{vs}$  is the failure probability of vertical direction sharing as given in 1, and  $P_z$  is

the failure probability of horizontal direction sharing is as follows:

$$P_z = 1 - P_{est}^M \left( (1 - P_b^M) (1 - P_{vs}') \right)$$

Where  $P_{vs}'$  is the failure probability of vertical direction sharing for macrocell  $M_i$  as given in 1, and  $P_{est}^M$  is the probability for staying at least one subscriber in early handoff area given by as follows:

$$P_{est}^M = 1 - \left( \frac{(R_e)^2}{(R_n)^2} \right)^{C_A^M}$$

$P_b^M$ , and  $P_{vs}^m$  can be derived as equation (3b) and (4b) respectively, but their values are different for different aggregate traffic rates. The horizontal direction sharing affects only traffics flows on macrocell, therefore  $\lambda_{ts}^m$  in microcell are same as that in the vertical direction frequency sharing discussed in section 4.1, but their value are dependent on  $P_b^M$ , and  $P_{vs}^m$  when they are derived as horizontal direction sharing is used.

In macrocell, the aggregate rate  $\lambda_{tf}^M$  incurred by new calls, handoff calls, and horizontal direction sharing calls for fast subscriber:

$$\lambda_{tf}^M = \lambda_{nf}^M + \lambda_{hf}^M + \lambda_{zf}^M$$

Where  $\lambda_{zf}^M$  is caused by horizontal direction sharing can be calculated as:

$$\lambda_{zf}^M = (\lambda_{nf}^M + \lambda_{hf}^M) P_b^M P_{vs} P_{est}^M$$

Which equals the new call arrival rate and handoff rate into macrocell  $(\lambda_{nf}^M + \lambda_{hf}^M)$ , times probability that they see no free channel in the macrocell  $P_b^M$ , times probability that they fail in vertical direction sharing  $P_{vs}$ , and times probability that at least one subscriber staying in early handoff area  $P_{est}^M$ . Similarly  $\lambda_{ts}^M$  is the aggregate traffic rate incurred by overflow calls, handoff calls, and

horizontal direction sharing in macrocell by slow subscribers:

$$\lambda_{ts}^M = \lambda_{os}^M + \lambda_{hs}^M + \lambda_{zs}^M$$

Where  $\lambda_{zs}^M$  is horizontal direction sharing by slow subscriber,

$$\lambda_{zs}^M = n(\lambda_{ns}^m + \lambda_{hs}^m) P_b^m P_b^M P_{vs} P_{est}^M$$

which equals the new call arrival rate and handoff rate of slow subscribers into the n microcells  $n(\lambda_{ns}^m + \lambda_{hs}^m)$ , times the probabilities that they see no free channel in the local microcell  $P_b^m$ , and neither in the macrocell  $P_b^M$ , times the probability that they fail in vertical direction sharing  $P_{vs}$ , and times probability that at least one subscriber staying in early handoff area  $P_{est}^M$ .

### 5. Numerical Examples and Discussion

We consider 4 cases denoted from (a) to (d) for comparison as follows:

a) The call loses probabilities of **Take Back (TB)** scheme in reference [13] for fast and slow subscribers are denoted by  $P_b^M P_b^m$ , and  $P_b^m P_b^M$  respectively.

b) The call loses probabilities of **Channel Rearrangement (CR)** scheme in reference [14] for fast and slow subscribers are denoted by  $P_b^M P_R$ , and  $P_b^m P_r P_b^M$  respectively.

c) The call loses probabilities of **Vertical Direction Frequency Sharing (VDFS)** scheme for fast and slow subscribers are denoted by  $P_b^M P_{vs}$ , and  $P_b^m P_b^M P_{vs}$  respectively.

d) The call loses probabilities of **Horizontal Direction Frequency Sharing (HDFS)** scheme for fast and slow subscribers are denoted by  $P_b^M P_{vs} P_z$ , and  $P_b^m P_b^M P_{vs} P_z$  respectively.

**Table 2: List of parameters taken for performance comparisons**

| S.No. | Parameter name                           | Value            |              |
|-------|--|------------------|--------------|
|       |  | Macrocell        | Microcell    |
| 1     | Radius                                   | 800 m            | 400 m        |
| 2     | Average velocity                         | 40 km/hr         | 4km/hr       |
| 3     | The call arrival rate of slow subscriber | $q\lambda$       | $q\lambda/n$ |
| 4     | The call arrival rate of fast subscriber | $(1 - q)\lambda$ | 0            |
| 5     | Number of channels                       | 37               | 9            |
| 6     | Guard channels                           | 8                | 2            |

We assume that the total traffic to the entire area follows the poisson process with the rate  $\lambda$  and the fraction q of this traffic from slow mobile subscribers.

To compare the different strategies listed (a) to (d), we have assume some parameters as shown in Table 2

Here  $q$  is the tune the amount of slow subscriber in an area and  $n$  is the take care of size difference

between macrocell and microcell. Here we use  $n=4$  and  $q=0.5$ .

The mean holding time for a call is 140 seconds.

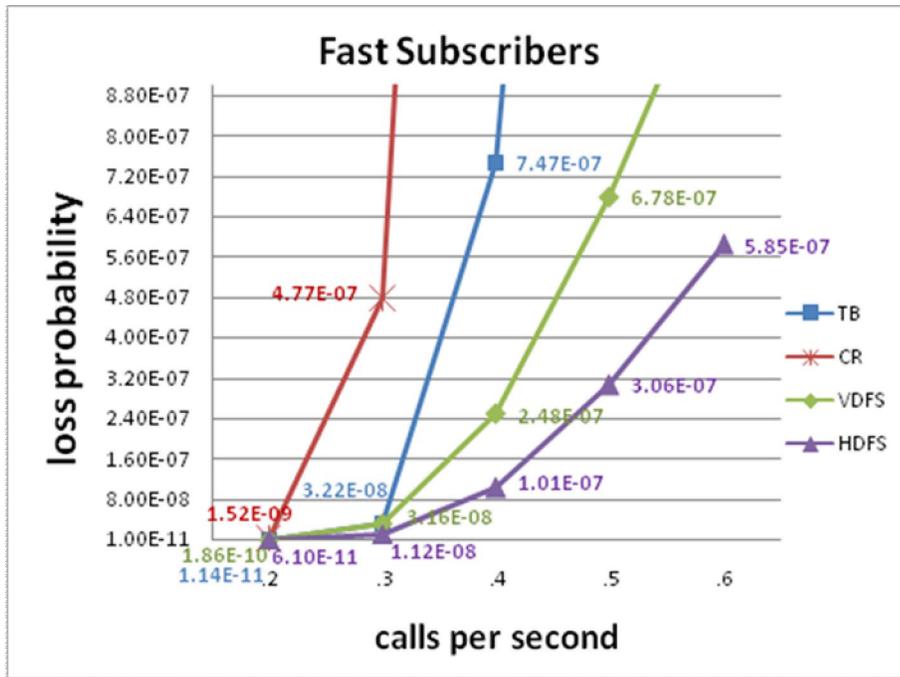


Figure 4 (A): Numerical analysis comparison on call loss probability for fast subscribers

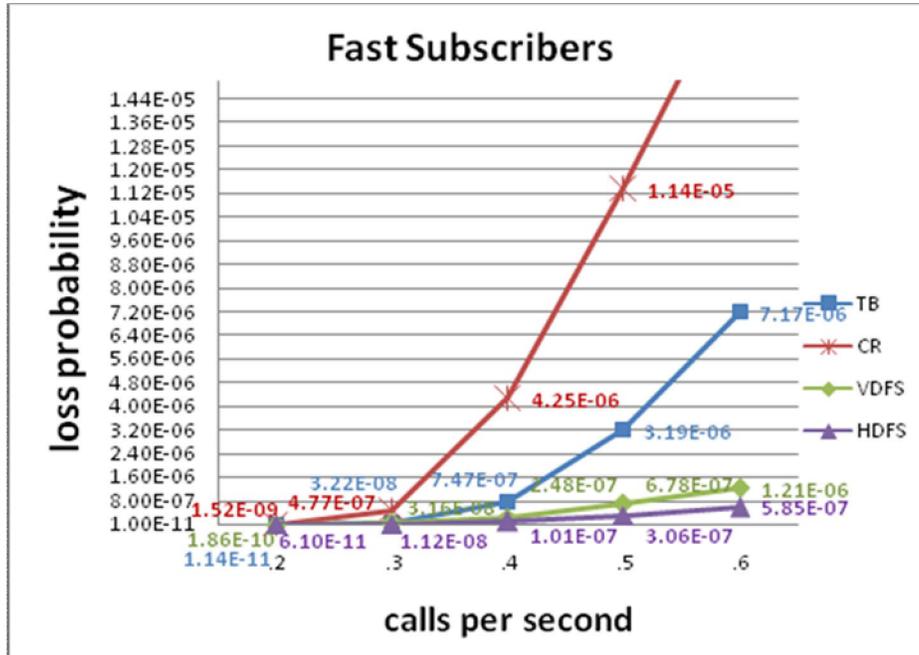


Figure 4(B): Numerical analysis comparison on call loss probability for fast subscribers

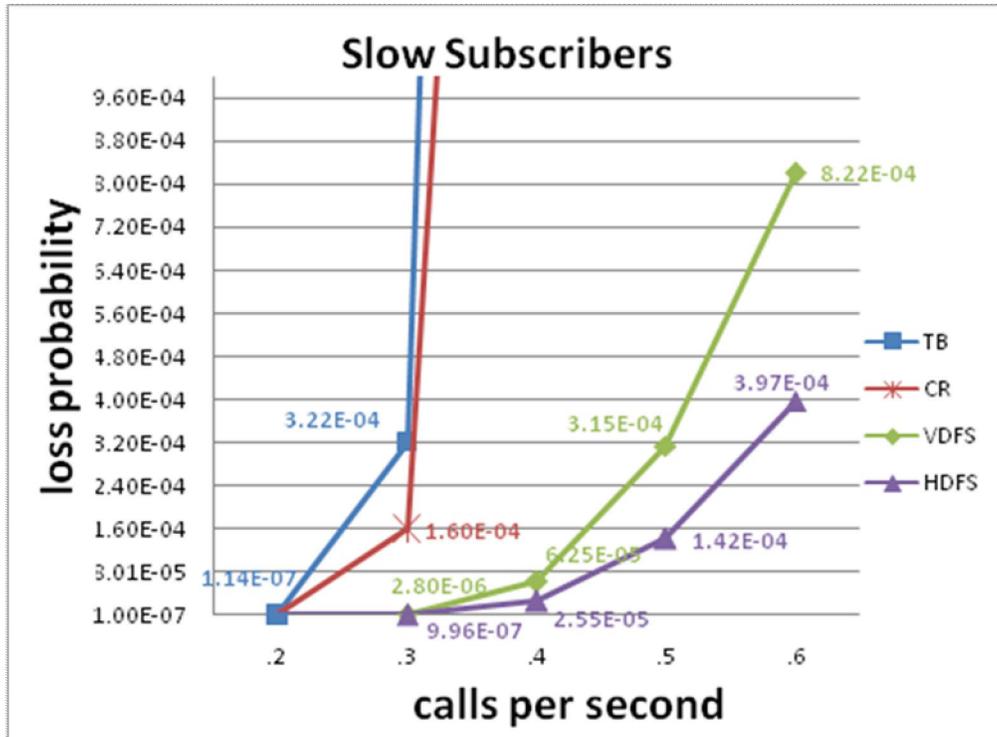


Figure 5 (A): Numerical analysis comparison on call loss probability for slow subscribers

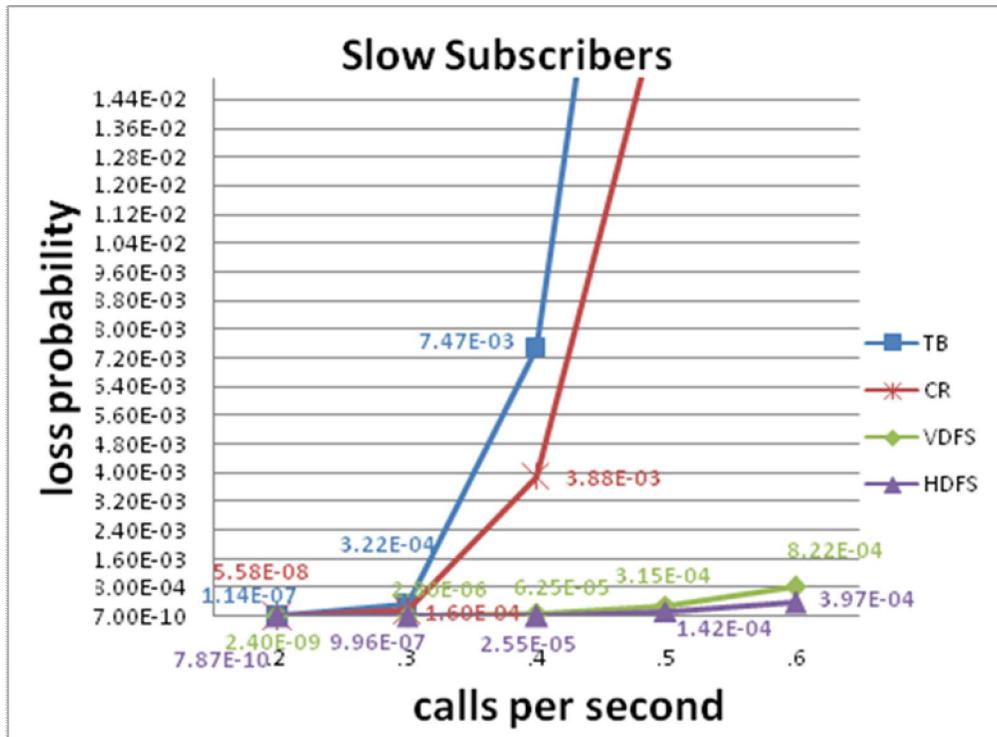


Figure 5 (B): Numerical analysis comparison on call loss probability for slow subscribers

In the different schemes as mentioned above from (a) to (d), the call lose probability is calculated and compared in figure 4 and 5 for fast and slow

subscribers respectively on mentioned number of available channels in the cell as follows on assumed data:

**Table 3: Number of available channels in the different schemes to be compared**

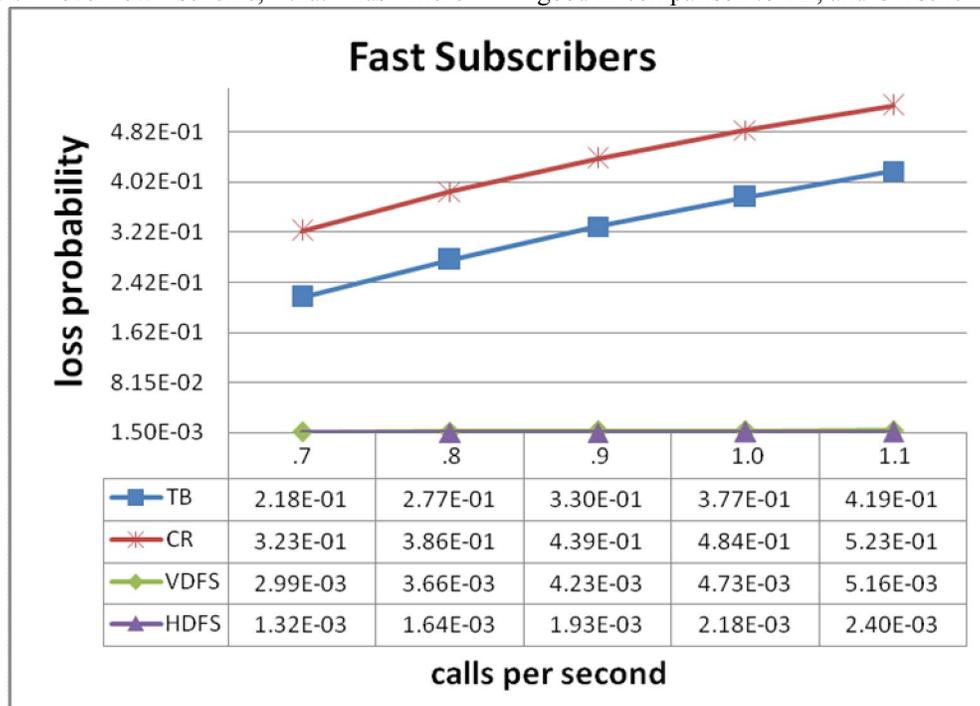
| S.No. | Scheme    | Guard Channels (microcell, macrocell) | Available number of channels |                 |
|-------|-----------|---------------------------------------|------------------------------|-----------------|
|       |           |                                       | Slow subscriber              | Fast subscriber |
| 1     | TB scheme | 0 , 0                                 | 9                            | 37              |
| 2     | CR scheme | 0 , 0                                 | 9                            | 37              |
| 3     | VDFS      | 2 , 8                                 | 7                            | 29              |
| 4     | HDFS      | 2 , 8                                 | 7                            | 29              |

We see that for fast subscribers, the CR scheme redirects the traffic only to neighboring macrocell if the current M macrocell is fully occupied. As shown in figure 4 it performs the worst as it does not release the traffic effectively. The TB scheme overflows a call to the overlaid microcell with take-back strategy at the time of handoff and thus performs better than CR for fast subscribers. The VDFS scheme performs better than CR even here channels are reserved for handoff calls, because it pushes slow subscribers on the macrocell to its overlaid microcells. There are multiple microcells to take the load of a macrocell. Figure 4 shows that VDFS scheme has less call loss probability compare to TB and CR scheme even VDFS scheme has guard channels (reserve channels) to handle only handoff calls. HDFS scheme performs even better than VDFS; because it also transfers the load to neighboring macrocell even contains the guard channels for provide the services to handoff calls.

For slow subscribers the CR scheme perform better than TB, as it has channel rearrangement strategy with overflow scheme, that has more

redirecting choices as compare to TB as figure 5 shows the comparison. The VDFS and HDFS schemes performs similar trend as fast subscriber. We also see that in figure 5, the call loss probability of VDFS and HDFS schemes are less than TB and CR schemes, even the both proposed schemes reserve the channels as the guard channels to handle the handoff calls only. Because our proposed schemes contains guard channels, therefore the dropping probability is also too low in the VDFS and HDFS schemes in compare to the TB and CR schemes.

The proposed schemes are suggested to provide the services to slow speed users with high intensity traffic area and macrocells are overlaid over more than one microcell cater mainly to lower density with high speed subscribers. Therefore, as soon as the total traffic rate is increased to the entire area and the value of tune the amount of the slow subscribers is increased to  $q=0.7$ , we have seen that in figure 6 and figure 7 for fast subscribers, and the figure 8 and figure 9 for slow subscribers, the results for proposed schemes are too good in comparison to TB, and CR schemes.

**Figure 6(A): Numerical analysis comparison on call loss probability for fast subscribers (TB & CR)**

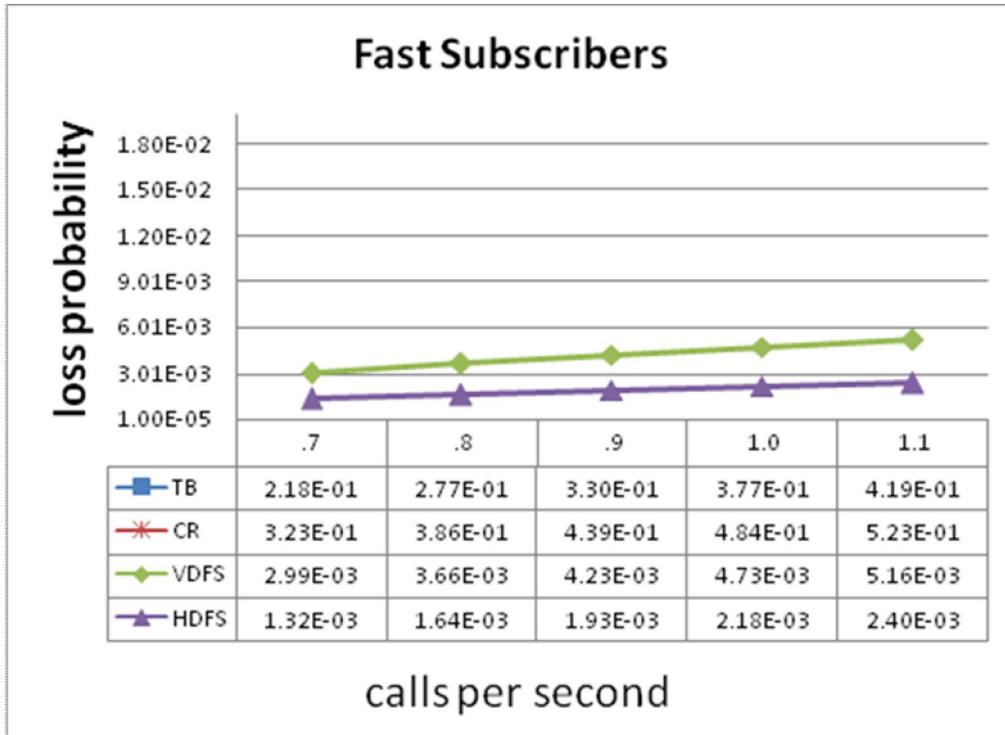


Figure 6(B): Numerical analysis comparison on call loss probability for fast subscribers (VDFS & HDFS)

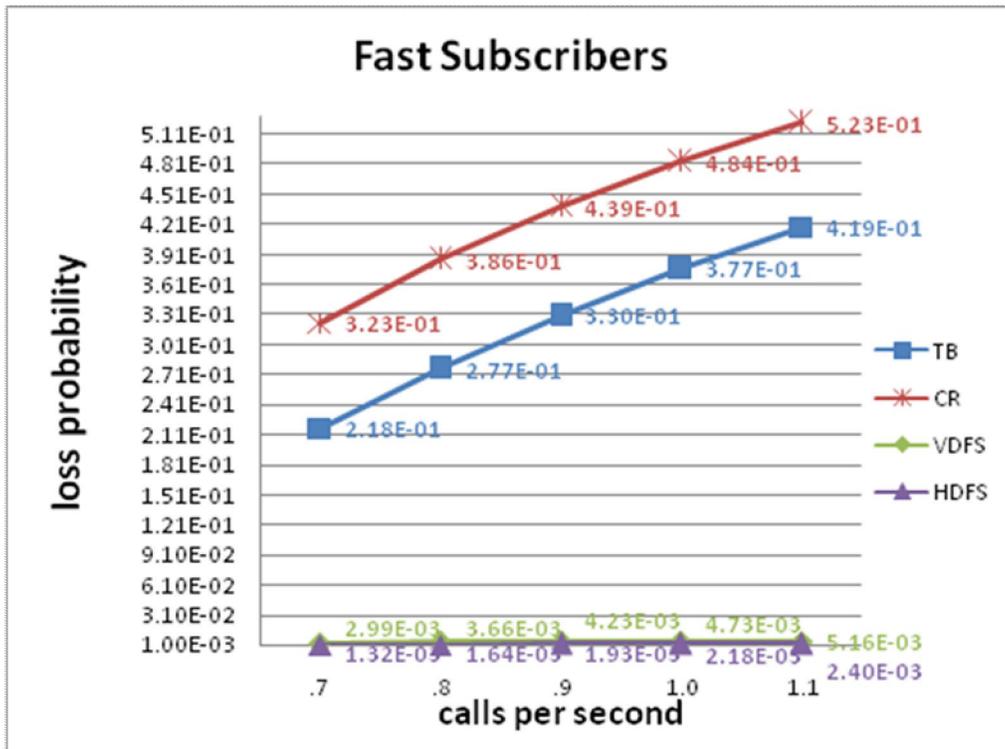


Figure 6(C): Numerical analysis comparison on call loss probability for fast subscribers

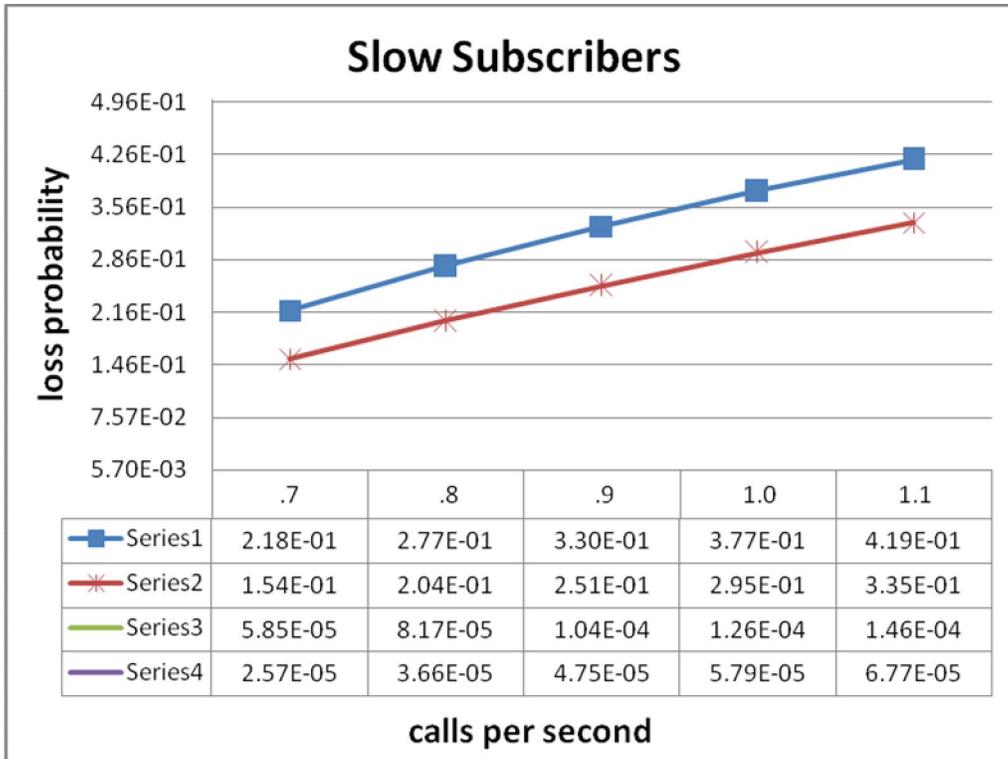


Figure 7(A): Numerical analysis comparison on call loss probability for slow subscribers (TB & CR)

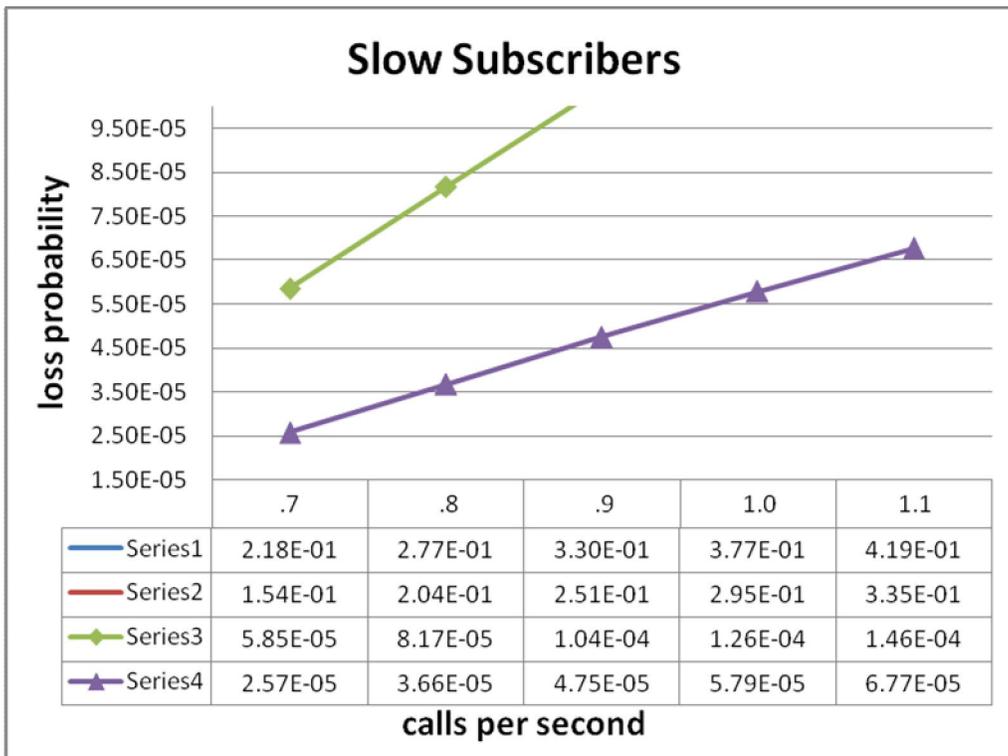


Figure 7(B): Numerical analysis comparison on call loss probability for slow subscribers (VDFS & HDFS)

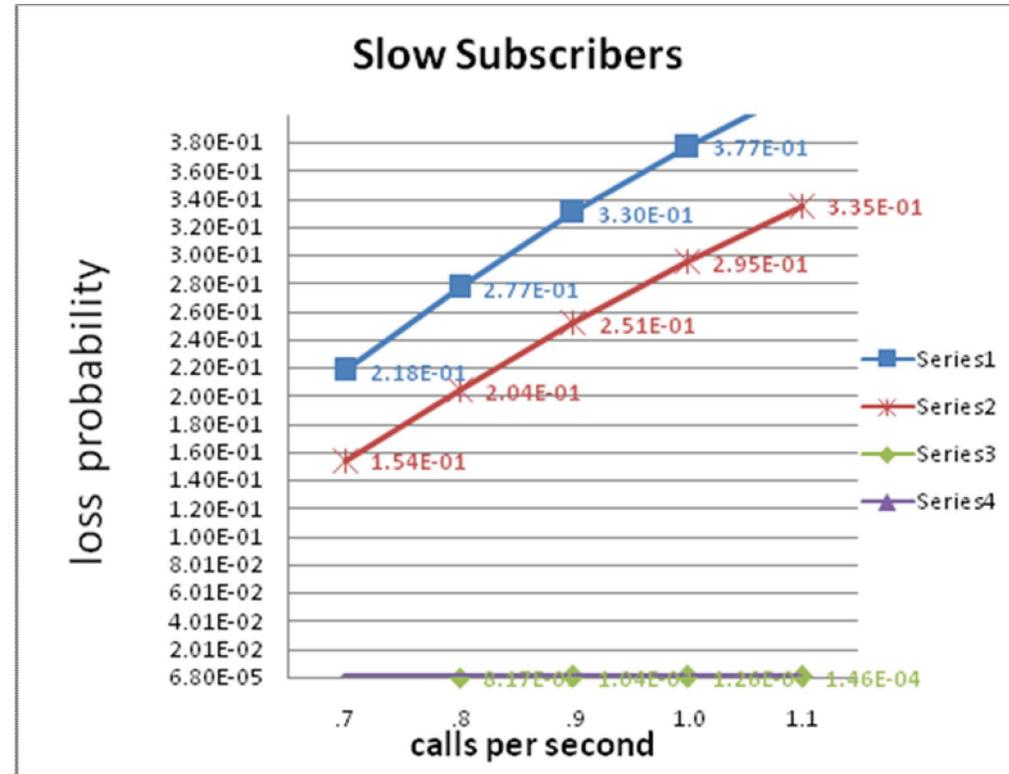


Figure 7(C): Numerical analysis comparison on call loss probability for slow subscribers

HDFS scheme performs even better than VDFS also. The call loss probability of the proposed schemes is, therefore, better than TB, and CR schemes in the area where services to slow speed users with high intensity traffic area and high speed subscribers with lower density area for both fast and slow subscribers even that the proposed schemes reserve the guard channels for the handoff calls as shown in figure 6 (TB & CR) & figure 7 (VDFS & HDFS) and figure 8 (TB & CR) & figure 9 (VDFS & HDFS). The VDFS and HDFS schemes performs similar trend for fast and slow subscribers also.

## 6. Conclusion

In this paper the proposed schemes perform better loss probability; even it contains guard channels as a reserve channels to handle the handoff calls. The call drop probability is the measure issue to any efficient system, therefore, reserves the channels for handoff calls. Our aim is to improve the call loss probability with less call drop probability of the subscribers to provide the handsome services. Here we take the advantage of overlapping coverage of two-tier system and therefore, able to share the load in between two-tier of highly populated area for slow subscribers and less dense to fast subscribers. We see that a significant reduction is obtained in call loss probability

over TB and CR schemes with reduction of call drop probability as here channels are reserve for handle the handoff calls in the proposed schemes.

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