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UTILISING SIGNAL MEASUREMENT IN BANDWIDTH RESERVATION SCHEME FOR QOS PROVISIONING IN MULTIMEDIA WIRELESS NETWORKS

Prihandoko
Department of Computer and Communication System
Faculty of Engineering, Universiti Putra Malaysia
43400 UPM Serdang, Selangor Darul Ehsan, Malaysia
email: fprihandoko@yahoo.com

M. H. Habaebi
Department of Computer and Communication System
Faculty of Engineering, Universiti Putra Malaysia
43400 UPM Serdang, Selangor Darul Ehsan, Malaysia
email: hadi@eng.upm.edu.my

Borhanuddin Mohd Ali
Department of Computer and Communication System
Faculty of Engineering, Universiti Putra Malaysia
43400 UPM Serdang, Selangor Darul Ehsan, Malaysia
email: borhan@eng.upm.edu.my

ABSTRACT

Next generation multimedia wireless networks require guaranteed quality of service (QoS) over the duration of mobile connections, and also require efficient use of network resources. In this paper, bandwidth reservation scheme is proposed for QoS provisioning in multimedia wireless networks. The proposed scheme integrates user mobility information obtained by measuring Received Signal Strength (RSS) for determining the next cell the mobile user is likely to move to. Simulation results demonstrate that the proposed scheme can guarantee the required QoS requirements in terms of handoff call dropping probability and new call blocking probability while maintaining efficient use of network resources.

Keywords**:* ***Multimedia Wireless Network, QoS, Bandwidth Reservation

1.0 INTRODUCTION

Future mobile communication systems are required to support broadband multimedia services with various Quality of Service (QoS) requirements. One of the important issues in the wireless multimedia networks is the user mobility that leads to a variation in both wireless and wireline resource demands [1]. This change in resource request can result in a major fluctuation in the availability of network resource, especially the resource in wireless networks. This is because wireless channels have limited available bandwidth and can be easily overloaded if many users attempt to access a base station at the same time. The overload situation can result in forced termination of the connection due to lack of bandwidth. Therefore, mobility has a direct impact on the connection-level quality-of-service (QoS) in terms of new call blocking probability and call handoff dropping probability [1].

Recently, there is an on-going research on the prediction of user mobility information [2, 3, 4] because user mobility information plays an important role in mobility management and network resources management. To guarantee QoS requirement over the lifetime of a connection and to maintain efficient resources usage, it is highly desirable for the system to know in advance the mobility information of a mobile terminal (MT). A scheme incorporating mobility information can determine whether there are enough resources available in cells along the path of the MT and reserve resources accordingly. Hence, the guaranteed QoS may be maintained regardless of frequent handoffs.

It has also been shown that the use of movement prediction is effective to improve the performance of resource reservation [7, 8, 9, 10, 11, 19], handover management [2, 12, 13], and location management [2, 14] schemes. It has also been shown that movement prediction can be used for adaptive resource management in wireless systems [13, 15]. In [5, 6] mobility patterns (e.g. the probability that a MT in cell i will travel to cell j) for the MT are required to accurately perform the proposed reservation algorithms. Levine [6] suggested that mobility patterns could be determined by GPS systems.

Based on user mobility information collected in the base station, a user mobility prediction algorithm based on RSS is developed. This algorithm is used for predicting the next destination cells the MTs are likely to move to. This information is then used for resource reservation. If the user movement is known in advance, the reservation can be completed efficiently.

In this paper, we propose a new scheme to predict the mobility movement of mobiles by utilising the user mobility information obtained using RSS. This prediction is then used to reserve bandwidth in advance for a connection in neighboring cells.

The rest of the paper is organised as follows. Section 2 illustrates our proposed model. Section 3 presents the bandwidth reservation scheme utilising RSS. In Section 4, we present the simulation model. Simulation results and analysis is discussed in Section 5. Section 6 concludes the paper.

2.0 SYSTEM MODEL

In this paper, we consider the micro-cell/pico-cell environments suitable for the high-speed multimedia wireless networks, such as Wireless ATM networks. In such an environment, the handoff rate will be relatively higher compared to the macro-cell environment. When an MT moves to an adjacent cell, a handoff process will maintain its connectivity in the new cell.

The traffic generated by each mobile terminal contains some information required by the network, i.e. the traffic type, the bandwidth requirements (the minimum, maximum and the average required bandwidth) and the connection duration time. The system has six priority levels and will assign one level for each type of traffic. Table 1 [10] shows the type of application and the bandwidth requirements for each traffic type. For simplicity, we are assuming one MT executes one application only.

Table 1: The characteristics of the traffic sources

Traffic Type	Media Type	Bandwidth Requirement	Average Bandwidth Requirement	Average Connection Duration	Priority
CBR	Voice Service & Audio Phone	30 Kbps	30 Kbps	3 minutes	6
CBR	Video-Phone & Video-Conference	256 Kbps	256 Kbps	5 minutes	5
Real-time VBR	Interactive Multimedia & Video on Demand	1-6 Mbps	3 Mbps	10 minutes	4
UBR	Email, Paging & Fax	5-20 Kbps	10 Kbps	30 seconds	3
UBR	Remote Login & Data on Demand	64-512 Kbps	256 Kbps	3 minutes	2
UBR	File Transfer & Retrieval Service	1-10 Mbps	5 Mbps	2 minutes	1

It is assumed that some of the user movements are random and some of them are highly directional. The latter means that a user is likely to move to one of the neighboring cells only.

We assume that each connection requires some specific amount of bandwidth to live with. The MT connection will be dropped if the bandwidth available in the next cell, where MT is about to move to, is insufficient to support the connection. Reserving a portion of the bandwidth for a particular cell in advance before the MT arrives at that cell can reduce the number of handoff drop. Due to the difficulties in predicting an MT's movement, one obvious method to reserve bandwidth for a connection will be to reserve bandwidth in all neighboring cells of the cell that the MT is currently in [5]. The call will not be admitted unless it has reserved bandwidth to all six neighbors' cells. However, this method wastes a significant amount of bandwidth from unnecessary reservation, and thus, new call blocking probability will be undesirably higher and bandwidth usage will be lowered.

3.0 BANDWIDTH RESERVATION USING RECEIVED SIGNAL STRENGTH (RSS)

In current mobile cellular system, the distance between the mobile and a known base station is practically observable. Such information is inherent in the forward link Received Signal Strength (RSS) of a reachable base station [2]. Thus, this RSS can be used to predict the MT movement as presented in [16] and [2]. From field measurements, a few points with known values of RSS is chosen as *anchor points* within the cell. Based on the RSS from the user and the RSS at the user from neighboring base stations, the anchor point closest to the user is computed. Then, the location of the MT is predicted relative to its closest neighboring anchor point whose coordinates are assumed to be known. As a byproduct of this approach, three neighboring cells closest to the current location of the MT can also be determined. The neighboring base station, from which the RSS is the maximum, is most likely the closest neighboring cell of the user. After the base station detects that a MT has entered the reservation region (by comparing its RSS with certain threshold, R_t), it instructs the MT to send the RSS measurements from all the neighboring BSs and the corresponding cell ids (Fig. 1).

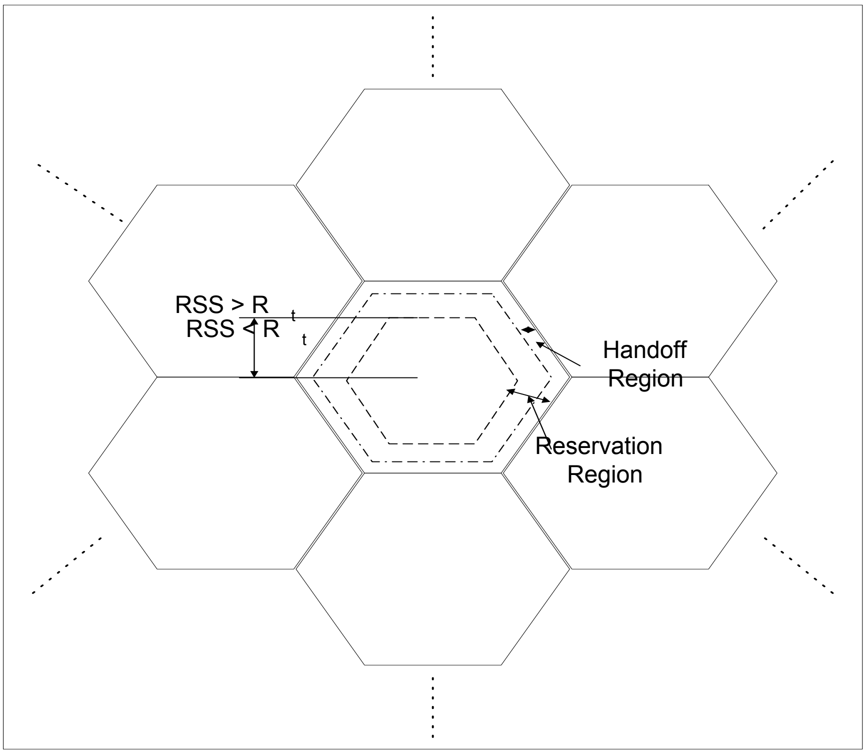

Fig. 1: Reservation and handoff regions

According to [2], RSS can be modeled as the sum of two terms: one due to path loss, and another due to shadow fading. Fast fading is neglected assuming that a low-pass filter is used to attenuate Rayleigh or Rician fade. Therefore, the RSS from a particular cell $cell_i$, p_i, can be formulated as [17]

$$p_i = p_{oi} - 10r \log d_i + \xi_i \qquad (1)$$

where p_{oi} is a constant determined by transmitted power, wavelength, and antenna gain of cell $cell_i$, r is slope index (typically, $r = 2$ for highways and $r = 4$ for microcells in a city), and ξ_i is the logarithm of the shadowing component, which is found to be a zero-mean Gaussian random variable with standard deviation 4-8 dB. d_i represents the distance between the MT and base station of $cell_i$, which can be further expressed in terms of the MT's position $(x(t), y(t))$ at time t and the location of base station (a_i, b_i)

$$d_i = [(x(t) - a_i)^2 + (y(t) - b_i)^2]^{1/2} \qquad (2)$$

This MT coordinate position then can be used to determine the location of MT in the cell. Similar to [16], we also propose *a reservation region* to predict the neighbor cell a MT is likely to move to (see Fig. 1). But unlike [16] where the reservation is performed in three cells, the proposed system performs a bandwidth reservation to one predicted destination cell [18].

In this bandwidth reservation scheme, the application priority is still maintained and checked to determine the need for bandwidth reservation. If the MT connection is real-time traffic (i.e., VBR or CBR) and it has crossed the reservation region, the bandwidth reservation algorithm is invoked. Otherwise, if the MT connection type is non real-time, the MT position will be ignored until it enters the handoff region (Fig. 1). When it does, the reservation algorithm is invoked.

The amount of bandwidth to reserve depends on the type of traffic. For example, because CBR traffic has only one bandwidth requirement, that amount of bandwidth will be reserved in the destination cell. However, real-time VBR traffic has two bandwidth requirements, i.e., the minimum required and the average required bandwidth. In this case, at first the system will request for the average bandwidth required. If the available bandwidth is sufficient, reservation takes place in the destination cell. Otherwise, the system requests for the minimum bandwidth required (see Table 1). If the available bandwidth can satisfy the bandwidth requirements, the reservation is successful; otherwise, the reservation fails.

4.0 SIMULATION MODEL

In order to study the proposed scheme, we built a simulation model for the mobile environment. The simulation model is developed using C++. The simulation model consists of a cluster of 96 hexagonal cells. The base station for each cell resides in the center. The cells are wrapped around so the topology of the simulated wireless network represents a sphere. This means that the handoff rates in all the cells are approximately similar. As the system is applied for micro/pico-cell network, the cell radius is set to 200 meters with the reservation and handoff regions set to 50 m and 10 m from the cell border, respectively. In addition, in order to compare our system with the proposed system in [10], the maximum bandwidth capacity for each base station is set similar to [10], i.e. 30 Mbps. Fig. 2 shows a sample topology with a 30-cells cluster.

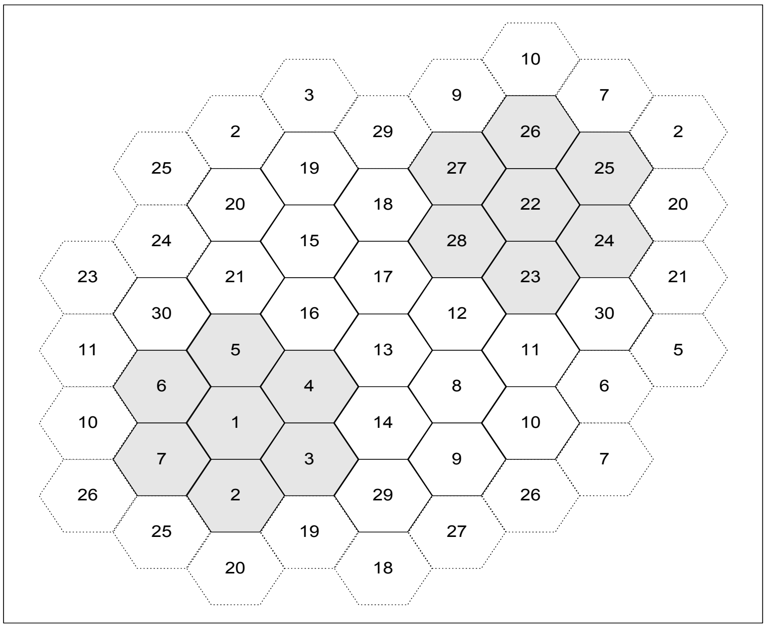

Fig. 2: A sample topology with 30 cells cluster

Data sources are generated according to Table 1 and are assumed to be of bursty nature, with the arrival rates of call requests of different traffic classes being Poisson distributed with an average value equals to λ. The call duration for each MT is exponentially distributed with rates equal to μ. The bandwidth required for VBR and UBR is assumed to follow a geometrical distribution between the minimum and maximum values shown in the table. The connection duration is also assumed to follow a geometric distribution. New connections from all the six application groups are generated with equal probability.

In this simulation, we have examined the performance of the two modes described in the previous sections, i.e. RSS-1 and RSS-3 models, in terms of system bandwidth usage, new call blocking probability and handoff dropping probability for real-time and non real-time traffic. RSS-1 is a model where the system reserves bandwidth to one destination cell only for supporting handoff. RSS-3 is a model where the system reserves to three closest neighbor cells simultaneously. The second model is similar to the one proposed by Jayaram [16]. In this paper, we prove that when the MT is getting closer to one neighbor cell, it is not necessary to reserve bandwidth to more than one cell.

Two different user movement patterns are considered: random movement pattern and highly directional movement pattern. In this manner, the two extremes of movement patterns are considered as the typical MT movement trajectory would be somewhere between a straight line and a random pattern. Since MTs are free to move in any direction, newly established connections have equal probability of ending up in any cell of its 6 neighboring cells. The movement direction of MT is divided into four directions (north, east, south, and west).

5.0 SIMULATION RESULTS

In the simulation, we have compared the performance of the models in terms of bandwidth usage, new call blocking probability and handoff call dropping probability. The speed for all MTs is set to 10 meters/second. The reservation ratio, that is the percentage of the amount of bandwidth that is allocated for reservation to support handoff in each cell, is set to 10% and 50% of the total bandwidth. Reservation ratio is the percentage of bandwidth allocation dedicated for reservation to support handoff.

Fig. 3 and Fig. 4 show the bandwidth usage of the two models, RSS-1 and RSS-3, for directional movement and random movement, respectively. Bandwidth usage is the ratio between the amount of bandwidth used by ongoing connections and the total bandwidth capacity of the network. In both figures, we find that the models with reservation ratio r = 10% produce higher bandwidth usage than that of r = 50%. This is due to the fact that as more bandwidth is dedicated for reservation, more new call connections that are attempting to get connections are denied. As a result, the new call blocking probability (NCBP) for lower reservation ratio (r = 10%) will be lower than that of higher reservation ratio (r = 50%), as shown in Fig. 5.

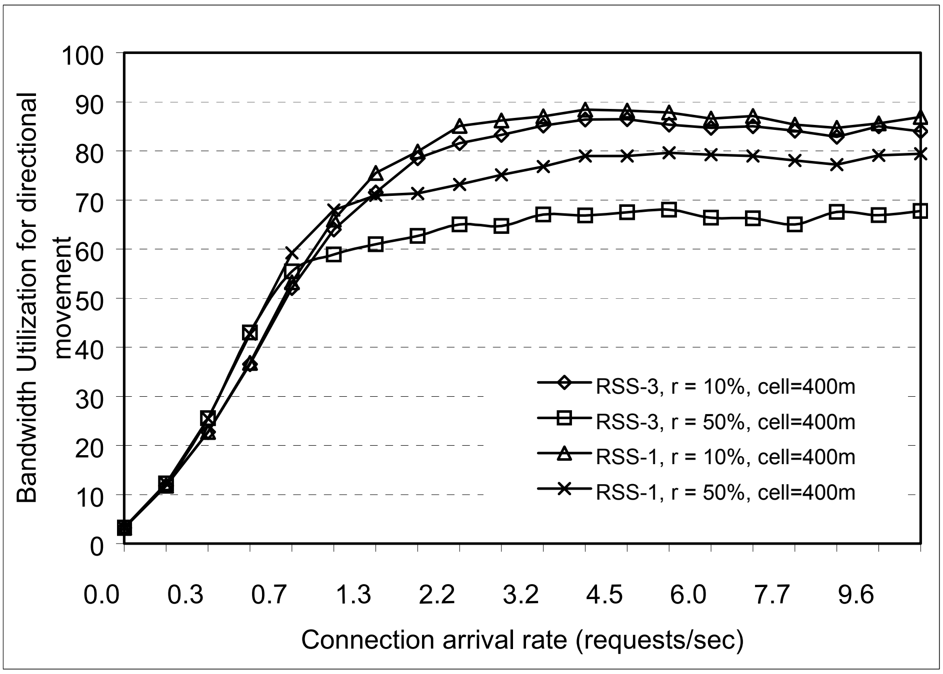

Fig. 3: Bandwidth Usage for directional movement

Interestingly, for r = 10%, both models produce similar bandwidth usage. This fact tells us that for r = 10%, reserving bandwidth to one cell or to three cells will produce the same bandwidth usage. However, when we increase the reservation ratio to 50%, the first model (RSS-1) results in 10% higher bandwidth usage than the second, RSS-3. This result tells us that for a higher reservation ratio, when the system reserves bandwidth to more than one neighboring cell, i.e. three cells in case of RSS-3 system, it reduces the amount of bandwidth allocated for new coming calls. Thus, this produces lower bandwidth usage for ongoing connections.

The bandwidth usage of the system is also influenced by the randomness of MTs movements. The system with all MTs moving randomly produces 10% higher bandwidth usage (Fig. 4) than that of a system with all MTs moves fully directional (Fig. 3). This is due to the number of new calls accepted in random movements are higher than in the directional movements.

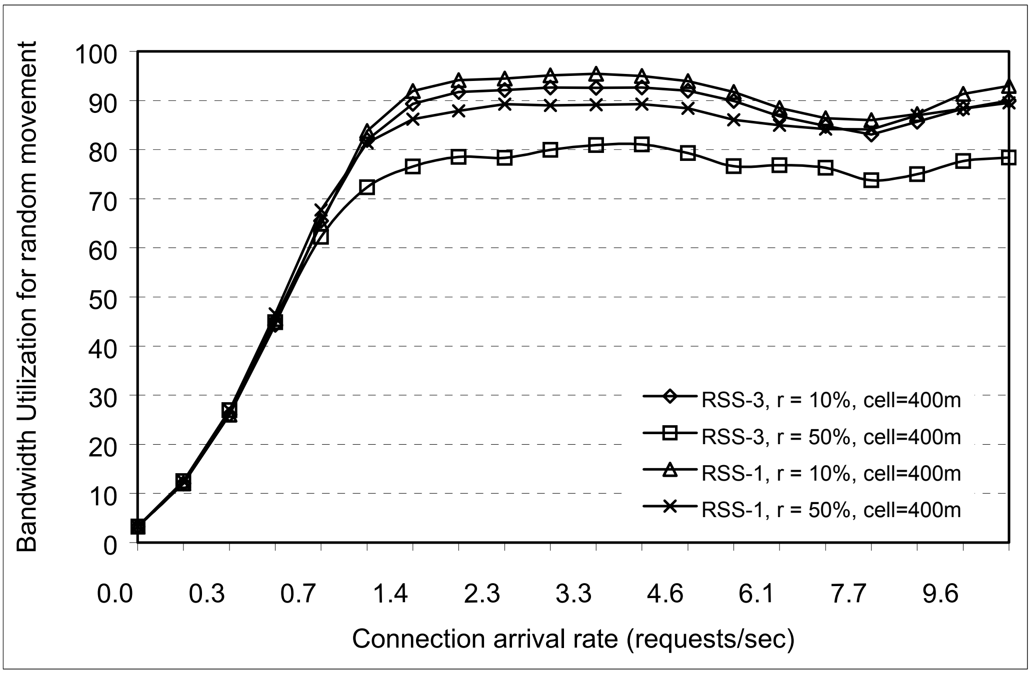

Fig. 4: Bandwidth Usage for random movement

Fig. 5 and Fig. 6 compare RSS-1 and RSS-3 on new call blocking probability (NCBP) for directional movement and random movement, respectively. The two figures show that the performance of the two models, in terms of NCBP, is similar. This informs us that the number of cells to reserve in neighboring cells does not affect the NCBP.

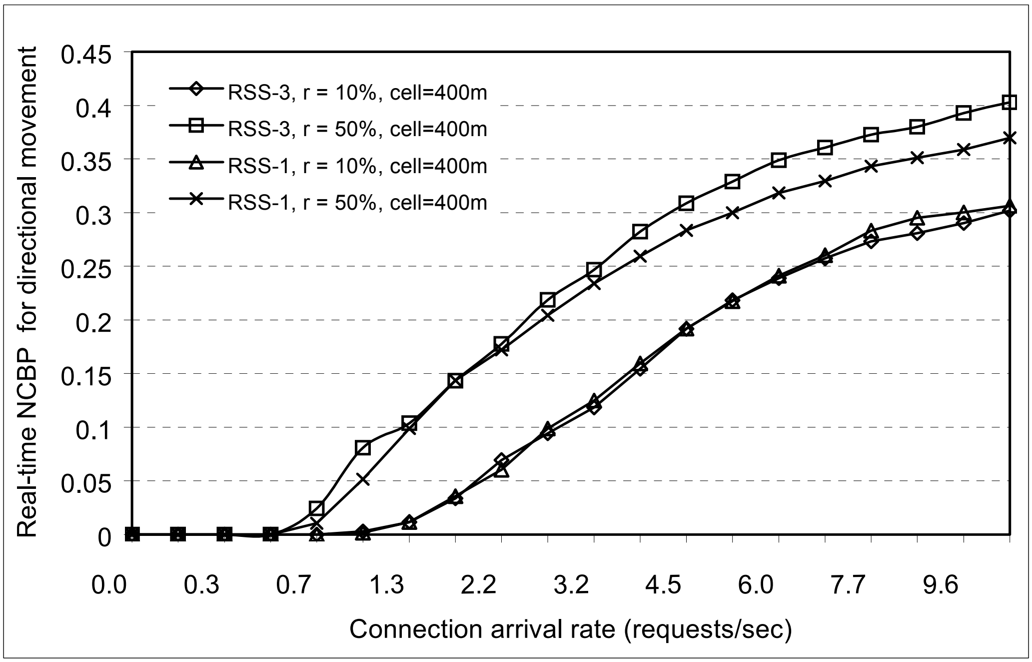

Fig. 5: New Call Blocking Probability for directional movement

From the figures, we find that the factors affecting the NCBP are the reservation ratio and the randomness of the mobile movements. For reservation ratio r = 10% and the directional mobile movement, the NCBP achieves 0.3 when the arrival rate reaches 10 requests/second. This outperforms the system with r = 50% by 10%, as shown in Fig. 5. For a system with random movement, as shown in Fig. 6, the NCBP for r = 10% achieves 0.5, which is 20%

higher compared to the one with directional movements. This fact tells us that a higher randomness of MTs movements results in higher NCBP.

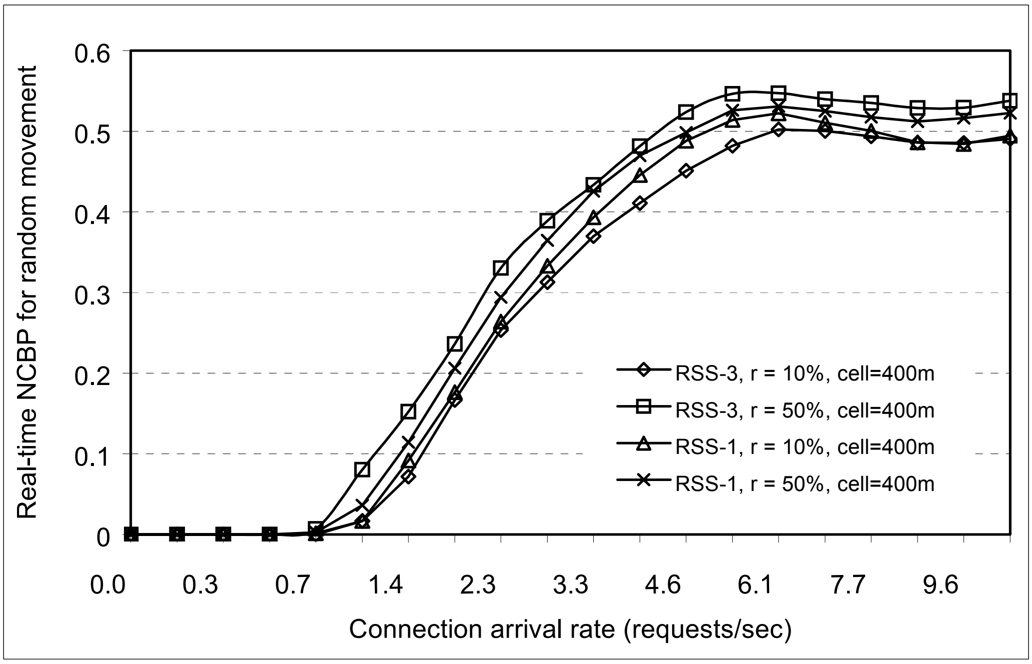

Fig. 6: New Call Blocking Probability for random movement

Fig. 7 and Fig. 8 demonstrate the performance of RSS-1 and RSS-3 on handoff call dropping probability (HCDP) for directional movement and random movement, respectively. The two figures illustrate that for r = 50%, the performance of both models is similar. However, for r = 10%, HCDP of RSS-1 model is 10% lower than that of RSS-3, because handoff dropping occurs, in this case, not due to inaccurate cell prediction, but rather due to insufficient bandwidth in the destination cell to support handoff connections.

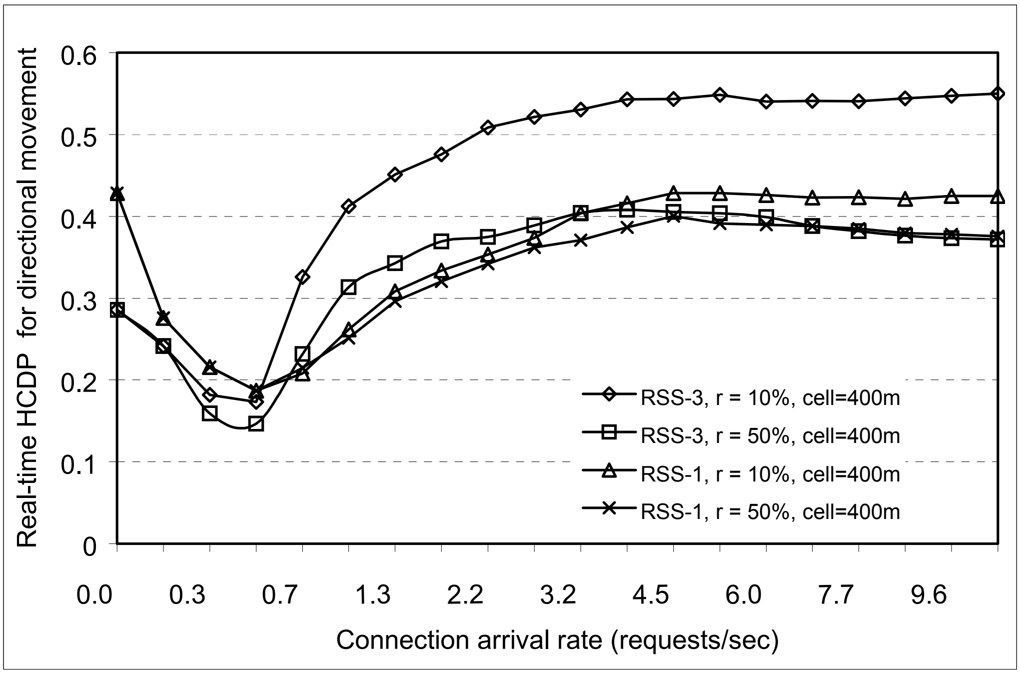

Fig. 7: Handoff Call Dropping Probability for directional movement

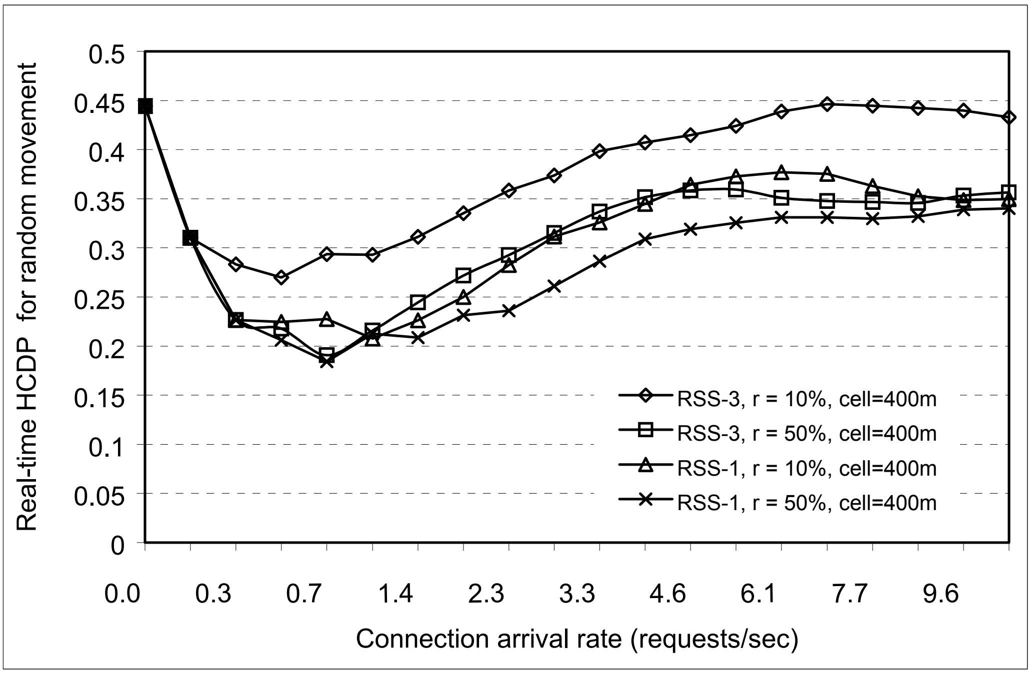

Fig. 8: Handoff Call Dropping Probability for random movement

There are two problems that can lead to handoff drop. First, when the MT reserves bandwidth to a wrong destination cell, i.e. the MT reserves in a cell that the call did not move to, and secondly, when the MT could not reserve bandwidth to the destination cell because of insufficient bandwidth. If any one of the above occurs to a MT, the connection will be dropped.

As mentioned in [5], when a MT reserves bandwidth to more neighbor cells, the probability of handoff drop will be smaller. This is true when reservation process is successful as the amount of bandwidth in the destination cells is adequate to support the connections; otherwise, the handoff call will be dropped due to insufficient bandwidth. When we increase the amount of bandwidth for reservation (reservation ratio *r*), the handoff drop is lower, because the base station in the cell, to some extent, can satisfy the bandwidth requirements for reservation.

When we compare the implementation of the models to two types of user movements, we found that the result of random movement is better than that of directional movement. From both figures, we conclude that for both directional and random movements, the RSS-1 system has a better performance than RSS-3 system in terms of HCDP.

For non real-time traffic, as shown in Fig. 9 and Fig. 10, the results of the simulation in terms of NCBP and HCDP are the same with that of real-time traffic. For NCBP, the two models produce the same results, while for HCDP, RSS-1 model outperforms RSS-3 for r = 10%. These results confirm that RSS-1 model is better for both real-time and non real-time traffic in terms of HCDP.

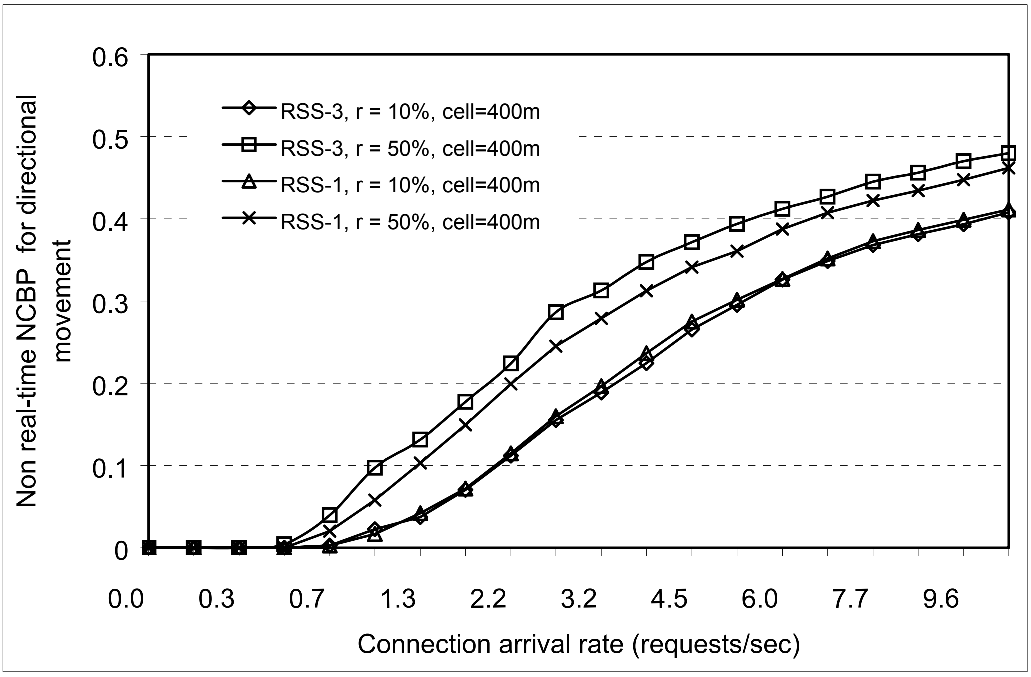

Fig. 9: Non real-time New Call Blocking Probability for directional movement

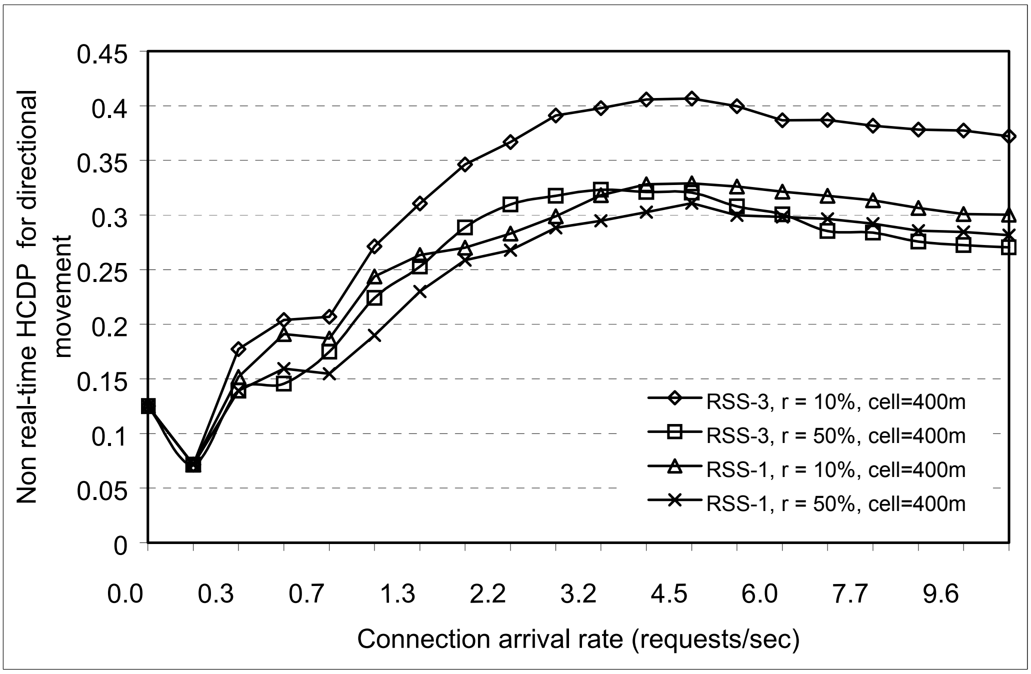

Fig. 10: Non real-time Handoff Call Dropping Probability for directional movement

Fig. 11 and Fig. 12 show the accuracy of cell prediction for directional and random movement, respectively. The accuracy of cell prediction is the probability of correct or accurate prediction of the next destination cell the MT is going to move to. For directional movement, as shown in Fig. 11, RSS-3 performs slightly higher precision than RSS-1 as expected. The accuracy of RSS-3 model achieves 87%, while RSS-1 reaches 85%. Unlike RSS-1 where the reservation is made to one neighbor cell only, RSS-3 model predicts and reserves bandwidth to three closest neighbor cells.

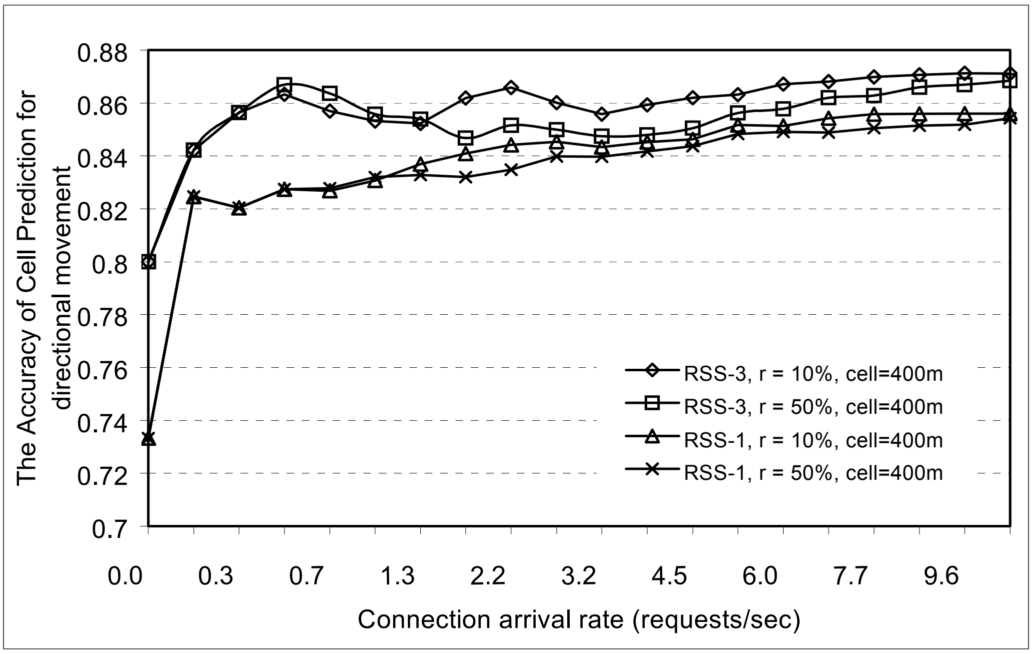

Fig. 11: The accuracy of cell prediction for directional movement

Fig. 12 shows the case for random movement. In this graph, the results of both models are very close, which is around 84%. This result is lower than that of directional movement. This result also shows us that the randomness of the MTs has a small effect on the accuracy of prediction.

Fig. 13 and Fig. 14 illustrate the probability of handoff dropping due to wrong cell prediction for directional and random movement, respectively. The graph shows the percentage of handoff dropping caused by wrong or inaccurate prediction of destination cell to make bandwidth reservation. For directional movement, the handoff drop touches 13% in a stable condition since the arrival rate is 0.3 requests/second. On the other hand, the random movement reaches 25% at the beginning, and fails off at 15% when the arrival rate is 2.2 and higher. This means that, as expected, the handoff drop due to wrong prediction in directional movement is lower than that in random movement.

Fig. 15 and Fig. 16 demonstrate the probability of handoff dropping due to insufficient bandwidth allocation in the destination cell. Fig. 15 shows the results for directional movement, where RSS-1 outperforms RSS-3. When the system is overloaded, for r = 10%, RSS-1 produces 22%, while RSS-3 results in 34%. For r = 50%, RSS-3 is better when the system is overloaded until the arrival rate is 7.5 requests/second, when it equals the RSS-1 (20%) as the system overload reaches 10 requests/second.

Fig. 16 presents the condition for random movement. The results of three graphs, i.e. RSS-1 for r = 10%, RSS-1 for r = 50%, and RSS-3 for r = 50% are very close. When the system starts to overload, the handoff drop grows until 18% when the system load is 5 request/second. Then it becomes stable when the system load increases, except when RSS-1 with r = 10%. The result of RSS-1 with r = 10% goes down to 15% when the system load is 10 requests/second. The worst result with RSS-3 with r = 10%, because it achieves 23% when the system load reaches 10 requests/second.

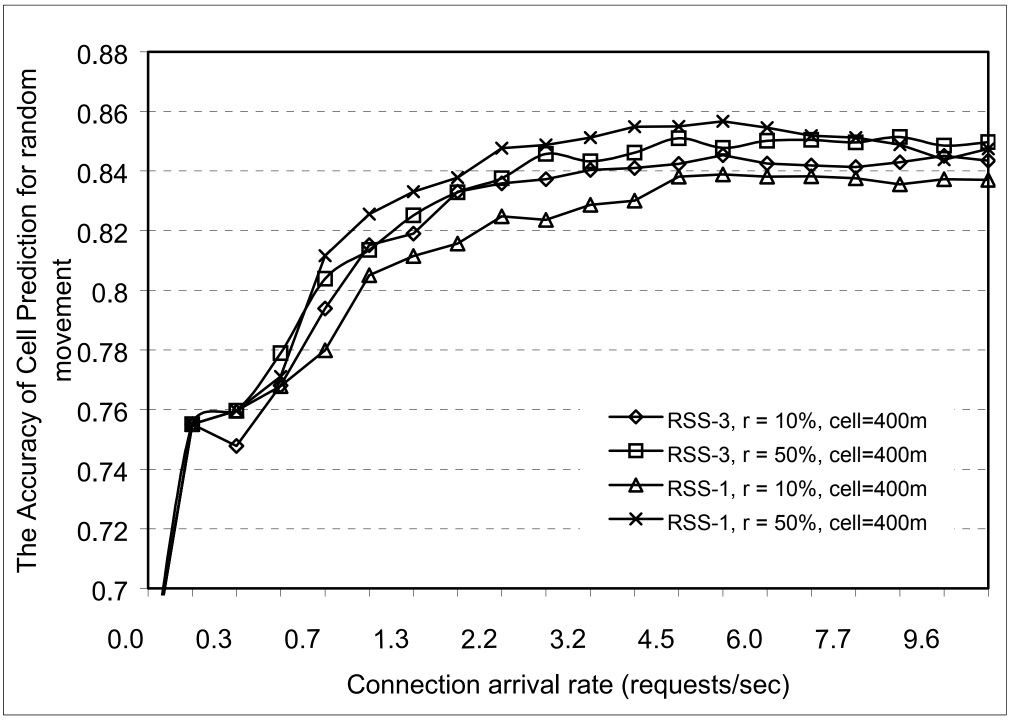

Fig. 12: The accuracy of cell prediction for random movement

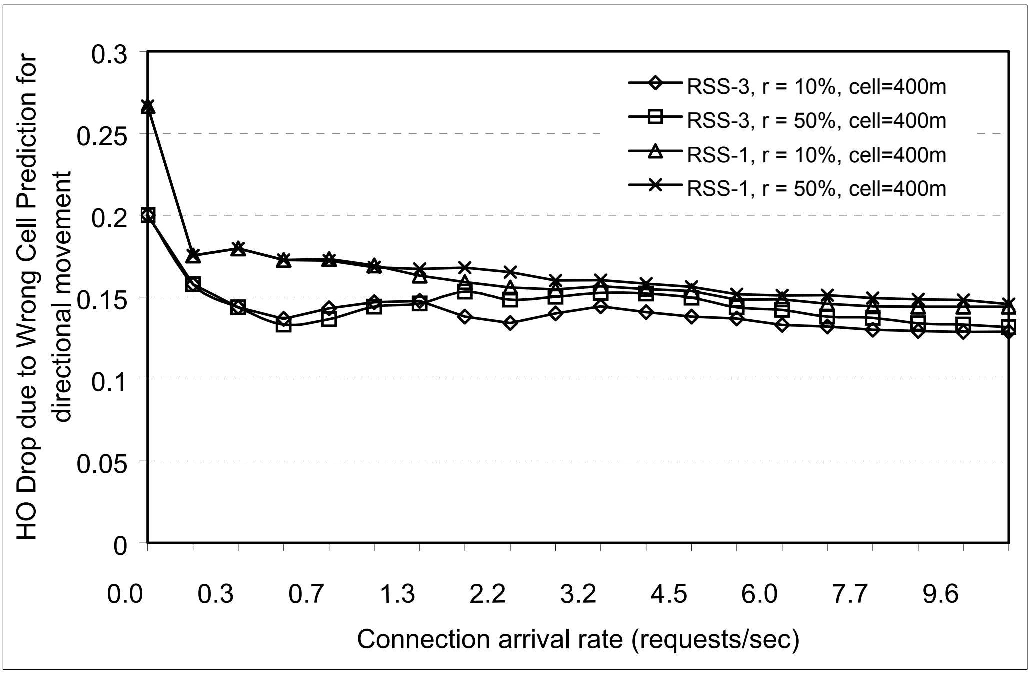

Fig. 13: Handoff Dropping Probability due to wrong cell prediction for directional movement

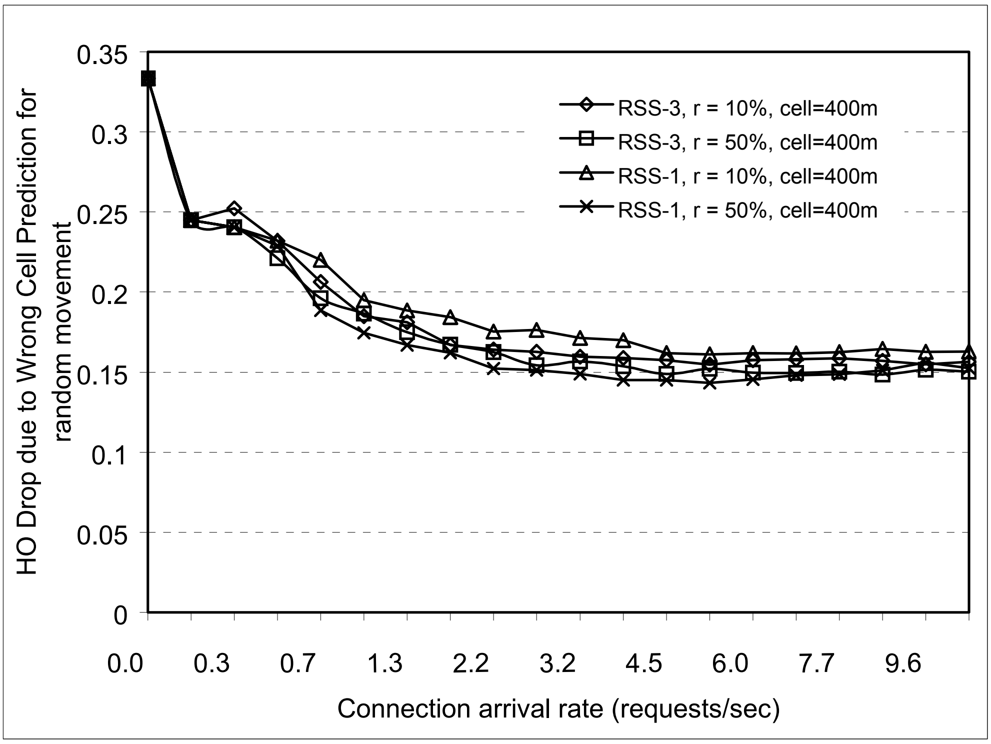

Fig. 14: Handoff Dropping Probability due to wrong cell prediction for random movement

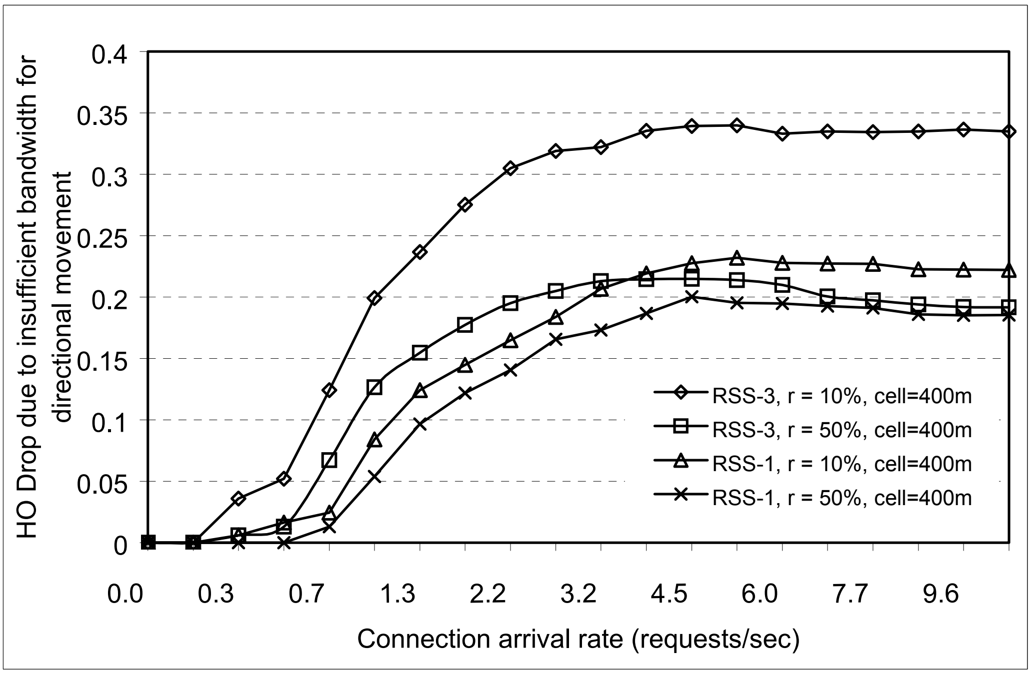

Fig. 15: Handoff Dropping Probability due to insufficient bandwidth reservation for directional movement

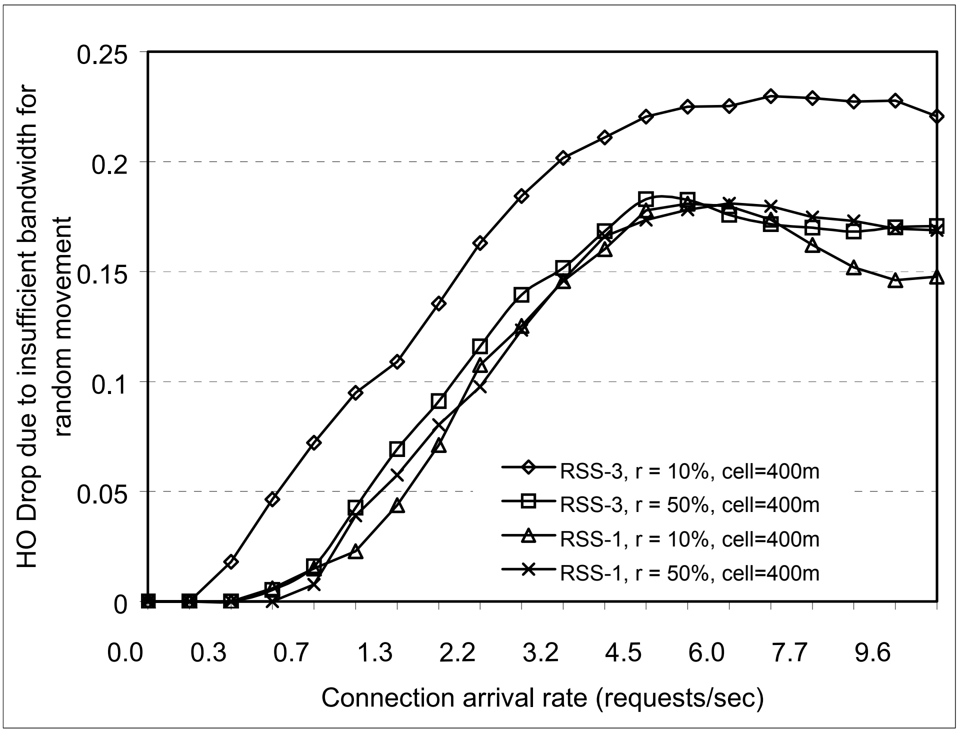

Fig. 16: Handoff Dropping Probability due to insufficient bandwidth for random movement

6.0 CONCLUSION

In this paper, we have presented and evaluated a new bandwidth reservation scheme utilising Received Signal Strength (RSS). The two models performance was evaluated for directional and random movement patterns representing the two extreme movement scenarios.

In terms of bandwidth usage, the results show that the amount of bandwidth for reservation, or the reservation ratio, is the major factor that influences the bandwidth usage. In this paper, we shows that the lesser the reservation ratio is, the higher the bandwidth usage would be, and vice versa.

In terms of new call blocking probability, we found that in addition to the reservation ratio, the randomness of MTs also affects the call blocking. The system with r = 10% produces better results compared with the one with r = 50%. The system with all MTs moving in a directional route achieves better results than the system where MTs move in random route.

In terms of handoff call dropping probability, the simulation shows that RSS-1 outperforms RSS-3 for directional and random movement, and for both r = 10% and r = 50%.

For system implementation, based on the results in this paper, we recommend the use RSS-1 model with reservation ratio r = 10%.

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BIOGRAPHY

Prihandoko obtained his PhD in Network and Communication Engineering from University Putra Malaysia in 2003. Currently, he is a lecturer at Gunadarma University, Jakarta, Indonesia. His research areas include mobile network, software engineering, and software quality assurance. He has several publications in international journal and conference proceedings.

M. H. Habaebi (PhD) is a visiting lecturer at the Faculty of Engineering, University Putra Malaysia. His active research areas are in wireless and high speed multimedia networks. He has several publications in international journals and conference proceedings and serves as a reviewer for the IEEE.

Borhanuddin Mohd Ali is the Professor at the Department of Computer and Communication Engineering, Universiti Putra Malaysia. Presently he is the Director of Institute of Multimedia and Software, Universiti Putra Malaysia. He has served actively in IEE and IEEE and is now the Chair of IEEE Malaysia Section. His research interest is in Wireless and Optical Communications, Networks and Services.