PREDICTIVE RESOURCE RESERVATION IN WIRELESS CELLULAR NETWORKS

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ABSTRACT

Recently, wireless networks have become a major sector in telecommunication industry. More and more applications seek to become wireless. However, a major obstacle in adapting wired applications to wireless is the quality of service problem. Although the wireless bandwidth is improving at a fast pace, it still is not enough for modern multimedia applications. Even if we solve the bandwidth problem, the mobility of users also poses challenges for QoS provision. If the user moves randomly, how and where can resources be reserved in advance for roaming users to move smoothly and seamlessly? In this paper, we propose a method for predictive resource reservation in wireless networks. Resources reserved but not used will seriously affect the system performance. Therefore, we also have mechanisms to relieve the resources when it is not used within a time limit and allow resources to be used temporarily when the mobile user has not coming in yet. We compare the performance of our method with those of fixed allocation scheme and shadow cluster scheme. The results indicate its effectiveness and feasibility.

Keywords: Wireless Networks, Quality of Service, Resource Reservation

1. INTRODUCTION

In recent years, more and more applications have adapted to wireless networks. Wireless cellular network constitutes the fastest growing segment of the communications industry today. With this trend, we can predict networks in the future are most wireless[1]. Recently, many researches have focused on wireless networks[2,3]. From them, two goals can be identified: effective resource utilization and QoS guarantee for wireless multimedia networks. With multimedia data flourishing in wireless networks, the issue of QoS has become very significant. However, the provision of QoS for the mobile users moving from one region to another creates a new set of challenges [4,5].

To achieve QoS guarantee in wireless cellular networks, it is important to use an admission control scheme that maintains an upper bound for the number of call admitted. The goal of the admission control scheme is to admit as many mobile users as possible with the requested QoS and achieve a very high utilization of the resources. When a new mobile user is starting to request its service, it will be admitted by the admission control scheme if the QoS guarantee can be satisfied. Otherwise, it is rejected. If there were no roaming, an admission control scheme can rely on local information. In other words, in resource reservation schemes with handoff, we must refer to the local and remote information, since remote users may roam into the local base station and the local base station must be prepared.

The basic idea of these admission control strategies is to reserve resources in each cell beforehand to deal with handoff requests. In conventional cellular networks, where the traffic and QoS needs of all connections are the same, the reservation of resources typically occurs in the form of “guard channels,” where a new connection request is established if and only if the total available channels or capacity is greater than a predetermined threshold. The strategies differ in how the number of guard channels is chosen by a base station [3-4,6-11,13-14]. The simplest approach is called fixed allocation [7]. In each base station, a fixed portion of the bandwidth is reserved for the handoff calls. Depending on the size of the portion, call blocking rate (if the portion is too large) or call-dropping rate (if the portion is too small) may be affected. To give priority to handoff calls seems to be a reasonable thought. Based on this, Levine et al. proposed a shadow cluster scheme [14]. Basically the shadow cluster consists of all the neighboring cells of the cell where the user is currently in. Resources in the shadow cluster are reserved in advance to provide for smooth handoff. It is obvious that the call dropping rate will be very good. However, the call blocking rate will be miserable. Approaches such as fixed allocation or shadow clustering result in reserving a huge amount of bandwidth. Wireless networks cannot tolerate wasting bandwidth. But QoS guarantee is as important as bandwidth efficiency. Therefore the tradeoff between QoS guarantee and effective bandwidth allocation must be carefully made. In this paper, we try to strike the balance by proposing a new method called predictive resource allocation in wireless cellular networks. The prediction is based on the past moving logs of mobile users. If the mobile user does not travel as predicted, we also have reservation time out mechanism to avoid wasting resources. Besides, reserved resources that do not seem to be needed in the near future can also be used by others temporarily. We compare our scheme to the fixed allocation scheme and the shadow cluster scheme. The results show that we do indeed have better call blocking rate than the shadow cluster scheme and better call dropping rate than the fixed allocation scheme.

The rest of the paper is organized as follows. Section 2 presents the basics of our strategies. Section 3 describes the detailed mechanisms and algorithms. Section 4 presents results of simulations. Section 5 provides the summary and conclusions.

2. BASIC CONCEPTS

In order to support QoS for the mobile hosts, there should at least exist two components in the network. One is admission control scheme, and the other is reservation scheme. The latter is more important. Generally speaking, the performance of a new user who seeks some QoS guarantee is as important as a handoff user. However, a handoff user dropped is more intolerable than a new call not getting through. Therefore, in our paper, we focus on how to support QoS for the handoff user.

First, we must reserve the bandwidth parsimoniously instead of reserving in all of the neighboring cells. To achieve this goal, we will predict the traveling route of mobile users. In most cases, users don't leave the cell where the call was initiated. In other cases, the direction of handoff usually follows along a fixed route such as the path of road and commuting. If we remember the past path of movement of each user, it will help us in predicting the current path. To implement this, each user in MSC (Mobile Switching Center) has a separate moving table to record the past moving trajectory. For example, in Figure 1, if the user powers on in cell *E*, travels through cells *A*, *B*, and *R*, then a moving sequence *EABR* will be recorded in the moving table. For each cell, there is only one sequence beginning with it. Only the newest one is recorded. This is to ensure that search can be done in constant time. To search the moving table, if a user starts at cell *X*, we search for the sequence beginning with *X*. If it is not found, we search for the first sequence that begins with one of *X*'s neighbors. For example, in Figure 1, assume a user powers on in cell *E* and there is no moving sequence begins with *E* and there is a moving sequence *ABR*. Since *A* is *E*'s neighbor, a matching sequence *ABR* will be found.

It is obvious that more resource reservation resulted in low bandwidth utilization. Therefore, we propose three methods to improve it. First, when a moving sequence is matched, not all the cells in the moving sequence will reserve the resources. Depending on the average connection time, the moving speed of the mobile user, and the cell size, only a subsequence of the moving sequence is used. For example, assume the moving sequence is *ABCDEFGH* and passing through each cell takes 3 minutes. If the average connection time is 15 minutes, then only the first 5 cells will have resources reserved. The second improvement is to add a time limit to indicate the lifetime of valid reservation. In the previous example, *A*, *B*, *C*, *D*, and *E* have time limits of 3, 6, 9, 12, and 15 minutes respectively. It means that when 6 minutes have passed and the user has not arrived at *B*, the reserved resource is released. The third improvement is to distinguish reservation into active and passive. In active reservation, the reservation is locked and only the user reserving this bandwidth can use it. In passive reservation, it can be used by others but it can be preempted. If the user reserving this bandwidth moves in, this allocated bandwidth will be reclaimed. A possible heuristic is to set the resources reserved for the current cell and the next cell as active. Or we can use the time limit as a guideline. For example, all reservations with time limit greater than 8 minutes are passive.

3. ALGORITHMS

When a new call logs into a cell, the algorithm to handle it is depicted in Figure 2, where *b* is the threshold of the blocking rate above which the system cannot handle any more requests. Otherwise, the call is accepted and the PRR (Predictive Resource Reservation) is run. If there is a matched moving sequence, we decide the actual pattern for reservation. If there isn't, the original system strategy (the one used by the wireless service provider) for admitting a call is used.

3.1 Predictive resource reservation strategy (PRR)

3.1.1 Call initialization:

(1) MSC will search the moving table for a match with the call's location. Then *Algorithm DMP* will decide the length of moving pattern (the number of cells) for resource reservation.
(2) If there is no match, MSC uses the neighboring cells for a match. If there is a match for the neighbor. Step (1) applies.
(3) Otherwise, accept the call using the original system method.

3.1.2 Algorithm DMP

Decide the length of moving pattern based on the radius of cells and the velocity [17] of mobile station.

For example, if the velocity is 80 km/hr and the radius of a micro cell is about 5 km, the maximum length of moving pattern should be 8 for 30 minutes of connection time.

Algorithm DMP /* Algorithm DMP to determines moving pattern for each user */

Step 1: Assume the matched moving sequence is *S*.
Calculate the maximum moving pattern length *W* based on the radius of cell, the velocity of mobile station, and the average connection time.

Step 2: IF the length of *S* is less than *W*;
Let the moving pattern be *S*;
Return *S*;

ELSE
Let *W* be the length of moving pattern;
/* shorten the moving sequence because of velocity */
S=substring(*S*,1,*W*)
Return *S*;

3.2 Local resource management algorithm

When the moving pattern is found, the MSC (Mobile Switching Center) must tell the BSC (Base Station Controller) to assign bandwidth. Besides bandwidth allocation, the base station controller has to decide a time-limit for each cell on the moving pattern. The time-limit is based on the cell's distance from the first reserved cell and the moving pattern. When time-limit counts down to zero, the reserved bandwidth is released. The mechanism for time-limit management is as follows

(1) The BSC assigns bandwidth and time-limit among cells based on the velocity of mobile user [17]. For example, assume the moving pattern is "*ABCDEFGH*" and the velocity is 30km/hr. BSC may set the time-limit as *A*[5min], *B*[8min], *C*[11min], *D*[14min], *E*[17min], *F*[20min], *G*[23min], *H*[26min]. If the time-limit counts down to zero in a cell, BSC releases its bandwidth. If the velocity is faster, BSC should set the time-limit smaller. If a mobile host enters into the cell that has bandwidth reserved for it, the time-limit will be frozen until the mobile leaves this cell.

(2) If a mobile host leaves *A* and enters to *B*, the BSC sets *A*'s time-limit to a smaller value instead of releasing the reserved channel instantly. It is to avoid the cyclical moving between *A* to *B*.

(3) We also classify the reserved resources as active or passive according to time-limit. For example, when time-limit is larger than 8 minutes, then the bandwidth reserved is passive. The active reserved resource is reserved and cannot be used by others. On the contrary, the passive reserved resource is reserved and allows other calls to use it. However, it will be preempted when the reserving call appears.

4. SIMULATION RESULTS

4.1. Model of Simulation

We compare the proposed scheme to two other methods. The first is the original method with 5 % of the channels reserved for handoff users (fixed allocation). The second is the shadow cluster scheme. The cell structure of the simulation is shown in Figure 1. Assume each cell has 128 channels. We test on three kinds of traffic classes shown in Table 1.

We use Java Language [18] to implement the simulation. Each call is a thread. There are 100 calls to 2100 calls that are randomly distributed in 19 cells. The residence time of each call is between 10sec to 100sec. The handoff rate is 33% of total calls. We observe the blocking probability of new calls, the dropping probability of handoff calls, and the condition of bandwidth usage.

4.2. Simulation Results

I. Homogeneous traffic

In the homogeneous traffic, each call is allocated and reserved the same number of channels. The simulation results are shown in Figure 3.

Figures 3(a) and 3(c) show the blocking probability and Figures 3(b) and 3(d) shows the dropping probability. As can be seen, our scheme improves the blocking probability without sacrificing the dropping probability compared to the shadow cluster scheme. Figure 3(e) shows the results of ping-pong effect, i.e., repeatedly roaming between two cells. Since we do not release the resource immediately after a mobile user left a cell (We only set the time-limit value smaller), it is expected that the performance will be better for our method. Figure 3(f) shows the effective bandwidth utilization. Since Class 2 traffic occupies 2 channels for each reservation, it has the worst bandwidth utilization. Our method is better than the shadow cluster scheme. Obviously there is room for improvement. However, the improvement may pay a price of increasing dropping rate. The trade off between them must be carefully weighed.

II. Mixed traffic

The results of Class 3 traffic are shown in Figure 4. The trend is similar to traffic classes 1 and 2.

5. CONCLUSIONS AND FUTURE WORK

5.1.Conclusions

The moving pattern and the time limit concept is likely to be very useful in any wireless cellular networks. Unlike the shadow cluster scheme, our strategy is more economical in terms of bandwidth utilization. In the future wireless networks, the provision of QoS guarantee is an important requirement. In this paper, strategies have been proposed to provide QoS guarantee in multimedia wireless cellular networks.

It is shown through simulations that the proposed scheme provides a substantially much lower connection-dropping probability than the schemes without bandwidth reservation and a much lower blocking probability than the shadow cluster strategy. Although the new connection blocking probability is high when the traffic is heavily loaded, it is tolerable. With future wireless networks, the available bandwidth will be much greater. Therefore, the connection dropping probability will have more influence on user than the new connection blocking probability.

When the traffic is heavily loaded, we may add some concepts such as channel borrowing and channel carrying [9,19] to our scheme. Finally, researches in RSVP [15] and MRSVP (Mobile RSVP) [16] may someday be finalized to benefit the QoS provision of mobile users.

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REFERENCES

[1] Ian F. Akyildiz, Joseph S. M. Ho, and Huseyin Uzunalioglu, "Mobility Management in Next-Generation Wireless Systems" in *Proceedings of the IEEE, Vol. 87, No. 8, August 1999*.

[2] Mahadevan I; and Sivalingam K.M, "An Experimental Architecture for providing QoS guarantees in Mobile Networks using RSVP" in *Personal, Indoor and Mobile Radio Communications, 1998. The Ninth IEEE International Symposium on Volume: 1 , 1998.*

[3] Ruay-Shiung Chang, and Andrew Chu, "Supporting Quality of Service Communications for Mobile Hosts with Advanced Resource Reservations" in *Conference ICOIN-14,Page(s): 5C-1.1 – 5C-1.8, 2000.*

[4] Jianping Jiang, and Ten-Hwang Lai, "Call Admission Control vs Bandwidth Reservation: Supporting QoS and Bandwidth Efficiency in Multimedia Mobile Networks" in *Department of Computer and Information Science The Ohio State University, Columbus*.

[5] K. Pahlavan, and A. H. Levesque, "Wireless data communication," *Proc. IEEE, vol. 82, pp. 1398-1430, 1994.*

[6] Taekyoung Kwon, Yanghee Choi, Bisdikian C, and Naghshineh M, "Measurement-based Call Admission Control for Adaptive Multimedia in Wireless/Mobile Networks" in *Wireless Communications and Networking Conference, 1999. WCNC. 1999 IEEE*.

[7] P. Agrawal, D. K. Anvekar, and B. Narendran, "Channel management policies for handovers in cellular networks," *Bell Labs Tech. J., vol. 1, no. 2, pp. 97-110, 1996.*

[8] Del Re, E., Fantacci R., and Giambene G. "Handover and Dynamic Channel Allocation Techniques in Mobile Cellular Networks" in *IEEE Transactions on Vehicular Technology, Volume: 44 2 , May 1995 , Page(s): 229 –237.*

[9] Ortigoza-Guerrero L., and Aghvami A.H. "A Prioritized Handoff Dynamic Channel Allocation Strategy for PCS" in *IEEE Transactions on Vehicular Technology, Volume: 48 4 , July 1999 , Page(s): 1203 –1215.*

[10] Ramanathan P., Sivalingam K.M., Agrawal P., and Kishore S "Dynamic Resource Allocation Schemes During Handoff for Mobile Multimedia Wireless Networks" in *IEEE Journal on Selected Areas* in *Communications, Volume: 17 7 , July 1999 , Page(s): 1270 –1283.*

[11] Chuang J.C.-I. "Performance Issues and Algorithms for Dynamic Channel Assignment"in *IEEE Journal on Selected Areas in Communications, Volume: 11 6 , Aug. 1993 , Page(s): 955 –963.*

[12] Bharghavan V.; Kang-Won Lee; Songwu Lu; Sungwon Ha; Jin-Ru Li; Dwyer, D. "The TIMELY Adaptive Resource Management Architecture" in *IEEE Personal Communications Volume: 5 4 , Aug. 1998 , Page(s): 20 –31.*

[13] Oliveira C.; Jaime Bae Kim; Suda, T. "An Adaptive Bandwidth Reservation Scheme for High-Speed Multimedia Wireless Networks" in *IEEE Journal on Selected Areas in Communications, Volume: 16 6 , Aug. 1998 , Page(s): 858 –874.*

[14] Levine, D.A.; Akyildiz, I.F.; Naghshineh, M. "A Resource Estimation and Call Admission Algorithm for Wireless Multimedia Networks Using the Shadow Cluster Concept" in *IEEE/ACM Transactions on Networking, Volume: 5 1 , Feb. 1997 , Page(s): 1 –12.*

[15] R. Braden, Ed., and L. Zhang, "Resource ReSerVation Protocol (RSVP) – Version 1 Functional Specification" in *RFC 2205.*

[16] Awduche, D.O., and Agu, E. "Mobile Extensions to RSVP" in *Computer Communications and Networks, 1997. Proceedings. Sixth International Conference on , 1997 , Page(s): 132 –136.*

[17] Theidire S. Rappaport "Wireless communications Principles & Practice" is *published by Prentice Hall PTR Upper Saddle River, New Jersey 07458, Page(s): 167-174.*

[18] Java(TM) 2 SDK, Standard Edition 1.2 is published in Sun corporation.

[19] Junyi Li; Shroff, N.B.; Chong, E.K.P. "Channel Carrying: A Novel Handoff Scheme for Mobile Cellular Networks" in *IEEE/ACM Transactions on Networking, Volume:* 7 (1), Feb. 1999 , Page(s): 38 –50.

Table 1 Traffic class for the simulation

Number of class connection	Reserved Bandwidth
Class 1: Normal call	1 channel reserved
Class 2: Multimedia call	2 channels reserved
Class 3: Mixed call	1 or 2 channels reserved

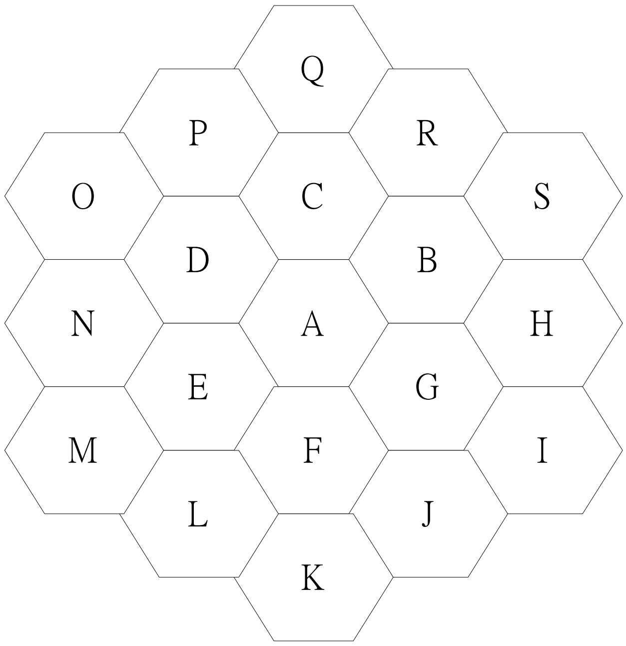

Figure 1. An example of cell structure

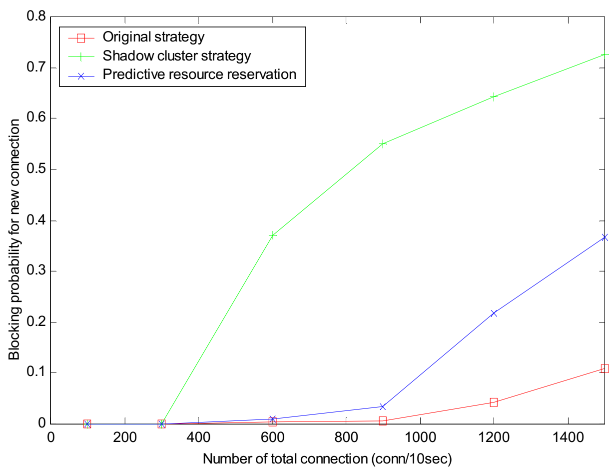

Figure 3(a). Blocking probability for new connection, Class1.

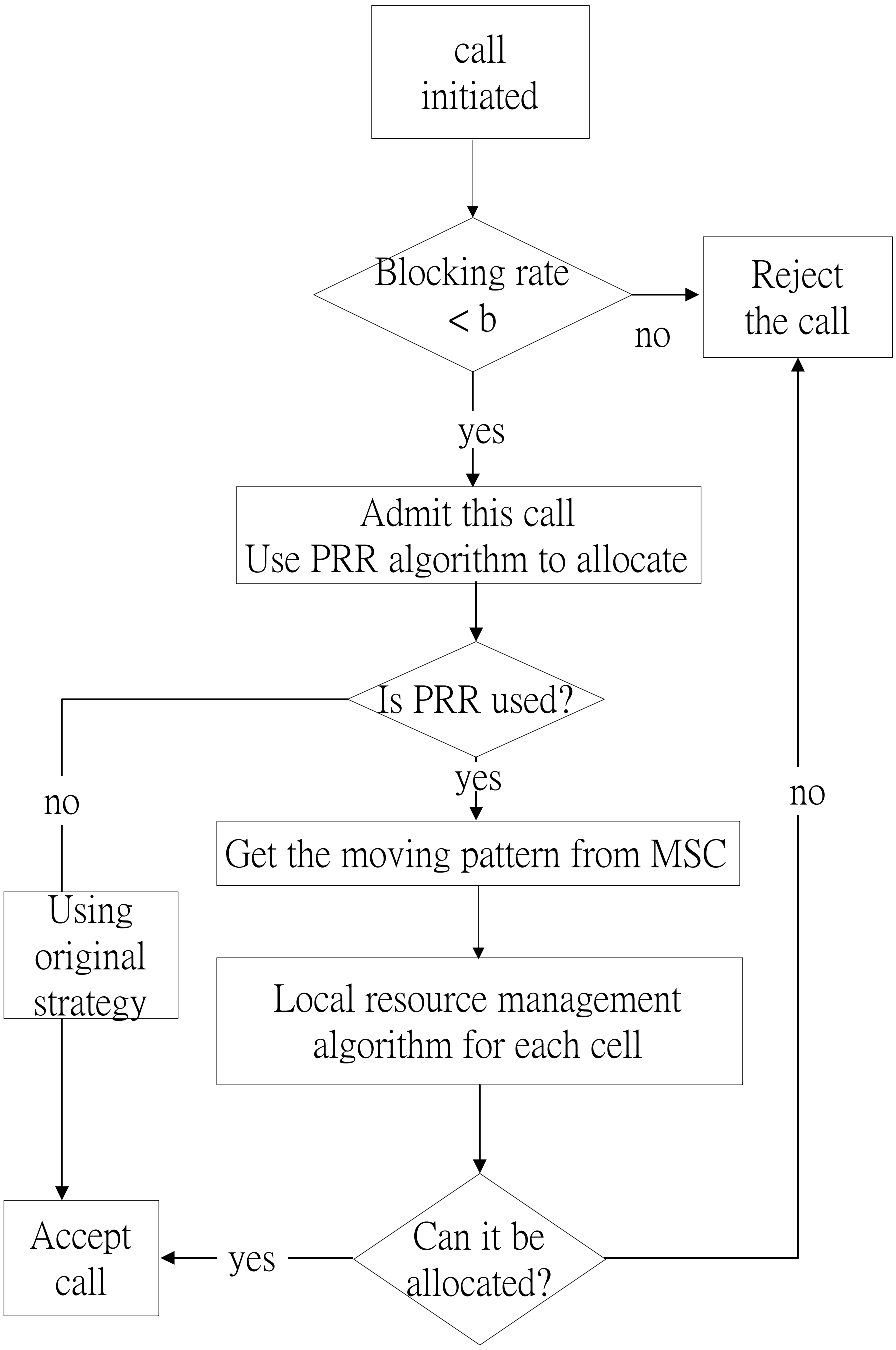

Figure 2. The flowchart

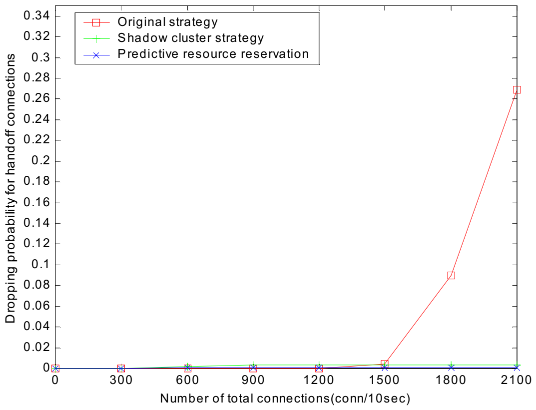

Figure 3(b). Dropping probability for handoff connection, Class1

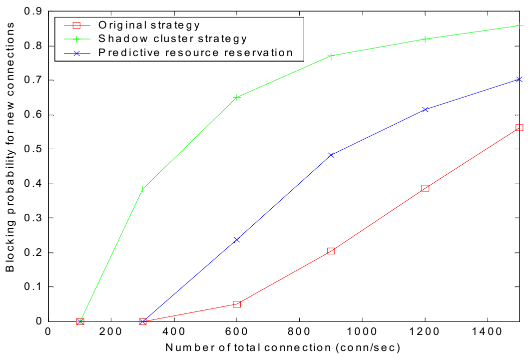

Figure 3(c). Blocking probability for new connection, Class2.

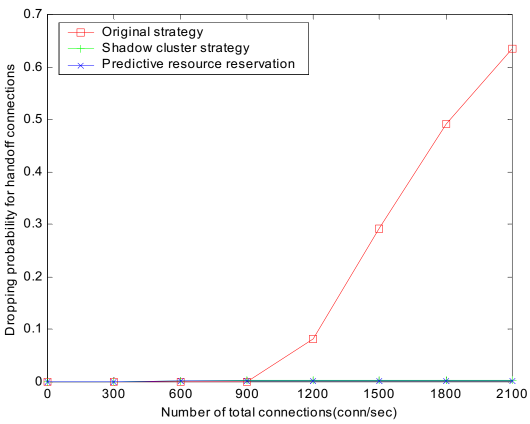

Figure 3(d). Dropping probability for handoff connection, Class2.

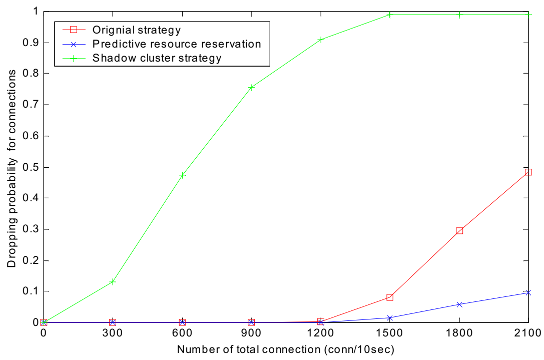

Figure 3(e). Dropping probability for handoff connection when roaming between 2 cells

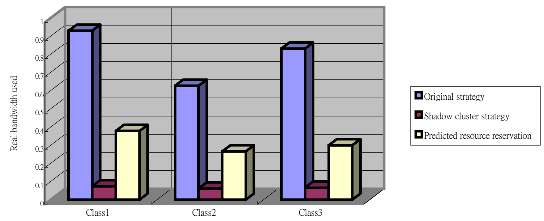

Figure 3(f). Real bandwidth used for connection

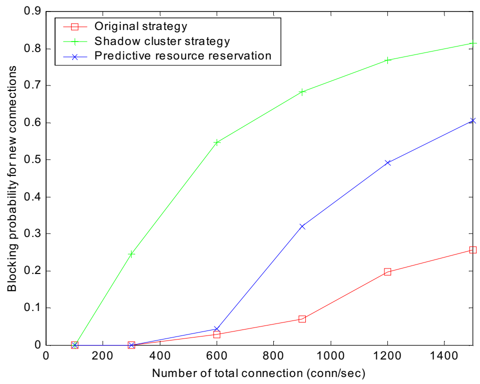

Figure 4(a). Blocking probability for new connection, Class3.

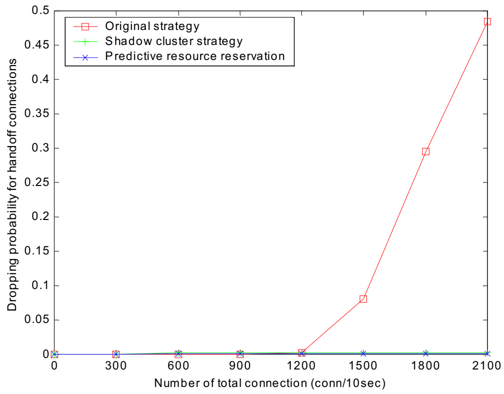

Figure 4(b). Dropping probability for handoff connection, Class3.