The Study of Handoff Prediction Schemes for Resource Reservation in Mobile Multimedia Wireless Networks

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Abstract

In this paper, the mobility-dependent predictive resource reservation (MDPRR) scheme is proposed to provide flexible usage of limited resource in mobile multimedia wireless networks. An admission control scheme is also considered to further guarantee the QoS of real-time traffic. The area of a cell is divided into non-handoff, pre-handoff, and handoff zones so that bandwidth is reserved in the target/sub-target cell as mobile stations move into the pre-handoff zone and leave the serving base station. The amount of bandwidth to be reserved is dynamically adjusted according to the location, the instantaneous variation of velocity and direction of mobile stations. Two scenarios of the MDPRR scheme are compared by considering the velocity threshold in the calculation of the weight of direction. The results show that employing the velocity threshold in the MDPRR scheme can indeed reduce connection dropping probability, and make better usage of the reserved bandwidth.

Keywords: *pre-handoff zone, admission control, direction weighting, velocity threshold, dynamic resource reservation.*

1. Introduction

Future wireless communications will be dominated by multimedia applications that require high data rates and diversified services with different quality-of-service (QoS) and different traffic profiles [1]. To provide seamless service in cellular networks, cells must provide sufficient resources for handoff connections.

The guard channel scheme is generally referred as the fixed bandwidth reservation (FBR) scheme [2] which can improve the dropping probability of handoff connections by reserving a fixed number of channels exclusively for handoff connections. The drawback of this scheme is that the reserved bandwidth is often wasted in the hot spot area. Dynamically reserving bandwidth for handoff calls is an effective way to reduce handoff dropping probability and increase bandwidth utilization. Existing approaches [3-6] of dynamic reservation for handoff connections can be classified into probabilistic [3,4] and dynamic [5,6] reservation.

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Oliveira et al. [3] proposed a mechanism that provides QoS guarantees and low connection dropping probability by taking the network condition into account in reserving the bandwidth. The resource estimation algorithm using the shadow cluster concept [4] is a virtual message system where information about position or movement pattern are exchanged with neighboring cells. However, these schemes induce large amount of overheads between BSs in the cellular system.

Choi et al. [5] proposed to use the mobility pattern profile and a 2-tier cell structure to determine the amount of bandwidth to be reserved in the cell. The drawback of this history-based scheme is the overhead to develop, store and update traffic profiles for different cells. In the predictive channel reservation (PCR) scheme [6] reservation requests are sent to neighboring cells by extrapolating the motion of MSs. The PCR scheme can provide real-time handoff predictions, however, multimedia traffic was not considered.

In this study, the 2-tier cell structure [5] is adopted to reduce unnecessary resource reservation for MSs near the BS. The location of MSs can be easily tracked with some efficient location control [7], meanwhile, the instantaneous velocity and direction may vary. The amount of bandwidth to be reserved is dynamically adjusted to reflect the mobility condition of MSs. An admission control scheme is also adopted to achieve lower dropping probability, better usage of the reserved bandwidth, and better bandwidth utilization.

The rest of this paper is organized as follows. Section 2 describes the system environment and assumptions. The proposed mobility-dependent predictive resource reservation (MDPRR) scheme is presented in section 3. Simulation results are provided and discussed in section 4, where performance measures of the MDPRR scheme are investigated and compared with the FBR scheme. Finally, concluding remarks are given in section 5.

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2. System Description

In this study, a seven-cell cellular system is considered where the traffic is assumed to be homogeneously distributed. The area of a cell is divided into non-handoff, pre-handoff, and handoff zones as shown in Fig. 1, where R is the radius of a cell, R_h is the radius of handoff boundary, and R_{nh} is the radius of non-handoff zone.

To determine the cell coverage, zone coverage, and pre-handoff threshold, the propagation model proposed by [8,9] is adopted where the received signal strength, *RSS*, can be expressed as

$$RSS = -10\gamma \times \log(d) \tag{1}$$

Where d is the distance of the transmitter to the MS and γ is the propagation path-loss coefficient. If the RSS is below the handoff strength, e.g., -80dbm [9], the MS is in the handoff zone preparing to handoff. If the RSS is below the pre-handoff threshold and decreases in the next location, the MS is in the pre-handoff zone preparing to reserve bandwidth in the target/sub-target cell for seamless handoff. The ping-pong effect [8] in the boundary of pre-handoff and handoff zone can be avoided by a number of methods proposed in [10].

As shown in Fig. 1, the target cell, cell *2*, is the next cell that an active MS will move to by extrapolation [6]. The sub-target cells, cell *1* and cell *3*, are adjacent cells of both the target and current cells. To achieve high bandwidth utilization and intimate the system processing and signaling time, no reservation is made in the non-handoff zone.

Assume MSs move randomly, the instantaneous velocity, location, and direction are checked every ΔT sec, the probing time, in the pre-handoff zone. Accordingly, the exact amount of bandwidth reserved is calculated. Upon a new or handoff connection request, an MS should provide such information as traffic categories, the desired amount of bandwidth (B_{req}), and the minimum required bandwidth (B_{min}) to the BS.

Table 1. Multimedia traffic classes

Categories of Traffic	Applic. Group	Bandwidth Requirement	Average Bandwidth Requirement	Connection Holding time	Average Connection Holding time	Example
rt	1	30Kbps (CBR)		1~10 minutes	3 minutes	Voice service
	2	256Kbps (CBR)		1~30 minutes	5 minutes	Video-phone
	3	1~6Mbps (VBR)	3Mbps	5~300 minutes	10 minutes	Video on demand
nrt	4	5~20Kbps (UBR)	10Kbps	10~120 seconds	30 seconds	E-mail
	5	64~512Kbps (UBR)	256Kbps	0.5~600 minutes	3 minutes	Data on demand
	6	1~10Mbps (UBR)	5Mbps	0.5~20 minutes	2 minutes	File transfer

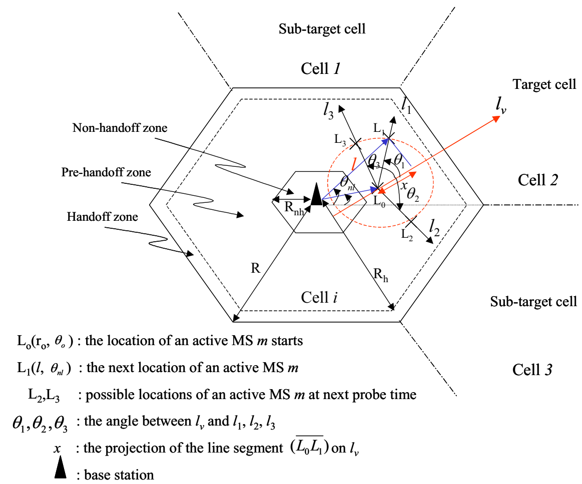

Fig. 1. The cellular systems

Two classes of traffic [3] are considered: real-time (rt) and non-real time (nrt) traffic, they are further divided into six application groups as given in Table 1. Note that, bandwidth is reserved only for rt traffic. The QoS of rt variable bit rate (VBR) traffic can be adjusted to a minimum of 1Mbps, so that the call can still be acceptable at congestion. Nrt traffic such as e-mail and TCP/IP packets, can either be buffered at the BS or transmitted at a lower rate when congestion occurs. The minimum required bandwidth of application groups 4, 5, and 6 are respectively assumed to be 5Kbps, 64Kbps, and 1Mbps.

3. The Mobility-Dependent Predictive Resource Reservation (MDPRR) scheme

Our goal is to dynamically reserve a proper amount of bandwidth by virtue of the instantaneous variation of velocity, location, and direction of an active MS. First, we consider the probability of reserving bandwidth based on the instantaneous variation of velocity, location, and direction. Accordingly, the total amount of bandwidth to be reserved in the target/sub-target cells can be evaluated. Intuitively, the larger the velocity, the more the probability of reserving is to be reserved. The μ -law function is used to map the velocity into the probability of reserving bandwidth. At probe time ΔT and with the normalized velocity v, the probability of reserving, $P_{rv}(\Delta T)$, is given by

$$P_{rv}(\Delta T) = \frac{\log(1+\mu v)}{\log(1+\mu)}, \tag{2}$$

where μ is the curvature. Similarly, the larger the distance of an MS to the BS, the higher the probability of reservation is. Accordingly, a linear relationship between location and probability of reserving is assumed. Let the starting location of an active MS m be $L_o(r_o, \theta_o)$ as shown

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in Fig. 1, the probability of reserving at distance l and at probe time ΔT is given by

$$P_{rl}(\Delta T) = \begin{cases} 1, x \geq \frac{\sqrt{3}}{2}(R_h - R_{nh}); \\ \frac{2x}{\sqrt{3}(R_h - R_{nh})}, \; 0 \leq x < \frac{\sqrt{3}}{2}(R_h - R_{nh}), \end{cases} \tag{3}$$

where $x = l - r_o \cos(\theta_{nl} - \theta_o)$ and $l = r_o + V\Delta T$.

To further improve the performance, two scenarios are investigated by considering the velocity threshold (V_t) in the calculation of direction weighting. The first scenario uses fixed direction weighting, i.e., MDPRR_FW. For example, the direction weighting of an active MS m moving from cell i to cell j in Fig. 1 is

$$d^m_{i,j} = \begin{cases} 1/3, \; -\pi/6 \leq \theta_1 \leq \pi/6, \text{ for } j = 2; \\ 1/3, \; -\pi/2 \leq \theta_2 < -\pi/6, \text{ for } j = 3; \\ 1/3, \; \pi/6 < \theta_3 \leq \pi/2, \text{ for } j = 1; \\ 0, \text{ otherwise, } \quad \text{for } j = 4, 5, 6. \end{cases} \tag{4}$$

The second scenario uses dynamic direction weighting based on V_t, i.e., MDPRR_DW. Initially, the direction weighting is fixed as given in *eq.* (4), then changes to the binary exponential backoff algorithm [11] at each probe time in calculating the direction weighting of the sub-target cell. If $V < V_t$, and if the target cell stays the same before handoff, the direction weighting at each probe time is given as

$$d^m_{i,j}(n\Delta T) = \begin{cases} 1 - \frac{2}{3}(\frac{1}{2})^{n-1}, \text{n} \geq 1, \text{ for target cell;} \\ \frac{1}{3}(\frac{1}{2})^{n-1}, \text{n} \geq 1, \text{ for sub-target cell.} \end{cases} \tag{5}$$

Otherwise, the direction weighting at each probe time is

$$d^m_{i,j}(n\Delta T) = \begin{cases} \frac{1}{2} + \frac{1}{3}(\frac{1}{2})^{n-1}, \text{n} \geq 2, \text{ for target cell;} \\ \frac{1}{2} - \frac{1}{3}(\frac{1}{2})^{n-2}, \text{n} \geq 2, \text{ for sub-target (previous target) cell;} \\ \frac{1}{3}(\frac{1}{2})^{n-1}, \text{n} \geq 2, \text{ for sub-target cell,} \end{cases} \tag{6}$$

where an appropriate direction weighting is obtained to the previous target cell in order to avoid direction changing back to the original direction.

When $V \geq V_t$, and the target cell stays the same before handoff, the direction weighting at each probe time is obtained as

$$d^m_{i,j}(n\Delta T) = \begin{cases} 1 - \frac{2}{3}(\frac{1}{4})^{n-1}, \text{n} \geq 1, \text{ for target cell;} \\ \frac{1}{3}(\frac{1}{4})^{n-1}, \text{n} \geq 1, \text{ for sub-target cell.} \end{cases} \tag{7}$$

Otherwise, the direction weighting at each probe time is

$$d^m_{i,j}(n\Delta T) = \begin{cases} \frac{3}{4} + \frac{1}{3}(\frac{1}{4})^{n-1}, \text{n} \geq 2, \text{ for target cell;} \\ \frac{1}{4} - \frac{2}{3}(\frac{1}{4})^{n-1}, \text{n} \geq 2, \text{ for sub-target (previous target) cell;} \\ \frac{1}{3}(\frac{1}{4})^{n-1}, \text{n} \geq 2, \text{ for sub-target cell.} \end{cases} \tag{8}$$

The term $(1/4)^{n-1}$ is used to reduce the direction weighting of the sub-target cell because $V \geq V_t$, in other words, to instantly increase the direction weighting of the target cell. The snapshot of direction weighting at each probe time is given in Table 2.

Table 2. The snapshot of direction weighting of the MDPRR_DW scheme

a(b): *a* is the cell no. .
b is the direction weighting from current cell to cell *a*.

	Current cell	Target cell	Sub-target cell	Sub-target cell
ΔT	*i*	*2*(1/3)	*1*(1/3)	*3*(1/3)
2 ΔT	*i*	*2*(10/12)	*1*(1/12)	*3*(1/12)
3 ΔT	*i*	*1*(37/48)	*2*(10/48)	*6*(1/48)
4 ΔT	*i*	*2*(154/192)	*1*(37/192)	*2*(1/192)

(*a*) $V \geq V_t$

	Current cell	Target cell	Sub-target cell	Sub-target cell
ΔT	*i*	*2*(1/3)	*1*(1/3)	*3*(1/3)
2 ΔT	*i*	*2*(4/6)	*1*(1/6)	*3*(1/6)
3 ΔT	*i*	*1*(7/12)	*2*(4/12)	*6*(1/12)
4 ΔT	*i*	*2*(16/24)	*1*(7/24)	*3*(1/24)

(*b*) $V < V_t$

The occupied bandwidth of an active MS m, B^m_{ocu}, is given by

$$B^m_{ocu} = \begin{cases} B_{req}, \text{for } B_{req} \leq B_{avl}; \\ B_{\min}, \text{for } B_{req} > B_{avl} \geq B_{\min}, \end{cases} \tag{9}$$

where B_{avl} is the available bandwidth. Let $\delta^m_i(t)$ represent the zone that MS m in cell i is located at time t,

$$\delta^m_i(t) = \begin{cases} 1, \text{ in pre-handoff or handoff zone;} \\ 0, \text{ otherwise.} \end{cases} \tag{10}$$

The amount of bandwidth to be reserved is also dynamically adjusted. Let α_1, α_2 be constant satisfying $\alpha_1 + \alpha_2 = 1$ and $0 \leq \alpha_1, \alpha_2 \leq 1$. Therefore, the amount of bandwidth to be reserved is expressed as

$$B^{rm}_{i,j}(t) = d^m_{i,j}(t) B^m_{ocu}[\alpha_1 P^m_{rv}(t) + \alpha_2 P^m_{rl}(t)] \delta^m_i(t) \tag{11}$$

The total amount of bandwidth reserved in cell j when all active MSs moving from cell i to cell j at time t is

$$B^r_{i,j}(t) = \sum_{\forall m \in i} B^{rm}_{i,j}(t). \tag{12}$$

Finally, the total amount of bandwidth reserved for cell i at time t is

$$B^r_i(t) = \sum_{j \in S'} B^r_{j,i}(t), \tag{13}$$

where S' is the set of neighboring cells of cell i. All the reserved bandwidth is shared for future handoff connections, with or without prior reservation, and is used prior to the available bandwidth.

A reservation request is sent from the old BS to the new one at each probe time when the MS is in the pre-handoff zone and moves away from the old BS. Intuitively, the system processing and signaling time of the proposed scheme compared to [3] can give an improvement of

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$$1-\frac{R^2-R_{nh}^2}{R^2}\times 100\% \qquad (14)$$

When reservation requests from neighboring cells arrive, the new BS will place them in queue. Reservation requests will leave the queue when bandwidth is allocated or timeout (i.e., probe time).

3.1. Admission control (AC)

To guarantee the bandwidth of ongoing rt connections, the BS must monitor its resource usage and properly adjust the bandwidth at congestion for the sake of increasing the system capacity. In this study, the available bandwidth of new rt-VBR arrivals can be adjusted from the required bandwidth B_{req} to the minimum bandwidth B_{min} if $B_{\min} \le B_{avl} < B_{req}$, and $B_{\min} \le B_{avl} + B_{res} < B_{req}$ for handoff arrivals, where B_{res} is the amount of bandwidth reserved for handoff arrivals. On the other hand, nrt arrivals will be blocked or dropped when the required bandwidth is larger than the available bandwidth for new or handoff arrivals.

In the negotiation process, bandwidth of a new or handoff arrival is first negotiated and if the available bandwidth is insufficient, the bandwidth of ongoing connections in application groups 3 to 6 are negotiated. When the negotiation of ongoing connection fails, new and handoff arrivals with rt traffic can preempt ongoing connection with nrt traffic in the preemptive scheme. The bandwidth of ongoing connection with the largest service time will be released.

4. Simulation Results and Discussions

In this section, performance measures of the proposed scheme are investigated by simulation using OPNET [12] and are executed using a Pentium IV 2G IBM/PC compatible machine, with the operating system of Windows 2000.

The 7-cell planning is used and our focus will be on the center cell. Simulation parameters are carefully chosen to closely represent realistic scenarios [3,9]. A path loss exponent $\gamma = 4$ is used in the simulation. Assume the cell radius (R) is 800m and MSs move randomly along six adjacent cell directions and a connection with rt traffic or nrt traffic are generated equally. The inter-arrival time of a new connection request is geometrically distributed with a mean of $1/\lambda$ in each cell. The connection holding time is assumed to follow a geometric distribution, and the mean holding times are provided in Table 1. The ratio of rt traffic are 70%, 25%, and 5% respectively for traffic groups 1, 2, and 3, but nrt traffic of groups 4, 5, and 6 are generated equally. The simulation terminates when the number of handoff arrivals in the center cell reaches 10^4.

The maximum bandwidth capacity is 30Mbps for each cell. The amount of bandwidth reserved for handoff arrivals is variable based on the MS's velocity, location, and direction at each ΔT. Initially, the velocity is uniformly distributed between 0~60 Km/hr, and will vary with normal distribution N($\overline{m}$, σ^2), where $\overline{m}$ is the mean velocity obtained at each probing time, the variation of velocity is the standard deviation σ at each ΔT. It is assumed that the MS has a probability of 2/3 moving in the previous direction and a probability of 1/6 in the sub-target cells direction.

4.1. Parameter setting

We first run simulations to find appropriate values for parameters α_1, α_2, ΔT, μ and σ. We find that velocity dominates in the determination of reservation probability. Therefore, a proper combination of α_1=0.9 and α_2=0.1 is selected to be used in the system. In the selection of probe time ΔT, there is a tradeoff between reservation accuracy and overhead in signaling and processing time. $\Delta T = 5$sec is selected to be used in the system. Larger μ may result in more reservation probability for handoff connections, it doesn't apparently result in higher connection blocking probability P_b. Therefore, $\mu = 100$ is selected to be used in the system. Smaller σ gives lower P_d, i.e. smaller variation of velocity generates more number of reservation requests. Therefore, the system can accurately reserve the amount of bandwidth with smaller variation of velocity. Therefore, σ=1 Km/hr is selected to be used in the system.

Higher V_t gives slightly lower P_d at heavy load, it means that for higher V_t, an appropriate bandwidth can be reserved for MSs which may handoff. Meanwhile, the blocking probability shows little difference when using different velocity thresholds. Therefore, V_t=50Km/hr is assumed. Let C_{ph}, i.e., $(R^2 - R_{nh}^2)/R^2 \times 100\%$, represent the percentage of the pre-handoff zone in the cell coverage. P_d of the pre-handoff zone of 86%, i.e, R_{nh}=300m, is not apparently smaller than that of 61%, i.e, R_{nh}=500m, cell coverage. It reveals that it is not necessary to reserve the bandwidth in advance when the MS is in the non-handoff zone. An appropriate value of a pre-handoff zone with 61% cell coverage is thus selected to be used in the system.

4.2. Comparison of the two scenarios

The proper values selected in section 4.1 are used in the following experiments. The connection dropping probability of the MDPRR_DW scheme is significantly

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smaller than the MDPRR_FW scheme for rt traffic, it means that the dynamic resource reservation is benefit for decreasing the connection dropping probability of rt traffic. In other words, it comes at the expense of a larger P_b for rt traffics as shown in Fig. 2. In addition, the connection dropping and blocking probability of nrt traffic is worse than the rt traffic.

Fig. 3 shows that the average usage rate of the reserved bandwidth of the MDPRR_DW scheme is larger than the MDPRR_FW scheme at light load. It means that the former can reserve bandwidth more accurately for handoff arrivals. Fig. 4 shows that the average number of ongoing connections to be adjusted is slightly higher for handoff arrivals in the dynamic scenario. It implies that the dynamic scenario have more number of ongoing connections with accurate bandwidth requirement for handoff arrivals. In other words, it comes at the expense of a smaller number of ongoing connections to be adjusted in new arrivals. The average number of ongoing connections to be adjusted decreases at heavy load, this is because new arrivals are blocked, and the number of handoff arrivals decreases at heavy load.

4.3. Enhancement of the performance measures

Finally, Let B_t represent the threshold of the occupied bandwidth. New arrivals will be blocked when $B_{ocu} > B_t$. Fig. 5(a) shows that smaller B_t gives lower P_d, thus implies that more bandwidth is available for handoff arrivals. This is achieved at the expense of a larger P_b as shown in Fig. 5(b). It can be seen that the connection dropping probability of the proposed scheme decreases dramatically by reserving the fixed bandwidth for handoff arrivals. On the contrary, the connection blocking probability increases dramatically.

Fig. 6 shows that at light load the bandwidth utilization of the proposed scheme is larger than the FBR scheme when 20% of the total bandwidth is reserved for handoff connections with rt traffic.

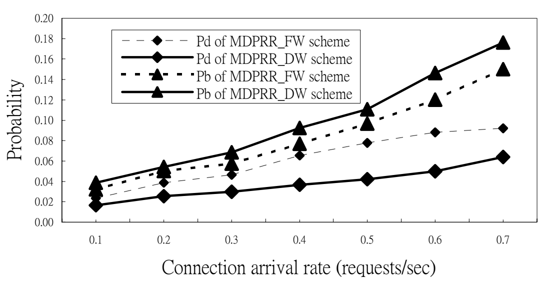


Fig. 2 Connection dropping and blocking probabilities for rt traffic in the MDPRR scheme

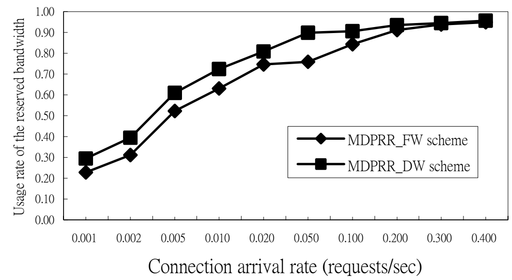


Fig. 3 Usage rate of the reserved bandwidth vs. connection arrival rate

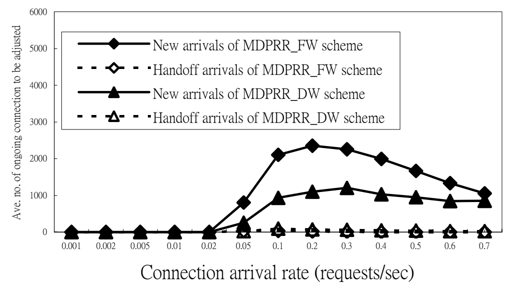
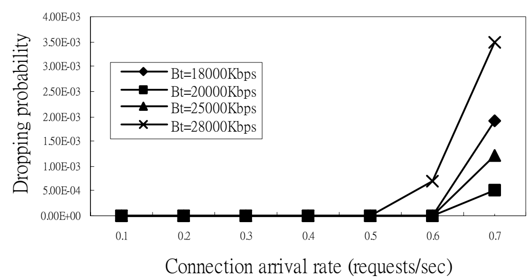
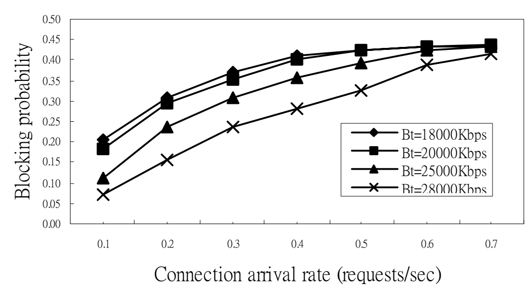


Fig. 4 Average number of the ongoing connections to be adjusted vs. connection arrival rate



(a) Connection dropping probability



(b) Connection blocking probability

Fig. 5 Connection dropping and blocking probabilities for different B_t

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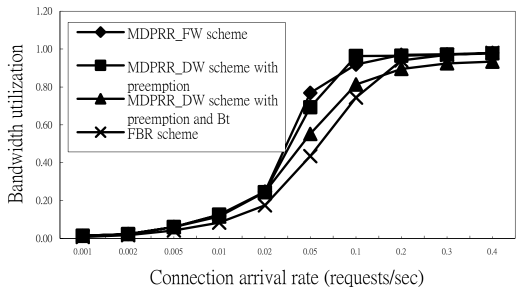

Fig. 6 Bandwidth utilization for different schemes

5. Conclusions

In this paper, the MDPRR scheme is proposed to decrease the dropping probability of rt traffic, increase the average usage rate of reserved bandwidth, and increase the system bandwidth utilization in mobile multimedia wireless networks. The area of a cell is divided into three zones so as to intimate the system processing and signaling load. Bandwidth reservation is dynamically made at each probing time, therefore, the system may accurately estimate the amount based on the mobility information.

Small probing time will provide more accurate estimation in bandwidth reservation, however, the large processing time can not pay off the gain. Therefore, a proper value of ΔT =5sec is used in the system. Larger μ may results in more reservation probability for handoff connections, it doesn't apparently results in higher connection blocking probability. Therefore, an appropriate value of $\mu = 100$ is selected to be used in the system. Small variation in velocity, i.e., $\sigma = 1$ Km/hr, generates more reservation requests before handoff, therefore the system can accurately reserve the amount of bandwidth. Although the bandwidth utilization of pre-handoff zone with 23% cell coverage is slightly higher than those with 61% and 86% at light load, it gives larger handoff dropping probability. A proper choice is a pre-handoff zone with 61% cell coverage.

Two scenarios of the MDPRR scheme are investigated. Although the connection blocking probability of MDPRR_DW scheme is 20% higher than that of the MDPRR_FW scheme, the connection dropping probability of the former can be improved for about 102% than the latter at heavy load. It means that the former can promote system capacity than the latter under the same requirement of the connection dropping probability. The average usage rate of the reserved bandwidth of the former is also better at light load.

Finally, by employing the occupied bandwidth threshold or preemptive service, the MDPRR_DW scheme can apparently improve the connection dropping probability at heavy load and induce better bandwidth utilization at light load. However, the processing load also increases.

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