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The study of handoff prediction schemes for resource reservation in mobile multimedia wireless networks

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SUMMARY

In this paper, the mobility-dependent predictive resource reservation (MDPRR) scheme is proposed to provide flexible usage of scarce 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. A number of designs are investigated to further enhance the performance of the proposed scheme. 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.

KEY WORDS: probing time; pre-handoff zone; admission control; direction weighting; velocity threshold; preemptive services; 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, 3] 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

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that the reserved bandwidth is often wasted in the hot spot area. Queuing schemes may be considered to allow new connections or handoff connections to be buffered until free channels are available, however, jitter and delay are major problems for real-time (rt) traffic [4]. Dynamically reserving bandwidth for handoff calls is an effective way to reduce handoff dropping probability and increase bandwidth utilization. Existing approaches [5–11] of dynamic reservation for handoff connections can be classified into probabilistic [5–8] and dynamic [9–11] reservation.

Oliveira *et al.* [5] proposed a mechanism that provides QoS guarantees and low connection dropping probability by taking the network condition into account in reserving the bandwidth. The semi-reservation scheme [6] estimates the mobile station's (MS) mobility probability to reserve bandwidth for flow-oriented connections in multimedia wireless networks. The resource estimation algorithm using the shadow cluster concept [7] is a virtual message system where information about position or movement pattern are exchanged with neighbouring cells. However, these schemes induce large amount of overheads between BSs in the cellular system. The one-step prediction (OSP) scheme [8] assigns relative priority to each call arrival to avoid blocking of the wide bandwidth calls at heavy load, however, mobility of MSs is not considered.

Choi *et al.* [9] 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. Zhang *et al.* [10] proposed a statistical model based on Wiener prediction theory that uses only local information to predict the resource requirements and reserve for future handoff connections, however, it did not consider the hot spot area and burst traffic. In the predictive channel reservation (PCR) scheme [11] reservation requests are sent to neighbouring 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 [9] 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 [12], 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.

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 Figure 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 in References [13, 14] is adopted where the received signal strength, RSS, can be

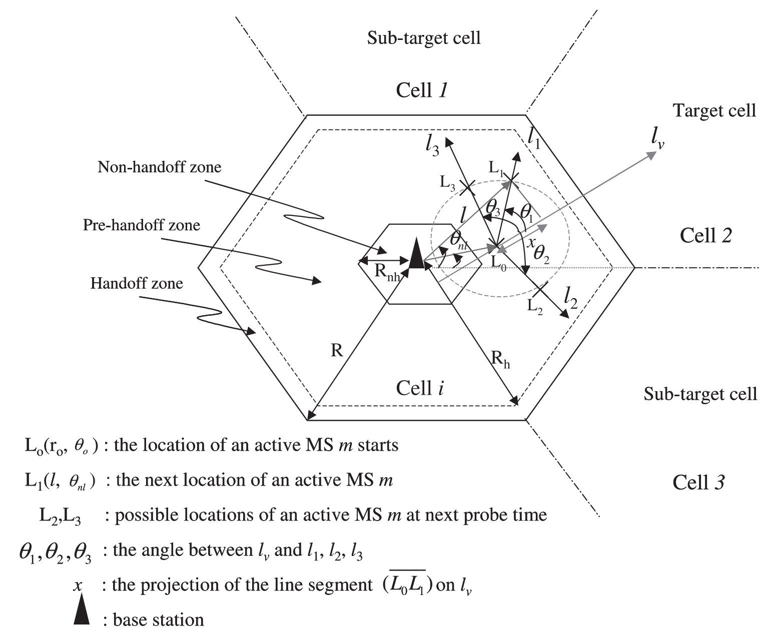


Figure 1. The cellular systems.

expressed as

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

where d is the distance of the transmitter to the MS and γ is the propagation path-loss coefficient. The shadowing effect is not considered in this study. If the RSS is below the handoff strength, e.g. -80 dbm [14], 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 [13] in the boundary of pre-handoff and handoff zone can be avoided by a number of methods proposed in [15].

As shown in Figure 1, the target cell, cell *2*, is the next cell that an active MS will move to by extrapolation [11]. The sub-target cells, cells *1* and *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 s, 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.

Two classes of traffic [5, 16] are considered: real-time (rt) and non-real time (nrt) traffic, they are further divided into six application groups as given in Table I. Note that, bandwidth is reserved only for rt traffic. The desired amount of bandwidth of rt variable bit rate (VBR) traffic can be adjusted to a minimum of 1 Mbps, 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

Table I. Multimedia traffic classes.

Categories of traffic	Applic. group	Bandwidth requirement	Average bandwidth requirement	Connection holding time	Average connection holding time	Example
	1	30 Kbps (CBR)		1–10 min	3 min	Voice service
rt	2	256 Kbps (CBR)		1–30 min	5 min	Video-phone
	3	1–6 Mbps (VBR)	3 Mbps	5–300 min	10 min	Video on demand
	4	5–20 Kbps (UBR)	10 Kbps	10–120 s	30 s	E-mail
nrt	5	64–512 Kbps (UBR)	256 Kbps	0.5–600 min	3 min	Data on demand
	6	1–10 Mbps (UBR)	5 Mbps	0.5–20 min	2 min	File transfer

a lower rate when congestion occurs. The minimum required bandwidth of application groups 4, 5, and 6 are respectively assumed to be 5 Kbps, 64 Kbps, and 1 Mbps.

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 reservation. 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, $P_{\mathrm{rv}}(\Delta T)$, is given by

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

where μ is the curvature. Similarly, the larger the distance of an MS to the BS, the higher the probability of reservation. Accordingly, a linear relationship between location and probability of reserving is assumed. Let the starting location of an active MS m be $L_{\mathrm{o}}(r_{\mathrm{o}}, \theta_{\mathrm{o}})$ as shown in Figure 1, the probability of reserving at distance l and at probe time ΔT is given by

$$P_{rl}(\Delta T) = \begin{cases} 1, & x \geqslant \dfrac{\sqrt{3}}{2}(R_{\mathrm{h}} - R_{\mathrm{nh}}); \\ \dfrac{2x}{\sqrt{3}(R_{\mathrm{h}} - R_{\mathrm{nh}})}, & 0 \leqslant x < \dfrac{\sqrt{3}}{2}(R_{\mathrm{h}} - R_{\mathrm{nh}}) \end{cases} \tag{3}$$

where $x = l - r_{\mathrm{o}} \cos(\theta_{nl} - \theta_{\mathrm{o}})$, $l = r_{\mathrm{o}} + V\Delta T$, and V is the velocity of MSs.

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. Intuitively, it means that MSs move into target and subtarget cells with the same probability. For example, the direction weighting of an active MS m moving from cell i to cell j in Figure 1 is

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

The second scenario uses dynamic direction weighting based on V_t, i.e. MDPRR_DW. Initially, the direction weighting is fixed as given in Equation (4), then changes to the binary exponential backoff algorithm [17] 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

$$d_{i,j}^{m}(n\Delta T) = \begin{cases} 1 - \dfrac{2}{3}\left(\dfrac{1}{2}\right)^{n-1}, & n \geqslant 1 \quad \text{for target cell;} \\ \dfrac{1}{3}\left(\dfrac{1}{2}\right)^{n-1}, & n \geqslant 1 \quad \text{for sub-target cell} \end{cases} \tag{5}$$

Otherwise, the direction weighting at each probe time is

$$d_{i,j}^{m}(n\Delta T) = \begin{cases} \dfrac{1}{2} + \dfrac{1}{3}\left(\dfrac{1}{2}\right)^{n-1}, & n \geqslant 2 \quad \text{for target cell;} \\ \dfrac{1}{2} - \dfrac{1}{3}\left(\dfrac{1}{2}\right)^{n-2}, & n \geqslant 2 \quad \text{for sub-target (previous target) cell;} \\ \dfrac{1}{3}\left(\dfrac{1}{2}\right)^{n-1}, & n \geqslant 2 \quad \text{for sub-target cell} \end{cases} \tag{6}$$

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

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

$$d_{i,j}^{m}(n\Delta T) = \begin{cases} 1 - \dfrac{2}{3}\left(\dfrac{1}{4}\right)^{n-1}, & n \geqslant 1 \quad \text{for target cell;} \\ \dfrac{1}{3}\left(\dfrac{1}{4}\right)^{n-1}, & n \geqslant 1 \quad \text{for sub-target cell} \end{cases} \tag{7}$$

Otherwise, the direction weighting at each probe time is

$$d_{i,j}^m(n\Delta T) = \begin{cases} \dfrac{3}{4} + \dfrac{1}{3}\left(\dfrac{1}{4}\right)^{n-1}, & n \geqslant 2 \quad \text{for target cell;} \\ \dfrac{1}{4} - \dfrac{2}{3}\left(\dfrac{1}{4}\right)^{n-1}, & n \geqslant 2 \quad \text{for sub-target (previous target) cell;} \\ \dfrac{1}{3}\left(\dfrac{1}{4}\right)^{n-1}, & n \geqslant 2 \quad \text{for sub-target cell} \end{cases} \tag{8}$$

The term $(1/4)^{n-1}$ is used to reduce the direction weighting of the sub-target cell because $V \geqslant V_t$, 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 II.

The occupied bandwidth of an active MS m, B_{ocu}^m, is subject to the admission control scheme and is given by

$$B_{ocu}^m = \begin{cases} B_{req} & \text{for } B_{req} \leqslant B_{avl}; \\ B_{min} & \text{for } B_{req} > B_{avl} \geqslant B_{min} \end{cases} \tag{9}$$

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

$$\delta_i^m(t) = \begin{cases} 1 & \text{in pre-handoff or handoff zone;} \\ 0 & \text{otherwise} \end{cases} \tag{10}$$

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

$$B_{i,j}^{rm}(t) = d_{i,j}^m(t) B_{ocu}^m [\alpha_1 P_{rv}^m(t) + \alpha_2 P_{rl}^m(t)] \delta_i^m(t) \tag{11}$$

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

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

	Current cell	Target cell	Sub-target cell	Sub-target cell
(a) $V \geqslant V_t$				
ΔT	i	*2*(1/3)	*1*(1/3)	*3*(1/3)
$2\Delta T$	i	*2*(10/12)	*1*(1/12)	*3*(1/12)
$3\Delta T$	i	*1*(37/48)	*2*(10/48)	*6*(1/48)
$4\Delta T$	i	*2*(154/192)	*1*(37/192)	*2*(1/192)
(b) $V < V_t$				
ΔT	i	*2*(1/3)	*1*(1/3)	*3*(1/3)
$2\Delta T$	i	*2*(4/6)	*1*(1/6)	*3*(1/6)
$3\Delta T$	i	*1*(7/12)	*2*(4/12)	*6*(1/12)
$4\Delta T$	i	*2*(16/24)	*1*(7/24)	*3*(1/24)

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

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 neighbouring 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 can give an improvement of

$$1 - \frac{R^2 - R^2_{\text{nh}}}{R^2} \times 100\% \tag{14}$$

when compared to scheme without pre-handoff threshold. When reservation requests from neighbouring 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 B_{avl} of new rt-VBR arrivals can be adjusted [18] from the required bandwidth B_{req} to the minimum bandwidth $B_{\min}$ if $B_{\min} \leqslant B_{\text{avl}} < B_{\text{req}}$, and $B_{\min} \leqslant B_{\text{avl}} + B_{\text{res}} < B_{\text{req}}$ 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 3–6 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 [19, 20] 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 centre cell. Simulation parameters are carefully chosen to closely represent realistic scenarios [5, 14]. A path loss exponent $\gamma = 4$ is used in the simulation. Assume the cell radius (R) is 800 m 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

Table III. Simulation parameters.

Parameters	Value	Description
B	30 Mbps	Maximum bandwidth capacity of a cell
ΔT	5, 10, 25, 40 s	Probing time interval
V	0–60 km/h	Velocity of MS
D	Six directions	Direction on MS
$P_{\text{direction}}$	2/3 (forward direction) 1/3 (change direction)	The probability of moving direction
σ	1,5,10 km/h	Standard deviation of velocity change
μ	0, 5, 100	μ-law coefficient
$1/\lambda$	10–10/7 s	Mean inter-arrival time
$\Gamma_{\text{handoff\_threshold}}$	-80 dbm	Handoff threshold
R_{nh}	300, 500, 700 m	Radius of non-handoff zone
C_{ph}	Variable	Percentage of the pre-handoff zone
V_t	30, 40, 50 km/h	Velocity threshold
B_t	Variable	Occupied bandwidth threshold

each cell. The connection holding time is assumed to follow a geometric distribution, and the mean holding times are provided in Table I. 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 centre cell reaches 10^4. All parameters used in the simulation are summarized in Table III.

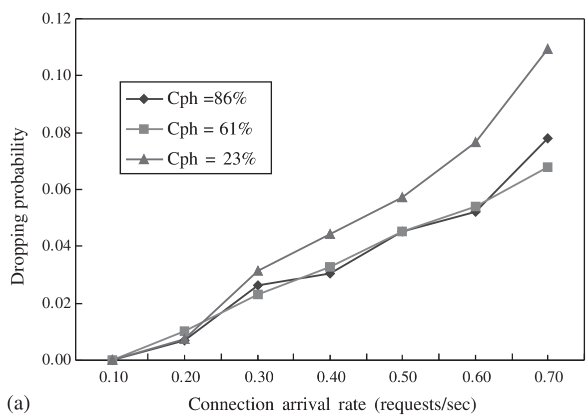
The maximum bandwidth capacity is 30 Mbps for each cell. The amount of bandwidth reserved for handoff connections B_{res} is variable based on the MS's velocity, location, and direction at each ΔT. Initially, the velocity is uniformly distributed between 0–60 km/h, and will vary with normal distribution $N(\bar{m}, \sigma^2)$, where $\bar{m}$ is the mean velocity obtained at each probing time, the variation of velocity is the standard deviation σ at each ΔT. The direction will vary depending on its previous direction. 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.

Because the performance measures of interest are focused on the centre cell, the difference between the wrapped-around configuration and the unwrapped configuration are also investigated. Performance measures of rt traffic are the focus of investigation in the proposed scheme.

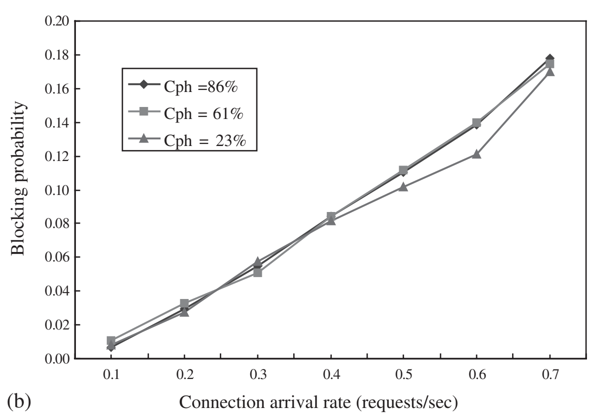
4.1. Parameter setting

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, because higher μ (i.e. $\mu = 100$) reserves more probability of reservation. Therefore, a proper combination of $\alpha_1 = 0.9$ and $\alpha_2 = 0.1$ 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. $\Delta T = 5$ s is selected to be used in the system. Larger μ may result in more reservation probability for handoff connections, it does not 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, $\sigma = 1$ km/h 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, $V_t = 50$ km/h 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. The case with pre-handoff zone of 23%, i.e. $R_{nh} = 700$ m, generates fewer number of reservation requests so that the connection dropping probability P_d is higher than others as shown in Figure 2(a). On the contrary, P_d of the pre-handoff zone of 86%, i.e. $R_{nh} = 300$ m, is not apparently smaller than that of 61%, i.e. $R_{nh} = 500$ m, cell coverage. It reveals that it is not necessary to reserve the bandwidth in advance when the MS is in the non-handoff zone. However, P_b differs little for different pre-handoff zone coverages as shown in Figure 2(b). An appropriate value of a pre-handoff zone with 61% cell coverage is thus selected to be used in the system. Accordingly, the processing and signaling time of the proposed scheme can be improved by 39% based on the statement in Section 3.



(a)



(b)

Figure 2. Connection dropping and blocking probabilities with different pre-handoff zone coverage. (a) Connection dropping probability. (b) Connection blocking probability.

4.2. Comparison of the two scenarios

We then investigate the performance measures of the proposed scheme based on the proper values selected in Section 4.1. The connection dropping probability of the MDPRR_DW scheme is significantly smaller than the MDPRR_FW scheme for rt traffic, it means that the dynamic resource reservation is beneficial 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 Figure 3(a). In addition, the connection dropping and blocking probability of nrt traffic is worse than the rt traffic as shown in Figure 3(b).

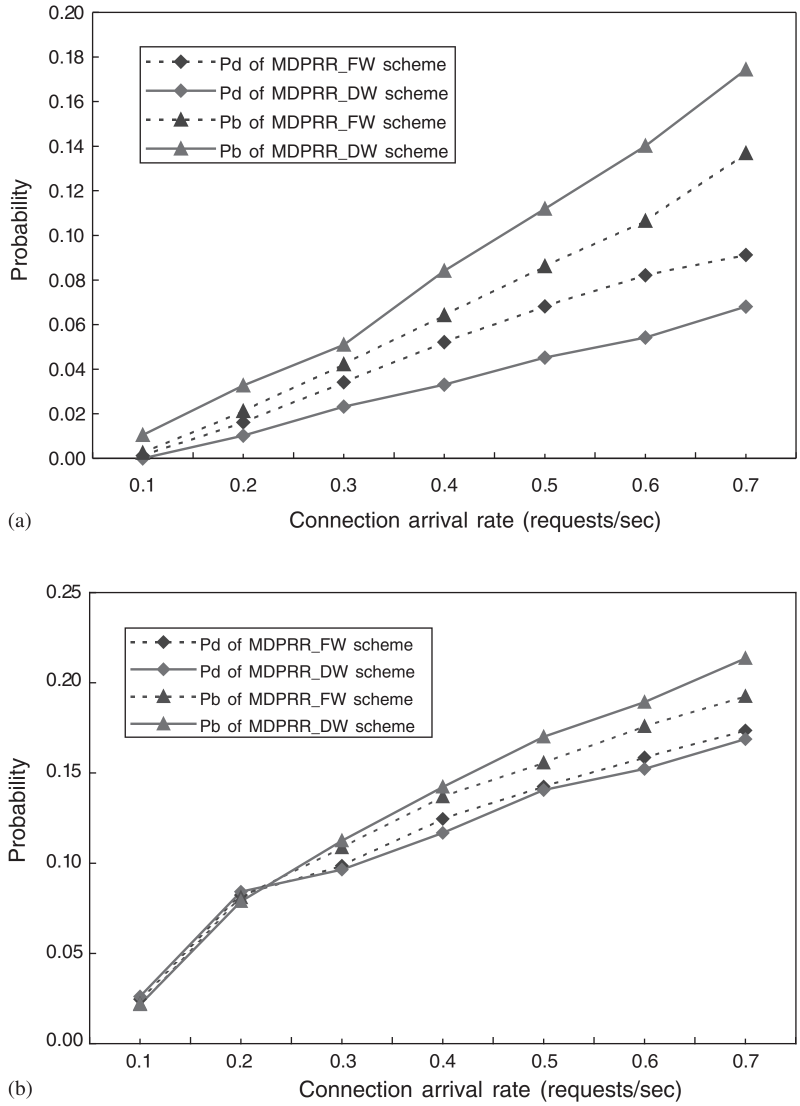


Figure 3. Connection dropping and blocking probabilities for rt and nrt traffic in the MDPRR scheme. (a) rt traffic. (b) nrt traffic.

Figure 4 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. Figure 5 shows that the average amount of reserved bandwidth B_{res}, the average amount of available bandwidth B_{avl}, and the average amount of occupied bandwidth B_{ocu} for the centre cell for the two scenarios. We see that the average amount of available bandwidth and reserved bandwidth of the fixed scenario decreases dramatically at arrival rate between 0.02 and 0.05. This is because handoff arrivals occur at arrival rate between 0.02 and 0.05, and the fixed scenario cannot properly adjust the amount of reserved bandwidth. Therefore, the slope of the reserved bandwidth of the fixed scenario is larger than that of the dynamic scenario when $\lambda \geqslant 0.1$. The average amount of reserved bandwidth of the dynamic scenario decreases at heavy load, it means that new arrivals are blocked and the number of handoff arrivals decreases at heavy load.

In the negotiation process, the average numbers of the self-adjusted connection and ongoing connection to be adjusted are investigated as shown in Figure 6. The average number of self-adjusted connections is significantly larger than that of the ongoing connections to be adjusted for the two scenarios. It implies that new arrivals are first negotiated. In the dynamic scenario, the average number of ongoing connections to be adjusted is slightly higher for handoff arrivals. 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 the minimum amount of bandwidth is occupied for each ongoing connections, then most of the new arrivals are blocked, and the number of handoff arrivals decreases at heavy load. Such that, the subsequent rise for

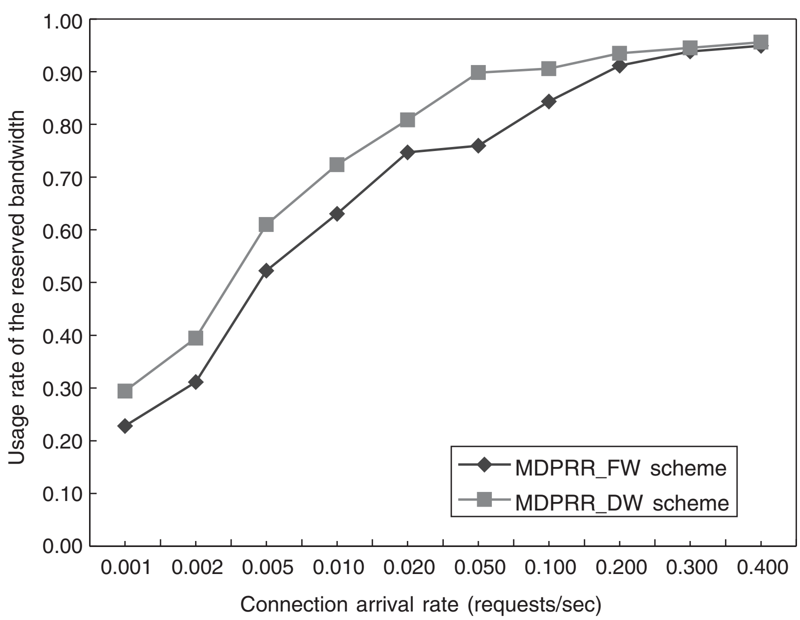


Figure 4. Usage rate of the reserved bandwidth vs connection arrival rate.

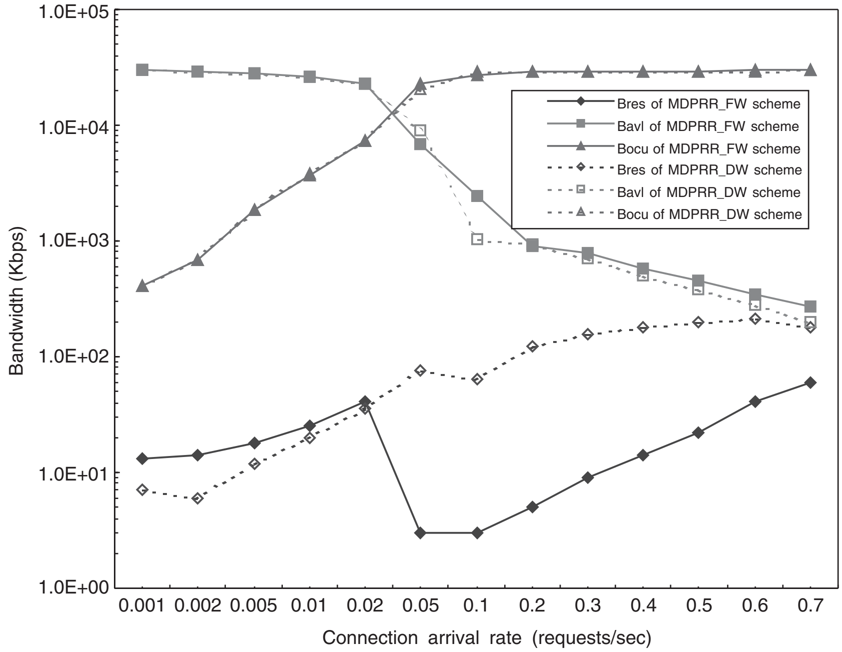


Figure 5. Bandwidth vs connection arrival rate with different scenarios of MDPRR scheme.

the dynamic scenario at around 0.6 is due to increase of the numbers of ongoing connection with desired amount of bandwidth.

4.3. *Enhancement of the performance measures*

Finally, a number of designs are also considered to further enhance the performance of the proposed scheme. Let B_t represent the threshold of the occupied bandwidth. New arrivals will be blocked when $B_{ocu} > B_t$. Figure 7(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 Figure 7(b). It can be seen that the connection dropping probability of the proposed scheme decreases dramatically by reserving the fixed bandwidth, i.e. occupied bandwidth threshold or guard bandwidth, for handoff arrivals. On the contrary, the connection blocking probability increases dramatically.

Figure 8(a) shows that the connection dropping and blocking probability of the MDPRR_DW scheme with preemptive service are apparently smaller than the MDPRR_DW scheme with non-preemptive service for rt traffic at heavy load, i.e. $\lambda \geqslant 0.3$. Although P_d and P_b of the former for rt traffic are significantly improved at heavy load, it comes at the expense of a larger P_d and P_b for nrt traffic as shown in Figure 8(b). In addition, it needs the extra overhead to process the signaling of preemption. Figure 9 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.

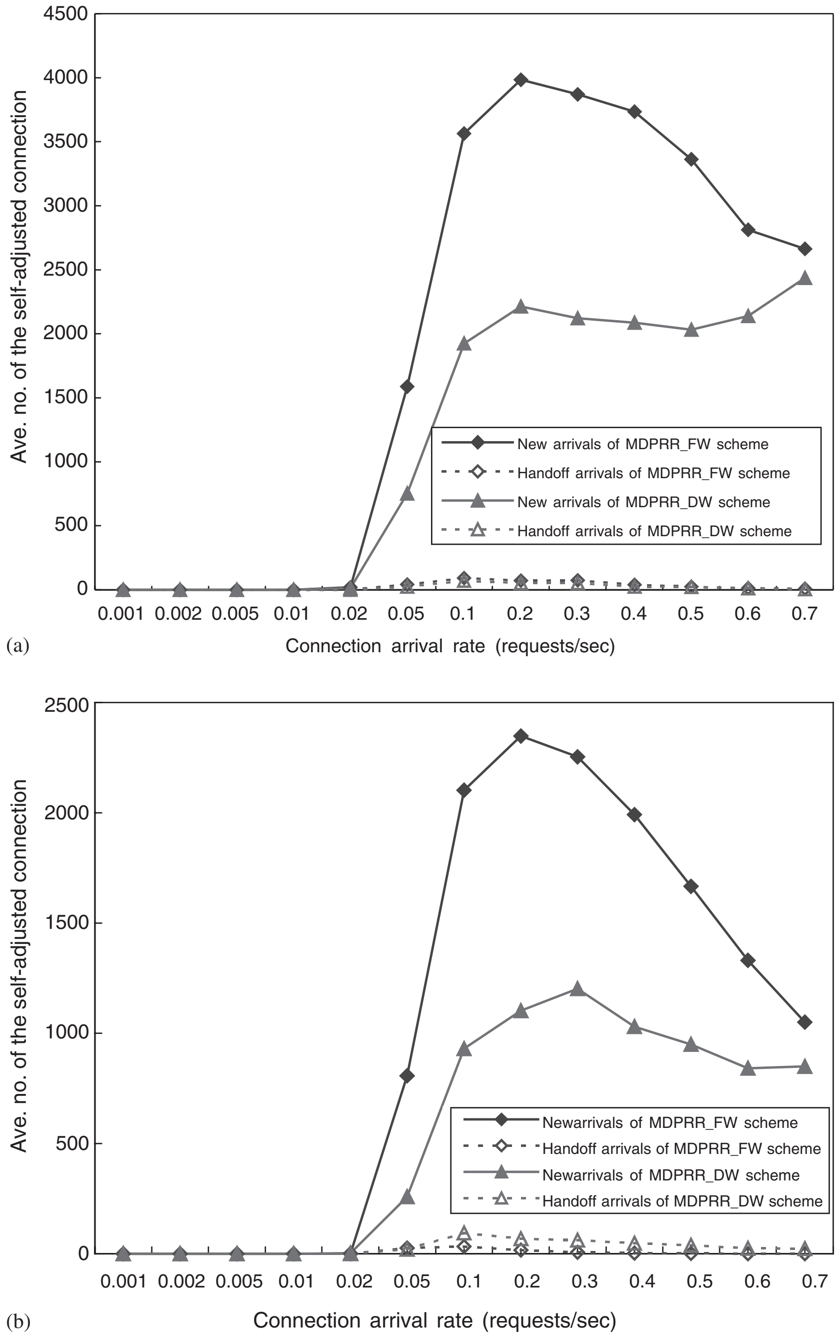
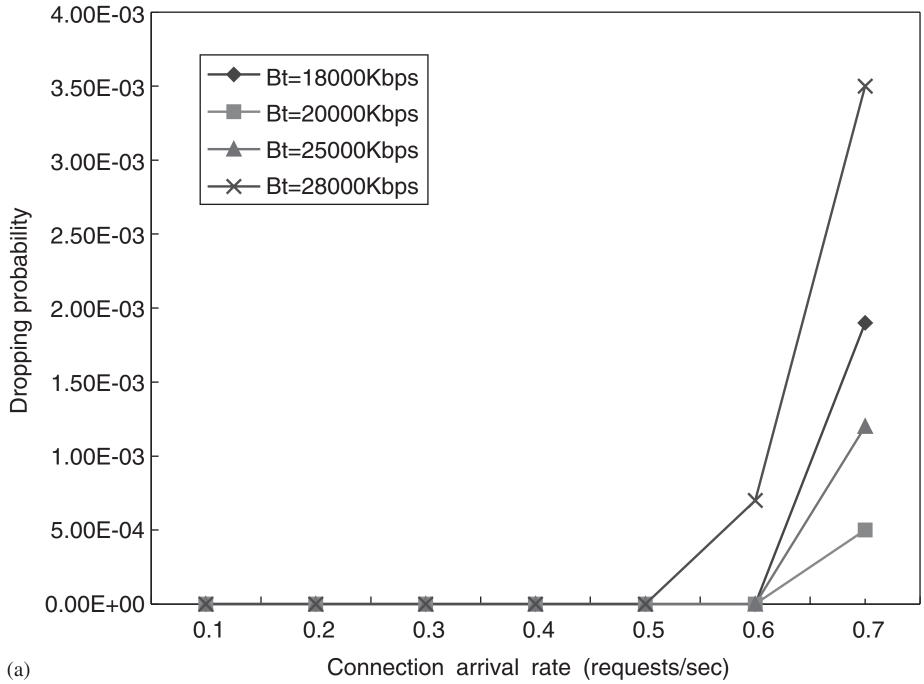
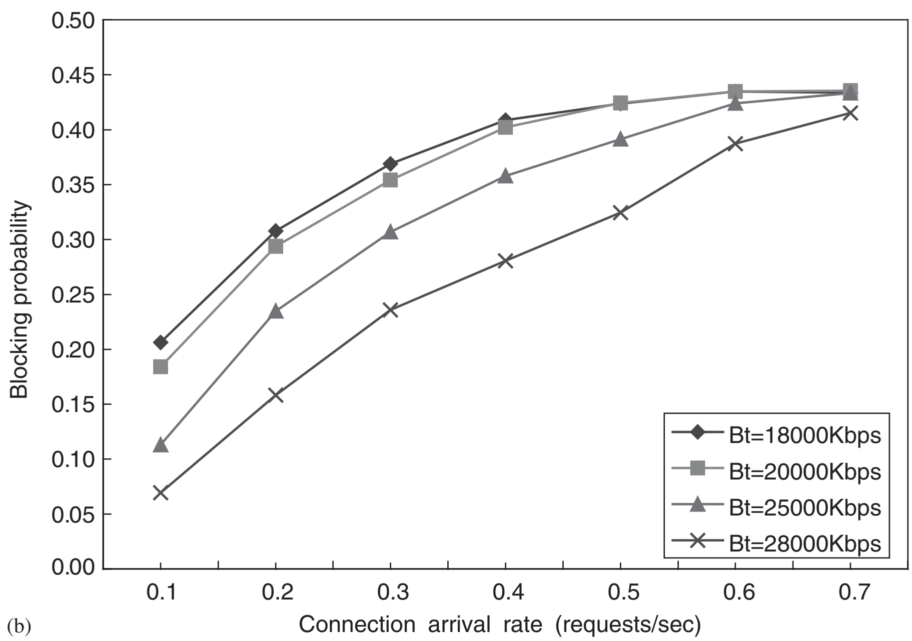


Figure 6. Average number of the self-adjusted connections and ongoing connections to be adjusted vs connection arrival rate. (a) Average number of the self-adjusted connections. (b) Average number of the ongoing connections to be adjusted.



(a)



(b)

Figure 7. Connection dropping and blocking probabilities for different B_t. (a) Connection dropping probability. (b) Connection blocking probability.

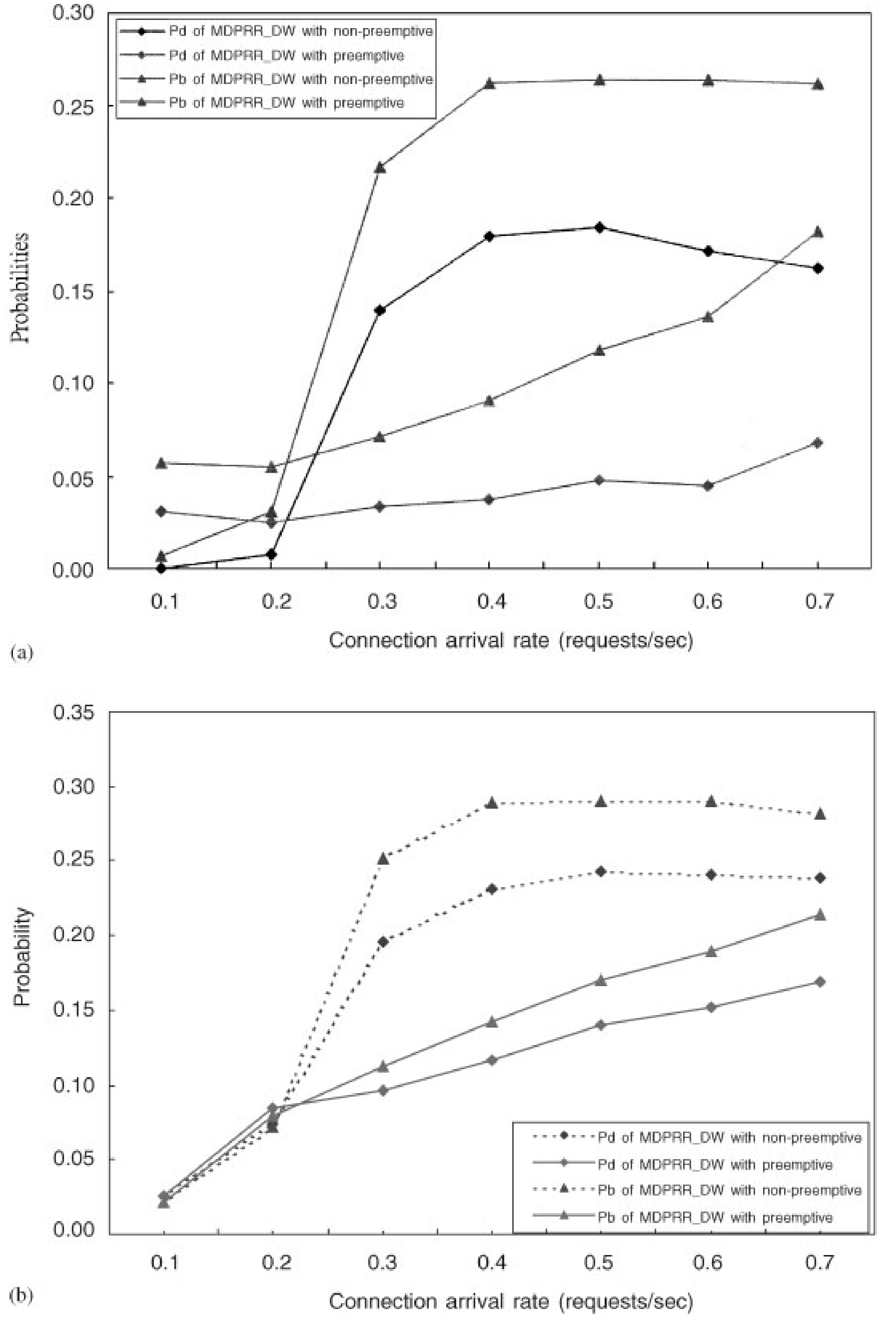


Figure 8. Connection dropping and blocking probabilities for rt and nrt traffic. (a) rt traffic. (b) nrt traffic.

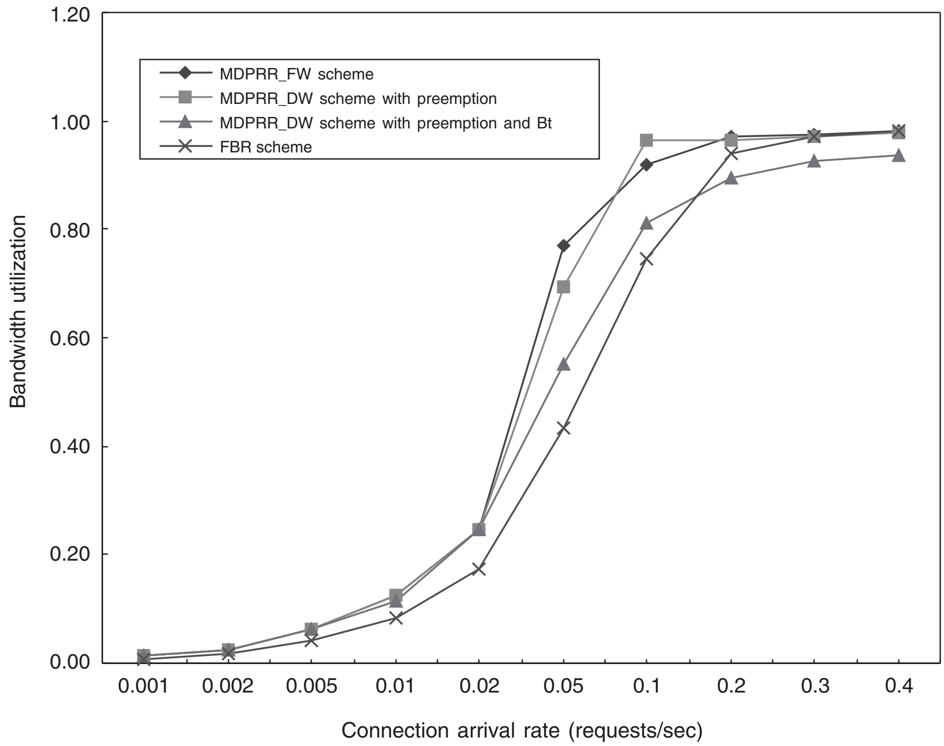


Figure 9. Bandwidth utilization for different schemes.

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. 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. An MS may vary in its velocity, location, and direction anytime and anywhere. 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 $\Delta T = 5$ s is used in the system. Larger μ may results in more reservation probability for handoff connections, it does not 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/h, 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. Both the wrapped-around configuration and the unwrapped configuration are considered in the investigation of the boundary effect on the system performances. Since the performance measures of interest are focused on the centre cell, the difference between them is negligible.

The comparison of the proposed schemes are summarized in the following:

- The connection dropping probability of the dynamic scheme is significantly smaller than the static scheme.
- The average usage rate of the reserved bandwidth under the dynamic scheme is higher than that of the static scheme.

These are because the dynamic scheme reserves bandwidth more accurately than that of the static scheme.

- For both dynamic and static schemes, the average number of self-adjusted connection and ongoing connection to be adjusted decrease at heavy load.

This is because new arrivals are always blocked and the number of handoff arrivals decreases at heavy 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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