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無線存取 ATM 網路的流量控制-子計劃三：無線 ATM 網路的智慧型基地台流量管理與控制(2/2)

Intelligent base stations traffic management and control in wireless ATM networks

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摘要

未來世代的通訊服務具有多元化的多媒體服務，因此頻寬的需求量大幅增加。為了滿足更多的應用，並且有效率的共用有限的無線資源，蜂巢式架構的通訊系統縮小了蜂巢的範圍。縮小蜂巢雖然可以提升資源的使用效能，卻造成了換手頻率的增加。假使行動裝置的目標蜂巢，其頻寬是高度使用的狀況，很容易因可用頻寬不足而致使連線必需中斷。為了降低連線中斷的發生，換手前事先預留頻寬給行動裝置是需要的。本論文嚐試以灰色理論預測行動裝置位置，進而得知行動裝置的目標蜂巢。因此，由行動裝置與基地台的距離、行動裝置的移動速度、行動裝置連線的需求頻寬以及目標蜂巢基地台的可用頻寬數量做為模糊邏輯系統的輸入變數，用以決定換手及預留頻寬。

關鍵詞：允許控制，換手機制，頻寬保留機制，灰色理論，模糊邏輯

Abstract

The diversification of multimedia service is the trend of future communication service, which makes the manifest increasing of bandwidth requirement. For satisfying more applications and efficiently using wireless resources, the cell size of the cell structure based mobile communication system is reduced. Reducing the cell size though can promote the utilization of resources, increases the handoff frequency in the meantime. If the bandwidth utilization of the target cell is high during the handoff process, connection break off is unavoidable. To reduce the occurrence of break off, reserving bandwidth for mobile terminal (MT) before handoff is feasible. In this thesis, we try to use the grey theory to predict the trajectory of MT, so as to judge the target cell of the (MT). Meanwhile, by using the measured information such as the distance between MT and base station (BS), the velocity of the MT, the required bandwidths of the MT and the available bandwidth of the target cell as input variables, we construct a fuzzy system to determine the necessity of handoff and the amount of reserving bandwidth.

Keywords: Call admission, handoff, bandwidth reservation, grey theory, fuzzy logic

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1. Introduction

In the wireless network, the requirement of high speed transmission of multimedia data makes the quality of service (QoS) much significantly. To provide high QoS, connection of MT without interruption is demanded. The high utilization of bandwidth, however, makes the maintenance of connection harder when handoff takes place. To deal with this problem, many researches focus on the study of reserving bandwidth for MT beforehand in the handoff process [1][2][3][4][5].

Two major problems should be addressed before reserving bandwidth for MT, one is the judgment of the necessity of reserving bandwidth, and the other is the amount of bandwidth required. For dealing with the first problems, [1, 2] used neural network to predict the location of MT by referring the past location trajectory, [3, 4] designed directional antenna to partition the cellular communication region into several areas, [5] used the traffic information and the GPS to develop a distributed system to predict the time and target cell of the handoff process, [12] designed a mobile database to record the moving trajectory of MTs to speed up the handoff process, [13] present a modified GSM network whose BS is also mobile enhancing the mobile computing.

For the second problem, not only the target cell but also the amount of reserving bandwidth should be determined. This process usually takes the bandwidth utilization and the handoff success rate as the performance indices. In this case, the authors in [1] adopted 2-tier cellular structure to determine the moment of reserving bandwidth. [5] used the traffic information and the MT's velocity to predict the target cell and compute the required reserving bandwidth. [11] applied the neural network to estimate the moving trajectory of the MT. The estimated trajectory was used to compute the handoff probability as well as the target cell, which can be used to compute the required reserving bandwidth.

The remaining of this report is: section 2 describes the simulation environment, section 3 demonstrates the developed methods, experimental results are presented in section 4, final section gives a conclusion.

2. The Simulation Environment

The simulation of the MTs contains two parts: the motion and the connection. The management of motion part is described in Fig. 2.1. In this part, four motion types are stated including very slow (walk), slow (bike), fast (motorcycle) and very fast (car). The connection part is described in Fig. 2.2, which demonstrates the handoff procedure between the original and target cells.

To simulate the motion of MTs, the velocity constrains, the possible direction variations and the probabilities of turning direction are given in Table 2.1, Fig. 2.3 and Table 2.2, respectively. Each MT is initialized with an velocity with the duration time restricted in Table 2.3. At the ending of the duration time, the MT is reassigned a velocity. Although the value of velocity is assigned randomly, the different duration time intervals for different velocities makes the relationship between velocity and time as a normal distribution as shown in Fig. 2.4.

There are two types of connection requests of MTs, one is the connection request of new calls, and the other is the one when handoff takes place. The second type has been stated in the above. For the first, this study uses Poisson distribution to state the probability of connection request. The applied Poisson distribution is

$$P(x,\lambda t)=\frac{e^{-\lambda t}(\lambda t)^x}{x!},\quad x=0,1,2,\ldots, \tag{2-1}$$

in which λ is the mean connection rate of new call. In this case, both t and x are set as 1, so that the distribution becomes

$$P(\lambda)=\lambda e^{-\lambda}, \tag{2-2}$$

which can be used to compute the probability of a new connection request of each cell within one unit of time.

The connections have various kinds of resource requests, in this study six kinds of requests are considered as listed in Table 2.4. The overall 11×24 cellular structure is shown in Fig. 2.5, in which the first and last columns are connected, as well as the first and last rows.

3 Connection Management by using Soft Computing

In this study, we apply the soft computing to manage the bandwidth reservation. It includes the prediction of MT location by grey theory and the design of fuzzy system to compute the amount of reserved bandwidth. Before presenting it, the operation mechanism of the MT and the BS are demonstrated.

3.1 *The operation mechanism of the MT*

The MTs operate at three statuses including standby, waiting (for connection) and connected. When a MT is standby, a mechanism is used to detect the request of connection. If the request is active, this mechanism sends a connection request message to the BS of the current cell, and the status of the MT is changed from standby to waiting for receiving the response of the BS. There is a timer to record the waiting time of the MT. If the MT does not receive any response from the BS after time is out, a request abandon message will be sent to the BS. On the other hand, once the connection is established, the MT must send the location information message periodically to the BS. The above procedure is demonstrated in Fig. 3.1.

3.2 *The operation mechanism of the BS*

The main jobs of the base stations include bandwidth management and handoff process. A BS must maintain high bandwidth utilization under low handoff failure. To achieve that, the operation mechanism of a BS is designed as shown in Fig. 3.2. The bandwidth utilization rate controller operates when the utilization of total bandwidth is over 80%. The message manager treats the messages received from the MTs and the BSs, such as the call request and the location information. The bandwidth reservation mechanism judges the necessity of reserving bandwidth for MTs. The handoff mechanism processes the handoff procedure. These four mechanisms are illustrated in the following.

A. The bandwidth utilization rate controller

Two policies are used to manage the total bandwidth, one focuses on the call admission control, the other concerns with the bandwidth reallocation. For call admission, if the bandwidth utilization is over 80%, then BSs reject the connection request which requires large amount of bandwidth. For bandwidth reallocation, if the bandwidth utilization is over 80%, the allocated bandwidths of the connected MTs are reduced to the values of minimum requirement. Furthermore, if the bandwidth utilization is over 90%, additional process that reducing the reserved bandwidth to its half is performed. Finally, if the bandwidth utilization reaches 100%, all the reserved bandwidth is released. The whole bandwidth is supplied only for the connected MTs.

B The message manager

A MT sends message to the BS periodically when it is in connection status. The message contains the recently location information of the MT obtained from the GPS, which can be used to compute the velocity and predict the location of the MT.

C. The bandwidth reservation mechanism

The judgment of reserving bandwidth is accomplished by using fuzzy system demonstrated later. Once the necessity of reservation is verified, the current BS of the MT will informs the target BS for reserving. The target BS will reserves suitable amount of bandwidth for the MT according to the motion of the MT, the required bandwidth and the available bandwidth.

D. The handoff mechanism

The requirement of handoff is also decided by using fuzzy system in BS. When handoff takes place, the BS informs the MT as well as the target BS about the process. The target BS then checks the available bandwidth, and acknowledges the current BS for handoff process if the bandwidth is enough. After receiving the connection information of the MT from the original BS, the target BS assigns suitable bandwidth to the MT and informs the original BS the completion of handoff. On the contrary, if the available bandwidth is not enough, then the target BS will acknowledge the original BS. The original BS keeps the connection if the MT is still in the current cell, else disrupt the connection and release the bandwidth as well.

According to the above demonstration, three problems arise: 1) the prediction of the location of MT; 2) the judgment of the necessity of reserving bandwidth for MT; 3) the computation of the amount of reserved bandwidth. In the following, we will apply the soft computing to accomplish all the three problems.

3.3 *Predict the location of MT by using grey theory*

The grey theory, presented in 1982 [14], has been applied in many fields such as industry, agriculture and meteorology. One of the major usages of this theory is the construction of prediction model. The prediction model, called $GM(n,1)$ model, can dynamically predict the next value of a time sequence by using the prior data. The parameters n represent the order of the model. Among various $GM(n,1)$ models, the $GM(1,1)$ model is a well-applied one. If one can obtain the time sequence $y(1), y(2), \ldots, y(k-1), y(k)$, then the $GM(1,1)$ model can predicts $y(k+1)$ by referring the dynamics behind the time sequence. The prediction formula is

$$\hat{y}(k+1) = (-a)\left(y(1) - \frac{u}{a}\right)e^{-ak} \qquad (3\text{-}1)$$

where

$$\begin{bmatrix} a \\ u \end{bmatrix} = [B^T B]^{-1} B^T y_N, \tag{3-2}$$

$$B = \begin{bmatrix} -\frac{1}{2}\left(y^{(1)}(1) + y^{(1)}(2)\right) & 1 \\ -\frac{1}{2}\left(y^{(1)}(2) + y^{(1)}(3)\right) & 1 \\ \cdots\cdots\cdots\cdots & \\ -\frac{1}{2}\left(y^{(1)}(k-1) + y^{(1)}(k)\right) & 1 \end{bmatrix}, \tag{3-3}$$

$$y_N = \begin{bmatrix} y(2) \\ y(3) \\ \vdots \\ y(k) \end{bmatrix}, \tag{3-4}$$

and $\hat{y}(k+1)$ is the predicted value at time instance $k+1$. In eq. (3-3), the series $y^{(1)}(1), y^{(1)}(2), \ldots, y^{(1)}(k)$ is computed by the accumulated generating operation (AGO)

$$y^{(1)}(k) = \sum_{i=1}^{k} y(i). \tag{3-5}$$

When a MT is in connection status, it sends the predicted location as well as the past location information periodically to the BS. The BS can then judge the moving trend of the MT. For example of Fig. 3.3, if the current distance between MT and BS, D_2, is smaller than that of the prior, D_1, then the MT is nearing the BS, otherwise (D_2' vs D_1') it is leaving. If the MT is leaving the current BS, then its moving trend and the distances between it and the neighbor BSs reflect the target cell. By using the motion information of the MTs, the BS determines the necessities of reserving bandwidth and the possibility of handoff, which will be demonstrated in the next section.

3.4 *Fuzzy logic approach for the judgment of reserving bandwidth and handoff*

To judge the necessity of reserving bandwidth and handoff by fuzzy logic system, four parameters are used as the input variables including the velocity of the MT (V_{MT}), the distance between MT and BS (D_{MT}), the required bandwidth of the MT (R_{MT}) and the available bandwidth of the target cell (A_{BS}). The membership functions for all the four input variables are shown in Fig. 3.4, whose term sets are

$T(V_{MT}) = \{\text{Slow(S)}, \text{Fast(F)}\}$,

$T(D_{MT}) = \{\text{Short(S)}, \text{Long(L)}\}$,

$T(R_{MT}) = \{\text{Little(L)}, \text{Slightly Much(SM)}, \text{Much(M)}\}$,

$$T(A_{BS}) = \{\text{Critically Not Enough(CNE)}, \text{Not Enough(NE)}, \text{Enough(E)}, \text{Very Enough(VE)}\}.$$

The membership function for the output fuzzy variable O_{HR} with term set $\{\text{Handoff(H)}, \text{Weak Handoff(WH)}, \text{Reserve(R)}, \text{Weak Reserve(WR)}, \text{No Action(NA)}\}$ is shown in Fig. 3.5. It reflects the degrees of the necessity of handoff and reserving bandwidth.

Basing on these membership functions, we construct 48 fuzzy control rules in Table 3.1 。The fuzzy inference is accomplished by Max-min inference method, and the Center of gravity method is used for defuzzification process. After the defuzzificztion process, the handoff takes place if the output value of the fuzzy system is greater than 0.8, the bandwidth reserving process operates if it belongs to $[0, 0.8]$, and no action is performed otherwise. The threshold value 0.8 is set by experience.

3.5 *Fuzzy logic approach for bandwidth reservation*

When the decision of the fuzzy system above is reserving bandwidth, another fuzzy logic system is applied to infer the allocated bandwidth. The input variables as well as their membership functions used in this system are the same as the above one. The output variable in this case is the reservation degree $\widetilde{O}_{RB}$ of the bandwidth requested by the MT. The membership function is shown in Fig. 3.6, which contains four linguistic terms Full(F), Half(H), Quarter(Q) and None(N). The applied fuzzy rules are list in Table 3.2 containing 48 rules also. Both of the inference method and the defuzzification process are the same as the previously one. After computing the reservation degree, the actual reservation bandwidth, *RB*, is obtained by

$$O_{RB} = \begin{cases} 1, & \text{if } \widetilde{O}_R >= 1 \\ \widetilde{O}_{RB}, & \text{if } 1 > \widetilde{O}_R > 0, \\ 0, & \text{if } 0 >= \widetilde{O}_R \end{cases} \quad (3\text{-}6)$$

$$RB = O_{RB} \cdot request, \quad (3\text{-}7)$$

in which *request* denotes the required bandwidth of the MT in connection status.

4 Experimental Results

In the experiment, the radius of the cell, *R*, is set as 500 meters, and the available bandwidth of each BS is 10MB. There are totally 5000 MTs. The parameters used in the input membership functions are listed in Table 4.1, and those used in the output membership functions are stated in Table 4.2.

In our experiments, three methods as stated in Table 4.3 are compared. Fig. 4.1 shows the new call reject rates under various values of the parameter λ. It can be found that as the value of λ increases, the rates are also increase. The method C exhibits lower reject rate than the other two. Fig. 4.2 shows the handoff failure rates, which also displays the superior performance of method C. Figs. 4.3 and 4.4 shows the bandwidth utilization under the three mechanisms. Both figures verify that the proposed fuzzy logic based handoff and bandwidth reservation schemes can achieve higher system utilizations.

5 Conclusion

In this project, we propose a fuzzy logic based mechanism for managing the call admission and handoff of the MTs in cellular mobile communication system. This mechanism includes three major parts: the bandwidth utilization rate controller, the fuzzy logic decision system for the necessity of bandwidth reservation, and the fuzzy logic approach for calculating the amount of reserved bandwidth. Some experiment results confirm the performance of the proposed mechanisms.

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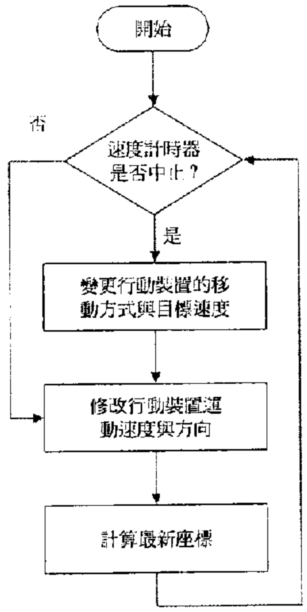

Figure 2.2 The motion process of MTs

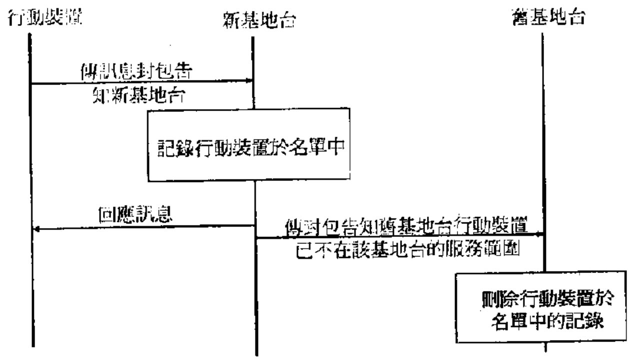

Figure 2.2 The handoff process of between BSs

Table 2.5 The velocity constrains of the four types of motions

移動方式	速度範圍
Walk	0~10 km/h
Bike	0~30 km/h
Moto	0~60 km/h
Car	0~120 km/h

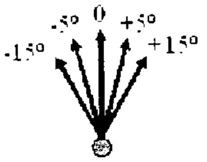

Figure 2.3 The possible direction variations of the MTs

Table 2.6 The probability of turning directions

	0	+5°	-5°	+15°	-15°	Sum
Velocity<=5km/h	0.200	0.200	0.200	0.200	0.200	1.000
5 km/h <Velocity<=15km/h	0.300	0.225	0.225	0.125	0.125	1.000
15 km/h <Velocity<=30km/h	0.400	0.200	0.200	0.100	0.100	1.000
30 km/h <Velocity<=45km/h	0.500	0.175	0.175	0.075	0.075	1.000
45 km/h <Velocity<=60km/h	0.600	0.150	0.150	0.050	0.050	1.000
60 km/h <Velocity<=75km/h	0.750	0.100	0.100	0.025	0.025	1.000
75 km/h <Velocity	0.850	0.075	0.075	0.000	0.000	1.000

Table 2.7 The velocity-duration relationship of the four motion types

velocity	Time
1	0~1 min
2	0~2 min
3	0~3 min
4	0~4 min
5	0~5 min
6	0~5 min
7	0~4 min
8	0~3 min
9	0~2 min
10	0~1 min

walk

velocity	Time
1~3	0~1 min
4~6	0~2 min
7~9	0~3 min
10~12	0~4 min
13~15	0~5 min
16~18	0~5 min
19~21	0~4 min
22~24	0~3 min
25~27	0~2 min
28~30	0~1 min

bike

velocity	Time
1~6	0~1 min
7~12	0~2 min
13~18	0~3 min
19~24	0~4 min
25~30	0~5 min
31~36	0~5 min
37~42	0~4 min
43~48	0~3 min
49~54	0~2 min
55~60	0~1 min

moto

velocity	Time
1~12	0~1 min
13~24	0~2 min
25~36	0~3 min
37~48	0~4 min
49~60	0~5 min
61~72	0~5 min
73~84	0~4 min
85~96	0~3 min
97~108	0~2 min
109~120	0~1 min

car

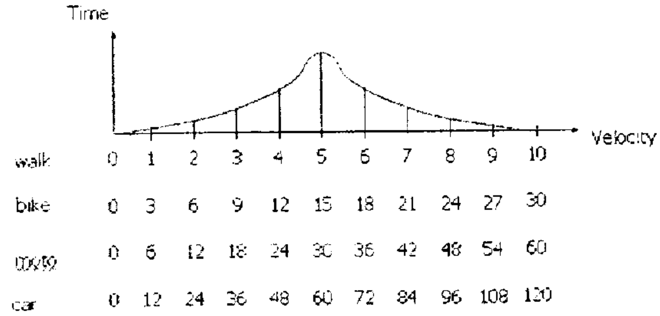

Figure 2.4 The velocity-duration relationship of the four motion types

Table 2.8 The six kinds of resource request

kinds	Bandwidth requirement	Mean connection time interval
Class 1	30kbps	3 min
Class 2	256kbps	5 min
Class 3	1-4Mbps	10 min
Class 4	5-20kbps	1 sec
Class 5	64-512kbps	3 min
Class 6	1-5Mbps	2 min

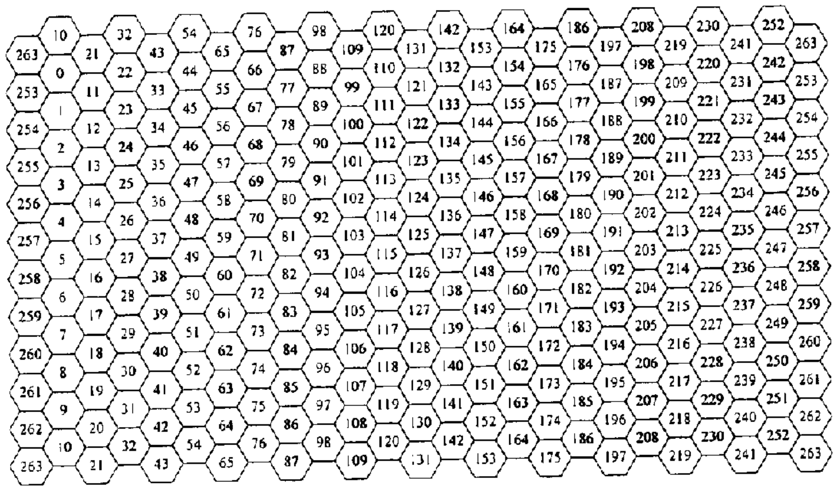

Figure 2.5 The cellular mobile communication system

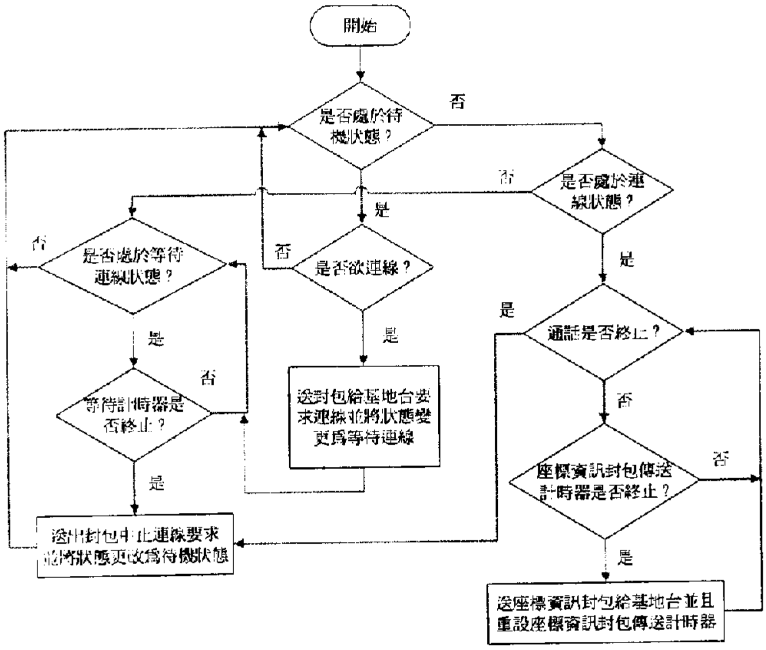

Figure 3.1 The connection mechanism of the MT

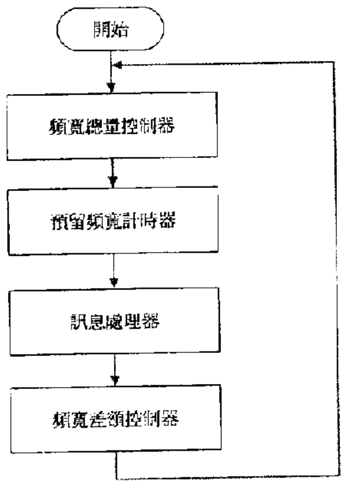

Figure 3.2 The operation mechanism of the BS

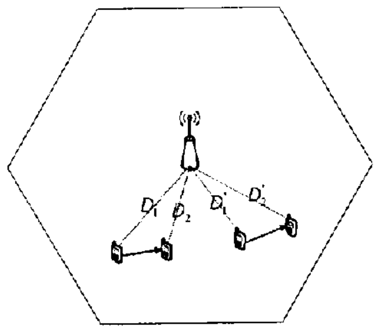

Figure 3.3 The moving trend of the MT relative to the BS

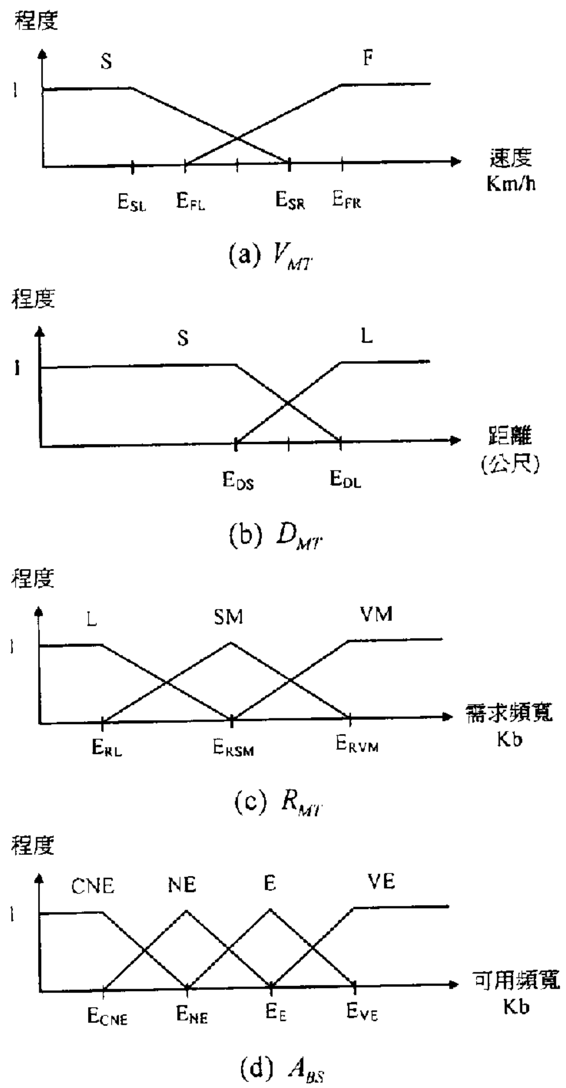

Figure 3.4 The membership functions of the input fuzzy variables

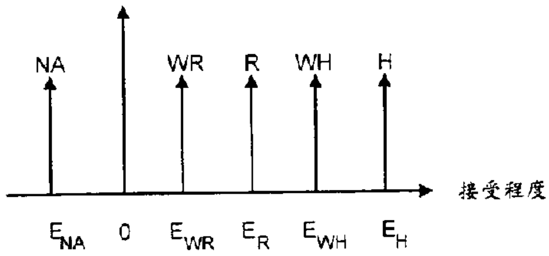

Figure 3.5 The membership function for the output fuzzy variable

Table 3.2 The fuzzy control rules for handoff and reserving bandwidth decision

Rule	V	D	A	R	O_{HR}
1	F	L	VE	M	H
2	F	L	VE	SM	H
3	F	L	VE	L	H
4	F	L	E	M	H
5	F	L	E	SM	H
6	F	L	E	L	H
7	F	L	NE	M	WH
8	F	L	NE	SM	WH
9	F	L	NE	L	H
10	F	L	CNE	M	NA
11	F	L	CNE	SM	NA
12	F	L	CNE	L	WH
13	F	S	VE	M	R
14	F	S	VE	SM	R
15	F	S	VE	L	R
16	F	S	E	M	WR
17	F	S	E	SM	R
18	F	S	E	L	NA
19	F	S	NE	M	WR
20	F	S	NE	SM	R
21	F	S	NE	L	NA
22	F	S	CNE	M	NA
23	F	S	CNE	SM	NA
24	F	S	CNE	L	NA
25	S	L	VE	M	H
26	S	L	VE	SM	H
27	S	L	VE	L	H
28	S	L	E	M	WH
29	S	L	E	SM	H
30	S	L	E	L	H
31	S	L	NE	M	NA
32	S	L	NE	SM	WH
33	S	L	NE	L	H
34	S	L	CNE	M	NA
35	S	L	CNE	SM	NA
36	S	L	CNE	L	H
37	S	S	VE	M	NA
38	S	S	VE	SM	NA
39	S	S	VE	L	NA
40	S	S	E	M	NA
41	S	S	E	SM	NA
42	S	S	E	L	NA
43	S	S	NE	M	NA
44	S	S	NE	SM	NA
45	S	S	NE	L	NA
46	S	S	CNE	M	NA
47	S	S	CNE	SM	NA
48	S	S	CNE	L	NA

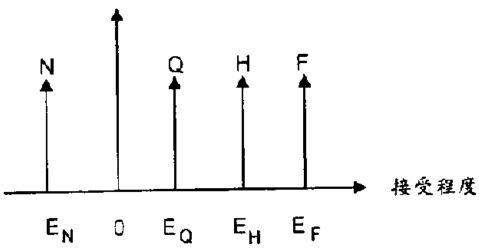

Figure 3.6 The membership function of the output fuzzy variable $\widetilde{O}_{RB}$.

Table 3.2 The fuzzy control rules used to infer the allocated bandwidth

Rule	V	D	A	R	O_{RB}
1	F	L	VE	M	F
2	F	L	VE	SM	F
3	F	L	VE	L	F
4	F	L	E	M	F
5	F	L	E	SM	F
6	F	L	E	L	F
7	F	L	NE	M	Q
8	F	L	NE	SM	Q
9	F	L	NE	L	H
10	F	L	CNE	M	N
11	F	L	CNE	SM	N
12	F	L	CNE	L	Q
13	F	S	VE	M	H
14	F	S	VE	SM	H
15	F	S	VE	L	H
16	F	S	E	M	Q
17	F	S	E	SM	Q
18	F	S	E	L	Q
19	F	S	NE	M	Q
20	F	S	NE	SM	Q
21	F	S	NE	L	H
22	F	S	CNE	M	N
23	F	S	CNE	SM	N
24	F	S	CNE	L	N
25	S	L	VE	M	H
26	S	L	VE	SM	H
27	S	L	VE	L	F
28	S	L	E	M	H
29	S	L	E	SM	H
30	S	L	E	L	F
31	S	L	NE	M	Q
32	S	L	NE	SM	N
33	S	L	NE	L	N
34	S	L	CNE	M	Q
35	S	L	CNE	SM	N
36	S	L	CNE	L	N
37	S	S	VE	M	N
38	S	S	VE	SM	N
39	S	S	VE	L	N
40	S	S	E	M	N
41	S	S	E	SM	N
42	S	S	E	L	N
43	S	S	NE	M	N
44	S	S	NE	SM	N
45	S	S	NE	L	N
46	S	S	CNE	M	N
47	S	S	CNE	SM	N
48	S	S	CNE	L	N

Table 4.1 The parameters of the input membership functions

Variable	Parameters
V_{MT}	$E_{SL}=15$, $E_{FL}=30$, $E_{SR}=60$, $E_{FR}=75$
D_{MT}	$E_{DS}=0.8R$, $E_{DL}=R$
R_{MT}	$E_{RL}=256$, $E_{RSM}=512$, $E_{RM}=1024$
A_{BS}	$E_{CNE}=512$, $E_{NE}=1024$, $E_{E}=3072$, $E_{VE}=5632$

Table 4.2 The parameters of the output membership functions

Variable	Parameters
O_{HR}	$E_{NA}=-2.0$, $E_{WR}=0.5$, $E_{R}=1.0$, $E_{WH}=1.0$, $E_{H}=1.5$
O_{RB}	$E_{N}=-2.0$, $E_{Q}=0.5$, $E_{H}=1.0$, $E_{F}=1.5$

Table 4.3 The three methods in the experiments

Method	with fuzzy logic based handoff and bandwidth reservation	with bandwidth utilization rate controller
A	No	No
B	Yes	No
C	Yes	Yes

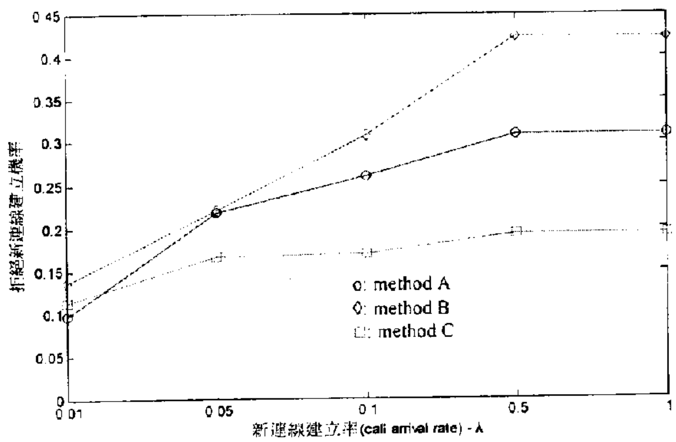

Figure 4.1 The new call reject rates of the three method under various values of λ

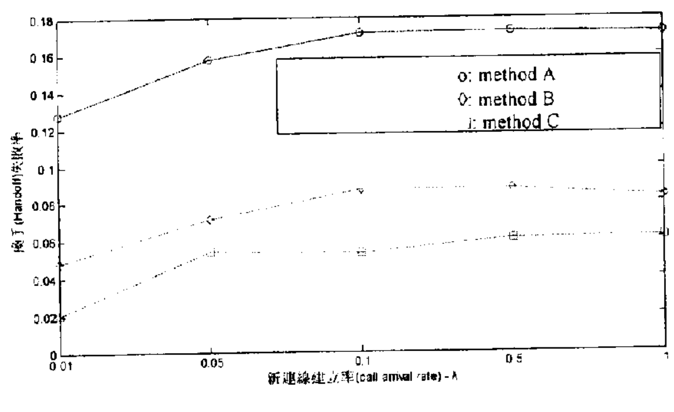

Figure 4.2 The handoff failure rates of the three method under various values of λ

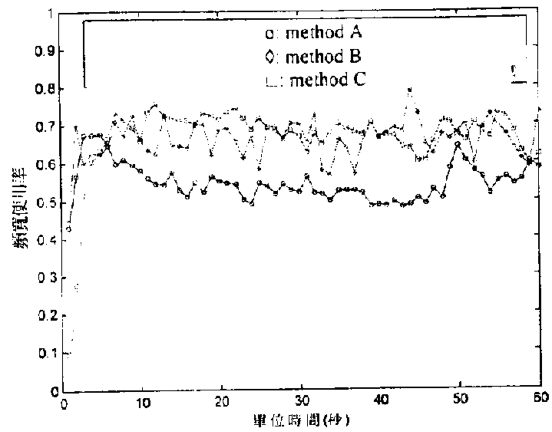

Figure 4.3 The bandwidth utilization under the three mechanisms, $\lambda = 0.05$

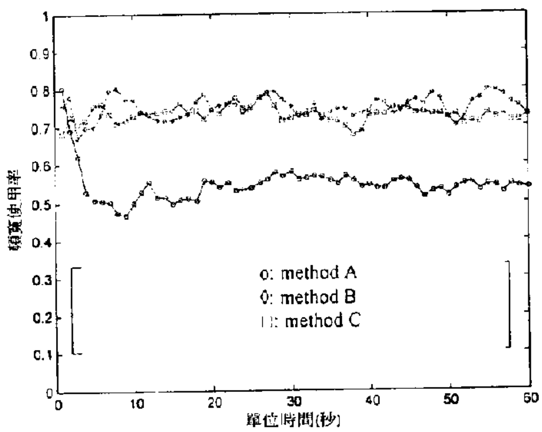

Figure 4.4 The bandwidth utilization under the three mechanisms, $\lambda = 0.5$