強化学習を用いたCDMA-ATM LANアーキテクチャ ための適応的な呼受付制御

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あらまし 本研究では、マルチサービスのCDMA/ATMネットワークの下り回線を半マルコフ決定過程(S-MDP)によって定式化し、強化学習による上述した半マルコフ決定過程(SMDP)を最適化することで、QoS保証ポリシーの最適化ソリューションを提案した。提案方式ではサービスの種類によって各コネクションの優先度を設定し、アクセスしたコネクションの優先度の集計値によってシステムのコストを計算し、コストを最大にさせることで最適ポリシーを発現する。最適ポリシーを発現する過程においては、システムにとって必要なネットワーク情報にはリソースの使用状況、コネクションのサービス優先度、コネクションの要求品質(送信速度、BERなど)、コネクションの保留時間、送信先ユーザの地理位置の5つの情報でけである

キーワード QoS,CDMA,下り回線、送信電力制御、ATM、呼受付制御、ハンドオフ制御、トラヒックパラメータ制御、強化学習、半マルコフ決定過程

Adaptive Call Admission Control of CDMA-ATM LAN Architecture Using Reinforcement Learning Algorithm

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Abstract A optimal policy with computer intelligence method used combining ATM's QoS protocol and CDMA's TPC is analysed in this work. A semi-Markov Decision Process(SMDP) is used for formulating the transmission power allocation control problem and have proposed a Reinforcement Learning Algorithm (RLA) for solving the problem of optimum QoS provision policy. This optimal policy can make a best decision based on network information maximize the long-term value of revenue function set according to sum of the priority of connections. But,for optimum the QoS provision policy, the system need only a little information such as the available resource unused by existed connections, the required quality of service(the BER and Transmission Rate)the connection's priority, the location of mobile terminal transmitted, and the dwell-time of connection .

Keywords QoS,CDMA,Downlink,TPC,ATM,CAC,UPC,Handoff,RLA,SMDP

1 Introduction

Most recently,a wireless ATM-CDMA interface architecture [1] is proposed, where the wireless network is intended to support the provision of broadband multimedia services for mobile terminals and is applied in wireless networks design such as a Local Area Network(LAN).
Particularly, in the future-generation CDMA system, emerging multimedia services are likely to require higher traffic capacity in the downlink compared with to in the uplink, and this makes the downlink a limiting one in determining the overall performance of network system[2]. In this paper, we specially solute the QoS provision police for the downlink of above CDMA/ATM system. For the downlink of the above hybrid system, a dynamic resource allocation algorithm is necessary since the required transmission resource varies according to near-far problem while a mobile terminal is moving in a basic service area (BSA) of wireless LAN. Here we classify QoS provision schemes into four elements: CAC,UPC,Handoff Control (HC) and TPC. In the previous works of downlink, we can find that handoff control related mobility of terminal[3],the TPC related channel attenuation such as multi-path fading or near-far problem[4],and rate-based UPC related network traffic condition [5] [6] are respectively researched, separately. But in a realistic system ,we have to make synthetic consideration about the mobility, channel attenuation, and network traffic and other conditions.
In this paper, for realizing a dynamic resource allocation algorithm based on the above synthetic consideration, we proposal a QoS provision algorithm combined CAC,UPC,HC and TPC. As our approach, we focus on application of the reinforcement learning algorithm(RLA) method [7] to optimum QoS provision in CDMA/ATM networks. As greatest potencial of RLA is that even with a little available information, the RLA tend to optimum a non-stationary system in predicting its behavior. The network agent collects revenue (payoff) from connections according to the priorities of connection's service and network event. Maximizing revenue while meeting QoS requirements is formulated as a semi-Markov decision process(SMDP) optimum problem. In this paper, the RLA applications draw on a closely related and more fundamental problem of optimization of SMDP, which has been studied by researchers of control theory ,e.g. We believe that this work has both theoretical and practical significance.
Section 2 introduce a available QoS Provision technology based on a CDMA/ATM architecture, Section 3 formulate the QoS Provision of CDMA/ATM as SMDP model and introduce a RLA-Q algorithm to solves the optimal problem modeled by SMDP. Section 4 We propose a QoS provision structure with resource reserved for UBR to improve the pure RLA scheme. Section 5 shows some Numerical results of computer simulations. Finally in Section 6 we conclude this paper.

2 CDMA-ATM System Model

In the following, we analyze the network related aspects of a combined CDMA-ATM multimedia architecture which can offer a viable solution for mobile wireless multimedia applications.The CDMA/ATM is a network model under consideration that a hierarchical ATM switching is used for interconnection of cells and mobile terminal(MT)s share the same radio spectrum using CDMA protocol. As showed in the figure.1,access point(AP) acts as the user network interface(UNI) between the MTs and the ATM backbone network. Especially,each AP is responsible for packet (data format) conversations, wireless connection set up, handoff control,and medium access control for its basic service area (BSA). In a CDMA/ATM network, QoS control incorporates four functions: CAC,UPC,HC, and TPC.

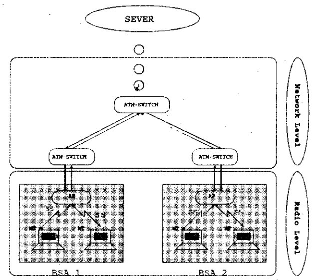

Figure 1: Structure of a CDMA/ATM WATM network

2.1 CDMA Physical Level

In a CDMA mobile network, as a principle of transmission power control(TPC),the transmission power of AP in each BSA is controlled so that the received SIR at all MTs can be equal to avoid near-far problem. However in power controlled CDMA networks significantly more transmission power per channel is required when MT is near the edge of a BSA than when it is closer to the AP. The high transmission power from AP to a MT near the edge of a BSA also introduces more interference for a neighboring BSA, which may not be tolerable if that the BSA is heavily loaded. So the total transmission power have to be limited under a maximum value P_{BT}.

Figure 2 shows the interference model for an user at downlink of CDMA system. Based on the pilot power received by a i-th MT, the AP can calculate the path gain from it α_{ij} and the ratio of the signal transmission power assigned to i-th MT in total transmission power of j-th AP except pilot signal power ϕ_{ij}.The ϕ_{ij}can be expressed as,

$$\phi_{ij} = \frac{(E_b/N_0)_i \sum_{j=1}^{m} \alpha_{ij} P_{BT}}{((E_b/N_0)_i + \frac{W}{R})\beta\alpha_{ij} P_{BT}} \tag{1}$$

where $(E_b/N_0)_i$ denotes the bit energy per interference power required for i-th MT,W does the common frequen-

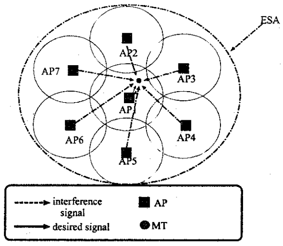

Figure 2: interference model on downlink

Table 1: simulation parameters

process gain	156
Eb／No required	5 「dB」
the field simulated	7 cells
radius of cell	1000m
propagation constant	4
shadowing standard deviation	8 「dB」
ratio of pilot power	0.2
$Pr_{quality}$	0.01

cy bandwidth and R does the chip rate,β is the ratio of power of assigned to MTs in a total transmission power of each AP,P_{BT} is total transmission power from each AP.

We can estimate the complexity of the above TPC method. We have to calculate the ϕ_{ij} value and update transmission power by a short discrete interval for all channels existed in a BSA. As a solution of the above problem, we can divide a BSA into number of Zones in which a same value of transmission power is required by all MTs. Consequently, the process of updating power is needed at only instance when handoff occurs between zones or BSAs. For satisfying requirements of mobiles in zone k, the follow transmission power ϕ_k is necessary

$$\mathbf{P_{out}} = \mathbf{Pr}(\phi_{\mathbf{ijk}} \geq \phi_{\mathbf{k}}) \leq \mathbf{Pr_{quality}} \qquad (2)$$

Figure 3 shows average power requirement ϕ_{ak} and the above ϕ_k versus distance of the MT and the AP, when conditions is as following table.2.1.

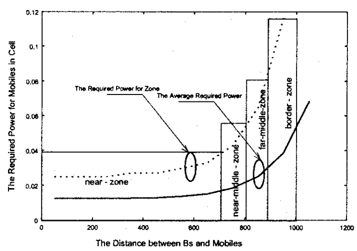

Figure 3: The Desired Power For CDMA's Downlink

From Figure 3,we can see clearly there are 4 step-regions where required transmission power for MTs are approximately same. So we divide a cell into 4 zones.

2.2 ATM Network Level

(1)CAC of CDMA/ATM here, We design a CAC preventing the introduction of more connections than can supported,based on measurement of available transmission power resources, service priority of connection transmitted requiring, and estimation of the resource utilization depending on the zone location of MT in a BSA and connection's holding-time. By the above information about the connection, we can make a differentiation of 'bad users' and 'good users' for make system cost higher.

(2)UPC of CDMA/ATM: We focuses a UPC method by adjusting transmission rate according to responding to the fluctuations in network:(rate-based UPC).As ideas of this method:

a. if a BSA is under-loaded or a connection complete its job, rate-based UPC tried to allocate as much transmission power resource as possible to connections in order to maximize the transmission rate of service.

b. When a BSA is over-loaded, if a new connection or a handoff connection arrives, some of the connections already existed in the BSA might be allocated as low transmission rate as possible to make needed transmission power resource reduced.

c. For realizing the Rate-based UPC, we can use multi-code CDMA (MC-CDMA) to support variable rate. It is possible to alter the chip rate to support multi-rate services[8].Correspondingly, we employ hierarchical coding method to adjust source rate.

(3)HC of CDMA/ATM: Regarding services such as CBR and rt-VBR, the connections must be permanently maintained during the connection lifetime since MT moves cross edge of zones or BSAs. Reservation of power resource becomes necessary for all handoff occurring possibly during connection life time when connection is set up, however resource utilization rates should be low. As a solution of this problem, we can set handoff connection higher priority than that of a newly connection.

3 A Reinforcement Learning Model for CDMA-ATM Network

3.1 About SMDP Model and Reinforcement Learning Algorithm

SMDP is a dynamic stochastic environment system with Markovian properties. This dynamic system at random points in time is observed and classified into one of a finite number states. At the same time, a decision has to be made, and cost are incurred due to the decision made. Markovian properties means that if at a decision epoch the action is chosen at the current state, the costs incurred, and the state at the next decision epoch depend only on the current state and the chosen action. Reinforcement Learning Algorithm(RLA) can get a optimal mapping between the state and behavior for SMDP process. A RLA framework is looked as a finite-state machine that interacts between a dynamic stochastic environment and a agent who are trying to learn the optimal policy through a learning process. The greatest potential of reinforcement learning algorithm is that it permits the analysis of complex dynamic systems and global optimum possible through with a very little available information. RLA seek action that bring about states of highest long-run value. Rewards are basically given directly by the environment, but state values must be estimated and re-estimated from the sequences of observations an agent makes over its entire life time. Q-learning algorithm works by estimation the values of state-action pairs. The value Q(s,a) is defined to be the expected discounted sum of future payoffs obtained by taking action a from state s and following an optimal police thereafter. Once these values have been learned, the optimal action from any state is the one with the highest Q-value for this state. the police π^* defined by

$$\pi^*(s,a) = argmax_{a \in A(s)} Q^*(s,a) \tag{3}$$

To estimation $Q^*(s,a)$,we update Q-value fuction as follows:

$$Q(s_t,a_t) \leftarrow Q(s_t,a_t) + \alpha[r_{t+1} + \gamma maxQ(s_{t+1},a_{t+1}) - Q(s_t,a_t)] \tag{4}$$

where $\gamma \in (0,1]$ is the learning rate, and $\alpha \geq 0$ is called as the discount factor.

3.2 Problem Description For CDMA-ATM Network Using RLA

The effectiveness of RLA techniques on wireless networks is justified by the fact that a QoS Provision policy for a network is modeled by a choice between a number of network behaviors. As it was explained above, RLA use a number of possible actions that in case of QoS provision problems represent all the available functions that can be carried out according to a network protocol operation. We can get a optimal mapping between the network state and network behavior included in communication protocols. Here, a optimal QoS provision policy mechanism using RLA is designed as figure.4:including a measurement module of available transmission power resource, a input module of network event, and an best action generator.

In this section, we explain the mechanism of above structure. As discussed in section 2,A CDMA/ATM BSA is divided into f zones.

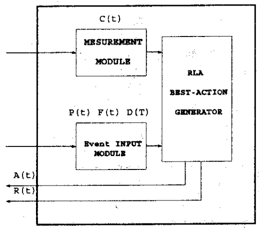

Figure 4: RLA QoS Provision Control Stucture

$$1,2,...i,...,f \tag{5}$$

and ,assume there are m specifies of service connections in a CDMA/ATM BSA.

$$1,2,3,.....m \tag{6}$$

for ith Service, there are K_i classes of available transmission rate.

$$(b_{i,1}, b_{i,2}, ..., b_{i,j}, ..., b_{i,K_i}) \tag{7}$$

For express a current configuration S of system,S is defined as following(x is number of users):

$$s = (x_1, x_2, ..., x_3, ..., x_f) \tag{8}$$

where :

$$x_s = (x_{s1}, x_{s2}, x_{s3}, ..., x_{sj}, ..., x_{sm}) \tag{9}$$

and

$$x_{si} = (x_{si,1}, x_{si,2}, ..., x_{si,k}, ..., x_{si,K_i}) \tag{10}$$

If we consider the constraints about system transmission power resource, a system configuration can be expressed as following:

$$S = (x : x_{sij} \geq 0; \sum_{s=1}^{f} \sum_{i=1}^{m} \sum_{j=1}^{K_i} p(s,b_{ij}) x_{si,j} \leq C) \tag{11}$$

where C is the total transmission power resource capacity, $p(s,b_{ij})$ is the required transmission power resource function for a i-th service user in zone 's' transmitted by rate b_{ij}.
At random times the event e can occur, where e is included in a event set E where includes elements such as connection arrival, connection handoff, connection departure ,and rate-update for VBR connection. Here the

configuration and event together determine the current state of network system,

$$c = (s, e) \tag{12}$$

where s is defined as above in (11) and event set is defined as following:
$E = (e_t | e_t \in (arrival, handoff,$
$departure, rate - update))$

$$\tag{13}$$

when a event arrives, for obtaining a optimal action decided by RLA BEST-ACTION GENERATOR, simultaneously, it is needed that EVENT-INPUT MODULE receive the following three information about the current event.

1. The Zone where MT transmitted located.

2. The service class transmitted to MT

3. The estimated Dwell time of Connection

the network configuration s is simplified by a available resource measurement function$\chi(s,t)$:

$$\chi(s,t) = \sum_{s=1}^{f} \sum_{i=1}^{m} \sum_{j=1}^{K_i} p(s, b_{ij}) x_{si,j} \tag{14}$$

The value of function $\chi(s,t)$ is measured by MEASUREMENT MODULE. Here ,we divide the available transmission power resource into 100 discrete levels.
so a state of network can be expressed by

$$c = (e, \chi) \tag{15}$$

According above the elements of MEASUREMENT-MODULE and EVENTINPUT-MODULE, the RLA QoS Provision Control can seize all available information about the current state of network system.
Upon a new connection arrival or a connection at handoff, the action set is
A(c)=(0=reject, 1=accept by high rate ,
2=accept by low rate)

$$\tag{16}$$

Upon a rate-update event for service of VBR, the action set is
A(c)=(3=update low rate to high rate ,
4=update high rate to low rate)

$$\tag{17}$$

Connection departures are not decision points. So no action needs to be taken. Symbolically, at such states :
A(c)=(-1=no action due to call departures)

$$\tag{18}$$

If adding a new connection or a handoff connection, or update a connection's transmission rate from low to high, the system state s will violate the resource constraint. the action set at that state should be 'reject'.

$$A(c) = 0 \tag{19}$$

$$\tag{20}$$

The revenue function for the RLA QoS Provision structure problem:

$$R_0(c,a) = \begin{cases} \eta_i & \text{if } e = e_i anda \geq 0 \\ 0 & \text{otherwise} \end{cases} \tag{21}$$

This cost function is :

$$\eta_i = \omega_{service} \times \lambda_{e_{i,service}} \tag{22}$$

where $\omega_{service}$ are weight constants set according to the priority of services;λ_{e_i} is called as the event-factor here.

$$\lambda_{handoff} \geq \lambda_{arrival} \tag{23}$$

The task of the learner machine is to determine a policies π upon given c, that maximizes the long-run average revenue, by exploration over a finite state machine while meeting the QoS Provision requirements. So that we maximize the revenue subject to the above capacity constraint. Formally, we consider the above problem of finding the optimal QoS Provision policy,π:

$$maximizes J_0(\pi) \tag{24}$$

$$sub : S = (x : x_{sij} \geq 0; \sum_{s=1}^{f} \sum_{i=1}^{m} \sum_{j=1}^{K_i} p(s, b_{ij}) x_{si,j} \leq C) \tag{25}$$

where:

$$J_0(\pi) = \lim_{n \to \infty} \frac{E^{\pi} \sum_{n=0}^{N-1} R_0(c_n, a_n)}{E^{\pi} \sum_{n=0}^{N-1} \tau(s_n, a_n)} \tag{26}$$

$J_0(\pi)$ characterizes the average network revenue value under policy π,and $\tau(s_n, a_n)$ are the average sojourn times. At the state s_n under decision a_n,and n index the n-th decision epoch.
We can learn a optimal policy using Watkins' Q-learning algorithm introduced before.

4 The QoS Provision Structure Using RLA

In this section, we proposal a QoS provision system structure for realizing the above RLA method. The service of ABR and UBR can tolerate delays and thus it can be buffered. But the ABR has higher priority than UBR, If a ABR connections has no chance to succeed to transmit until delay limit time T_A, the cells of connections will be discarded. For a connection of UBR ,it will be queued to transmit until final success transmission. For maximize the capacity of transmission for service of UBR while preventing the QoS of other services from lowing notably, a appropriate D units of transmission power resource always allocated for queued UBR connections. Besides the D units of power resource, UBR either use the fraction of power resource left unused by other services controlled by RLA controller. Here,we propose a QoS provision structure using following Queue system showed in figure.5.

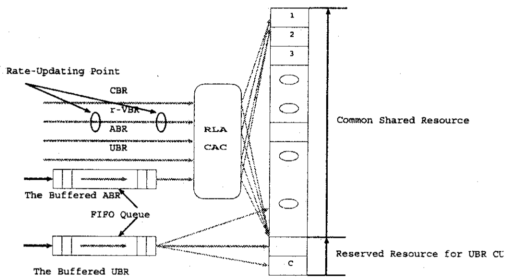

Figure 5: a RLA QoS provision structure using Queue

The above proposed QoS Provision schemes is summarized as in figure.6.

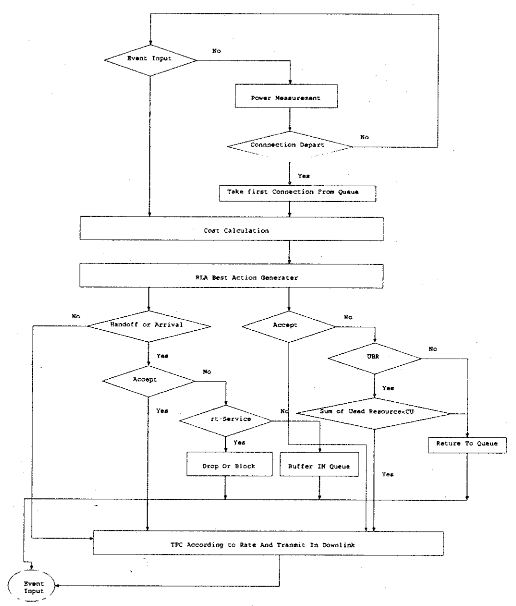

Figure 6: QoS Provision Process Using RLA

5 Numerical Results

In this section, We show the computer simulation performance results of the two CDMA/ATM-RLA QoS Provision policies, namely CDMA/ATM-RLA QoS Provision policy without Resource reserved for UBR, and the CDMA/ATM-RLA QoS Provision policy with resource reserved for UBR.

5.1 About Handoff Model Used in this Simulation

As discussed in section 2,we divide a BSA into four zones, consequently we have to make consideration of both handoffs between zones and handoffs between B-SAs. For modeling the Handoff for zone-divided cell networks, we use the following 'mean dwell time vector' and 'handoff flow matrix' to define the model of the network.
Here we make a computer simulation in condition of mean velocity of 20(m/s) with Gauss. Distribution and uniform initial geographical Distribution. As a movement model for a MT, we assume that in the initial movement, MT move in each directions by the same probability of 0.25.Therefore,the probability MT going straight on is 0.8,the probability of MT's turning to right or left is 0.1.And ,we assume that when a MT move from $i-th$ BSA toward $j-th$ BSA, inevitablely, simultaneously a MT exiting in $j-th$ BSA move toward $i-th$ BSA. This assumption is like as a reflection on the edge of BSA.
The result of 'mean dwell time vector' for four divided-zones cell network is expressed as following:

$$\begin{pmatrix} t_1 = 60.50 \\ t_2 = 13.49 \\ t_3 = 13.61 \\ t_4 = 15.28 \end{pmatrix} \tag{27}$$

and the handoff flow matrix A is :

$$A = \begin{pmatrix} 0 & 1.0 & 0 & 0 \\ 0.42 & 0 & 0.58 & 0 \\ 0 & 0.42 & 0 & 0.58 \\ 0 & 0 & 0.53 & 0.47 \end{pmatrix} \tag{28}$$

In this matrix, rows and columns are numbered from 0 to 4,the element A_{ij} represents the probability that a MT exiting the ith zone move toward the jth zone at handoff.

5.2 Simulation Assumption

1.Service Model
Here, we assume that the holding time of each service is exponentially distributed. The transmission rate which is available among 32,64[kbps] selected by RLA QoS Provision Controller. And in this simulation, we assume that arrival rate of no real time data service is more offered than real time service such as voice or vedio.
2.System Parameter

In this paper, we analyze a system of W-CDMA system. The table.5.2 shows system parameters of the above W-CDMA/ATM system. In order to provide various transmission rate services, the multi-codes with different process gain and a method of hierarchical source coding is employed.

Table 2: CDMA/ATM service model

Serv.	Rate [kbps]	Target $E_b/(N_0)$	Mean Dwell[s]	Limit Delay[s]	Traffic Ratio
CBR	64	4[dB]	100	0	0.1
VBR	32-64	4[dB]	100	0	0.1
ABR	32-64	5[dB]	10	1.0	0.4
UBR	32	5[dB]	10	∞	0.4

Table 3: CDMA/ATM System parameters

Power Control	Ideal
Bandwidth of Service	5MHZ
Process Gain	78-156
Mod./Demod	QPSK
Pilot signal power	20 percent
Length of ABR Queue	10
Length of UBR Queue	no limit
Souce Rate of PCM Coding	64[kbps]
Souce Rate of H.261	64[kpbs]
Souce Rate of MPEG	32[kpbs]
Souce Rate of UBR	16[kbps]
Number of States in SMDP Space	600
Learning Rate α	0.2
Discount Rate γ	0.01
Interval Time of Update-Rate for VBR	5[sec]
Interval Time of RLA Running	0.01[sec]

5.3 Performance Analysis According to Connection Loss Ratio of rt-Service

Figure 7 shows the mean loss Probability of real time service according to dropping or blocking versus connections generation rate(connections/s).The Loss Probability under No-reservation-scheme or reservation-scheme proposed above are smaller than that of the direct-access policy .The reduction in Loss Probability provided by the proposed two policies can be a high about 10 percent. This is because, the proposed policies that rejects certain low level service connections at some instance of time may admit more high level service connections on the average than a policy that always accepts any connections, whenever there are available resources. It is also found that the proposed structure using reservation-scheme for UBR doesn't lower the performance of rt-service notably, through D units of transmission power resource always allocated to the UBR.

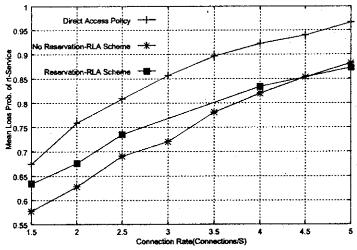

Figure 7: rt-Services Loss Probability via Connection Rate

5.4 Performance Analysis According to Connection Loss Ratio of ABR

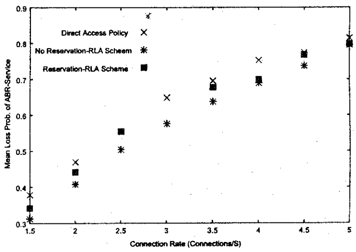

Figure 8: ABR Service Loss Probability via Connections Rate

Figure 8 shows the Loss Probability of ABR service versus Connections generation rate. It is found that the performance of ABR service is only improved slightly by the proposed two policies compared with the that of rt-service. Especially, the reservation-scheme is almost the same as that of the direct access policy. This is because, in the proposed structure, the ABR have to be set lower priority to contend available resource than rt-Services. In reservation-scheme, among the resource left unused by rt-service, a part of resource is always allocated to low UBR, the ABR's performance becomes worse.

Table 4: parameters

$\lambda_{handoff}$	$\lambda_{arrival}$	λ_{rate_update}	D
4	1	0.1	20
ω for CBR	ω for VBR	ω for ABR	ω for UBR
40	30	2	1

5.5 Performance Analysis According to Mean Connection Delay of UBR

Figure 9 shows the mean delay of UBR versus Connections generation rate. It is found that under no-reservation-scheme the performance of UBR become

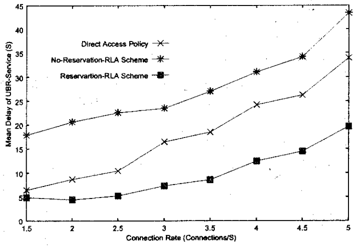

Figure 9: UBR Service 's Mean Delay via Connections Rate

worse than that of direct access policy, on the other hand, under the reservation-scheme policy, the performance of UBR is improved obviously. This is because, in non-reservation-scheme, the RLA controller allocate more smaller section of available resource to UBR than rt-Service or ABR-Service, but in reservation-scheme,by always allocating D units of resource to UBR, the performance of transmission delay can be improved clearly. From figure.7 to figure.9,it is found that by the proposed policies based on RLA QoS provision structure, real time delivery is guaranteed, the long-term Loss rates of real time traffic are minimized, the middle level service such as ABR was shown to be improved only slightly, and the delay of UBR is lowered by using whatever capacity is left unused by the other services plus a small fraction of the capacity reserved for them under reservation-scheme policy. By RLA QoS provision policy for downlink of CDMA/ATM network, it can reject certain connections that are low level services, in bad link conditions, or long-term consuming the available resource. And on the other hand, it tends to admit more connections that are high level services, in good link conditions, or short-term consuming the available resource. We can estimate that, certain part of lower services in good link conditions are admitted more easily than high level services but in bad condition for getting higher utilization efficiency of resource. A optimal QoS provision policy can simultaneously improve all global service performance by different level respectively.

6 Conclusion

This paper proposed a optimum QoS provision policy method using Reinforcement Learning Algorithm(RLA) for downlink of CDMA/ATM networks realized by two schemes. One is the non-reservation-scheme, and the other is the reservation-scheme. In conventional access method, it can be looked as the direct access policy that always accepts calls by single transmission rate, whenever there are available transmission power resource. Simulation results shows that the proposed RLA QoS provision controller performs better than the conventional direct access policy, with evaluation function of the Loss Probability of real time services, Loss Probability of ABR service and delay of UBR service. It is because that the optimal QoS provision policy using RLA method can intelligently computer to predict the traffic condition, to regulate contending connections at allocating contention resource by the information about the connections and to determine the best network behavior including in network protocols at a network event.

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