Utilizing Dynamic Resource Adjustment to Improve QoS of Streaming in Multimedia Wireless Network

Chow-Sing Lin, Fang-Zhi Yen, Cheng-Chi Lu
Institute of Information Management
Southern Taiwan University of Technology
E-mail:{mikelin, frank, cclu}@msrg.mis.stut.edu.tw

Abstract*-With the rapid advances in wireless network communication, multimedia presentation has become more applicable. However, due to the limited wireless network resource and the mobility of Mobile Host (MH), QoS for wireless streaming is much more difficult to maintain. How to decrease Call Dropping Probability (CDP) in multimedia traffic while still keeping acceptable Call Block Probability (CBP) without sacrificing QoS has become an important issue to be addressed. In this paper, we propose a novel Dynamic Resources Adjustment (DRA) algorithm, which can dynamically borrow reserved resource for handoffing MHs to compensate the shortage of bandwidth in media streaming. The experimental simulation results show that compared with traditional No Reservation(NR) and Reservation Resource(RR), DRA not only increases bandwidth utilization by 13%, but also efficiently decreases CDP by 25% while still keeping CBP within 13%.*

Keywords: Multimedia Wireless Network, Dynamic Resource Adjustment, Bandwidth Allocation, QoS, Resource Reservation

1. Introduction

For the last few years, the demand for mobile networks has been greatly increasing such that the whole world has been on the road to mobilization. Surfing on the Internet via Access Points (AP) of wireless network from anywhere at any time makes people’s life more convenient. Compared with nowadays wireless network applications, traditional ones only can assist users in accessing plain text through networks. Nevertheless, with the rapid development in wireless network bandwidth, streaming real-time multimedia traffic has already become inevitably in the future wireless network [1]. In general, the size of multimedia is usually larger than that of the general data. In order to maintain the QoS, a multimedia presentation is used to requiring larger bandwidth [2,3]. Yet, with the limited wireless network resource and the mobility of a Mobile Host (MH), maintaining QoS is more challenging and difficult.

In this paper we assume that multimedia streams are delivered on the most common wireless cellular network framework. Fig. 1 illustrates the cellular system model. Its configuration is composed of multiple hexagonal cells and adjoining cells constitute a vast of cellular network [4,5]. Clients can freely migrate to different cells. The wireless communication in a cell is supported by a Access Point (AP) [6,7]. In turn, APs are connected to each other by wired links. Several APs are connected to a Mobile Switching Center (MSC) acting as a gateway from the cellular network to existing wired networks.

Wireless cellular network has two important QoS parameters, which are Call Blocking Probability (CBP) of a new connection and Call Dropping Probability (CDP) of a handoff connection [8]. Due to the lack of resource, decreasing CDP leads to the increase of CBP, and vice versa. From a user’s perspective, a connection terminated in the middle of a call is far more annoying than having a new call attempt blocked [8]. Therefore, QoS guarantees mainly aim to decrease CDP to the lowest [9,10]. The existing cellular network architecture tends to adopt microcell/picocell [11,12]. A consequence of using small cell sizes is the increased rate of handoffs as mobile hosts seamlessly migrate between cells during the holding time of their calls. Frequently varied, Bandwidth utilization of cells makes maintaining QoS guarantees become much more difficult [13,14,15]. In this case, how to affectively decrease CDP while keeping CBP still acceptable and improve QoS guarantee in media streaming is a challenging research issue.

In this paper, we propose a novel Dynamic Resource Allocation (DRA) algorithm which applies Borrow-Return (BR) strategy to dynamically borrow reserved resource of current, neighboring cells. When reserved resource of a MH is not yet utilized, it can be borrowed to meet their needs of other MHs with insufficient resource. The DRA can efficiently minimize CDP, keep CBP in an acceptable condition and improve the QoS of delivering media streams on multimedia wireless network.

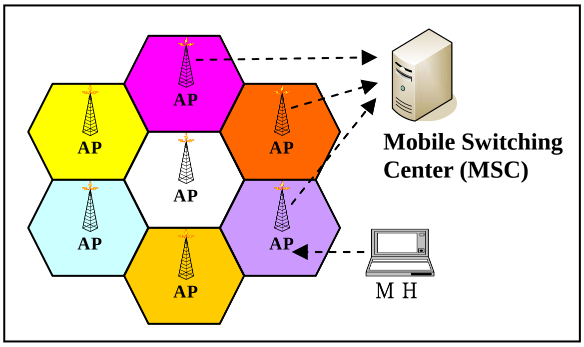

Figure 1. Wireless Cellular Network

The rest of this paper is organized as follows. In section 2, we describe the background of wireless network bandwidth allocation. In section 3, we present our proposed DRA for maintaining the QoS of media streaming during the migration of MHs among cells. In section 4 we present the simulation and analysis. Finally, the concluding remarks are given in Section 5.

2. Related work

Oliveira et al. [16] suggests that if there is no adequate resource to accept a new connection, it is blocked; On the other hand, when the call is a handoff connection, it is accepted only if the destination cell satisfies the minimum acceptable network bandwidth for real time connection or has any available network bandwidth for non real-time connection. Such a reservation in neighboring cells may cause resource idle. It leads to the degradation of bandwidth utilization and hence increases the CBP of new connections.

Lee et al. [15] proposes that when there is adequate network bandwidth for a connection, it temporarily borrows bandwidth from other MHs residing in the current cells. It returns the borrowed bandwidth to the MH when some bandwidth in the cell is released. This approach accepts more calls in the cost of degrading the QoS of a connecting MH. Furthermore, lacking resource reservation mechanism results in the increase of CDP when the load of a cell is high.

Malla et al. [17] proposes a fair network bandwidth allocation algorithm. A bandwidth of a cell is divided into two fixed portion reserved for new and handoff connections. When a new connection arrives, it is accepted if the requested bandwidth is less than or equal to the total of bandwidth reserved for new calls divided by the number of the existing connections in the cell. Nevertheless, by adopting fixed reservation resource technique, every cell only reserves fixed resource for handoff connections. Such an approach cannot dynamically allocate adequate bandwidth to rapidly increased handoff calls. In the case, the CDP is increased even if there is some available bandwidth reserved for new calls.

Based upon the aforementioned, in this paper we propose DRA mechanism in which a MH with scarce resource during a handoff borrows unused reserved resource to minimize the CDP and increase resource utilization. The DRA is described in the following section.

3. Dynamic Resource Adjustment (DRA)

The proposed DRA can dynamically borrow resource reserved by MHs in existing cells or handoff cells. Many ways have been proposed to accurately predict user location, such as received signal strength (RSS) [18], Direction Antenna [19], and Neural Networks [20]. We use RSS measurement to determine which adjacent cell that a specific MH would probably move to. In this way, the MH can only issue a request of resource reservation to the destination cell. Assume that before MH_a is handoffed to $cell_j$, a request is made for $cell_j$ to reserve the needed resource, $C_{rv}^{a,j}$. When the request cannot be accepted, MH uses DRA mechanism to borrow network resource in the order of following of the three steps.

1) Step① in Fig. 2 shows MH_a can borrow reserved resource $C_{rv}^{b,i}$ unused by MH_b from $cell_i$.

2) Step② in Fig. 2 shows when setp1 fails, MH_a can borrow reserved resource $C_{rv}^{y,j}$, $C_{rv}^{z,j}$, $C_{rv}^{g,j}$ and $C_{rv}^{x,j}$ unused by MH_y 、MH_z 、MH_g and MH_x from $cell_j$.

3) If step① and step② still fail, MH_a requests the remaining resource from AP in $cell_i$, as showed in step③ in Fig. 2.

If the three steps fail, AP rejects the requesting connection. In the paper, the reason why we put step3 in the last is that MH_a occupies network resource, which increases the CBP. In the following sections, we describe how DRA mechanism adjusts the aforementioned three steps to borrow network resource in AP of originating cells and destination cells.

3.1 Resource Reservation (RR)

When a new connection MH_a is accepted by $cell_i$, MH_a can use resource allocated by AP. In order to overcome changes of network resource, MH_a first download needed length of videos and access it in the buffer. Assume that M_{total} is the total length of a video, $C_{cr}^{a,i}$ is the resource provided by $cell_i$, and

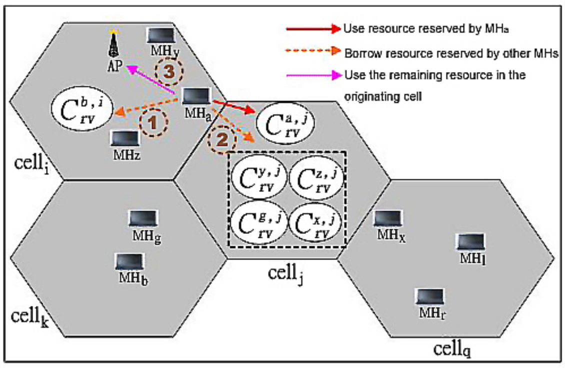

Figure 2. Borrow Resource Framework

Playback is the playback rate. We can use (1) to calculate the length of initial buffering for MH_a：

$$B_{init} = \left(\frac{M_{total}}{C_{cr}^{a,i}} - \frac{M_{total}}{Playback} \right) \times Playback, \quad C_{cr}^{a,j} < Playback \tag{1}$$

The video can start to be played after B_{init} is downloaded and accessed in the buffer. If the present time is T_{cr}^{a} and the playback time of a video is $T_{playback}^{a}$, we can use (2) and (3) to calculate the length of a video, B_{cr} and the remaining length of a video, M_{left}^{cr} :

$$B_{cr} = \left((T_{cr}^{a} - T_{playback}^{a}) \times C_{cr}^{a,j} + B_{init} \right) - \left((T_{cr}^{a} - T_{playback}^{a}) \times Palyback \right) \tag{2}$$

$$M_{left}^{cr} = M_{total} - \left((T_{cr}^{a} - T_{playback}^{a}) \times C_{cr}^{a,i} + B_{init} \right) \tag{3}$$

Assume MH_a is handoffed from $cell_i$ to destination cellj at handoff time, $T_{handoff}$. Let T_{sw}^{a} is $T_{handoff}^{a} - T_{cr}^{a}$, we can use (4) to calculate the remaining length of a video in the buffer, $B_{handoff}$ at $T_{handoff}$. :

$$B_{handoff} = \left(T_{sw}^{a} \times C_{cr}^{a,i} + B_{cr} \right) - \left(T_{sw}^{a} \times Playback \right) \tag{4}$$

Before MH_a is handoffed to destination $cell_j$, it issues a request to $cell_j$. The request contains T_{cr}^{a}, $T_{handoff}^{a}$ and the amount of reserved resource of MH_a, $C_{rv}^{a,j}$. If MH_a is not handoffed to $cell_j$ within T_{sw}^{a}, the reserved resource requested by MH_a can be returned to $cell_j$. Using (5), we can calculate the total remaining length of the video, $M_{left}^{handoff}$ after MH_a is handoffed to $cell_j$. As MH_a issue a resource reservation request, $cell_j$ decides whether to reserve resource based on (6).

$$M_{left}^{handoff} = M_{total} - \left(B_{init} + \left(T_{handoff} - T_{playback} \right) \times C_{cr}^{a,j} \right) \tag{5}$$

$$B_{handoff} \geq \left(\frac{M_{left}^{handoff}}{C_{rv}^{a,j}} - \frac{M_{left}^{handoff}}{Playback} \right) \times Playback \tag{6}$$

If the equality in (6) can not be satisfied, cellj fail to reserve resource, $C_{rv}^{a,j}$ for MH_a. At this time, in order to minimize CDP and to efficiently improve QoS guarantees in media streaming, MH_a must employ DRA to dynamically borrow reserved resource unused by other MHs.

3.2. Borrow and Return Reservation Resource (BR)

We can use (7) to calculate the remaining length of a video, $B_{sufficient}$:

$$B_{sufficient} = \left(\frac{M_{left}^{handoff}}{C_{rv}^{a,j}} - \frac{M_{left}^{handoff}}{Playback} \right) \times Playback - B_{handoff} \tag{7}$$

$MH_{a\ must}$ finish downloading $B_{sufficient}$ within T_{sw}^{a};thus, we can use (8) to calculate the resource, $C_{sufficient}$.

$$C_{sufficient} = \frac{B_{sufficient}}{T_{sw}^{a}} \tag{8}$$

MH_a can adopt BR strategy to borrow $C_{sufficient}$ reserved by MHs from either the originating cell or the destination cell. It first borrows reserved resource with the shortest remaining time by DRA. In this way, reserved resources with the longest time are left for later MHs with scarce resource, such that the bandwidth utilization can be increased. Assume T_{sw} is the time spent in handoffing MHs to $cell_i$ in MH_a. MH_a returns borrowed resource at T_{sw} . If the length of a downloaded video is still less than $B_{sufficient}$, MH_a continues to borrow resource reserved by MHs until the length of a video equals $B_{sufficient}$, i.e. , the originating $cell_i$ has no sufficient reserved resource for MH_a , MH_a can borrow resources reserved by other MHs from destination $cell_j$ based on the above approach. If the length of a video exceeds $B_{sufficient}$, DRA returns surplus resource to avoid occupying the time spent in other MHs' borrowing reservation resource. If the above steps still fail, MH_a requests available resource from originating $cell_i$ to compensate the needed resource. Finally, if the borrowed resource fails to satisfy MH_a, it can be dropped immediately. Fig. 3 and Fig. 4 depict DRA Algorithm and BR Module, respectively.

***DRA* Algorithm**

1.MH_a issue reservation resource request to handoffing $cell_j$;

2.**IF** resource reservation is successful in handoffing $cell_j$ **THEN** accept connection ;

reserve $C_{rv}^{a,j}$ in the $cell_j$;

ELSE /* not adequate resource to reserve in $cell_i$ */

Execute *BR(i)* to borrow reservation resource from current $cell_i$;

IF resource borrowed is adequate **THEN** accept connection ;

ELSE /* not adequate resource to borrow in $cell_i$*/

Execute *BR(j)* to borrow reservation resource in the handoffing $cell_j$;

IF resource borrowed is adequate **THEN** accept connection ;

ELSE /* not adequate resource to borrow in $cell_j$ */

Acquire resource from available resource of current $cell_i$;

IF resource acquired is adequate **THEN** accept connection;

ELSE drop connection;

Figure 3. DRA Algorithm

***BR* (*k*)Module**

$B_{rv} = 0$;

$a = 1$;

while ($B_{rv} < B_{sufficient}$){

Find the reserved resource of MH_a (a=1 to n), $C_{rv}^{a,k}$, with the smallest Switch Time, T_{sw}^{a} , from $cell_k$;

$B_{rv} = B_{rv} + C_{rv}^{a,k} \times T_{sw}^{a}$;

/* borrow resource from $C_{rv}^{a,k}$ */

IF ($B_{rv} > B_{sufficient}$){

/* return surplus resource */

$C_{rv}^{a,k} = C_{rv}^{a,k} + \frac{B_{rv} - B_{sufficient}}{T_{sw}^{a}}$;}

IF ($B_{rv} < B_{sufficient}$ && $a == n$){

/* no more resource can be borrowed */

exit *BR*; }

$a = a + 1$;}

return B_{rv};

Figure 4. BR Module

4. Stimulation and Analysis

In this section, simulation results are presented to evaluate the proposed scheme. The simulation environment is composed of 36 cells, each of which keeps contact with its six neighboring cells. MHs are randomly distributed in all cells and each has different moving speed and handoff probability. They are generated according to predefined arrive rate. We compare the efficiency of bandwidth allocation of DRA, NR (No Reservation) and RR (Reservation Resource) by measuring CBP, CDP and bandwidth utilization in our simulation. NR and RR approaches will be introduced as follows:

- **NR:** The destination cell does not reserve resource for a MH requesting handoff connection.
- **RR:** When the call is a handoff connection, it reserves resource in all neighboring six cells.

Table I lists the definition of parameters. In this simulation, we assume MH has different three kinds of moving speed listed in Table II, slow, medium and fast.

Table I. Simulation parameters

Parameter	Description	Value
M_{total}	The total length of videos	25MB
Playback	Playback speed of streaming	620kbps
T_{movie}	The time of the requested videos	5minutes
C_{req}	The resource of the requested videos	600kbps
C_{ap}	The total resource of AP	60Mbps
cell_ms	The diameter of every cell	1km

Table II. Mobility Speed of MH

Speed	Rate
slow	0 and 2 m
medium	2 and 12 m
fast	12 and 25 m

Fig. 5 shows the bandwidth utilization of these three approaches with the increasing call arrival rate. When arrival rate equals 100 requests per second, the bandwidth utilization of DRA, RR and NR is 93%, 82% and 86%, respectively. In this case, the bandwidth utilization of DRA is 10% and 13% more

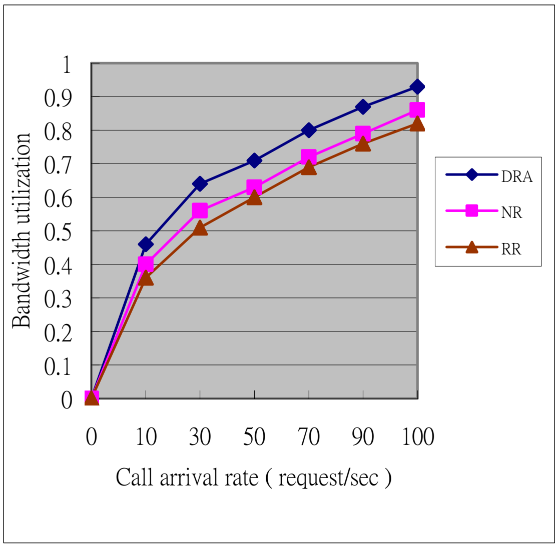

Figure 5. Bandwidth Utilization

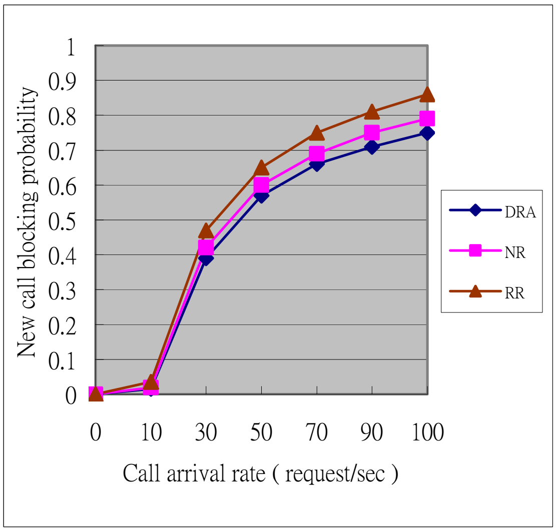

Figure 6. Connections Blocking Probabilities

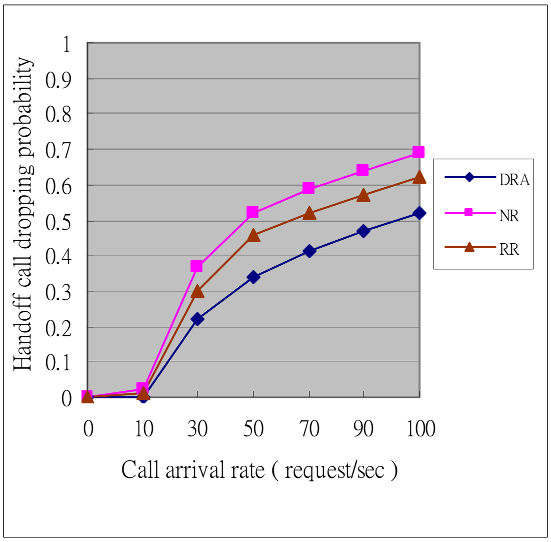

Figure 7. Connections Dropping Probabilities

than that of RR and NR. With RR resources reserved in six neighboring cells are only dedicated to the requesting call for handoff. It inevitably wastes some bandwidth without actually being used. With NR MHs compete against each other in acquiring bandwidth. Compared with RR, NR has higher bandwidth utilization because it does not reserve resource for handoff connections in advance. With DRA the resources reserved by a MH can be dynamically borrowed by other MHs before it has been used. Its flexibility in borrowing resource between cells leads to the highest bandwidth utilization.

Fig. 6 shows the CBP of these three approaches with the increasing arrival rate of new connections. When the arrival rate is low, as shown in the figure less than 30 requests per second, NR and DRA perform almost equally well. The CBP of RR is worse than that of the other two because RR reserves resource in all six neighboring cells. Only reserved resource of a cell will be used for the handoff call. On the contrary, DRA only requests destination cell to reserve resource for a handoff connection, which does not cause resource idle. As the arrival rate increases, the DRA gradually outperforms RR and NR. When arrival rate equals 100 requests per second, CBP of DRA, RR, and NR is 75%, 86% and 79%, respectively. CBP of DRA is 13% and 5% less than that of RR and NR.

Fig. 7 illustrates the CDP of these three approaches with the increasing arrival rate of handoff connections. DRA outperforms the other two approaches. Again this is because DRA is capable of dynamically borrowing unused reserved resources to compensate bandwidth shortage for handoff connections, whereas RR and NR are not. When arrival rate equals 100 requests per second, the CDP of DRA, RR and NR is 52%, 62% and 69%, respectively. CDP of DRA is 16% and 25% less than that of RR and NR. Without reserving resource in advance, obviously, NR suffers from higher CDP than RR.

5. Conclusion

The provision of QoS guarantees in multimedia wireless networks is a complex problem. Bandwidth allocation is a very crucial task in the current even limited wireless bandwidth. Our proposed DRA algorithm can fully utilize unused reserved resources to effectively decrease the CDP while still keeping acceptable CBP without affecting QoS. DRA significantly improves CBP, CDP and bandwidth utilization. In the future, we are going to further extend DRA to cope with VBR traffic. In addition, the amount of resource reservation based on the probability of a handoff connection will also be considered.

6. Reference

[1] V.O.K. Li and W. Liao, "Wireless multimedia networks," *Parallel Architectures, Algorithms and Networks*, pp.22-24, May, 2002.

[2] H. Kanakia, P.P. Mishra and A.R. Reibman, "An Adaptive Congestion Control Scheme for Real-Time Video Packet Transport," *IEEE/ACM Trans. Networking*, vol. 3, no. 6, pp.671-682, 1995.

[3] M.I. Kim and S.I. Kim, "A 2-Level Call Admission Control Scheme Using Priority for Decreasing New Call Blocking & Handoff Call Dropping," *IEEE Vehicular Technology Conference*, vol.1, pp. 457-461, April, 2003.

[4] H. Matsuoka, M. Yoshimura, and T. Ohya, "A robust method for soft IP handover," *IEEE Internet Computing*, vol.7, no.2, pp.362-368, March-April, 2003.

[5] G. Andras and G. Valko, "Cellular IP: A NEW Approach to Internet Host Mobility," *ACM Computer Communication Review*, Jan., 1999.

[6] L. Sunho, C. Guohong and C.R. Das, "An Admission Control Scheme for QoS-Sensitive Cellular Networks," *IEEE Wireless Communications and Networking Conference*, vol.1, pp.296-300, March, 2002.

[7] H. Yosuke and Z. Yongbing, "Adaptive QoS-Guaranteed Channel Reservation in Multimedia Wireless Networks," *IEEE on International Conference*, vol.1, pp.404-408, July, 2002.

[8] L. Zheng, Z. Yang and J. He, "A QoS Provisioning Framework for High-speed Multimedia Wireless Networks," *IEEE Mobile and Wireless Communications Network*, pp.179-182, Sept., 2002.

[9] C.-C. Chao and W. Chen, "Connection Admission Control for Mobile Multiple-Class Personal Communication Network," *IEEE J. Selected Areas in Comm.*, vol.15, pp.1618-1626, 1997.

[10] S. Chen and K. Nahrstedt, "Distributed Quality-of-Service Routing in Ad-Hoc Networks," *IEEE J. Selected Areas in Comm.*, vol.17, no.8, pp.1488-1505, 1999.

[11] C.-J. Ho, C.-T. Lea and G.L. Stuber, "Call Admission Control in Microcell/Macrocell Overlaying System," *IEEE Trans. on Vehicular Technology*, vol.50, no.4, pp.992-1003, 2001.

[12] M. Chiu and M.A. Bassiouni, "Predictive Scheme for Handoff Prioritization in Cellular Networks Based on Mobile Positioning," *IEEE J. Selected Areas in Comm.*, vol.18, pp.510-522, 2000.

[13] M. El-Kadi, S. Olariu and H. Abdel-Wahab, "A Rate-Based Borrowing Scheme for QoS Provisioning in Multimedia Wireless Networks," *Proc. IFIP Sixth Int'l Conf. Intelligence in Networks*, vol.13, no.2, pp.156-167, Feb., 2002.

[14] B.M. Epstein and M. Schwartz, "Predictive QoS-Based Admission Control for Multiclass Traffic in Cellular Wireless Networks," *IEEE J. Selected Areas in Comm.*, vol.18, no.3, pp.523-534, 2000.

[15] J.-H. Lee, T.-H. Jung, S.-U. Toon, S.-K. Toum and C.-H. Kang, "An Adaptive Resource Allocation Mechanism Including Fast and Reliable Handoff in IP-based 3G Wireless Networks," *IEEE Personal Communications*, vol.7, no.6, pp.42-47, Dec., 2000.

[16] C. Oliviera, J. Kim and T. Suda, "An Adaptive Bandwidth Reservation Scheme for High Speed Multimedia Wireless Networks," *IEEE J. Selected Areas in Comm*, vol.16, no.6, pp.858-874, 1998.

[17] A. Malla, M. El-Kadi, S. Olariu and P. Todorova, "A fair resource allocation protocol for multimedia wireless networks," *IEEE Trans. on Parallel and Distributed Systems.*, vol.14, no.1, pp.63-71, Jan., 2003.

[18] R. Jayaram, N.K. Kakani, S.K. Das and S.K. Sen, "A call admission and control scheme for quality-of-service (QoS) provisioning in next generation wireless networks," *ACM/Blatzer Journal on Mobile Networks*, 1998.

[19] T.K. Fong, P.S. Henry, K.K. Leung, Qiu Xiaoxin, and N.K. Shankaranarayanan, **"**Radio resource allocation in fixed broadband wireless networks," IEEE Trans. on Communications, vol: 46 , June, 1998.

[20] S.-C. Liou and H.-C. Lu,**"**Applied neural network for location prediction and resources reservation scheme in wireless networks,"Communication Technology Proceedings, 2003., vol:2, April, 2003.