A Design and Performance Evaluation of 2-Level Call Admission Control Scheme in Mobile Multimedia Networks*

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Abstract. Multimedia applications are much more sensitive to the quality of service(QoS) than text-based ones due to their data continuity. In order to provide a fast moving mobile host(MH) supporting multimedia applications with a consistent QoS, an efficient call admission mechanism is in need. This paper proposes the 2-level call admission control(2LCAC) scheme based on a call admission scheme using the priority to guarantee the consistent QoS for mobile multimedia applications. The 2LCAC consists of the basic call admission and advanced call admission; the former determines call admission based on bandwidth available in each cell and the latter determines call admission by utilizing delay tolerance time(DTT), priority queue(PQueue), and upgrade queue(UpQueue) algorithms. In order to evaluate the performance of our scheme, we measure the metrics such as the blocking probability of new calls, dropping probability of handoff calls, and bandwidth utilization. The result shows that the performance of our scheme is superior to that of existing schemes such as complete sharing policy(CSP), guard channel policy(GCP) and adaptive guard channel policy(AGCP).

1 Introduction

The provision of QoS in mobile multimedia networks becomes more complex due to user mobility. The problem becomes even more challenging as recent wireless networks are constructed based on small-size cells(microcells or picocells). Small-size cells increase the number of handoffs, which results in complex and rapid handling in call admission control(CAC), thus increasing the handoff dropping rate.

It is important to reduce the dropping rate caused by lack of available bandwidth in the handoff target cell. If the cell's available bandwidth is not sufficient enough to satisfy a handoff call, this call has to compete with other calls to acquire the bandwidth. To solve this problem, several schemes have been proposed in literature for efficient channel assignment.

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One well-known scheme is priority-based *CAC* and channel assignment. From the user's point of view, dropping an ongoing call is more undesirable than blocking a new call[1],[2],[3]. As a result, many researches have been devoted to *CAC* and channel assignment using prioritized handoff requests. Another well-known scheme is bandwidth reservation based *CAC* which reserves bandwidth for handoff calls in all or some cells that MH might pass through, resulting in potentially lower bandwidth utilization and higher new call blocking probability.

In this paper, we propose the 2-level call admission control(*2LCAC*) scheme using the priority to guarantee the consistent QoS for mobile multimedia applications. A cell is assumed to be small and overlapped partially with its neighboring cells. MH calls are classified into new calls, hand-off calls, and QoS upgrading calls. The *2LCAC* consists of two stages: basic call admission control(*BCAC*) and advanced call admission control(*ACAC*). The former determines call admission based on available bandwidth in each cell and the latter determines call admission by utilizing delay tolerance time(*DTT*), priority queue(*PQueue*), and upgrade queue(*UPQueue*) algorithms according to the type of call blocked at *BCAC*.

We compare the performance of *2LCAC* scheme with that of the other *CAC* schemes. Simulation results show that our scheme outperforms the others by satisfying the constraint on call blocking probability of new calls(*CBP*), call dropping probability of handoff calls(*CDP*) and bandwidth utilization.

This paper is organized as follows. We describe our *CAC* scheme in Section 2. Section 3 shows simulation results and compares the performance of our scheme with that of the other schemes under various scenarios. Finally, Section 4 contains the concluding remarks.

2 *2LCAC* Scheme Based on Priority Queue

Generally, it is assumed that a cell is hexagonal in mobile networks. However, in real world, a cell is close to a circle, and there are overlapped areas with neighboring cells as shown in Fig. 1. MHs residing in overlapped areas have higher possibility to move to another cell than MHs not residing in those areas.

Fig. 1. Overlapped Cell Structure

Fig. 2. 2LCAC Procedure

As shown in Fig. 2, 2LCAC consists of *BCAC* and *ACAC*. At the *BCAC* stage, each call(new, handoff and QoS upgrading) requests required bandwidth from its base station(BS). That is, *CAC* is performed at the *BCAC* stage when a call is requested for the first time from a specific cell. If available bandwidth of the BS satisfies each call's request, it assigns the bandwidth to the MH; otherwise, it blocks the call and passes its control to the *ACAC* stage.

Table 1. The Policies related to *BCAC*

Call Type	Triggered Time	Conditions	Actions
New	When MH_i requests	$B_{j}^{avail} \geq B_i^{new}$	Accept
		$B_{j}^{avail} < B_i^{new}$	Block and perform <i>ACAC</i> stage
Handoff	When MH_i enters overlapped area	$B_{j}^{avail} \geq B_i^{handoff}$	Accept
		$B_{j}^{avail} < B_i^{handoff}$	Block and perform <i>ACAC</i> stage
QoS Upgrading	When B_i^{avail} is higher than Th_{up}	$B_{j}^{avail} \geq B_i^{up}$	Accept
		$B_{j}^{avail} < B_i^{up}$	Block and perform <i>ACAC</i> stage
		$B_{j}^{avail} < Th_{up}$	Block and perform <i>ACAC</i> stage

2.1 Basic Call Admission Control (BCAC)

Table 1 shows the policies related to *BCAC*, which are chosen by the type of calls. B_i^{new} and $B_i^{handoff}$ represent MH_i 's required bandwidth of new call and handoff call, re-

spectively. Whereas B_i^{up} represents required bandwidth of QoS upgrading call, B_j^{avail} represents the amount of bandwidth available in cell j . B_j^{avail} can be calculated by Eq. (1):

$$B_j^{avail} = B_j^{total} - \left(\sum_{i=0}^n B_i^{handoff} + \sum_{k=0}^m B_k^{new} \right) \quad (1)$$

where B_j^{total} is the total amount of bandwidth provided by cell j and n and m are the number of handoff calls and new calls currently residing in cell j , respectively.

In case of a new call, the CAC is triggered when MH requests the call admission. If B_j^{avail} is larger than B^{new} , the call is admitted; otherwise, blocked. In case of a handoff call, the CAC is triggered when the MH enters an overlapped area. If the B_j^{avail} is larger than $B^{handoff}$, the call is admitted; otherwise, blocked. In order to upgrade the current QoS level of an ongoing call, additional bandwidth can be requested by triggering CAC. If B_j^{avail} is larger than Th_{up} , the call is accepted, where Th_{up} is the threshold used for determining the acceptance of QoS upgrading call; otherwise, blocked. The control of blocked new, handoff and QoS upgrading call will be treated at the ACAC stage.

2.2 Advanced Call Admission Control (ACAC)

Priority Queue and QoS Upgrading Queue

In ACAC, each cell requires space to store information about MH: priority queue(PQ) and QoS upgrading queue(UpQ). PQ stores information on an MH such as ID and the priority that has been blocked as a result of BCAC for its handoff. For example, when MH_1 and MH_2 move towards the overlapping area with cell D from cell C and E, respectively, as shown in Fig. 3, BCAC is triggered. If both MHs are blocked, the priorities of MH_1 and MH_2 are calculated by cell D's BS and the information on those blocked MHs are inserted into PQ. Furthermore, if an MH_3 residing in cell D moves towards cell B through the overlapped area between the two cells and is blocked as a result of BCAC, the priority of MH_3 is inserted into cell B's PQ.

Fig. 3. A Snapshot of Cell Status

The call priority of MH is calculated using Eq. (2):

$$\text{Call priority} = w_1 DP + w_2 TP + w_3 VP \quad (2)$$

where DP , TP and VP are the distance priority, traffic priority and velocity priority, respectively, and w_1 , w_2 and w_3 are weight factors. The rationale behind this equation is that an MH has the highest priority as it gets closer to the target cell(DP) at a high mobility speed(VP) and require the service with high TP like multimedia services.

QoS upgrading calls that have been blocked as a result of $BCAC$ are inserted into UpQ . When the amount of bandwidth available in a cell is greater than Th_{up} , the bandwidth is allocated to the calls in UpQ in the FIFO order.

DTT, PQueue and UPQueue Algorithm

In $ACAC$, different CAC algorithms are adopted according to the type of each call; new, handoff and QoS upgrading calls are tested using DTT , $PQueue$ and $UPQueue$ algorithm, respectively. In case of a new call, it requests a call admission to BS periodically until DTT expires, where DTT is set when the MH is powered on. If available bandwidth of BS is not enough to satisfy the new call's request after DTT , it is dropped.

In case of handoff calls, call classification and bandwidth borrowing algorithms are invoked. Call classification algorithm as below is applied to MHs that have just entered the overlapped area. It classifies handoff calls into two classes: *high* and *low*. Class *High* contains handoff calls that have relatively higher priority than the others. Once being classified into this class, the calls will not be degraded into class *low* and bandwidth assignment to them will be also guaranteed. On the other hand, class *low* contains handoff calls that have relatively lower priority than the others. They have high chances of being dropped during $ACAC$ and bandwidth assignment to them will not be guaranteed.

Pseudo Code for Call Classification Algorithm

```

Call_Classification() {
  Input  :  $B^{avail}_j$ ,  $B^{TPQ}_j$ ,  $n$ ,  $BSP_j$ 
  Output : Priority of MHs in  $PQ_j$ 
  if ( $B^{avail}_j \geq B^{TQB}_j$ ) {
    for (i=0; i≤n; i++)
      Priority of  $MH_i$  = High;
  }
  else {
    for (k=0; k< $BSP_j$ ; k++)
      Priority of  $MH_k$  = High;
    for (m= $BSP_j$ ; m≤n; m++)
      if ( $MH_m$  enters  $PQ_j$  for the first time)
        Priority of  $MH_m$  = Low;
      else
        Maintain the current Priority of  $MH_m$ 
  }
}

```

In the pseudo code above, B^{TPQ}_j (Total Bandwidth of PQ) is the sum of bandwidth requested by all the MHs that reside in cell j 's PQ . Bandwidth satisfaction point (BSP_j) points out the right most MH in PQ of which bandwidth request can not be satisfied from cell j 's available bandwidth. To be specific, if B^{avail}_j is equal to or higher than B^{TPQ}_j , the priorities of all the MHs residing in PQ become *high*. However, if B^{avail}_j is lower than B^{TPQ}_j , only the priorities of MHs that are at the left-hand side of BSP_j become *high* and the others become *low*. The MHs that are at the right-hand side of BSP_j and have a *high* priority maintain its current priority. MHs residing in PQ are sorted based on their priorities.

When the priority of MH_i becomes *high* during its stay in the overlapped area, the required bandwidth is assigned to it if the amount of bandwidth available in the target cell is sufficient enough, or bandwidth borrowing algorithm[1],[3],[4] is triggered to assign the amount of bandwidth requested by MH_i . On the other hand, the algorithm is not triggered immediately if the priority of MH_i belongs to class *low*, and the triggering of the algorithm is delayed until its priority is upgraded to class *high*. A handoff call of MH_i is dropped, if the priority of MH_i cannot be upgraded to class *high* until it leaves the overlapped area.

In case of QoS upgrading call, an MH is stored into the QoS upgrading queue in order to upgrade the QoS level. This happens either when the MH wants to upgrade its service quality or to reclaim as much bandwidth as it has lent to the other MH. Only when the amount of bandwidth available in BS is above the threshold, the required bandwidth is assigned. Just because there is sufficient bandwidth in a cell, the QoS will not be upgraded immediately by $UPQueue$ algorithm. To be specific, if the available bandwidth is below the threshold, MH_i is stored in the QoS upgrading queue. Next, only when the available bandwidth is above the specific threshold, the QoS of MH_i is upgraded in the FIFO order. Note that the available bandwidth below the threshold is assigned to new calls and handoff calls, because the QoS upgrade calls have the lower priority than both new calls and handoff calls.

3 Performance Evaluation

In this section, we compare the performance of proposed scheme with that of other schemes such as *CSP*, *GCP*, and *AGCP*. In *CSP* [5], new and handoff calls are not distinguished from each other and are admitted as long as available bandwidth of a cell can provide the required bandwidth to the MH. In other words, the same priority is given to both the new and handoff calls. This scheme has the low *CBP*, but high *CDP*.

GCP [5],[6],[7] reserves a fixed amount of bandwidth for multimedia handoff calls. This scheme reserves as much bandwidth as required by an MH requesting multimedia services and having high probability of entering a certain cell. The bandwidth is assigned later when the MH actually enters the cell. This scheme has an advantage of having the low *CDP* for multimedia handoff calls by assigning reserved bandwidth to them. However, since the available bandwidth is reserved for multimedia calls, new

and non-multimedia handoff calls have high *CBP* and *CDP*. Moreover, the reserved bandwidth may turn out not to be used, thus resulting in low bandwidth utilization.

AGCP [2],[8],[9] is a policy that adaptively reserves a portion of bandwidth for multimedia handoff calls depending on network condition. If the *CDP* of a cell is above the specific threshold (e.g., 0.05), the amount of reserved bandwidth is increased. On the other hand, if the *CBP* is below a certain threshold, a certain amount of reserved bandwidth is decreased only when the utilization of reserved bandwidth is below specific threshold (e.g. 0.5). This scheme has the lower *CDP* than *GCP*. When the number of new calls increases dramatically, however, the *CDP* is increased as well.

Table 2. Traffic Classes Used in the Simulation

Traffic Class	Bandwidth Requirement	Call Duration (minutes)	Typical Service
Class I	30Kbps	1~10	Voice Service
	256Kbps	1~30	Video-Phone
	1~6Mbps	5~300	Video on Demand
Class II	32Kbps	0.2~2	E-mail, Paging
	64~512Kbps	0.5~600	Remote Login & Data on Demand
	1~10Mbps	0.5~20	FTP

In this simulation, we suppose that the mobile multimedia network is comprised of 100 hexagonal cells, each of which diameter is 1 km. We also suppose that each cell provides the bandwidth of 30Mbps and communicates with its six neighboring cells. The client moves at a speed from 1 to 100 Km/h. New call requests are generated according to a Poisson distribution with the arrival rate λ (calls/second) in each cell. A new call is assumed to be requested at any place in the cell with an equal probability. Table 2 shows six typical traffic classes used in the simulation[8].

Performance metrics considered in the simulation are *CBP*, *CDP* and bandwidth utilization. The metrics are measured with respect to *CSP*, *GCP*, and *AGCP* as the arrival rate of new calls vary.

We first attempt to find out the most reasonable rate of class I calls by performing our simulation under the situation as follows; the arrival rate of new calls is fixed at 0.1(MH/sec) and the proportion of class I calls is incremented by 10% from 10% to 90%. We find that the *CBP*, *CDP*, and bandwidth utilization showed the best performance when the proportion of class I call is 50%. We then perform our simulation under the following situation; the proportion of class I calls is fixed at 50% and the arrival rate of new calls is incremented by 0.01(MH/sec) from 0.01 to 0.1.

Fig. 4 shows the *CBP* for each of four schemes as the arrival rate of new calls increases from 0.01 to 0.1. According to the figure, *2LCAC* has the lowest *CBP* followed by *CSP*. It also shows that *AGCP* has the highest *CBP*. This is because *2LCAC* allows an MH to request the acceptance of its blocked new call repeatedly at the

BCAC stage until *DTT* expires without human-user's intervention. The *CBP* of *AGCP* and *GCP* are lower than that of *CSP*. The reason for that is that *AGCP* and *GCP* assign higher priority to handoff calls than new calls and reserve some bandwidth for handoff calls. As a result, as the amount of bandwidth assigned to new calls decreases, the *CBPs* of *AGCP* and *GCP* are higher than those of *2LCAC* and *CSP*. On the other hand, the *CSP* treats new and handoff calls equally and does not reserve bandwidth for handoff calls.

Fig. 4. Blocking Probability of New Calls

Fig. 5. Dropping Probability of Handoff Calls

Fig. 5 shows the *CDP* of each scheme as the arrival rate of new calls increases from 0.01 to 0.1. *2LCAC* has the lowest *CDP*, followed by *AGCP*, *GCP*, and *CSP*. This is because *2LCAC* gives a priority to both class I and class II handoff calls efficiently and fairly. Fair bandwidth assignment is guaranteed by *2LCAC* based on the type of calls, the speed of MH, and MH's distance from the target cell. Even when there is not

enough bandwidth available in a cell, handoff call admission is guaranteed for handoff calls with high priority by reclaiming bandwidth at the *ACAC* stage. If there are many new call requests, the *CSP* has the highest *CDP* because it does not assign higher priority to handoff calls than new calls. In case of *AGCP* and *GCP*, both have the high *CDP* because the reserved bandwidth might not be used at all and be eventually wasted.

Fig. 6. Bandwidth Utilization

Fig. 6 shows the bandwidth utilization of each scheme. *2LCAC* has the highest utilization followed by *CSP*, *GCP*, and *AGCP*. This is because *2LCAC* uses available bandwidth of a cell more efficiently than other schemes. When there is available bandwidth in a cell, it is assigned to QoS upgrade calls. Since QoS upgrade calls of an MH reclaim bandwidth which has been previously lent to handoff calls with high priority, *2LCAC* manage to utilize the bandwidth efficiently. On the other hand, *AGCP* and *GCP* have low bandwidth utilization, because reserved bandwidth can be unused and be wasted.

4 Conclusion

For efficient and fair *CAC*, we proposed *2LCAC* scheme using priority queue. We classified MH calls into three types: new, handoff, and QoS upgrade call. The priority of each type is assigned in the order of handoff, new, and QoS upgrade call, and each type uses the different call admission policy. *2LCAC* consists of two stages: *BCAC* and *ACAC*. At the former stage, calls from an MH are admitted without distinguishing new and handoff calls just as the *CSP*, when the amount of bandwidth available in a cell satisfies the required bandwidth of the MH. In case of QoS upgrading calls, they are accepted if the available bandwidth is above the specific threshold; otherwise, the calls are blocked and *ACAC* is triggered. The latter stage tests whether the calls

blocked at the former stage can be accepted or not using *DTT*, *PQueue*, and *UPQueue* algorithms depending on the type of calls.

In order to evaluate the performance of our scheme, we measured the metrics such as *CBP*, *CDP*, and bandwidth utilization. We then compared the performance of *2LCAC* with that of three different schemes: *CSP*, *GCP*, and *AGCP*. Because *CSP* does not distinguish new calls from handoff calls, it has the low *CBP* and high *CDP*. Since *GCP* reserves a fixed amount of bandwidth, it has the low *CDP*, but the highest *CBP*. This scheme has the lowest bandwidth utilization because it cannot adaptively readjust the amount of bandwidth for handoff calls. The performance of *AGCP* is better than that of other schemes, but still worse than that of *2LCAC*. To be specific, *2LCAC* lowers its *CBP* and *CDP* by 6~11% and 5~8%, respectively, compared to *CSP*, *GCP* and *AGCP*. The bandwidth utilization of *2LCAC* is also better than that of other schemes by 7~8%. All in all, *2LCAC* utilizes the bandwidth of BS more efficiently than other conventional schemes.

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