A New Approach to Fair Bandwidth Sharing among Multimedia Cellular Networks

Md. Akhtaruzzaman
Assistant Professor, Department of Computer Science and Engineering,
Asian University of Bangladesh, Uttara, Dhaka-1230, Bangladesh
And
Mohammad Abu Nawar Siddique
Senior Lecturer, Department of Computer Science and Engineering,
Asian University of Bangladesh, Uttara, Dhaka-1230, Bangladesh

Abstract

Future generation cellular networks, both civilian and military, are envisioned to provide integrated services via inexpensive low powered mobile computing devices. End users often expect seamless connectivity from wire-line to wireless networks. On the other hand, cellular networks are limited in terms of resources like bandwidth, power, and the transmission medium. Therefore, meeting stringent quality of service requirements requires efficient resource management. For this purpose, we need to have an understanding of the user's requirements and subsequently design the resource allocation techniques to satisfy the specific objectives. We conclude here that space dependent contention is an inherent feature of cellular networks. Thus, it turns out that the scheduling of different links is interdependent in cellular networks, whereas different links can be scheduled independent of each other in cellular networks. As a result, bandwidth allocations inherently differ. In addition, several flows share the same wireless link and the issue of contention between flows sharing the same link arises as in cellular networks. Since link scheduling is interdependent, the bandwidth requirement of the flows in one link affects the scheduling of flows in other links as well. The challenge is to obtain a globally fair allocation in spite of this mutual independence.

I. INTRODUCTION

The authors first study several possible qualities of service objectives. Each user may specify individual service requirements, and subsequently the network may allocate resources to meet the desired objectives. However, the pitfall is that there needs to be an elaborate negotiation associated with each session initiation. For wireless networks, where sessions are short-lived, and nodes are continuously on the move, such negotiation may generate significant overhead. The basic idea behind rate-based fairness is to first allocate desired bandwidth to all contending users. If a user cannot utilize its bandwidth, because of constraint elsewhere, then the residual bandwidth is distributed among others. Thus, no user is penalized excessively, and a certain minimum quality of service is guaranteed to all users. User's satisfaction is often a concave function, i.e., satisfaction increases rapidly with an increase in bandwidth in the low bandwidth region, and increase slowly with increase in bandwidth in the high bandwidth range. As a result, bandwidth allocations inherently differ. In addition, several flows share the same wireless link and the issue of contention between flows sharing the same link arises as in cellular networks. Since link scheduling is interdependent, the bandwidth requirement of the flows in one link affects the scheduling of flows in other links as well. The challenge is to obtain a globally fair allocation in spite of this mutual independence. The main contribution of this paper was to propose policies, which attain maximum fair allocation. The novelty of the scheme was that, for the last few connections, some bandwidth would be reserved virtually and would be maintained or distributed at a priority basis (which are changeable for time) that could reduce the fuzzy and silly connections of an emergency period. And the proposed rate based borrowing scheme was fair in the sense that it would borrow the bandwidth from all satisfied existing connections and the amount of Borrowing bandwidth was the proportion of their difference of desired and minimum bandwidth. Another factor that needed to be considered was that the bandwidth allocation should also depend on the bandwidth demands of the individual flows. For example, if a flow did not utilize most of its bandwidth because of low traffic demand, then the excess might be allocated to contending flows. In addition, the traffic demands of different flows change with time, and typically the wireless nodes do not have any knowledge about the traffic pattern. Thus, the resource allocation policies need to be online in order to cater to the changes efficiently. The bandwidth allocation policy should have provisions to regulate the amount of reclaim, as also to distribute any bandwidth not utilized by flows with less overall traffic demand. Finally, the Rate-based borrowing scheme treated fair allocation of bandwidth equitably and according to their demand. Rate-based borrowing scheme had studied before by M. El- Kadi but the idea of borrowing share was different to the proposed one [1]. M. El-Kadi mentioned that the borrowing amount would be the same for all subscribers. However, as it is argued later, the borrowing amount of bandwidth of subscribers would depend on the proportion of the difference of their desired and minimum bandwidth. Firstly, the algorithm has been formulated for fairness of the borrowing scheme, which is called Fair_Redistribution policy. Then an algorithm has been developed for new call admission, class I hand-off and class II hand-off.

II. BACKGROUND STUDY

Many works have been done previously in the area of cellular communication and channel allocation. The authors have put their concentration mainly on Mona el Kadi's rate based policy [1]. However, substantial research works have been done on connection admission control [6] [8] [10] [11] [12] and handoff [7] [14].

Also some research works have been completed on resource reservation [9] [13]. The authors have carefully studied all these papers to complete their research. Keeping a small pool of bandwidth always reserved for handoffs, as described in Oliviera's scheme [2], obviously reduced the call dropping probability. However, in their scheme, the size of the reserved pool was not determined by requests from neighboring cells, instead they reserved this amount by the sum of differences of all existing connection's expectation level to minimum level. On the other hand, for new call admission they gave the share of such amount, which was the sum of differences of all existing connection's maximum level to expectation level. The proposed scheme does not allow bandwidth for incoming call and hand-offs to use below the minimum level of existing connections. Their scheme gave precedence to class I connections. Class II did not use the reserve bandwidth. In order to lower the call blocking probability, the scheme allowed fair borrowing resources from existing connections. The fair borrowing strategy had the following interesting features:

A. No class I connection would have to give up bandwidth beyond the expectation level negotiated at call set up time and not give up beyond the minimum level for negotiating at hand-offs management.

B. If the cell did not have enough free bandwidth for accommodating an incoming call and hand-offs, the existing connections would temporarily have to give up a certain amount of bandwidth based on their tolerate level for both new call and hand-offs.

C. If bandwidth was borrowed, it was borrowed by maintaining a formula that they could call fair share borrow. The fair share was the proportion of all satisfied existing connection, which was the difference of their desired and minimum level.

D. When any existing call was terminated or any mobile host left the cell, as soon as possible the borrowing amount of bandwidth would be returned to the degraded connections following the same way means which amounts were borrowed that are to be returned.

E. The proposed scheme was fair in the sense of borrowing policy because all the satisfied existing connections would have to give up their fair share however some could give more shares and some could give fewer shares, which was defined by the proportion of their desired and minimum bandwidth allocation.

Now Let,

C = the given cell

$B^T{}_C$ = Total Bandwidth of the cell

$B^f{}_C$ = Free Bandwidth of the Cell

x = given service

BW = Bandwidth

$B^{max}{}_x$ = Maximum Bandwidth. /Desired Bandwidth of a given service.

$B^{exp}{}_x$ = Expectation Bandwidth of a given service.

$B^{min}{}_x$ = Minimum Bandwidth of a given service.

ABB = Actual Borrow able Bandwidth.

FBB = Fair Borrow able Bandwidth.

$B^S{}_C$ = Surplus Bandwidth.

= $\sum_{k=1}^{N}(B_k{}^{max} - B_k{}^{exp})$ $\sum_{k=1}^{N}(B_k{}^{max} - B_k{}^{min})$

For new call. For hand-off

N = Number of satisfied calls.

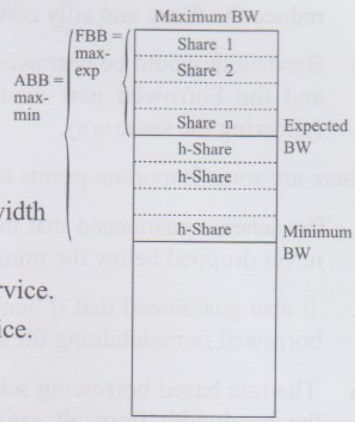

Fig 1 : Parameter of Bandwidth Sharing.

III. NOVELTY OF THE PROPOSED SCHEME

The main contribution of the paper was to propose a novel, fair rate-based borrowing scheme for bandwidth sharing among multimedia services in cellular networks. The key of our approach was to provide a fair rate of bandwidth and priority basis service in bandwidth allocation.

At call setup time the mobile hosts deliver the following parameters to the cell:

1. The desired class of traffic.
2. Their desired amount of bandwidth.
3. The minimum amount of bandwidth in which amount they can maintain their quality.

Class I- real-time multimedia traffic, such as interactive audio and video, and

Class II- non-real-time data traffic, such as email and web applications.

After finding desired amount and minimum amount, they determine their expectation or medium level.

Their scheme attempted to allocate at least an expectation level for new call admission and we could consider the minimum bandwidth for hand-off services.

The novelty of the proposed scheme was that:

a) In crisis for last few connections, the scheme would reserve some bandwidth virtually and be maintained or distributed it in priority basis ways that could reduce the fuzzy and silly connections of emergency period.

b) Bandwidth would be borrowed on a temporary basis from existing connection and the borrowed part would be returned to the degraded connections following the same way.

There are some important points to note about the scheme that they explain next:

i. The scheme guaranteed that the bandwidth allocated to a real time connection never dropped below the minimum bandwidth requirement.

ii. It also guaranteed that if bandwidth was borrowed from a connection it was borrowed in maintaining the fair share.

iii. The rate based borrowing scheme was fair in the sense that it would borrow the bandwidth from all satisfied existing connections and the amount of borrowing bandwidth was the proportion of their difference of desired and minimum bandwidth for every satisfied existing connection.

iv. For last few connections, the policy would reserve some bandwidth for priority basis policy.

v. Bandwidth would borrow on a temporary basis from existing connection and the borrowing part would be returned to the degraded connections following the same way.

IV. FAIR REDISTRIBUTION ALGORITHM

A. Redistribution algorithm

A fair redistribution algorithm has been proposed named as Fair Redistribution algorithm. This is to implement in the base station of the cell when one or more new services or hand-off services send their request to be connected.

Here is the algorithm for Fair Redistribution policy:

Set

$B_c^s = \sum_{k=1}^{N} (B_k^{max} - B_k^{exp})$ [N = no. of satisfied call]

Set Surplus BW = B_c^s

While Surplus BW > B_x^a

Set fair_share = $\dfrac{B_x^a}{\sum_{k=1}^{N} \dfrac{(B_k^{max} - B_k^{exp})}{B_k^{exp}}}$

So, BW given for new connection = each connection * fair share

Where 1^{st} share = $\dfrac{(B_1^{max} - B_1^{exp})^2}{B_1^{exp}}$ * fair share

2^{nd} share = $\dfrac{(B_2^{max} - B_2^{exp})^2}{B_2^{exp}}$ * fair share

....

N^{th} share = $\dfrac{(B_n^{max} - B_n^{exp})^2}{B_n^{exp}}$ * fair share

Adjust, $\sum_{k=1}^{N} (B_k^{max} - B_k^{exp}) \quad \sum_{k=1}^{N} = (B_k^{max} - B_k^{exp}) - B_x^a$

B. Call Setup

When a new call requested admission into the cell or network, the cell first attempts to provide the connection with an amount of its expectation level; where the calculation of expectation is followed by Mahfuz and Monjur Murshed presented formula [3]. Because they assumed that, the services demanding less amount of bandwidth should be given more priority than the services demanding more bandwidth.

$$B^{exp}_x = 2B^{min}_x - \frac{B^{min}_x}{B^{max}_x}$$

If the amount of free bandwidth and the total FBB from all existing connections were greater than or equal to the expected level of new call then it established the call and checked again that the free bandwidth of the cell was greater than or equal to the new call's maximum or desired need. If there was enough free bandwidth than new call's maximum wants then they provided maximum BW for new call and adjusted the amount of free bandwidth. If there were no more bandwidth than new call's maximum need then they checked the resource of the cell, where it was in crisis moment or not and if the resource was in crisis moment then they applied another proposed scheme which was known as priority basis scheme and it is described next.

According to rate based [5] when there is no free bandwidth then the new connections and the hand-off connections use the share from existing connection. But the situation arises when all the existing connection give up their tolerable amount of shared bandwidth and there is no rest for new connection.

All other schemes do not describe them what is happened for a new emergency connection.

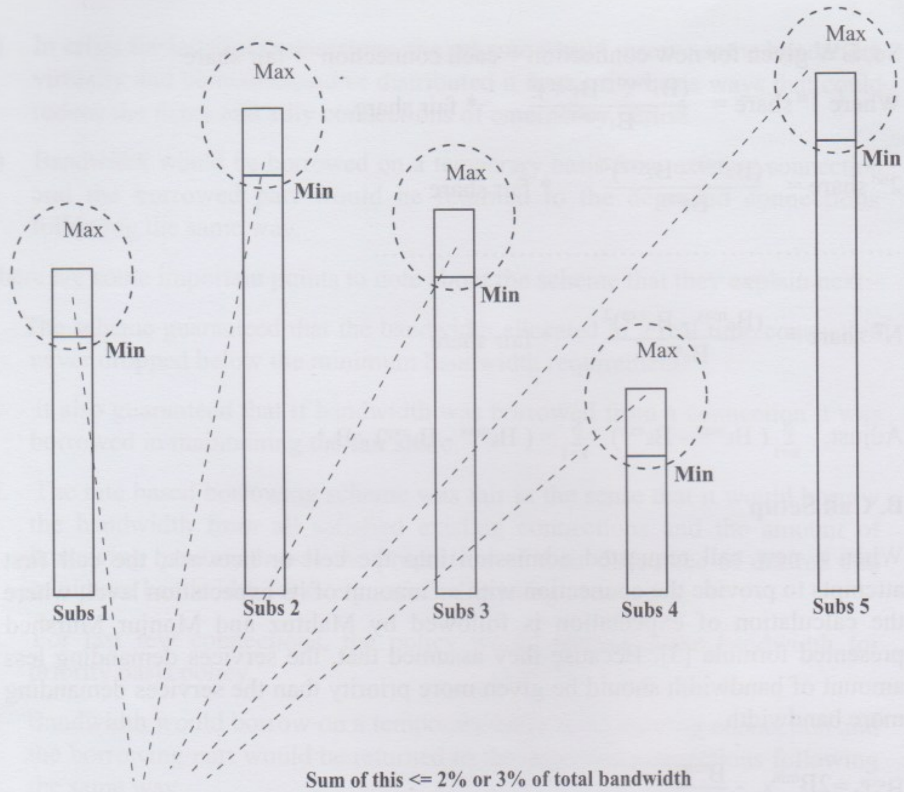

Figure 2: Amount of Bandwidth for Crisis Moments.

a. Proposed Priority Basis Policy

In the proposed priority basis policy, the authors went for the action of taking policy when the amount of sharing bandwidth was less than or equal to 2% or 3% of total bandwidth.

At that time, they used the priority basis policy and the subscriber could establish their connection, which could satisfy this policy. In this policy, they reserved 2% or 3% of the total bandwidth. However, they reserved it virtually that meant only on the crisis time they would use it.

For the protection of less used subscriber in the crisis time, on priority basis policy 1 could use more than one channel which could be denoted priority level 1, priority level 2, priority level 3 etc. and the priority level 1 is obviously more costly than priority levels 2 and 3.

When the resources were almost used, only a little resources were left and the amount was less than or equal to 2% or 3% of the total bandwidth. Only one or two subscribers could enter in the cell. They assumed the rest amount of bandwidth only could connect one subscriber and these types of subscribers wanted to connect in the mean time.

After observing the entire subscribers' psychology it can be said strongly that at least this policy can protect the less need able or fuzzy or silly call entrance at the crisis moment. So type of number 1 and number 2-call entrance could protect at priority level 1. In the case of number 3 it will kill, some time for understanding with itself was an emergency or not to connect at priority level 1 and in the mean time other real emergency call could enter into the queue.

```
IF (B_c^f + Σ_{k=1}^{N} (B_k^max - B_k^exp)) < a*B_c^t

          IF (agreed) Then
                    Priority basis
          method=True.
          Else
                    Call rejected by
          user.
          End IF
End IF
```

$$\text{IF } \left(B_c^f+\sum_{k=1}^{N}\left(B_k^{max}-B_k^{exp}\right)\right)<a*B_c^t$$

Figure 3: Priority Level Choosing Algorithm.

When the amount of free bandwidth of the cell (B_c^f) and the sum of all borrowing bandwidth was less than a * total bandwidth of the cell.

Here is a variable and the users can adjust it by pick and off pick. Because during pick hour the probability of emergency call is obviously greater than off pick hour. Therefore, the value of a will decrease off pick hour when it will increase in pick hour.

If the situation was not in crisis moment and there were no more bandwidth of maximum need then effort had been made to satisfy new call's expectation level. These bandwidths were supplied from free bandwidth of the cell and FBB for all satisfied existing connection using Fair Redistribution policy.

It is important to note that the scheme never borrowed ABB from satisfied connections and it did not provide maximum bandwidth for new calls, hampering the maximum bandwidth of other existing calls. In addition, the schemes maintained this policy so strongly that those existing calls, which were never given bandwidth as borrowed to others during new call admission.

Every time bandwidth became available in a cell due to connection releasing its bandwidth allocation.

Here is the algorithm for new call admission:

IF $(B_c^f + \sum_{k=1}^{N} B_k^{max} - B_k^{exp}) \geq B_x^{exp}$ Then

IF $B_c^f \geq B_x^{max}$ Then

Allocate $= B_x^a = B_x^{max}$

Adjust $B_c^f = B_c^f - B_x^{max}$

Else

IF $(B_c^f + \sum_{k=1}^{N} B_k^{max} - B_k^{exp})) < a * B_c^t$

IF (agreed) Then

Priority-basis

method=True.

Else

Call rejected by user.

End IF

End IF

Allocate $B_x^a = B_x^{exp}, B_x^a = B_x^a - B_c^f$

Adjust $B_c^f = 0$

Re-distribute Bandwidth based on Fair

Re-Distribution policy.

End IF

Satisfied_call=Satisfied_call+1

Figure4: New Call Admission Algorithm.

b. Class I and Class II Handoff

In their proposed scheme the hand-off admission policies were different between Class I and Class II connections. When a Class I connection requested admission into a cell as a hand-off [4], the cell was checked to see if the minimum bandwidth requirement could be met with the sum of the available free bandwidth and ABB from all satisfied connection in the cell. In this case, the call was admitted into the cell and gave bandwidth for hand-off services. Then it was checked again if the cell had more or equal bandwidth for maximum requirments. If there was no more or equal bandwidth then it was tried to satisfy its expectation level from free bandwidth of the cell and if it was not possible to provide, they tried to give expectation level using free bandwidth of the cell and ABB from all satisfied connections. Moreover if it was not possible then several works had been done to satisfy minimum bandwidth for hand off from free bandwidth of the cell. And if it was not possible then they gave minimum bandwidth from free bandwidth of the cell and ABB from all satisfied connections.

Now here is the proposed C1 Hand-off algorithm:

IF $(B_c^f + \sum_{k=1}^{N} (B_k^{max} - B_k^{min}) \geq B_x^{min}$ Then

  Accept Service

  IF $B_c^f \geq B_x^{max}$ Then

    Allocate $B_x^a = B_x^{man}$

    Adjust $B_c^f = B_c^f - B_x^a$

  Else IF $B_c^f \geq B_x^{exp}$ Then

    Allocate $B_x^a = B_x^{exp}$

    Adjust $B_c^f = B_c^f - B_x^a$

  Else IF $B_c^f + \sum_{k=1}^{N} (B_k^{max} - B_k^{min}) \geq B_x^{exp}$ Then

    Allocate $B_x^a = B_x^{exp}$

    Adjust $B_c^f = B_c^f - B_x^a$

  Else IF $B_c^f \geq B_x^{min}$ Then

    Allocate $B_x^a = B_x^{min}$

    Adjust $B_x^a = B_x^a - B_c^f$

    $B_c^f = 0$

  End IF

  Re-distribute Bandwidth based on fair_Redistribution policy.

Else

  Reject the Service.

Figure 5: C1 Hand-off algorithm.

On the other hand, Class II traffic would only be dropped if there was no free bandwidth left in the cell which included free bandwidth and ABB of the cell.

Now here is the C2 Hand-off algorithm:

IF $(B_c^f + \sum_{k=1}^{N} (B_k^{max} - B_k^{min}) \geq 0$ Then

Accept the Service

IF $B_c^f \geq B_x^{man}$ Then

Allocate $B_x^a = B_x^{max}$

Adjust $B_c^f = B_c^f - B_x^a$

Else

Allocate $B_x^a = B_x^{min}$

Adjust $B_x^a = B_x^a - B_c^f$

$B_c^f = 0$

Re-distribute Bandwidth based on fair_Redistribution policy.

Figure 6: C2 Hand-off algorithm.

V. Results

MATLAB for simulation purposes was used to assess the performance of the predictive bandwidth reservation and call admission scheme in terms of keeping the CDP low and bandwidth utilization high. For this purpose, the predictive scheme was compared to a fixed-rate scheme that sets aside 5 percent of a cell's bandwidth for the exclusive uses of Class I handoffs. A one-dimensional array of 36 cells each with a static bandwidth allocation of 30Mbps was simulated. In the fixed reservation scenario, an amount of bandwidth equal to 1.5Mbps(i.e. 5% of 30Mbps) was set aside for Class I handoffs. So, the scheme was better than the fixed reservation protocol.

VI. Concluding Remarks

The proposed scheme successfully reduces the call dropping probability and runs faster than the previous schemes. As the proposed scheme has not yet been adopted it requires commercial testing. If it can be deployed the telecom industry of the country would benefit a lot, as well as the common people because the call dropping probability is much less in the proposed scheme.

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