A FAIR SOLUTION FOR BANDWIDTH RE-ALLOCATION MANAGEMENT IN 3G WIRELESS CELLULAR NETWORKS

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ABSTRACT

In this paper a new solution is proposed to manage the bandwidth. In this scheme, bandwidth, which is not utilized by fewer mobile nodes will be re-allocated to the needy ones. In order to maintain the QoS (Quality – of – Service) for the higher priority handover call (multimedia call), focus here is to allocate the required bandwidth to this call and maintain constant during its connection life time. For the lower priority handover call (data call) at least minimum bandwidth will be allocated in the worst case scenario. The unutilized bandwidth will be distributed fairly among active lower priority nodes which will be utilized later by either handover calls or incoming local calls. With this method maximum bandwidth in the cell will be reached, will remain available whenever new call, either handover or locally generated comes in and the wastage of network resources could be avoided. Dropping probability of handover calls will be reduced to minimum and blocking probability of newly generated calls will be maintained to minimum by this method. In this scheme QoS could be maintained for multimedia call and flexible in changing the bandwidth for data calls will keep the network always in maximum utilization of network resources.

Keywords: Bandwidth (BW), Fixed Channel allocation (FCA), Dynamic channel allocation (DCA), Hybrid channel allocation (HCA), QoS (Quality – of – Service), Base Station (BS)

1 INTRODUCTION

Bandwidth Management in wireless cellular networks is a critical issue, especially if the mobile node is a multimedia one and wants to transmit video information or video and data together. In wireless mobile cellular networks, if bandwidth is not managed properly, either it gets wasted or it does not reach the needy sources who want to connect to the network. Also dropping probability of handover calls and blocking probability of locally generated calls will be increased. With the proper bandwidth management, the service provider can gain benefit in generating more revenue and increasing the number of users who could be accommodated by the network.

Many solutions have been proposed regarding bandwidth allocation and management. Scalable QoS architecture for mobile Ad Hoc networks is proposed in [17]. Increase of utilization of resources by accurate prediction using mobile tracking method is mentioned in [13]. On line load balancing solution for multimedia cellular network is proposed in [12] and [9]. Adaptive bandwidth allocation to increase system utilization with degradation of QoS is shown in [2]. In [8], distributed adaptive bandwidth allocation and admission control scheme is proposed, where the authors tried to limit the dropping probability for handover call based upon number of successes and failures of handover calls. In [15] a novel QoS management scheme based per class degradation is proposed. In [12] an admission control and Dynamic Bandwidth Management scheme that provides fairness in the absence of distributed link level weighted fair scheduling is proposed. A dynamic and adaptive bandwidth management scheme is proposed to provide as satisfactoty QoS guarantee as possibile for wireless multimedia services under variable traffic conditions in [4]. An Adaptive Bandwidth Management and Reservation Scheme in Heterogeneous Wireless Networks is proposed in [7]. A resource Management strategy for heterogeneous adptive-rate traffic which is a combination of CAC management strategy and bandwidth management is proposed in [11].

This paper is organized as follows. Section 2 will talk about bandwidth allocation schemes used in mobile wireless cellular networks. Proposed architecture and bandwidth management schemes in three scenarios are presented in section 3. Proposed algorithm is mentioned in section 4. Sections 5 will show the performance evaluation followed by analytical results in section 6. This paper ends with conclusions.
2 CHANNEL ALLOCATION SCHEMES

Bandwidth is allocated in the form of channels. Channels are allocated to cells and these channels are used to communicate within the cell by mobile nodes. Three major categories are used for assigning the channels. They are - 1. Fixed Channel allocation (FCA) 2. Dynamic channel allocation (DCA) and 3. Hybrid channel allocation (HCA).

Fixed channel allocation (FCA) is a widely used channel allocation method. In fixed channel allocation (FCA), fixed numbers of channels are assigned to each cell in the network. It is a static channel allocation method and cannot be changed. In this method, if calls arrive more than the allocated number of channels, the assignment of channels to these calls becomes difficult and dropping and blocking probability of handover and local calls will be increased, also if a high enough number of calls are not available in the queue, then some channels will not be used and it is a wastage of resources. This is not an appropriate method for non-uniform traffic in the cell. In the dynamic channel allocation (DCA) method, the channels are allocated whenever needed by the cell following the channel reuse distance rules should not be violated. The bandwidth in the network will be utilized in a more efficient manner and wastage of resources can be avoided. Whenever, bandwidth is needed channels can be assigned from a pool, if enough channels are not available in the cell. Many schemes have been proposed in dynamic allocation of channels [6], [18], [14], [3], [5]. In hybrid channel allocation (HCA) method both the techniques static and dynamic are used in assigning the channels [1]. Many sub schemes have been proposed in this hybrid method. One of them is channel borrowing from neighboring cell [10], [16]. If the fixed allocated channels are exhausted then channels will be borrowed from neighboring cell following the non-violation of frequency reuse.

3 PROPOSED ARCHITECTURE AND BANDWIDTH MANAGEMENT SCHEME

3.1 Architecture

In this proposed architecture all base stations (BS) in cells are connected together wirely and communicate to one another regarding their status of bandwidth information. There is no centralized managed system used in this architecture. The main drawback in a centrally controlled system is that if any problem occurs in the central system or central controller, the whole network will be affected. To overcome this problem, each base station in the cell should be given the responsibility to manage its own bandwidth with the knowledge of bandwidth available at other base stations in the network. To do this, all base stations in the network should be connected together wirely and should be capable of communicating with one another. With this method if any problem occurs in network, only a part of the network will be affected and the number of users in other parts of the network can utilize the resources without being interrupted.

Every base station maintains its bandwidth table as shown in Table 1 below and updates at every averaging interval according to changing conditions of the network. The Bandwidth table in each cell contains the information about the bandwidth negotiation, allocation and utilization of each multimedia node (higher priority node), minimum guaranteed bandwidth for each data node (lower priority node) and unutilized bandwidth of both types of nodes and if any freely available bandwidth in the cell.

![Figure 1: Cellular Network Architecture](image)

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<thead>
<tr>
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<tbody>
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<td>2</td>
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<tr>
<td>Node2</td>
<td>2</td>
<td>1</td>
<td>1</td>
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<tr>
<td>Node3</td>
<td>0.75</td>
<td>0.75</td>
<td>0.5</td>
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<tr>
<td>Node4</td>
<td>0.75</td>
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<td>Node5</td>
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<td>Node6</td>
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<td>Node7</td>
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<td>Node8</td>
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Node1: Multimedia node (Higher Priority Node)
Node2: Data node (Lower Priority Node)
3.2 Proposed Bandwidth Management Scheme in Three Scenarios

Bandwidth Management for different services in wire line ATM networks is proposed by Raj Jain group. In this paper basic idea was adapted from ERICA algorithm [19], [20], [21], [22], [23], [24] and modified to suit to handover calls in mobile wireless cellular networks. The Bandwidth management scheme is proposed here in three scenarios. 1. Bandwidth managed for Existing calls, 2. Bandwidth managed when higher priority calls arrived and 3. Bandwidth managed when lower priority calls arrived. In this proposal, two types of calls are used, one is higher priority calls and the other is the lower priority calls. A Higher priority call is a video call and delay sensitive and negotiated bandwidth has to be allocated and maintained during the connection life time. A Lower priority call is a data call whose bandwidth is flexible and changes according to the changing network conditions. This is delay tolerant and minimum bandwidth has to be maintained for this call. A Lower priority call will utilize maximum freely available bandwidth if the network does not have many higher priority calls. As the number of higher priority calls increases, the lower priority calls are asked to reduce their transmission rates.

Each higher and lower priority call can be in any one of the three forms. The first one is active form (active call), which will utilize fully 100% allocated bandwidth. The second one is semi active form (semi active call), which will utilize a portion of allocated bandwidth and the third and the final one is a passive form (passive call) which will never utilize the allocated resource.

3.2.1 Bandwidth Management for existing calls

All the calls in a cell may not use fully allocated bandwidth (semi active) during their connection period for various reasons, such as for some calls due to bottle neck problems and for some calls they may not need part of the allocated resources. Also some calls may not use any allocated bandwidth (passive calls) at all due to line of sight problems or large variation in their signaling power. We are assuming that no calls are waiting in queue and there is no request for channels received from neighboring cells. In this situation part of the bandwidth will be wasted. In order to avoid the wastage, this portion of unutilized bandwidth will be distributed fairly among active lower priority calls. If any part of allocation is not being used after this distribution, it will be left in an unutilized section. In this method the network condition is changing from under load to normal load.

Figure 2: Bandwidth in Cell with no handover calls in Queue

3.2.2 Bandwidth Management when higher priority handover calls arrived

If the higher priority call wants to travel from one cell to another neighboring cell, the base station in the existing cell will inform the base station in the neighboring cell about the bandwidth requirement. The neighboring cell will reserve bandwidth following the procedure specified below.

For higher priority handover call, initially the base station will check if enough bandwidth is available in the unutilized section. If available then that will be reserved for this call, otherwise a portion of the bandwidth from lower priority calls will be added to this unutilized bandwidth in order to fulfill the request. If also at this stage requirement is not fulfilled, then it will borrow part of the bandwidth from a neighboring cell and will be added to the above sum. This bandwidth will be reserved and allocated for this call.

Since it is a higher priority call, this bandwidth will be allocated and maintained constantly during its connection life time. Priority will be given to this call against lower priority handover calls and locally generated calls.

Figure 3: Bandwidth in Cell with handover Calls in Queue

3.2.3 Bandwidth Management when lower priority handover calls arrived

High Priority calls B. W.  
Lower Priority calls B. W.  
Unutilized B.W.

High Priority calls B. W.  
Lower Priority calls B. W.  
Unutilized B.W.
If the migrated call is a lower priority one, the base station in the cell will first check as above in the unutilized section for adequate availability of bandwidth or at least a minimum availability. If available, that will be allocated to this call. If this bandwidth is not enough or not even minimum, then part of the bandwidth from the active lower priority calls will be added to the unutilized part as above and will be reserved. If at this stage it is also not getting the minimum, then part of the bandwidth from neighboring cells will be borrowed and added. This bandwidth will be reserved and allocated to this call. Even though, it is not getting the minimum, then this call has to negotiate the minimum bandwidth or wait in queue. Preference will be given to this handover call against a locally generated call.

4 PROPOSED ALGORITHM

BEGIN
IF (no calls in queue & no bandwidth requests from neighbor)
   Bandwidth leftover by semi active calls +
   total unutilized bandwidth from passive
   calls and distribute among active calls
ELSEIF (the call in queue is higher priority call)
   Reserve & allocate enough bandwidth
   either from unutilized portion, Or from
   part of active lower priority calls or barrow
   from neighbor or combination of all
ELSEIF (the call is lower priority call)
   Allocate at least the minimum either from
   unutilized portion or from active lower
   priority calls or barrow from neighbor
Else
   Negotiate Bandwidth or wait in queue
END

5 ANALYTICAL EVALUATION

Analytical evaluation has been done for three Scenarios. 1. For existing calls, 2. When Higher priority handover call arrives and 3. When lower priority handover call arrives.

5.1 Bandwidth managed for existing calls

In this scenario, assuming that when no calls are waiting in queue and no bandwidth requested from neighbor.
Let Total Bandwidth allocated to calls = BW_T
Total Bandwidth utilized by calls = BW_UT
Total Bandwidth not utilized BW_NUT = BW_T – BW_UT

Total number of Active Lower Priority calls = C_ALN = [C_AL1 C_AL2 C_AL3 ......... C_ALN]
Bandwidth for Active Lower Priority call = BWC_AL
Total Bandwidth utilized by Active Lower Priority calls = BW_UTAL
Bandwidth Distribution among Active Lower Priority calls = BW_NUT / C_ALN
New Total Bandwidth for Active Lower Priority calls = BW_UTAL + BW_NUT
Added Bandwidth for each Lower Priority Call = (BW_T – BW_UT) / C_ALN = BW_NUT / C_ALN
New Total Bandwidth for Active Lower Priority calls = (BW_NUT / C_ALN) + [BWC_AL1 BWC_AL2 BWC_AL3 ......... BWC_ALN]
New Total Bandwidth for Active Lower Priority calls BW_ALT = (BW_NUT / C_ALN) + \sum_{C_AL1} BWC_ALN

Bandwidth Management when Local call generated within the cell

Bandwidth reduction from each Active Lower Priority Call =
\[ \text{Total Bandwidth of Active Lower Priority Calls after Minimum} = \frac{\text{Total Number of Active Lower Priority Calls}}{C_ALN} \]

New Bandwidth for each Active Lower Priority Call = (C_ALN) – [BWC_AL1 BWC_AL2 BWC_AL3 ......... BWC_ALN]

BW_ALT(Old) \rightarrow BW_ALT(New)

In this scenario, every averaging interval base station in cell will evaluate and try to keep its unutilized section to minimum.

5.2 Bandwidth management when Higher Priority Handover call arrived

Bandwidth Requested by Higher Priority Handover Call = BW req_H
Total Bandwidth utilized by Active Lower Priority Call = BW_UTAL
Total Bandwidth of Active Lower Priority Calls calculated after minimum = BW_ALTM
Bandwidth Barrowed from Neighboring Cell = BW_Borrow

IF (BW req_H <= BW_ALTM )
   Obtain BW req_H from BW_ALTM
ELSE
   Obtain BW req_H from (BW_ALTM + BW_Borrow)

5.3 Bandwidth management when Lower priority Handover call arrived

Bandwidth Requested by Lower Priority Handover Call = BW req_L
IF (BW\textsubscript{reqL} \leq BW\textsubscript{ALTM})
    obtain BW\textsubscript{reqL} from BW\textsubscript{ALTM}
ELSE
    BW\textsubscript{reqL} ← (BW\textsubscript{ALTM} + BW\textsubscript{Barrow} OR BW\textsubscript{ALTM})
    BW\textsubscript{reqL} ← BW\textsubscript{min} ← BW\textsubscript{ALTM}

6 PERFORMANCE EVALUATION & ANALYTICAL RESULTS

6.1 Performance evaluation of Bandwidth management for Existing Calls

Using the above analytical evaluation and compute it using Matlab, the performance has been evaluated at different intervals of time $t$. CH refers to Higher Priority calls and CL refers to Lower priority call. The Bandwidth utilized by different calls at different time intervals is shown in figure 4 below.

Total Bandwidth in the cell is fixed as 10Mbps. CH1 and CH2 are allocated data rate as 2Mbps and rest of lower priority calls are allocated 1Mbps. At Time $t = 1.1$ the data rate for CH2, has dropped to 1.6Mbps and data rate for CL1 and CL2 has dropped to 0.8Mbps and Call CL6 has not at all used its rate from $t = 1.1$ onwards. Cell utilization becomes under load. At time $t = 1.2$ Base station in cell distributed the unutilized bandwidth fairly among active Lower priority calls CL1, CL4 and CL5. Their bandwidth changed from 1Mbps to 1.6Mbps. We can see from evaluation that network has been brought back from under load to normal load condition. Base station always tries to make 100% utilization of bandwidth in the cell.

6.2 Performance evaluation for Bandwidth Management when Higher Priority Handover Calls arrived.

Performance has been evaluated on the following four conditions.

1. When Higher priority call arrived & B.W allocated at $t = t1$& $t2$, B.W allocated from local cell
2. When Higher priority call arrived & B.W allocated at $t = t3$, B.W allocated from neighboring cell
3. When Higher priority call left the cell & B.W managed at $t = t4$, B.W distributed equally among active lower priority calls
4. Bandwidth management when channel requested from neighboring cell

![Figure 5: Allocation within the cell](image)

![Figure 6: Allocation from neighboring cell](image)

![Figure 7: Bandwidth Management after Node left](image)
Two higher priority calls (CH1 and CH2) are allocated the bandwidth of 2Mbps each and CH2 is using 1.8Mbps and 0.2Mbps is left in the unutilized section. Bandwidth allocated to lower priority calls (CL1 to CL6) is less than 1Mbps. CL1, CL2 and CL5 are utilizing their allocation fully and in which two calls (CL3 and CL4) are utilizing part of allocation and one call CL6 is not at all utilizing its allocation. This part of bandwidth is fairly distributed among active lower priority calls. At t=1, the unutilized part has been distributed fairly among CL1, CL2 and CL5. CH3 arrived at t = 1.1 and bandwidth allocated to this call is from lower priority calls. CH4 entered at t = 1.5, again bandwidth allocated as above but the minimum bandwidth is maintained for these active lower priority calls. For call CH5, the bandwidth is borrowed from a neighbor cell as a minimum is maintained for lower priority calls. At every averaging interval, base station calculates the bandwidth and brings back the cell from under load to normal load condition. At t = 3.2 CH2 has completed the call and bandwidth is again distributed among lower priority calls. When bandwidth is requested from a neighbor at time t = 3.6, a portion of lower priority call has been transferred to the requested neighboring cell as shown in results. If a higher priority call is going to enter, the lower priority calls are asked to reduce their rates and in absence of higher priority calls, they are asked to increase their rates.

6.3 Performance Evaluation when Lower Priority handover Calls Arrived

Performance has been evaluated on the following four conditions.

1. When Lower priority call arrived & B.W allocated from a local cell.
2. When Lower priority call arrived, Bandwidth allocated minimum (worst case).
3. When Lower priority call arrived & B.W allocated from neighboring cell.
4. When Higher priority call arrived, Bandwidth allocated from lower priority calls.
In this scenario, CH1 and CH2 are allocated 2Mbps and CL1 to CL6 are allocated 1Mbps. CL7 entered at \( t = 0.4 \) and bandwidth has been allocated from a portion of CL1 to CL6 and adjusted as shown in figure. In the same manner bandwidth was allocated to CL8 and CL9. CL10 entered at \( t = 1 \), and requested for 1.5Mbps. Bandwidth allocated to this call is equal to the portion of bandwidth of lower priority calls plus bandwidth borrowed from the neighbor. When CH3 entered at \( t = 1.2 \), the allocation is done from lower priority calls, but maintained the minimum (0.5Mbps) for all lower priority calls. For CL11 at \( t = 1.3 \), bandwidth 1Mbps was borrowed from neighbor which was later adjusted. At \( t = 1.4 \), bandwidth is requested and transferred to a neighboring cell and is adjusted for all lower priority calls so that all lower priority calls should maintain the same amount of bandwidth. The same procedure could be applied to locally generated calls.

7 CONCLUSION

In this paper, a new solution for bandwidth management is proposed. In this proposed solution he unutilized bandwidth will be allocated among active lower priority calls. Higher priority calls will obtain the bandwidth without any difficulty and remain constantly during its connection life time. If there are not many higher priority calls in the cell, lower priority calls will utilize maximum and during network overload condition the lower priority calls will be asked to reduce their rates. Also bandwidth will be borrowed from a neighboring cell if enough bandwidth is not available in the cell. In the worst case, minimum bandwidth will be allocated and maintained for lower priority calls. At every averaging interval, the base station will check its table and bring back the network to normal condition. In this method, bandwidth in the cell will be at maximum utilization (100%) and wastage of resources can be avoided. With this scheme dropping probability of handover calls will be minimized and blocking probability of locally generated calls will be decreased. QoS could be maintained.

REFERENCES


Figure 12: Worst case allocation


